COMMISSION OF THE
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COORDINATION OF
AGRICULTURAL RESEARCH

UTILIZATION OF MANURE BY LAND SPREADING

1977

EUR 5672 e

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MANURE BY LAND SPREADING

JANSSEN SERVICES. 14 The Quay, Lower Thames St., London, EC3R 6BU.

COMMISSION OF THE EUROPEAN COMMUNITIES

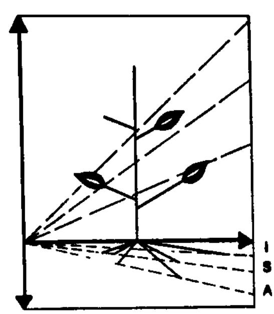
UTILISATION OF MANURE BY LAND SPREADING

Edited by

J.H. VOORBURG

A Seminar in the EEC Programme of Co-ordination of Research on Effluents, organised by the "Istituto Sperimentale Agronomico" 41 100 Modena - Italy

September 20 - 24 1976



Sponsored by the
Directorate General for Agriculture
Co-ordination of Agricultural Research

EUR 5672 e

Published by

The Commission of the European Communities,
Directorate-General for Scientific and Technical
Information and Information Management,
European Centre, Kirchberg,
Luxembourg.

Printed in Belgium

The Seminar on Utilisation of Manures by Landspreading was held in that part of Europe where the earliest known reference to this subject was made by Virgil:

> "..... whate'er
> The sets thou plantest in the fields, thereon
> Strew refuse rich."

Virgil, Georgics, Bk. 2, lines 346-348. (Translated into English verse by James Rhoades in the series Great Books of the Western World - No.13 Virgil - published by Encyclopaedia Britannica, 1952).

As a souvenir of that time this coin of Titus Flavius Sabinus Vespasianus, Roman Emperor from 70 to 79 AD, was found near Modena. His statement: "(pecunia) non olet" is well known.

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PREFACE

This publication contains the Proceedings of a Seminar held in Modena (Italy) on September 20 - 24, 1976, under the auspices of the Commission of the European Communities as a part of the CEC programme of co-ordination of research on effluents from livestock.

The subject of the Seminar was Utilisation of Manures by Landspreading. This subject was subdivided into the following themes:

- Manure and crop production
- Manure and pollution of surface waters
- Manure and pollution of soil and groundwater
- Regional aspects
- Veterinary aspects
- Miscellaneous
- Models on landspreading of manure
- Sampling and analysis

One of the functions of the Seminar was to assess the current situation and the available knowledge. For that reason no selection was made from the papers presented. This may result in repetition of some information in different papers.

An important objective was to review the present analytical methods with a view to assessing an improved homogeneity in the expression of the results. A rough inventory of the analytical methods applied on soil, water, crops and manure, was made and a list of the most important parameters was discussed. These are the first steps towards more harmonised sampling and analytical methods. On the basis of this survey it is proposed to set up a working group which will improve the work already done and study the possibility of writing a 'recipe book' for proposed standard techniques.

The Commission wishes to thank those representatives of the member States who were responsible for the organisation and conduct of this Seminar, notably Ir. J.H. Voorburg (Chairman), Professor F. Lanza and Professor V. Boschi (local organisers); the chairmen of the sessions, Dr. D. Strauch, Professor J.R. O'Callaghan and Dr. H. van Dijk; also Mr. J.C. Hawkins and Dr. K. Robinson who checked some of the papers.

THEME I

CROP PRODUCTION

Chairman: J.H. Voorburg

AGRICULTURAL USE OF EFFLUENT FROM LIVESTOCKS: PROBLEMS AND PERSPECTIVES IN ITALY

F. Lanza
Istituto Sperimentale Agronomico, Bari, Italy

INTRODUCTION

In the cattle and pig husbandry field, Italy comes last among the EEC countries since it is only able to provide on average two-thirds of its total consumption, even though its consumption rate is one of the lowest in the Community. National production cannot keep pace with growing needs; in fact, Italy imports more meat than any other EEC country. In order to reduce this meat deficit, or at least to avoid any increase in it, an expansion in national livestock by means of large-scale farms is advisable, as is the elimination of structural weaknesses in the organisation of Italian farms, which are notoriously much too small. However, it is precisely this increase in the size of farms which poses enormous problems as regards the use and disposal of liquid manures, particularly in northern Italy where two-thirds of the livestock is produced. Under these conditions, while the problem of cattle effluent is at present relatively minor because it is still closely connected to the farm, the problem of pig effluent is of pressing urgency because of the concentrated and industrial nature of pig rearing without bedding.

In the Emilia-Romagna region, which has a highly intensive livestock production, with over a million head of cattle and a quarter of the country's pig production, two kinds of systems are to be found: firstly, the large, industrial kind of production, not linked to the agricultural farm, and few in number, and secondly, the small-scale kind of production, part of the cheese-producing co-operatives.

While the former system is in the process of adopting purifying equipment, the latter, which forms the bulk of the livestock production, can utilise the soil made available through the co-operative system, for the landspreading of liquid pig manure. For these reasons the Modena section of the Experimental Institute of Agronomy is interested primarily in pig slurry and at this seminar my collaborators will talk about a five-year trial in landspreading. I will limit myself in this paper to giving a general survey of the problems and perspectives in Italy, as indicated by our studies in Modena.

PROBLEMS AND PERSPECTIVES

The problems caused by livestock effluent in this region are well-known: the lack of natural purification because of the excess amount of organic matter; eutrophication of canals: the lack of oxygen in waters where anaerobic bacterial flora is prevalent leading to production of CO_2, H_2S, CH_4 and NH_3 especially during the dry season.

However, in the vast majority (85 - 90%) of cases of pig husbandry in the region, both as regards numbers (less than 500 head per farm) and as regards the modest size of the farms, it is impossible to use a system of artificial purification for liquid manure (biological and chemical systems), which is applicable only for the large industrial kind of animal husbandry. The only possible system is the agricultural system, that is, landspreading, because, as has already been mentioned, there is land available.

The problems of landspreading are:

a) quantity of slurry produced by livestock, possibilities of reducing volume of slurry and its storage.

b) composition and fertilising value of slurry.

c) crops suitable for organic irrigation, rates per ha and best times for spreading; spreading methods and optimal ratio of heads of livestock per ha.

d) systematic study of effects of slurry on different crops and soils.

From our experiences, the amount of pig slurry produced is on average 9 m^3 per head per year, of which four-fifths is washing water. The capacity of tank storage, which is always very low because of the very high cost, is filled up within 15 - 20 days on the average farm. Furthermore, when the slurry cannot be used in the fields, it is discharged into public waters, creating pollution problems.

The large amount of water needed for cleaning can be appreciably reduced by the use of compressed air or eliminated by a management system not requiring water. However, the most common solution to the problem of slurry storage is that of lagoon storage which,if used as straightforward accumulation pits, can have a depth of over 3m and a capacity of not less than 3 m^3 per head. If the pits are to be used as oxidation tanks, then the depth must be halved.

This appears to be the most popular method in the area, and we feel it to be the most economical and rational method as well, even though we have one or two doubts, such as the possibility of polluting the ground water in light and permeable soils.

Frequent analysis over a period of three years has shown that, as regards the livestock under examination, 1 m^3 of pig slurry contains an average of 24 kg of dry matter (of which 17 kg are organic matter) with almost 7 kg of N, P_2O_5, K_2O, with the approximate ratio of 1 : 0.5 : 1. Its value as fertiliser, considering the present cost of fertilisers in Italy, is much higher than 1 500 lire per m^3, while landspreading in less favourable conditions, costs no more than 1 000 lire per m^3.

Through our experimental trials carried out over a period of five years, forage crops have been found to respond best to slurry application, because of its diluted state and neutral reaction, particulary annual rye grass, maize (green forage and silage crops), fodder sorghum and winter cereal forage crops (barley, rye and oats). However, even sugar beet and alfalfa reacted positively in tests carried out this year.

The doses which allow for the highest production are, on average around 500 m^3 per hectare, but the most "economical", or those which give the best yield, do not go above 250 m^3 per ha. We may conclude that the optimal situation is 25 - 50 pigs per ha, also taking into account the annual slurry application and the possibility of negative repercussions on the soil and on the underground water. While on the subject of soil, research being carried out in our Institute would appear to show that the soil destroys a vast amount of organic matter through its self-regulating power.

A useful indication concerning the conditions of the Po Valley, based on the right times for spreading and thus minimising wastage and discharges into canals, is the following.

During the whole of the autumn/winter period, the slurry can be spread on forage crops (barley, rye, oats, annual rye-grass), sown in October and on wheat until the end of March, and even on old alfalfa fields as well as on ploughed fields awaiting the spring sowings. In April spreading can be carried out on fields of annual ryegrass which have already been given their first cut, and on fields of maize and sugar beet immediately before and after sowing. During May and the summer months, the ideal crop for spreading is fodder sorghum (before and after sowing and after every cut) and fodder maize (green and silage) in the second crop after wheat.

On the hillsides, and also in higher altitudes, it is obviously meadow land which responds the best because it is essentially made up of grasses.

The best landspreading methods, in our opinion, are by liquid trailer or organic irrigation.

CONCLUSIONS

In Italy, most pig production is undertaken on too small a scale for purification plants to be used economically; in fact only the large industrial concentrations can make use of them.

The agricultural farms of limited size are turning more and more to landspreading, as well as trying to overcome the seasonal difficulites which prevent landspreading, using, primarily, artificial lagoon storage, and reducing the volume of washing water.

The fertilising value of slurry, even when diluted, more than compensates for the expense of spreading, and an even greater use of landspreading is advisable. This would avoid pollution of canal waters and would reduce energy consumption.

The farms involved in livestock production, and above all the co-operatives, should plan wisely among their members the annual spreading times as well as choosing the crops which are to be spread.

FERTILISER VALUE OF ANIMAL MANURES

Hubert Tunney
The Agricultural Institute
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INTRODUCTION

For centuries animal manures were used as the principal source of maintaining soil fertility. In recent years, however, the fertiliser value of animal manures has been ignored in many developed countries, because of the availability of convenient and relatively inexpensive chemical fertilisers.

The large quantities of manures produced at farm level by intensive methods of animal rearing, coupled with availability of chemical fertilisers has given rise to a situation often referred to as the animal manures disposal problem.

The extent of the problems of manure disposal were not envisaged in the early stages of intensive animal rearing, which developed in response to economic pressures. Solutions to these problems are becoming available slowly. With present technology the only acceptable method for disposal of animal manures is application to agricultural land with or without pretreatment.

THE VALUE OF MANURES

In the Republic of Ireland approximately 90% of arable land is devoted to grassland for dairy and beef production. The cattle population is equivalent to approximately five million livestock units (Lee and Diamond, 1972). One livestock unit is equivalent to one 455 kg animal (Attwood and Heavey, 1964). The winter feeding period varies from 120 to 150 days and grass silage or hay supplemented with meals is the principal feed. Approximately one third of the total faeces and urine is produced during the winter feeding period. There are about one million pig places.

On most farms in Ireland it is possible to recycle the nutrients in the manure to the conserved area for production of the subsequent year's winter feed. On pig and poultry farms this simple recycling relationship does not exist as most of the feed is purchased, however, there is normally adequate land available locally for spreading manure. Manure produced by cattle in the 4 months winter period, and by pigs and poultry in a year, has a fertiliser value of approximately £45 million sterling in terms of the nitrogen (N), phosphorous (P), and potassium (K) content.

A similar calculation for the 9 EEC countries assuming 70 million livestock units and 70 million pig places (Anon. 1976) would give manure with a fertiliser value of approximately £550 million for cattle and £250 million for pigs. Manure from all farm animals, including poultry, in the EEC has a potential annual fertiliser value in the region of £1 000 million per annum. To avail of this value, considerable investment in storage and spreading equipment is necessary on the farm. If used efficiently, this manure represents an asset to the community and reduces our dependence on imported fertilisers. On the other hand if it is disposed on land at rates greatly in excess of crop needs it is a potential source of soil and water pollution.

Where manure is applied at rates to supply adequate nutrients for crop needs, normally less than $55m^3$/ha (9% DM slurry) equivalent to 5 tonnes dry matter/ha would be required, and at this level the pollution risks would be minimal. Much of our research efforts on animal manures in the last five years have been devoted to integrating manures into a fertiliser programme.

COMPOSITION OF ANIMAL MANURES

In Ireland there are three main types of manure storage:

a) Farmyard manure - where straw is used as beddding material;

b) Dungstead manure - where the manure without bedding is scrapped into a compound about 1.5 m deep, liquids are allowed to drain off and drying takes place during the summer. This manure is usually spread as a solid (mainly faeces) on grassland in the autumn. The liquid from this type of storage is usually irrigated by a small electrically operated pump.

c) Slurry - consists of a mixture of faeces and urine together with variable quantities of rain and wash water. Most of the pig manure and a small (perhaps 10%) but increasing proportion of cattle manure is now being stored and spread as slurry.

Samples of the different categories of manures were collected from farms between 1973 and 1975, with a view to obtaining up-to-date information on the N, P and K content of manures. The results of the analyses are summarised in Table 1. Details of methods are described elsewhere (Tunney and Molloy, 1975).

TABLE 1

SUMMARY OF THE N, P, K AND DRY MATTER CONTENT OF CATTLE AND PIG MANURES FROM DIFFERENT FARMS

		% DM	kg/10m^3 or kg/10 tonnes N	P	K
Cattle (dairy and beef)					
Farm Yard Manure (18 farms)	Mean	20	45	10	68
	Range	13-26	32-65	8-17	33-128
Dungstead Manure (16 farms)	Mean	17	33	8	42
	Range	10-23	20-52	5-12	30-60
Slurry (33 farms)	Mean	8	40	7	42
	Range	1-14	8-60	1-12	8-62
Pigs (sows and fatteners)					
Slurry (20 farms)	Mean	8	43	18	20
	Range	1-21	12-70	1-45	6-34

These values give an indication of the average composition of the different categories of manures. In particular, they show the wide variation between farms in the composition of pig and cattle slurries. This variation is due mainly to dilution with water. The solid manures, namely farmyard and dungstead manures, by comparison, were relatively uniform with a two-fold variation in composition between the highest and lowest farms. The high K content of cattle slurry reflects the grass silage diet and the high P in pig slurry reflects the mainly cereal diet.

A highly significant correlation exists between the dry matter and the N, P, Ca and Mg content of both cattle and pig slurry (Tunney and Molloy, 1975). The K content was also related to dry matter with a lower statistical significance. The relationship between dry matter and the N content of pig slurry is illustrated in Figure 1. This relationship also shows the relatively uniform distribution over the range.

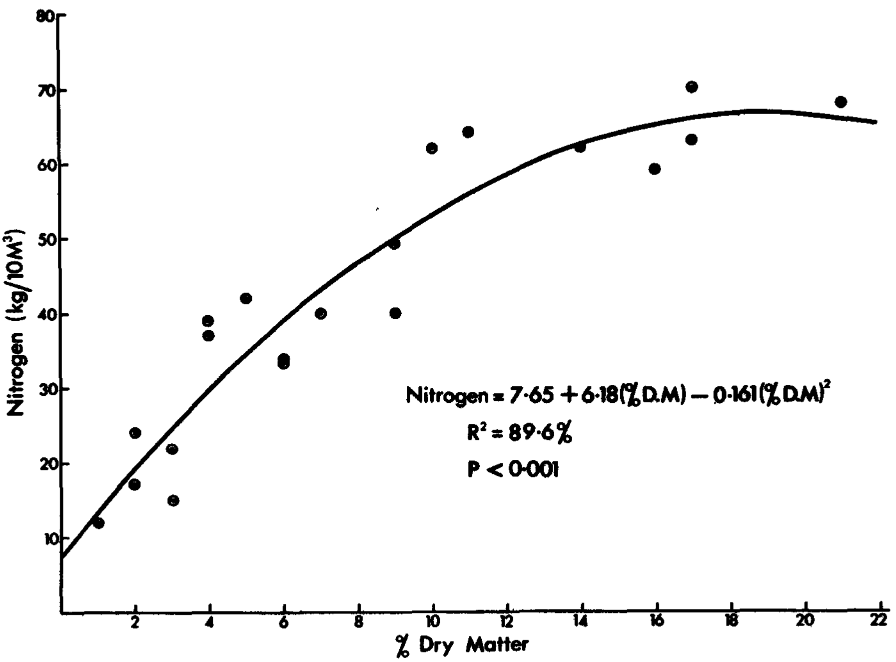

Fig. 1 Relationship between dry matter and nitrogen content of pig slurry (20 farms)

Undiluted pig slurry contains approximately 9% dry matter (O'Callaghan et al., 1971). It appears from Figure 1 that values with less than 9% dry matter were due mainly to dilution with water, and values over 9% were probably due to the liquid fraction being drawn off, and the accumulation of the more solid material in tanks that were not agitated properly.

This work demonstrates one of the major difficulties in attempting to integrate manures into a fertiliser programme, namely the wide variation in composition.

The close relationship between dry matter and fertiliser nutrients indicated that a simple field test for dry matter would be of value in solving the problem of variation in manure composition. A number of approaches were investigated. The close relationship found between dry matter and specific gravity of slurry (Tunney and Molloy, 1975) formed the basis of a hydrometer that could be used under field conditions to estimate dry matter and fertiliser value of both cattle and pig slurry.

Figure 2 shows the relationship between dry matter and the specific gravity of cattle and pig slurries from a number of farms.

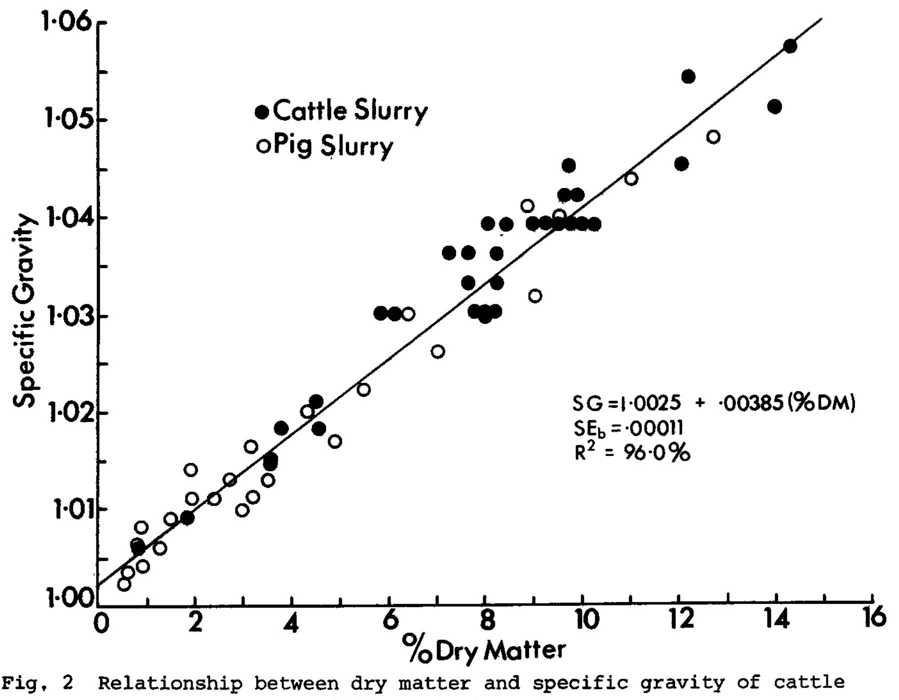

Fig. 2 Relationship between dry matter and specific gravity of cattle (33 farms) and pig (25 farms) slurry.

Figure 3 illustrates the hydrometer, calibrated in percent dry matter, being used to estimate the dry matter of two samples of pig slurry.

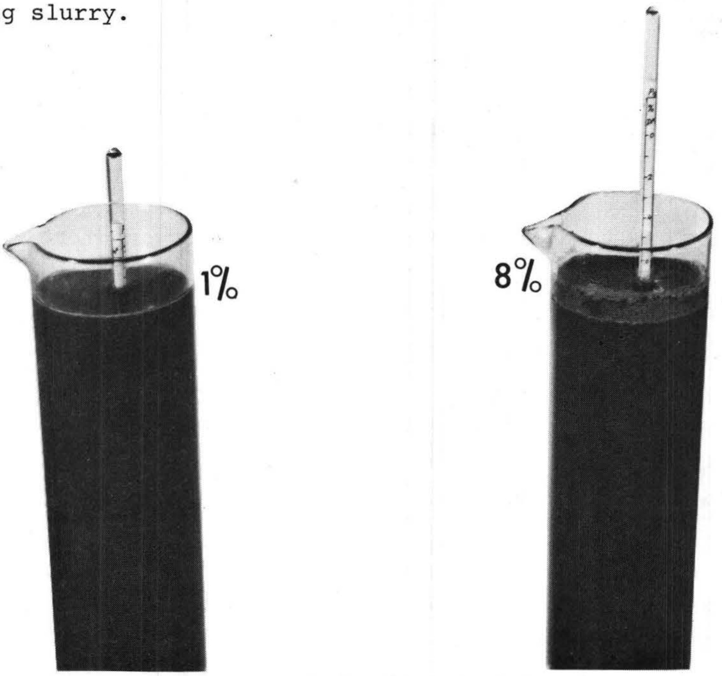

Fig. 3 Estimating dry matter of pig slurry by hydrometer

ANIMAL MANURES AS FERTILISER

The results of experiments to date with cattle and pig manures for grass silage production (Tunney, 1975), indicate that to obtain maximum benefit from nutrients in pig slurry it should be applied at rates to supply adequate P and N and supplemented with K fertiliser. Cattle slurry should be applied at rates to supply adequate K and be supplemented with P and N. At equal rates of N, pig slurry gave consistently better grass dry matter yields than cattle slurry. This may be due in part to the higher nitrogen availability of pig slurry. However, it appears that other factors may be involved. In these experiments it was noted that cattle slurry at $33m^3/ha$ gave higher yields than at $55m^3/ha$ (Table 2). This indicates that cattle slurry may have an adverse physical or chemical effect on grass growth. It has been noted that cattle slurry forms a coating on the grass surface which may last for several weeks under dry weather conditions. It is likely that this coat of slurry reduces the light available to the grass for photosynthesis. Pig slurry, because of its granular nature, in comparison to the fibrous nature of slurry from cattle fed on hay or silage, does not form a dense coating on the grass surface.

The grass yields for this work in 1973 and 1974 are summarised in Table 2.

TABLE 2

COMPARISON OF GRASS YIELDS WITH CATTLE SLURRY, PIG SLURRY AND CHEMICAL FERTILISERS (Tunney, 1975)

	Slurry m^3/ha (two applications)	Yield tonnes DM/ha 1973 (means of 10 plots)			
		Cut 1	Cut 2	Cut 3	Total
Fertiliser	Standard	5.43	4.35	1.86	11.64
Pig Slurry	73	5.27	4.38	2.31	11.96
Cattle Slurry	73	5.21	3.81	2.19	11.27
Standard Error		.24	.22	.14	.41
		1974 (means of 5 plots)			
Fertiliser	Standard	7.14	4.86	1.94	13.85
	High	7.04	6.20	2.29	15.53
Pig Slurry	68	6.36	4.40	2.62	13.49
	112	5.94	5.46	3.30	14.63
Cattle Slurry	68	6.00	3.74	2.56	12.30
	112	5.50	3.25	2.86	11.54
Standard Error		.28	.25	.24	.59

In an experiment to compare the response of different grass species to pig slurry and chemical fertiliser it was found that none of the species tested were particularly well suited or unsuited for use with pig slurry (Tunney, 1975). The grasses tested included cocksfoot, timothy, meadow fescue, tall fescue, perennial ryegrass, perennial ryegrass plus clover, RVP Italian ryegrass.

In another experiment it was found that both pig and cattle slurry can be used successfully for sugar beet production. Particularly good yields were obtained with pig slurry. At $45m^3$/ha, pig slurry should be supplemented with K, and cattle slurry with P. Borax supplementation is necessary with both slurries.

Slurry is not well suited for production of cereals because of their critical nitrogen requirements and the variation in composition of manures. However, pig slurry of known composition can be used to replace the chemical fertiliser requirements of cereal crops.

RECOMMENDATIONS FOR THE USE OF MANURES IN A FERTILISER PROGRAMME

Based on results and experience over the past few years information on the use of slurry in a fertiliser programme is being passed on to farmers through the agricultural advisory services. These recommendations take into account the fertiliser requirements of the crop and the quantity of animal manure in combination with chemical fertiliser that will supply these needs.

It is assumed that half the N in cattle slurry and two-thirds of the N in pig slurry becomes available in the year of application. The K in slurry is assumed to be as available as the K in chemical fertilisers. The P is also regarded to be as available as in chemical fertiliser where soil P levels are medium or high. It is also assumed that the manures are being used to obtain maximum benefit from the nutrients present.

Under Irish conditions it is recommended that cattle slurry should be applied to land conserved for silage or hay. Cattle slurry is not suited for grazing land as it is too high in K and a dressing as low as $10m^3$/ha would mean excess K being used. In addition, there may be risks to animal health where slurry is applied for grazing. Pig slurry on the other hand is particularly well suited for pasture and $17m^3$/ha of good pig slurry (7% to 9% DM) will supply the annual P and K requirements. Pig slurry is also ideal for hay and silage land. Slurry should be applied to grassland that has been closely grazed or cut. Applying slurry to long grass increased the risk of contamination and can reduce yield. Slurry for silage should be applied 7 to 8 weeks before cutting. In Ireland the most suitable time for application is April for first cut silage and in June for a second cut. Table 3 is an example of the recommendations for the use of pig and cattle slurry of average composition for grass silage production. Further details of recommendations are available elsewhere (Tunney, 1976).

TABLE 3

RECOMMENDATIONS OF SLURRY AND FERTILISER FOR GRASS SILAGE PRODUCTION

	Spring	Autumn
Cattle Slurry	$35m^3$/ha + 30 kg N/ha	10 kg P/ha
Pig Slurry	$25m^3$/ha + 30 kg N/ha	60 kg K/ha

EFFECTS OF SLURRY ON SOIL AND GRASS COMPOSITION

Soil analyses on experimental plots (Tunney, 1975) indicate that land receiving cattle slurry has a high K value and land receiving pig slurry has high P values. In a recent study there are indications that P in pig slurry gives higher available P readings (Morgan's extractant) than equivalent amounts of fertiliser P. Soil receiving pig slurry showed a slight increase in pH and a reduction in available manganese. Grass receiving pig slurry showed higher Calcium (Ca) and Magnesium (mg) and lower Manganese levels than fertiliser treated grass. The Mg level of grass from cattle slurry treated plots was significantly lower than with fertiliser treatments (Tunney, 1976). The results obtained are summarised in Table 4. Slurry and fertiliser treatments were applied before each cut.

TABLE 4

EFFECTS OF SLURRY ON MAGNESIUM (% ON DM) CONTENT OF GRASS

	1974 Cut 1	1974 Cut 2	1974 Cut 3	1975 Cut 1	1975 Cut 2	1975 Cut 3
Cattle Slurry	.19	.19	.13	.18	.19	.22
Pig Slurry	.25	.28	.33	.25	.26	.29
Fertiliser	.22	.24	.28	.25	.23	.25

The K content on the grass on the cattle slurry plots was not significantly higher than the fertiliser plots. However the soil K readings were higher with cattle slurry. These results suggest that slurry use without careful attention to nutrient balance could lead to animal health problems. Regular soil analysis is the most reliable way of ensuring that a satisfactory nutrient balance is maintained on land receiving manure.

EEC RESEARCH PROJECTS

Effects of cattle slurry and pig slurry on yield and quality of grass silage.

This experiment consists of 30 plots of 0.4 ha each. Ten of these plots receive fertiliser at the standard rate and ten plots receive cattle slurry at 45 m^3/ha in April for first cut silage and 35 m^3/ha in June for second cut silage. The other ten plots receive pig slurry at the same rate. The silage from the three treatments are made into separate pits of silage and will be fed to three separate groups of beef animals during the winter of 1976/77 to study the effects of slurry on animal silage intake and liveweight gain. There will be 20 animals per treatment.

Yield, % dry matter, N, P, K, Ca and Mg of the herbage is being measured. Silage pH, dry matter, digestibility and protein content, are being measured. Soil pH, and available P and K are also being monitored.

Incremental slurry and fertiliser N interactions on grassland.

In this experiment 0, 30, 60 and 90 kg fertiliser N/ha was applied in factorial combination with 0, 20, 40 and 60 m^3/ha of cattle slurry. There is one pig slurry treatment at 40 m^3/ha in combination with the same rates of fertiliser nitrogen. There is a washed and an unwashed treatment superimposed on the above treatments to obtain information on the effects of washing the slurry from the grass surface. There are six replications and each plot measures 3m by 8m. Figure 4 shows cattle slurry being applied to this experiment. Slurry was applied in April and three grass harvests will be taken in 1976.

The primary aim is to obtain information on slurry N response at different levels of fertiliser N. The residual effects of slurry N will also be estimated. Grass and soil will be analysed for the parameters listed for the previous experiment.

Fig. 4 Spreading cattle slurry on experimental plots.

CONCLUSIONS

The variation in composition of manures presents difficulties in utilising effectively the fertiliser value of manures. This practical difficulty will be familiar to research workers who have attempted to apply predetermined quantities of nutrients in manure to experiments over a period of time. It is more meaningful to express manure rates in terms of tonnes DM/ha rather than volume/ha.

The optimum levels of slurry in combination with fertiliser that should be applied for different crops and special problems of contamination and nutrient imbalance must be more fully understood.

The cost of storing and spreading manure is considerable and maximising the fertiliser value of the manure will help recover part of the cost. There is need for more information on methods of treating manure. However, it is important to keep in mind that practically all manure must eventually be spread on land. Research and policies that will make it possible for farmers to spread manure for its fertiliser value rather than simply as a disposal problem, will be of definite help in reducing the problem of animal manures and avoid pollution risk.

Fertiliser recommendations to farmers should provide information on the extent to which animal manures can be substituted for chemical fertilisers.

ACKNOWLEDGEMENTS

I wish to thank the staff of Johnstown Castle Research Centre for help in this work. In particular I wish to acknowledge the expert technical assistance of Mr. S. Molloy and Mr. F. Codd.

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DISCUSSION

<u>L.C.N. de la Lande Cremer</u> *(The Netherlands)*

I have some questions for Professor Lanza and Dr. Tunney. Firstly, Professor Lanza, what is the cleaning system you are using with compressed air, can you explain this? Why do you fear ground water pollution through storing the slurry, are your pits not sealed up? With regard to the discharges on open surface water, are there any regulations governing this method of disposal of animal waste in Italy?

Now, my questions for Dr. Tunney; I would like to make some comments on the estimation of the nutrient content of slurry by measuring the specific gravity. I also believe that it is helpful for farmers to have an easy method of determining the amount of nutrients in slurries. The oldest method is a Flemish one; it was used by the dung traders - they just put their fingers in the slurry and sniffed it! However, the question of the aerometer was introduced in Germany in about 1915/1916. It was studied in Switzerland by Duserre and in the Netherlands by Lagers in 1922 and the correlation between dry matter and the specific gravity was very good although there was a very great variation of the nutrients in the dry matter content with very big differences for the same specific gravity. Later the Germans studied slurries again and people in the southern part of Germany, in Switzerland and in Austria, all found the same difficulties - the big variation of nutrients at the same specific gravity. A better idea originated in France from Jouis and Angard who added nitrogen and potassium and thus had a better correlation with the specific gravity. A wide variation is apparent in your own figures - at 9% DM, 20% for nitrogen and at a lower DM content, 40%. Also, it is only possible to make a very rough estimate of the nutrient content with this method. Returning to our Flemish traders, I wonder if it is not possible to have a better field method by using the conductivity of the slurry for determining the amount of nutrients.

J.H. Voorburg *(The Netherlands)*

Professor Lanza will prepare his answers and give them this afternoon because he wants to have a good translation in English. Would you like to comment on Dr. de la Lande Cremer's remarks Dr. Tunney? Perhaps I can make some remarks first.

Dr. de la Lande Cremer mentioned the old Flemish method and information from the experiences of Germany and France. This is a good indication that we should co-operate within the European Community to exchange experience from the different countries.

My second point is that before starting new projects we should study the literature carefully because often old information is available and we should not forget that.

I am still very pleased about the method developed by Dr. Tunney because it is a demonstration of the need of the practical farmer to have a rough estimate of the quality of the manure.

Now I will give the floor to Dr. Tunney.

H. Tunney *(Ireland)*

When I started to speak I mentioned that it is 2 000 years since Virgil started writing about spreading manure on land. That's going back a long time and many things have been said since; in fact, there is very little that is new.

When we started working on this project we were looking for a simple field test that could be used at farm level. We looked at a lot of possibilities, for example, conductivity, which Dr. de la Lande Cremer referred to, and we found a very poor relationship. We looked at colorimetry where we diluted the manure and passed light through it to see the effect. That was also quite a good method but it was very complicated because a thousandfold dilution was needed to get results. We looked at a number of other methods but our experience indicated that the relationship between specific gravity and dry matter was the most simple and most accurate.

At the time we were not aware of the German work. Later, as I began to do some literature research I discovered a lot of work going back almost to 1900, on the use of specific gravity to estimate nutrient content. It was used with varying degrees of success. I am not pretending that this method is a perfect analytical method - it is not that. Normally one would not recommend its use in a laboratory except for approximate testing. However, I would suggest that it has a place in trying to overcome the problem of the great variation that exists in dry matter, particularly as a tool to educate farmers. I see that as its primary function. From my experience of looking at slurries, it is not easy to tell whether a sample is 3% or 6% DM. For a farmer who just has his own slurry tank it is even more difficult to try to estimate the DM.

This method is first and foremost a method for estimating DM in the field; I think it is very effective for doing that. I think it has a definite place and could be of great value. I see it primarily as an educational tool, to educate the farmer to the variation and the importance of knowing the approximate DM composition; he would then have some rational basis for deciding what quantity to apply. At the moment we have a situation where a farmer puts out so many cubic metres, so many tanker loads, per hectare, irrespective of composition. Maybe this is not the best idea but I put it out as a suggestion. We need something which is simple to use. The important relationship is that between DM and specific gravity. This method does not claim to be any more than a field estimate of DM but there is some justification for it because the higher the DM content, normally the higher the fertiliser value.

B.F. Pain *(UK)*

I would like to refer to Dr. Tunney's remarks on the adverse effect of cattle slurry on grass yields because we have had similar results at my Institute where we find the fibre content from relatively low applications of cattle slurry has a smothering effect, thus producing a taller but less dense sward with less grass per unit area. We suspect that one way to overcome these problems is to separate the slurry mechanically and to use only the liquid for grassland.

H. Tunney

We have another experiment running as part of our EEC project with three rates of application of cattle slurry. We are washing off half the plots with water and the other half is left. We are combining this treatment factorially with different rates of nitrogen and we are hoping to look at the nitrogen response curve to see if there is a physical effect or perhaps a toxic effect. We have one result already; we have cut the grass once and the washed plots are much better than the unwashed ones. This seems to indicate a physical effect but there is one small disturbing factor here - we had control plots as well with different rates of nitrogen; we washed them as a control and they gave a much better yield as well!

J.H. Voorburg

It wasn't the influence of the washing water in the dry summer?

H. Tunney

I doubt it, no. There was so little water, the quantity was about 5 mm. I doubt if it would be significant. The yield difference was 25%. It may have been an effect of nitrogen availability, the nitrogen being washed into the soil. Perhaps there was less loss of nitrogen - I don't know the reason for it - it is something we are looking at. I think it is mainly a physical effect but I wouldn't rule out a chemical effect as a possibility.

J.R. O'Callaghan *(UK)*

I would like to make three points. Firstly, with regard to the washing of the slurry, it seems to me quite an extra-ordinary operation insofar as there is a risk of ground water pollution, run-off of material, as a result of applying wash water after you have put on slurry.

Secondly, the cost of distribution of slurry is fairly marginal and this is an additional operation which will raise the cost.

The third point is really the reason I am up on my feet at all. Looking at Dr. Tunney's table of results I cannot see in the results he gets, the effect which he mentioned in his presentation. It does seem to me that the total yield from the high and low applications are not significantly different. So really I feel, all in all, where is the experimental evidence for the need to carry out these operations?

H. Tunney

I think it is important I should comment on that. During my presentation I didn't have time to go into all the details. I refer you again to Table 2. We applied slurry for the first and second cuts. You can see, looking at the last two lines for cattle slurry, at the first cut we had 6 t/ha DM with the low rate of slurry and 5.5 t/ha with the high rate. In the second cut, with the low rate we had 3.74 t DM/ha and with the high rate 3.25 t DM/ha. I think that is significant.

J.R. O'Callaghan

But are they significant?

H. Tunney

Well ... no, not quite perhaps. But this is a consistent effect. I think it explains our experimental error maybe. It is a consistent effect we have obtained. Another point which it is important to make is that for the third cut we didn't apply any slurry and you will notice that the slurry plots are considerably higher there than the fertiliser plots. This is a residual effect of the nitrogen which was applied in the slurry which is offsetting the earlier effect, and that goes in to make up the total. So I think it is important to point that out. This is just one year's results; we have quite a few more results which I haven't compiled for this paper but I am quite happy with these results.

A. Dam Kofoed *(Denmark)*

It is very interesting to hear Dr. Tunney's information about the effect of farmyard manure or slurry on clovergrass, that it was not very good. We have had the same results.
(Dr. Dam Kofoed showed his own slides to illustrate his point)
I wonder why this is so because a lot of farmers in Denmark

want to use slurry on grass fields - to some extent there is nowhere else for them to put it - and yet it has a bad effect. I think one could achieve a very much better effect by the use of irrigation. Could you say a little more about this aspect because it appears that farmyard manure, slurry, is not very well suited to grassland.

H. Tunney

The results you referred to there are for pig slurry. We looked at the effects of pig slurry on ryegrass and on ryegrass plus clover. There seemed to be a definite indication that the ryegrass plus clover did slightly better with the pig slurry. It was a significant effect. It appears to me that what was happening was that there was less nitrogen available from the pig slurry so there was less suppression of clover growth. This is how I explain it to myself.

J.H. Voorburg

I guess we will not obtain a definitive conclusion about this problem but it is very interesting.

R.G. Gerritse *(The Netherlands)*

I have a question for Professor Lanza.

J.H. Voorburg

Will you please write it down and then you will get your answer later.

R.G. Gerritse

Yes, all right. I also have a question for Dr. Tunney. There are certain modified celluloses which have the effect of solidifying the slurry but when you start agitating it it becomes liquid. Usually it is only necessary to use very minor doses to obtain this effect. I would think this would improve your hydrometer method because when you use the hydrometer you will always get a separation. Maybe this would also be useful in practice when spreading slurry on the land so that you have a homogeneous slurry when spreading that would not separate.

I wonder if it would be useful to investigate this aspect.

H. Tunney

Yes, I welcome a suggestion such as that. I think there are a lot of possibilities. From the point of view of the hydrometer, we have to shake it very well for two reasons, firstly to mix the solid and liquid material thoroughly and secondly, to ensure that we get rid of all the air bubbles because there are a lot of gases present in the slurry and it is important to get rid of them before making a measurement. We find it necessary to make the measurement within one minute after mixing. Something along the lines of your suggestion could be helpful but it is even more significant from the point of view of treating the slurry in some way before it is applied to grassland so that when rain does come the slurry is washed off the grass and into the soil much more quickly. Slurry on grass has two effects: firstly, it does not contribute any nutrients to the grass because it is not getting down to the roots; secondly, it is having an adverse effect on the foliage. I think it is a good suggestion from Dr. Pain that we should separate the solid from the liquid and apply the liquid to the grass and the solid to other land. Of course, it is a problem on many farms which are now exclusively either dairy or beef but if you are going to get an increased value from the manure it may offset the cost of separating. Maybe there is some other method of treating the manure before spreading, perhaps with detergents or celluloses. These are the kind of questions we must get answers to.

G.J. Kolenbrander *(The Netherlands)*

Dr. Tunney, this coating effect can have two results, one is that nitrogen volatilisation is higher. We can explain the difference as a nitrogen effect of cattle slurry and pig slurry but it is also possible that it is a photosynthetic effect.

With regard to the experiment on residual nitrogen which you mentioned, how long have you been running this experiment? The total residual effect can take 30 to 40 years but if you are looking only at the short-term residual effects, that is part of the total, you can have results in one, two or three years perhaps.

H. Tunney

The only comment I want to make is on the length of time of the experiment which is a very practical problem for most research workers launching experiments on animal manures. I certainly think there is a need to run the experiment for a number of years. When you apply slurry and then eight weeks later take a cut of grass, only a fraction of the nitrogen is taken out at this stage. Most of the organic nitrogen is still in the soil and is gradually mineralised. However, we find that twelve months after the slurry is applied there is a very noticeable effect of the slurry residual effects, which I assume is mostly from the nitrogen. As I say, it is important to run experiments for a number of years but it may be that residual effect is something that should be looked at separately.

J.H. Voorburg

Thank you Dr. Tunney. We must close this discussion session now.

FARMYARD MANURE AND CROP PRODUCTION IN DENMARK

A. Dam Kofoed
Director, Askov Experimental Station, Denmark

INTRODUCTION

In Denmark for many years the use of 20 - 30 t/ha solid farmyard manure and 10 - 15 t/ha liquid manure on root crop fields every third and fourth year has been common practice. The farmer returned plant nutrients with the organic manure to the crops which, following the experiments, showed the greatest ability to utilise that slowly released manure, and size of the herd kept depended on the amount of food grown in the field.

In recent years new methods of concentrated production have left some farms completely without organic manure and others with a surplus.

These procedures may give rise to problems in maintaining the productivity of the soils in question and too heavy application of manure might result in pollution of soil, surface waters and ground water. With regard to both the first and second possibilities,useful experiments have been carried out at Askov Experimental Station and I now have the honour to present some of the results.

VALUE OF ANIMAL MANURE

Content of plant nutrients

The value of animal manure depends primarily on its content of nitrogen, phosphorus and potassium, but the content of minor elements is also important. In recent years interest has also been shown in the content of some heavy metals.

From numerous analyses the content of different minerals in solid manure (FYM), in urine (liquid manure) and in a mixture of these (slurry) may be estimated as shown in Table 1.

TABLE 1

CONTENT OF DRY MATTER (DM) AND MINERALS (ELEMENTS) IN FYM, LIQUID MANURE AND SLURRY, kg/metric t. (AES, 1958 - 1975)

	Samp-les	DM	N	NH_4-N	P	K	Na	Ca	Mg
FYM	253	(200)	5.6	-	1.8	3.6	-	-	-
Liquid manure	218	-	3.8	-	-	6.7	-	-	-
Solid manure, pigs	15	245	7.6	3.3	3.7	4.5	-	-	-
Solid manure, poultry	21	461	22.0	4.5	7.6	10.4	-	-	-
Slurry, cattle	120	92	4.5	2.5	0.8	4.0	0.8	1.1	0.6
Slurry, pigs	21	68	6.8	4.8	1.6	2.7	1.1	1.6	0.5

AES = Askov Experimental Station

As an average, samples were taken after three months of storing.

Samples of FYM, slurry and liquid manure were analysed for content of some heavy metals as shown in Table 2.

TABLE 2

CONTENT OF HEAVY METALS IN FYM, SLURRY AND LIQUID MANURE, ppm OF DRY MATTER (DTU, 1972 - 1974, AES, 1975)

	Samp-les	Cd	Co	Cr	Cu	Mn	Ni	Pb	Zn
FYM	10	0-2	1-5	2-15	20-350	150-500	1-36	5-15	100-800
Liquid manure	10	0-1	1-2	1-3	2-40	20-350	1-5	5-15	10-100
Slurry, cattle	117	-	-	-	43	261	-	-	141
Slurry, pigs	21	-	-	-	265	442	-	-	853

DTU = Denmarks Technical University

Effect of plant nutrients

Classical Danish field experiments have made it possible to evaluate animal manure in terms of commercial N, P and K, based on the uptake in crops. The uptake was measured in four succeeding crops, as shown in Table 3.

TABLE 3

EFFECT OF ANIMAL MANURE AND NPK (AES, 1942). UPTAKE IN 4 CROPS, % IN SUPPLY

	FYM	NPK	Factor
Nitrogen	30	70	0.43
Phosphorus	24	22	1.09
Potassium	79	79	1.00

As a rule of thumb, when FYM is evaluated against NPK, the factors used are: 0.4 for N and 1.0 for P and K. With the help of these factors and the current price of commercial fertiliser, it is now possible to calculate a price per ton of manure, either on actual analyses or on the average contents mentioned in Table 1. An example is given in Table 4.

TABLE 4

EVALUATION OF 1 TON OF FYM, DKr. - March 1976

	%	Factor	kg/t	DKr/kg	DKr/t
Nitrogen (N)	0.56	0.4	2.2	3.36	7.39
Phosphorus (P)	0.18	1.0	1.8	7.78	14.00
Potassium (K)	0.36	1.0	3.6	1.50	5.40
Total					26.79

This value of 27 DKr. depends on a 100% utilisation of N, P and K. If one or more of the plant nutrients are fully supplied for previously the value has to be reduced relative to this.

As mentioned before, two alternatives are likely to arise as farming is rationalised away from the balanced rotation husbandry. Firstly, lack of animal manure in addition to the supply of organic matter supplied with roots and stubble, and secondly, surplus of animal manure in relation to the turnover ability of the surrounding area.

Lack of animal manure

The introduction of commercial fertilisers into Danish agriculture gave rise to many questions, among them that of maintaining the productivity of the soil by exclusive use of mineral fertiliser in which only inorganic salts are provided, whereas farmyard manure supplies organic materials also. The supply of organic material was thought to be important for maintaining the humus content and the structure of the soil.

The main purpose of the experiments established at Askov 1894 and still running, was to compare the value of mineral fertilisers (NPK) and animal manures (FYM). The same amounts of N, P and K are supplied in two treatments and compared to unmanured plots.

The experiments supply very important information about the humus content in the soils after the different long-term equivalent treatments on different plots.

Soil conditions

Askov loam field has a clay content increasing from 11% in the 0 - 20 cm top-soil to 24% in sub-soil 50 - 100 cm. The soil is drained down to 125 cm.

Askov sand field has rather fine sand with a clay content decreasing from 4% in 0 - 20 cm top-soil to 2% in the 50 - 100 cm sub-soil. About 2 m of this sand is overlying clay of the same type as in the loam field.

Figures 1 and 2 illustrate the average yield for the loam field and the sand field respectively during the period 1894 - 1972, the curves are based on averages for four successive years calculated by running means every two years. The dotted vertical lines for the years 1907, 1923, 1949 and 1972 indicate the years of changes in nutrient supply. Resulting from the method of calculation the curves begin in 1896 and end in 1970. The shape of the curves clearly shows the yield relations between FYM and NPK and indicate that to a great extent NPK has been able to maintain the productivity. One has to remember that in supplying the same amounts of N in FYM and NPK the latter has more effective nitrogen than the former, but as the curves are running parallel during the first three periods no depression following the NPK treatment has taken place.

During the period 1949 - 1972 some mineral N was given to the FYM treatment in order to even the differences between the two treatments.

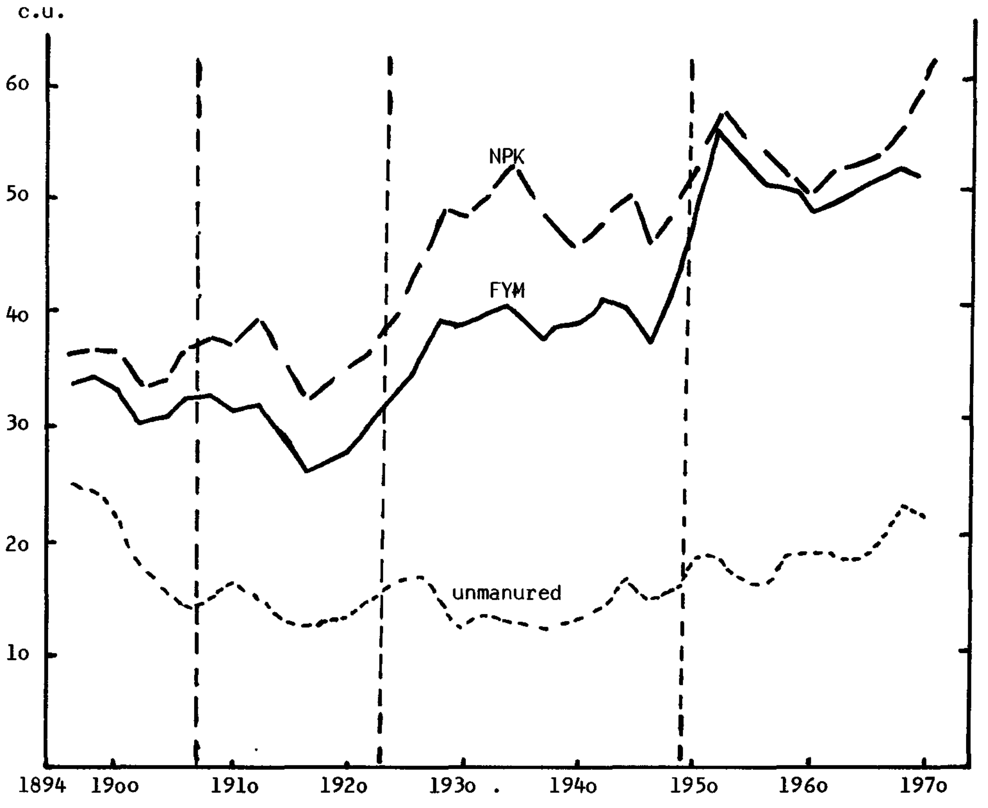

Fig. 1 Askov loam field 1894 - 1972. Average of yields, c.u./ha/year.

As illustrated in Figures 1 and 2, crop yields are higher after NPK than after FYM, but the difference is greater for the loam field than for the sand field. Generally one can say with confidence that productivity for these soils under Askov climatic conditions and with the rotations used has been well maintained by exclusive use of commercial fertilisers when supplied in quantities replacing the nutrients taken away by crops.

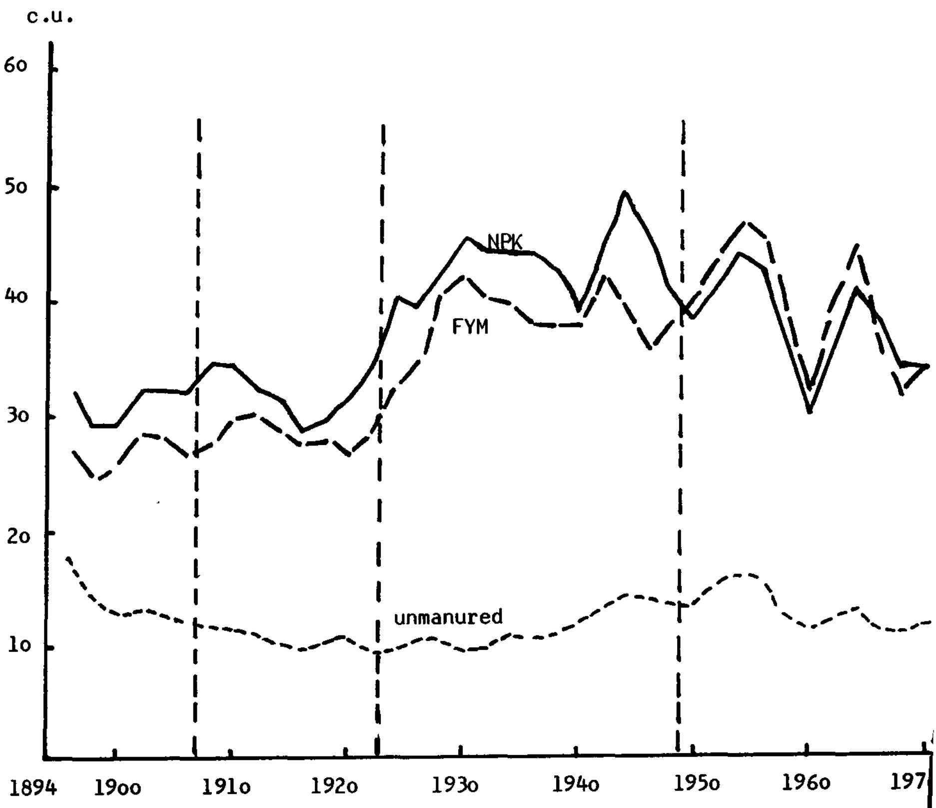

Fig. 2 Askov sand field 1894 - 1972. Average of yields, c.u./ha/year.

The changes in humus content over the years are illustrate in Figure 3 for the treatments: unmanured, FYM and NPK, in both fields. For comparison the figures back to 1923, when the firs samples were taken, have been included.

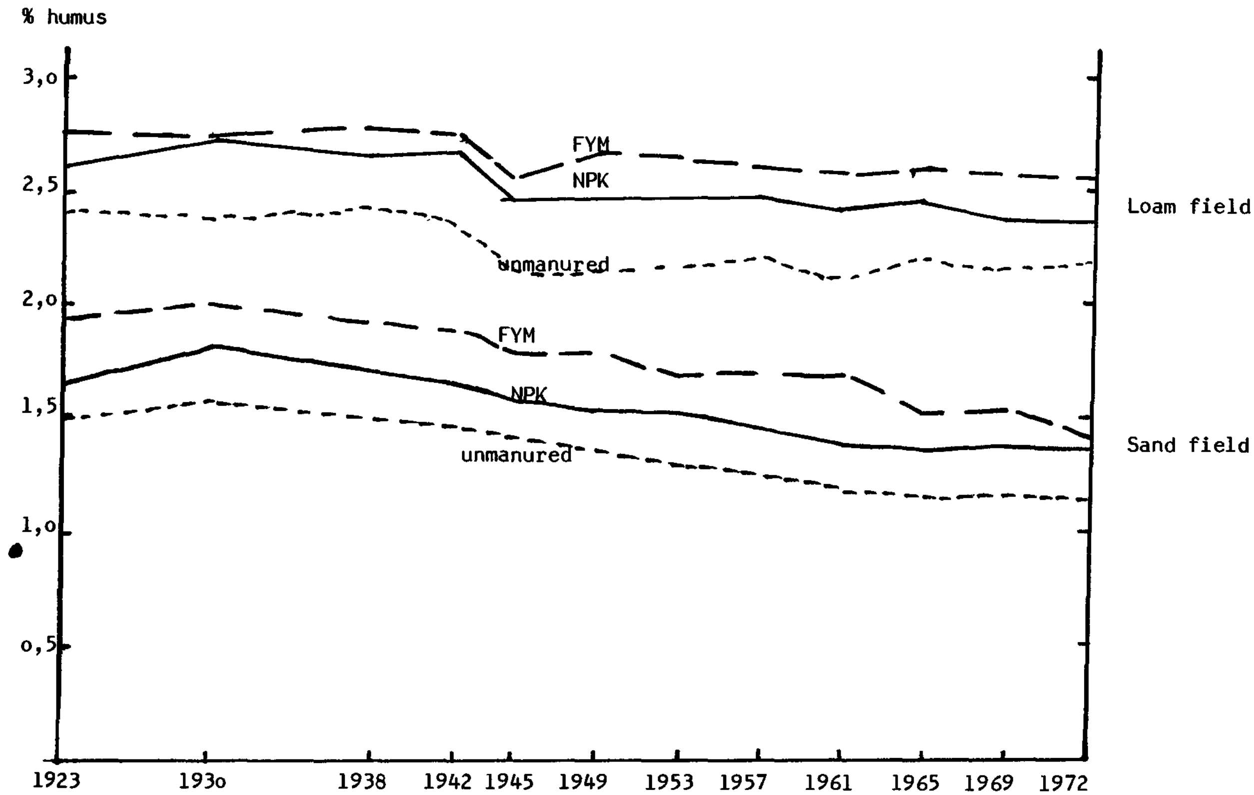

Fig. 3 The humus content in soil, 0 - 20 cm. Askov loam field and sand field 1923 - 1972, % C x 1.72

The curves indicate that the relative humus contents associated with the treatments have not changed since 1923. Therefore the decline in the humus levels during the years is probably not a result of increased mineralisation of humus. It is more likely to be dilution following, for example, the ploughing up of increasing amounts of subsoil into the topsoil from which the soil samples were taken. Apart from an increase in the amounts of fertiliser given, only minor changes have taken place during the years.

A comparison between the humus curves in Figure 3 and the yield curves in Figures 1 and 2, illustrates the decrease in N-effect of FYM.

SURPLUS OF ANIMAL MANURE

Information about the potential risks originating from high levels of application of animal manure is lacking and problems have been spotlighted in recent years.

In older experiments at Askov experimental station, an amount of up to 96 t/ha of manure has been applied every fourth year for a period of more than fifty years resulting in yield increases and, as far as it has been observed, giving no pollution risks.

At Askov experimental station in 1973 experiments on soil under heavy charge of animal manure were established on loam soil and in the following years also on sandy soil.

The aims of the experiments were to:

a) Throw light on the effect of animal manure on the yield and quality of crops and on the structure of soil and quality of surface water in relation to types of soil, charge of manure, types of manure, date and method of application, climate and crop.

b) Work out methods for handling animal manure, methods partly to satisfy the requirement for an abundant yield and a good quality of the feeds, and partly to reduce the potential risk of pollution as far as possible by setting maximum hectare rates of manure to be applied and indicating optimal periods for application, etc.

c) Carry out experiments in fields and lysimeters followed up by analyses of crop, soil, water and manure samples.

The experiments began in 1973 on loam soil and in 1974 on sandy soil. Up to 400 t/ha of FYM and slurry respectively given every fourth year is compared to application of up to 100 t/ha given every year and up to 200 t/ha given every second year. In two parallel sections the rotation used is: 1. root crop, 2. barley, 3. grass and 4. barley.

Besides the effect on yields, the effect on content of different plant nutrients in the soil is also investigated. Part of this investigation is dealt with in another paper presented to this seminar by Dr. Lindhard.

In Tables 5 and 6 preliminary yield figures are shown for loam soil and sandy soil respectively. The figures are increasing with increasing quantities of animal manure for all the years in question indicating an after effect of manure. As for the fertilising, some after effect is seen in the loam field whilst this is not the case in the sand field.

As an example, Table 7 gives the quantities of nitrogen, phosphorus and potash used for the loam field in 1973.

By comparison with the average use of plant nutrients in Denmark, about 170 kg/ha of N, 39 kg/ha of P and 108 kg/ha of K (figures 1973/1974), the application in these experiments is rather high.

TABLE 5

MANURE APPLIED IN INCREASING AMOUNTS FOR LOAM SOIL, ASKOV 1973 - 1975

	Yields of dry matter in beet, grain and grass, dt/ha							
	Beet 1973				Barley 1974		Ital. ryegrass 1975	
	FYM		Slurry		FYM	Slurry	FYM	Slurry
	Root	Tops	Root	Tops				
1 NPK every year	61.8	25.5	72.5	27.5	44.6	40.5	44.6	43.9
2 " " "	77.0	32.2	84.3	33.0	49.6	53.1	62.9	62.1
4 " " "	91.2	40.6	96.0	42.1	62.9	62.6	76.2	71.3
25 t manure every year	43.6	20.8	64.1	25.1	42.5	43.4	37.0	43.1
50 " " " "	51.3	23.6	70.3	27.9	51.7	53.5	48.0	55.2
100 " " " "	67.1	29.5	80.5	32.3	58.4	60.7	70.3	69.7
50 t manure every 2nd year*	52.6	25.5	65.7	26.3	26.8	26.1	43.7	50.5
100 " " " " "	62.9	28.5	72.1	30.2	29.8	29.1	65.5	64.6
200 " " " " "	67.7	29.6	83.6	37.7	39.5	37.9	85.1	82.1
100 t manure every 4th year**	62.1	28.2	79.4	31.0	31.5	31.7	30.6	25.3
200 " " " " "	68.3	28.9	87.0	34.5	40.0	37.8	35.4	31.4
400 " " " " "	76.6	32.7	89.1	33.1	51.3	50.7	47.8	42.5

*1973 and 1975 **1973

1 N given in NPK fertiliser equals 40 kg N for barley and 80 kg N for beet and grass

TABLE 6

MANURE APPLIED IN INCREASING AMOUNTS FOR SANDY SOIL, LUNDGARD 1974 and 1975

	Yields of dry matter in beet and grain, dt/ha					
	Beet 1974				Barley 1975	
	FYM		Slurry		FYM	Slurry
	Root	Tops	Root	Tops		
1 NPK every year	97.8	30.5	103.1	35.7	15.7	16.0
2 " " "	96.4	31.8	103.5	36.2	15.4	18.2
4 " " "	85.9	43.2	96.6	47.0	14.8	17.9
25 t manure every year	75.4	17.7	91.6	21.0	17.6	18.4
50 " " " "	104.6	27.4	126.7	37.1	19.5	17.4
100 " " " "	128.8	40.7	138.6	49.2	19.4	13.3
50 t manure every 2nd year (1974)	103.5	24.7	119.7	35.6	12.8	13.1
100 " " " " "	121.9	37.9	130.4	43.4	15.7	15.5
200 " " " " "	129.4	47.1	136.2	58.3	17.8	18.1
100 t manure every 4th year (1974)	118.0	37.3	134.8	51.9	15.3	15.5
200 " " " " "	134.6	49.2	133.8	56.9	19.6	17.1
400 " " " " "	133.7	53.9	128.6	58.9	22.4	20.1

1 N given in NPK fertiliser equals 40 kg N for barley and 80 kg N for beet

TABLE 7

QUANTITIES OF N, P AND K IN FERTILISER AND ANIMAL MANURE, 1973

	Nutrients, kg/ha							
	FYM experiment				Slurry experiment			
	N	NH_4N*	P	K	N	NH_4N	P	K
1 NPK	80	40	68	112	80	40	15	95
2 NPK	160	80	136	224	160	80	30	190
4 NPK	320	160	272	448	320	160	60	380
Manure t/ha								
25	151	40	68	112	108	64	15	95
50	302	80	136	224	216	128	30	190
100	604	160	272	448	432	256	60	380
200	1208	320	544	896	864	512	120	760
400	2416	640	1088	1792	1728	1024	240	1520

* Part of Column 'N'

The question of crop quality following the increasing use of animal manure now arises. As an example Table 8 shows the content of nitrate-N in beet and grass from the loam field experiment. The border of toxicity is often set at 0.2 - 0.4% NO_3-N of the dry material; many of the figures in Table 8 are quite near to this border.

CONCLUSION

The experiments mentioned here have an interest in the sense of economic husbandry concerning animal manure. The value of animal manure and commercial fertiliser estimated from the amount consumed in 1973 - 1974 and calculated on prices applicable in March 1976, is the following in million DKr:

	N	P	K	Total
Commercial Fertiliser	913	550	286	1749
Animal manure	136	374	220	730
Total	1049	924	506	2479

TABLE 8

CONTENT OF NO_3-N, % OF DRY MATTER, ASKOV 1973 AND 1975

	1. Beet 1973				3. Grass 1975	
	FYM		Slurry		FYM	Slurry
	Root	Tops	Root	Tops		
1 NPK every year	0.07	0.06	0.09	0.06	0.03	0.02
2 " " "	0.09	0.06	0.12	0.08	0.04	0.04
4 " " "	0.18	0.14	0.16	0.15	0.29	0.31
25 t manure every year	0.06	0.07	0.10	0.07	0.03	0.03
50 " " " "	0.07	0.08	0.10	0.10	0.02	0.03
100 " " " "	0.09	0.11	0.15	0.25	0.07	0.06
50 t manure every 2nd year	0.07	0.12	0.11	0.24	0.02	0.02
100 " " " " "	0.11	0.14	0.17	0.35	0.04	0.04
200 " " " " "	0.15	0.25	0.27	0.37	0.15	0.27
100 t manure every 4th year	0.12	0.19	0.17	0.27	0.02	0.02
200 " " " " "	0.17	0.23	0.34	0.59	0.02	0.02
400 " " " " "	0.23	0.29	0.43	0.74	0.02	0.02

The total value of the plant nutrient consumption in Denmark thus amounts to 2 479 million DKr. of which 730 million is from animal manure.

In older agricultural systems using no commercial fertiliser, or only small amounts, any loss of necessary plant nutrients had to be stopped, thus keeping the nutrient circulation as intact as possible.

Nowadays, the handling of solid and liquid spillings from intensive animal husbandry forms a considerable expense factor and with the possibility of making up for losses of nutrients from the field by application of commercial fertilisers the farmer has less interest in careful storing of solid and liquid manure and thus there is a potential risk of pollution of surface waters.

Buying feeds for the animals has released the owner of the stock from dependence on the land for crop production. This means that in such a system of animal production the animal manure tends to be a waste product, difficult to dispose of in an economic way. Such animal concentrations have existed for a long time in the USA and USSR but only to a very limited degree in Denmark except for poultry.

In 1969 Sweden made provision to control the handling of animal manure. This means that it must be distributed in an area large enough to ensure mineralising of the manure and uptake of the nutrients in plants.

Experience from Danish field experiments shows no problems in mineralisation of 40 - 60 t solid + 16 - 24 t liquid manure applied every fourth year for the root crop. Swedish experience states that not more than 20 - 30 t/ha of slurry ought to be applied per year in order to prevent damage to the environment.

A handling system for solid and liquid manure which gives the best utilisation of their plant nutrients at the same time may be the best security against a potential pollution of air and surface water. This means that animal manure must be incorporated in the soil soon after spreading and has to be spread in limited amounts and in the right season for the crops which are utilising the plant nutrients the best way.

Until now no economic alternative to the age-old method of utilising animal manure in the arable field has been discovered. This method may, with appropriate regard to the surroundings, continue to be used in the future.

The present agricultural structure in Denmark is the principal reason why the fertiliser problem is regarded as an agricultural problem. Little by little the non-agricultural population is becoming more aware of the nuisances from farms even though most Danes have a certain amount of knowledge about rural life and therefore some tolerance about smells and noise from it. Restrictions have to be expected in Denmark following the increasing awareness and concern of the public regarding the quality of the environment.

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CONSEQUENCES OF SEMI-LIQUID PIG MANURE SPREADING

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The spreading of semi-liquid pig manure on cultivated soils is not only the cheapest solution for disposing of the effluents of animal breeding, but also allows the recycling of important quantities of nutrients. This is, therefore, a good solution for the farmer with regard to the economy of fertilisers.

However, due to the growth of pig breeding and the structure of the farmholdings concerned, problems of the judicious limits of spreading semi-liquid pig manure arise in two different aspects: one agronomic (yield and quality of crops, fertility of soils), the other environmental (particularly the quality of waters).

Estimation of such limits can be made by two procedures. We have given preference to the experimental method but the global approach, as illustrated by Coppenet (1974 - 1975), although not producing immediate results, has already provided some answers to the problem.

EXPERIMENTS ON THE CONSEQUENCES OF SEMI-LIQUID PIG MANURE SPREADING

A number of research projects have been undertaken in several departments of the Centre de Recherches de Dijon.

Studies of situations (climate, type of soil, crops) with experiments on field scale

The first experimental design has been set up at present on an experimental farm, INRA. The crop is a fodder grass (red fescue, cultivar manade) fitted to utilise heavy dressings; the soil is a calcic brown soil. Three treatments are compared:

a) Usual mineral manuring

b) Fertilising by semi-liquid pig manure (non-diluted manure of fattening pigs), in such a quantity that it contains as much nitrogen as in mineral manure

c) Fertilising by a five-fold quantity of semi-liquid pig manure as in b).

A second experimental design, on the same principle, is going to be installed in the loamy soil of the Bresse. Two types of cultivation are envisaged: a temporary grassland and the usual crop rotation of the farm (barley, maize, maize, wheat).

Each plot of our experimental design has a device for collecting the drainage waters. In the first experiment two types of equipment were used. Although the textural homogeneity of the soil is correct throughout the profile, a scrutiny of that profile shows natural or man-made discontinuities (plough sole at top of B horizon) which induces free water in rainy periods, which are an indication of accumulation and even preferential circulation of water. Thus we have in that case set up:

a) Classical buried lysimeters filled up with reconstituted soil profile

b) Water gathering devices, six per plot, set out on each side of a pit under the undisturbed profile, at two different levels (the lower one at the limit between the soil and the underlying gravel layer, and the other at the level of cultivation). They are made of 'drawers', filled up with materials which are able to ensure a continuous circulation of waters.

The result obtained by comparing the two water gathering devices has a special interest, as the arrangement of the structural elements that determine the water circulation cannot be the same in the original and in the reconstituted soils.

We are studying the following parameters: yield and quality of crops, quality of drainage water, evolution of physical, physico-chemical and also biological properties of the soil (microflora and fauna).

A lysimeter study on the comparative behaviours of different types of soils (reconstituted soil profiles)

Four soils, very different in their permeability, have been studied. The experimental protocols are the same as those in the field scale.

A land drainage experiment

This is justified by the observations showing flows in the drainage system after spreading large amounts of semi-liquid pig manure. In addition to the direct pollution risks of the natural outlets, such a state of things sometimes produces the silting of drains following bacterial development. In this experiment we have to appreciate the effectiveness of the methods of soil cultivation affecting drainage (e.g. subsoiling), on the functioning of the soil as a purifying system.

The results obtained up until now, in all the experiments, are too limited to give details.

The climatic conditions of the year (1976), remarkable for high temperatures and great water deficiency (at Dijon, between 1st January and 31st August, rainfall was 252 mm, whilst cumulated potential evapotranspiration was 734 mm), made the trials management difficult. This is especially true for the field trial where crop establishment was poor and sampling of drainage water was only possible in a few instances.

The experiments on comparative behaviour of soils in lysimeters have been easier to carry out. However, the yields of fescue (on two cuttings) have not been separately identified for all treatments. Quantities of waters percolated under 85 cm depth are small, independently of soil type or treatment; because of their volume, concentrations of solutions are fairly high, but the quantities of transported elements are small.

BALANCE-SHEET STUDIES

Until the results of the agronomic experiment become available the approach given by Coppenet (1974, 1975) from whom we borrowed the following ideas, is of undeniable interest.

It seems reasonable to speak in terms of, 'balance-sheet of nutrients in an animal breeding farm'. That balance-sheet is relatively easy to establish in a case, for example, of a farm where the crop production is only used for pig fattening (piglets bought when weighing 30 kg and sold when weighing 100 kg). In this case the residues of crops go directly to the soil and gains of nutrients are represented by those contained in the feeds bought outside the farm. Losses come from the sale of animals and from elimination by drainage in the soil or volatilisation on the surface of the soil or in the stock vat.

Let us suppose that a farm uses the grains grown on one hectare of maize to fatten 35 pigs. The pigs are given additional feed as soya bean cake and mineral supplements. The balance-sheet of N, P_2O_5 and K_2O is shown in Table 1.

TABLE 1

BALANCE-SHEET (kg/ha) OF NUTRIENTS FOR A FARM PRODUCING 35 PIGS/ha FOR SLAUGHTER

	N	P_2O_5	K_2O
GAINS			
Soya bean cake (2 300 kg)	153	36	63
Mineral supplement		59	
LOSSES			
Sale of pigs (2.5 t)	60	24	12
Losses in drainage*	50	1	20
BALANCE-SHEET	+43**	+70	+31

* Evaluation from lysimeter observations in Quimper, the mean annual rainfall is about 1 089 mm.

**This figure does not take into account the losses of ammonia during the storage of semi-liquid pig manure. The balance-sheet of N is probably zero and even showing a slight deficit.

The spreading of semi-liquid pig manure produced by the 35 pigs provides a small enrichment in P_2O_5 and K_2O.

In the case of a farm which uses its own maize crop and is able to produce more than 35 pigs per year with additional outside purchases of feed, the positive balance of nutrients increases very rapidly. Consequently agricultural and environmental risks also increase. (Table 2)

TABLE 2

RELATION OF NUMBERS OF ANIMALS TO VOLUME OF UNDILUTED MANURE AND NUTRIENT GAINS

Pigs produced per year	Volume of undiluted manure m^3/year	Gains kg/ha/year		
		N	P_2O_5	K_2O
35	28	0	70	30
70	56	150	180	115
100	80	285	270	180
125	100	395	350	245

In a 'hors-sol' pig breeding situation, where pigs are fed only bought-in feed, the amount of nutrients in relation to the number of pigs is much larger; 125 pigs produced (100 m^3 of pig manure) correspond to 500 kg N, 400 kg P_2O_5, 300 kg K_2O.

The amount of supplied N is the first agronomic limit for spreading semi-liquid pig manure. It might be argued that this amount of N should not exceed the uptake of crops. However, some limiting factors have to be considered:

a) In some situations, especially grassland, large amounts of N may be retained temporarily

b) The possibility of N losses from the soil by denitrification, especially in anaerobic conditions and by organic matter fermentation

c) The applied N immediately available for plants is only in the proportion of about 50%.

Thus, 50 m^3/ha of pig manure spread during the month before sowing will be a good nitrogen fertiliser for maize (250 kg N with 150 kg in the mineral form). A farmer who fattens 'hors-sol' 70 pigs should have one hectare maize at his disposal for spreading the pig manure produced, and 14 hectare if he is feeding 1 000 pigs. With intensive grassland (rye grass or fescue) the amount of pig manure can be larger, for example, 75 m^3/ha divided into three or four spreadings, but there is a risk of burn on the grass during summer and grazing animals will less easily accept the herbage.

It is obvious that other agronomic risks cannot be dealt with in a similar manner, for example, salinity of soils which can occur in a limited soil layer following heavy dressings of pig manure with minimal cultivation, or long-term phytotoxicity of minor elements, Cu and Zn. Nevertheless, after the experience obtained on vineyard soils which have supported many treatments with Cu, we can admit that accidents on crops can occur when 600 kg/ha and more of Cu and Zn are spread (in a soil with pH = 6.0). That amount could be reached in about a century with the larger mineral feed supplements used nowadays (mineral supplement with 5% Cu and Zn).

A concern for the environment, especially the problem of quality of ground waters or superficial waters, also dictates limits to the spreading of semi-liquid pig manure. Nevertheless, it is difficult to determine, without experiments, the largest amount of manure which is tolerable in a given situation. Meanwhile, some recommendations are obvious, for example, since drainage is most critical during the rainy period in winter, we have to avoid a major pig manure spreading on bare soil because of its contribution of nitrates and soluble organic matter to the ground water.

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SLURRY UTILISATION ON THE DAIRY FARM

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INTRODUCTION

There are 3.2 million dairy cows in the United Kingdom (UK Dairy Facts and Figures, 1975) which produce about 25 million tonnes of manure annually during the housed winter period. The number of holdings with dairy cows has decreased by 20% in the past five years but the number of cows has slightly increased. The average herd size is forty-one with 10% of herds with more than 100 cows. Most of the larger herds are housed in cubicles with little or no bedding material and faeces, urine and some washing down water accumulate as a semi-liquid slurry.

Median values for the composition of cow slurry (MAFF, 1970) are given in Table 1.

TABLE 1

MEDIAN VALUES FOR COMPOSITION OF COW SLURRY

DM%	N	P	K
10.0	0.500	0.087	0.498

The values vary greatly from farm to farm depending on the degree of dilution and type of management. In calculating the fertiliser value of cow slurry applied to land in the spring it is assumed that 50% of the nitrogen and phosphorus and all the potassium is in a plant available form in the first year of application.

The potential of livestock wastes to pollute surface and ground waters is large, particularly when plant nutrients are supplied in excess of crop requirements. Most dairy enterprises are associated with sufficient land to spread manure at acceptable rates. Only 0.3% of the total are in a potentially difficult situation, in this respect, compared with 35% of poultry holdings (Richardson, 1976). In practice soil type, climate and management systems often dictate where and when slurry is spread. The provision of winter-long storage is expensive. Difficult soil and topographical conditions limit the area available to receive slurry. Even so, the rapid increase in the costs of inorganic fertilisers and stricter control of all sources of pollution is encouraging farmers to utilise slurry for crop production rather than to regard it solely as a problem of disposal.

MAXIMUM RATES OF SLURRY APPLICATION

The initial experiments at NIRD were designed to determine the maximum rates of slurry that could be applied to grassland. Between 0 and 550 t slurry ha^{-1} were applied to a short-term rye grass (*Lolium multiflorum*) ley in early spring. The effects on crop yields and the composition of the herbage, soil and land drainage water were monitored over a two-year period. More than 150 t slurry ha^{-1} smothered the sward and reduced herbage yields unless the slurry was incorporated into the soil in the spring or autumn following application and the area reseeded. Under these conditions high levels of potassium were recorded in the cut herbage (Table 2).

TABLE 2

EFFECT OF HEAVY SLURRY DRESSINGS ON THE MINERAL COMPOSITION OF GRASS AND FORAGE MAIZE

%	Rate of slurry* application (t ha^{-1}) 0		500	
	grass	maize	grass	maize
N	2.15	1.27	5.50	1.41
P	0.25	0.21	0.46	0.25
K	1.06	1.13	4.15	1.30
Mg	0.16	0.10	0.22	0.08

* Slurry at 15% DM contained 0.35% N, 0.12% P, 0.28% K on w/w of wet material basis.

In the second year satisfactory herbage yields, with acceptable mineral composition, were obtained without the addition of extra fertiliser.

Intensely reducing conditions under the heaviest slurry applications prevented nitrification for several weeks following application in spring (Burford et al., 1976). Up to 250 kg N ha^{-1} of nitrate accumulated in the soil profile during the summer and autumn. Drainage water in the winter contained as much as 60 mg Nl^{-1} but the BOD_5 did not exceed 5.5 mgl^{-1}. Because of the low winter rainfall only a small part ($<1\%$) of the nitrogen added to the plots in slurry entered the drainage waters. Concentrations of nitrous oxide in the soil atmosphere suggested that gaseous loss of nitrogen was significant where slurry was applied. In contrast, concentrations of nitrous oxide indicated only minor losses by denitrification when inorganic nitrogen was applied in late spring.

Heavy slurry applications had less effect on forage maize (Table 2) than on grassland (Pain and Phipps, 1974) but 500 t ha^{-1} incorporated into the land shortly before drilling delayed plant maturity and depressed dry matter yields.

Heavy dressings applied to grassland or maize ground in early spring as semi-sacrifice areas could provide a useful means of disposal under the particular soil and climatic conditions at NIRD. Loss of plant nutrients by leaching could increase the risk of water pollution in wetter areas. Plant nutrients are clearly supplied far in excess of crop requirements and only a small proportion of applied nitrogen and phosphorus is recovered in the crop.

SLURRY UTILISATION ON GRASSLAND

Conserved grassland

Cow slurry is not a balanced grassland fertiliser and can only be used effectively by supplementing with inorganic nitrogen.

An example of how this could be achieved, based on data from NIRD farms, for an intensive, all-grass dairy enterprise is given in Table 3.

TABLE 3

SLURRY UTILISATION FOR ALL-GRASS SYSTEM STOCKED AT 2.5 COW ha^{-1}

	20 ha grazing	20 ha silage	available from slurry (100 cows)	fertiliser for silage less NPK from slurry
N	350 kg ha^{-1} = 7000 kg	400 kg ha^{-1} = 8000 kg	2600 kg	5400 kg
P	15 kg ha^{-1} = 300 kg	50 kg ha^{-1} = 1000 kg	550 kg	450 kg
K	25 kg ha^{-1} = 500 kg	125 kg ha^{-1} = 2500 kg	3250 kg	0 kg
Cost	£1500	£2000		£1170

The winter-produced slurry contains sufficient potassium for all the associated grassland acreage but nitrogen for only 15 - 20%. To exploit fully the fertiliser value of slurry on grassland it is necessary to apply in aliquots in spring and after harvesting during the season. In practice crusting and settling during long-term storage can make it difficult to handle and spread slurry during spring and summer. Under dry conditions, a poor response of herbage dry matter to slurry nitrogen was obtained because the high fibre content of the material tended to smother the sward and delay growth (Table 4).
Better results were recorded when dilute slurry was applied in several aliquots (Appleton, 1976) but dilution can greatly increase the volume of material that has to be handled on the farm.

Grazed grassland

The herbage intake of cattle grazing pasture tainted by cow slurry may be reduced. Grazing trials with dairy young-stock have shown that the animals can detect very light applications for seven to eight weeks after application (Broom et al., 1975) (Table 5).

TABLE 4

EFFECTS OF INORGANIC N FERTILISER AND SPRING APPLIED COWS SLURRY ON HERBAGE DM YIELDS (t ha^{-1}) FROM PERMANENT PASTURE

Rate of slurry application (t ha^{-1})	Rate of N fertiliser application (kg ha^{-1})					
	0		150		300	
	conserved	grazed	conserved	grazed	conserved	grazed
0	5.0	6.5	6.5	6.1	8.2	6.8
30 (≡ 150 kg N ha^{-1})	7.0	5.6	7.0	7.0	8.8	7.1
60 (≡ 300 kg N ha^{-1})	6.3	5.6	7.4	6.9	8.8	7.2

TABLE 5

EFFECT OF SLURRY ON HERBAGE DM PRODUCTION AND ON AMOUNT REMOVED BY HEIFERS DURING 4 DAY GRAZING PERIODS

	Rate of slurry aplication (t/ha^{-1})				
	0	25	50	100	
Herbage DM available (t ha^{-1})	2.32	2.36	2.26	1.98	Grazing 1; 7 weeks after slurry aplication
Herbage DM removed (t ha^{-1})	2.20	1.69	1.39	0.89	
Herbage DM available (t ha^{-1})	1.89	2.43	2.61	3.00	Grazing 2; 13 weeks after slurry aplication
Herbage DM removed (t ha^{-1})	1.53	2.03	2.10	2.08	

TABLE 6

EFFECT OF INORGANIC N FERTILISER AND SLURRY ON DM YIELD (t ha^{-1}) OF FORAGE MAIZE

Rate of slurry* applications (t ha^{-1})	Rate of N fertiliser application (t ha^{-1})			
	0	40	80	120
0	13.1	15.1	15.6	15.2
35	14.0	15.5	16.2	16.0
70	14.9	15.8	16.0	16.5
105	15.1	15.6	15.0	14.7

* slurry at 14.4% DM contained 0.47% N, 0.14% P and 0.40% K.

Satisfactory animal intakes can be maintained by leaving sufficient time between spreading and grazing and by keeping stocking rates low. Under these conditions the grazing behaviour of the cattle is modified so that they are more selective in the choice of herbage (Pain et al., 1974). Alternatively, herbage rejection problems can be avoided by using machinery for the direct injection of slurry into soil. Trials have been carried out with commercially available machinery which was developed primarily for controlling odours by deep injection. Dairy cows grazed on paddocks which were either injected with slurry at 25 $t \cdot ha^{-1}$ (≡ 60 kg available N ha^{-1}) 10 cm deep eight weeks previously, or had slurry spread on the surface at the same rate and time, received ammonium nitrate at 60 kg N ha^{-1} as a control. (Pain,1976_1). Similar quantities of herbage were produced on each paddock. Animal intakes were similar when slurry was injected or inorganic fertiliser applied but reduced by 30% when slurry was spread on the surface.

A further constraint on the use of slurry on grazed grassland is the possibility of disease organisms contained in the material infecting healthy stock. To safeguard against this risk from salmonella bacteria, slurry should be stored for at least a month before spreading, because the number of organisms decline during storage (Jones, 1976). Research on the survival time of salmonella indicates that pasture should not be grazed for at least a month after spreading slurry (Taylor and Burrows, 1971).

SLURRY UTILISATION FOR FORAGE MAIZE

The amount of plant available nitrogen, phosphorus and potassium in the slurry from one dairy cow per winter was sufficient to grow the forage maize she required the following winter (Pain, 1976_2). Replacing inorganic fertiliser with slurry reduces production costs by over 20%. The quantities of nutrients contained in the slurry closely matched those removed by the maize crop, but the residual levels of phosphorus and potassium in the soil after maize harvest were sufficient to grow a following cereal crop with the addition of nitrogen fertiliser only. Loss of nitrogen from winter applications did not markedly affect yields because, under UK conditions, forage maize is not very responsive to nitrogen fertiliser (Phipps and Pain, 1975). Injecting slurry into a maize seed-bed two to three days before sowing, however, gave better yields than spreading on the surface and ploughing four to five weeks earlier.

Using a combination of spring applied slurry and inorganic nitrogen fertiliser gave higher yields of maize than either source of nutrient alone (Table 6). High rates of slurry and/or high rates of nitrogen fertiliser delayed the maturity of the crop and depressed yields. There was only a small effect on the mineral composition of the crop.

SLURRY UTILISATION FOR SPRING BARLEY

Factorially designed field trials have demonstrated the yield benefits that can be obtained by using slurry, or a combination of slurry and inorganic nitrogen fertiliser, for spring barley. Cow slurry was applied in late winter and incorporated into the soil during seed-bed preparations. Inorganic nitrogen fertiliser was applied as a top-dressing shortly after plant emergence. The main effects of the slurry was to increase grain yield, grain size and crude protein production per unit area (Tables 7 and 8). As with forage maize, high rates of slurry and/or nitrogen fertilisers tended to decrease grain yields. The highest crude protein content (15.8%), however, was recorded when the highest rates of slurry and nitrogen fertiliser were used. The levels of phosphorus, potassium and magnesium in the soil were still high in the slurry treated plots after harvest in the autumn. To see the residual effects of the slurry only, the inorganic nitrogen fertiliser treatments were reapplied to the plots in the second year. Even though grain yields were approximately half those recorded in the first year, the effects of the slurry were still evident especially where the highest rates were applied.

TABLE 7

EFFECT OF INORGANIC N FERTILISER AND SLURRY ON YIELD OF SPRING BARLEY GRAIN (AT 15% MOISTURE)

Rate of slurry application (t ha^{-1})	Rate of N fertiliser application (t ha^{-1}) 0	40	80	120
0	1.83	2.52	2.89	2.98
37.5	4.17	4.34	4.56	4.76
75.0	4.87	4.59	4.60	4.60
112.5	4.66	4.62	4.21	3.42

TABLE 8

EFFECT OF INORGANIC N FERTILISER AND SLURRY ON YIELD OF CRUDE PROTEIN (kg ha^{-1}) IN SPRING BARLEY GRAIN

Rate of slurry application (t ha^{-1})	Rate of N fertiliser application (t ha^{-1}) 0	40	80	120
0	218	298	392	422
37.5	492	579	610	693
70.0	623	601	627	665
112.5	617	660	629	514

FERTILISER VALUE OF MECHANICALLY SEPARATED COW SLURRY

There is little information on the fertiliser value of the liquid and fibre resulting from mechanical separation. An example of the composition of the products of mechanical separation is given in Table 9.

TABLE 9

COMPOSITION OF MECHANICALLY SEPARATED COW SLURRY

	Total kg t^{-1} fresh material					
	DM%	N	P	K	Mg	Output ratio liquid/fibre
Unseparated slurry	7.3	4.37	0.60	2.33	0.44	
Fibre	19.5	3.99	0.49	1.89	0.33	4.8
Liquid	4.4	4.41	0.74	2.90	0.48	

Values are given for total plant nutrients but preliminary evidence suggests that more of the nitrogen is in a plant available form in the liquid than in unseparated slurry.

Since separation produces a free-flowing, relatively homogeneous liquid which remains pumpable during long-term storage, there is the potential for much greater flexibility in the timing and rate of application. It is feasible, for example, to apply accurately a calculated volume of liquid to conserved grassland after each harvest to supplement inorganic nitrogen fertiliser. Preliminary trials at NIRD, where the liquid was used as a grassland fertiliser and the fibre for maize, have given promising results. An example of how separated materials could be utilised in a grass/maize cropping programme is given in Figure 1, and the potential cost benefits that could be achieved are shown in Figure 2.

The possibility of fortifying separated liquid with inorganic N to give a balanced compound fertiliser for grass is also being investigated.

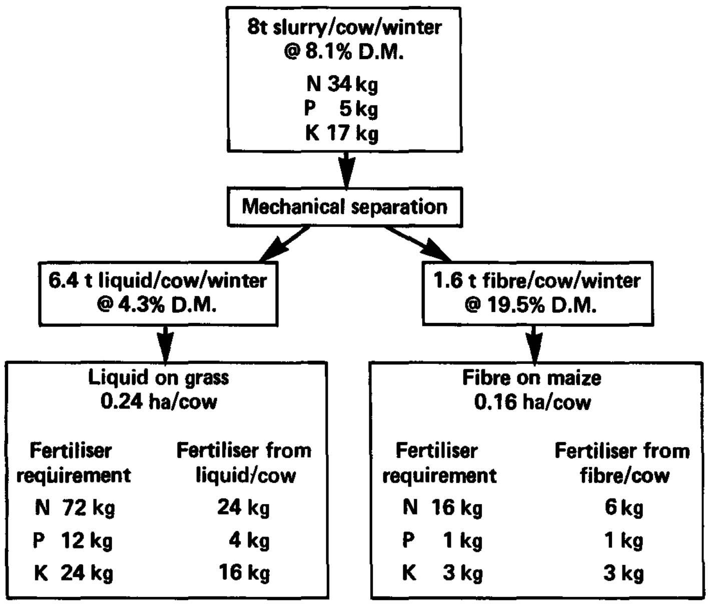
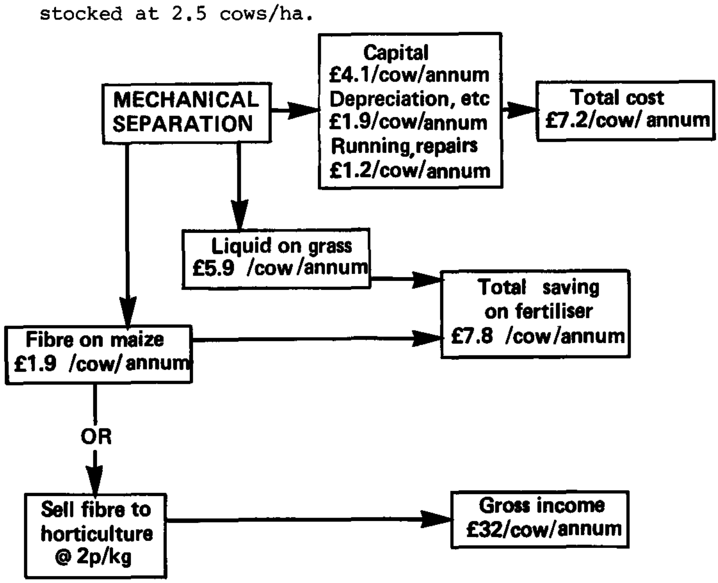


Fig. 1 Utilisation of separated cow slurry in a grass/ maize farming system stocked at 2.5 cows/ha.



Note
a. values based on 250 cow herd with capital cost of separator installation written off over 5 years
b. fertilizer value of liquid for grass and fibre for maize based on 1976 artificial fertilizer prices in UK

Fig 2. Cost benefits from using separated cow slurry.

ENERGY OUTPUT-INPUT RELATIONSHIPS

Apart from the cost benefits that can be achieved by replacing inorganic fertiliser by slurry on the dairy farm, appreciable savings in the energy input to crop production are also obtained. Calculations of energy involved in the production of forage maize at NIRD showed that the major inputs come from nitrogenous fertiliser and tractor fuel which represented 50% and 30% respectively, of the total inputs (Pain and Phipps, 1975) Replacing inorganic fertiliser by slurry reduced the energy input from 21442 MJ ha^{-1} to 9797 MJ ha^{-1} and improved the energy ratio $\left\{ \frac{\text{metabolisable energy output}}{\text{energy input}} \right\}$ from 4.8 to 10.5. The magnitude of savings that can be made on grassland are limited because slurry is not a balanced fertiliser for the crop and nitrogen fertiliser needs to be imported onto the farm. These type of calculations suggest that, in a maize/grass cropping system, it is more efficient to use winter produced slurry to grow maize and reserve the expensive, but more precise, inorganic fertilisers for grassland (Phipps and Pain, 1976).

FUTURE OBJECTIVES

The long-term objectives of research on livestock effluents at NIRD is to examine means of incorporating slurry into cropping programmes to replace or supplement inorganic fertilisers without endangering the purity of surface and ground waters. To this end, factorially designed experiments with combinations of inorganic fertiliser and cow slurry are being carried out to compare nutrient budgets and assess the long-term fertiliser value of slurry for grassland and forage maize. Further trials are being carried out with spring barley and lucerne. To provide meaningful results these type of experiments need to be carried out on different sites with contrasting soils and climates.

More information is also required on the effects of class of livestock, feed, management, type and period of storage on the composition of cattle slurry. The problem of accurately predicting the plant nutrient content of stored slurry and handling difficulties tend to discourage farmers from fully exploiting its fertiliser value at the present time. Techniques, such as mechanical separation, could help overcome these problems by providing materials of more predictable composition which are relatively easy to handle. Integrated systems of handling and utilising slurry need to be developed where savings in inorganic fertiliser usage can be set off against the machinery and storage required to simplify management problems.

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DISCUSSION

L.C.N. de la Lande Cremer *(The Netherlands)*

Dr. Dam Kofoed, I would like to have some information about the use of nitrogen in your long term fertilisation experiments with farmyard manure - what quantity of nitrogen you are giving and whether it is given yearly?

I also have a remark to Dr. Duthion. You mentioned losses of nitrogen and said that the losses are so great that you can ignore the effect of the nitrogen of pig slurry. I don't believe this. I calculate that with one appliction, in spring time about 70% nitrogen will remain in the slurry, and in autumn about 50%. If the application is repeated year after year on the same soil the nitrogen effect will be much greater after a number of years.

With regard to the accumulation of copper, you mentioned a delay of about 100 years or more. This is true for arable land but it will be much sooner for grassland. You have to take into account the upper layer, the first 2 - 5 cm. The first problems will arise for sheep with concentrations of 15 - 20 ppm of copper in the grass. It is not only a problem of copper in the soil but also a problem of copper on the grass, as opposed to in the grass.

Now the last speaker, Dr. Pain. Do you have any effects on the damage of your sward by using this implement for injecting slurries and what is the extent of this damage? Also, what is your recommendation for the maximum amount of slurry on grassland, using cattle or pig slurry? Did you apply the total amount of slurry on the maize in one amount or in different applications perhaps between autumn and spring?

I would like to make a comment both to Dr. Pain and Dr. Tunney. I have found with my own experiments on grassland that with the different kinds of animal manures, slurry and farmyard manures, there are injurious effects on grass production which can be physical or chemical. The higher the amount given, the lower the quality of the sward will be, and the grass will be less dense. The chemical effect is the loss of nitrogen by the volatilisation of the ammonia, already mentioned. However, there will also be a very rapid change in pH, especially with slurries and manures from poultry. With cattle and pig slurry there is not this effect on pH but there will be an accumulation of copper which may also be injurious to the grass.

J.H. Voorburg *(The Netherlands)*

Thank you very much. There is plenty of material to start the discussion. Firstly, I will ask Dr. Dam Kofoed to give his reactions.

A. Dam Kofoed *(Denmark)*

Thank you for your questions Dr. de la Lande Cremer. With regard to the first point about the amount of nitrogen applied: at present it is 400 kg overall; 100 kg for winter or spring, 225 kg for sugar beet; 75 kg for spring barley; zero for the clovergrass. Previously it was 280 kg as an average for four years and the relation between the different crops was as I have already mentioned.

J.H. Voorburg

Have you any comments on what Dr. de la Lande Cremer has said, Dr. Duthion?

C. Duthion *(France)*

No comment.

J.H. Voorburg

Dr. Pain?

B.F. Pain *(UK)*

With regard to your question on the effect of using the implement on the sward, there were some short term mechanical effects which tended to reduce grass yield. As you saw from the slide, the grass yield or the amount of herbage available, was lower on the injected plots than it was where the slurry was spread on the surface. So, yes, there was some mechanical damage.

On your second question about the maximum applications to grassland, I think we generally accept now that the rates of application to grassland should depend very much on the nutrient content of the slurry. It should be applied primarily as a source of P and, more particularly, K, with cattle slurry. In the trials we have done I would have thought we have applied something in the region of 30 - 40 t/ha/year.

L.C.N. de la Lande Cremer

At what level of dry matter?

B.F. Pain

Normally about 10%. Whether or not slurry is applied in one application or several depends very much on the experiment. In the first experiment I mentioned there was one application in mid-winter. The trials with separated liquid on grassland involved several applications during the season. In the forage maize and spring barley experiments the slurry was applied in a single application in the spring.

H. Tunney *(UK)*

I would like to make a comment on the questions from Dr. de la Lande Cremer and ask a question of Dr. Pain.

We have found in our work that after two years of applying pig slurry we get a small but highly significant increase in pH. I understand this hasn't been your experience?

L.C.N. de la Lande Cremer

In our experience there was a slow drop of the pH but it was not significant. This experience was over about 5 or 6 years. With the other manures we had an increase in pH from 4.4 to 8.0 over several years.

H. Tunney

We started with a pH of 6 and after two years it increased to 6.2. We had a lot of replications and it was highly significant.

Now, my question for Dr. Pain. Could you expand a little on the use of cattle slurry for grassland? I am not sure whether you mean grazing or land for conservation when you say 'grassland'. You mentioned a figure of 30 - 40 t/ha. If you are thinking in terms of grazing alone without cutting for conservation I would estimate that perhaps something in the region of 5 m^3/ha would supply adequate potassium for grazing. A very, very small quantity of slurry gives adequate potassium for a grazing situation.

B.F. Pain

In the relatively dry part of the country where we do our experiments we have a lot of difficulty in using slurry on grassland because of the smothering effect that we spoke about earlier. We have found that more than 30 t/ha with a DM between 10 and 12% will reduce the amount of grass per unit area. Very often it will increase the height of the sward but it certainly depresses the weight of the grass per unit area. The other problem in talking about very low applications, such as 5 t/ha, is how do you spread that amount in farming practice. There is no machine to do it unless, of course, you intend to separate the slurry first, in which case you may well be able to get down to those low rates of application. In that particular instance I was talking about land solely for conservation.

P. Graffin *(EEC)*

Dr. Pain, is it possible to have a further explanation for your balance of nitrogen in the case of very low losses in mid-winter? There will be low rainfall in that case and at the time of rainfall is there, or is there not, a higher loss of nitrogen?

B.F. Pain

Again, I must make the excuse that we operate in a very dry area. To do this experiment we constructed special plots which we isolated from the surrounding land by cutting a deep trench down to the base clay and lining the trench with polythene sheets, subsequently installing land drains inside the isolated plot of land. We had these plots for four years and during that time we never had sufficient rain to get a significant flow of land drainage waters to be able to answer the question you have just posed.

<u>A.V. Dodd</u> *(Ireland)*

Dr. Pain, in your experiments where you laid down the heavy dressings of cattle slurry, did you bother to check whether or not there were any nutrients of COD manifested in surface run-off?

<u>B.F. Pain</u>

We had no significant surface run-off that we could see. It was a very flat experimental site.

<u>J.H. Voorburg</u>

Later on there will be further discussions on run-off I suppose.

<u>J.H.A.M. Steenvoorden</u> *(The Netherlands)*

I have a question for Dr. Pain. What denitrification did did you measure, did you have something in micrograms per litre of soil per day? During what time did you measure it, by what technique, and how? Was it as nitrogen gas?

<u>B.F. Pain</u>

I should perhaps mention that the work on denitrification was carried out by my colleagues at Reading University which is why I only mentioned it briefly. The work is published and I have one or two reprints with me if you would like to have one. It would take me a little while to describe precisely how we did it.

<u>J.H.A.M. Steenvoorden</u>

Thank you. I have a question for Dr. Duthion concerning Table 1 in his paper. He gives a table with gains and losses of nitrogen but I wonder why he has not included denitrification. Also, he has measured losses in the drainage water and he gives rainfall intensity but does he know the evapotranspiration or the drainage water quantity? I think that is more important to know about than the concentration.

<u>B.F. Pain</u>

May I just add a point? We have found that the problem is that it is exceedingly difficult to quantify the denitrification. We have detected the occurrence of it by measuring the concentrations of N_2O in the soil over a period of time but we were never able to quantify the amount of denitrification which occurred. This probably explains why it is missing from Dr. Duthion's balance sheet.

<u>C. Duthion</u>

I have no evaluation of the denitrification. I think that the balance sheet is nearly equilibrated for nitrogen; for this reason I don't know the quantity of nitrogen which is denitrified.

<u>J.H.A.M. Steenvoorden</u>

Do you know something about evapotranspiration because you only give rainfall?

<u>C. Duthion</u>

We have only drainage figures, but no data on evapotranspiration.

<u>J.H.A.M. Steenvoorden</u>

The phosphate shown in Table 1, is that total phosphate or orthophosphate?

<u>C. Duthion</u>

Orthophosphate.

<u>G. Steffens</u> *(West Germany)*

Dr. Pain, you said that a high rate of nitrogen fertiliser delays the maturity of the crop and depresses growth. Did you make a distinction in your experiments between the yield of cobs and the rest of the plant? We have only short term experiments but we suppose that with increasing N dressings the yield of the cobs increases. I mean that the cobs are also very important for the quality of forage maize.

B.F. Pain

The answer is yes, we did distinguish between the cobs and the stover; with increasing amounts of slurry and/or nitrogen there was a decrease in the proportion of cob in the whole plant.

G. Steffens

Can you give percentages?

B.F. Pain

I can't offhand. I think normally we were thinking of 60% cob - if you think in terms of dry matter yield - 60% cob, and that would reduce by between 10 and 15%.

J.R. O'Callaghan *(UK)*

I would like to make a comment on the question of nitrogen balance. I think the papers we have had have raised more questions for me than answers because it is extremely difficult to get the balance. Sometimes terms are left out of the balance and you are left with only half the information. I would like to ask, Mr. Chairman, whether an opportunity could be made some time during the Seminar for us to discuss how we might measure a nitrogen balance and get a basis for it.

J.H. Voorburg.

Has anybody any suggestions about a suitable time and place to discuss this problem?

Anon

It is certainly very important.

A. Cottenie *(Belgium)*

At the end we have our sessions on methodology.

J.H. Voorburg

May I have a comment from Dr. van Dijk, will there be enough time?

<u>H. van Dijk</u> *(The Netherlands)*

I don't know, perhaps on Friday afternoon.

<u>P. Graffin</u>

In my opinion it would be useful to do it before then in connection with landspreading and water pollution - nitrogen balance is very important for water pollution considerations.

<u>J.H. Voorburg</u>

Maybe we can find an opportunity when we discuss the topics of landspreading and pollution of ground water and soil.

If there are no more questions on this morning's papers we will close this session now.

EFFECT OF RATE OF APPLICATION OF ORGANIC AND INORGANIC NITROGEN ON CROP PRODUCTION AND QUALITY

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INTRODUCTION

The consumption of concentrated feeds by Dutch cattle operations has increased considerably since 1950. Furthermore, on the mixed farms in the sandy areas of The Netherlands, considerable expansion and concentration took place of housed livestock enterprises which are not dependent on land (pigs, poultry, feeder cattle, etc.). This resulted in a situation in which more nutrients are produced in manure than can be utilised by crops grown on or around these enterprises. There is a surplus of manure which must be removed from these farms and areas on the basis of agricultural and ecological considerations.

During the same period new systems were developed for manure collection and storage. Mixed storage as slurry, being cheaper and requiring less labour, replaced separate storage of solid and liquid fractions. However, an important disadvantage of the slurry system is its bulkiness resulting from uncontrolled dilution with water (drinking water, wash-water, precipitation). Slurry is, therefore, per unit of volume, less valuable than solid manure, which in turn means that slurry can only be economically utilised within short distances from the site of its production. This makes disposal of surpluses difficult and can lead to excess applications on available land. Some consequences of excess rates of manure application on yield and quality of field crops will be discussed below.

NITROGEN IN ORGANIC MANURE

In terms of permissible amounts of manure, nitrogen is by far the most common factor that limits yield and quality of field crops.

In organic manure, nitrogen is present both in inorganic and organic form. The former is immediately available to the crop, the latter must first be mineralised. About 50% of the organic fraction can be expected to be mineralised already in the year of application (Sluijsmans and Kolenbrander, 1976). The other half, more difficult to decompose, will be transformed in the course of subsequent years. Thus, organic manures usually have a greater or lesser residual effect (Table 1).

TABLE 1

RESIDUAL EFFECT ON WINTER WHEAT, UNFERTILISED IN 1974, OF CATTLE AND POULTRY SLURRY APPLIED IN THE AUTUMN OF 1972

Type of manure	Quantity autumn '72, t/ha	Additional yield as %-age of unmanured
Cattle slurry	50	13
	100	25
	150	27
Poultry slurry	20	15
	40	23
	60	37

Preceding crop in 1973: potatoes. Soil type: clay, 55% particles <16 μm

Grain yield, unfertilised: 5768 kg/ha for cattle slurry,
5545 kg/ha for poultry slurry.

When organic manures are used only once every three or four years on the same field, their residual effect is usually not taken into account. However, where surpluses exist large amounts of organic manure will be used annually on the same field; a store of nitrogen will be built up in the soil which will gradually become available to the crop. If it is not taken up it will be lost by leaching. The residual effects will increase until an equilibrium has been reached between N input via manure and output through uptake by crops and losses. If these residual effects are ignored, one may be faced with undesirable effects of excessive nitrogen levels on yield and quality of crops and/or losses to the environment. In cereals a level which is too high will become evident first in the form of an increasing sensitivity to lodging. In root crops, yield reductions as well as quality deterioration may be the result. The nitrate content of fodder crops may become undesirably high for cattle.

Table 2 shows the accumulation of available nitrogen in the profile of a sandy soil following application of different amounts of cattle slurry to maize during three years.

TABLE 2

AMOUNTS OF RESIDUAL PLANT-AVAILABLE NITROGEN IN A SANDY SOIL (0 - 80 cm) IN kg/ha FOLLOWING APPLICATION OF DIFFERENT AMOUNTS OF CATTLE SLURRY ON MAIZE

	Amount of cattle slurry, t/ha/yr		
	50	200	300
9-10-1973	117	186	240
31-10-1974	167	269	352

The amounts of available nitrogen shown above were found in the soil after the maize had been harvested in the autumn! A part of this nitrogen may remain in the soil for utilisation by crops in the following year, but, depending on weather conditions, another important part may be lost to the environment during winter.

EFFECT OF ANIMAL MANURES AND FERTILISERS ON SOME QUALITY CHARACTERISTICS OF POTATOES

The underwater weight (u.w.w.) of a given quantity (here 5 kg) of potatoes is a measure of the specific gravity, which in turn is correlated with dry matter and starch content. The u.w.w. is especially important to growers of industrial starch potatoes, who are paid on the basis of u.w.w. Figure 1 shows the effect of application of fertiliser nitrogen, nitrogen contained in cattle slurry and poultry slurry, and combinations of inorganic and organic nitrogen on the underwater weight of ware potatoes grown on a clay soil containing 55% particles <16 µm. The amounts of inorganic nitrogen ranged from 0 to 200 kg/ha, of poultry slurry from 0 to 60 t/ha, and of cattle slurry from 0 to 160 t/ha. The organic manure was applied in the preceding autumn.

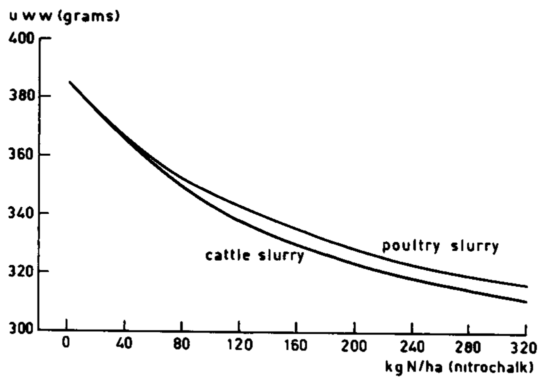

Fig. 1 Effect of applications of nitrogen, cattle slurry and poultry slurry on underwater weight (u.w.w.) of 5 kg ware potatoes, var.Bintje,1973

A very close correlation was found, regardless of the N source; therefore no separate data points are shown in the figure. There is a slight difference between the two types of organic manure with respect to their effect on the u.w.w.

In that experimental year (1973) no investigation was yet made on the amount of plant-available (= nitrate) nitrogen present in the profile. Hence no relation can be shown here between the amount of soil nitrogen added to the fertiliser applied and yield of potatoes. A number of other experiments clearly demonstrates the presence of such a relationship (Figure 2). In 1973, for instance, it was apparent that on a loam soil (29% particles <16 µm) a total of about 280 to 300 kg available soil N plus fertiliser N was needed to obtain the maximum yield. In 1974 on a similar soil at a lower yield level, 220 kg sufficed. Furthermore, in 1973 the yield level was lower for fertiliser and cattle slurry than for farmyard manure and poultry slurry, while the amount of available soil N present in spring was the same. Thus, although a clear relationship exists, it is not yet possible to predict with certainty how much available nitrogen is needed in a given year to obtain maximum production.

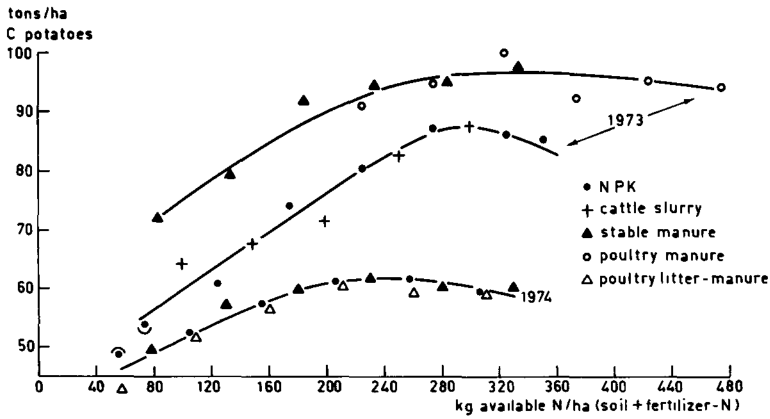

Fig. 2 Relationship between available nitrogen in soil (0 - 60 cm) in spring plus fertiliser N and the yield of ware potatoes in 1973 and 1974. Loam soil (29% particles <16 μm)

It should be noted that the peak of the yield curve for the lower level is so broad, that a few dozen kilograms of nitrogen in excess of need would only cause a limited reduction in yield (Figure 2). However, the dry matter and starch contents would be distinctly reduced by such an excess! (Figure 1)

In Tables 3 and 4 several other quality characteristics of potatoes are reported, determined after the experiment with cattle and poultry slurry mentioned earlier.

The sensitivity to blackening was slight and became still less following a heavier (inorganic nitrogen) fertilisation.

Boiling quality improved with increasing organic and inorganic nitrogen application. However, potato texture changed from floury to firm to somewhat wet. The tubers did not turn grey, and taste and flavour were good regardless of types and amounts of manure used. For the preparation of chips and French fried potatoes, colour of the chip is an important

TABLE 3

QUALITY OF POTATOES (VAR. BINTJE) IN A TRIAL WITH CATTLE SLURRY

	N application (kg N/ha) as nitrochalk					
	0	40	80	120	160	200
RATING FOR BLACKENING (< 10 = good)						
Fertiliser	2.3	0.5	-	0.0	-	0.0
Cattle slurry 50 t/ha	1.2	0.5	-	0.7	-	0.3
" " 100 "	1.2	1.7	-	1.0	-	0.0
" " 150 "	0.0	0.3	-	0.0	-	0.3
BOILING TEST (1 = firm; 5 = broken; f = floury; fi = firm; sw = somewhat wet)						
Fertiliser	3-f	4-f	2-fi	2-fi	2-fi	1-fi
Cattle slurry 50 t/ha	2-fi	1-fi	2-fi	2-fi	2-fi	1-fi
" " 100 "	2-fi	2-fi	1-fi	1-fi	2-fi	1-sw
" " 150 "	2-fi	2-fi	3-fi	2-fi	2-fi	3-f
CHIP COLOUR (1 = dark brown; 9 = yellow; <5½ = unacceptable)						
Fertiliser	5	4	5	5	5	4
Cattle slurry 50 t/ha	5	5	5	5	5	5
" " 100 "	5	5	4	4	4	4
" " 150 "	5	5	5	4	3	3
SCAB (Scale 1 - 10; 10 = good)						
Fertiliser	7.7	8.3	8.5	8.7	8.7	8.2
Cattle slurry 50 t/ha	8.7	8.3	8.5	8.5	8.5	7.7
" " 100 "	8.5	8.2	8.5	8.7	8.7	8.3
" " 150 "	8.7	8.8	8.8	8.5	8.8	9.0

TABLE 4

QUALITY OF POTATOES (VAR. BINTJE) IN A TRIAL WITH POULTRY SLURRY

	N application (kg N/ha) as nitrochalk					
	0	40	80	120	160	200
RATING FOR BLACKENING (<10 = good)						
Fertiliser	0.5	0.5	-	0.7	-	0.0
Poultry slurry 20 t/ha	2.8	0.8	-	0.2	-	0.3
" " 40 "	0.5	0.0	-	0.0	-	0.0
" " 60 "	0.8	0.3	-	1.0	-	0.3
BOILING TEST (1 = firm; 5 = broken; f = floury; fi = firm; sw = somewhat wet; sf = somewhat floury)						
Fertiliser	3-sf	2-fi	2-fi	3-fi	2-fi	1-sw
Poultry slurry 20 t/ha	2-fi	3-fi	2-fi	2-fi	2-fi	2-sw
" " 40 "	2-fi	2-fi	2-fi	1-sw	2-sw	1-sw
" " 60 "	2-sf	3-fi	2-fi	2-fi	1-fi	1-sw
CHIP COLOUR (1 = dark brown; 9 = yellow; <5½ = unacceptable)						
Fertiliser	5	5	5	4	5	5
Poultry slurry 20 t/ha	6	5	5	5	5	5
" " 40 "	5	5	5	5	5	3
" " 60 "	6	5	5	6	5	4
SCAB (Scale 1 - 10; 10 = good)						
Fertiliser	8.5	8.5	8.3	8.3	8.5	8.2
Poultry slurry 20 t/ha	7.7	7.7	8.5	8.5	8.7	8.8
" " 40 "	8.2	8.2	8.3	8.5	8.7	8.3
" " 60 "	8.0	8.0	8.3	8.2	8.0	8.8

aspect of quality. A rating lower than 5½ is unacceptable. For all treatments in this trial, including the check, chip colour was insufficient. Probably the rather immature polder soil contained so much available nitrogen that the unfertilised potatoes also could not meet this quality requirement.

The incidence of scab was slight, there was hardly any effect of fertilisation. There was slightly less scab in the heaviest treatments. Tuber shape was good and was even somewhat better at the higher levels of manure combinations.

The keeping quality of 20 kg lots of potatoes, obtained from a trial in which since 1971 increasing amounts of pig slurry in combination with mineral nitrogen had been applied, was tested in cold storage in the autumn of 1975. After at least five months of storage weight losses and numbers of rotten tubers were noted (Table 5).

TABLE 5

LOSSES IN WEIGHT AS A PERCENTAGE OF THE INITIAL WEIGHT AND NUMBERS OF ROTTEN TUBERS IN A STORAGE TRIAL WITH WARE POTATOES (14-10-1975 to 22-3-1976)

Fertiliser treatments kg/ha			Pig slurry treatments t/ha			
N	1PK*	2PK*	40sp**	80 au**	80 sp**	160 au**
WEIGHT LOSS %						
0	-	9.3	6.5	8.1	6.7	8.0
100	-	-	5.8	6.0	5.9	6.3
280	6.5	6.3	-	-	-	-
NUMBER OF ROTTEN TUBERS						
0	-	7	5	8	3	12
100	-	-	3	3	1	8
280	3	4	-	-	-	-

* 140 P_2O_5 and 140 K_2O; 280 P_2O_5 and 280 K_2O, kg/ha

**sp = applied in spring; au = applied in autumn

The weight losses were found to have risen with increasing amounts of pig slurry from 6.5% to 8%. When the slurry applications were combined with 100 and 280 kg inorganic nitrogen, the losses for all quantities of slurry did not exceed about 6%. Also the number of rotten tubers was lower when organic and inorganic applications were combined.

EFFECT OF ANIMAL MANURES AND FERTILISERS ON SOME QUALITY CHARACTERISTICS OF SUGAR BEETS

The content of amino N in the juice of sugar beets is one of the criteria used by the sugar refinery for the extractability of the sugar. As this content increases it becomes more difficult to obtain pure sugar, while greater losses occur, ending up in the molasses. About 200 mg amino N per 100 g sugar is considered the maximum acceptable amount. The amount of amino N is related to the sum of the available nitrogen present in the soil(to 60 cm) in spring and the amount of fertiliser nitrogen applied (Figure 3). The data are from a trial with poultry slurry (0 - 60 t/ha) in combination with fertiliser nitrogen (0 - 200 kg/ha) on a clay soil (55% particles <16 µm). The content of amino N (mg) corresponds in this case to 12.5 x the amount of available N (kg).

As the content of amino N in beet juice increases, the sugar content decreases (Figure 4). Although a clear relationship exists regardless of the N source (soil, animal manure or fertiliser), considerable scatter around the mean is evident ($\pm$ 0.4% sugar). The two outer lines in this figure constitute the limits within which 96% of the 144 individual observations made in this trial occur regularly.

Figure 5 shows the relation between the amount of available soil plus fertiliser N in spring and yield of sugar. In 1975 the maximum sugar yield was obtained with about 220 kg available N in spring. According to Figure 3 this corresponds to an amino N content of 274 mg, which according to Figure 5 corresponds to a sugar content of 16.94% (possible range 16.54% to 17.34%).

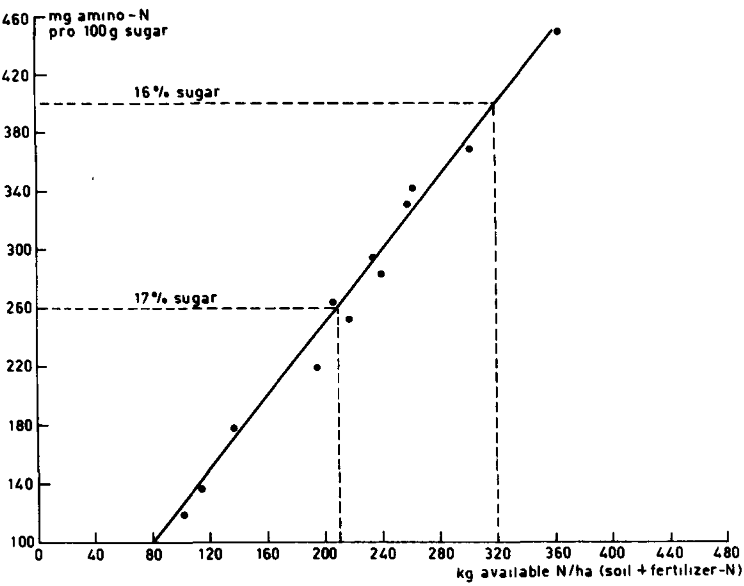

Fig. 3 Relationship between available nitrogen in soil (0 - 60 cm) in spring plus fertiliser N and the content of amino N in juice of sugar beets. Experiment with poultry slurry on clay soil (55% particles <16 μm).

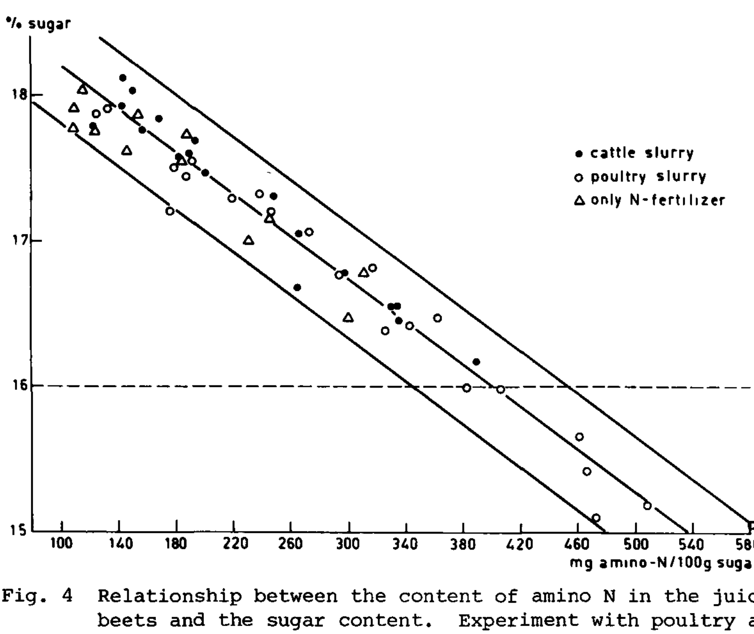

Fig. 4 Relationship between the content of amino N in the juice of sugar beets and the sugar content. Experiment with poultry and cattle slurry on clay soil (55% particles <16 μm).

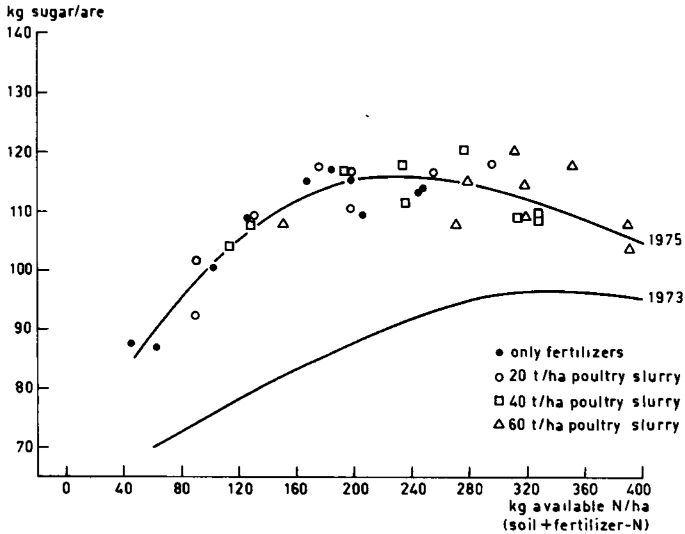

Fig. 5 Relationship between available nitrogen in soil (0 - 60 cm) in spring plus fertiliser N and the yield of sugar. Experiment with poultry slurry on clay soil (55% particles <16 μm).

The content of amino N is considerably higher than the 200 mg considered acceptable by the refining industries. If we take this value as the limit, then at most 160 kg of soil plus fertiliser N should have been available in the spring of 1975. This quantity corresponds to a sugar yield of 97% of the maximum production obtained in that year (Figure 5).

Although a rather close correlation exists between the content of amino N in beet juice and the sugar content in a given year and on a given trial field, considerable differences in response occur between years and trials (Figure 6). As long as these differences cannot be explained, it will be impossible to establish N fertiliser recommendations on the basis of soil analysis that will be acceptable both to the growers of sugar beets and the beet processing industry!

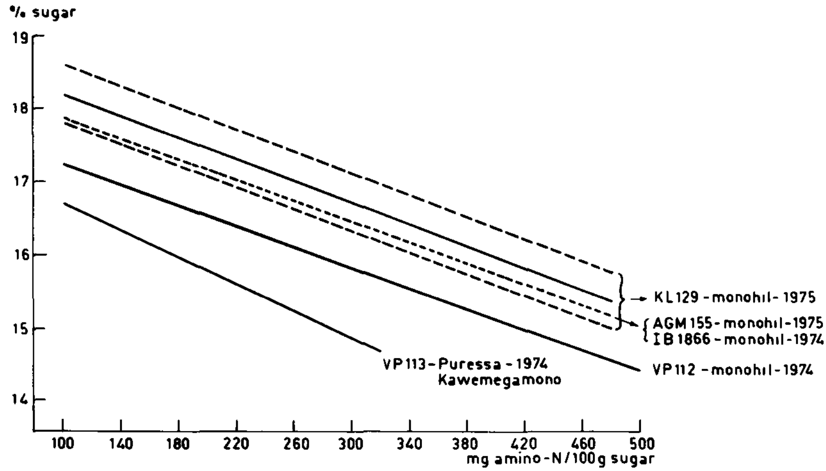

Fig. 6 Relationship between the content of amino N in juice and the sugar content of different varieties of sugar beets grown on different soils, in different years and with different nitrogen fertilisers (organic and inorganic).

SUMMARY AND CONCLUSIONS

Annual applications of considerable amounts of animal manure to the same field may give rise to a large accumulation of plant available nitrogen in the soil. Part of any unused surplus will disappear at the end of the growing season. If this store of nitrogen is disregarded in the calculation of the necessary amount of fertiliser, yield and quality of crops will suffer. Various quality characteristics of potatoes and sugar beets have been found to be related to the amount of available soil N present in spring and the fertiliser applied. In principle, two possibilities exist to prevent excess applications of animal manure. The first consists in gradually assuming higher nitrogen-effectiveness coefficients (= effect relative to mineral nitrogen) for the nitrogen contained in animal manure; in doing so the cumulative residual effect of this nitrogen is taken into account (Sluijsmans and Kolenbrander, 1976). The second method consists in determining the amount of available N in the soil profile before the start of the growing season; the amount of additional nitrogen needed in the form of fertiliser is then calculated. Yield and quality of crops from the same trial and grown in the same year have been found to be well correlated with the amount of available N, regardless of its source (soil, fertiliser, organic manure). As far as quality aspects are concerned, considerable variation between trials and years exists, so far making practical application of the correlation impossible!

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EFFICIENT RECYCLING OF NUTRIENTS

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There have been marked changes in agriculture and agricultural practices this century and especially during the past forty years. The objective has been greater and more efficient output of both crop and animal products.

Northern Ireland agriculture has a tradition of livestock production arising mainly from the influence of climate and farm structure. The moist climate restricts tillage and harvesting operations and at present only 10% of the agricultural land is under arable crops. The mean size of farm holding is small and although it has increased considerably in recent years is still only 22 ha. To augment income on such holdings, the farmer often keeps pigs and/or poultry as well as cattle and sheep. Population movements and mechanisation may also have tended to restrict the area under cultivation.

A further consequence of the humid climate, is that to avoid severe damage to swards and soils by poaching, most of the cattle population is housed during the winter months. Consequently large quantities of livestock excreta have to be collected and disposed of with the attendant risks of public nuisance and possible pollution.

The stocking intensity in the province is at present approximately 1.65 dairy cow equivalents per hectare of agricultural land. As illustrated in Figure 1, this is mainly the result of a steady increase in the cattle population which has approximately doubled since 1939. During this period there have been large fluctuations in the pig and poultry populations arising mainly as a result of variation in market demands. While the latter stock are largely dependent upon imported feeding stuffs, the large increase in cattle has been accompanied by greatly increased output from grassland. This is reflected in the use of fertilisers during this period as shown in Table 1. Prior to 1940, most of the fertiliser was applied to arable crops especially potatoes but now grassland receives a very large proportion of the total amount used. This partly accounts for the change in the $N:P_2O_5:K_2O$ ratio from 1:2-3:1 in 1938-58 to 2-3 : 1:1 from 1968. These data also show that the use of P and K fertilisers has levelled off since 1963.

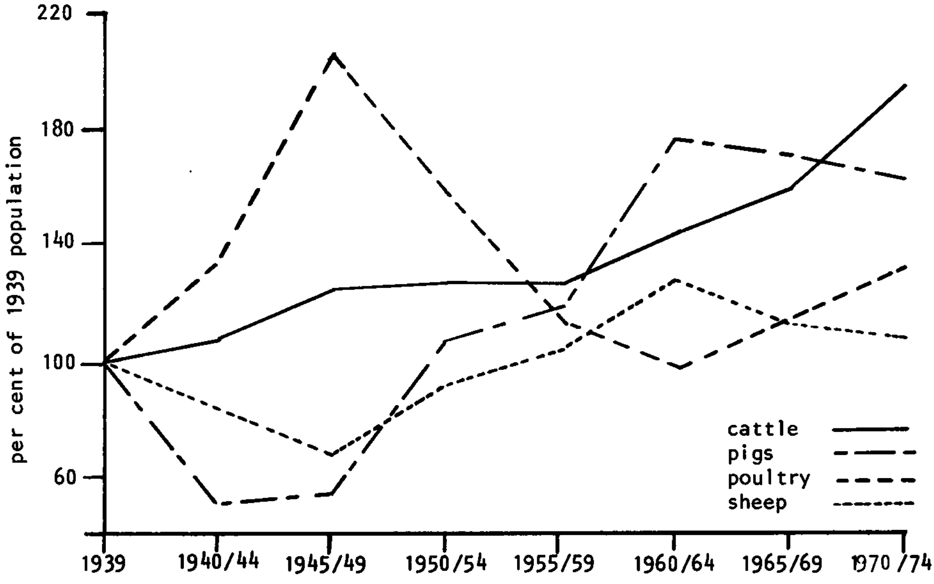

Fig. 1. Variations in livestock populations, Northern Ireland, 1939-74

TABLE 1

FERTILISER DRESSINGS IN NORTHERN IRELAND, 1938-75

Period	Fertiliser Dressing (kg ha^{-1}) N	P_2O_5	K_2O
1938-43	4.9	11.1	4.9
1943-48	8.6	24.7	8.6
1948-53	9.9	23.5	11.1
1953-58	12.4	23.5	12.4
1958-63	21.0	32.1	19.8
1963-68	28.4	28.4	22.2
1968-73	50.7	28.4	23.5
1973-75	70.4	23.5	21.0

In the early 1960's it was apparent that on many of the more intensive and well managed farms, the soil nutrient levels were increasing. A nutrient balance for the province in 1965 based on farm imports and exports was calculated by McAllister (1971). This indicated an input surplus of 20 kg P and 25 kg K ha^{-1} y^{-1} and a more recent calculation in 1974 showed little change. With these mean values it was evident that very high excesses of P and K could develop on some farms especially those with appreciable pig or poultry enterprises. This was confirmed by calculation of the balance for a selected 26 ha farm with dairy cows, pigs and poultry which showed surpluses of 149 kg P and 203 kg K ha^{-1} y^{-1}.

On farms where such surpluses occur there will be an accumulation of nutrients in the surface soil similar to that illustrated by the data in Table 2.

TABLE 2

CHEMICAL PROPERTIES OF A GRASSLAND SOIL:-
A - untreated
B - treated with 1 700 m^3 ha^{-1} pig slurry over 8 years

Soil Depth (cm)	% C		% N		Extractable*					
					P		K		Cu	
	A	B	A	B	A	B	A	B	A	B
0-15	4.47	5.08	0.58	0.71	15	154	135	570	16	38
15-30	2.03	2.16	0.21	0.25	2	15	50	115	11	15
30-46	0.77	0.87	0.07	0.11	1	2	37	60	5	8
46-61	0.38	0.46	0.03	0.04	1	1	39	62	4	5
61-76	0.27	0.37	0.02	0.03	2	1	41	79	3	4

* Nutrients extracted by normal ammonium acetate/acetic acid solution at pH 4.2 : mg kg^{-1} air dry soil.

The high levels of potassium which can arise increase the risk of hypomagnesaemia and the build-up in copper levels may also be important. In this soil there appeared to be little movement of phosphorus below 45 cm. This is not always so and increases in phosphorus at greater depths have been observed by McAllister (1971) and the movement of phosphorus is most probably due to the fine solid particles in slurry moving down channels in saturated soil. This also indicates the possibility of phosphorus entering drainage water from slurry dressings applied to wet soil or to soil with a rapid drainage system as illustrated by the data in Table 3 (McAllister,1974). This is the major reason why extreme care is advised where it is necessary to spread slurry on land during the winter months.

TABLE 3

COMPOSITION OF DRAINAGE WATER FROM SITES A AND B AFTER APPLICATION OF SLURRY

Period after application (hours)	Flow ($l/hour^{-1}$)		BOD (mg/l^{-1})		COD (mg/l^{-1})		N (Mg/l^{-1})		P (mg/l^{-1})	
	A	B	A	B	A	B	A	B	A	B
-	955	1022	3	4	14	128	18	6	0.06	1.27
0 - 0.5	964	1076	10	530	21	947	18	91	0.28	9.54
0.5 - 1	976	1106	5	215	15	427	19	36	0.20	3.69
1 - 2	970	1031	3	34	18	179	17	12	0.13	1.17
2 - 4	942	1104	2	7	18	90	8	6	0.07	0.37
4 - 8	888	570	2	7	14	46	10	7	0.06	0.45
8 - 24	1042	783	-	3	16	27	10	5	0.05	0.16
24 - 48	1042	4200	-	3	12	69	7	5	0.04	0.65

At present most farmers use manures and fertilisers in a somewhat haphazard manner though recent increases in the cost of fertilisers have probably made them more careful. Normally little account is taken of soil nutrient levels or nutrients in organic manures produced on the farm.

It seems desirable therefore to develop a system which could enable the intensive livestock farmers to manure in a more logical manner. McAllister (1971) suggested that a procedure proposed by the Netherlands Ministry of Agriculture (1967) might be the answer. This suggests that the net need of livestock farms for fertiliser P and K can be assessed by relating the P and K produced in the excreta of housed livestock with the requirements of the crops grown - the need for N on predominantly grass farms being largely dependent upon management. Calculation of the nutrient balance for the 26 ha farm mentioned earlier using the

Netherlands data and procedure gave P and K surpluses of 99 and 144 kg $ha^{-1}y^{-1}$ respectively. These are approximately 70% of the values obtained by direct calculation which made no allowance for losses during collection and storage.

To assess the value of this approach a pilot scheme on 100 farms in Northern Ireland was started in November, 1972 and a further 100 farms were brought into the project during 1975-76. Preliminary results for the first group have been published by Adams and McAllister (1975). These indicate that the use of P and K fertilisers is at best indiscriminate. No deficits of P were recorded on any of these farms and overall deficits of K occurred on only 9 farms. Many of the farms with pigs and/or poultry had surpluses of these nutrients prior to the purchase of fertiliser: the surpluses ranged up to 108 kg ha^{-1} for P and up to 163 kg ha^{-1} for K.

Satisfactory operation of this system in advisory work will depend upon a number of factors. A major one will be logical use of the organic manures on the farm, that is their application to areas where demanding crops are grown - for grassland farms this will be the fields where the grass is to be cut and removed. It will also be important to obtain reliable data on the amounts and availability of the nutrients in excreta from different types of animals under varying conditions. In the practical operation of the system it would be useful to have periodic checks on soil nutrient levels. Such analyses will be affected by the release or fixation of nutrients by soils and research is required into the sampling and analytical techniques to use. Results of some studies in Northern Ireland on the availability of nutrients in slurry and on the effects of slurry dressings on soils are outlined in the following sections.

AVAILABILITY OF NUTRIENTS IN SLURRY

Nitrogen

An experiment in 1962 compared pig slurry with various inorganic nitrogen fertilisers on the basis of total nitrogen content. The yield response to slurry nitrogen was approximately two-thirds of that to ammonium sulphate (McAllister, 1966). In subsequent experiments "soluble" nitrogen contents of slurry have been used for comparison with inorganic nitrogen levels. The "soluble" nitrogen fraction is extracted by shaking with cold 0.1 N HCl over a period of 24 hours, a procedure suggested by Hoyle and Mattingly (1954) as a basis for comparing composts as sources of available nitrogen. Subsequent work indicates that "soluble-N" is very similar to the ammonium-N content.

Results from 13 barley experiments carried out during 1964-69 comparing ammonium sulphate, urea and slurry are given in Table 4 (McAllister, 1970).

TABLE 4

MEAN YIELDS AND NITROGEN CONTENTS OF BARLEY (13 EXPERIMENTS 1964-69)

Treatment		Yield of grain, 85% DM (t/ha^{-1})		N content of grain (% DM)
Manure	N applied ($kg\ ha^{-1}$)			
None	Nil	2.86		1.70
Ammonium sulphate	37.7	3.29	3.33	1.77
	75.3	3.35		1.91
Urea	37.7	3.34	3.40	1.79
	75.3	3.45		1.90
Slurry	37.7*	3.44	3.40	1.77
	75.3	3.44		1.90

* "Soluble" nitrogen

These show that both yield and N-uptake responses to "soluble-N" in slurry were equivalent to those to nitrogen applied as ammonium sulphate or urea.

A long term experiment on grassland comparing a fertiliser dressing supplying 200 kg N ha^{-1} with three levels of both pig and cow slurries (50, 100 and 200 $m^3\ ha^{-1}y^{-1}$) was commenced in 1970 and is still in progress. The relationship between the mean annual yields from the different treatments for the 1970-75 period and the mean annual dressing of soluble nitrogen is shown in Figure 2 (McAllister et al., 1976). These data indicate that there is a reasonable correlation between the responses of grass to the "soluble" or ammonium nitrogen in slurry and that to fertiliser nitrogen.

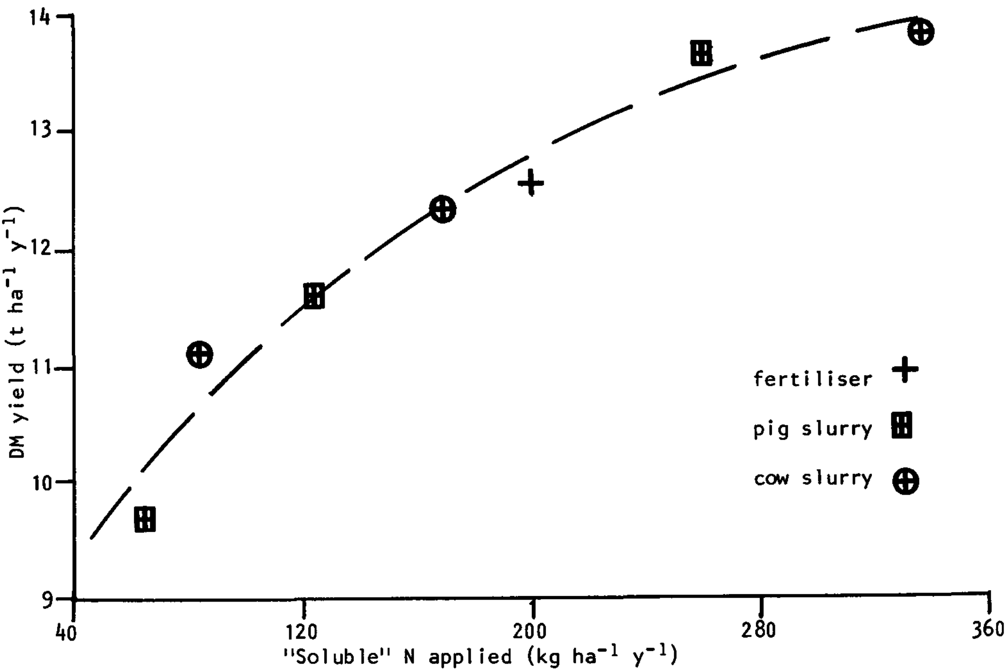

Fig. 2: Relationship between DM yield and dressing of "soluble" N (long term experiment - 1970/75 data)

In a laboratory experiment McAllister (1965) showed that the level of "soluble-N" could be markedly altered by storage conditions - increasing when stored under anaerobic conditions, the extent of the increase depending upon temperature and duration of storage period. In slurry stores exposed to the atmosphere there was a large loss of "soluble-N" compounds. Similar work on a field scale does not appear to have been carried out although Greenmount Agricultural College (1976) have reported a 12 per cent loss of total N in slurry stored in an open tank. It is urgent to obtain more detailed information on the extent and nature of such losses in practice so that efficient storage facilities can be designed.

Phosphorus and Potassium

Responses to phosphorus and potassium are more difficult to assess. Results of an experiment on barley (Table 5) show that poultry slurry could replace P and K fertilisers. Results from more recent experiments (Table 6) confirm the value of the P and K in slurries for barley. However, it is recognised that the use of slurry for cereals presents problems in application, the possibility of excessive nitrogen causing lodging and in weed infestation. It is therefore expected that most of the slurry will still be applied to grassland.

TABLE 5

RESPONSES OF BARLEY TO POULTRY SLURRY AND FERTILISER DRESSINGS

Treatment (kg ha^{-1})			Relative yield of grain
N	P_2O_5	K_2O	
0	0	0	100
0	75	75	123
45*	0	0	154
45**	0	0	168
45*	75	75	168
45**	75	75	167

* N source - ammonium nitrate ** N source - poultry slurry

Treatment P_2O_5 - K_2O dressings from potassic superphosphate

TABLE 6

RESPONSES OF BARLEY TO PHOSPHORUS AND POTASSIUM

P or K Source	Relative yields			
	P experiment	K experiments		
	Site 1	Site 2	Site 3	Site 4
None	100	100	100	100
Fertiliser	121	110	109	98
Slurry	125	111	106	103
Fertiliser + slurry	126	114	110	106
Soil level of nutrient	Low	Low	Medium low	Medium

The mean contents of P and K in the herbage from the long term slurry experiment for the 1970-75 period are shown in

Table 7. The responses to applied phosphorus were small and there was little difference whether the phosphorus was supplied by fertiliser or slurry. Responses to applied potassium, as would be expected, showed greater variations. The mean K contents of herbage from all the pig slurry treatments were lower than for the fertiliser or any of the cow slurry treatments. This was despite the fact that the heaviest pig slurry dressing supplied more potassium than the fertiliser and the lightest cow slurry treatments and could suggest a difference in availability between K in pig slurry and that in cow slurry or fertilisers. It should be noted however that due to the dilute nature of the slurries used in some years only the two heaviest rates of cow slurry on average supplied more potassium than was removed in the herbage. Adams (1973) also has suggested from its effect on herbage-K level that slurry-K may not be so effective as fertiliser-K.

TABLE 7

DRESSINGS AND UPTAKE OF P AND K (LONG TERM SLURRY EXPERIMENT, 1970-75)

Nutrient Source	Phosphorus applied (kg $ha^{-1}y^{-1}$)	Phosphorus per cent in herbage DM	Potassium applied (kg $ha^{-1}y^{-1}$)	Potassium per cent in herbage DM
Fertiliser	32	0.27	160	1.76
Pig slurry	29	0.27	53	1.26
	58	0.29	107	1.40
	117	0.30	214	1.59
Cow slurry	18	0.27	140	1.68
	36	0.28	279	2.12
	73	0.28	557	2.53

EFFECTS OF SLURRY DRESSINGS ON SOILS

Soil Analysis

In many areas the increasing use of fertilisers and manures has been reflected by increases in the levels of nutrients in soils. Results for the analyses of soil samples from the long term slurry experiment (Table 8) indicate the type of data which may be obtained.

TABLE 8

SOIL ANALYSES FROM LONG TERM SLURRY EXPERIMENT, 1970 AND 1975

Sampling Date		Treatment	pH	mg kg^{-1} extractable* P	K	Mg
Spring, 1970		Nil	6.3	21	71	ND
Winter, 1975		Fertiliser	5.4	18	61	37
		50 m^3 $ha^{-1}y^{-1}$	5.6	18	61	68
	Pig slurry	100 " "	5.6	25	62	86
		200 " "	5.7	44	66	127
		50 $m^3ha^{-1}y^{-1}$	5.7	14	66	82
	Cow slurry	100 " "	5.9	19	110	113
		200 " "	6.1	30	338	170

* Extracted by normal ammonium acetate/acetic acid solution of pH 4.2; sample depth - 15 cm.

Increases in the extractable P and K levels in this soil were recorded where the amounts of these nutrients applied exceeded the amounts removed in the harvested herbage, that is for P the 2 heavier rates of pig slurry and the heaviest rate of cow slurry and for K the 2 heavier rates of cow slurry. Both types of slurry supplied more Ca and Mg or at least did not displace the same amounts of these nutrients as did the fertiliser treatment.

The relationship between the P and K applied and removed are shown in Figures 3 and 4. For phosphorus any increase in the amount of extractable P in 2500 tonnes soil was about 15 per cent of the excess dressing per hectare. This probably indicates the extent of P fixation and therefore could vary with different soil types.

The soil on which this experiment is sited can become depleted rapidly in exchangeable-K but is also capable of releasing non-exchangeable-K fairly readily. The data in Figure 4 indicates that between 60 and 90 kg $ha^{-1}y^{-1}$ were released when K application was inadequate to meet the requirement of the herbage. At the only very high application of K in this experiment, most of the excess remained in the soil in exchangeable form.

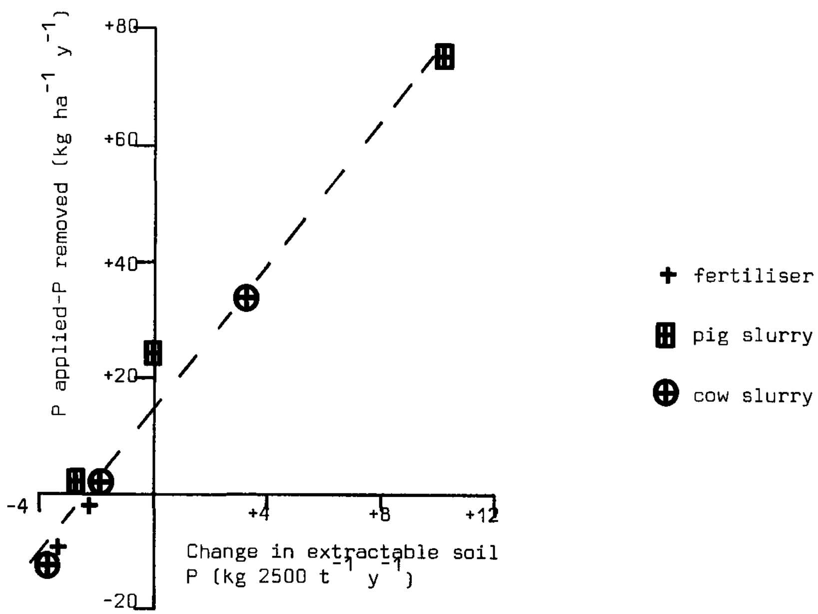

Fig. 3: P balance, 1970-75 data.

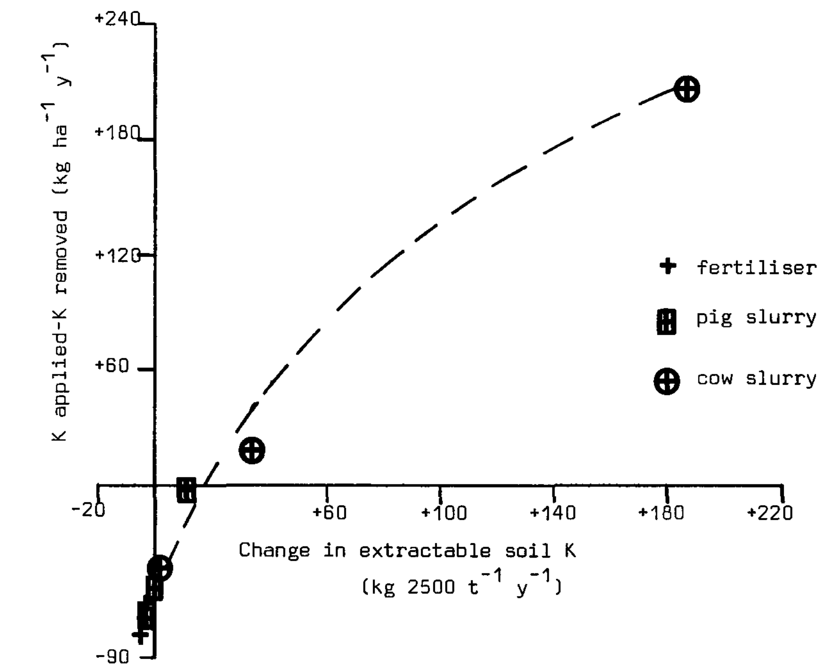

Fig. 4: K balance, 1970-75 data.

These results were obtained on plots where treatments were applied uniformly and the herbage was cut and removed. Under such conditions, uniform sampling is not a major problem. For advisory work and especially on intensively grazed pasture, the collection of representative samples can present problems.

As illustrated in Table 9, there can be large variations in nutrient levels between relatively shallow layers of a soil. It will be essential therefore to standardise the depth of sampling.

TABLE 9

VARIATIONS IN SOIL NUTRIENT LEVELS WITH DEPTH (LONG TERM SLURRY EXPERIMENTS, (1975)

	Mean values for all treatments			
		mg kg^{-1*}		
Sampling depth	pH	P	K	Mg
0-50 mm	5.66	37	163	152
50-100 mm	5.70	19	98	85
100-150 mm	5.80	16	67	56

* Extracted with normal ammonium acetate/acetic acid solution at pH 4.2

A problem more difficult to overcome will be the variation in nutrient levels that arises from the uneven return of dung and urine to pastures by grazing animals. An extreme example of this is where the sward can be killed off by severe scorching resulting from excessive dressings of urine. The "dead" areas may subsequently be recolonised by inferior grasses (Poa spp.) or by stoloniferous ryegrass. Such recolonised areas are susceptible to further damage by severe climatic conditions or disease although the farmer normally considers that the sward has recovered. McAllister et al. (1971) showed that wide variations could occur between the nutrient levels of these areas and adjacent healthy areas.

The analyses in Table 10 are from a recent advisory investigation into such a problem. The two samples were collected within 15 cm of each other and they show the normal features associated with such problems ie on the affected area there is a higher concentration of soluble salts, a higher degree of acidity possibly the result of excessive nitrogen and a very much greater level of extractable potassium. While such results may be extreme, they suggest that considerable variations could arise even on moderately intensively grazed pastures.

TABLE 10

VARIATIONS IN SOIL NUTRIENT LEVELS UNDER INTENSIVE GRAZING

Analysis		"Dead" area	Adjacent "Good" area
	pH	4.9	5.3
	pC	3.25	3.63
Extractable (mg kg^{-1})	P	40	40
	K	583	82
	Mg	191	281
	Ca	4210	6000

Decomposition of slurry in soil

Studies on the decomposition of slurry in soil have been reported by Cornforth and Stevens (1972), Cornforth (1973) and Stevens (1973). It would appear that when slurry is applied to soil, the coarser fraction accumulates on the surface. If this material is not broken down ie if the dressings are excessive, it will form an organic layer, slow to dry out and render the soil more liable to poaching. The finer slurry solids under 250 µm block soil pores and restrict aeration. Some of the blocking materials are composed of polysaccharides produced microbially during slurry storage.

Applying slurry to land thus adds easily decomposable organic matter to the soil, increasing its demand for oxygen and at the same time slowing gaseous diffusion by blocking soil pores. In the long term experiment the dressings of pig slurry were found by Cornforth and Stevens (1972) to decrease the oxygen content of the soil atmosphere to 5 per cent with a corresponding increase in carbon dioxide. They also found in laboratory experiments that under the anaerobic conditions induced by frequent slurry applications methane and ethylene are produced, methane production being typical for slurry decomposition under such conditions. They were unable, however, to identify methane or ethylene in the soil atmosphere of the long term experiment but Burford (1972) after applying thick cow slurry - 15 per cent DM - to land, found up to 6 per cent methane and 3 $\mu l\ l^{-1}$ ethylene in the soil air. It is probable that even moderate applications of slurry will result in anaerobic zones developing in soil, the effect being greater if the soil is initially wet or poorly drained.

Furthermore, when slurry is applied, anaerobic bacteria and the products of their metabolism, which accumulate in slurry during anaerobic storage, will be introduced into the soil. Conditions in slurry treated soils are such that these bacteria can continue to thrive and their metabolites, which may be phytotoxic eg volatile fatty acids, may persist.

CONCLUSIONS

In Northern Ireland, it is expected that work will continue to develop the nutrient balance concept to provide a simple system which will enable farmers to manure on a logical and efficient basis. Assessment of the availability of the various nutrients in different types of slurry and the effects of storage conditions on the solubility of the nitrogen compounds in slurry will also be continued.

Analysis of large numbers of slurry samples for soluble-N or ammonium-N contents is not practicable and it would therefore be useful to develop a simple technique, eg test papers, to give some indication of the amounts of these nitrogen fractions in slurry.

Further studies on the effects of slurry dressings on soil nutrient levels are required. The work carried out suggests that it might be useful to have information on the use of more powerful extracting solutions for phosphorus and on the amounts of potassium which different soil types may release under field conditions. The problems outlined in soil sampling suggest that for advisory purposes and field experimental work it would be useful to adopt a standard depth for sampling. For this purpose and also to ensure the collection of more representative samples, the development of new sampling equipment may be necessary. The essential requirements would be to collect greater numbers of soil cores to a fixed depth than can be done with present equipment.

The liquid condition of slurry is responsible for some of the major problems that may arise when slurry is spread on land, eg, the risk of pollution and nutrient enrichment of drainage water, the slow breakdown of the solids on the surface of grassland and the possibility of phyto-toxic compounds being produced by anaerobic decomposition of the finer solids in the soil. The extent of these problems would be reduced if much of the water in slurry could be removed before spreading on the land.

Most of the existing methods of separation or drying are expensive requiring either a considerable input of energy or the provision of absorbent materials. Laboratory studies suggest that it may be possible to develop a settlement technique with a low energy requirement. Combined with this the use of physical and chemical processes for treating the effluent should be assessed. There will be a lot of soluble nitrogen compounds during such treatment but complete recovery of the other nutrients.

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THE AGRONOMIC UTILISATION OF PIG SLURRY: EFFECT ON FORAGE CROPS AND ON SOIL FERTILITY

(Summary of a five-year investigation)

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INTRODUCTION

Italian pig production has doubled in the last ten years, but despite this it represents only 12% of the total EEC production. Italy has the lowest productivity (60 - 70 kg) and number of heads per inhabitant (15 head per 100) and, for this reason, can supply only 4/5 of the consumption.

It follows that pig husbandry and, in consequence, pollution problems must increase. This is particularly true of the northern regions that are responsible for more than half of the pig production.

AIMS AND ENVIRONMENTAL CONDITIONS

The investigation that we have been carrying out for the past five years, and which is still in progress, has the following aims:

1) to evaluate the quantity of slurry produced by livestock,
2) to determine the chemical composition of slurry,
3) to ascertain whether this slurry can be used at heavy rates as fertiliser for various crops,
4) to study the effect of slurry dressing on soil.

Our research was carried out in the Parmigiano-Reggiano district, an area of over one million hectares, mostly in Emilia. Here there are 1300 dairy co-operatives where the production of grana cheese is associated with the rearing of two million pigs. These farms are of limited size and on the average carry 300 heads. In these conditions, it would not be economical to use depuration plants. However, it is possible to spread the slurry on nearby crop lands owned by associates, which cannot be done on industrial pig farms where there is no crop land.

The climate of the Emilian plain is continental, rain falls mainly in spring and autumn, whilst the summer tends to be some-what dry.

Soils are heavy (sand 24.5%, silt 28.6%, clay 46.9%), have medium N and P_2O_5 contents and are very rich in K_2O and lime-stone.

SLURRY PRODUCTION AND COMPOSITION

We investigated a typical dairy farm owned by 40 associate who work 350 ha; 900 tons of milk are produced and processed annually. Five hundred pigs are fed on the milk serum.

Twenty-four volumetric measurements were made on slurry production during a three-year period. The results are given in Table 1. As there are over two million head in the area, the yearly slurry production can be estimated to be 18 million m^3. On the basis of the 'equivalent population' concept, this is equal to the pollution power of a city of over 3 million inhabitants.

TABLE 1

AMOUNT OF PIG SLURRY PRODUCED PER HEAD (average of 24 determinations)

Daily average of washing water	kg	20
Daily averages of faeces, urine, bran	kg	5
Total	kg	25
8 months average (husbandry period)	m^3	6
Yearly average	m^3	9

Concurrently with the volumetric measurements, slurry samples were collected after prolonged air-bubbling in the tank The average chemical composition of the slurry is shown in Tabl 2.

TABLE 2

ANALYSIS OF PIG SLURRY (average of 24 samples)

	Mean*	Coeff. of variation (percent)		Mean*	Coeff. of variation (percent)
Dry matter	2.418	47	Total P_2O_5	0.131	5
Organic matter	1.733	54	Soluble P_2O_5	0.045	145
Mineral matter	0.685	32	Total K_2O	0.298	7
Soluble salts	0.261	36	Soluble K_2O	0.137	32
Total N	0.261	19	Total Ca	0.040	55
Organic N	0.130	16	Total Mg	0.038	65
NH_4-N	0.131	34	Total Na	0.063	14
NO_3-N	0	-	Chloride	0.097	17
Uric N	0	-	Sulphate	0.023	37
BOD 5 days	3685	12	pH at 20°C	7.4	4

* % on W/W: BOD mg/l

It should be noted that 1 m^3 slurry contains about 7 kg N, P_2O_5 and K_2O in the ratio of 1 : 0.5 : 1.1. At the present cost of chemical fertilisers 1 m^3 slurry has a value of L.1500.

Half of the N is in organic and half in ammonium form; a third of the P and half of the K are in soluble form; the slurry nutrient release is, therefore, part fast, part slow.

EXPERIMENTS OF SLURRY APPLICATION

All fertilisation experiments were carried out on forage crops of the grass family. These species give a clear response to fertilisers and, in addition, have a prolonged disposal throughout the year.

The main aims of these experiments were:

1) to establish the optimum dose for the crops ('agronomic dose'),
2) to establish the maximum dose for crops and/or soil,

The effects of repeated applications of huge quantities of slurry of up to 1500 m^3/ha/year on the quantity and quality of crops and on soil characteristics have also been studied.

Experimental trials were carried out over a period of five years. Materials, methods and results are reported in the figures.

Effect on crops

Trials on relatively low doses were conducted on silage maize at the dough stage during 1970 and, in 1971, on sorghum (Figure 1). The results demonstrate a clear response of both crops to slurry application; dry matter yield and protein content both increase with increased doses.

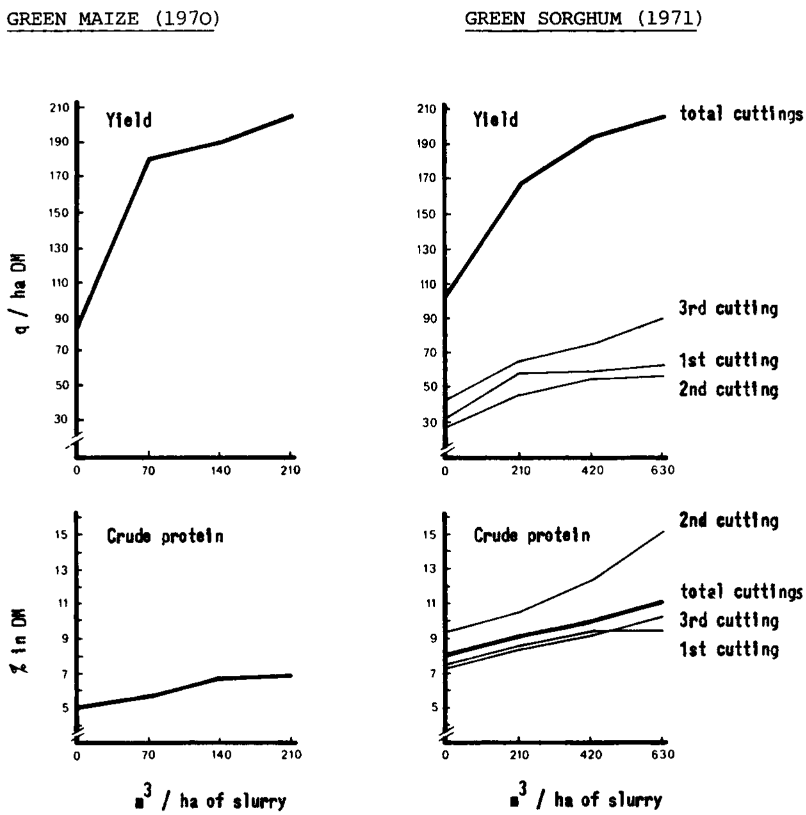
Sorghum has a particular ability to take advantage of heavy slurry rates (up to 630 m^3/ha).

Two crops, autumn sown Italian ryegrass and summer sown maize, in succession, responded well to slurry rates of up to a total of 400 m^3/ha (Figure 2). These two crops gave an average total of 34 t/ha dry matter with 12.9% of crude protein content. No significant differences were found between slurry and equivalent mineral N-P-K doses.

Barley, rye and oats for forage (Figure 3) were treated with high slurry doses in winter and at the beginning of spring. The best quantitative results were obtained with 400-500 m^3/ha, whilst does of over 500 m^3/ha proved to be excessive and produced lodging. Mineral fertilisers also resulted in lodging. The DM yield curve reached its maximum at 150-200 kg/ha N. The crude protein content increase was greater than that of the DM yield. The average limits were 750 m^3/ha slurry and 300 kg/ha mineral N.

Figure 4 indicates that there was a significant response of maize yield to increasing slurry rates of up to 500 m^3/ha.

Whereas doses over 500 m^3/ha did not umprove the protein content of maize at dough stage, they did produce a consistent increase in the percentage of CP in maize grown for green forage.



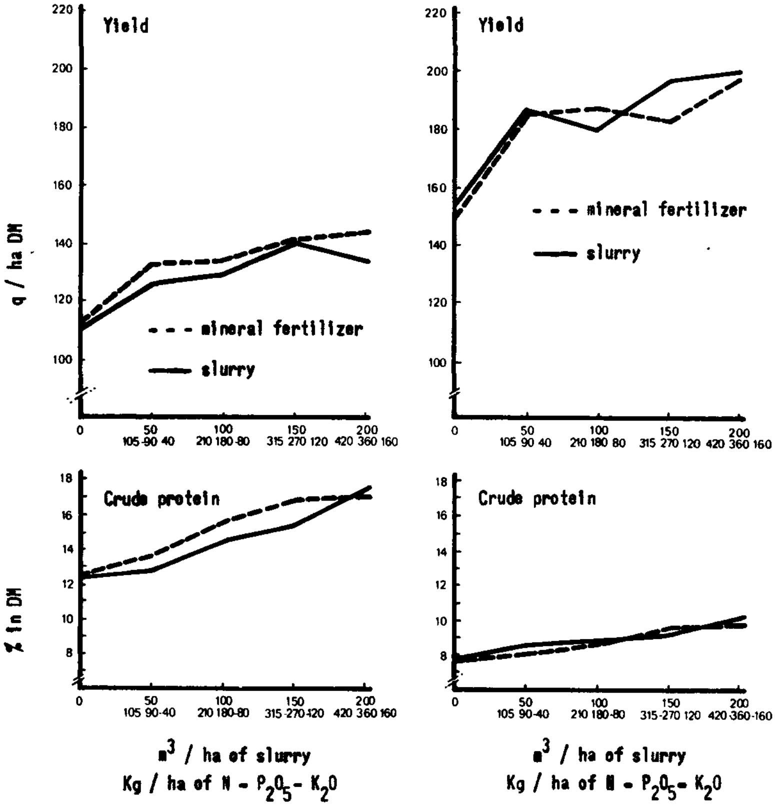
Spring sowing and average plant density at harvest 9 plants/m^2 for maize and 51 for sorghum (3 cuttings)

Slurry dressings in two equal parts for maize, just before and after the sowing; in three equal parts for sorghum, just after sowing, at first and second cutting.

Irrigation according to the need of the crop.

Fig. 1. Effect of increasing slurry dressings on yield and crude protein content of maize and sorghum for forage

ITALIAN RYEGRASS 1972-73 GREEN MAIZE

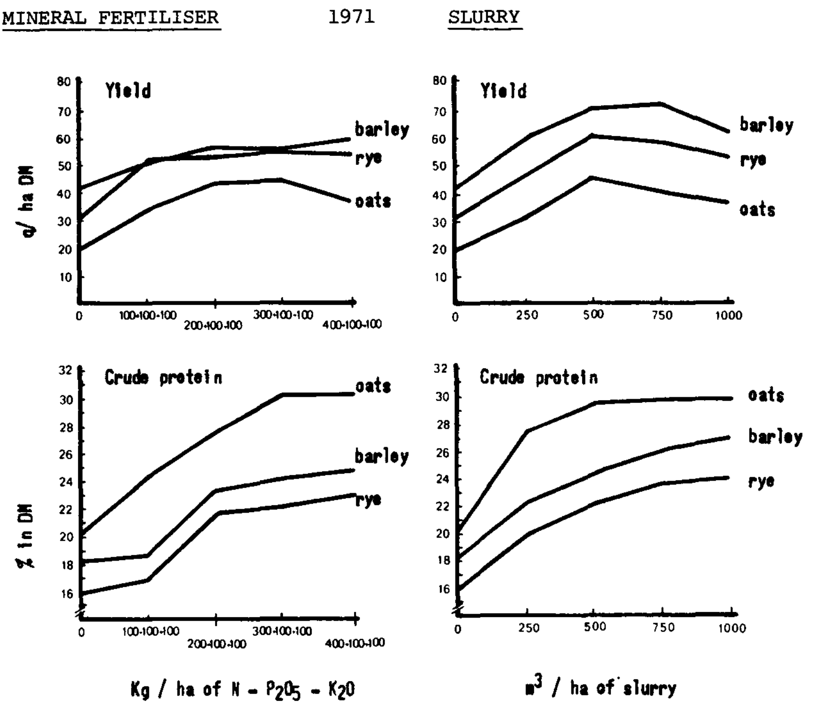


Autumn sowing of Italian ryegrass (3 cuttings), and summer sowing of maize (16 plants/m^2).

Dressings of slurry and mineral fertilisers in three equal parts for Italian ryegrass, in December, early in April and May; in two equal parts for maize, early and late in August.

Irrigation according to the need of the crop.

Fig. 2. Effect of increasing slurry dressings, in comparison to mineral fertilisers like N, P and K, on yield and crude protein content of the double forage crop of Italian ryegrass followed by maize.



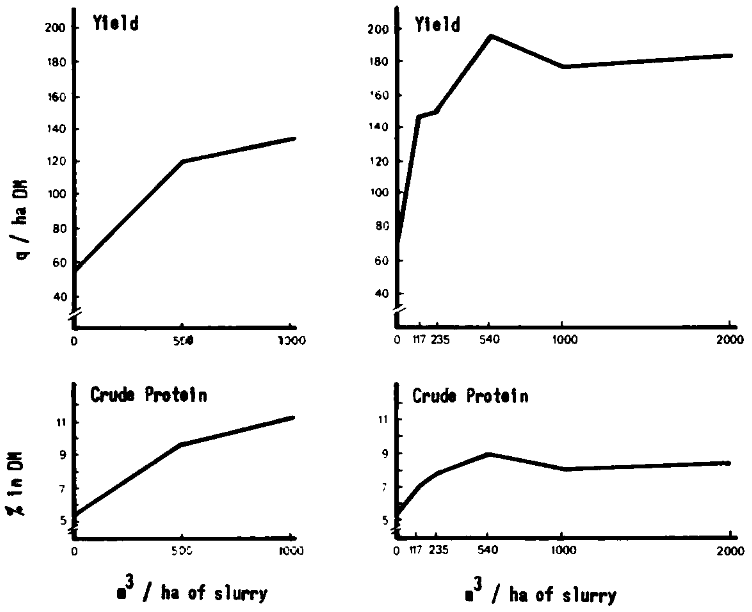
Autumn sowing and average plant density at harvest of 421 plants/m^2 for barley, 212 for rye, 272 for oats; harvested in the first ten days of May.

Slurry and N fertiliser dressings in three equal parts, early in February, March and April; P and K fertilisers before sowing.

N, P and K fertilisers not equivalent to slurry.

Fig. 3. Effect of heavy slurry dressings, in comparison to normal rates of mineral fertilisers, on yield and crude protein content of barley, rye and oats for forage.

GREEN MAIZE (1970) SILAGE MAIZE (1971)



Summer sowing and average plant density at harvest of 28 plants/m^2 for green maize; spring sowing and plant density of 7 plants/m^2 for silage maize.

Slurry dressings in four equal parts for green maize, in April, May, June and just after sowing; in two equal parts for silage maize, in November and just after sowing.

Irrigation according to the need of the crop.

Fig. 4. Effect of increasing slurry dressings, up to very high rates, on yield and crude protein content of forage maize.

Figure 5 shows sorghum to be the crop best able to take advantage of, or tolerate, large quantities of slurry. Sorghum also allows for slurry disposal after each cutting throughout the summer.

As only small differences were observed between the various years, it may be concluded that both maize and sorghum were indifferent to 'accumulation effect' during the five years of slurry application and that they only made use of the last application.

From these data, we can calculate the amounts of N uptake by crops. At maximum yield, barley, rye and oats uptake about 200 kg/ha N, silage maize 250 kg/ha, sorghum 400 kg/ha and Italian ryegrass the same.

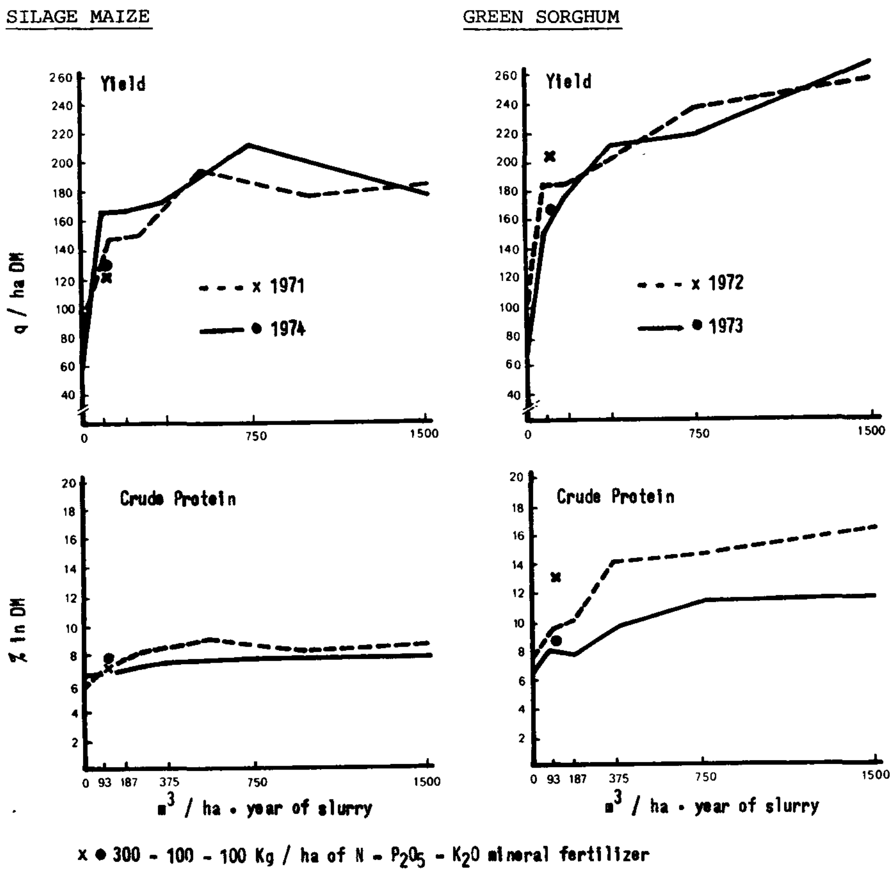
Effect on soil

Five year slurry application on the same plots influenced the nutrient content of the soil. The results of soil analysis performed at the end of the five-year period are reported in Figure 6.

N, organic matter, total and available P and exchangeable K show a consistent increase as a consequence of increasing applications of slurry.

Accumulation rates of the different compounds were not equal throughout the period. N and organic matter in the plots receiving the highest slurry doses had, for instance, reached or exceeded the fifth year level after only two years. On the other hand, P and K accumulated progressively during the entire period. The same progressive accumulation occurred with N in plots receiving low rates of slurry. These facts seem to suggest that heavy doses of slurry stimulate the soil metabolism of N and organic matter through microbiological phenomena.

Exchangeable and soluble sodium and soluble potassium increased as a consequence of slurry application. However,



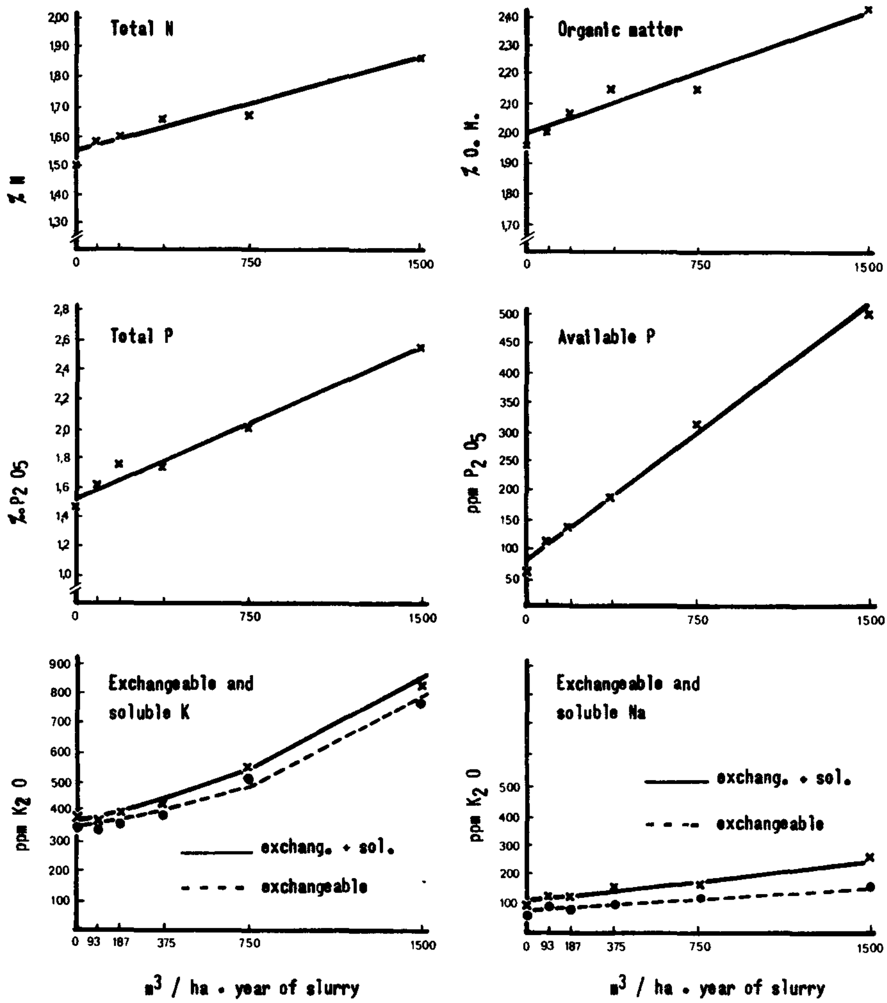
These figures concern the last four years only, when the design of the experiments for slurry amounts and the types of maize and sorghum were identical.

Spring sowing with average plant density at harvest of 8 plants/m^2 for maize and 103 for sorghum (3 cuttings).

Slurry dressings in two equal parts for maize, just before and after sowing; in four equal parts for sorghum, just before and after sowing, at first and second cutting; N fertiliser dressings in three equal parts (once before the sowing and twice as top dressing), P and K fertilisers before sowing.

Irrigation according to the need of the crop.

Fig. 5. Slurry dressings, up to very high rates, repeated successively for five years on the same plots: effects on yield and crude protein content of maize and sorghum for forage.



Methods of soil analysis - Total N: Kjeldahl method; organic matter: mineralisation with hot mixture of $K_2 Cr_2 O_7 + H_2 S O_4$; total P: digestion with $H_2 S O_4 + K_2 Cl O_4$; available P: extraction with Na - acetate and acetic acid buffered to pH 4.8; exchangeable K and Na: extraction with 1N NH_4 - acetate; soluble K and Na: extraction with soil to water ratio of 1 : 1. Data expressed on air-dry soil.

Fig. 6. Slurry dressings, up to very high rates, repeated successively for five years on the same plots, cultivated with sorghum or maize: nutrients in soil at the end of this period.

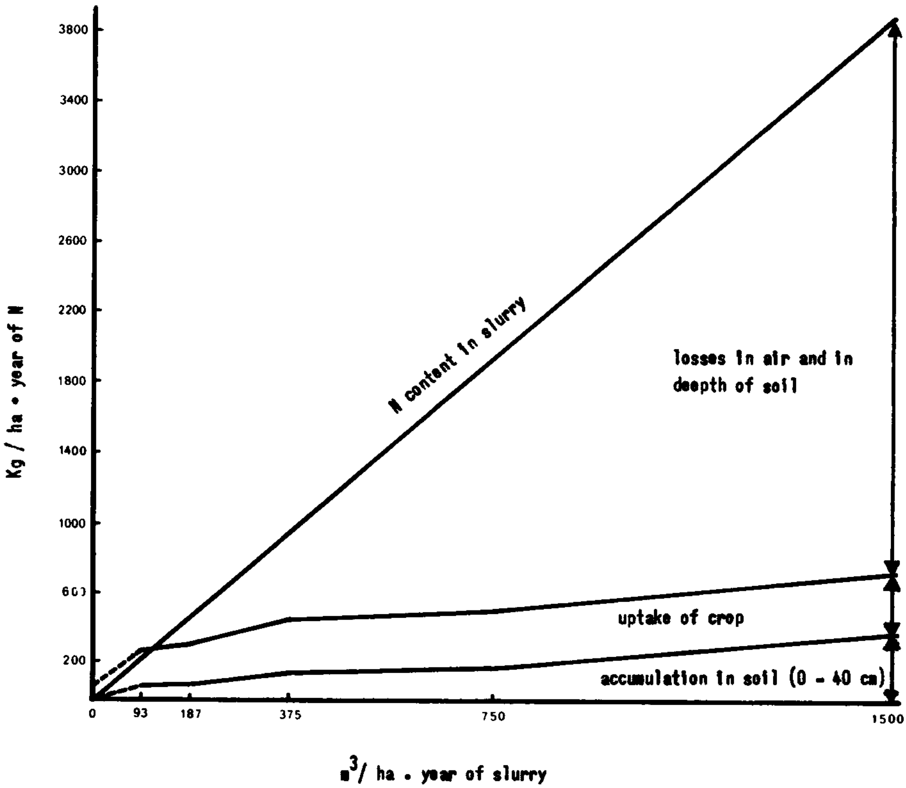


Fig. 7. Slurry dressings, up to very high rates, repeated successively for five years on the same plots cultivated with sorghum or maize: a tentative of N balance sheet of an average year.

despite the rather high quantities of soluble salts which were applied with the slurry, the salt variation is very limited and does not cause concern either from the point of view of exchangeable Na (in control 0.78 and in maximum slurry rate 1.53% of cation exchange capacity) or of salinity (in control 0.46 and in maximum rate 0.95 mmhos/cm on soil/water extract ratio of 1 : 1.

The analyses of pH (min. 7.8 - max. 8.0), total (min. 13.3 - max. 14.0% as $CaCO_3$) and active limestone (min. 10.4 - max. 10.9% as $CaCO_3$) and cation exchange capacity (min. 26.8 - max. 28.4 meq/100 g) did not show any important changes.

A tentative N balance sheet is shown in Figure 7. It is clear that the ratio between the utilised (crops + soil) and the applied N decreases as the slurry rates increase. This means that plants and soil can only use limited amounts of N and that N excess has to be eliminated in some way.

CONCLUSIONS

The trials have emphasised that in the district in which we have operated, the husbandry of one pig produces an average of 9 m^3/year of slurry. To simplify the lagoon storage, the mechanical separation and the land dressing, it is advisable to use husbandry systems which reduce the washing waters.

In our conditions, it would not be economical to use depuration plants and slurry spreading on land is preferable.

At the present cost of chemical fertilisers, 1 m^3 of slurry has a N, P_2O_5 and K_2O value of L.1500.

The best DM yields of tested fodder grasses are obtained with 400 - 500 m^3/ha of slurry but, at these doses, the nutrients' utilisation ratio is low.

The dose which gives a high enough yield and utilises the nutrients well ('agronomic dose') is half of the above volume.

Sometimes the crude protein of forage also increases at dressings of over 500 m^3/ha.

During the five years of the repeated slurry dressings (up to very high doses) in the same plots, maize and sorghum were indifferent to 'accumulation effect' and it seems they only made use of the last application.

In the same scheme, the soil nutrients increased without reaching dangerous levels; in particular, with heavy doses of slurry, the soil can eliminate high amounts of N, organic matter and salts.

In order to evaluate the influence of slurry dressing on the soil physical properties and on the quantities of N lost dangerously by leaching and harmlessly by denitrification, it is necessary to intensify our study.

DISCUSSION

J.H. Voorburg *(The Netherlands)*

Are there any questions on the three papers we have had this afternoon?

C. Tietjen *(West Germany)*

Dr. de la Lande Cremer, when you were speaking of available nitrogen I assume you meant nitrate. When did you take the soil samples and what do you think is the best depth to take samples from, 60 or 80 cm, you have both?

L.C.N. de la Lande Cremer *(The Netherlands)*

We use 60 cm for grain crops; we have no fixed depth so far for potatoes and sugar beets - we are using 1 m but we are trying to determine the minimum depth. We take the soil samples in the period from March to May/June. The first samples are taken out in March for the potato and we are trying to find out if there is a better correlation in the period April/June.

C. Tietjen

You find there is still some transformation of the soil, and there is still some uptake, after June?

L.C.N. de la Lande Cremer

Yes.

A. Cottenie *(Belgium)*

Dr. McAllister, what is the precise meaning of 'soluble nitrogen' and how is it determined, also in relation to time?

J.S.V. McAllister *(UK)*

There was a method developed about 1954, I think by Tinsley and Maddingley, for use with composts. It is determined simply by shaking up ....

A. Cottenie

The chemical form first, if you please, you speak about 'soluble nitrogen'.

J.S.V. McAllister

It is mainly ammonium compounds ...

A. Cottenie

Ammonium, not nitrates?

J.S.V. McAllister

There may be some other compounds there but there wouldn't be much nitrate in slurry; there could be nitrate in it from a compost. However, it is really quite a simple method. As far as slurry is concerned it is essentially the ammonium compound. You just shake with decinormal hydrochloric acid overnight, then filter and determine the nitrogen in the filtrate.

J.H.A.M. Steenvoorden *(The Netherlands)*

Dr. de la Lande Cremer, you looked at the relationship between available nitrogen and amino acids and sugar in the beet. Is there also such a clear relationship for total nitrogen from the point of view of the nitrogen balance?

L.C.N. de la Lande Cremer

I haven't looked at this relation of total nitrogen, I cannot answer this question.

H. van Dijk *(The Netherlands)*

Dr. McAllister gave a paper on efficient recycling of nutrients. Now, I may have overlooked it but I didn't find any data of the chemical or physical properties of the soil. Do you consider that the soil properties are quite irrelevant to the question of efficient recycling?

J.S.V. McAllister

No .... I'm not quite sure what you mean. I took recycling to mean the kind of nutrients coming out of the animals and going back round. The kind of system I am proposing should work with any soil type as far as phosphorus and potassium are concerned.

H. van Dijk

Have you experimented on different types of soils?

J.S.V. McAllister

We have had experiments on lots of different types of soil.

H. van Dijk

And you found no difference, no effect of soil type and soil properties?

J.S.V. McAllister

We have found very little effect really. Most of our soils would be medium loams. We wouldn't have any very sandy soils. There would be some peat soils but, again, there was no big difference compared with the results from other soils.

L.C.N. de la Lande Cremer

Dr. McAllister, you mentioned methane and ethylene production by slurries in relation to soil. I know you do not have very many potatoes in your country but did you find a relationship between the ethylene production in slurries and eventual damage to the potatoes?

J.S.V. McAllister

You are talking about the effect of methane or ethylene produced from slurry applications on potatoes but we just would not apply slurry to potatoes at all so I couldn't really say whether or not there would be any effect. Actually, our two workers didn't find any ethylene in the field where there was a very dense application of slurry. However, I believe John Burford at Reading found pretty high concentrations of ethylene where fairly thick cow slurry was being applied to grassland.

L.C.N. de la Lande Cremer

I believe there were some kind of symptoms on potatoes in England such as are caused by ethylene, that is why I asked the question.

J.S.V. McAllister

I think the disease is a virus.

L.C.N. de la Lande Cremer

Dr. Spallacci, you talked about accumulation effects from the use of slurries and you said there was no danger of such accumulation effects but surely, if you are using copper ....

P. Spallacci *(Italy)*

Only three major nutrients were measured: nitrogen, phosphorus and potassium.

L.C.N. de la Lande Cremer

It is possible that at some time you will have difficulties with your maize through the copper content in the soil.

J.H. Voorburg

What is the amount of copper in your concentrates? 200 ppm?

P. Spallacci

I don't know at the moment.

J.H. Voorburg

It can be an important problem if you have the same amount of copper that we have and that the UK has, that is about 200 ppm of copper in concentrates. Then you have 1‰ in the DM of the manure and set up an accumulation.

J.C. Brogan *(Ireland)*

Dr. McAllister spoke of balance for the whole farm. I would like to ask whether he noticed an imbalance within farms in his studies - that the fields near the cattle housing received a lot of slurry but that there was a depletion of, say, potassium, in the fields far away from the cattle housing?

J.S.V. McAllister

Yes, there is an imbalance; it is quite common I think. We hope that our advisers running this sytem will encourage farmers to start applying the material in the proper places. We only propose to sample every type of field - not every single field.

G.J. Kolenbrander *(The Netherlands)*

Dr. McAllister gives the relationship between soluble nitrogen and dry matter yields in Figure 2. It strikes me that the point with fertiliser is within the line with pig slurry and cow slurry. I do not understand this because soluble nitrogen, as he mentioned, is a mineral form as ammonium nitrogen but 50% of total nitrogen is of organic form. I don't see any effect of all this organic nitrogen in the curve. I would also expect that part of the organic nitrogen would have an effect and it can never be exactly the same as fertiliser. You must have losses by ammonia from the slurry at such a rate that it is compensated by the nitrogen that is mineralised from the organic form. That is the only way I can see and I do not understand this correlation.

J.H. Voorburg

You are sure that 50% of the nitrogen is in organic form?

G.J. Kolenbrander

Yes.

J.S.V. McAllister

I would agree that 50% is in organic form. In some ways it may be difficult to explain but it is what we get. We are only working with grassland and we have had it in lots of other experiments. A possible explanation may be that our soils already have high nitrogen contents because they have been under grass for a long time. It may be that for cereal crops, barley for example, we wouldn't need more than 20 - 30 kg of nitrogen per ha because so much becomes available. The amount of nitrate produced in our soils under arable conditions is about twice what would be produced in the east of England. Also, if you take the Netherlands winter rainfall, in theory we should need even more, but we don't. For potatoes we only use 40 kg/ha of nitrogen. So there is quite a lot there anyway, in organic form.

J.H. Voorburg

Again it is the complicated problem of the nitrogen balance.

G.J. Kolenbrander

This effect of the organic nitrogen and perhaps the high mineralisation rate of your soil will also be in the fertiliser. So, you stress the fact that you have an amount of nitrogen mineralised from organic form.

J.S.V. McAllister

Yes, but therefore any kind of additional response in the year of application would just be from the extra mineral forms applied.

G.J. Kolenbrander

I have another question regarding Dr. Boschi's paper. In Figure 3 he shows amounts of 100 and 300 kg of mineral nitrogen with barley, rye and oats. I do not understand how you can apply 300 kg of nitrogen to such crops without rotting the crop. Should I read it, not as nitrogen per ha, but as total fertiliser? The figures show 300 kg N/ha, 400 kg P_2O_5, and 100 kg K_2O. 300 kg seems to me much too high. In the Netherlands we apply 100 kg of nitrogen.

P. Spallacci

The normal rate is about 200 kg. The 300 kg rate is in excess. It is not grain barley, it is forage barley.

G.J. Kolenbrander

It says: barley, rye and oats.

Anon

For forage.

J.H. Voorburg

I propose you discuss it in the coffee break - you could have a useful exchange of experience.

A.V. Dodd *(Ireland)*

Just by way of a comment, listening to the figures given by Dr. Spallacci, when I first read his paper I was quite astounded by the magnitude of the hydraulic load that he was proposing but one must always keep in mind that the dilution factor is something like 5 : 1. When one allows for this dilution factor the actual loadings involved are not all that significantly greater than those that we heard this morning.

R.G. Gerritse *(The Netherlands)*

What do you mean by the dilution factor?

A.V. Dodd

Over 9 m^3 per pig place per annum something like 7½ of which is water - one would want to keep that constantly in mind.

R.G. Gerritse

So his 1500 m^3 would be 300 m^3 each year?

A.V. Dodd

That is what I assume from reading the paper.

R.G. Gerritse

But even this would be a fairly large amount.

A.V. Dodd

It would, I agree.

H. van Dijk

I would like to ask Dr. McAllister a question. I quote from his paper, "The finer slurry solids under 250 μm, block soil pores and restrict aeration. Some of the blocking materials are composed of polysaccharides produced microbially during slurry storage". That is not written as a possibility but as a statement. How did you get your evidence? How did you determine the amount of polysaccharides microbially produced?

J.S.V. McAllister

Well, actually that work was not done by me; it was done by Cornforth and Stevens and I can send you a copy of their paper.

H. van Dijk

Thank you, I would like to have it.

R.G. Gerritse

I know of some people in Holland who have developed methods of soil sampling which are very fast and very efficient. If you are interested ....

J.S.V. McAllister

Yes, I am. Of course, there are probably more stones in our soils.

J.H. Voorburg

We have a few minutes left and Professor Lanza proposes to give the answers to the questions raised this morning.

F. Lanza *(Italy)*

The first question was from Dr. de la Lande Cremer. The cleaning system consists of compressed air. With regard to the second question, our idea is that the repeated use of the land-spreading system on the same soil creates some ground water pollution.

L.C.N. de la Lande Cremer

It's not a storage problem?

F. Lanza

No. We do have to pay attention to accumulation problems because we have lagoon pits, not metal tanks.

Our colleague, Dr. Bonciarelli, is going to reply to the third question regarding the Italian regulations for the disposal of animal wastes.

F. Bonciarelli *(Italy)*

When I accepted the invitation to participate in this meeting I was unaware that two days previously a law had been published by the Italian authorities in connection with the protection of waters against pollution. This law may render this meeting anachronistic, at least for Italy. The law concerns the disposal of waste on surface waters, in rivers, seas, lakes, canals, etc. on agricultural soil too, into soil.

Disposal of waste on agricultural soil is permitted only where wastes have a composition in accordance with a fixed standard: 250 BOD ppm for the first three years and then no more than 40 ppm of BOD. I can tell you these standards: insoluble material - none; sedimentable material - 2 ml/l in the first three years after the law, 0.5 ml/l after six years; suspended solids - 200 mg/l for the first three years, no more than 80 mg/l after six years; BOD - after 5 days, 250 mg/l for the first three years, 40 mg/l afterwards; COD - 500 mg/l for the first three years, 160 mg/l after nine years.

I consider myself fortunate to have carried out experiments on distributing up to 200 m^3/ha of slurry before the law was published, otherwise I should be running the risk of being jailed! It is a pity that such a law has been passed because a lot of results, including my own, demonstrated the possibility of fertilising wheat, for instance, by a slurry top dressing. Now I can't see how farmers or livestock breeders can make use of the results of research when they are constrained by such a law.

P. Graffin *(EEC)*

This law is actually enforced?

F. Bonciarelli

Yes, since May of this year. No agronomists, no chemists, no technical authorities, were consulted - I don't know who wrote this law. Maybe it would be useful to suggest to our Government that the people who formulate the regulations should take advice from the scientists in order to render the regulations less prohibitive to the farmers.

J.H. Voorburg

Thank you very much Dr. Bonciarelli. We must close this session now.

THE YIELD EFFICIENT NITROGEN PORTION IN TREATED AND UNTREATED MANURE

C. Tietjen
Institut für Pflanzenbau und Saatgutforschung in der Forschungsanstalt für Landswirtschaft, Braunschweig-Völkenrode, West Germany

INTRODUCTION

Livestock manures contain organic matter and nutrients. Both groups of ingredients are valuable for improving and conditioning the soil and for the nutrient supply of the crop. The significance of the nutritive substances is greater where other sources are not available and in periods of shortage of commercial fertiliser supply.

Estimates of the amount of excrements, faeces as well as urine, and also data of analyses will always show a great variation. There are many influences effective depending on the animal and on environmental factors.

Data in Tables 1 and 2 were obtained on the base of comprehensive feeding experiments with weight control and analyses of a great number of samples, they show as an example the relation between animal weight and the amount of daily excreted faeces and urine and also the influence of pregnancy (Sauerlandt, 1970).

With regard to the content of crop nutrients, fresh manure of laying hens ranks first, followed by pig and cow manure; the latter calls attention to the high potassium content.

Based on the data in Tables 1 and 2, the graphs shown in Figures 1 and 2 were developed. They show the amounts of manure and of nutrients from cows in a period of 1 000 animal-days and from pigs over 10 000 animal-days: the increase of the total mass by combined collection of faeces and urine and also the changing of the ratio of nutrients. Because of the low contents of Ca, P and Mg in urine, these quantities are not remarkably influenced by increasing portions of urine. Potassium (cows) and nitrogen show a steep increase by the addition of urine.

TABLE 1

FAECES AND URINE EXCRETED DAILY BY DAIRY COW AND FATTENING PIG

	Faeces kg	Urine kg	Faeces + urine kg	Faeces	Urine	Faeces + urine
				percent of liveweight		
Dairy cow, 630 kg						
Period of lactation	34.4	21.2	55.6	5.5	3.3	8.8
Period of pregnancy	23.4	20.4	43.8	3.6	3.2	6.8
Average	29.5	20.8	50.3	4.6	3.3	7.9
Fattening pig, cereals						
Liveweight 40 kg	1.02	2.60	3.62	2.4	6.2	8.6
60 kg	1.51	2.57	4.08	2.5	4.3	6.8
90 kg	1.90	2.55	4.45	2.1	2.8	4.9
130 kg	2.15	2.74	4.89	1.7	2.1	3.8
Average 87 kg	1.73	2.62	4.35	2.0	3.0	5.0

TABLE 2

CONTENTS OF NUTRITIVE ELEMENTS IN THE TOTAL EXCREMENTS CALCULATED ON A FAECES/URINE RATIO OF 3 : 2 WITH DAIRY COW AND 2 : 3 WITH FATTENING PIG, PERCENT FRESH

	N	P	K	Ca	Mg
Dairy cow	0.46	0.07	0.48	0.29	0.06
Fattening pig	0.91	0.29	0.28	0.34	0.06
Laying hen in cage	1.53	0.47	0.49	0.87	0.17

The ratio of nutrients is continuously shifting, thus changing also the fertilising effect and its influence on the growth development of the crop. This demonstrates the difficulty of matching the demand of nutrients of crop and soil by liquid manure application without some kind of standardisation by well adjusted mechanical equipment for the steps of procedure:

collection of faeces and urine, storage and treatment, mixing, loading, uniform spreading.

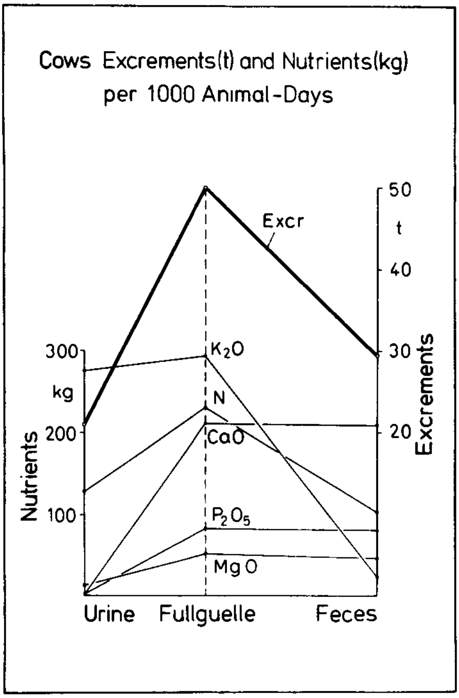


Fig. 1. Cows: Excrements (t) and Nutrients (kg) per 1 000 animal-days

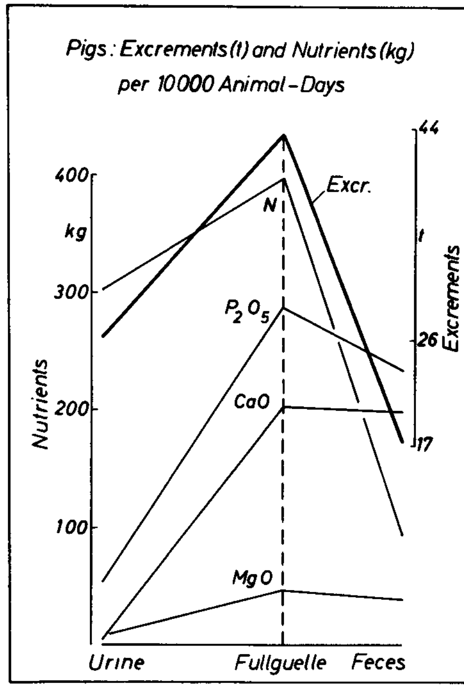


Fig. 2. Pigs: Excrements (t) and Nutrients (kg) per 10 000 animal-days

MANURE EFFECT DEPENDENCES AND THE YIELD EFFECTIVE NITROGEN

The effect of manure on soil conditioning and crop yield depends on several factors; the influence of three of them is shown in Table 3. These are significant conditions:

TABLE 3

MANURE EFFECT DEPENDENCES

Spreading	C : N	Available Nitrogen	Effect on yield
1. Coarse	20:1	Medium	Low
2. Fine	20:1	Portion	>1
3. Liquid	20:1	of N_{total}	>2
4. Coarse	15:1		>1
5. Liquid	15:1		High
6. Coarse	20:1	Great	= 4
7. Liquid	20:1	Portion	4 - 5
8. Fine	15:1		= 7
9. Liquid	15:1		Very high
10. Coarse	25:1	Small	Depressing
11. Liquid	25:1	Portion	>10

a) The tools and implements for manure distribution on the land, i.e. with a pitchfork only a coarse distribution is possible; a manure spreader gives a fine, closed cover; liquid manure penetrates at once into the upper layer of the soil, thus decreasing loss of volatile matter.

b) The ratio of carbon to nitrogen which is influenced by various treatments that decrease the loss of nitrogen or accelerate the decomposition process of organic matter; in general, the narrower the C : N ratio, the higher the manure effect on crop growth.

c) The available nitrogen portion of total nitrogen in the manure depends again on various treatments; the greater the urine portion together with an appropriate quantity of water added, the higher the content of ammonia nitrogen.

Depending on different arrangements of these three factors, different effects on crop yield are to be observed, ranging from depressing to very high. According to this scale, only liquid manure has a very high or very high yield effect.

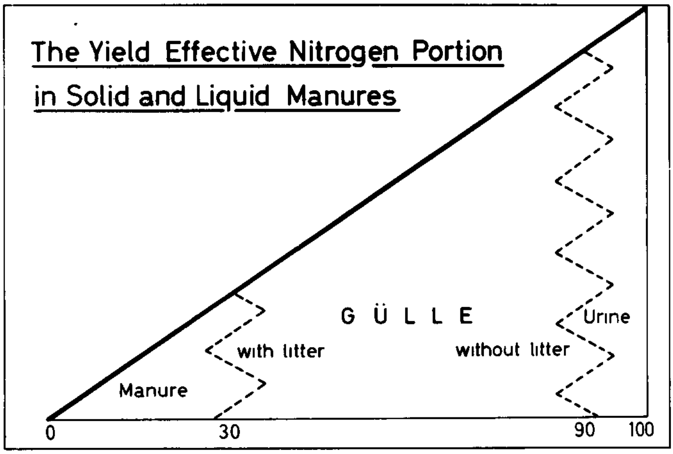
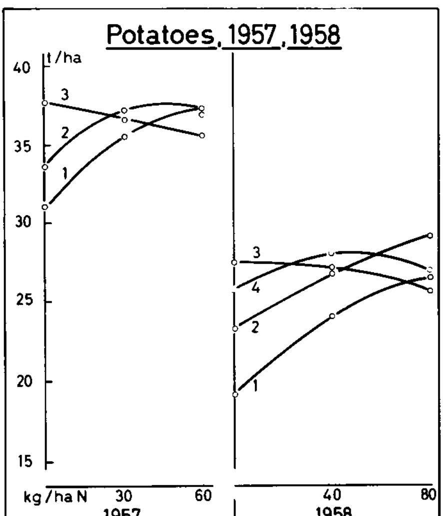


Fig. 3. Manure classification according to the portion of nitrogen that is effective on crop yields



	Fertilizer N kg/ha 1957			Fertilizer N kg/ha 1958		
	0	30	60	0	40	80
1 No Manure	30,9	35,5	37,1	19,3	24,0	26,7
2 Barnyard Manure	33,6	37,3	37,2	23,3	26,9	29,2
3 Gulle I	37,6	36,7	35,5	27,5	27,1	25,7
4 Gulle II	—	—	—	25,7	27,9	26,9
LSD 5%	2 5	1 8	2 7	2 3	2 7	3 7

Fig. 4. Reciprocal effect of nitrogen fertiliser and manures on the yield of potatoes.

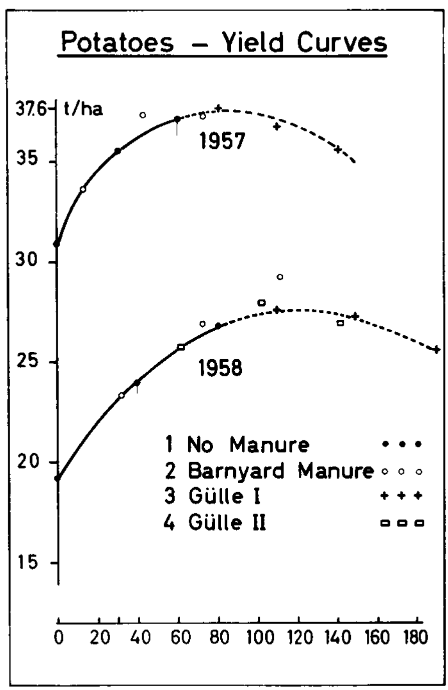


Fig. 5. Yields obtained with manures arranged along yield curves obtained with nitrogen fertiliser.

Results of field and pot experiments with various kinds of manures have been summarised in Figure 3 to demonstrate the differences in yield effect. The basis of comparison was the amount of nitrogen applied with the specific manure and the yield effect of known amounts of mineral nitrogen fertiliser, thus showing the portion of nitrogen in the manure which was effective on crop yield. In general, the nitrogen in urine has about the same effect on crop yield as mineral nitrogen; 100 nitrogen units in solid barnyard manure are equal to 0 to 30 units in mineral fertiliser. The broad range between barnyard manure and urine is created by various kinds of guelle. Guelle with litter is in the lower range and guelle without litter is in the upper range. Other variants occur by changing the portions of faeces and urine. A so-called full-guelle which contains solid and liquid excrements in the amounts excreted by the animal is classified at about 50.

Collection and storage of barnyard manure and guelle differ not only in the fact that guelle contains all urine but in addition, guelle stored in a pit with restrained air access retains almost all of its plant nutrients. Figure 4 shows two year results of two field experiments with different manures at the same location. Equal amounts of fresh excrements and litter were stored for eight weeks, on the one hand in a heap and on the other hand in air-tight concrete pits. One closed pit had been heated to 30°C to produce manure gas by the anaerobic decomposition of carbonaceous material; the other one was not heated and its temperature was about 15°C. These manures were applied to potatoes. Equal amounts of mineral phosphate and potassium fertilisers were applied and three stages of nitrogen were differentiated. Average yields in the first year were significantly higher than in the second year because of different weather conditions. However, in both years the same yield trend was observed: variants No. 1 and No. 2, no manure and barnyard manure, showed the well-known yield increase by nitrogen application. The reciprocal effect of both liquid manures, guelle I and guelle II, and nitrogen fertiliser showed a noteworthy result. High yields were obtained by the liquid manures without nitrogen fertiliser. Variant 3, guelle with a narrower C : N ratio as a consequence of the heat treatment, proved superior to variant 4. Nitrogen did not increase remarkably the yield effect of those manures (Tietjen, 1963).

With reference to the same experiments the suggestion is made in Figure 5, to elongate the yield curves obtained with variant 1 showing the yield increasing effect of nitrogen fertiliser without application of animal manure. The elongation presents yield curves of the well-known shape with a descending part which is obtained by applying growth promoting substances beyond the optimum quantity. The elongated curves are in good accord with the yield results obtained with the animal manures; this demonstrates that the decreasing yields by guelle 1 and guelle 2 result from an oversupply of plant nutrients (Tietjen, 1970).

In these experiments, equal quantities of fresh animal excrements and litter had been compared after differentiated treatment; the results can be taken as an evaluation of the treatment method. The conclusion is that the products of liquid manure practices exercise a higher yield effect than solid manure, and that the quantities applied together with fertilisers should be in good accord with the nutrient requirements of the crop and the supply of the soil.

FEED ADDITIVES INFLUENCE THE MANURING EFFECT OF EXCREMENTS

Supplementation of animal feed by antibiotics and other additives is aimed at increasing weight gains, increasing feed conversion efficiency, and the maintenance or the restoration of animal health. A lasting effect in the excrements after defaecation cannot be excluded.

In pot experiments with oats, pooled fresh excrements from pigs and from broilers were used which were collected during investigations on the nutritive effect of feed supplementation with carbadox, oleandomycin, oxytetracycline, flavophospholipol, virginiamycin, zinc bacitracin, payzone, and quindoxin. As interaction with increasing rates of nitrogen fertiliser we observed hindering as well as furthering of crop growth. Remarkable increase of dry matter production was caused by carbadox; higher nitrogen contents were related to flavophospholipol, oxytetracycline, and oleandomycin. Soil application of chlortetracyclin, zinc bacitracin, and streptomycin did not affect the production of dry matter and the nitrogen content, but applied together with two varieties of chicken manure, dry matter production was decreased and nitrogen content was increased to a remarkable extent.

Dietary supplementation by antibiotics and other kind of additives may modify the biodegradation of the excrements as well as their manuring effect in crop production and in the uptake of nitrogen.

THE NORMAL AND THE ADMISSIBLE RATE OF MANURE APPLICATION

The traditional type of farming with a balanced ratio of crop production and livestock husbandry in the same enterprise gives the base of calculation. Knowledge and site experience of the nutrient requirements of crops are decisive for the amount of manure application. Nitrogen and phosphorus are considered the most important constituents with concern of both, crop yield and environment contamination. Recommended rates are based on experience and research. But they do not match the needs of crops, because only little information on the annual rate of biological decay of the organic materials is ready for use and no prediction can be given about the availability of the organic bound nutrients with satisfying certainty.

Recommended rates of application are mostly based on the nitrogen content and on the available portion of it which is estimated. The graph in Figure 6 demonstrates by comparison with a few manures how great the differences can be between the applied nitrogen and the nitrogen uptake by the crop. While about 80 percent of the nitrogen applied as NH_4NO_3 has been

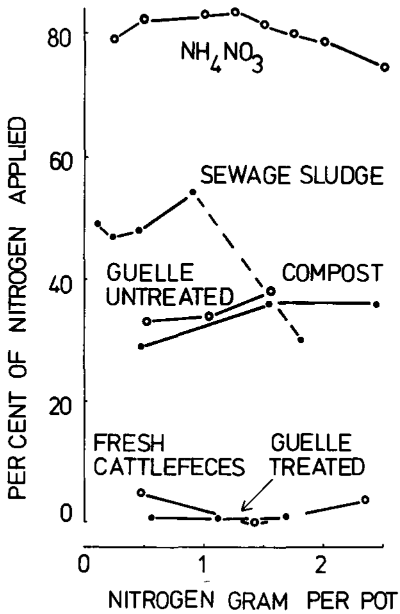


Fig. 6.

Nitrogen uptake by oats as percent of nitrogen applied with increasing doses of five organic manure varieties and of NH_4NO_3

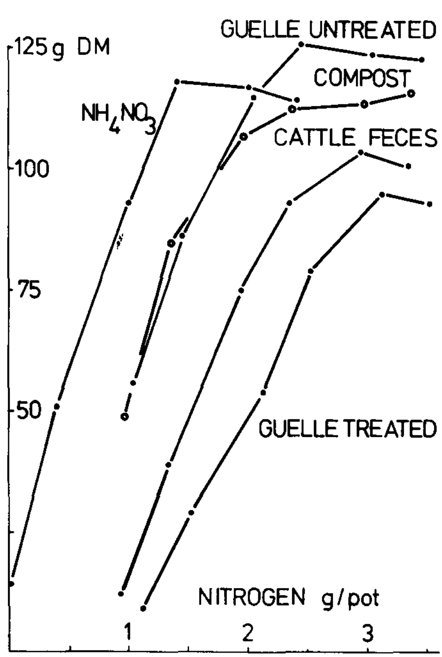


Fig. 7. Yields of oats, dry matter, by four manure varieties (first marks, lowest yields) and increasing supplementary NH_4NO_3 rates.

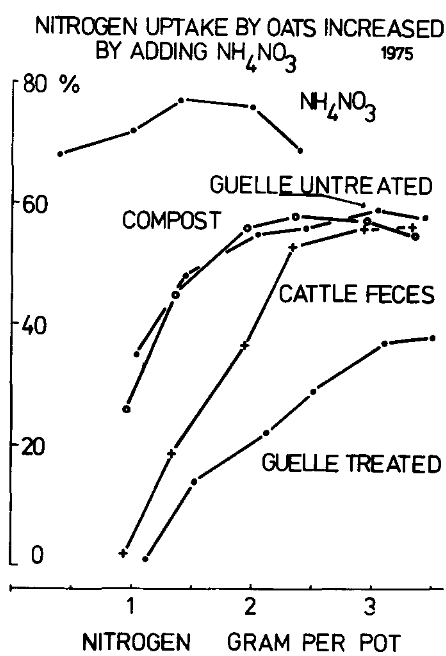


Fig. 8. Nitrogen uptake by oats as percent of nitrogen applied with manure varieties (first marks, lowest values) and supplementary NH_4NO_3 rates.

taken up by oats in pot experiments without loss by leaching, the portion was 30 to 50 percent with pumpable sewage sludge, with untreated cattle guelle and with compost prepared of droppings from cage hens and peat. Nitrogen in fresh cattle faeces and in cattle guelle treated by aeration was almost unavailable in the first period of growth; perhaps, the longer and the higher will be the after effect with the next crops, if no greater losses occur (Thaer, 1975).

The yield increasing effect of available nitrogen supplements to manure varieties is shown in Figure 7. Even the yields by fresh cattle faeces and treated cattle guelle (aeration) are raised from a very low level to a more satisfying height by the additional nitrogen application.

This effect on the yield of crop mass can be transmitted to the input-output ratio of nitrogen, shown in Figure 8.

Results of yield and nitrogen uptake by oats obtained in pot experiments with another group of animal manures are summarised in Table 4. They show the great difference in the nitrogen efficacy, i.e. between cattle faeces and cattle urine, both applied fresh and untreated, or between pig faeces and pig urine, or between cattle guelle which was stored in a pit and pellets originating from the same cattle excrements, made by a biological dehydrating process and mechanical pressing. While a good yield was achieved with the guelle and 40 percent of the applied nitrogen was regained, only a poor crop growth and yield was observed with the pellets and the nitrogen uptake was nearly zero (Baader, 1975).

The examples mentioned manifest the great variation between livestock manures. Pratt et al. (1973), developed computer programmes to calculate a number of manure decay series in combination with various rates and times which demonstrate the nitrogen accumulating effect of annual applications of manure varieties with a different availability coefficient. We may transfer this calculation to other nutrients, i.e. to phosphorus with a still lower availability. We quite see that every accumulation with environmental concern must be controlled, but its importance or weight can be reduced by increasing the availability and by narrowing the input-output ratio. Our proposal is to match the nutrient supply with the need of the crops as closely as possible in order to produce maximum yields with highest rates of uptake.

TABLE 4

EFFECT OF COMPARABLE AMOUNTS OF NITROGEN IN DIFFERENT LIVESTOCK MANURES ON THE YIELD OF OATS AND THE UPTAKE OF NITROGEN IN POT EXPERIMENTS (Tietjen,1976)

Manure	Nitrogen in manure	Yield grain + straw	Nitrogen in crop yield	
g/pot	g/pot	g/pot	g/pot	percent of added N
Cattle guelle				
200	1.1	61.8	0.44	40.0
Pellets of cattle guelle				
75	1.3	12.1	0.03	2.3
125	2.1	10.7	0.07	3.3
Cattle faeces				
450	1.7	28.0	0.29	17.1
Cattle urine				
140	1.0	75.0	0.86	86.0
Pig faeces				
150	1.6	33.7	0.31	19.4
Pig urine				
100	1.4	87.9	0.92	65.7
Compost of chicken manure and peat				
105	1.2	57.4	0.46	38.3
175	2.0	83.1	0.80	40.0
Nitrogen in NH_4NO_3	1.4	108.6	1.20	85.7
	2.0	114.2	1.61	80.5

SUMMARY

Livestock manures consist of faeces and urine with different contents and ratios of nutrients. By changing the portions of faeces and urine the ratio of nutrients in the manure is

shifting, the fertilising effect is changed and also its influence on the growth development of the crop.

The difficulty of matching the demand of crop and soil requires some kind of standardisation by well adjusted mechanical equipment for the collection of faeces and urine, for the storage and treatment, for mixing, loading, and spreading on the land.

In general, the nitrogen in urine has about the same effect on crop yield as nitrogen in mineral fertiliser. A hundred nitrogen units in solid barnyard manure are equal to 0 to 30 units in mineral fertiliser. The broad range between barnyard manure and urine is covered by various kinds of guelle. A so-called 'full guelle' which contains faeces and urine in the amounts excreted by the animal is classified at about 50.

Dietary supplementation by antibiotics and other additives may modify the biodegradation of the excrements as well as their manuring effect in crop production and in the uptake of nitrogen.

Recommended rates of manure application are mostly based on the nitrogen content and on the available portion of it which is estimated. However, only little information on the annual rate of biological decay of the organic materials is ready for use and no prediction can be given about the availability of the organic bound nutrients with satisfying certainty.

Manure accumulations with environmental concern must be controlled. The importance can be reduced by increasing the availability and by narrowing the input-output ratio of nutrients. The nutrient supply must be matched with the need of the crops as closely as possible in order to produce maximum yields with highest rates of uptake and reduced potential of environmental contamination.

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THE INFLUENCE OF ANIMAL MANURES ON THE GRAZING BEHAVIOUR AND HERBAGE INTAKE OF CATTLE

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INTRODUCTION

With the concentration into intensive units of large numbers of animals, problems have been created in the collection, storage and disposal of the excreta and litter. In some situations, large poultry units have developed on small farms which have inadequate land to spread the excrements. On some intensive pig farms, the soil type and the terrain are unsuitable for disposal of the quantities of slurries which accumulate. Soil conditions frequently restrict large cattle units applying slurry except in the growing season.

Ideally, both from the point of view of ease in disposal and fertiliser value, animal manures should be returned either to cultivated areas or grassland which has been cut for silage. In regions such as Ireland, where cultivated land is only 10% of the total area and even this is concentrated in particular sections of the region, disposal of animal manures is almost exclusively on grassland. On many occasions, disposal of manures onto silage or hay areas is unsuitable or inopportune, hence the necessity to apply manures on grassland which is to be grazed.

The distribution of cattle and sheep excrements and their influence on grass production and utilisation in the grazing situation has received much attention (Marsh and Campling, 1970; Martin and Donker, 1966; Collins, 1967, 1968), but only limited attention (Reid et al.,1972; Pain et al., 1974) has been given to animal behaviour and production where slurries have been applied. In the case of dung droppings spread by the grazing animals, the affected area is limited but with animal manures spread mechanically, the total sward is affected.

The experiment undertaken here was designed to determine whether or not cattle would reject grass swards which were treated with cattle, pig and poultry slurries and if so, for how long and what effect this might have on animal performance.

EXPERIMENTAL

Treatments

Forty plots, each measuring 0.1012 ha, were set out on a perennial ryegrass *(Lolium perenne)*, white clover *(Trifolium repens)* sward on a moderately well drained brown earth soil. Analysis of soil samples indicated that the site had adequate P and K. The plots were divided into four blocks of ten treatments. In early April of this year (1976) slurry was applied at 0, 32.5, 65 and 97.5 t/ha (9.1% DM) of cattle slurry, 65 t/ha pig slurry (8.8% DM) and 32.5 t/ha poultry slurry (9.8% DM). Further application of cattle slurry namely 97.6 t/ha to be applied (a) in two applications of 65 t/ha in spring and 32.5 t/ha after a silage cut in early June; (b) in three applications of 32.5 t/ha each, and (c) in three applications of 32.5 t/ha each, for (i) spring grazing, (ii) early June for mid-season silage, (iii) after silage for autumn grazing. Finally there is a fertiliser nitrogen treatment of 162 kg N/ha per year applied in four dressings. The control plot received 54 kg N/ha for the year also in spring. Treatments were randomised within the blocks and there are four replications. Details of the treatments are outlined in Table 1.

Animal manures

Cattle slurry was obtained from beneath the slatted floor of a house in which finishing cattle were fed grass silage plus barley. Pig slurry was collected from fattening pigs and was stored overground in a steel tank. The poultry slurry was collected from laying hens in Californian cages and stored for a few days in an overground tank to which water was added. All the slurries were well agitated before spreading particularly the pig slurry, and they were spread with a Fleming vacuum tanker.

TABLE 1

ANIMAL MANURE TREATMENTS AND RATES OF APPLICATION (t/ha)

Treatment A	Control - 54 kg N/ha
" B	32.5 t/ha cattle slurry
" C	65.0 t/ha cattle slurry
" D	65.0 t/ha pig slurry
" E	97.5 t/ha cattle slurry
" F	97.5 t/ha cattle slurry (3 applications of 32.5 t/ha)
" G	97.5 t/ha cattle slurry (2 applications of 65 and 32.5 t/ha)
" H	97.5 t/ha cattle slurry (3 applications of 32.5 t/ha)
" I	32.5 t/ha poultry slurry
" J	162 kg N/ha in 4 applications

Animals

Thirty Friesian steers, 16 to 20 months old, were used to graze the experiment. Their average liveweight at the start of the grazing was 320 kg (range 307 - 342 kg). They were divided into three groups of 10 animals according to their liveweight. On May 7, one animal from each group was allocated randomly to each of the treatments in block 1. There are three steers per treatment and when each block is grazed they move to the same treatment in the next block. A stocking rate of 7.41 steers/ha is used and the grazing cycle is 24 days.

MEASUREMENTS

Herbage Production

Prior to grazing each plot and again when the stock are removed, two 4.5 m^2 grass samples are taken from the sward with a powered rotary mower. Cutting height is 1 - 2 cm above soil level. Samples from each sub-plot are weighed and sampled. Two 100 g aliquots are used for percentage dry matter determinations. Samples are dried for 18 hours at 80^{o}C in a force draught oven. The pre-grazing samples are used to determine the amount of herbage dry matter presented to the grazing animals, while the post grazing samples are used to estimate the herbage removed in grazing and to indicate herbage rejection.

After drying samples are ground to pass a 1 mm sieve. The following parameters will be measured, organic matter content, in vitro digestibility, total N, P and K.

Herbage Intake

Herbage intake by the steers is being measured using the Chromium sesquioxide marker technique. The following relationship is used to measure intake:

$$OMI = \frac{100 \times OMO}{100 - OMD}$$

where OMI = organic matter intake

OMO = organic matter output

OMD = organic matter digestibility.

Cattle are dosed for a period of four days prior to sampling at 1400 hr with a 10 g capsule of chromium sesquioxide using a balling gun. Dosing continues for a further seven days with the capsules and with coloured polystyrene particles, the colour of which is different for each animal in the group. In this period faeces samples are collected each day from the fresh dung pats in the paddock, the colour of the particles permitting identification of the dung droppings. Faeces samples are pooled for each animal period and a sub-sample is dried and used for ash and chromium analysis. A second sub-sample is analysed for faeces nitrogen concentration to estimate digestibility of the herbage eaten.

Animal Behaviour

To monitor the grazing behaviour of the animals on the different treatments, Vibracorders are being used. In this technique the grazing time is automatically recorded through a pendulum and stylus on to an eight day recording chart. Work elsewhere (Werk et al. 1974; Castle et al. 1975) has shown that Vibracorders are simple, reliable and accurate instruments for measuring grazing behaviour and they save many tedious hours of day and night observations. Times that grazing started and ended and the actual length of time spent grazing are recorded.

Animal Liveweight Gain

At the end of each grazing cycle the cattle are weighed to assess performance and daily liveweight gain.

RESULTS

As the experiment did not commence until May 7 this year, it will be appreciated that only limited research data have been collected to date.

Herbage Production

The mean herbage DM production per treatment before the first and second grazing period is given in Table 2.

TABLE 2

THE EFFECT OF SLURRY APPLICATIONS ON HERBAGE PRODUCTION (100 kg/ha)

Period	Treatments									
	A	B	C	D	E	F	G	H	I	J
7/27 May	18.4	20.0	17.8	21.1	11.8	16.5	16.1	19.6	20.2	16.4
27 May/ 24 June	31.6	32.9	30.0	34.2	27.7	29.3	-	31.9	28.6	27.8

The dry matter data in Table 2 indicate the general nature of the swards when grazed. The first grazing cycle started 24 days after the slurry was applied. The quantities of herbage presented to animals was much lower than in the second grazing cycle which happened to coincide with the normal period of peak herbage growth in Ireland (Collins and McCarrick, 1969). With the exception of treatment E, slurry applications generally had only minor effects on herbage yields. Treatment E (97.5 t/ha of cattle slurry) significantly reduced grass production in the first grazing cycle but in the second period the effect was minor. Dry weather following the application of the slurry in

April caused it to form a dry skin on the soil surface, smothering the grass and delaying its regrowth. Had wet weather followed application it is unlikely that such a reduction in herbage yield would have been recorded. Both pig and poultry slurries increased the herbage yields slightly over the other treatments in the first cycle with the pig manure producing the highest yields of grass in both grazing periods.

Herbage Intake

Initially the animals on the slurried pasture were reluctant to eat the herbage, particularly on treatment E, i.e. high cattle slurry, and treatment I, i.e. poultry slurry. In time they became accustomed to it with the result that treatment E was grazed bare but in treatment I the animals selected mainly the top of the sward.

At the time of writing no definite data on herbage intake is available due to the unavailability of the chromium analysis of the faeces samples. However, estimates of intake based on herbage dry matter yield differences indicate some treatment effects (Table 3).

TABLE 3

HERBAGE INTAKE - kg/100 kg LIVEWEIGHT (BASED ON PRE- AND POST-GRAZING HERBAGE YIELDS)

Grazing Period	Treatments									
	A	B	C	D	E	F	G	H	I	J
1	0.93	1.00	0.77	1.66	0.40	0.68	-	0.71	0.97	0.97
2	2.22	1.59	1.48	1.69	1.23	1.75	-	1.73	1.11	1.61

Intakes were low particularly in the first grazing period. It is suggested that this was due somewhat to no account being taken of herbage growth in the six day period between the pre and post grazing herbage determinations. The data do show, however, that cattle slurry reduced intakes and especially the high application of 97.5 t/ha, i.e. treatment E. Poultry slurry i.e. treatment I, reduced intake at the second grazing period.

Animal Behaviour

In the first grazing period animal behaviour was recorded on the control and the high cattle slurry plots; in the second period on all treatments using a single animal in each case. Some details are given in Table 4.

TABLE 4

INFLUENCE OF CATTLE SLURRY ON ANIMAL GRAZING BEHAVIOUR - MAY 13 to 17

	Control	97.5 t/ha
Start of grazing	0618 hrs	0512 hrs
End of grazing	2115 hrs	2230 hrs
Grazing time before noon	155-160 mns.	228 mns.
Grazing time after noon	350 mns.	373 mns.
Grazing time for the day	510 mns.	601 mns

There was little doubt that the grazing behaviour of the animals on the high cattle slurry treatment was modified. Grazing started earlier in the day and ended later at night; it was much more intermittent and lasted over 90 minutes longer in the day. Most of this extra time grazing occurred in the morning and mainly through the animals starting to graze earlier. Approximately 35% of all grazing took place before noon and 65% between noon and the end of the day's grazing, with the most concentrated grazing occurring between 1700 and 2200 hrs.

Some details of the grazing behaviour for the second period are given in Table 5.

Differences in grazing behaviour due to the application of the slurries was not as marked in the second grazing period (Table 5) as those recorded in the first grazing period (Table 4). With the exception of the pig slurry (treatment D) grazing on slurry plots started earlier than in the control and ended at about the same time, i.e. 2230 hrs. There was more intermittent grazing on all the slurry treatments which meant less total time spent at this activity than in the control or the nitrogen plots (treatment J) (478 x 538 mins). Overall, 27% of all grazing occurred before noon with 73% in the afternoon and particularly in the five hours before sunset.

TABLE 5

INFLUENCE OF ANIMAL MANURES ON ANIMAL BEHAVIOUR IN THE PERIOD JUNE 16 TO 24

Period	Treatments									
	A	B*	C	D	E	F	G	H	I	J
Start of grazing	6.54	-	6.15	7.06	6.22	5.46	-	6.52	5.50	6.40
End of grazing	22.30	-	22.30	22.37	22.20	23.08	-	22.30	21.52	22.29
Grazing time before noon (mins.)	144	-	147	126	157	161	-	137	151	158
Grazing time after noon (mins.)	378	-	288	342	311	359	-	361	330	397
Total for the day (mins.)	522	-	435	468	468	520	-	498	481	555

* Only 1 day

Animal Performance

Details of animal performance and liveweight gain/day on the various treatments are given in Table 6.

TABLE 6

ANIMAL PERFORMANCE AND LIVEWEIGHT GAIN/DAY

	Treatments									
	A	B	C	D	E	F	G	H	I	J
Animal performance (kg/head)										
Period 1	36	34	35	35	14	29	-	24	31	28
Period 2	24	9	24	22	27	27	-	19	27	32
Total (1 + 2)	60	43	59	57	41	56		43	58	60
Liveweight gain/day (kg)										
Period 1	1.38	1.30	1.34	1.34	0.53	1.11	-	0.92	1.19	1.07
Period 2	1.09	0.40	1.09	1.00	1.22	1.22	-	0.86	1.22	1.45
Total (1 + 2)	1.25	0.89	1.22	1.18	0.85	1.16		0.89	1.20	1.25

Modifications in the animal grazing behaviour were reflected in the animal performances but the negative effects were very small in some instances and occurred mostly in the first grazing period. Treatment E (97.5 t/ha cattle slurry) had a very distinctive negative effect in the first grazing period which was not evident in the second period. This was to be expected in view of the reduction in herbage growth by the slurry. Animal performance in general was very satisfactory on the treatments and it appears that any negative effects which arose initially due to the slurries will be offset during the remainder of the grazing season.

DISCUSSION

Because the experiment has existed for only a short period the findings to date cannot be considered definitive. However, the trends in the results are somewhat analogous to other findings (Reid et al.,1972; Pain et al., 1974), and indicate the type of ultimate findings likely. It appears that with slurry application to pasture, provided that the rate applied is not excessive as in the case of treatment E, rejection of such swards by grazing animals will be small. The experiment also demonstrates that cattle will graze herbage grown with very high rates of slurry provided no other choice exists. Animal behaviour because of the slurry is modified and this is reflected in the grazing time and performance of the animal. Such effects, however, appear to be of a temporary nature and whilst a reduction in liveweight gain by the animal occurs it is felt that this can be recovered later in the grazing season.

If the slurry had been applied earlier in the season, i.e. February or March, there is the possibility that the longer time that would elapse between spreading and grazing would have allowed the rain to wash the slurry into the soil more thoroughly and no effect from it might have been evident. We do not know, of course, what effect mid and late season applications of slurry will have or what will be the cumulative effect of the slurries over two or three years. Only time will answer some of these queries.

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ANIMAL ORGANIC MANURES IN DUTCH FORESTRY: APPLICATION AND RESTRICTIONS

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ABSTRACT

Effects of application of animal organic manure in conifer stands on rather poor sandy soils are discussed, based on research on relationships between growth, healthiness and soil fertility. Conifer stands are not very suitable for heavy and continuous application of animal organic manure. Such dressings should therefore be avoided.

Poplars and possibly some other hardwoods tolerate heavy dressings of manure much better, although only some evidence on short-term effects exists. From some experiments it is concluded that Euramerican poplar can be manured in spring with ca. 100 t pig slurry/ha for ca. 5 years. N and Cu have no harmful effects on growth and healthiness.

INTRODUCTION

Application of organic manure in Dutch forestry has not played a very important role. During the period of large-scale afforestations of heathlands, between World Wars I and II, mainly phosphate was applied in inorganic form (basic slag and rock phosphate). Incidentally, compost was also used (50 - 100 m^3/ha). Forest nurseries are usually dressed with farmyard manure (80 - 100 m^3/ha) once during a crop rotation. In general, after the success of the phosphate fertilisation of former heathlands, interest in fertilisation of forest decreased for economic reasons. Also there has been a tendency to choose tree species according to actual site conditions; soil amelioration (soil cultivation, fertilisation, etc.) is sometimes considered to be more or less harmful to forest soils.

During the last decade, Dutch forestry has been confronted with the fact that some areas of intensive animal production coincide with areas where pine forests are situated, viz. the province of North-Brabant and the Veluwe area. Both areas are made up of rather poor sandy soils (humus podzols) which bear only poorly to moderately growing pine forests (Scots pine and Corsican pine). It is likely that farmers took an interest in these forests because they had a surplus of organic manure (poultry wastes and pig slurry).

In 1970 the State Forest Service asked the Forest Research Station to examine possibilities for spreading surpluses of pig slurry in conifer stands in North-Brabant. The reason for this request was the fact that many pine stands have been impoverished by removal of litter and raw humus. It was supposed that growth and healthiness of these stands could be improved by fertilisation, i.e. by manuring with pig slurry. A study of existing data on consequences of heavy dressings and high levels of soil fertility on healthiness of conifer stands showed, however, that this proposed method of fertilisation was not safe (see 1 and 5). Therefore the Forest Research Station advised against application of large quantities of animal organic manure in conifer forests, but started experiments with poplar, a species which presumably tolerates high dressings of organic manure. A field trial, established by the State Forest Service in some stands of Corsican pine in North-Brabant was also included in the research.

This paper deals with consequences of heavy dressings of organic manure in conifer stands and with provisional data of current research with Euramerican poplar.

1. CONIFER STANDS AND ORGANIC MANURE

1.1. The removal of litter and raw humus, its consequences and restoration

In North-Brabant much litter and raw humus has been removed from many stands of conifers (Van Goor and Tiemens, 1963). This has been a common practice in central Europe where litter removal by man has been continued for centuries. As a result, organic matter and total nitrogen content have decreased, while the C/N quotient has increased which in fact means a deterioration of N supply (Baule and Fricker, 1967). Much research has been done on amelioration of these soils, principally because the N content of the soil must be increased, the aim of ameliorations must be the increase of soil organic matter and increase of its N content. This is a time-consuming process which is not completed by a few dressings of organic manure.

Much more important is the fact that roughly two-thirds of the fine roots of Scots pine stands occur in the litter and raw humus layer (Van Goor and Tiemens, 1963; Stichting Bosbouwproefstation, "De Dorschkamp", 1972). Thus after removal of these organic layers the tree is deprived of most of its roots. As a result, losses of increment of Scots pine stands amount to one half to three-quarters of its original growth (Baule and Fricker, 1967). Once the tree has lost the majority of its roots, high dressings with fertilisers are ineffective because there is no way that these nutrients can be taken up. Research in North-Brabant on the influence of litter and raw humus removal on growth of a stand of Scots pine and of a culture of Douglas fir, planted after removal of the Aoo and Ao, showed that this type of forest management could not be corrected by NPK fertilisation and compost (Knol, 1973).

Apart from being a rooting medium, litter and raw humus are the environment in which mycorrhiza live. For their mineral nutrition many conifer species depend on mycorrhizal activity, which of course is cut off when litter and raw humus are removed. Their role cannot be taken over completely by fertilisation.

Intensifying mineralisation of litter and raw humus is as dangerous as removal of litter and raw humus. This can be initiated by liming and nitrogen fertilisation. Based on results of current and former research, Laatsch (1963) concluded that this intensive break-down of raw humus results in an increase in vitality of the fungus *Fomes annosus* which attacks living conifer trees (*Pinus sp., Picea sp.* Douglas fir). Control of this fungus is almost or completely impossible. Research on the influence of amelioration of poor sandy soils in the Dorst forest in North-Brabant led to the conclusion that intensification of amelioration methods (soil cultivation alone; cultivation + one year lupins; 4 years agricultural crops; 8 years agricultural crops) caused an increase in attack of Scots pine stands by *Fomes annosus* resulting in die-back of the pines (IUFRO, 1954).

The above mentioned evidence has been used to discourage the application of large amounts of animal organic waste in conifer stands on rather poor sandy podzol soils

1.2. Application of liquid poultry waste in stands of Corsican pine

1.2.1. Description of the experiment

In July 1970, nine stands of Corsican pine (*Pinus nigra sp. laricio*) were fertilised with liquid poultry waste. During 1970, 1971 and 1972, no clear reactions were visible, but in 1973 the foliage of the manured treatments was darker. This indicated some reaction of the pines and it was decided to measure growth and to sample foliage and soil. These activities took place in the winter of 1973/1974. A summary of the data (Van Marle, 1974) is given below. All stands are situated on dry inland dune sand. Soil chemical data are mentioned in Table 1.

TABLE 1

SOIL CHEMICAL PROPERTIES OF NINE STANDS OF CORSICAN PINE IN THE SINT ANTHONIS FOREST (MARCH 1974; 0 - 25 cm)

Section of the forest	pH KCl	Organic matter %	Total N (%)	N org (%)	Total P (mg P_2O_5/100 g)
15c	3.4	4.7	0.074	1.58	14
35a	3.9	2.2	0.043	1.93	10
43b	3.8	2.0	0.032	1.60	11
50d	3.9	1.8	0.031	1.72	9
53e	3.9	2.7	0.040	1.48	14
58a	3.3	4.9	0.079	1.62	15
63a	3.4	3.2	0.047	1.47	13
63f	3.4	3.4	0.052	1.54	13
64k	3.5	4.3	0.075	1.74	14
Mean	3.6	3.2	0.053	1.63	13

These data show that the N status of the soils for Corsican pine is not optimal (N org. should be 2.0%) and that its P status is more or less sufficient for moderate growth of Corsican pine (site class III).

Manuring of the stands took place in July 1970. Data on quantities of liquid poultry waste and estimated amounts of N, P_2O_5 and K_2O (computed from standard tables of the Consulentschap IAD, 1974) are summarised in Table 2.

Measurements of height and diameter growth were done in winter 1973/74, soil samples were taken in March 1974, foliar samples in December 1973.

TABLE 2

QUANTITIES OF LIQUID POULTRY WASTE (t/ha) AND AMOUNTS OF N, P_2O_5 and K_2O (kg/ha) IN POULTRY WASTE, APPLIED IN THE SINT ANTHONIS FOREST (STANDS ARRANGED IN ORDER OF INCREASING PHOSPHATE QUANTITIES)

Section of the forest	Poultry waste (t/ha)	Nutrients in poultry waste (kg/ha)		
		N	P_2O_5	K_2O
53e	22 x	198	209	99
50d	25 x	225	235	112
58a	33 x	297	310	148
63a	33 x	297	310	148
63f	38 x	342	357	171
35a	39 x	351	367	176
43b	48 x	432	451	216
64k	25 xx	575	525	400
15c	26 xx	598	546	416

x: waste of full-grown hens
xx: waste of chickens

1.2.2. Growth reactions

Differences in height growth caused by manuring were too small to be detected. Data on diameter growth led to the conclusion that manuring had positive effects, but not immediately after fertilisation. Data are summarised in Table 3.

Positive reactions on manuring appeared in 1972 (i.e. two years after fertilisation) and continued in 1973.

1.2.3. Soil properties and manuring

The chemical composition of the upper 25 cm of the soil was not affected, except for its total P content; the mean total P content increased from 13 (unmanured stands) to 26 (range: 15 - 44 mg P_2O_5/100 g).

TABLE 3

DIAMETER GROWTH OF MANURED AND UNMANURED STANDS OF CORSICAN PINE IN THE SINT ANTHONIS FOREST, 1970 - 1973 (RELATIVE GROWTH: 1969 = 100; GROWTH OF UNTREATED STANDS = 100) (NB: ORDER OF STANDS AS IN TABLE 2)

Year	1969 (= year before fertilisation)	1970	1971	1972	1973
Relative growth of stands					
Unmanured	100	100	100	100	100
Manured					
53e	100	110	94	107	107
50d	100	92	99	105	120
58a	100	112	106	97	85
63a	100	97	101	106	128
63f	100	84	87	85	102
35a	diameter growth not measured (only height growth)				
43b	100	102	125	134	118
64k	100	106	83	92	100
15c	100	94	113	111	124
Mean of manured stands	100	100	101	105	110

1.2.4. <u>Mineral nutrient status of trees and manuring</u>

In Table 4 the mean contents of N, P, K, Ca and Mg of the foliage of unmanured and manured stands are recorded.

These data can be interpreted as follows: from experience it is known that conifers react to N dressings by increasing the N content of the foliage in the year of fertilisation and by increasing growth in the next year. The N content of the foliage drops the second year after fertilisation. If nitrogen had positive effects, they should have appeared in 1971. However, positive reactions only occurred in 1972 and 1973. Combining this evidence with the fact that the P status of the soil was not adequate and that foliar P content of the unmanured stands was only 0.10%, which is near the critical level for appearance of visible P deficiency symptoms, it can be concluded that the effect of the poultry waste was caused by phosphate. It is also known that conifers react more quickly to N than to P fertilisatic

TABLE 4

FOLIAR COMPOSITION OF UNMANURED AND MANURED STANDS OF CORSICAN PINE, IN THE SINT ANTHONIS FOREST, DECEMBER 1973. (CONTENTS AS PERCENTAGE OF DRY MATTER)

Nutrient	N	P	K	Ca	Mg
Unmanured stands	1.43	0.10	0.66	0.14	0.08
Manured stands	1.40	0.13	0.82	0.14	0.08

1.2.5. Raw humus and manuring

Research on the influence of manuring on the properties of the raw humus layer was not possible because in the manured stands the raw humus layer (which had a thickness of ca. 3 cm before manuring) was almost completely mineralised. Fine roots which were abundant in the raw humus of the untreated stands, were almost absent in the manured stands.

2. CURRENT RESEARCH ON POPLAR

2.1. Effects of disposal of pig slurry on Euramerican ('Robusta') - poplar

In spring 1972, the Institute for Soil Fertility at Haren put at our disposal a part of an experimental field where the influence of manuring with pig slurry on production of agricultural crops was being studied. The soil is a humic sandy soil with water table at ca. 1 m below soil surface during the growing season. Soil chemical data are recorded in Table 5.

The experiment started in spring 1972. Per treatment 16 trees (*Populus x euramericana* "Robusta") were planted. Treatments were as follows (Table 6).

TABLE 6

TREATMENTS IN THE POPLAR EXPERIMENTAL FIELD AT HAREN

No. of treatment	Treatment	Time of application	Quantities of nutrients per treatment (kg/ha/year)			
			N	P_2O_5	K_2O	Cu
1	NPK* (140-140-140)	spring 1972,73,74,75	140	140	140	0
2	NPK (280-280-280)	spring 1972,73,74,75	280	280	280	0
3	40 t/ha pig slurry	spring 1972,73,74,75	280	190	160	3.2
4	80 t/ha pig slurry	spring 1972,73,74,75	560	380	320	6.5
5	80 t/ha pig slurry	autumn 1971,72,73,74	560	380	320	6.5
6	160 t/ha pig slurry	autumn 1971,72,73,74	1120	760	640	13.0

*N - P_2O_5 - K_2O

TABLE 5

SOIL CHEMICAL DATA OF THE POPLAR EXPERIMENTAL FIELD AT HAREN (APRIL, 1971)

Depth of layer (cm)	pH KCl	Organic matter (%)	Total N (%)	N org. (%)	Total P (mg P_2O_5/100 g)
0 - 10	4.8	3.6	0.13	3.3	80
10 - 20	4.8	3.6	0.11	3.0	80
20 - 30	4.7	3.7	0.11	3.0	80

Height growth was measured annually and foliar samples were taken in August 1972 - 1975. Data on height growth per treatment during the period 1972 - 1975 are summarised in Table 7.

TABLE 7

HEIGHT GROWTH OF 'ROBUSTA' POPLAR IN THE EXPERIMENTAL FIELD AT HAREN

No. of treatment	Mean height in spring (cm)				
	1972*	1973	1974	1975	1976
1 (NPK)	145	212	329	485	656
2	151	223	322	478	640
3	152	221	337	510	698
4	141	233	382	547	736
5 (pig slurry)	142	204	313	479	685
6	130	221	366	529	711
Even-aged poplar stand of maximum growth class in the Netherlands	-	150	320	480	650

* height at planting time (April, 1972)

Three conclusions can be drawn from the data mentioned in Table 7:

a) Pig slurry applied to poplar stands for four years up to 80 t/ha (application in spring), and up to 160 t/ha application at harvest) respectively promotes good growth.

b) Quantities applied at harvest time, being twice as high as in spring, have roughly the same effect on growth.

c) Differences between rates per time of application are small.

Data on N and Cu content of the foliage are recorded in Table 8.

TABLE 8

FOLIAR N AND Cu CONTENTS OF 'ROBUSTA' POPLAR IN THE EXPERIMENTAL FIELD AT HAREN (AUGUST 1972 - 1975)

	N (percentage of dry matter), August				Cu (mg/kg of dry matter) August			
No. of treatment	Year 1972	1973	1974	1975	Year 1972	1973	1974	1975
1 (NPK)	2.66	3.34	3.38	3.22	5.0	7.1	8.7	8.8
2	2.53	3.48	3.75	3.29	3.4	5.8	7.0	7.0
3	2.85	3.44	3.46	3.21	6.3	7.1	11.0	9.6
4	3.47	3.48	3.57	3.40	6.5	7.6	9.3	10.0
5 (pig slurry)	2.38	3.43	3.74	3.11	5.2	7.7	10.3	8.6
6	3.10	3.30	3.53	3.21	5.8	6.8	9.5	9.0

Except for the first year of fertilisation, all treatments have a foliar N content between 3.1% and 3.8%. This level is optimal and still higher levels are permitted, because N contents of poplar foliage up to 4.8% have no harmful effects (Van den Burg, 1974). The Cu level increases in general, differences in Cu contents due to Cu added as component of pig slurry are small, a level of 8 - 11 mg Cu/kg in poplar foliage is not unexpected for this species and below the critical value at which Cu toxicity appears.

2.2. Effects of disposal of cattle slurry on various poplar clones

A former grassland near Sint Oedenrode (North-Brabant) was planted with various poplar clones in spring 1973. In 1974 and

1975 this clonal field trial was manured with 60 t/ha cattle slurry. Also a fertilisation with magnesamon (20% N) was carried out three times during the growing season. Thus the poplars were fertilised in 1974 and 1975 with 60 t cattle slurry/ha (estimated amount of N: ca. 250 kg/ha) and 3 x 300 kg magnesamon/ha (180 kg N/ha) which makes a total fertilisation of ca. 430 kg N/ha/year.

Growth of eleven clones and of 'Robusta' (standard) was measured over a period of three years. Data are recorded in Table 9.

Although growth in 1974 was less than growth of maximum site class poplars, this does mean that heavy dressings of cattle slurry and N fertiliser have a negative effect on growth: trees were suffering from some K deficiency (which is quite common on the moist sandy soils where the experimental field is situated) which however, may disappear gradually. In 1975 growth was satisfactory, in any case for the standard clone 'Robusta'.

3. DISCUSSION AND CONCLUSIONS

Research on influence of heavy and continuous dressings of animal manure in Dutch forests has been done for a few years, so that only short-term effects can be discussed. The effects of long-term manuring can only be guessed, although from earlier research on soil amelioration some conclusions can be drawn.

For a discussion on effects of growth and healthiness of tree species, difference can be made between:

a) Poplars

b) Other hardwoods

c) Conifers

a) It is already known from many fertilisation experiments that poplar has a high tolerance against heavy dressings of N. The results of the experiments at Haren and Sint Oedenrode are

TABLE 9

HEIGHT DEVELOPMENT OF POPLAR CLONES IN THE SINT OEDENRODE EXPERIMENTAL FIELD 1973 - 1975

Clone	Mean height (cm) in spring				Height growth (cm)		
	1973	1974	1975	1976	1973	1974	1975
'Donk'	203	256	344	532	53	88	188
'Agatha F'	190	255	333	490	65	78	157
'Rochester'	185	205	284	416	20	79	132
'Fritzi Pauley'	219	274	381	570	55	107	189
'Blom'	222	274	344	451	52	69	108
'Oxford'	212	233	276	426	21	44	149
'Barn'	195	248	371	550	53	124	178
'Spijk'	223	268	352	532	45	84	180
'Heimburger'	185	234	303	419	49	69	116
'Florence Biondi'	185	236	321	488	51	85	167
'Rap'	246	307	425	603	61	117	178
'Robusta' (= standard)	142	202	278	418	60	76	140
Even-aged poplar stand of maximum growth class in the Netherlands	-	150	320	480	-	170	160

completely in agreement with this experience: manuring with 80 t/ha of pig slurry (ca. 320 kg total N/ha) and 60 t/ha of cattle slurry (ca. 250 kg total N/ha) had no detrimental effects. In September/October 1974 and 1975 some trees in the Haren experimental field were slightly attacked by poplar rust (*Melampsora sp.*) but this attack occurred after the growing season was finished. It must be kept in mind that poplar rust is activated by heavy nitrogen dressings (Van der Meiden and Van Vloten, 1958) but up to now, the situation has not been very dangerous. Moreover, it is always possible to use poplar clones which have been selected for rust resistance.

b) Practically nothing is known about other hardwoods than poplar. This means that their tolerance against manuring must be investigated. About a species such as oak (*Quercus robur*) it is known that high uptake of nitrogen results in shoots which are not completely lignified in harvest so that they may be damaged or killed by early night frosts. Positive reactions on heavy N fertilisation have been found for red oak (*Quercus rubra*) by Sopper and Kardos (1972), who irrigated this species with municipal waste water, at N rates of 0, 108, 217, and 430 kg/ha for eight years. Rates of 430 kg N/ha still gave a positive growth reaction. However, it must be kept in mind that the composition of the wood changed and that this may not always be considered an advantage.

c) Discussion on possibilites of animal waste disposal in conifer stands must always take into account both growth and healthiness of trees. It can be concluded from the results of the Sint Anthonis experimental field that liquid poultry manure has a positive effect on growth of Corsican pine. However, the fact that this effect could be ascribed to the phosphate content of the manure raises the question whether inorganic phosphate fertilisation might have been more suitable. Moreover, the almost complete destruction of the humus layer on this poor sandy soil is a warning against application of high dressings of animal manure. Estimates of maximum amounts of animal manure must be based on the fact that a fertilisation with 100 kg (inorganic) N/ha/ year is optimal for conifers. Higher rates must be avoided. Stephens and Hill (1973) investigated the reactions of white pine (*Pinus strobus*) to heavy dressings with liquid poultry manure (25 - 225 t/ha/year) and found that an annual application of 64 t/ha (ca. 300 kg total N/ha) was an acceptable amount. If one supposes that this 300 kg total N/ha is roughly equivalent to ca. 150 kg N/ha in inorganic form, it may be concluded that this assumption agrees with the concept of 100 kg N/ha/year. However, cumulative effects of repeated annual applications of animal manure must not be disregarded Sopper and Kardos (1972) fertilised red pine (*Pinus resinosa*) with municipal waste water for eight years at rates of 0, 108, 217 and 434 kg total N/ha/year. There was only a small positive effect of 108 kg N/ha, growth diminished at higher rates and wood quality deteriorated at all rates of waste water application.

Thus, ideas on suitability of forest stands for disposal of animal manure must always be based on the effects of high applications of nitrogen. Although increasing amounts of N may lead to increased growth, tree healthiness can often decrease and make them more liable to attacks by diseases, insects, etc.

Equally important are effects of animal waste disposal on soil fertility and resulting effects on healthiness of the forest. Increased N supply by the soil and increase of pH improves conditions for root rot (*Fomes annosus*) and exposes conifers to attacks by this very dangerous fungus (Baule, 1975). Another problem is the amount of Cu which is added to the soil with pig slurry disposal. In the Haren experimental field, annual manuring of 160 t pig slurry/ha adds ca. 13 kg Cu/ha to the soil. This is rather high, compared with the Dutch practice, to fertilise stands which suffer from Cu deficiency, with 50 kg/ha copper sulphate (ca. 12.5 kg Cu/ha). Cu toxicity (resulting in visible symptoms or retarded growth) will appear at total Cu contents of the soil somewhere between 20 and 100 mg/kg, depending on pH and organic matter content. If one supposes that practically all Cu is situated in the upper 5 cm of the soil (Commissie voor Diergezondheid in Overijssel, 1976;

Henkens, 1975) then addition of 160 t pig slurry/ha results in an increase of the total Cu content of the top soil with 13 mg/kg. From data on foliar composition of poplar at Haren the increase of Cu content during a period of four years seems to be not very alarming, but this may be misleading: Henkens (1975) reported data on the influence of high rates of Cu fertilisation on some agricultural crops, from which may be concluded that increasing Cu contents of the soil are not always clearly reflected in Cu contents of the foliage. However, without visible symptoms of Cu toxicity, a decrease of production may occur.

Summarising evidence from former fertilisation and amelioration experiments in Dutch forestry and from some recent experiments with animal organic manure, it may be stated that:

a) Hardwoods, in particular poplars, seem more suited for disposal of animal organic manure than conifers.

b) Not only growth, but also healthiness of trees is a very important or even decisive criterion for judging possibilities of disposal of organic manure.

c) Only data on short-term effects are available, long-term effects for conifers can reasonably be estimated. About hardwoods much less is known.

d) The most important parameter for estimating permissible amounts of animal organic manure is nitrogen: annual addition of ca. 100 kg N/ha (inorganic) is considered optimal, the amount of organic manure can be estimated from data on effectiveness of total N in manure. This means roughly that those quantities of organic manure which contain 200 - 400 kg total N/ha can be applied, but not for too long a period (some years) in order to avoid overdosage.

e) Disposal of ca. 100 t pig slurry/ha for some years in poplar stands seems to be acceptable.

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DISCUSSION

J.H. Voorburg *(The Netherlands)*

Are there any questions on the three papers we have just had?

A.V. Dodd *(Ireland)*

I would like to ask Dr. Collins a question. You referred to the source of manures; it seemed to me that there was little or no dilution water. Would you confirm whether this was so and whether or not the nutrient content of the various manures was measured because this might give some interesting correlations between nutrient input and the herbage production indicated in your paper.

D.P. Collins *(Ireland)*

There was little dilution of the cattle slurry; there was some slight dilution of the pig and poultry slurry, but it was minor. In the case of the poultry slurry it was basically to help distribution. We have carried out an analysis of the slurry and we are going to correlate the nutrient levels applied to the responses in terms of dry matter production.

B.F. Pain *(UK)*

Dr. Collins, since there is clearly a disease risk to healthy stock from grazing pasture tainted with slurry, I wonder if you consider it wise for stock to graze after disseminating this slurry by using a very high stocking rate?

D.P. Collins

This raises the question of adult stock being contaminated with slurry which is unlikely because they have their own in-built immunity. I think a colleague of mine will probably deal with this in a talk tomorrow. With the high stocking rate that we use we felt this was necessary to control the sward because if we didn't do so it would become unpalatable and a lot of rejection would take place which might be blamed on the application of slurry when, in fact, it could properly be laid at the door of low stocking.

A. Dam Kofoed *(Denmark)*

I was very interested in Dr. van den Burg's lecture, and the subject - slurries for forests. As far as Denmark is concerned, a couple of years ago we started experiments with sewage sludge for forestry, with pines. I noticed, as far as our experiments were concerned, the effect of this sewage sludge on the leaves and the production of wood. You have measured the height, what about the production of wood? That's one thing.

A second point: you mentioned copper, could you say a little more about why you find copper so important in this respect?

J. van den Burg *(The Netherlands)*

We are interested in copper because of the high amounts involved. We have a rotation of poplars, for example, of 25 years. After that time they are cut down. There are instances of copper deficiency requiring a single dressing of perhaps 50 kg of copper sulphate (roughly 12.5 kg copper) once in 25 years. Now, we do it, say, for 100 m^3 - 8 kg copper/year for 20 years, i.e. 8 x 20 = 160 kg. Thus there is a heavy metal dressing - in this case, copper. With sewage sludge we do the same, in co-operation with the Institute of Soil Fertility at Haren. Their knowledge and ours are complementary. We do this with hardwoods, not with conifers, because during the first years after plantation you see a very good growth. What happens after 10, 20 or 30 years depends on how you manage the forest. There are bound to be problems; it is very difficult to demonstrate this to agricultural people but now some of my Dutch colleagues do realise why we need such a long period of time.

That deals with copper but we are also interested in heavy metals, for instance, the behaviour of hardwoods and zinc.

Up until now the indications from an experiment with five hardwoods grounded in pure sewage sludge are very hopeful but this is only after three years. We don't know what will happen after the mineralisation of the organic matter and the increase of availability of at least some heavy metals. It is rather dangerous to give results after three or four years. I am not quite sure what will happen after twenty years. We are now organising land from the State Foresters; they are somewhat reluctant but next year we will start with dressings of,say, 100, 200, 300 or 400, and on some species for year after year, to discover the long term effects.

With regard to what you said about dressing of sewage sludge on pines in Denmark, I consider this very dangerous. In the USA they have conducted such an experiment and a pine species reacted positively at 100 kg of total N (that is about the usual amount in forestry). At higher dressings, the reaction was negative both in growth and state of health. This is more or less in accordance with our own experience. The more intensive the dressings, the better the growth of the pines, but also the higher the attack by *Fomus annosus*. So what you gain in growth you will lose in health. Therefore we say - no conifers. Maybe you will be lucky with your pines but see how they are in ten or twenty years.

W.R. Kelly *(Ireland)*

My questions are for Dr. Tietjen. They relate to his comments in the paper where he describes the results of reaction of antibiotics and other antibacterial substances. I would be interested to hear a little more about the methods used in regard to this study, particularly whether all the work was done with slurry samples from animals which have been receiving various levels of these antibacterial substances and antibiotics. What quantities were being given and were the direct soil applications made as seems to be implied? Following on from that, if the study was done with slurries containing antibiotics and antibacterials, how long had they been stored and were any values determined for them before they were applied to the soil?

C. Tietjen *(West Germany)*

So many questions! The most important thing is that we worked in co-operation with our Institute for Animal Nutrition. They run large experiments with pigs. Seven or eight antibiotics (not only antibiotics but also feed additives) were used in these experiments and we got the excrements. The material was cold stored so that we had enough together. The experiment started in January and we began our work in March so over this period of feeding we collected the faeces; we used it at once.

On your next question, no evaluation was done by us on this experiment because the soil application was done with chicken manure before the use of antibiotics was allowed in Germany. When we finished this experiment the use of antibiotics was allowed so we had to start again. From that point on we used only excrement from animals fed with controlled rations. We did not make an evaluation of the material, nor of the uptake in the crop. Our primary objective was to find out the effect of the nitrogen availability.

P. Graffin *(EEC)*

Have you any idea of the quantity of nitrogen leached in your experiment, Dr. van den Burg?

J. van den Burg

I have no idea but this experiment is part of the experiment by the Institute of Soil Fertility. Some data may be available, I don't know. Perhaps Dr. de la Lande Cremer can help us here.

L.C.N. de la Lande Cremer *(The Netherlands)*

Yes, this experiment was carried out on maize, potatoes, sugar beets, poplars and small conifers. The quantities ranged from 0 - 160 t of pig slurry per year, applied in autumn, and from 0 - 80 t in spring, in combination with nitrogen in inorganic form. There are also two treatments with fertilisers only. We have drainage under the plots and we can take the drainage waters for analysis. We started the experiment in 1970/71. The soil was poor in phosphorus. To date we have not found any drainage of phosphorus in the subsoil. The nitrogen detected in the drainage waters is increasing with the quantity of fertiliser and slurry used. I think that is all I can tell you about this experiment.

J.S.V. McAllister *(UK)*

Dr. Collins, with regard to Treatment J in your Table 1, I am not quite sure whether there is a mistake in it or not. It says, "162 kg N/ha in four applications". That is actually

3 x 54 but I am not too worried about that. What does worry me is that high nitrogen can have an effect on herbage profusion and slurry might be getting blamed for the effect caused by high levels of nitrogen application. I wonder whether you can pick out the effect of high levels of nitrogen from your treatments.

D.P. Collins

I am not quite sure I understand you. Treatment J had 162 kg N/ha in four dressings. The first application was 54 and then the remainder was in three applications. That is the maximum level of nitrogen that we have applied.

With regard to the second part of your question, we are not putting on mineral nitrogen with the slurry.

J.S.V. McAllister

Do you know how much nitrogen you are putting on?

D.P. Collins

We will know that when we get our analysis back.

J.S.V. McAllister

But you haven't got mineral nitrogen to compare it with.

D.P. Collins

You are saying that we are putting on a lower level of nitrogen in our slurry. That's true, but the level of nitrogen we selected was the level which we have found from our basal experiments is the optimum amount to use to get high level performance. I suppose it is possible we could be confusing it; that we are not putting on as much nitrogen as is in the slurries, but the level of slurry that we would be recommending to use would be a maximum of 65 t/ha. The high level of slurry we used in the experiment was only to give us an extreme treatment and in that case I think we may not be very far removed from the level of nitrogen put on as straight nitrogen.

H. Tunney *(Ireland)*

I would like to ask Dr. Tietjen about the question of phosphorus availability. I think you referred to it purely in relation to nitrogen availability - that phosphorus is just as available as nitrogen. I wonder if you have any information on the availability of phosphorus from your studies. In particular, I would like to know this from the point of view of calculating the fertiliser value of slurry. Can one assume that 100% of the phosphorus is available?

C. Tietjen

No, it is not 100% that is available. Ask Gerritse!

R.G. Gerritse *(The Netherlands)*

About 80% of the phosphorus in slurry is inorganic, calcium hydrogen phosphate. The remaining 20% is organic phosphorus which is built up of phytate, of cell material, micro-organisms and cell debris material. The bulk of the phosphorus in slurry is inorganic and in my opinion its effect is the same as inorganic phosphorus.

C. Tietjen

If you relate it to the application of mineral phosphorus you are very close together here.

H. Tunney

I am understanding that it is equivalent to 100%.

C. Tietjen

We would agree in general.

G.J. Kolenbrander *(The Netherlands)*

We did this research twenty years ago. We made a comparison between the phosphorus effect of slurry with fertiliser phosphorus. The amount of nitrogen as well as potassium was compensated. In these conditions you get the same dry matter yield with phosphorus in slurry and phosphorus in mineral fertiliser. It does not mean that all the mineral phosphorus is taken up by the plant and is available. It is only a relationship between application rate and dry matter yield that means 100% available.

C. Tietjen

Just a small point: phosphorus, as well as nitrogen, is very often available in relation to the carbon content in the same environment. So we have to take account of the C : N ratio as well as the C : P ratio. If this C : P ratio is very wide, phosphorus is not available to the crop. If you come closer to a kind of saturation then more of it is available to the crop. This is a general indication of the phosphorus availability according to work done in the 30s and 40s, I believe.

J.S.V. McAllister

In my paper I give some results from barley experiments where the phosphorus was equivalent to fertiliser phosphorus. However, I would like to express one word of warning. We had some experiments in Northern Ireland in a soil low in phosphorus, where the establishment of barley was bad with only slurry applied. So, on a soil which is low in phosphorus it might be necessary to apply water soluble phosphate to get good establishment.

H. Tunney

You are talking about using slurry mostly for maintaining fertility?

J.S.V. McAllister

Yes, topping-up.

H. Tunney

In that situation we take a different percentage for calculations.

J.H. Voorburg

There seems to be agreement. Does anybody else wish to make a comment?

H. van Dijk *(The Netherlands)*

I would like to make one remark on the paper by Dr. Tietjen. He says that no prediction can be given about the availability of organic bound nutrients, also organic bound nitrogen, with satisfying certainty. We are slightly less pessimistic at the present time and if there is some time on Friday morning I would like to make some remarks about the situation as we see it. We think we can be somewhat more optimistic.

A.V. Dodd

Just one comment comes to my mind on reading Dr. Tietjen's paper. Referring to his Table 1, I think it is worthwhile mentioning that the figures for faeces and urine, particularly in relation to pigs, are greatly dependent on the water intake by the animal. This reminds me of some work done some years ago by myself and Professor O'Callaghan. I believe it is referenced in O'Callaghan's paper. An answer to the problem would be a method of reporting quantities of manure produced which would eliminate the confusion that seems to abound due to dilution water. The figures could be expressed as a function of dry matter intake and water intake rather than as absolute figures, as given in Table 1 of Dr. Tietjen's paper.

J.H. Voorburg

You want to distinguish between dilution water and water that was in the ration?

C. Tietjen

I would say that it is always difficult to come to conclusions if we speak about variations of values, combinations, in this field. The data are taken from nutrition experiments with a big effect on the growth of pigs, so they are not practical data at the moment but they might become practical data in ten years or so. Perhaps this question of dilution is one that specialists in animal nutrition should decide. This is only an extract of 1 100 samples analysed in this experiment over several years so we didn't report more completely how the ratios were made to give the results the animal nutrition people want, and I only took their analysis data for faeces and urine.

<u>A.V. Dodd</u>

The figures given for pig manure correspond almost identically with those from the work I have referred to in which the water : meal ratio was 2.5 : 1, with 87% DM in the feed, which was composed of 85% to 87% barley.

<u>J.H. Voorburg</u>

Well, thank you very much everybody. That brings us to the end of today's session.

THEME 2

MANURE AND POLLUTION OF SURFACE WATERS

Chairman: J.H. Voorburg

RUNOFF AS A FACTOR IN EUTROPHICATION OF SURFACE WATERS IN RELATION TO PHOSPHORUS MANURING

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INTRODUCTION

In the process of eutrophication the element phosphorus holds a key position. Phosphorus is the only element essential for algae growth that can easily be made growth limiting (Golterman, 1975). Therefore the phosphorus load of our surface waters has to be reduced in order to improve water quality.

Here, the most important question is which P_t load is the maximum acceptable. It is clear that the answer will depend on the purposes intended (drinking, swimming or fishing water).

For shallow lakes in Florida (USA) Brezonik (1972) concluded that the"permissible" load was about 0.28 g P_t per m^2 fresh surface water and the "dangerous" load about 0.50 g P_t per m^2. The question is, however, to what extent these results are applicable to Western European conditions.

To get an impression of the possibilities of reducing the P_t load of fresh surface water under Dutch conditions, we can estimate the P_t load present about 1940, starting from the situation found in 1970 (Kolenbrander, 1974). In 1940 eutrophication had not yet caused problems in the Netherlands.

In Table 1 the results are given for a population of 9 000 000 in 1940 and 13 000 000 in 1970. The contributions from population and industry in 1940 were calculated from those in 1970 by multiplying by 9/13 = 0.7. This "population" factor is also used for industry for lack of a better estimation. According to Golterman (1975), the use of phosphorus in detergents in 1940 was zero, whereas the P_t consumption in 1936/1938 by the population per head was about the same as in 1970 (Verslag Nederlandse Landbouw over 1948)

TABLE 1

THE P_t-LOAD OF FRESH SURFACE WATER IN THE NETHERLANDS

	1940	1970	After 90% P_t removal
	10^6 kg $P_t.Y^{-1}$		
POPULATION			
Detergents	0	5.2	0.5
Faeces	2.8	4.0	0.4
Total	2.8	9.2	0.9
INDUSTRY	1.2	1.7	0.2
AGRICULTURE			
Runoff	0.3	0.4	0.4
Animal waste	0.6	1.1	0.1
Total	0.9	1.5	0.5
NATURAL SOURCES			
Soil leaching	0.7	0.7	0.7
Rainwater	0.3	0.3	0.3
Total	1.0	1.0	1.0
Contribution Netherlands Rivers Rhine and Meuse	5.9	13.4	2.6
(Imported)	3.0	11.5	2.2
Total load	8.9	24.9	4.8
Load fresh surface water			
P_t in g P per m^2 per year	2.2	6.2	1.2

The losses by runoff in 1940 are estimated at 70% of those in 1970, due to a lower fertility level of the soil induced by a total P_t input which in 1940 was about 70% of that in 1970 (De la Lande Cremer, 1971). The livestock population in 1940 was about 50% of that in 1970. So the discharge of animal waste was also put at 50% of 1970.

Unpublished results of Salomons (1976) show that in the period 1940-1970 the P_t concentration in the sludge of the Rhine water increased fourfold. Assuming that the P_t load is proportional to the P_t content of the sludge, the contribution from Rhine and Meuse in 1940 can be calculated to be about 3×10^6 kg P_t.

For a 90% P_t removal level, which is technically practicable (Koot, 1970), it was assumed that from all point sources the amount of P_t was reduced by 90%, whereas the contribution from the non-point sources as runoff, drainage and rainfall, remained the same as in 1970. The contribution from the rivers Rhine and Meuse was in this case reduced in proportion to the total Dutch contribution, assuming that foreign countries will also take measures analogous to those in the Netherlands.

For a fresh water surface area in the Netherlands of 0.4 x 10^6 ha (Kolenbrander, 1974), a P_t load of 2.2 g P per m^2 can be calculated for 1940. In 1970 this load was about 6 g P per m^2; this will be reduced to about 1 g P per m^2 after a 90% P_t removal treatment.

If we take into account that considerable urbanisation took place after 1950, then a load of 2 g P per m^2 fresh surface water may be an acceptable estimate of the situation around 1940.

It will be evident that these values are higher than those of Brezonik (1972), but, whichever value is chosen, it also becomes clear from Table 1 that the maximum permissible P_t load is low and that the contribution from agriculture via point sources has to be reduced, while that via non-point sources such as runoff should not arise. Therefore it might be very useful to analyse the process of surface runoff under Dutch conditions. As in the Netherlands direct quantitative measurements of runoff are lacking, the results in the following paragraphs will have, to some extent, a speculative character.

Two aspects will be taken into account:

1) The runoff volume which can reach the surface water during the growing season (March-December) and in winter (December-March). The effects in the case of sloping land will not be considered

2) The effect of P-manuring on P_t losses through runoff.

1. RUNOFF VOLUME

1.1. Runoff volume during the growing season

Generally surface flow or runoff will appear if the water supply by rainfall and for irrigation exceeds the capacity of the soil to accept water. This is influenced by:

1) Amount and intensity of rainfall,

2) Water storage capacity of the topsoil, and,

3) Permeability of the subsoil.

1.1.1. Amount and intensity of rainfall.

Total rainfall in the Netherlands is about 750 mm per year, reasonably distributed over the seasons. The total number of rain days (> 0.1 mm rain per day) is about 216 per year: rainfall exceeds 10 mm per day on 23 days.

Intensities which can induce surface runoff will generally only be found during heavy rainshowers of short duration. As clay soils have a water storage capacity (WSC) in the topsoil at field capacity of 20 mm or less (Table 3) in spring and autumn, we shall confine ourselves to those days on which rainfall exceeds 20 mm per day. In central Holland this can be expected to occur on 5 days per year. In 94% of these cases rainfall is within the limits of 20-35 mm per day. On 0.7 day the rain occurs in the winter period (December-March).

Table 2 shows the number of rain days, in the period 1964-1974, on which rainfall intensity (mm per hour) exceeded a specific limit. This intensity was calculated from the daily rainfall and duration in hours and therefore represents an average intensity. In this period of 10 years there was only one rainfall (about 20.4 mm per day) with an intensity of 24.1 mm per hour. This intensity is just below the limit of 25 mm per hour above which soil erosion is supposed to start in hilly regions (Ripley et al., 1961). In all other cases the intensities were below 12 mm per hour (Table 2).

TABLE 2

NUMBER OF RAIN DAYS EXCEEDING A SPECIFIC LIMIT OF RAINFALL INTENSITY (De BILT 1964-1974)

Rain intensity, mm per hour	Days per year
> 0.8	5.1
> 2	3.9
> 4	1.5
> 6	0.6
> 8	0.3
> 10	0.3
> 12	0.1

TABLE 3

WATER STORAGE CAPACITY (WSC) IN THE TOPSOIL (20 cm DEPTH) AT A GROUND-WATER TABLE LOWER THAN 150 cm

Type of soil	Moisture content, % v/v		WSC	
	pF 0.4*	pF 2.0	% v/v	mm
Dune sand	40	10	30	60
Sandy soils	50	35	15	30
Loess, light clay	45	35	10	20
Heavy clay	56	53	3	6
Peat	83	65	18	36

* Soil is nearly saturated

1.1.2. Water storage capacity of the topsoil

Table 3, calculated from pF-curves of different types of soil (Handboek voor de Akkerbouw II, 1973), shows that the water storage capacity (WSC) ranges from 60 mm to 6 mm per 20 cm topsoil at a ground-water table lower than 150 cm. At a higher water table the WSC will be somewhat smaller. However, from Table 3 it is clear that, if the soil is at field capacity (pF 2.0), WSC of the topsoil is in many cases already high enough to absorb a rainfall of 20-35 mm per day. On light, but especially on heavy clay soils the WSC may be too small.

Recent research of Boekel (personal communication, 1976) has shown that on arable clay soils the moisture content at pF 2.0 decreases by drying during the growing season. This will result in an increased WSC. So the data in Table 3 will, for summer conditions, underestimate the WSC on arable light and heavy clay soils. Besides this there may be a supplementary WSC in summer if the moisture content of the topsoil is below field capacity (pF 2.0).

Also on permanent grassland, where structure of the topsoil is even more compact than on arable land, the WSC of the topsoil may give rise to difficulties on light and heavy clay soils if water permeability of the subsoil is too small.

1.1.3. Water permeability of the subsoil and rainfall intensity

Using the data in Table 2, Figure 1 has been constructed to show the number of rain days per year (Y-axis) on which a specific limit of rainfall intensity (X-axis) is exceeded.

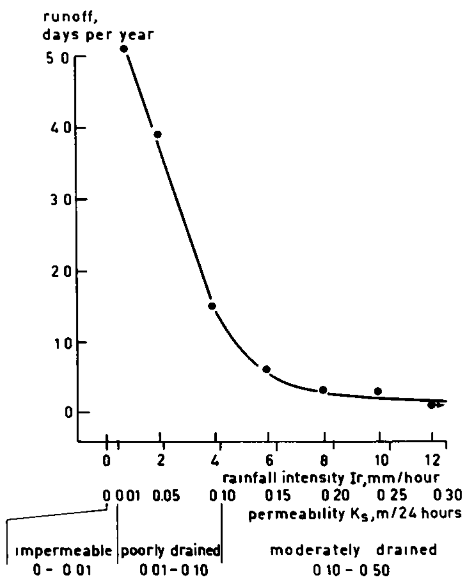


Fig. 1: Relation between number of potential runoff days per year and rainfall intensity (Ir) exceeding specific soil permeability limits (K_s). Rainfall > 20 mm per day.

The X-axis also shows the water permeability of the soil, expressed as the "capillary conductivity factor (K_s) of the soil at water saturation" (m per 24 hours). The permeability factor K_s can also be expressed in mm per hour and is then directly comparable with rainfall intensity.

From Figure 1 it is evident that only on soils with a K_s $<$0.12 m per 24 hours is there a possibility that on 1 - 5 days per year rainfall intensity may exceed water permeability of the subsoil. This concerns only the "impermeable" soils (K_s = 0 - 0.01 m per 24 hours) and "poorly drained" soils (K_s = 0.01 - 0.10 m per 24 hours).

1.1.4. Conclusion

From the previous sections it is apparent that only on "impermeable" and "poorly drained" arable and grassland soils, on at most 5 days a year, runoff may occur. It takes place because on these soils water permeability of the subsoil as well as water storage capacity of the topsoil may be too small.

As a result of these properties, these soils often do not have a really flat but rather a somewhat spherical surface. The farmer tries to dispose of excess water as quickly as possible by discharging it through a number of furrows, to the surface water.

However, soils with an excellent water permeability of the subsoil may also have runoff symptoms if water storage capacity is less than 20-30 mm, due to a high water table during the growing season.

1.2. Runoff volume during winter

In winter the situation will be quite different from the growing season. When the soil is frozen, the WSC of the topsoil as well as the permeability of the subsoil of all soil types may be negligible. Under these conditions precipitation may accumulate as snow and ice on the soil, which retards the thaw of the topsoil afterwards.

In spring when the temperature rises and the snow melts, the melt-water cannot penetrate into the topsoil. So it will move over the surface, taking with it plant nutrients from the soil and from organic manure applied in autumn and winter and/ or solid particles of soil, crop residues and manure.

In the period 1954-1974 about 87 periods with frost were counted in the central Netherlands ranging from 1 to 71 days. A frost period was characterised by a mean 24 hour temperature of $0^{o}C$ or lower. Two frost periods, interrupted by a period of 2 or 3 days with a mean 24 hour temperature above $0^{o}C$ but with a minimum temperature below $0^{o}C$, were considered as one frost period.

In 22.5% of the cases the length of the frost period was between 7 and 28 days, with a mean duration of about 14 days and a chance of occurring about once a year during January and February.

Only frost periods from 7 to 28 days will be considered here. Periods shorter than 7 days are of little significance in relation to runoff, because accumulation of precipitation will be small. Periods longer than 28 days can be expected to occur only twice in 20 years. During January and February, (total of 59 days), 120 mm of precipitation falls on 40 days (68% of the total number of days). This is a mean of 3 mm per precipitation day. In an average frost period of 14 days, about 0.68 x 14 x 3 = 28.6 mm of precipitation can accumulate.

In cold, very dry winters an important part of the snow may evaporate directly. As such winters have occurred only six times in the last 50 years, evaporation does not play an important role. However, assuming that in normal years about 10% of the snow is lost in this way, the average runoff volume can be estimated at about 25 mm, which is about 3% of the yearly precipitation (750 mm).

2. P-LOSSES BY RUNOFF

Unfortunately, Dutch data concerning the composition of runoff water are lacking. So the P losses by runoff can only be estimated indirectly.

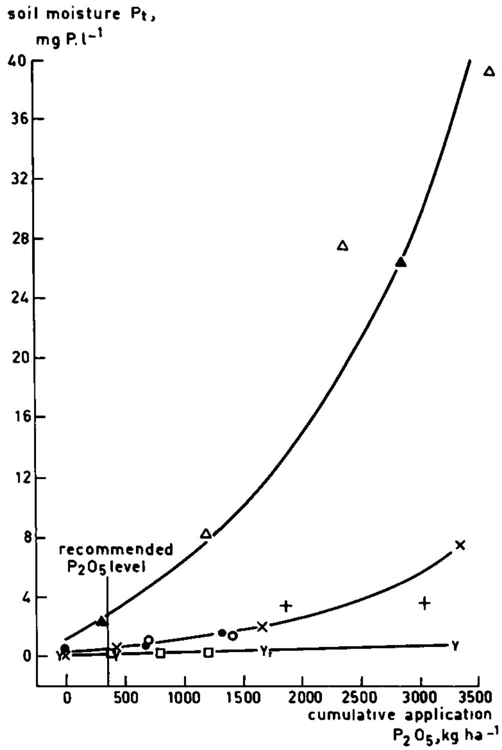
Figure 2, taken from unpublished data of De la Lande Cremer and Sissingh, shows the relationship between cumulative phosphorus application during 5 to 7 years and the P_t concentration of the soil moisture in the topsoil (20 cm) for different soils. The soil moisture was extracted by centrifugation (2500-3000 rpm) of a water-saturated soil sample. The P_t fraction consists of water soluble mineral and organic phosphorus compounds.

The results in Figure 2 represent the sum of different processes, such as P adsorption, P mineralisation in farmyard manure (FYM), P uptake by crops, and P leaching. Figure 2 shows that the effect of a P application on the P_t concentration of the soil moisture varies with the different soil types.

Before an approximation of the P_t concentration of soil moisture under field conditions can be made, it is necessary to estimate the average phosphorus application rates in diverse agricultural areas in the Netherlands. Table 4 shows the situation in 1970.

The mean yearly P_2O_5 requirement of crops on arable land in the different soil types is about 60 kg P_2O_5 per ha. It is apparent from Table 4 that in the regions with a low livestock density (low application rates of P_2O_5 in FYM) P_2O_5 application in the form of mineral fertiliser meets this demand, but that no correction was made for the phosphorus applied as FYM.

As livestock density increases, fertiliser use decreases somewhat, but not to the same extent as the increase in P_2O_5 applied as FYM. So a number of soil types receive an overdose of phosphorus which will result in higher P_t concentration levels in the topsoil than is necessary for optimum crop productions.



Reclaimed peatsoil: △ pig slurry in autumn; ▲ double super in spring

Loess soil: X super in spring

Sandy soil: O double super in spring; ● pig slurry in spring; + pig slurry in autumn

Marine clay soil: Y Westmaas, super in spring; □ Lovinkhoeve, super in spring

Fig. 2: Relation between P_t concentration of soil moisture and the total amount of P_2O_5 applied during a period of 5 - 7 years. (Data: De la Lande Cremer and Sissingh, personal communication).

TABLE 4

PHOSPHORUS IN FARMYARD MANURE AND IN APPLIED FERTILISER IN DIFFERENT REGIONS IN THE NETHERLANDS (1970)

Type of soil	Cultivated land x 10^6 ha	Application rate kg P_2O_5 per ha per year			Total P_2O_5 x 10^6 kg	
		FYM	Ferti-liser	FYM + ferti-liser	FYM	Ferti-liser
Sandy soils	0.90	106	40	146	95.4	36.0
River clay soils	0.14	70	50	120	9.8	7.0
Loess soils	0.04	60	50	110	2.4	2.0
Grassland area	0.39	65	55	120	25.3	21.5
Horticultural area	0.05	35	65	100	1.7	3.2
Marine clay soils	0.53	20	65	85	10.6	34.5
Reclaimed peat soils	0.09	20	65	85	1.8	5.9
Netherlands total	2.14	-	-	-	147.0	110.1
kg/ha average	-	69	51	120	-	-

Table 5 shows the P_t concentration of soil moisture at different P application levels taken from Figure 2, and the concentration corresponding to the level of 60 kg P_2O_5 per ha per year, the amount recommended for soils having a P fertility level classified as "sufficient". The concentrations shown are those found after 6 years of application.

TABLE 5

P_t CONCENTRATION OF SOIL MOISTURE IN ARABLE LAND WHICH RECEIVED DIFFERENT TOTAL AMOUNTS OF P_2O_5 OVER A PERIOD OF 6 YEARS

Type of soil	Actual farming		Recommendation*:
	P_2O_5 added (cumulative,kg/ha	P_t concentration mg P/l	P_t concentration, mg P/l
Marine clay	6 x 85 = 510	0.20	0.18
Reclaimed peat	6 x 85 = 510	3.6	2.8
Loess	6 x 110 = 660	0.8	0.6
Sandy soil	6 x 146 = 876	1.0	0.6

* 60 kg P_2O_5/ha.y.

However, a reduced solubility of soil phosphorus at lower temperatures has been found in soil extractions, which will have to be taken into account. In winter, the solubility will be about 50% of that at summer temperatures (unpublished results of Sissingh).

As a matter of fact, by centrifugation only the amount of phosphorus dissolved in water is obtained. Runoff materials, however, also contain insoluble P components. As any Dutch information is lacking, the results of Harms et al. (1974) will be used. They found in the USA in runoff water from melting snow on sandy loam that about 57% (55 - 59%) of the total amount of phosphorus present was in solution. So the total P content of the runoff water at the lower temperature in winter can be calculated by multiplying the concentrations in Table 5 by the factor 0.5 x (100/57) = 0.88.

At a runoff volume of 25 mm during winter, the amounts of phosphorus in runoff are shown in Table 6.

TABLE 6

P LOSSES IN RUNOFF IN WINTER FROM ARABLE LAND FOR DIFFERENT SOIL TYPES AND P FERTILISATION LEVELS

Type of soil	P losses, kg/ha.y. at recommended level (60 kg P_2O_5/ha.y.)	At level in actual farming
Reclaimed peat soil	0.62	0.79
Sandy soil	0.13	0.22
Loess soil	0.13	0.18
Marine clay soil	0.04	0.04

These results are of the same order of magnitude as mentioned in the literature (Ryden et al., 1973; Harms et al., 1974; Kolenbrander, 1973).

From an agricultural point of view high P fertility levels cause no direct harm to crop production and crop quality. But in relation to eutrophication of surface waters they may do so, because higher P fertility levels will result in higher P concentrations of the soil moisture and therefore in higher contributions via runoff, as is shown in Table 6. The results on the sandy soil type suggest that loss is about 1.5 times as high as would be necessary for optimum crop production.

If the results of Figure 2 may be generalised it becomes clear that the FYM surplus in regions with sandy soils, resulting from a high livestock density, should be removed, preferably to moderately well- or well-drained marine clay soils. In these soils, the absolute effect on concentration will be considerably less than in sandy and other soil types. In this way the regional contributions to eutrophication by runoff may be the lowest. This is necessary in view of the low maximum permissible phosphorus limit in surface waters (Table 1).

Experiments concerning the relation between phosphorus application and increase in water extractable phosphorus (Kolenbrander, 1974) may suggest that river clay has a still higher adsorptive capacity than marine clay soils. But on these soils the FYM (Table 4) already contains sufficient phosphorus for optimum crop production.

These conclusions are supported by the fact that in 1970 as much as 50% of the soil samples collected on sandy soils on arable land and 61% of the samples from reclaimed peat soils fell within the classes "high" and "very high". On marine clay soils, however, only 12% was found to be within these classes (Ris and Van Luit, 1973).

Unfortunately, experiments as mentioned in Figure 2 are lacking for grassland. Soil sampling in practice has shown that on all soil types 50 - 70% of the grassland plots are in the classes "high" and "very high". Only loess soil with 26% constitutes an exception, (Lammers, 1974). So it is clear that on grassland the P level is also high in many cases, and that the possibility exists that losses of runoff are also relatively high.

Moreover, on grassland there is an additional danger, namely the application of organic manure in winter. This manure will greatly increase the P_t concentrations in the surface soil, and may cause additional P losses by runoff.

In view of the low permissible amounts that may be contributed from different P sources to the P load of surface water, this method of application should always be considered as a potential danger to the quality of surface waters in those areas where surface runoff can be expected. This holds true not only for hilly but also for flat regions.

CONCLUSIONS

In view of the low maximum permissible P contributions from different P sources to the P_t load of surface waters, the agricultural contribution via point sources should be reduced, those via non-point sources, such as surface runoff, should not be allowed to increase in the future.

Under Dutch climatic conditions runoff will play a minor role during the growing season (March-December). Only on arable land and grassland with clay soils of the classes "impermeable" and "poorly drained", some runoff may occur on at most 5 days a year, because permeability of the subsoil and water storage capacity of the topsoil may be too small if rainfall exceeds 20 mm per day.

In January and February a frost period can be expected of about 14 days during which the soil is frozen and water storage capacity is negligible. During this period about 25 mm of precipitation can accumulate on the soil surface. After the spring thaw this precipitation may reach the surface water by runoff.

P_t loss by runoff was roughly estimated at about 0.04 - 0.8 kg P_t per ha per year. As this loss depends on the P_t concentration of the soil moisture in the topsoil, the highest loss may be found on reclaimed peat soils, the lowest on marine clay soils.

P losses by runoff may be aggravated by high application rates, because such rates increase the P_t concentrations of the moisture in the topsoil. The effect of high rates was much higher on reclaimed peat soil and sandy soil than on marine clay soil.

Surpluses of farmyard manure produced in regions with sandy soils as a consequence of high livestock densities, should preferably be used on marine clay soils.

The application of organic manure in winter on grassland constitutes a potential danger to the quality of surface waters because the phosphorus it contains may be lost by runoff.

SUMMARY

In the Netherlands, runoff during the growing season is of minor importance, because in most cases the water storage capacity of the topsoil is sufficient to absorb rainfall amounting to 20 - 35 mm per day.

Only arable and grassland clay soils of the classes "impermeable" and "poorly drained" may give rise to some runoff on 1 - 5 days a year.

In winter, when the soil is frozen, about 25 mm of precipitation may accumulate and reach the surface water in spring as meltwater. This form of runoff from arable land was estimated at 0.04 - 0.8 kg P_t per ha per year, depending on the type of soil and the amount of phosphorus applied.

FYM surpluses produced in regions with sandy soils should be utilised on marine clay soils. The fact that these soils have a high phosphorus adsorption capacity tends to keep the P_t concentration of the soil solution low, thereby reducing the risk of P losses by runoff. The application of organic manure in winter on grassland must be considered a potential danger to the quality of surface waters.

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RELATIONS BETWEEN PEDOLOGICAL ORGANISATION OF THE SOIL AND PIG SLURRY LANDSPREADINGS IN BRITTANY

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INTRODUCTION

The importance of the problems which have arisen through semi-liquid pig slurry landspreading in Brittany (France) are underlined by the following considerations: Brittany produces about 4 million pigs, which represent 35% of total French production, and this productions takes place only on 7% of the total agricultural area of France. Moreover, in recent years there has been a considerable concentration of housed livestock enterprises, which are not dependent on land.

Climatic conditions play their part in this problem. If we compare rainfalls (P) and potential evapotranspiration (ETP) we find that (ETP - P) is positive only during the three summer months. Cumulative excess (ETP - P) then reaches 200 mm. Pig slurry could be used as irrigation water during that period, besides its fertilising action. However, landspreading is illegal in July and August for environmental reasons; the odour of pig slurry spreading is offensive to the tourists, who are numerous in summer. Landspreading is therefore applied in autumn, winter and spring where (ETP - P) is negative. Risks of run-off, leaching and loading of water tables and the rivers, must be taken into consideration.

THE PEDOLOGICAL POINT OF VIEW

Several studies have been undertaken in Brittany regarding agronomical consequences of pig slurry spreading, especially at the Quimper - INRA station (Coppenet, 1974, 1975). The Soil Science Laboratory of Ensa - INRA (Rennes) has chosen a pedological approach; characterisation of the different types of soils (brown soils, leached soils, podzolic soils hydromorphic soils); study of their adsorbing complex; of the stability of their physical properties (structure. porosity), before and after landspreading.

A particular importance is given to the circulation of the water, moreorless loaded with slurry products in the soil. Indeed, other studies undertaken at our laboratory in Brittany concerning the consequences of the removal of shelter-belts, (Ruellen, 1976), have suggested that lateral circulation of water is important in these landscapes, not only on the surface (runoff during a few days), but also within the soil, especially at two levels:

- at discontinuity between A (eluvial) horizons and B (illuvial) horizons,
- just above the rock, or at the bottom of the B horizon.

One of the purposes of this research programme is, therefore, to appreciate the influence of the pedological organisation of the soil (surface crusts, cracks, structural discontinuities) on the circulation of slurry diluted by rainwater. These drainage waters, moving by gravity, could contribute to the pollution of the groundwaters and of the rivers.

METHODOLOGY OF THE STUDY: COMPARISON OF TWO DRAINAGE-BASINS RECEIVING TWO DIFFERENT RATES OF SLURRY.

The two drainage basins, each one covering nearly twenty hectares, are localised near Lamballe. The first receives a moderate rate of semi-liquid slurry: 50 m^3/ha/year. The second receives a high rate of application: more than 300 m^3/ha/year. In each of them, the observations and measurements concerning soil, soil-water and water table are on soil profiles, arranged along two axes following the slope. Those two "soil catenas" have 200 m length and most of their features are similar:

- slope (3%) and its orientation.
- geological substratum (Precambrian soft schists, common in Brittany.

- soils are rather shallow (depth of 70 to 150 cm) and rich in silt.

The same vertical sequence of horizons is observed in the two cases:

A_p : clay 15 - 20%; silt: 40 - 45%; organic matter: 2%.

A_2 : slight illuviation of clay.

B_t : slightly enriched with clay, sometimes presenting a few features of hydromorphy.

C : weathered schist.

Thickness of those horizons vary along the slope. Hydromorphy is more developed in the low parts. The two basins are used in the same way: the upper part is grassland (ryegrass) and the lower part maize.

The two basins, or "soil catenas" show, therefore, influence of two quite different rates of slurry application on the circulation of the slurry (mixed with rainwater) in the soil and the effects on soil properties.

INITIAL REPORT

This study was started in October 1973 and interim results have already been published (Cavaille et al., 1974; Buson et al., 1975: Menetrier, 1976, in press).

<u>Surface runoff</u>

In the basin receiving 50 m^3/ha/year, infiltration of slurry is quite good and runoff is not observed. In the other basin, a map of the main ways of movement of the slurry by runoff has been drawn. It shows that there is a very close connection with:

a) the ancient pathway network, removed ten years ago: runoff probably takes place here because permeability of the subsoil has been decreased by compaction.

b) the ruts left by corn harvesters.

In each case one can observe the formation of a grey-blackish crust on the surface of the soil, a slight decrease of the structural stability of soil aggregates (Henin method) is noticed in the lower parts of the basin and maize growth is poor.

Movement of drainage in the soil

In the basin receiving 50 m^3, infiltration of slurry does not present peculiar aspects; the black colour disappears just under the surface and in one case of rapid percolation this takes place along a few vertical worm-galleries (lombrics). In the other basin, it is quite different.

In the vertical plane, and in spring, rapid infiltrations of slurry are locally observed in A_p horizons, by the way of micro-cracks, between a few coarse aggregates. At B level, many worm-galleries are black coloured.

In the horizontal or sub-horizontal plane, two ways of lateral circulation of drainage water must be taken into account:

a) At the base of the A_p horizon, (eg at the discontinuity due to recent grassland ploughing) free water, yet very loaded with slurry products (values are collected in Table 1) flows away at this level, into the lower part of the drainage basin.

b) At the base of the B horizon. One can observe in winter a shallow perched groundwater table. Composition of this water is already rather different to that of the slurry. This difference is stronger from an organic point of view (COD) than from a mineral point of view (Na,K,...)

TABLE 1

PARTIAL ANALYSIS OF 4 DRAINAGE WATERS, SAMPLED "IN SITU" IN A SOIL PROFILE IN THE BASIN RECEIVING 300 m^3/HA/YEAR. (Menetrier, 1976, in press)

Sample no.	COD	pH	Conduc.	Ca^{++}	Mg^{++}	K^+	Na^+
1	3030	7.9	5.7	237	62	670	150
2	3430	7.7	5.4	302	85	820	207
3	490	7.1	2.5	436	59	300	190
4	220	5.7	0.5	40	13	5	20

COD - mg/O_2/l. Conductivity - m.mhos.cm^{-I}: Ions - mg/l.

Sample no. 1: water sampled in micro-cracks of A_p

2: water circulating laterally at the base of A_p

3: water at the base of B (little perched groundwater table)

4: water at the base of B, in a profile of the same basin but above the zone receiving slurry.

Effects on the composition of brook water

Down the basin receiving 300 m^3, a brook flows. Its water has been sampled in spring at the same season as the soil waters.

TABLE 2

COMPOSITION OF SAMPLES OF BROOK WATER, SPRING, 1975. (Buson, 1975)

Date of sampling	COD	NH_4	NO_2	NO_3	PO_4	K	Ca	Na	Mg
21/4	90	0.6	0.8	2.4	1.1				
19/6 Point 1	81	0.2	0.1	2.4	0.6	5.4	13	24	4.7
Point 2	42	0.5	0.3	2.5	1.0	9.7	20	27	6.5
8/7	45	1.1	0.2	2.0					

COD: mg/O_2/l: Ions: mg/l

Soil water circulating either by runoff or drainage, influences the uptake in mineral elements by the brook, but the relative importance of that process, in comparison with the process owing to water movement in unsaturated flow (soil moisture diffusivity, hydraulic conductivity of the soil notwithstanding the peculiar structural properties described here), is not known.

Changes in the chemical composition of the soil after landspreading.

We have observed the following tendencies with regard to the chemistry of the soils in the basin receiving 300 m^3/ha/ year:

a) Soil has become enriched in P.

b) Ratio Mg/K on the adsorbing complex decreases

c) More generally, we notice a slight redistribution of the elements at the slope of the basin; calcium, in particular, is leached away into the lower part of the basin, probably in consequence of its partial substitution on the adsorbing complex by NH_4^+.

Chemical modifications of the soils of the other basin (50 m^3/ha) are not very significant in this 3 year period.

CONCLUSION: PEDOLOGICAL ORGANISATION OF THE SOIL AND PROBLEM OF MODELLING.

The modelling of the consequences of pig slurry landspreading will be an important research purpose in the coming years. The model of Dutt (1972), often discussed regarding salinised soils (Rieu et al., 1976), has also been taken into account for manure landspreading (Graffin, 1974).

The moisture flow programme of this model is based on the usual equation for unsaturated flow and in one dimension (vertical). Partial data described in this paper suggest that, in cases of landscapes with some slope and with rather shallow soils, with a strong differentiation between horizons, the problems of vertical discontinuities and of lateral movement of free waters inside the soil must be taken into account.

In future, pedological organisation of the soil should either enter: that type of model as an additional factor - that seems probably too difficult - or as a corrective factor at the time of assessing the risks of pollution.

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THE EFFECT OF SOIL TYPE AND SEASON OF APPLICATION ON INFILTRATION AND RUNOFF OF NUTRIENTS FROM ANIMAL MANURES

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The disposal of animal manures in Ireland is not a national problem, but there are localitites where animal manures contribute to pollution of surface waters. Most of the pollution incidents occur in the inland lakes located in the Drumlin belt. A recently published survey of fifty-three Irish lakes covering four major areas of the country, showed that eight lakes which exhibited definite enrichment were all located in the Drumlin area (Flanagan and Toner, 1975). The unusual topography of the area, together with the impermeability of the soil (sometimes as low as 3×10^{-4} m/day) make conventional farming difficult and many farmers are forced to supplement their incomes by intensive pig and poultry production. It is ironic that these soils which are indirectly responsible for the intensive pig production are particularly unsuitable for disposal of pig slurry. The steep slopes make spreading difficult, the impermeable soil favours high runoff and they are in the catchment basins of inland lakes which have retention periods of up to six months.

The extent to which animal manures contribute to pollution is difficult to assess. There is no doubt that some of the incidents arise from the mismanagement of slurry during storage but some may also be due to runoff of nutrients from slurry spread on land. The amount of runoff, which will be influenced mainly by soil type, effective rainfall, slope and the hydraulic load of slurry can only be quantified by researching the relative contributions of these variables.

FACTORS WHICH AFFECT RUNOFF

There is a great deal of information available in the literature on runoff water and nutrients from irrigation of fertilised and unfertilised grassland and arable crops, particularly in the United States. Much less is known about the run-off of nutrients from animal slurries appled under European conditions and the need for this information was evident in the OECD report on eutrophication (Vollenweider, 1971). Some important reports, however, have appeared in recent years. O'Callaghan et al. (1971, 1973) made practical recommendations and stressed the importance of having a minimum soil moisture deficit of 12.5 mm before spreading slurry on soil. They subsequently showed (Pollock and O'Callaghan, 1975) that with a 15 mm soil moisture deficit, a slurry application of 12.5 mm to tile drained plots at two different sites, resulted in only a very small fraction of slurry reaching the drainage water even when spreading was followed by heavy rains.

The consequence of spreading even low hydraulic loads of slurry on an impermeable soil without a moisture deficit was demonstrated by Dodd et al. (1975). They conducted a comprehensive experiment on mole drained plots on both brown podzolic and gley soils and collected both drainage and surface runoff water. There was nutrient loss in surface runoff water from gley soils where heavy rains followed an application of 2.8 mm, when the slurry was applied to soil at field capacity out of the growing season. There was no surface runoff from the brown podzolic plots with applications of 11.2 mm but the drainage water from these plots had more inorganic pollution and higher inorganic nitrogen than the drainage water from the gley soils. Burke et al. (1974) had a comparable experience with fertilisers and found that up to 72% of applied nitrogen fertiliser could be lost in runoff from a gley soil at field capacity when heavy rain followed soon after fertiliser application. There was very little phosphate lost in surface runoff. Mole drainage reduced the phosphate loss to zero but tended to increase the nitrogen losses.

Hanley (1974) applied 8 mm slurry to a permeable soil three times per year and found very little phosphate in runoff water, but the amount was dependent on the intensity and duration of the rainfall event. Mean phosphorus concentrations of 39 ppm and 7 ppm were found in runoff water after slurry application, when rainfalls were greater than and less than 20 mm respectively, in the twenty-four hours prior to sampling.

In summary, the indications are that there is very little nitrogen or phosphate in runoff water from slurry treated grassland provided there is a soil moisture deficit of 12.5 mm at the time of spreading and hydraulic load does not exceed 5 mm on very impermeable soils. Under these conditions it is also unlikely that there will be phosphate in drainage water but some nitrogen may reach the drains if heavy rains follow the slurry application.

In practice, a farmer's storage facilities may not be adequate to contain the slurry until there is a 12.5 mm soil moisture deficit and, in fact, a smaller deficit may suffice on the more permeable soil types. Further research is needed to define the interactions between soil moisture deficit, hydraulic load and surface runoff on a number of different soil types.

FACTORS WHICH AFFECT LEACHING

The factors which govern leaching of nutrients have been reviewed by Kolenbrander (1973) and are fairly well understood. The question then is whether the leaching of nutrients from slurry will differ significantly from that of fertiliser nutrients.

At low dressings of slurry there is unlikely to be any significant difference, but extremely high levels of slurry may induce temporary anaerobic conditions in the soil. This situation will favour (a) inhibition of nitrification which will result in retention of the NH_4^+ from the slurry and (b) denitrification, aided by the extra carbon substrates in the slurry. Both these factors will tend to reduce the amount of nitrate being leached. The reducing conditions may lead to some slight solubilisation and movement of phosphate.

It seems, therefore, that the danger of pollution of ground water through leaching of nutrients is small unless very heavy dressings are used. Hewgill and LeGrice (1976) using in-filled lysimeters, found that with up to 200 m^3/ha pig slurry or 377 kg N/ha applied to summer grass, the nitrate concentrations in the leachate remained below 5 mg/l and there was less than 1% of the total N in the leachate. With 600 m^3/ha there was only 3% of the total N in the leachate compared with 4% when 600 m^3 was applied to winter grass. Similarly McAllister (1974) found no nitrate leaching from lysimeters with slurry dressings which contained the equivalent of 274 kg N/ha per year.

Thijeel and Burford (1975) found considerable leaching of nitrate from applied cow slurry, but the application rate was unusually high at 550 m^3/ha. This was a field experiment and it may be worth noting that in a field experiment at Johnstown Castle, we found levels of 22 mg/l NO_3 - N in the soil solution at 0.9 m depth in the winter following fertiliser application of 240 kg N/ha to old pasture compared with 2 - 3 mg/l in the control. This is a much higher level than is reported from any lysimeter studies and the reason for the difference between these field experiments and the reported lysimeter studies is not immediately obvious. A comparison of infiltration of nutrients under field and lysimeter conditions would seem to be a useful study.

RESEARCH FOR EEC

Following is the description of an experiment which we have recently set up at Johnstown Castle to give information on both infiltration and runoff of nutrients resulting from land spreading of animal manures on different soil types.

Three sites have been chosen to give soils of poor drainage, imperfect drainage and free drainage. Each site has six experimental plots (2m x 30M) with uniform 8% - 10% slope equipped to collect surface runoff water. Each plot receives a different treatment, as follows:

1 Control 22.5 m^3/ha water
2 Fertiliser NPK plus 22.5 m^3/ha water
3 Cattle slurry @ 45 m^3/ha
4 Pig slurry @ 22.5 m^3/ha
5 Pig slurry @ 45 m^3/ha
6 Pig slurry @ 90 m^3/ha.

Ceramic probes are installed at depths of 0.15, 0.3, 0.6 and 0.9 m, at two locations in each plot.

The treatments will be applied approximately every eight weeks, if the land is trafficable and the grass will be yielded between treatments.

PARAMETERS TO BE MEASURED

Soil moisture tension, rainfall, soil temperature to be measured twice weekly. Actual evapotranspiration data will be obtained at one site only.

Grass

Yield, N, P, K, Mn, Ca, Mg and Na content to be measured after each cutting i.e. approximately every eight weeks.

Slurry

Total solids, BOD, pH, N, P, K, Ca, Mg, Mn, Cl^-, NH_3^+, NO_3^- in each slurry sample at application.

Runoff water

pH, NH_4^+, NO_3^-, P, K, conductivity and BOD in representative sample from each tank after each heavy rainfall event.

Infiltration water

NO_3^-, NH_4^+, conductivity in soil water from each ceramic probe (total 144) approximately every two weeks.

Soil

pH, P, K, NH_4^+, NO_3^- in 0 - 2.5; 0 - 15, 15 - 30, 30 - 45, 45 - 60, 60 - 75, 75 - 90 cm approximately four times a year. Organic carbon and nitrogen once a year. Physical properties such as mechanical analyses, permeability, infiltration rate, porosity, bulk density etc., will also be determined.

RESULTS

The treatments were applied for the first time on June 10th at a soil moisture deficit of approximately 60 mm. There was no direct surface runoff from any treatment at any site.

The rainfall at Johnstown Castle for the month of July is shown in Table 1, and although there was intensive precipitation during thunderstorms on July 6th and 8th, and prolonged precipitation on July 14th, there was no surface runoff at any of the three sites.

The plots were harvested after seven weeks and the nitrogen in the grass and in the top 15 cm soil was determined. There were differences between sites, but the trends were similar and the results from the three sites are averaged in Table 2. It was noticeable that the cattle slurry depressed grass yield at all three sites. It was also evident that slurry applied in summertime compared very unfavourably with calcium ammonium nitrate as a source of nitrogen for grass.

It is hoped that this experiment will give information on the effect of soil type on the runoff of nutrients under a variety of seasonal conditions. It is hoped that the ceramic probes will yield qualitative information on the infiltration of nutrients with frequent spreading of slurries, thus simulating dumping conditions.

ACKNOWLEDGEMENTS

I am grateful to many of the staff members of An Foras

Taluntais for helpful discussions, to the workshop staff for their help and co-operation and in particular to Messrs. A. Fanning and T. O'Donnell for their technical assistance.

TABLE 1

RAINFALL AT JOHNSTOWN CASTLE, JULY 1976

Date	Rainfall (mm)	Date	Rainfall (mm)
July 5	3.2	July 13	1.3
6	8.6	14	20.7
7	0.05	15	5.6
8	7.6	19	0.4
9	1.6	20	3.0
10	2.3	21 - 30	Nil
11	2.6		
12	5.5	Total	63.15

TABLE 2

RECOVERY OF NITROGEN ADDED IN TREATMENTS

Treatment	N recovered in grass	Residual inorganic N in top 15 cm soil (NH_4^+ + NO_3^-) kg/ha	Total recovered	N added in treatment
Control	43.3	11.0	54.3	0
Fertiliser	104.8	16.5	121.3	120
Cattle slurry	30.0	20.3	50.3	162
Pig slurry (1)	49.5	11.1	60.6	96
Pig slurry (2)	47.1	14.9	62.0	153
Pig slurry (3)	44.2	19.3	63.5	306

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DISCUSSION

J.H. Voorburg *(The Netherlands)*

We can now discuss the three papers which we have had this morning.

R.G. Gerritse *(The Netherlands)*

The phosphate data mentioned in your paper, Mrs. Sherwood, are they inorganic phosphates?

M.T. Sherwood *(Ireland)*

They are total, but we also hope to have data on ortho phosphates.

J.H.A.M. Steenvoorden *(The Netherlands)*

I have a question for Mrs. Sherwood. You showed us a slide with the precipitation and potential evapotranspiration but there is the question of crop evapotranspiration.

M.T. Sherwood

That is not the figure for crop evapotranspiration but at our station we also have figures for actual evapotranspiration.

J.H.A.M. Steenvoorden

Thank you. Now I have a question for Dr. Kolenbrander. First of all, I appreciated your contribution very much, especially Figure 2 which shows very clearly the danger of enriching the topsoil for areas where runoff can be a problem. On the vertical axis in Figure 2 there is 'soil moisture' - I wonder if this is what you withdraw in the field or is it a laboratory determination?

G.J. Kolenbrander *(The Netherlands)*

It is the amount of water that can be extracted from soil by using a centrifuge - so it is the real water in the soil.

J.H.A.M. Steenvoorden

I have another question about the water quantity. You say that the risk of runoff is especially high on soils with a low permeability of the subsoil, particularly in summer time. I wonder if the permeability of the subsoil is a problem because I would think the structure and the condition of the topsoil would be the greater problem and I do not think the problem will be confined to soils with a low permeability, like clay soils, but also with other soils.

J.H. Voorburg

Can you suggest situations?

J.H.A.M. Steenvoorden

Well, it may also be in sandy soils with a large content of loam for example, but it is not related to the permeability of the subsoil.

G.J. Kolenbrander

I know you have this difficulty with different types of soils. The point was only to make a differentiation between the soils. You can say that you have the possibility of runoff from all soils.

H. van Dijk *(The Netherlands)*

Dr. Cheverry, you mentioned that you got a displacement of organic matter visible in worm galleries after applying pig slurry. You also mentioned that in that case you had ploughed under grass the year before. That is a situation, after you have ploughed in grass, where the next year you almost always find displacement of organic matter; you have an unstable situation and a displacement of organic matter along worm galleries. If you find a difference between 50 m^3 and the higher levels, that is very normal because you are leaching the soil with a more concentrated ammonia solution. So when you want to be sure that the organic matter which is displaced along worm galleries is organic matter from the manure, then you should turn to arable land and not the unstable situation shortly after ploughing in grass.

C. Cheverry *(France)*

But we observed this picture one year after returning to arable land and during this year landspreading was an important factor. We could see the water flowing and we think that this water is important from the point of view of pollution. Perhaps it is an unstable situation.

H. van Dijk

Yes, but you can have a rather heavy pollution of organic matter in the ground water within a year of ploughing-in grass. You are adding a tremendous amount of organic matter moreorless comparable with the organic matter in slurry. It contains much degradable material and just by adding water you can see displacement of organic matter. When you also apply slurry, that is an ammonia solution, it may help to displace the organic matter. When you want to observe whether there is an organic matter leaching from the slurry, you are better off with arable land. I do not know whether the fields you have chosen are all ploughed under grass or whether you have some arable land.

C. Cheverry

In the two basins we have chosen, the upper part is always grassland each year and the lower part is arable land with maize and so on.

H. van Dijk

Did you observe displacement of organic matter also where you have maize, arable land?

C. Cheverry

No, only in the case of the grassland.

A.V. Dodd *(Ireland)*

Dr. Cheverry, I would like to hear some more data on the spreading programme employed, whether the 50 m^3 was applied in one dressing. Equally, I would like data for the other, larger dressings. Furthermore, can you tell us, with regard to the drainage waters (or, as you call them, the ground waters) and also the brook waters, how often they were sampled in relation to rainfall and date of application?

C. Cheverry

On the first question, there are a lot of dressings for the two different basins. In the basin that received 50 m^3, I recall there were 10 dressings during the winter and spring. For the second question, we observed ground water at the end of winter, that is to say, during the season where the difference between rainfall and evapotranspiration is greatest. We sampled the drainage waters during February and April. I do not know if I have answered your questions satisfactorily.

A.V. Dodd

Do I understand that you had 10 dressings of the low rate of application each of 50 m^3?

C. Cheverry

No, no. 50 m^3/ha/year - total.

J.H. Voorburg

Maybe you can explain your question.

A.V. Dodd

Yes, I am trying to decide whether 50 m^3 was a light dressing or a heavy dressing. Was 50 m^3/ha applied in one application with no subsequent dressings on that area during the year in question?

C. Cheverry

No. Ten different applications were made, each of 5 m^3.

A.V. Dodd

Could I ask you how the farmer applied 5 m^3/ha?

J.H. Voorburg

I think that Dr. Tietjen wants to comment on this.

C. Tietjen *(West Germany)*

Yes, I believe we are arriving at a very important point. You cannot apply 5 m^3/ha in one dose; it is impossible with the implements in current use. However, we have to consider what we are doing. We apply 1 000 and even 3 000 m^3 of 4% DM sludge on arable land without drowning the soil. We apply it in 30 doses from autumn to spring although we might even start in spring and go on into the summer period providing the soil can take it without becoming anaerobic. This is a very important point. We must consider that the organic material in this liquid form must be transformed by the organisms in the soil as they need air for this purpose. So the ratio of water added to the soil must be adjusted so that it is always moist but not wet. If we adjust the application rates in this situation we are performing an excellent sheet composting procedure which gives us wonderful structural conditions and you will not see any black colouring. We must adjust the application rates exactly so that the soil is always aerated.

C. Cheverry

Yesterday somebody said that the problem was that of farmer education. Two years ago in Brittany the problem of pollution by landspreading was unknown and the farmer is only just beginning to take this problem into account. The researchers are only just beginning to study this problem. On the question of the 5 m^3, this amount is not spread over the whole area but if we consider the average per hectare, per year, it comes out at 50 m^3.

P. Graffin *(EEC)*

Dr. Kolenbrander, did you try to set up such a balance for phosphorus on a small scale, I mean for typical regimes, intensive and less intensive?

G.J. Kolenbrander

No. I was asked to do this but I believe it is impossible to do it for a small scale because we have to know, in each region, how many people are living there to take a mean quantity.

It is necessary to know how much feed is imported from outside the region, and so on, and we have no data on this. You can say, "I have so many cows eating so much feed", then it is possible to make a balance and that is mostly what we are doing. In the Netherlands, exports and imports are registered and thus it is possible to make such a balance but, in small regions, it is impossible to do this.

P. Graffin

What kind of practical conclusion can you reach if you know there are different conditions for surplus waters?

G.J. Kolenbrander

You can calculate a total average, but not for each region, but this balance shows what is the most serious factor. We have found that it is the people themselves who are the worst polluters so if we want to clean up we have to start with the population. At the same time we must take into account that the contribution by agriculture will increase the level of pollution so we must be careful that the level is at least down to its present rate, if not reduced, but we will not have the risk that the level from agriculture is increasing because we have too much phosphorus. So the balance is useful in that way. Furthermore, you can see that if you want to reduce the P load from 6 down to 1 milligram, you have to reduce all point sources by 90% and that is a high level of reduction.

J.H. Voorburg

It is just an inventory of the problems.

A.V. Dodd

Could I ask you Dr. Kolenbrander, has any of the data presented on runoff in you paper ever been tested?

G.J. Kolenbrander

Not in our country - we have not measured runoff because it is very incidental. However, the level I have calculated from field experiments and the rainfall data is in agreement with results from the USA where research on runoff has been much more intensive and they have done research not only in hilly regions but also in more flat regions.

H. Tunney *(Ireland)*

I would like to comment on the results that Marie Sherwood presented and on one point in particular: the depression of grass yield with cattle slurry. I think this is an important practical problem for farmers who are using slurry. The rate used here was quite low, I think about 40 m^3/ha in one dressing. At this rate there was a lower yield than from the control plots which received no fertiliser and no nitrogen. There has been very little emphasis or discussion on this from other countries. Dr. Pain from England mentioned that he had observed this type of thing but there has been very little comment from Holland, Germany, or anywhere in southern Europe. I wonder if it is a problem of nothern Europe. There are a few points to consider when you are applying slurry it is important to apply it on very short grass and I think that in the situation Mrs. Sherwood was talking about there was very short grass. If the slurry sticks to the grass the nitrogen does not get down into the soil and so it is very difficult for it to be taken up by the plant. Obviously there is more to it than that because that effect would mean that you had no nitrogen applied, but you have a nitrogen depression relative to where no nitrogen is applied so presumably you have a reduction of photosynthesis as well. I would like to know whether everybody has this experience or whether it is some kind of exclusively Irish/English situation.

A. Cottenie *(Belgium)*

I think I have a partial answer to this but there are controversial factors involved. When you measure the conductivity of the saturation aspect of the soil in the top layer, you find values between 4 and 8 micro-siemens/centimetre and then you are already in the range of altering the plant growth due to excess of conductivity. That is one of the factors. Also, on other crops when you have a decrease in growth, it is the counterbalance against input of nutrient elements, eg, excess of salts.

F. Bonciarelli *(Italy)*

In Italy we have no experience of applying slurry on natural meadows but we use it mainly on arable lands. A few studies have been carried out on landspreading of slurry on arable crops. I carried out some trials on top dressing slurries on winter wheat and I observed, just two or three weeks after the application, poor production of wheat vegetation. I do not know whether the reason for this slow growth is an increase in the salinity of the soil but I think the main reason is the coating of the foliage by the insoluble part of the slurry blocking the photosynthesis. We had a reduction of efficient leaf surface but later we observed a re-growth of new leaves and much better nitrogen nutrition improved fast re-growth. So, after three weeks the vegetation was much improved by the slurry application although at the beginning we had observed reduced growth. Maybe something like that happens on pasture land.

J.R. O'Callaghan *(UK)*

About three years ago my colleagues and I carried out this sort of experiment. I must say, with hindsight, I would now question the wisdom of this approach. In doing this sort of experiment you create a very artificial way of applying fertiliser. In practice, farmers do not apply slurry at frequent intervals and then carry out the harvesting three weeks later. I think the more practical situation is where one applies it in early spring and then allows it to be harvested six weeks or two months later. Therefore, I think the researcher is creating a very artificial situation. That is point no. 1. My second point is that I feel that if you want to carry out a balance you do not want to do this sort of field experiment; I would not do it again because of lack of control over the way in which you put on the application and also because you cannot measure clearly all the components that make the balance. Therefore, I think that in many ways this is a rather futile experiment that takes a lot of effort and, in the end, does not give very reliable results.

M.T. Sherwood

In the situation I described it was cropped after seven weeks and I do not think the conditions were so unusual compared with the practical situation.

J.R. O'Callaghan

In the trial we did, in fact, when we put the slurry on we probably got some scorch and some patches 'knocked out' a bit which you do not get with inorganic nitrogen. It's the same kind of situation about which I was arguing with Dr. Tunney yesterday; the rate of release of the nitrogen from the cattle slurry and from the inorganic N is involved and if you go on over a period of time you will find that the residual effects will begin to take over from this. So the explanation goes but I do not think that you are doing a fair comparison - comparing the different treatments at the one time. You have got to do it over a longer period.

M.T. Sherwood

At Johnstown Castle there is another research worker who also has an EEC type of study where he studies the time and rate of application. He is putting on both cattle and pig slurry in spring, summer, autumn and winter, and then measuring the residual effects afterwards. Now, I shouldn't quote his results but the indications are that he did get some response, a small response, to cattle slurry in the spring but that he got a slight reduction in summer. So it seems to be a highly seasonal effect, that's true!

J.H. Voorburg

I am afraid you still have the differences in weather conditions.

M.T. Sherwood

As Dr. Cottenie said, maybe you get more rain in the spring and it is diluted and then if you have a very dry summer you get the high salt density.

A.V. Dodd

I have a comment on Pr. O'Callaghan's point as regards the methodology of the experiment. On the one hand we heard from Dr. Cheverry regarding 10 hectare plots and on the other hand from Mrs. Sherwood regarding, perhaps, .1 hectare plots. From experiments which I have carried out on small plots, I also found it extremely difficult, in fact quite impractical, in the end, to produce a balance sheet, except, perhaps for phosphorus. It was quite impractical for nitrogen. A discussion on how one should tackle the question of loss of nutrients on an experimental level might well be useful to this seminar. I leave it for someone to take that point up.

J.H. Voorburg

Thank you. On Friday afternoon Dr. Kolenbrander will try to propose a nitrogen balance and discuss it - perhaps that will be an opportunity.

A. Cottenie

I would like to make a remark. As a matter of interest, we have studied and reproduced Mitscherlich curves, the function of increasing quantities of fertiliser rates and in the classical Mitscherlich curve, everybody knows it very well, the flattening out seems to be really explicable merely by salinity effects. You have the same curve, but at different levels, when you apply dilution with the same quantities. You can add equal quantities of, say, potassium sulphate, or any soluble fertiliser in a mineral fertiliser experiment, but when you apply the same quantity by a larger dilution, the flattening out of your Mitscherlich curve will occur later than in high concentrations. I believe this proves that it is really a salinity effect and you obtain exactly the same thing when applying slurry, so long as you work with soluble materials.

J.H. Voorburg

Thank you. This morning we have had an important discussion on runoff. When you visit a conference or a meeting on animal waste disposal in the US I guess half of the time is spent on runoff problems, mostly livestock runoff but also runoff from the fields. I believe this morning we have made an important start on the problems of runoff in the European countries. Our discussion then went on to grassland research which is a subject that really merits an entire seminar.

Thank you all very much.

THEME 3

MANURE AND POLLUTION OF SOIL AND GROUNDWATER

Chairman: J.H. Voorburg

SOIL, WATER, PLANT RELATIONSHIP AS INFLUENCED BY INTENSIVE USE OF EFFLUENTS FROM LIVESTOCK

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INTRODUCTION

During the past fifteen years, intensification of livestock raising has led, in some parts of Belgium, to a pronounced increase of the ratio between the number of animals and the land surface. As a consequence, the production of animal waste locally reaches such a level that its content of NPK largely exceeds the normal fertiliser requirements of the soil.

An inquiry, conducted in order to obtain information concerning soil treatment, showed that the combination of inorganic and organic fertilisers lead to the following excessive yearly input of nutrient elements in kg/ha: 75 to 150 kg N, 250 to 780 kg P_2O_5 and 0 to 240 kg K_2O (van de Maele, 1975).

This is not only economically wrong, but has also a negative effect on the soil and the soil water, as well as on qualitative and quantitative plant production. These different aspects of intensive use of effluents from livestock are discussed in this paper.

1. POTENTIAL POLLUTING AGENTS IN EFFLUENTS FROM LIVESTOCK

Besides the fact that heavy doses of liquid manure contribute to the degradation of soil structure, more attention has been paid to its content of major nutrient and trace elements. This has been established by the analysis of sixty-three samples of liquid manure from cattle, pigs or poultry (Table 1). The mean N/P/K ratios of such liquid manures showed values

TABLE 1

CHEMICAL COMPOSITION OF THE MOST IMPORTANT SPECIES OF MANURE: AVERAGES ($\bar{x}$) AND STANDARD DEVIATIONS (s), MINIMUM (m) AND MAXIMUM (M) VALUES.

Species		%DM	% in dry matter (DM)									ppm in DM			
			Na_2O	K_2O	CaO	MgO	P_2O_5	Cl^-	C	N	C/N	Fe	Mn	Cu	Zn
Cattle (n:17)	$\bar{x}$	3.9	0.9	6.1	2.8	1.0	2.5	1.9	34.4	6.2	6.1	2600	310	110	330
	s	4.5	0.8	2.7	1.4	0.5	1.5	0.8	5.0	2.2	1.6	1780	140	170	190
	m	0.4	0.2	2.6	1.3	0.2	1.4	1.2	22.7	3.9	2.2	590	150	20	190
	M	16.3	3.4	13.8	6.4	2.4	7.5	4.2	40.8	12.7	9.0	7920	610	570	930
Pigs (n:33)	$\bar{x}$	5.5	1.8	8.0	4.2	1.7	5.0	2.7	33.8	8.1	4.3	2360	350	490	890
	s	4.8	1.1	5.8	1.5	0.8	1.9	1.8	6.8	1.9	0.9	1020	130	240	570
	m	0.7	0.2	1.0	1.3	0.4	1.4	0.3	16.3	3.3	2.3	980	180	50	190
	M	20.3	5.3	26.1	8.6	2.6	9.9	8.0	41.7	13.4	6.2	4980	600	1030	2650
Poultry (n:13)	$\bar{x}$	26.4	1.1	3.9	14.0	1.3	5.4	1.3	30.1	5.1	6.4	2050	410	70	460
	s	19.2	0.7	2.5	7.9	0.5	1.7	0.8	6.4	1.8	1.6	1390	80	50	180
	m	5.0	0.4	0.9	5.9	0.7	2.8	0.4	13.1	1.8	4.3	740	260	30	80
	M	64.1	2.8	10.5	37.0	2.0	8.1	3.1	36.4	8.1	8.9	5020	500	230	770

between 1/1/1 and 2/1/2 and mean C/N ratios between 4.3 and 6.3. However, large variations of element and dry matter content were observed. A general recommendation from the Agricultural Extension Services, proposing, for example, 30t liquid manure for a crop such as spring barley, may therefore, result in a real fertiliser rate which is completely different from the expected one,as shown by the following figures:

Quantities of elements corresponding with 30t liquid manure per ha.		
Expected		Really introduced
N	107*	between 3 and 220 kg
P_2O_5	67	between 3 and 110 kg
K_2O	163	between 9 and 260 kg

* 165 kg of which 65% is estimated to be utilised.

This example illustrates how difficult it is to make general statements without basing the advice on chemical analysis which can easily characterise the livestock waste in a given local situation. This is indeed the only possibility for obtaining an objective knowledge of the quantities of elements being applied.

The trace element contents are even more variable, especially in pig manure, which contained 190 to 2650 ppm of Zn and 50 to 1030 ppm of Cu in dry matter (Table 1). These elements accumulate in the topsoil and may reach, in course of time, phytotoxic concentrations when heavy doses are repeated annually. At the same time these toxic elements stick to leaves and roots representing a real danger when taken up by grazing animals.

2. INFLUENCE OF LIQUID MANURE FERTILISATION ON THE CHEMICAL COMPOSITION OF SOIL AND SOIL WATER

The soil constitutes the natural reservoir of all nutrient elements. At the same time it is normally used as the receptacle of diverse waste products assuming their breakdown or fixation and consequently their incorporation in a natural cycle. In this way, the soil has been used in the past as the most important recycling agent of the environment. As long as an element takes part in a normal turn-over process, there is no danger of pollution. If the input exceeds the possibility of such normal cycling there will be accumulation at some of its stages. The excess is a real pollution when it harms soil quality, crop production or surface water quality. In this way, soil pollution can be caused by useful fertiliser products as well as by foreign, for example, industrial waste elements.

On soils belonging to bio-industrial holdings, or being used for dumping, chemical analysis revealed a considerable difference from the normal situation (Cottenie and van de Maele, 1974). As a consequence, several crops presented unfavourable effects and have been eliminated from the usual rotation (sugar beets, barley, potatoes).

Faced with the problem of the disposal of excessive manure production, the question arises of how much livestock effluent a soil can normally receive and recycle.

2.1. Material and Methods

The following pot experiment was carried out in a glasshouse at optimal moisture conditions: three soils of different texture (sand, sandy loam and clay) chemically characterised in Table 2 were treated with increasing quantities of liquid pig manure (Table 3). The quantities applied were 0, 9.6, 19.2, 28.4 and 57.6 g liquid manure/kg soil, corresponding with respectively; 0, 2.5, 5, 7.5 and 15 t dry matter/ha.

Soil samples were taken for chemical analysis after 0, 5, 15, 30 and 60 days of equilibration. At the same time saturation extracts were made in order to study the chemical composition of soil water, The following analyses were carried out: pH, %C, NH_4^+ and both in soil and saturation extracts: Na^+, K^+, Ca^{++}, Mg^{++}, P_2O_5, Cl^-, NO_3^- and conductivity.

TABLE 2

CHEMICAL CHARACTERISTICS OF THE SOILS

	Sand	Sandy Loam	Clay
pH	5.70	6.40	7.55
Conductivity in mmho/cm	1.60	1.13	2.40
m eq/100g: Na^+	0.14	0.10	0.20
K^+	0.14	0.27	0.59
Ca^{++}	4.38	7.05	19.80
Mg^{++}	0.56	0.51	3.26
mg/100g: P_2O_5	10.00	6.70	32.00
Cl^-	1.76	3.52	6.15
NH_4^+ (N)	0.56	0.38	0.32
NO_3^- (N)	2.96	2.16	6.00
$N_{tot.}$	140.50	103.10	167.90
%C	1.33	0.76	1.18
C/N	9.50	7.60	6.90
CEC (m eq/100g)	6.42	7.15	22.50

TABLE 3

CHEMICAL COMPOSITION (% IN THE DRY MATTER; DM) OF THE LIQUID PIG MANURE (DM: 8.7%)

Na_2O	2.6	C	42.5
K_2O	10.4	total N	3.4
CaO	5.0		
MgO	2.0	ppm in DM	
P_2O_5	6.9	Zn	940
		Cu	555

2.2 Results and discussion

2.2.1. pH

In all treated soils, the pH increased immediately and almost proportionally with the applied quantities (Figure 1). In the heavy soil this effect remained however, much less pronounced than in the light or medium textured ones.

After a short incubation time, a pH decrease was observed bringing its value at the end of the experiment below the original pH. Once again this phenomenon was more pronounced in light and medium than in heavy soil.

2.2.2. Ammonium

The ammonium contents of the soil change in an analogous way as the pH (Figure 1). This means:

a) A large increase soon after treatment directly related with the applied quantities of manure.

b) A progressive decrease of soil ammonium content in function of time after treatment.

c) In heavy soil, the original ammonium content was reached again after 30 days, in medium soil after 60 days, while in light soil it was still relatively high after two months of equilibration and when more that 5 t dry matter were applied.

2.2.3. Nitrates

Figure 1 shows a complementary increase for nitrates in the soils treated with liquid manure compared with the disappearance of ammonium.

A sharp increase of the nitrate content was noticed until 30 days after treatment and this was the more important as the doses increased. After that time, it levelled off for all treatments except at the heaviest dose on the clay soil where the nitrate content kept rising after two months of equilibration.

In contrast with ammonium, any nitrate enrichment could

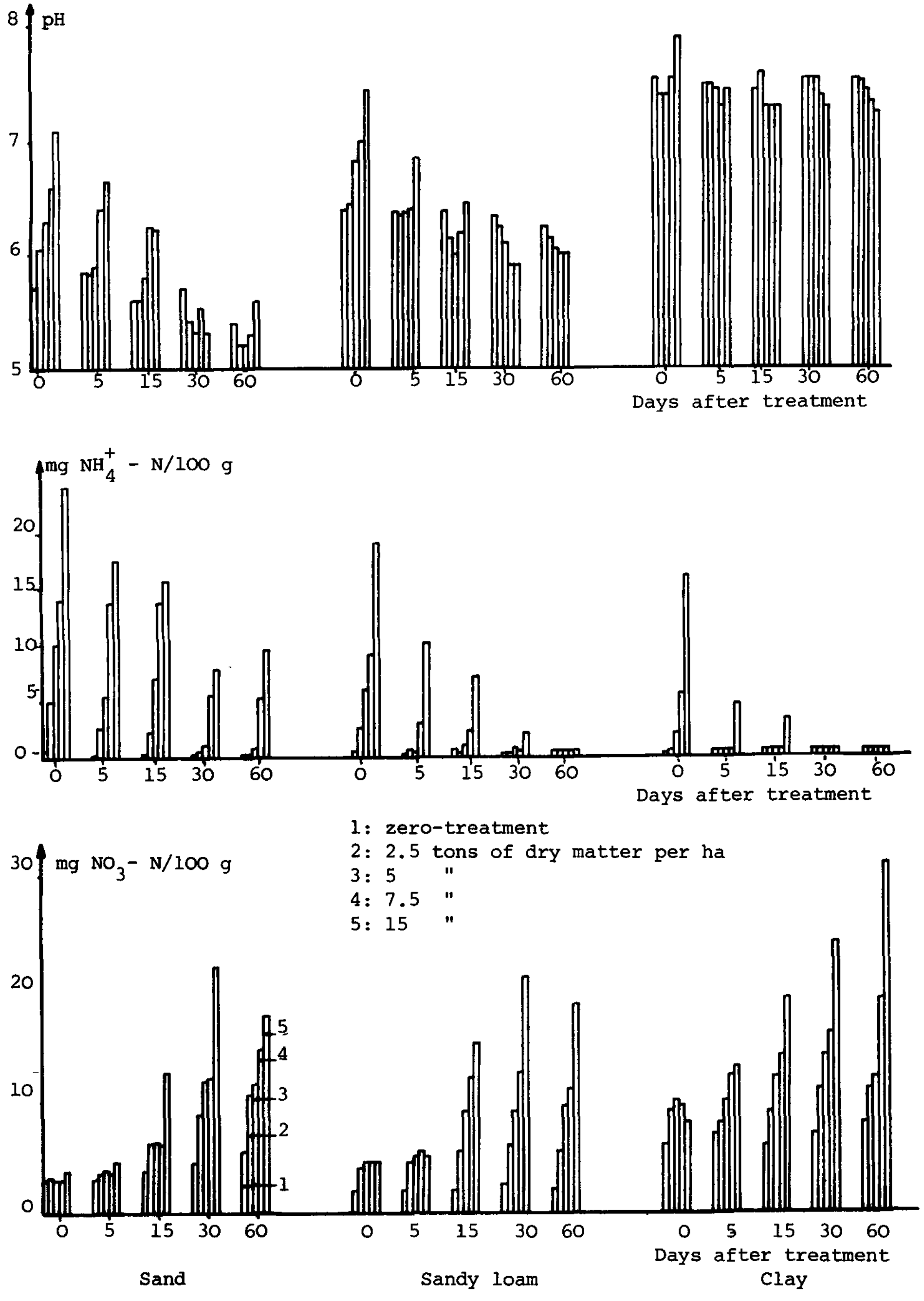


Fig. 1. Evolution of pH and contents of ammonia- and nitrate-nitrogen in function of dose, equilibration time and soil texture.

hardly be noticed immediately after mixing soil and liquid manure. After some days of incubation, nitrification continuously raised the nitrate content of the soils.

This phenomenon illustrates the relationship between changing ammonium and nitrate contents in function of fertilisation and equilibration time.

2.2.4. Cations, phosphates and chlorides

Changes in soil K^+ and Na^+ consequently increasing manure treatments, were observed in heavy as well as in light textured soil. A sudden increase of Na^+ after the heaviest manure treatment disappeared after some five days (Figure 2).

In all cases a considerable increase of extractable Na^+ and K^+ directly related to the applied dose of liquid manure was observed and these higher contents remained present after 60 days of experimentation.

Similarly, increasing contents were noticed for the nutrient elements Mg^{++}, P_2O_5 and Cl^-.

No clear tendency could be noticed concerning the Ca^{++} content of the soils in function of treatment and time.

2.2.5. Conductivity

Figure 3 shows the increase of the conductivities of the saturation extracts of the soil in function of dose and time. There is not only a pronounced relationship between quantitative treatments and conductivity, but the latter also increased with time.

Though this measurement is not specific for any particular ion species, it is narrowly related to the total soluble ion content of the soil and may be a valuable indication for salt excesses, leading to crop injury. As a matter of fact, Table 4 gives the nature of plant response towards different conductivity classes.

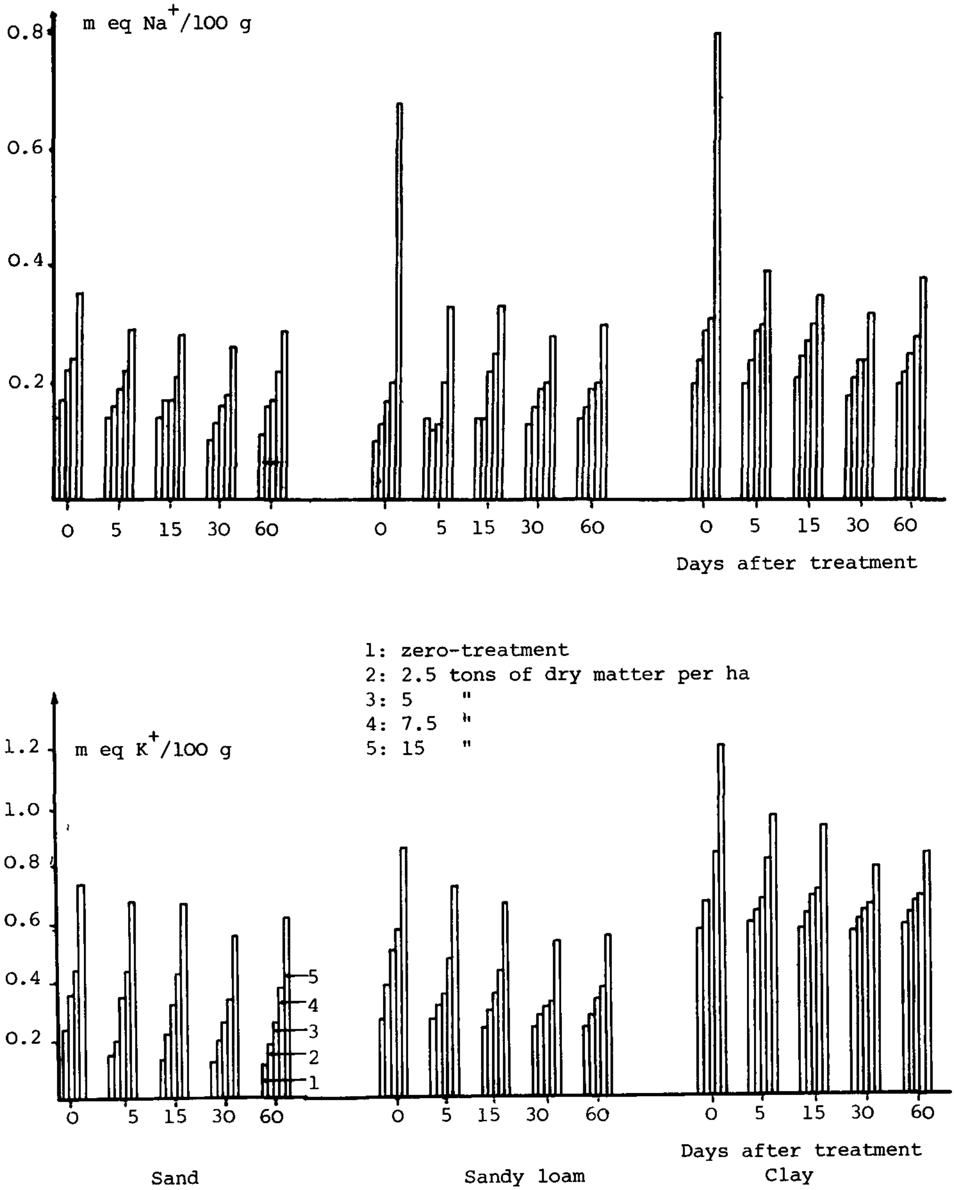


Fig. 2. Evolution of Na^+ and K^+ content of the soil in function of dose, equilibration time and soil texture.

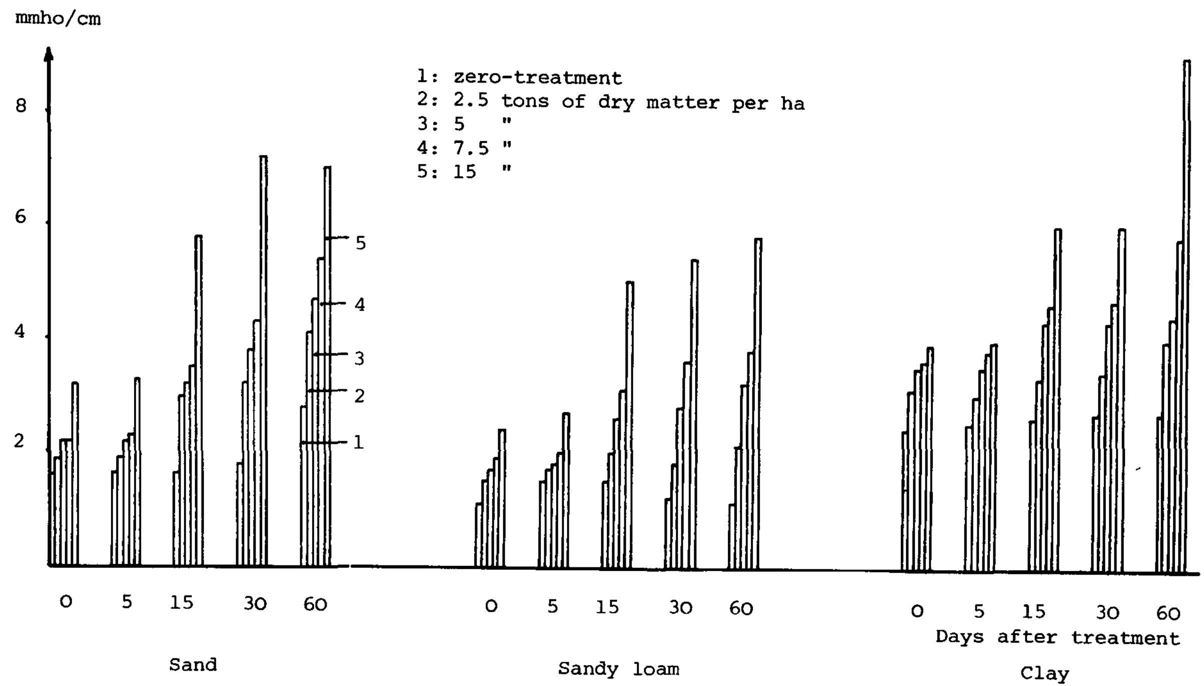


Fig. 3. Evolution of the conductivity of the soil solution in function of dose, equilibration time and soil texture.

TABLE 4

PLANT RESPONSE TOWARDS DIFFERENT CONDUCTIVITY CLASSES

Conductivity class mmho/cm	Plant Response
< 2	negligible
2 - 4	yield decrease of sensitive crops
4 - 8	yield decrease of most crops
8 - 16	growth of tolerant crops
>16	only growth of very tolerant crops

From this we see that there is a real danger for yield decreases as soon as manure applications correspond with 7.5t dry matter/ha. This salt effect persists over more than two months, which means, in practice, over the whole growth period.

These observations show that measuring the electrical conductivity of the saturation extract of the soil is a practical method for diagnosing the general effect of excessive use of livestock effluents and for indicating whether detailed analyses are required.

2.2.6. Influence of livestock effluents on soil water quality

The abovementioned increase of soil conductivity is of course narrowly related to the ion content of the soil water. In connection with the evaluation of mineral elements as discussed earlier, the chemical composition of soil water results from input of elements and the consecutive equilibrium rearrangements taking place. This resulting composition of the soil water (saturation extract) was measured after 60 days equilibration and gave the values represented in Figure 4. In all cases the mineral charge of the soil solution reflects narrowly the application rates as measured after a two months observation period. Furthermore notwithstanding the texture of the soil, the order of increasing charges was: K^+, $Na^+ < Mg^{++}$, Cl^- $< NO_3^-$, Ca^{++}.

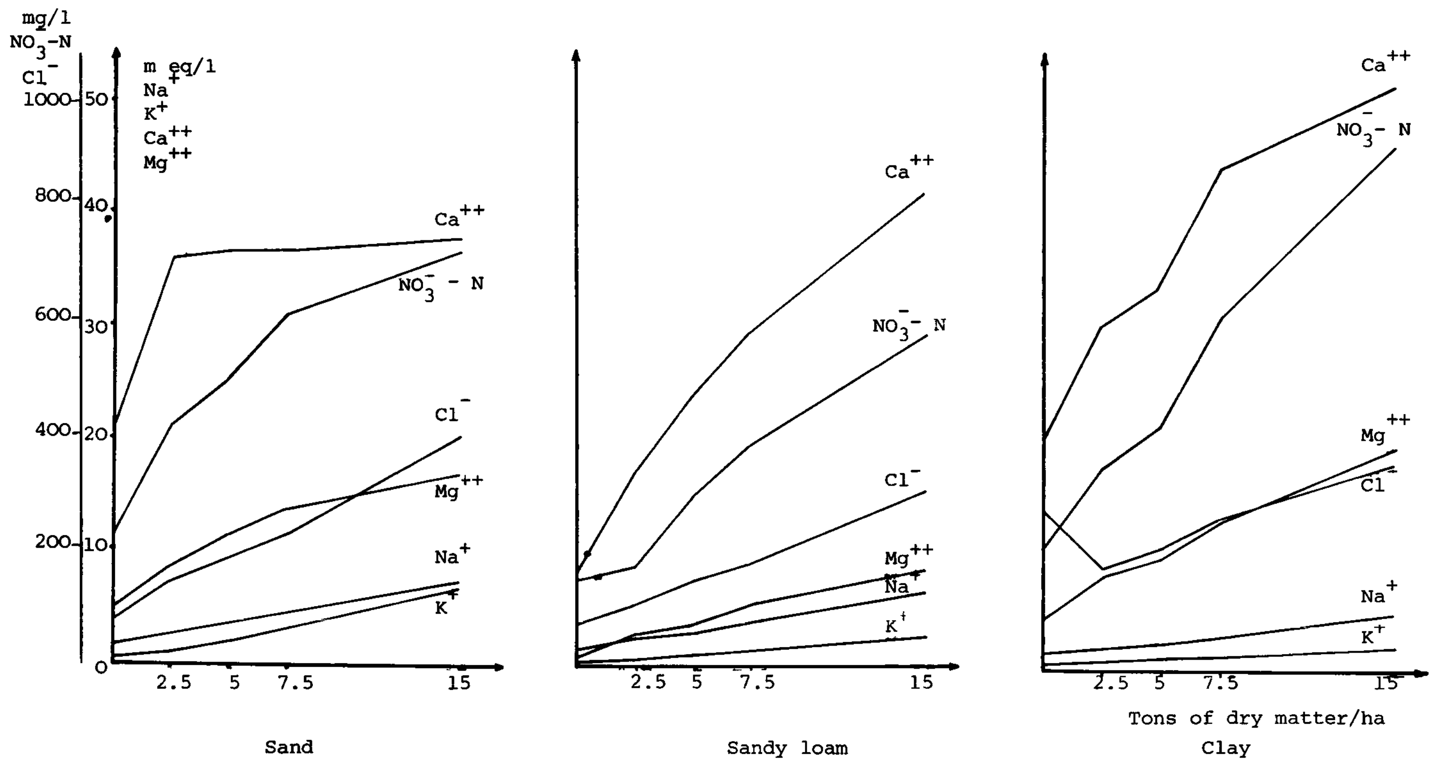


Fig. 4. Chemical composition of soil solution after 60 days of equilibration in function of dose and soil texture.

Thus soil water is most affected in relation to Ca^{++} and NO_3^- and the nitrate excess could be harmful, for example to the quality of certain crops. Also, the amounts of Cl^-, Mg^{++}, Na^+ and K^+ were all largely in excess compared with normal soil and surface waters as illustrated by the following comparative figures:

	Saturation extract of a normal soil (CEC: 7.5 m eq/100g)	Saturation extract of the treated soil (CEC: 7.15 m eq/100g)
mg/l Na^+	12.4	147
K^+	23.1	107
Ca^{++}	26.6	840
Mg^{++}	8.4	104
NO_3^- (N)	13.1	590
mmho/cm	0.56	5.3

3. QUALITATIVE AND QUANTITATIVE INFLUENCE OF MANURE TREATMENT ON CROP GROWTH

Finally crop response has to be considered as a criterion with regard to the use of animal waste as a source of nutrient elements because yield and chemical composition of the plants are the result of all the influencing factors.

Therefore, also from the point of view of the experimental technique, plants are very useful as indicators of possible consequences of over-fertilisation. Thus Neubauer and other pot experiments were set up in order to study the influence of different soil treatments on yield, growth and chemical composition of plants.

3.1. Neubauer experiments

3.1.1 Material and methods

Neubauer experiments were carried out using liquid manure from pigs and poultry as chemically characterised in Table 5.

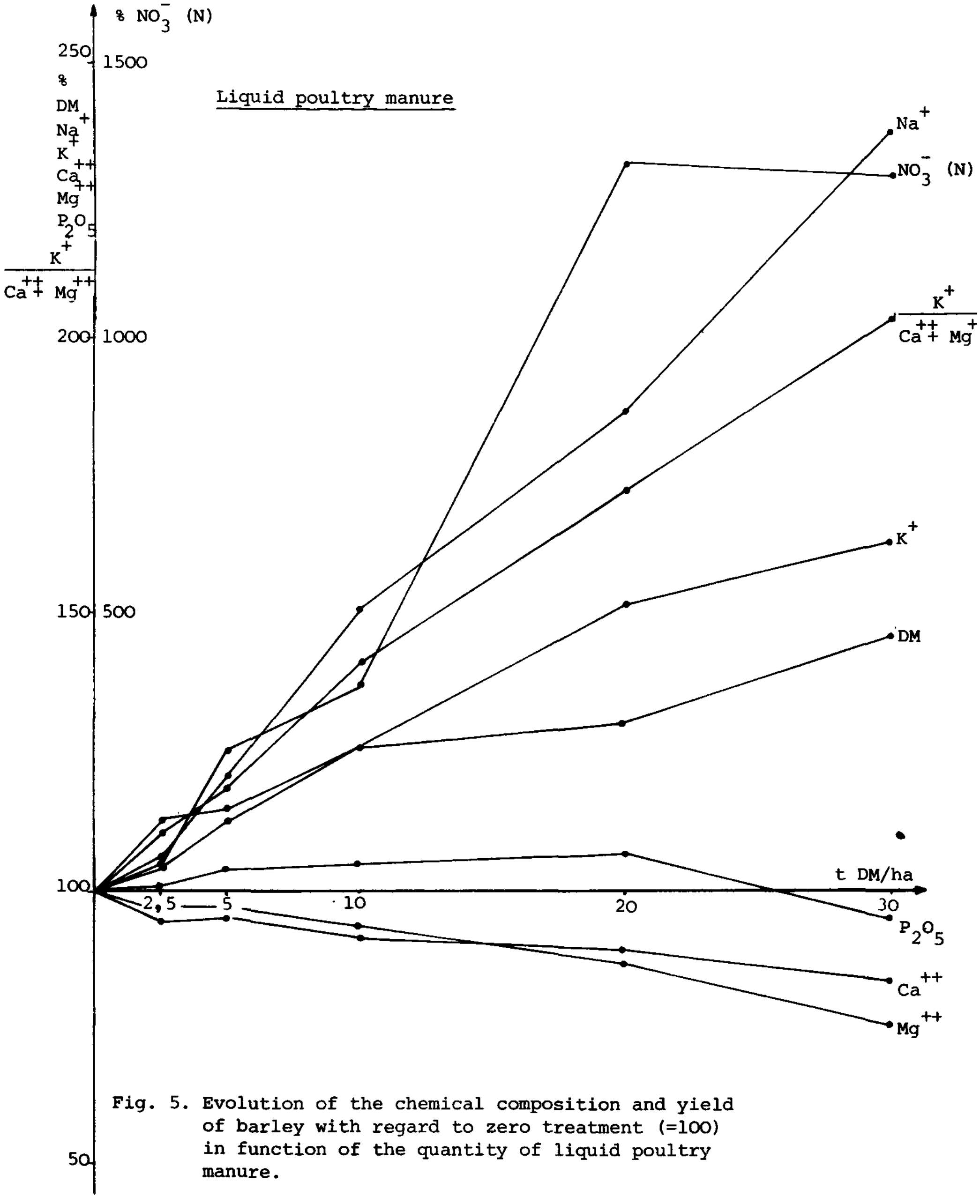


Fig. 5. Evolution of the chemical composition and yield of barley with regard to zero treatment (=100) in function of the quantity of liquid poultry manure.

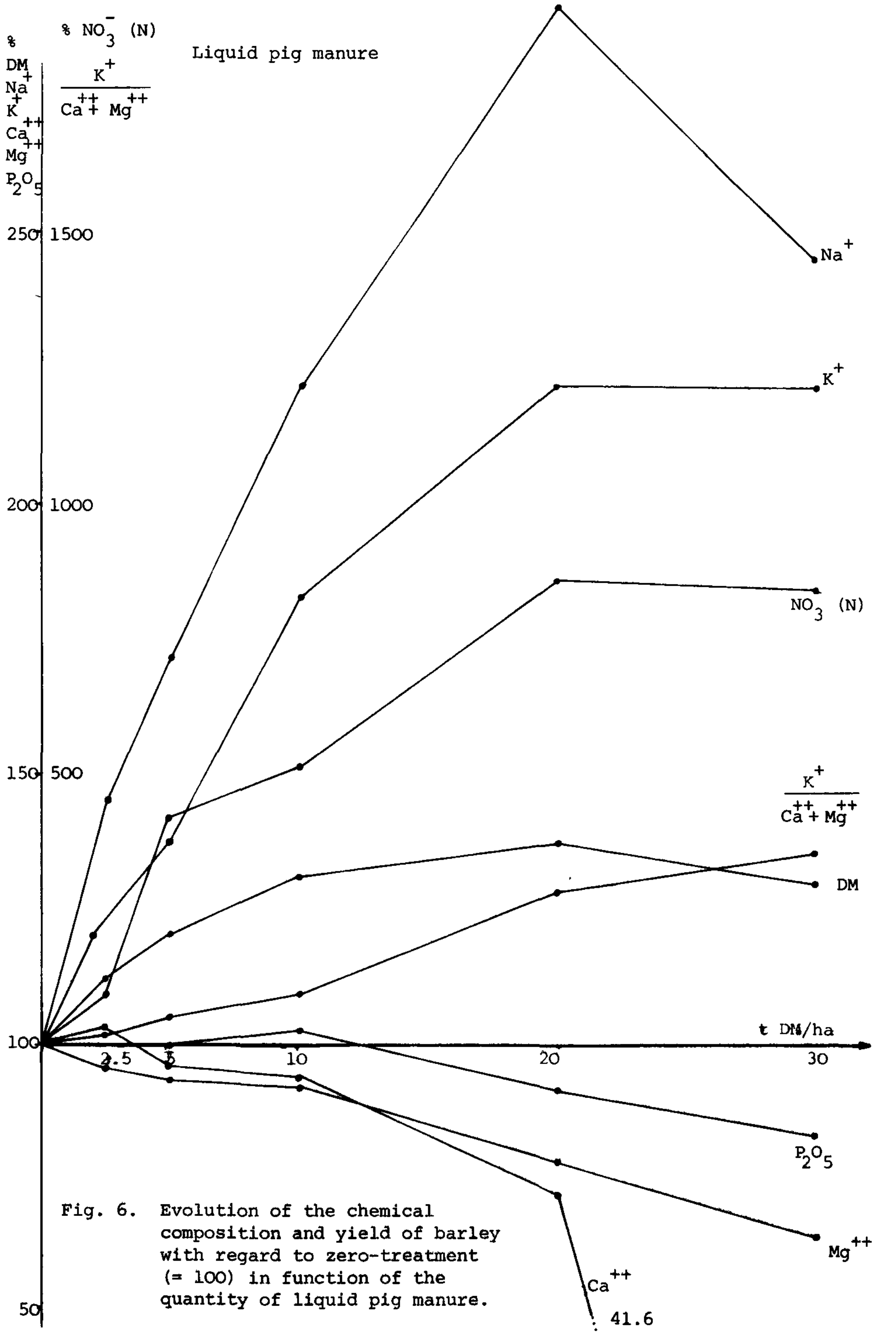
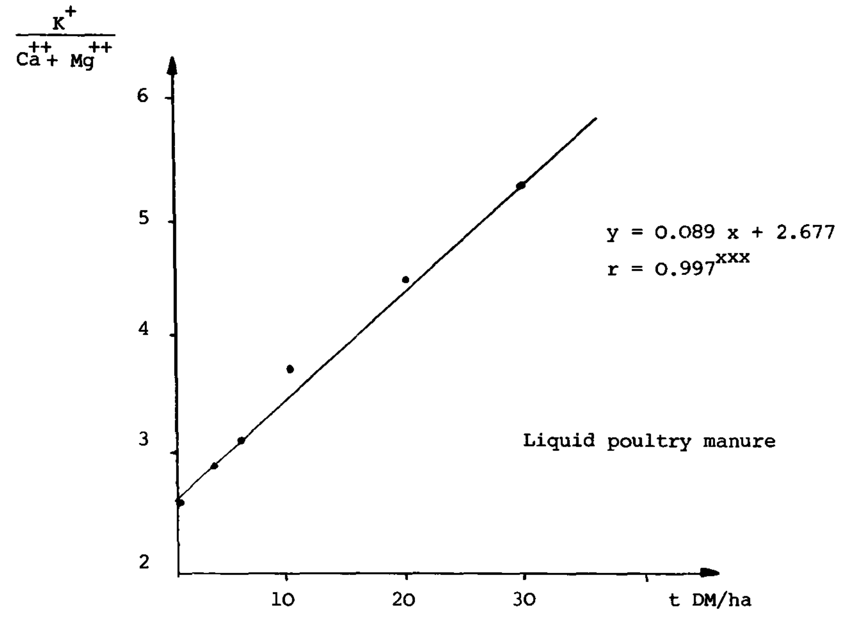


Fig. 6. Evolution of the chemical composition and yield of barley with regard to zero-treatment (= 100) in function of the quantity of liquid pig manure.



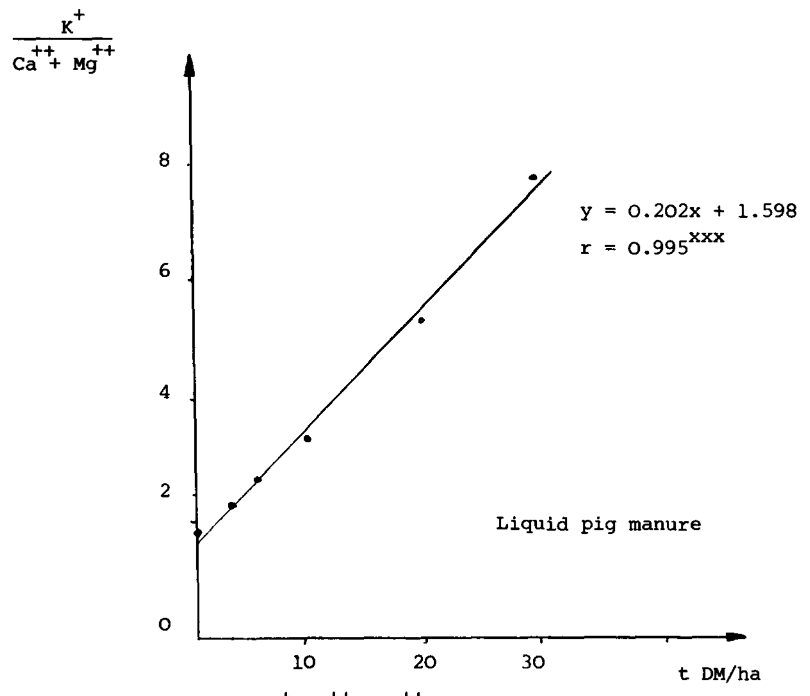


Fig. 7. Evolution of $K^{+}/Ca^{++} + Mg^{++}$ ratio in barley in function of the liquid manure dose.

TABLE 5

CHEMICAL CHARACTERISTICS OF THE LIQUID MANURE

	Pigs	Poultry
% dry matter (DM)	9.00	25.8
% Na_2O in DM	0.95	0.71
% K_2O " "	3.61	3.61
% CaO " "	4.38	13.90
% MgO " "	1.28	0.72
% Cl^- " "	0.91	0.34
% P_2O_5 " "	7.03	5.05
% N " "	3.00	2.95
% C " "	33.90	31.8
C/N	11.30	10.8
ppm Cu in DM	540	230
ppm Zn in DM	780	410

A sandy soil was used and its nutrient situation was as follows: pH 5.70; electrical conductivity: 1.60 mmho; %C: 1.33; P_2O_5: 10.0 mg/100 g, exchangeable bases in m eq/100 g: Ca^{++}: 3.83; Mg^{++}: 1.21; K^+:13.

Besides a zero treatment, the following doses were applied: 2.5, 5, 10, 20, and 30 t expressed as dry matter/ha.

3.1.2. Results

Yields and analytical results converted to percentages with respect to the zero treatments are given in Figures 5 and 6, while Figure 7 gives the evolution of the $K^+/Ca^{++} + Mg^{++}$ ratio in the barley germ plants in function of the quantities of liquid manure applied.

In order to link these values to real concentrations, it should be mentioned that the 100% value corresponds with the following figures:

100% concentration in barley seedlings (mg/100g DM)		
	Experiment 1	Experiment 2
Na^+	46	117
K^+	3225	2379
Ca^{++}	748	794
Mg^{++}	490	534
P_2O_5	3100	2575
NO_3^- (N)	34	77
$K^+/Ca^{++} + Mg^{++}$	2.6	1.8

3.2 Pot experiment

The same soil and liquid manure as mentioned in the Neubauer tests have been used in a pot experiment with spinach as a test plant. Treatments were 0, 2.5, 5, 10, 20 and 30 t dry matter (given as liquid manure) per ha, followed by equilibration during two weeks before sowing. After one month, spinach was cut. Yields of fresh and dry matter and analytical results are given in Table 6.

After harvest the soil was used again for another pot experiment with Italian ryegrass during four weeks. A maintenance fertilisation of 50 mg NH_4NO_3/kg soil was given. Yields and chemical composition of the ryegrass are shown in Table 7.

3.3 Discussion

In the Neubauer experiments, dry matter yields increased with increasing manure fertilisation (Figures 5 and 6). However, one must distinguish the two manure species: at the heaviest dose a yield decrease was caused by pig manure, but not by poultry manure. A similar decrease has also been observed in the pot experiment with pig manure and with spinach as test plant; it became noteworthy from a dose of 20 t dry matter/ha.

Concerning the influence of increasing liquid manure doses on the chemical composition of the plants, the following points were observed: barley germ-plants, grown on soils treated with increasing doses of manure contained much more Na^+ and K^+ while their Ca^{++} and Mg^{++} contents showed a decreasing pattern.

TABLE 6

POT EXPERIMENT: YIELDS AND CHEMICAL COMPOSITION OF SPINACH

Liquid pig manure in t DM/ha	Yield in g/pot		mg/100 g DM						ppm in DM		$K^+/Ca^{++} + Mg^{++}$
	Fresh matter	Dry matter	Na^+	K^+	Ca^{++}	Mg^{++}	P_2O_5	NO_3^- - N	Cu	Zn	
0	4.8	0.56	644	5709	1500	1595	6500	174	9.0	273	1.84
2.5	9.3	1.43	485	3656	1516	1482	5750	320	10.0	261	1.22
5	12.6	1.88	573	3378	1756	1880	5025	480	11.5	288	0.93
10	19.5	2.50	784	4125	1770	1915	5250	905	11.0	354	1.12
20	18.2	2.02	692	8641	1800	1545	7575	1406	9.5	591	2.58
30	13.9	1.47	382	13274	1736	1195	10850	1479	9.5	640	4.53

TABLE 7

POT EXPERIMENT: YIELDS AND CHEMICAL COMPOSITION OF RYEGRASS

Liquid pig manure in kg DM in ha	Yield in g/pot		mg/100 g DM						ppm in DM		$K^+/Ca^{++} + Mg^{++}$
	Fresh matter	Dry matter	Na^+	K^+	Ca^{++}	Mg^{++}	P_2O_5	NO_3^- - N	Cu	Zn	
0	10.4	2.2	103.0	2346	1110	424.3	915	2.9	10	54	1.52
2.5	7.3	1.7	80.0	2659	1026	409.8	925	2.5	9	81	1.85
5	8.3	1.8	75.9	2776	1056	364.8	985	2.9	8	51	1.95
10	14.4	2.8	158.7	3167	1570	651.8	1505	4.6	13	71	1.42
20	26.7	3.7	627.9	2620	1460	682.2	1125	468.0	12	64	1.22
30	23.9	3.3	478.4	4575	1630	725.9	1050	1125.0	16	63	1.94

As a consequence, the $K^+/Ca^{++} + Mg^{++}$ ratio is significantly correlated with the manure treatment (Figure 7). This $K^+/Ca^{++} + Mg^{++}$ ratio is very important in animal nutrition, especially when the maintenance ration of cattle is provided by grass or other forage crops such as corn. A high K^+ content in forage crops corresponding with Mg^{++} deficiency has indeed been related to an increasing danger of hypomagnesaemia.

While our experiments were carried out with barley as a test plant, Gisinger (1950)cites several reports, showing also an increasing K^+ content in grass after manure treatments and suggests that the only way to prevent this evil is to lower the liquid manure dose.

The same tendency concerning $K^+/Ca^{++} + Mg^{++}$ was also noticed for spinach plants of the pot experiment (Table 6).

In ryegrass, grown on the same soils but after two to three months, the Ca^{++} and Mg^{++} concentrations increased together with the K^+ contents so that the $K^+/Ca^{++} + Mg^{++}$ ratio remained practically at the same level (Table 7).

Nitrate contents in crops were more variable than any other mineral component as influenced by the treatments.

A maximum acceptable nitrate content in forage crops can hardly be proposed because nitrate toxicity is narrowly related to the nature of the given ration and to the general condition of the animals. Nevertheless, Adams and Guss(1965) stated that food containing less than 0.1% $NO_3 - N$ in dry matter is safe under all circumstances, while contents higher than 0.4% should be avoided. In our pot experiments, $NO_3 - N$ contents went up to 1.48% in dry matter of spinach and 1.12% in ryegrass.

Since it is known that pig manure is often high in Cu and Zn contents, these elements were also determined in spinach and ryegrass from our pot experiment (Tables 6 and 7). There was a striking response of Zn concentration in spinach plants, but

Cu did not show any significant difference in comparison to the controls. This confirms the fact that Zn in plant tissue is more variable than Cu (Cottenie et al., 1968). We may conclude that one single, even heavy, treatment with liquid pig manure, rich in Zn and Cu does not cause an immediate danger for plant growth and consumption. However, careful attention should be given when such treatments are frequently repeated, such as happens when dumping is practised.

SUMMARY AND CONCLUSIONS

It is stated that a positive element input balance sheet in top soil is only to be considered as soil pollution when it harms soil quality, crop production or surface water quality.

Soils belonging to bio-industrial holdings or being used for dumping, differentiate from the normal status and become finally unsuited for certain crops.

This situation has been created as a consequence of the concentration of such holdings and of farmers' ignorance of the actual content of nutrient elements in liquid manure.

Equilibration tests with different textured soils showed the influence of heavy doses of livestock effluents on the chemical composition of soil and soil water. Drastic changes were observed after such treatments.

The electrical conductivity of the saturation extract of the soil turns out to be a practical criterion regarding excessive use of liquid manure.

The excess of several nutrient elements in soil and soil water is clearly reflected by the chemical composition of crops. Thus, different pot experiments showed increasing contents of Na^+ and K^+, together with decreasing Ca^{++} and Mg^{++} concentrations. Furthermore, nitrate contents in plants were unacceptably high after heavy treatment with livestock effluents.

In practice, repeated use of liquid manure and its dumping is to be avoided and an even more moderated use of such effluents should be accompanied with chemical soil analysis as a warning system.

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LEACHING OF NITRATE AND DENITRIFICATION IN A SANDY SOIL AS INFLUENCED BY MANURE APPLICATION

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INTRODUCTION

Nitrate is one of the major elements reducing the quality of ground water and surface water, especially with regard to eutrophication and drinking water quality. In surface waters sometimes nitrate concentrations as high as some tens of mg. $N.l^{-1}$ are measured and in ground water values up to 100 mg. $N.l^{-1}$ can occur whereas at other sites nitrate is completely absent. This points to the fact that soil-chemical and soil-biological processes in which nitrate is involved during its transport to ground water or surface water are of essential influence.

Much is known about the leaching of nitrate from the unsaturated zone (Kolenbrander, 1972) but processes in which nitrate is involved in the ground water are largely unknown. Denitrification seems to be the most important process in the saturated zone, but the quantitative effect is limited by the amount of organic matter available in the soil solution (Steenvoorden, 1975; Kolenbrander, 1975). In this paper some field and laboratory experiments on the leaching of nitrate and organic matter and the possible role of denitrification are discussed.

FIELD EXPERIMENTS

General

The transport of nitrate and organic matter was followed in four experimental fields from the soil surface to a depth of some 2.5 m. Three of the four fields are situated at the Vreedepeel Farm of the Crop Husbandry Research Station, Lelystad (The Netherlands), which since 1970 has been used in experiments on the effect of different application rates of pig manure on production and quality of sugar beets. The fourth field is on a privately owned farm in the same area, where during the last two years, sugar beets and broad beans have been grown and poultry manure is used. The application rates of manure and fertiliser are given in Table 1. The manure is given in two applications, one in winter, the other in early spring.

TABLE 1

AVERAGE MANURE AND FERTILISER APPLICATION (kg N ha^{-1} $year^{-1}$) ON THE FOUR EXPERIMENTAL FIELDS DURING 1974 and 1975 (1 - 3, EXPERIMENTAL FARM; 4 PRIVATELY OWNED)

Field	1	2	3	4
Manure	-	280	560	400
Fertiliser	150	-	-	32

The quantities of nitrogen are not directly comparable, however, as they differ with regard to the plant available mineral nitrogen. On a long term basis an application of 280 kg N in pig manure and 214 kg N in poultry manure is equivalent to 150 kg fertiliser N. The fields are situated on a sandy soil; under peaty sand topsoil (0 to 20 cm), humus-rich sand is found (20 to 30 cm) and at greater depths (> 30 cm) humus-poor sand.

In the unsaturated zone, and to 2 m depth in the saturated zone, water samples were taken at every 20 cm depth by means of suction with porous ceramic cups (length 100 mm, outer diameter 19 mm, inner diameter 16 mm). Ground water samples were taken at a depth of some 2.40 m below the soil surface. For this purpose a PVC tube of 5 cm diameter and perforated at the desired depth was installed in a borehole. The water samples were analysed for nitrate, ammonium, Kjeldahl-nitrogen, organic matter (Chemical Oxygen Demand) chloride and pH according to the NEN procedures for drinking water and waste water (Nederlands Normalisatie Instituut, Rijswijk). The redox potential was measured at depths of respectively 60, 100 and 200 cm with a calomel electrode. The readings were corrected to Normal Hydrogen

Electrode readings by adding +245 mV.

Results

The concentrations of nitrate and organic carbon in the soil solution at the various sampling depths in April 1976 are shown in Figure 1.

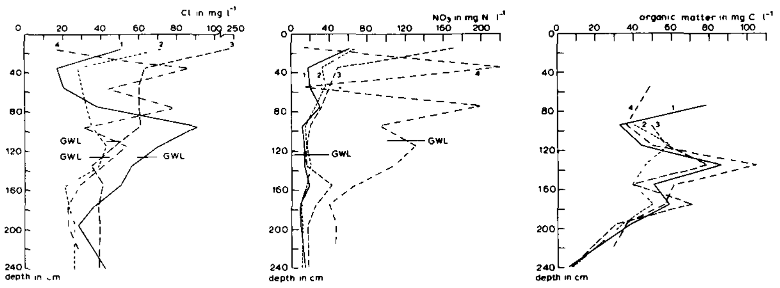

Fig 1. Concentration of nitrate and organic matter (COD) in the soil solution and ground water on April 7, 1976 in sandy soils with yearly applications of 150 kg N as fertiliser (1), 280 kg N as pig manure (2), 560 kg N as pig manure (3) and 400 kg N as poultry manure plus 32 kg N as fertiliser (4); (GWL = ground water level)

The transport of organic carbon is of importance to a depth of roughly 2.5 m. The shape of the curves for the different fields is quite similar and the organic carbon content at the various depths is nearly the same. Taking into account the large differences in nitrogen dressing between the fields 1, 2 and 3 the differences in nitrate concentration below 60 cm depth can be qualified as being small. At an overdose of 280 kg N as pig manure on field 3 as compared with field 2, the nitrate concentration does increase by 8 mg $N.l^{-1}$. Assuming an average yearly precipitation surplus in 1974 and 1975 of 250 mm, only roughly 7% of the nitrogen surplus can be traced in the ground water. The use of poultry manure and the broad bean crop in 1975 has led to a relatively high nitrate concentration (under favourable) soil conditions arable crops of the legume type may fix from the atmosphere as much as 300 kg N ha^{-1} annually (Mulder et al., 1974). The changes of the nitrate concentration in the soil profile of field 4 are closely related to the changes in the chloride concentration which indicates that dilution plays an important role during leaching.

The other nitrogen compounds: ammonium, nitrite and organic nitrogen (Kjeldahl-N minus NH_4-N) only play a minor role in the leaching of nitrogen (see Table 2).

TABLE 2

AVERAGE CONCENTRATION OF NITROGEN COMPOUNDS (mg $N.l^{-1}$) IN THE GROUND WATER OF THE EXPERIMENTAL FIELDS OVER THE PERIOD DECEMBER 1975 TO MAY 1976 (6 SAMPLES) AT 2.40 m BELOW SOIL SURFACE

Field	1	2	3	4
NO_3	12.6	11.7	19.6	43.8
NO_2	0.02	0.01	0.01	0.01
NH_4	0.33	0.31	0.35	0.15
Organic N	0.89	1.29	0.90	1.85

The conditions for denitrification are favourable in the subsoil as organic carbon is present in the soil solution and the redox potential ranges from +250 to +500 mV at a depth of 1 to 2 m (for denitrification the redox potential should be less than +500 mV). The rate with which denitrification will proceed depends on the biodegradability of the leached soil organic matter

LABORATORY EXPERIMENTS

General

A well known technique to study the denitrification process is percolation of a watery solution through a soil column. The column experiments mentioned in the literature show a wide variation in experimental conditions reflecting the purpose of the research. In some experiments the soil organic matter was the only available carbon source, in other experiments glucose or methanol was added as an artificial one. The temperature varied from 20°C to 30°C and the average pore flow rate sometimes amounted to 700 mm per day.

The experiment with soil columns discussed here was set up to study the fate of nitrate in the saturated zone at different feeding rates. The pore flow rates were approximately 25, 70, and 125 mm per day.

The experiment was carried out in plexi-gum tubes (length 66.0 cm, outer diameter 12.0 cm, inner diameter 11.4 cm). The tube was filled for 62.5 cm with a sandy soil with an organic matter content of 0.7%. Prior to filling,the soil was air-dried and passed over a 2 mm sieve. The water content of the soil in the column was 35.8% by volume. Before the start of the experiment the soil in the columns was flushed with CO_2 gas to expel the air after which the soil was quickly saturated with demineralised water. Natural deoxygenated ground water was used as feeding water for the columns. The pH (KCl) of the soil was 4.6. During the experiment the pH of the water in the column ranged between 6.0 and 7.0 due to the higher pH of the influent. The water was enriched with nitrate to the desired level of 25 mg. $N.l^{-1}$. One column was used as control and percolated with ground water without nitrate. The room temperature during the experiment was 20°C. In the columns the redox potential was measured at three depths with a calomel electrode. Nitrate was measured chemically as well as with a specific electrode. The ammonium concentration in the influent was 0.75 mg. $N.l^{-1}$ and for Kjeldahl-nitrogen 2.0 mg. $N.l^{-1}$. The C/N quotient of the influent was approximately 4.

Results

The results of the column experiments can be represented in so-called breakthrough curves, as shown for column 2 (Figure 2). As chloride is not involved in any conversion processes, the difference between the two curves is a measure of the nitrate removal by biochemical and possibly chemical processes. The redox potential, which ranged between +200 and +400 mV, was favourable for denitrification. In the effluent only traces of nitrite could be detected. The results of the analysis of nitrogen compounds in the effluent at the moment V/Vo = 2.5 are shown in Table 3.

TABLE 3

CONCENTRATION OF NITROGEN COMPOUNDS (mg $N.l^{-1}$) IN INFLUENT (Co) AND EFFLUENT (Ce) FOR DIFFERENT TRANSPORT VELOCITIES OF THE SOIL WATER (v*) AT THE MOMENT V/Vo = 2.5

Column	v*	Co	Ce				
		NO_3	NO_3	NO_2	Kjeld. N	NH_4	org. N
1	25	0	0	0.01	2.5	0.9	1.6
2	25	25	12.5	0.03	2.5	1.1	1.4
3	70	25	18.8	0.10	2.8	2.0	0.8
4	125	25	19.3	0.04	2.5	1.3	1.2

The nitrate removal rate can be calculated from the difference between the breakthrough curves for chloride and nitrate. This is done for columns 2, 3 and 4 and the results are used to construct Figure 3, which gives the relation between the average pore flow rate and the nitrate removal rate for a NO_3 concentration in the feeding water of 25 mg $N.l^{-1}$. Lines have been drawn for different values of V/Vo. At higher V/Vo values (the longer the experiment), lower values of α are obtained. The reason for this is that with time the more stable organic matter is left, resulting in a lower nitrate removal rate.

A higher transport velocity of the ground water resulted in a higher removal rate of nitrate from the soil solution. No explanation can be given for this phenomenon. Extrapolation to the average field conditions in the Netherlands, where v* is 3 mm day^{-1}, leads to a value α of 0.6 mg $N.l^{-1}$. To evaluate the importance of denitrification in the field situation one should make corrections for the pH and the temperature. According to Nommik (1956) a decrease in temperature from 20°C to 10°C, which is normal temperature for ground water, will cause a decrease in the denitrification rate by a factor 7.5.

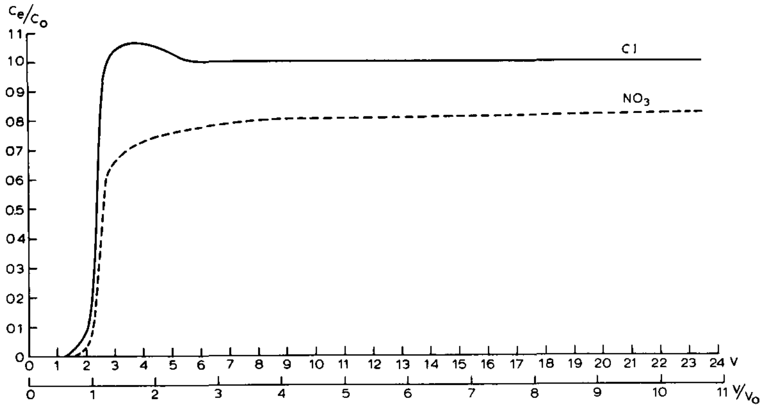

Fig. 2. Breakthrough curves of nitrate-N and Cl^- for column 4. (V, total volume of effluent (cm^3); Vo, total water content of column soil (cm^3); Ce, concentration in effluent (mg l^{-1});Co concentration in feeding water (here 25 mg $N.l^{-1}$ at a pore flow rate of 125 mm/day) .

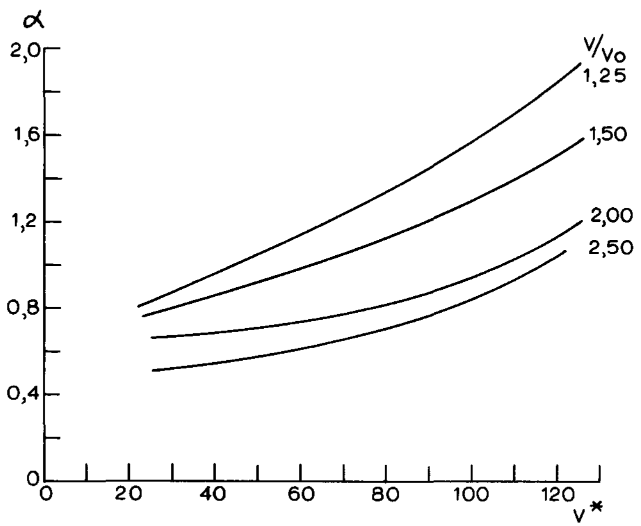

Fig. 3. Relation between pore flow rate v* (mm day^{-1}) and nitrate removal rate (mg $N.l^{-1}$ day^{-1}) at a nitrate concentration of 25 mg $N.l^{-1}$, for different values of V/Vo (see subscript of Fig. 2.)

SUMMARY

In field and laboratory experiments attention has been given to the leaching of nitrate and organic matter and to the possible role of denitrification, especially in the saturated zone.

In four experimental fields with large differences in manure application rate, the differences in nitrate concentration below ground water level were small. Transport of soluble organic matter could be measured to a depth of some 2.5 m and was quite similar for the four fields. This suggested likelihood of denitrification in the subsoil.

In soil columns this denitrification process in the saturated zone was studied. A sandy soil (0.7% organic matter) was percolated at different flow rates with natural ground water enriched with nitrate to the desired level. The longer the experiment was continued, the more stable organic matter was left and the lower the nitrate removal rate. A higher pore flow rate resulted in a higher nitrate removal rate. No explanation can be given for this phenomenon. Extrapolation to the average field conditions in the Netherlands leads to a nitrate removal rate of 0.6 mg. $N.l^{-1}$ day^{-1} under the given experimental conditions ($20^{o}C$; pH: 6.0 - 7.0; 0.7% organic carbon.

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PHOSPHORUS COMPOUNDS IN PIG SLURRY AND THEIR RETENTION IN THE SOIL

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INTRODUCTION

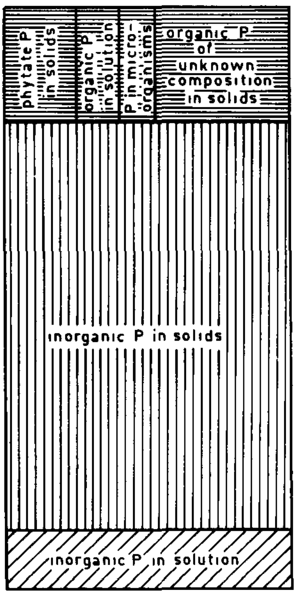
Phosphorus in animal wastes, which in some agricultural areas are applied to the soil in excessive amounts, is a potential pollutant of surface and ground water. With shallow surface waters and an intensive use of both surface and ground water, phosphorus is a highly undesirable pollutant, especially in the Netherlands.

Animal wastes contain both inorganic phosphorus and phosphorus as part of organic molecules. Inorganic phosphorus is usually assumed to be effectively filtered by the soil, though excessive application of solutions of moderate phosphate concentration have been shown to give a rapid movement of inorganic phosphorus in the soil (Goodrich, 1970). The predominance of organic phosphorus in phosphorus movement in the soil has been noted by Hannapel et al. ($1963_{1,2}$) Rolston et al. (1975) and Campbell and Racz (1975).

Phosphates, especially organic phosphates, due to their complex properties may also play an important role in the transport of heavy metals in the soil.

CHEMICAL AND (MICRO)BIOLOGICAL ASPECTS

Data on phosphorus compounds in pig slurry have been given by Gerritse and Zugec (1976). In Figure 1 these data are shown schematically. Pig slurry contains 1 - 2% of its dry weight as P. The bulk of this phosphorus (75 - 85%) is inorganic phosphate. From solubility data this inorganic phosphorus can be said to consist of calciumhydrogenphosphate ($CaHPO_4.2H_2O$) and calciumphosphates of lower solubility (apatites). The rest of the phosphorus in pig slurry is contained in organic molecules. This organic phosphorus is mainly contained in solids. Liquid chromatographic analysis has shown that 20 - 30% of this organic P is phytate phosphorus. 2 - 3% of total P in pig slurry is contained in micro-organisms.



	% of D.M.	average % of total P
total inorganic P	0.7 - 1.7	80
total organic P	0.2 - 0.4	20
inorganic P in solution	0.01- 0.2	10
phytate P	0.05- 0.1	5
P in microorganisma	0.02- 0.04	3
organic P in solution	0.01- 0.03	1.5

Fig. 1 The relative distribution of phosphorus compounds in pig slurry. Total P content of pig slurry lies between 1 - 2% of dry matter weight. Dry matter content of pig slurry is of the order of 5 - 10%.

The solution resulting after 30 minutes centrifugation of pig slurry at 40 000 g and subsequent filtration of the supernatant through a membrane filter of 0.2 µm contains 10 - 20 mg organic P per litre. Inorganic P content of this solution depends on the feed composition and is usually about 10 - 100 mg P per litre, though, at low Ca/P ratio in the feed, can be much higher.

Gel filtration studies have shown the dissolved organic P compounds to be mainly of high molecular weight. Further analysis of the gel filtration fractions indicated that these organic P compounds of high molecular weight are complexes of

DNA with inorganic phosphorus, and various cations (DNA may originate from micro-organisms but also from viruses). Some results are shown in Table 1.

TABLE 1

DISTRIBUTION OF PHOSPHORUS, CALCIUM AND COPPER IN GEL FILTRATION FRACTIONS OF PIG SLURRY SOLUTION.

	Pig slurry solution before fractionation. volume = 1 ml	High molecular weight fraction ($M.W. > 10^5$)	Intermediate molecular weight fraction	Low molecular weight fraction
pH	8.6	6.55	6.7	8.35
total P	390 μg	20 μg	1 μg	350 μg
inorganic P	370 μg	5 μg	0.5 μg	340 μg
organic P	20 μg	15 μg	0.5 μg	10 μg
Ca	15 μg	3 μg	1 μg	10 μg
Cu	1 μg	0.3 μg	0.1 μg	0.6 μg

The gel used was Sephadex G-100 (Pharmacia) with water as eluent.

By adding radioactive phosphorus as $^{32}PO_4$ to pig slurry and measuring the increase of radioactivity in various phosphate fractions obtained after centrifuging, gel filtration and extraction with selective extractants, it is found that in all fractions the specific activity approaches the value calculated for complete distribution of ^{32}P among all phosphates. It thus appears that all phosphorus in pig slurry is mobile and must be part of a microbial cycle. From a simplified model (Figure 2) microbial turnover times for phosphorus in pig slurry were calculated from the rates of incorporation of radioactive phosphorus. Turnover times at a temperature of 20 - 25°C are of the order of 10 - 20 weeks. Similar turnover times are found for aerated and non-aerated pig slurry.

From data in the literature and own analyses (Gerritse and Zugec, 1976) it can be further concluded that the analysis results for phosphorus compounds in pig slurry can be applied to animal wastes in general. When fresh, however, animal wastes may show large differences in organic P content. On storage of these wastes the relative organic P contents tend to approach the same values as in pig slurry, which can thus be taken to be equilibrium values in the microbial phosphorus cycle. This constant microbial cycle also explains the fact that prolonged storage and feed composition hardly affects the contents and distribution of the various phosphorus compounds in pig slurry as well in wastes of other animals.

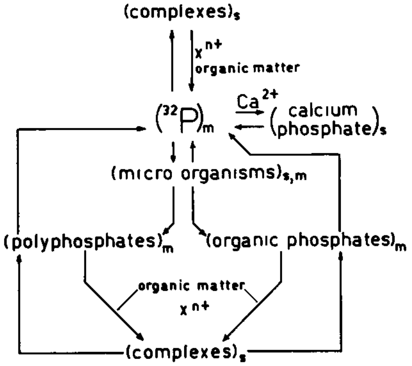


Fig. 2. Model for the phosphorus cycle in pig slurry, according to which labelled phosphorus (^{32}P) is distributed. s = solids, m = in solution.

Phosphatase, an enzyme a.o. produced by micro-organisms, affects the degradation of organic P compounds and thus the cycling of P. The level of phosphatase activity in pig slurry was determined from the decomposition rate of p-nitrophenylphosphat[e]. Results are given in Table 2 together with average values from a number of soils in The Netherlands.

Assuming Michaelis-Menten kinetics to apply the decomposition rate of organic phosphorus is given by:

$$v = \frac{V_{max} \cdot S}{K_m + S} \qquad (1)$$

where: V_{max} = maximum rate of decomposition (µmoles/g.h.)

K_m = reaction constant (μmoles/l)

S = substrate concentration (μmoles/l)

g = grams dry weight

TABLE 2

PHOSPHATASE ACTIVITIES IN PIG SLURRY AND MEASURED AT 30°C.

Matrix	pH of measurement	K_m (μmoles/l)	s.d. (K_m) (%)	r	V_{max} (μmoles/g.h.)	n
pig slurry	5	680	7	0.995	700	8
pig slurry	8	1000	10	0.99	1100	12
soils (0 - 20 cm)	5	140	50	0.90	80	30
soils (20 - 50 cm)	5	175	40	0.91	25	30
soils (50 - 100 cm)	5	140	25	0.96	4	30

Soil samples were taken at various depths

r = the correlation coefficient in the plot of (S_o - S) versus $\ln(S/S_o)$.

n = total number of analyses.

s.d. = standard deviation in K_m.

Integration of Equation 1 gives:

$$V_{max}.t = (S_O - S) - K_m \ln(S/S_O) \qquad (2)$$

where: t = incubation time in hours

S_O = substrate concentration at t = 0

The results in Table 2 were obtained by incubating one hour with substrate concentrations (S_O) in the range of 50 - 500 μmoles/l and applying Equation 2.

If it is supposed that the decomposition rate v is a measure for the turn-over time of phosphorus and that the K's and V_{max}'s in Table 2 are also applicable to organic phosphorus in soil and manure, it can be reasoned that phosphorus turn-over time in the soil is at least of the same order as in pig slurry. However, in the soil sorption may cause an increase of the turn-overtime, which is difficult to estimate. These aspects of the P-cycle in the soil have still to be investigated.

RETENTION IN THE SOIL

The retention of inorganic phosphate in the soil is determined by the adsorption characteristics of the soil. The main factors influencing adsorption in the soil are organic matter, aluminium and iron content, specific surface area of the soil and soil pH. Especially soils low in aluminium and organic matter and with a pH of 4 - 6 have a small adsorption capacity for inorganic phosphorus.

Retention in the soil will decrease strongly when the adsorption capacity of the soil has been reached. In general the inorganic P concentration in the soil solution will then be above 0.2 mg P/litre. For the sandy soils mentioned in Table 5 it was found from short term (24 h) adsorption experiments that the average adsorption capacity was about 10 kg inorganic P/ha per cm depth, so that for every cm soil a total of 8 - 12 tons/ha of slurry with ∼ 8% dry matter can be given before the soil complex is saturated. This saturation however temporary. Apart from uptake of phosphorus by the crop there is a gradual immobilisation of inorganic P due to slow migration of P within the soil structure and phase transitions of minerals (e.g. calciumhydrogenphosphate to apatite). This long term immobilisation is very important but is still difficult to predict (Larsen, 1965).

The organic phosphorus compounds in solution in pig slurry are much less adsorbed by the soil than inorganic phosphate.

TABLE 3

CHARACTERISTICS OF SOILS USED IN THE DETERMINATION OF PHOSPHORUS ADSORPTION FROM PIG SLURRY

No.	Soil type	Organic matter (%)	Fe_2O_3 (%)	pH/KCl	Al (%)	Ca (%)	Mg (%)
1	"Beek" earth	15	2.0	5.4	0.6	0.60	0.018
2	"Beek" earth	14	35.2	5.3	0.8	0.34	0.036
3	peat/clay	59	3.2	4.1	3.2	0.90	0.12
4	peat/clay	45	16.7	5.1	2.3	1.56	0.10

TABLE 4

ADSORPTION OF PHOSPHORUS FROM PIG SLURRY IN SOILS. 5g OF DRY SOIL WERE SHAKEN WITH 10 ml OF A 0.2 μm FILTERED SLURRY SOLUTION FOR 24 HOURS AFTER WHICH TOTAL AND INORGANIC P WERE DETERMINED IN THE SUPERNATANT

Soil no.	C_o^{in}	C_o^{org}	C_m^{in}	C_m^{org}	C_s^{in}	C_s^{org}	K^{in}	K^{org}
	(μmoles/ml)				(μmoles/g)		(ml/g)	
1	1.0	0.45	0.03	0.3	2.0	0.3	67	1
2	1.0	0.45	0.05	0.03	1.9	0.3	38	1
3	0.8	0.45	0.001	0.15	1.6	0.6	1600	4
4	0.85	0.4	0.001	0.2	1.7	0.4	1700	2

C_o = initial concentration of phosphorus (as P) in the slurry solution.

C_m = concentration of P after 24 hours equilibration with soil in the soil solution.

C_s = amount of P adsorbed to the soil.

K = distribution constant = $C_s/.C_m$.

The indexes in. and org. refer to inorganic and organic P, respectively.

TABLE 5

CHARACTERISTICS OF SOIL PROFILES IN WHICH TOTAL AND ORGANIC P WERE DETERMINED

Soil	Depth (cm)	pH-KCl	Sand	Humus	Fe_2O_3	Al_2O_3	P_{total}	$P_{organic}$
			%				µg/g	
Black "beek" earth soil	5 - 14	4.6	85	5.1	1.27	0.53	550	280
	14 - 30	4.6	87	3.4	2.65	0.71	330	190
	30 - 55	4.7	93	0.5	0.46	0.31	40	20
	55 - 85	4.7	95	0.1	0.39	0.32	45	10
	85 - 100	-	-	-	-	-	50	10
"Veld" podzol soil	5 - 17	4.9	88	4.7	0.32	0.70	510	170
	17 - 27	4.5	95	1.4	0.24	0.59	80	35
	27 - 40	4.6	94	0.6	0.32	0.52	50	30
	40 - 75	4.6	95	0.4	0.29	0.56	40	20
	75 - 85	4.6	96	0.3	0.38	0.60	50	10
	85 - 110	4.6	93	-	0.35	0.65	50	10
Black "enk" earth soil on moderpodzol	0 - 22	3.8	86	5.5	0.45	0.32	690	330
	22 - 52	3.9	86	5.6	0.57	0.36	460	240
	52 - 64	3.8	88	3.7	0.61	0.34	380	210
	64 - 77	4.6	92	1.3	0.51	0.05	290	170
	77 - 91	4.5	92	1.2	0.44	1.23	190	60
	91 - 108	4.8	94	0.5	0.35	0.94	120	20
Reclaimed "haar" podzol soil	5 - 19	4.2	90	5.3	0.22	0.59	550	220
	19 - 28	4.1	90	5.2	0.08	0.03	110	90
	28 - 41	4.2	92.5	3.2	0.22	0.76	70	50
	41 - 50	4.5	95.5	1.3	0.28	0.71	50	30
	50 - 60	4.6	96.5	0.8	0.29	0.61	40	20
	60 - 75	4.6	97	0.5	0.32	0.59	50	20
	75 - 100	4.7	97	0.3	0.31	0.53	50	0
	100 - 120	4.7	95.7	0.3	0.38	0.72	70	10

Results of some static adsorption experiments with four soils differing in organic matter, aluminium and iron content, are given in Table 4. Characteristics of the soils are given in Table 3. It can thus be expected that dissolved organic phosphorus in pig slurry will be transported rapidly through the soil. To be able to forecast the transport of total organic phosphorus to deeper layers in the soil it is however, necessary to know the interaction with the microbiological phosphorus cycle, especially since even down to a depth of 70 cm in soils in The Netherlands 50 - 80% of the phosphorus is present in organic compounds. Results of phosphorus analyses in a number of soils are given in Table 5. Organic P is found from the difference between total P, determined after destruction, and inorganic P, determined after extraction with a solution of $TiCl_4$ in concentrated HCl (Tinsley and Özsavasci, 1975; Gerritse and Zugec, 1976).

To be able to evaluate inorganic and organic phosphorus movement in the soil properly, columns of undisturbed soil of 80 cm length have been set up under unsaturated flow conditions and treated with the equivalent of 800 m^3/ha of pig slurry (7% DM). Phosphorus, chloride and phosphatase activity are monitored in the column effluent, resulting from a simulated rainfall of about 1 cm per day. From the preliminary results it already follows that there are organic phosphorus compounds which move almost as fast as chloride. Chloride breakthrough in the column effluents occurred after one month and organic phosphorus broke through less than a week later, and reached concentrations of 1 - 2 mg P/litre. The organic phosphorus compounds in the effluent were mainly (70 - 80%) of high molecular weight, as has also been found for organic P in solution in pig slurry. Inorganic P in the effluent up to now has not significantly increased and is of the order of 0.01 - 0.1 mg P/litre. After about 1 - 2 years the soil profile will be analysed for inorganic and organic phosphorus and phosphatase activity. On the basis of various parameters a computer model of phosphate transport in the column will be made and the results of simulation compared with practice.

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DISCUSSION

J.H. Voorburg *(The Netherlands)*

We now have half an hour for discussion on the three papers we have just had.

R. de Borger *(Belgium)*

I completely agree with Dr. Cottenie when he expresses a warning against the danger of zinc. From our analysis of soil plants and especially of water, we came to the conclusion that zinc is an element that is cycling in nature in relatively high concentrations, especially in soluble forms. So when we apply large quantities of manures we are adding more zinc to the cycle and the danger is increased.

J.H. Voorburg

You think the accumulative effects of copper and zinc should be added then?

R. de Borger

Yes.

J.H. Voorburg

Has anybody else had experience with zinc in agriculture? Dr. Bonciarelli?

F. Bonciarelli *(Italy)*

No, but would someone mind telling me where zinc comes from in farmyard slurries?

J.H. Voorburg

It is in the concentrates.

F. Bonciarelli

So it is the manufactureres of concentrates for feeding animals who put zinc in. I wonder if the levels are excessive. Maybe we can suggest to the manufacturers that they limit the amount of salts, of mineral incorporation, in their products.

Perhaps they add more micro-elements than are necessary.

L.C.N. de la Lande Cremer *(The Netherlands)*

We are studying this in a working group in the Netherlands. There is a relationship between the feed taken up by livestock and the production of minerals in the faeces and urine. In the concentrates you have the minerals from the original product and also additives. Most companies making concentrates exaggerate the quantities of additives of minerals; it can be copper, phosphorus or zinc. It is known that there is a direct relationship between the copper content and the growth and health of pigs. Zinc is added to neutralise the effects of copper and this brings me to a question I would like to put to Dr. Cottenie.

Your zinc level in Belgium is much higher in relation to the copper level than in the Netherlands. What is the explanation? According to what you said you can give a certain quantity of minerals in the feed, in the concentrates, but the factories have to reduce these quantities to meet the needs of the cattle. We have found in our conditions in the Netherlands that there are some very high excesses in the additives. You can reckon that about 95 - 99% of heavy metals - copper, zinc and so on, will be rejected in the faeces. We are not so worried about zinc as copper; before problems arise with zinc you will already have had problems with the copper content of the soil.

I would like to comment on the drop in pH which you mentioned, Dr. Cottenie. It is already known from several experiments that there is a pH increase when manures are first applied but it drops again to a normal level after several weeks or months. It can easily be calculated by Sluijsman's formulae.

A. Cottenie *(Belgium)*

First of all, with regard to zinc, I have only one explanation - it is cheap! It is not expensive to add a lot of zinc, it is much cheaper than copper compounds, so the manufacturers don't need to be so exact when using it.

J.H. Voorburg

Is it also cheaper than the concentrates?

L.C.N. de la Lande Cremer

I don't believe that zinc is so cheap.

A. Cottenie

Yes, it is much cheaper than copper.

L.C.N. de la Lande Cremer

We discussed the zinc additives in concentrates with a representative of the concentrate plants in the Netherlands; he told us it is an expensive additive.

W.R. Kelly *(Ireland)*

I would like to make a comment on the zinc situation. It is very interesting. Zinc is added to pig feed not only as an additive but also as a prophylactic against disease. The levels added are variable. However, what interests me is the cycling situation. I am not a soil chemist; I am a veterinarian with an interest in toxicology. Dr. Cottenie mentioned that the phytotoxic levels of zinc were somewhere between 1 000 and 1 500 ppm, I believe. Now, does this phytotoxicity arise as a result of surface pollution of the zinc or as a result of uptake of zinc from the soil?

A. Cottenie

Uptake, without any doubt.

W.R. Kelly

Yes, well I think what is essential here is to study the zinc cycle more closely as between the pig, the slurry, the soil and the herbage. As yet there is no clear indication as to the level at which zinc becomes toxic to animals. I consider this a highly relevant question in this whole situation. As a matter of fact, I have sent a project for consideration by the Environmental Committee of the EEC on this very question - to study the effect of zinc toxicity on animals with particular reference to cattle. There are some reports in the literature to indicate that zinc can be toxic at a level of about 80 ppm in the diet, but there are many other publications which refute that, and which show that zinc at quite high levels is not toxic to animals. So this is an area that needs to be cleared up.

A. Dam Kofoed *(Denmark)*

Dr. Cottenie, you said that you had an average of 330 ppm of zinc in the samples from farmyard manure in cattle. In Denmark we have had samples ranging from 100 - 800 ppm in farmyard manure. Following on from this, in nature you find zinc and cadmium going very closely together. Therefore, when we talk about zinc it is important to consider cadmium also. In our experiments in Denmark we have found that the natural uptake of cadmium is very, very low. We are concerned about introducing cadmium into the food cycle, therefore, if it is not necessary, as you say, it is quite clear that we should avoid the zinc concentrate.

In Denmark we have found that the copper level in manures varies; in slurry it is about 250 ppm.

Now I would just like to ask Dr. Steenvoorden how dangerous he considers nitrates to be in drainage water. I know it is a tricky question but in Denmark 90 - 95% of the ground water is totally free from nitrogen. We know the arguments about nitrate and drinking water - it is 10 or 15 ppm and so on, but what is the situation really? Probably we need another forum to discuss this.

Then, Dr. Gerritse, when you talk about 'P' is it P or P_2O_5?

R.G. Gerritse *(The Netherlands)*

That is P.

A. Dam Kofoed

Thank you. Could we recommend, once again, from this audience that we use P and K when we mean P and K and not P_2O_5 and K_2O?

J.H. Voorburg

Thank you. First, are there any more comments on zinc?

H. van Dijk *(The Netherlands)*

I would like to make one additional remark to what Dr. Dam Kofoed has already said. When zinc becomes a real danger to the plants I would expect that there would be signs of manganese deficiency because zinc interferes with the manganese uptake. When you have too much zinc, as we have along the Rhine for example, you find a manganese deficiency.

A. Cottenie

I would expect that to happen when the ranges of zinc are five to ten times higher.

Now, coming back just for a moment to what Dr. de la Lande Cremer said, that copper is more of a danger than zinc, it is on another level. The copper concentrations in soils, soil water and plants are on a completely different level from zinc. Zinc is easily ten times higher. With regard to toxicity of zinc, this has happened in certain circumstances but not due to the application of manures but rather due to fall-out in industrial dusts. In that case we find on the plants not 1 500 but 15 000 ppm.

J. van den Burg *(The Netherlands)*

Recently we have studied the problem of zinc toxicity in forestry and therefore I have studied the literature. I am worried about the phytotoxic level of 1 000 - 1 500 ppm when from the literature it would appear that at something like 200 ppm there is at least a decrease in growth. So I think the level of 1 000 - 1 500 is somewhat too optimistic.

A. Cottenie

Yes, but I am referring to ryegrass. It is lower for other crops. The specificity of the crop varies but with rye-grass the level can be 800 - 1 000 before there is a decrease in growth. Other crops are much more sensitive; the normal content is 50 - 60 - 70 ppm.

J. van den Burg

That is also typical for forestry. Some trees, like poplar, will take up zinc in amounts of say, 1 000, 2 000 or 2 500 ppm. There are other trees growing on the same soil that have a normal content of 30 or 40 ppm. So zinc accumulation between different crops may be very important, not only for toxic level but also for their normal rate of uptake.

Now I have a short question for you Dr. Cottenie. In your paper you give an NPK ratio of 2 : 1 : 2. Is it NPK or N : P_2O_5 : K_2O?

A. Cottenie

If it says NPK, it is NPK. When we speak about fertilisers we still use K_2O and P_2O_5 because these terms are used in the fertiliser trade.

J.H.A.M. Steenvoorden *(The Netherlands)*

I strongly support Dr. Dam Kofoed's suggestion regarding terminology. Often the word 'phosphate' is mentioned and you have to work out whether what is meant is P or P_2O_5.

A. Cottenie

I agree, but we must not forget that in the most recent papers from the EEC concerning fertilisers, the terms P_2O_5 and K_2O are still used.

J.H. Voorburg

I still have a note of two questions remaining unanswered. First, Dr. Cottenie, will you comment on the question from Dr. de la Lande Cremer about pH?

A. Cottenie

Yes. What I have given here is a very small part of what is available, of course. However, there is one remark, the pH shock is a shock which lasts for the whole growth period in light or medium soils. So the whole effect is there, even though the pH drops down again to more or less original values it remains during crop growth and strongly influences the mobility of different elements. That is during this period of two months.

J.H. Voorburg

There is also the question from Dr. Dam Kofoed to Dr. Steenvoorden about the nitrate.

J.H.A.M. Steenvoorden

First of all I think it will depend on the type of soil. In peat soils we never find nitrate in the ground water. In sandy soils presence of nitrate depends on the type of crop. In grassland it will be much lower than on arable land. I made a survey of drainage water in part of our country and only about 10% of the samples contained nitrate. However, in the drinking water stations there is sometimes a constant increase of nitrate and then it is very difficult to trace the source. That is why we started an investigation on the shallow drainage water on grassland and on sandy soils. We used a number of farms with differences in cattle intensity and nitrogen fertilisation to discover the relationship, if any, between cattle density and manures, fertilising and nitrate in the drainage waters below grassland. The only data available indicated that the leaching on grassland is very small but these are all from farms with normal cattle intensities like two cows/ha.

F. Bonciarelli *(Italy)*

I would like to return to the question of zinc and copper. In my opinion the important thing is not to establish the maximum toxicity level of concentrate feeds for animal health but rather to establish the minimum zinc and copper levels. We can then recommend a maximum level to the authorities concerned which the manufacturers of concentrates must not exceed in adding zinc and copper. I would like to know from the veterinarians the quantities of zinc and copper strictly necessary to ensure the health of animals, so that we can make these recommendations. This is much better than limiting the quantity of slurry which may be spread on the fields.

J.H. Voorburg

I don't know who would like to comment on this, perhaps Dr. Kelly? As far as I know there is a regulation within the

European Community. I think it is forbidden to add more than 200 ppm of copper to the concentrates.

W.R. Kelly

I believe that is to be reduced to 125 ppm which appears to be adequate. It is dangerous to extrapolate what little we know about copper metabolism, its build-up in the environment and its potential toxicity to zinc, because we know much less about the zinc situation. There is no doubt that pigs would remain healthy with much lower levels of copper in the diet; their greatest requirement for copper and also iron is in the early stages of their growth when they are subject to anaemia. Even at that time their absolute requirements are quite small to maintain normal health. However, in this day and age the name of the game as far as producers are concerned is maximising productivity. To a certain extent we have to accept that this is a valid requirement but it doesn't absolve us from the responsibility of investigating further and acquiring more information so that we can say, on the basis of scientific evidence, what is correct and proper to do. I am afraid it is impossible to answer this rather general question in a satisfactory way.

J.H. Voorburg

Thank you. If everyone is in agreement we will close the discussion on zinc.

H. Laudelout *(Belgium)*

May I ask Dr. Steenvoorden if I understood correctly what he said, that leaching efficiency of nitrates decreases when the flow velocity increases?

J.H.A.M. Steenvoorden

As far as I understand the question I think Professor Laudelout didn't understand the text. Do you mean it should decrease? At high rates it does increase.

<u>H. Laudelout</u>

But there is more nitrate removed per unit of flow when you had higher flow velocity. It is not quite clear.

<u>J.H.A.M. Steenvoorden</u>

It is not quite clear, I agree.

<u>H. Laudelout</u>

Normally, from the experience that is available, the higher the flow velocity, the higher the hydrodynamic dispersion, so the lower the leaching efficiency and consequently, the lower the amount of nitrate removed. This is the general universal observation and I was not quite clear whether your observations were in agreement with that.

<u>J.H.A.M. Steenvoorden</u>

With regard to hydrodynamic dispersion, in Figure 3 I have worked it out; it is already calculated in the results. I have calculated the breakthrough curves from Figure 2 by subtracting the nitrate curve from the chloride curve. So hydrodynamic dispersion is already in the result. There is a problem remaining but I do not think it is in hydrodynamic dispersion.

<u>H. Laudelout</u>

I will put it another way; the more mixing you have between the displacing and displaced solutions, the less efficient the removal is. The more mixing you have, the higher the hydrodynamic dispersion and consequently, the higher the flow velocity must be. Does this agree with your results?

<u>J.H.A.M. Steenvoorden</u>

It doesn't agree.

<u>R.G. Gerritse</u>

I would like to disagree. Under normal conditions in the soil the hydrodynamic dispersion decreases with increasing flow velocity, in the diffusion rate of the soil. This is according to my experience which is, perhaps, limited.

A. Dam Kofoed

It was very interesting to hear from Gerritse about the virus that was found in the USA at 6.5 m. According to my knowledge of the present biology there is only one example in the literature from the USA. I think it was reported from New York that virus would be found at a depth of 1 m. We have done a little experimentation at our Station but we have found no virus. My question is, is this a field experiment, or what type of experiment is it?

R.G. Gerritse

This is not a field experiment. In your experiment you did not detect viruses but did you detect organic phosphorus? I suppose that what I found as organic phosphorus was probably also virus material or, in fact, intact viruses. This is supported by an article I have found which I haven't read yet because I only came across it recently.

H. Tunney *(Ireland)*

I have a number of questions for Dr. Gerritse. First of all, some of the figures you presented in your slides are not in the paper and I wonder whether copies could be made available. Can they be included in the publication?

R.G. Gerritse

These results will be published in various journals within a year or so but I will try to have them ready for publication in the Proceedings.

H. Tunney

Thank you. Now, two questions. First of all, with regard to the soluble organic phosphorus, does the plant absorb this phosphorus?

R.G. Gerritse

I am not a plant physiologist and I have not done any research on this. Perhaps it would be something for a physiologist to investigate.

H. van Dijk

I think a molecular weight over one million would be too high.

R.G. Gerritse

There is a range of molecular weight in compounds containing phosphorus and I know various ions are taken up by the plant in the form of a complex within an organic molecule. This is also the mechanism for a plant to take up various metals which it needs for growth but in my work I have no interest in investigating this.

H. Tunney

One other point: we have noticed in our work that pig slurry gives a very big increase in phosphorus in soil tests. We extract with Morgan's Acid Extract for soil phosphorus testing. Do you use this type of method?

R.G. Gerritse

I just look at the natural situation as nearly as possible. However, as I said, in the case of inorganic phosphorus there is long term absorption and if you use Morgan's Extract within a month or two of application of slurry you find a very high availability of phosphorus. In time, with long term absorption, there will be a strong decrease of available phosphorus.

H. Tunney

We have noticed this in sampling land that has been receiving pig slurry; it has a very high extractable P level in comparison with land receiving equivalent amounts of inorganic fertiliser phosphate.

R.G. Gerritse

This is very complex. Dr. de Haan knows more about the effects of long term absorption and the various factors involved.

J.H. Voorburg

It is very difficult for me to stop the discussion because it is so interesting but it is my task as Chairman to close the session on time.

HEAVY APPLICATION OF LIQUID MANURE ON SOIL: EFFECT ON SOIL SALINITY

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INTRODUCTION

Farmyard manure preparation is increasingly being abandoned in modern animal husbandry in industrialised countries. New methods of breeding and rearing livestock without bedding have been studied in order to save manpower. Fluid, not classic manure is produced by these methods and we shall call this material "liquid manure" or "slurry".

Because depuration plants are very expensive, both in initial capital costs and running costs, and their functioning is not completely satisfactory, the most interesting method of using liquid manure is as fertiliser thus exploiting the ability of the soil to recycle the nutrients contained in it.

Nevertheless, in big livestock farms the number of animals and the area of agricultural land tends to be disproportionate and, as a consequence, great quantities of liquid manure are repeatedly applied to the soil. These high rates of slurry could result in potential damage to the soil fertility by:

a) Reduction of crop yield due to excess of nutrients,

b) Pollution of underground water due to leaching of nitrates, nitrites, salts, micro-organisms, etc.

c) Pollution of surface water due to run-off of organic matter, salts, chemicals, etc.

d) Damage to soil properties (pH, structure, salinity, etc.)

At present our knowledge on these matters is insufficient. However, the limited literature that there is would seem to indicate that even enormous quantities of liquid manure do not damage soil properties. Despite this, scientists are all agreed that prolonged experiments are needed to study this subject in more detail.

Several authors (Manges et al., 1971; Wallingford et al., 1974; Mathers et al., 1971) have pointed out that salinity and alkali hazards can be a consequence of heavy and repeated applications of liquid manure. In fact, this material contains remarkable amounts of cations (K, Ca, Mg, NH_4 and, especially harmful, Na) and anions (mainly Cl). Not very much is known about the behaviour of soil salinity along the soil profile nor about the risks of salt pollution of underground water.

The aim of the present research was to investigate the effect of repeated application of different rates of liquid manure on soil salinity. The first year results are the subject of the present paper.

MATERIALS AND METHODS

Experimental trial

In May 1975, a field experiment was started in which duplicated plots received different doses of liquid manure (0 - 200 - 400 and 600 m^3/ha) in two applications (on 2nd and 21st May). Soil samples were collected at varying intervals after application on 28th June, 2nd August and 10th October.

Subsequently, plots received 0 - 75 - 150 and 225 m^3/ha of liquid manure every 3 - 4 months, approximately. So, liquid manure was applied on 27th October, 24th February and 13th May 1976. Samples of soil were collected some time after each application.

Soil was sampled at three depths: 0 - 20, 20 - 40 and 40 - 60 cm. Its salinity was measured on saturated paste extract by using an EC Measuring Set MC1 Mark V, manufactured by Electronic Switchgear.

Rainfall and evaporation (Piche) during the period May 1975 - May 1976 are shown in Figure 1. Soil characteristics are indicated in Table 1.

TABLE 1

SOIL CHARACTERISTICS

pH	8.20
$CaCO_3$	11.60%
Organic matter	1.53%
Available P_2O_5 (meth. Olsen)	22 ppm
Available K_2O (meth. Dirk-Shaffer)	2.03 mg/100 g soil
Coarse sand	1.0%
Fine sand	18.5%
Silt	38.5%
Clay	42.0%
Field capacity (Ψ = -0.3 bar)	
Wilting point (Ψ = -15 bar)	

Liquid manure always came from a nearby livestock farm of dairy cattle where animals were on loose housing with a slatted floor. Liquid manure characteristics are reported in Table 2.

TABLE 2

MANURE COMPOSITION (kg/m^3)

	Samplings				
	2nd May 1975	21st May 1975	27th Oct. 1975	10th Feb. 1976	13th May 1976
Total solids	38.3	43.0	23.8	31.3	47.0
Organic content	28.5	30.7	12.9	22.3	34.4
K_2O	2.68	4.05	5.85	2.93	3.57
P_2O_5	0.63	0.72	0.21	0.66	0.99
Total nitrogen	2.15	3.00	3.73	2.06	3.01
Ammonium N	1.40	2.14	3.15	1.49	2.08
NH_4- N on total N (%)	65	71	84	72	69

The average salinity (EC in mmhos/cm at 25°C) of the different plot soils at the various dates is shown in Table 3 and in Figure 1.

Moreover, in the autumn of 1975 and the spring of 1976, all plots were cross-sown with different crops in order to observe whether seed germination was adversely affected by the preceding liquid manure applications. In autumn the crops sown were wheat, rape, broad beans, crimson clover; in spring, maize, sugar beet, sunflower, lucerne. Some days after the observations on emergence, all plots were tilled and cleared of vegetation.

Farm investigation

On a farm near Gubbio ("Fassia" farm), high quantities of pig and cattle liquid manure have been disposed of on a limited cropland area since 1970, i.e. for six years.

An average number of 550 calves are housed on slatted floors, so that liquid and solid excreta fall into an underground reservoir. About 1000 pigs are housed in closed buildings the floors of which are hosed clean every day.

The total live weight of animals is about 215 tons. No solid manure is prepared, but all the excreta plus the washing water from the pig houses is collected in two large lagoons.

The total amount of slurry produced can be estimated as about 40 m^3 per day. This slurry is pumped from the lagoon to fields and disposed of on 40 hectares which are continuously cropped with maize for silage.

As a result, each hectare receives an average of 365 m^3 of slurry per year.

The soil is on a gentle slope, very rich in clay, poorly drained, low in organic matter and in bad structural condition Its infiltration rate and hydraulic conductivity are extremely low.

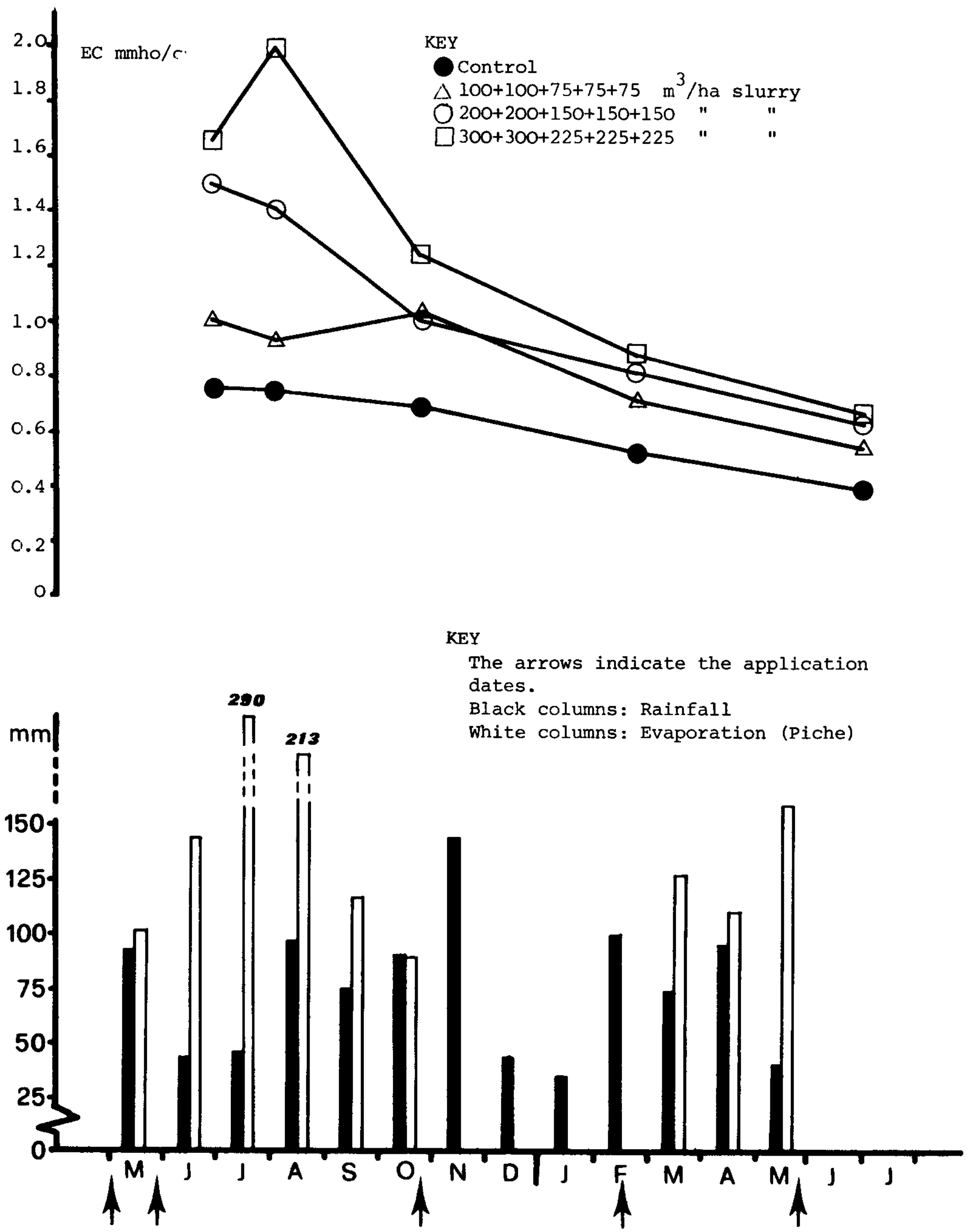

Fig.1. Electric conductivity of saturated paste extract of soil in which different rates of slurry had been disposed of.

TABLE 3

EC OF SATURATED PASTE EXTRACT OF SOIL AT DIFFERENT DEPTHS AFTER APPLICATION OF DIFFERENT RATES OF LIQUID MANURE

Liquid manure m^3/ha	Sampling dates and depths (cm)														
	28.6.1975			2.8.1975			25.10.1975			24.2.1976			1.7.1976		
	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
0	0.74	0.77	0.78	0.76	0.73	0.74	0.66	0.72	0.68	0.47	0.58	0.51	0.35	0.37	0.40
75	1.25	1.11	0.86	1.08	1.01	0.73	1.16	1.23	1.07	0.72	0.68	0.72	0.52	0.52	0.51
150	2.04	1.43	1.07	1.70	1.50	1.02	1.08	1.04	1.22	0.75	0.76	0.91	0.55	0.61	0.69
225	2.50	1.46	1.02	2.35	2.07	1.66	1.39	1.32	1.01	0.77	0.81	1.01	0.60	0.67	0.70
Depth averages	1.63	1.19	0.93	1.47	1.33	1.04	1.07	1.08	1.00	0.68	0.71	0.80	0.51	0.54	0.58
Significance															
Doses Lin.comp.		**			*			*			**			*	
Depths Lin.comp.		**			**			n.s.			**			**	
Doses x Depths		**			**			n.s.			n.s.			n.s.	

Soil has been sampled at different depths and its salinity has been measured. Table 4 shows the results in comparison with the soil of a nearby field where liquid manure has never been disposed of.

Because there were some wet patches caused by a high water-table in some fields, samples of the saturating surface and sub-surface water were taken and their salinity (EC) and NO_3-N content were measured. Table 5 shows the results.

TABLE 4

FASSIA FARM - EC OF SATURATED-PASTE EXTRACTS OF SOIL (mmho/cm at 25°C)

Depth (cm)	Samples					
	Controls					
	I	II	1	2	3	4
0 - 30	0.87	0.54	0.47	0.70	2.25	1.40
30 - 60	0.52	0.37	0.40	0.45	0.91	0.56
60 - 90	0.47	0.58	0.38	0.48	0.76	*

* This sample could not be taken.

TABLE 5

FASSIA FARM - CHARACTERISTICS OF WATER OF DIFFERENT WATER-TABLE OUTCROPS

No of sample	EC mmho/cm	NO_3 - N ppm
1	1.07	28
2	2.80	6
3	0.65	2
4*	2.75	6
5	0.89	6

* Water-table at 60 cm of depth.

DISCUSSION

Field experiment

The liquid manure application had a consistent effect on EC of the soil, but the salinity never reached dangerous levels.

The highest EC was generally found in the upper 20 cm soil layer; lower amounts of salts were present in the deeper 20 - 40 and 40 - 60 cm layers. In the autumn-spring period the differences between the salinity of different layers diminishes (Table 3).

The maximum rise in soil salinity was found one month after the first heavy applications, up to 600 m^3/ha. Afterwards EC decreased, perhaps as a consequence of leaching.

Salt accumulation seems not to be a hazard not even after a total application of more than 1200 m^3/ha in a year.

Salts proved to move slowly through the soil profile according to the seasonal water fluxes which depend on evaporation and rainfall. Only in the first samplings (June and July 1975) did EC values rise up to 2 mmho/cm.

Autumn sown wheat, rape, crimson clover and broad beans emerged regularly in all the plots, as did sugar beet, maize, sunflower and lucerne in the spring sowing.

Farm investigation

The data in Table 4 indicate that the salinity hazard does not exist in a clay soil where since 1970 about 400 m^3/ha of liquid manure per year have been disposed of. Only in samples 3 and 4 is soil salinity higher than the average, but problem levels have not been reached or approached.

Salts appear to be located mainly in the upper 30 cm soil layer. A somewhat high salinity (6.5 mmho/cm) was found only on a sample of the surface soil just near a water-table outcrop where salt effluorescence was evident.

Only two samples (Table 5) of surface and sub-surface water-tables had a rather high EC (about 2.8 mmho/cm). Only one sample had an appreciable, but harmless, nitrate content.

This fact suggests that ammonium evaporation and/or denitrification play an important role in harmlessly eliminating the nitrogen excess.

Maize does germinate and grow well in this soil. The only limiting factor seems to be the bad soil structure; soil is poorly aggregated and appears very hard when dry,and sticky when moist. It is impossible to say whether the bad soil structure is due to its low content of organic matter or to and excess of harmful cations.

CONCLUSIONS

No problem level of salinity was found in experimental plots which had received up to a total amount of 1275 m^3/ha of liquid manure in a year, nor in farm fields where for six years about 365 m^3 slurry per hectare have been disposed of annually. Crops germinated and grew regularly both in experimental plots and in fields.

ACKNOWLEDGEMENTS

The author wishes to thank Dr. P.L. Guisquiani, assistant at the Agricultural Chemistry Institute of the Perugia University for his valuable help on the chemical analysis of slurry.

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ASPECTS OF Cu ACCUMULATION IN SOIL FOLLOWING HOG MANURE APPLICATION; SOME PRELIMINARY RESULTS OF STUDIES ON THE MOBILITY OF Cu

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INTRODUCTION

Copper has been recognised as one of the micro-nutrient elements essential for plant growth for about fifty years. As a consequence, its action in soil in relation to means and methods of meeting plant requirements has received considerable attention.

Toxicity of copper to plant growth has also been a point of major concern, especially in those areas where high copper levels are found, e.g. due to mining activities or to repeated applications of fungicides and fertilisers containing inorganic Cu compounds.

Mobility of Cu in soil is usually reported as low, predominantly as the result of a strong bonding on soil organic matter compounds.

Other sources of possible contamination of soil with excess amounts of copper are sewage sludge, municipal compost and relatively recently, hog manure. The latter contains Cu which is added as copper sulphate to the rations for porkers in order to decrease the feed conversion. This copper is almost quantitatively (more than 97%) excreted by the animals. Particularly in those areas where intensive pig feeding practices lead to an excess of organic manure, this source of Cu contamination deserves special attention, the more so as the concurrent presence of organic compounds from the manure may influence the mobility of this copper in the soil system.

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This contribution describes some preliminary results of experiments directed towards the measurement of such effects.

SCOPE OF THE PROBLEM FOR THE NETHERLANDS

The figures mentioned here are provided to outline the problem of Cu excess resulting from manure in general terms under Dutch conditions.

The combined burden on the environment of Cu originating from livestock waste is estimated at 875 metric t Cu on an annual basis. The majority of this amount (about 765 metric t) results from pig feeding (Anon, 1975). This production is not equally distributed over the total surface area of the country but a number of specific regions occur where this type of intensive agriculture has developed in the last decades. The main provinces of Cu production via hog manure can be listed as Noord-Brabant with about 220 metric t per year, Gelderland with 205, Overijssel with 115 and Limburg with 100 metric t of Cu.

Cu is added to swine feed at levels of roughly 225 ppm. This amount, combined with the Cu already present, results in average Cu contents of 250 ppm. The Cu content of swine manure amounts to roughly 80 ppm Cu for slurry with 8% dry matter and 180 ppm Cu for solid manure with 23% dry matter. Thus a moderate application of slurry, e.g. in the order of magnitude of 20 metric t/ha/year implies the addition of about 1 600 g Cu.

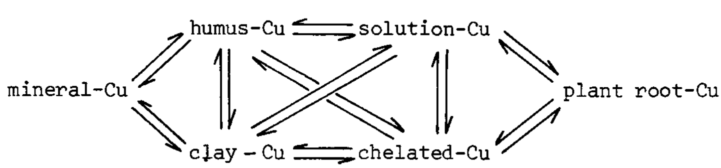
The removal of Cu from soil on an annual basis may be estimated at 30 g/ha for pasture and 80 g/ha for arable land. This leads to a total removal of roughly 100 metric t Cu/year for the entire country. The total annual application of Cu to soil as a fertiliser amounts to about 200 metric t. This figure exceeds the above removal value because of the occurrence of a number of Cu deficient soils, which require more Cu than is removed by the crops in order to establish an acceptable Cu nutrition level.

Estimates performed by Henkens (1976) indicate that an adjustment of the Cu level of Dutch soils in order to meet plant requirements for a period of about six to seven years would require a single Cu addition of 1 500 metric t. This is in fair agreement with the value of about 200 t for continuous (annual) adjustment.

The problem of the total Cu excess of roughly 670 metric t on an annual basis for the entire country is strongly augmented by the fact that the hog manure is not primarily used to adjust the Cu level of the soil, and that the production of about 80% of this Cu is established in several very confined areas, thus giving rise to considerable local additions of Cu to the soil.

CHEMISTRY OF Cu IN RELATION TO ITS MOBILITY IN SOIL

Copper may constitute part of the following main components known to occur in a soil system: the soil mineral fraction, the soil organic fraction, in adsorbed state on the ion exchange complex (clay and organic matter), in the soil solution either as free ion or in chelated form, and in plant roots. The complexity of the inter-relationships between these various states of occurrence may be presented in the following scheme, taken from Baker (1974):



The states which are of major interest from an environmental consideration are the soil solution and plant material, in regard to water and food quality, respectively.

The main reactions to which copper may be subjected after addition to the soil are:

a) Adsorptive bonding on the ion exchange complex of clay minerals and organic matter; this bonding is of a reversible type, but particularly at low Cu concentration ranges very strong preferential adsorption may be found due to specific bonding on certain sites.

b) Fixation on Al atoms at the edges of clay platelets; this bonding mechanism is presumably of the chemisorption type.

c) Fixation on organic matter compounds following the formation of organic matter-copper complexes.

d) Precipitation as low soluble copper salts e.g. phosphates.

The relationship between the concentration (or preferably the activity) of copper in solution and the amount in these different solid states as a function of the main parameters governing such distribution may be described by the use of equilibrium equations as derived from thermodynamic considerations. In a comparable manner the distribution of total copper over different chemical forms can be calculated. This is demonstrated by the following set of equations pertaining to the equilibrium between Cu^{2+} and Cu^{+}:

		log K^o	
$Cu^{2+} + e^-$	$\rightleftarrows Cu^+$	2.68	(1)
$\frac{1}{2}H_2O$	$\rightleftarrows e^- + H^+ + \frac{1}{4} O_2$ (g)	-20.77	(2)
$Cu^{2} + \frac{1}{2} H_2O$	$\rightleftarrows Cu^+ + H^+ + \frac{1}{4} O_2$ (g)	-18.09	(3)

Thus at normal conditions in a soil, i.e. an oxygen pressure of 0.2 atmosphere corresponding to a redox potential of 800 mV it is found that:

$$\frac{(Cu^{2+})}{(Cu^{+})} = 10^{18.09} \cdot (H^+) \cdot 10^{-0.699/4} = 10^{17.91} (H^+) \qquad (4)$$

which means that at a pH value of 7, copper is almost quantitatively present as cupric ions, the activity of Cu^{2+} being almost 10^{11} times larger than the activity of Cu^+, according to equation (4). The relative contribution of Cu^+ will increase at reducing conditions, (Cu^+) equalling (Cu^{2+}) for an oxygen pressure of $10^{-44.36}$ at pH = 7, corresponding to a value of the redox potential of about 160 mV.

Lindsay (1972) suggested that the interactions between Cu in solution and Cu "adsorbed" in any of the abovementioned different ways be described with the equation:

$$Cu^{2+} + soil \rightleftarrows Cu\text{-}soil + 2H^{+}$$

with a log K^{o} of -3.2 as found by Norvell and Lindsay (1969). Thus the activity of Cu^{2+} in solution as a function of the pH is then found from the relationship:

$$(Cu^{2+}) = 10^{3.2}(H^{+})^{2}$$

Although such an approach may be useful in the construction of solubility diagrams, Equation (5) covers all Cu reactions that may pertain in soil and thus no information is gained about the prevailing bonding mechanism.

The mobility of Cu in soil may be considerably influenced by the formation of soluble chelates. Such influence is basically caused by a change in ionic behaviour as the result of the fact that the former metallic cation can be completely enveloped by the chelating agent. This may even transform the copper cation into an anionic complex with the corresponding enhanced opportunity for displacement in the soil. Since many of such complexing agents are of organic nature it may be expected that the concurrent presence of organic conpounds in manure increases the mobility of Cu in soil as compared to Cu originating from freshly added Cu salts.

MATERIALS AND METHODS

The preliminary experiments described here were directed towards the measurement of break-through curves for small soil columns of Cu solutions in which Cu occurred in various forms. An additional purpose of this first approach constituted the testing of the reproducibility of the measurements.

The soil used was a sandy soil of the so called "old arable land soil" type (in present nomenclature indicated as "loopodzolgrond") which in fact are manmade soils with a relatively thick cover enriched with organic matter following repeated former additions of sheep manure. These and closely related soils are pretty common in the specific regions of present manure excess. The organic matter content amounted to 2.5% as measured by loss on ignition.

Glass tubes containing a sintered glass plate at the bottom were carefully filled with the soil to a height of 5 cm. Pore volumes were maintained around 45% and were exactly calculated for each single column. The top of the column was covered with a layer of glass beads in order to avoid structural disturbance following solution addition, and to obtain an equal distribution of the solution over the total surface area of the column.

In order to avoid wall effects as much as possible, percolation of solutions was performed in unsaturated flow by dropwise addition of the solution on the one side and maintenance of a negative pressure at the end of the column at the other; addition and effluent discharge were controlled by the use of a multichannel dosing pump. The percolate was collected in an automatic sample collector which could be adjusted to various volumetric portions. The percolation rate amounted to 80 cm/day. The experimental set-up is shown in Figure 1.

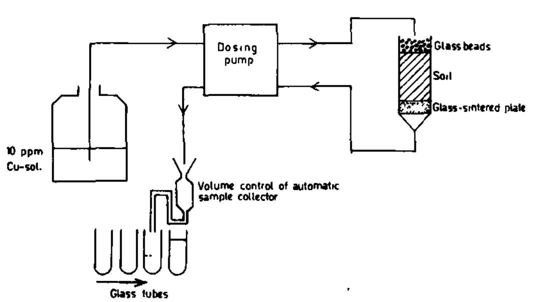


Fig. 1 Experimental set up of percolation tests.

In this way breakthrough curves could be measured simultaneously on four different soil columns.

The solutions used,all had a background composition of 0.01 n $CaCl_2$, again in order to avoid structural disturbance of the soil e.g. by peptisation of soil particles.

Cu concentrations of 10 ppm in the application solutions were obtained by adding $CuSO_4$, and $CuSO_4$ and Na_2EDTA, respectively. The solutions were buffered at a pH of 5.0. This implies that at a molar ratio EDTA : Cu^{2+} of 2 : 1 in fact all copper was present in chelated form.

Percolation of the columns with slurry centrifugate so far caused considerable problems by blockage of the pores in the glass sintered plate at the bottom of the column. This stoppage even occurred at 20 x and 50 x dilution of the supernatant after centrifugation of slurry at 3 000 rpm.

The concentration of Cu in solution was measured by atomic absorption spectrophotometry.

RESULTS AND DISCUSSION

The experimental results are expressed by means of so called breakthrough curves, in which the ratio between the concentration of Cu in the effluent solution and in the feed solution, C_e/C_f is plotted as a function of the volume of percolate; this volume is expressed here in terms of the pore volume of the column.

Figure 2 presents the experimental results for duplicate measurements of percolation with solutions of 10ppm $CuSO_4$ and 10 ppm Cu EDTA. It is shown that the duplicates are very close to each other in both cases. Moreover, a striking difference is found in behaviour of Cu from Cu EDTA and from $CuSO_4$; whereas the former shows a complete breakthrough after percolation with about 5 - 10 times the pore volume of the

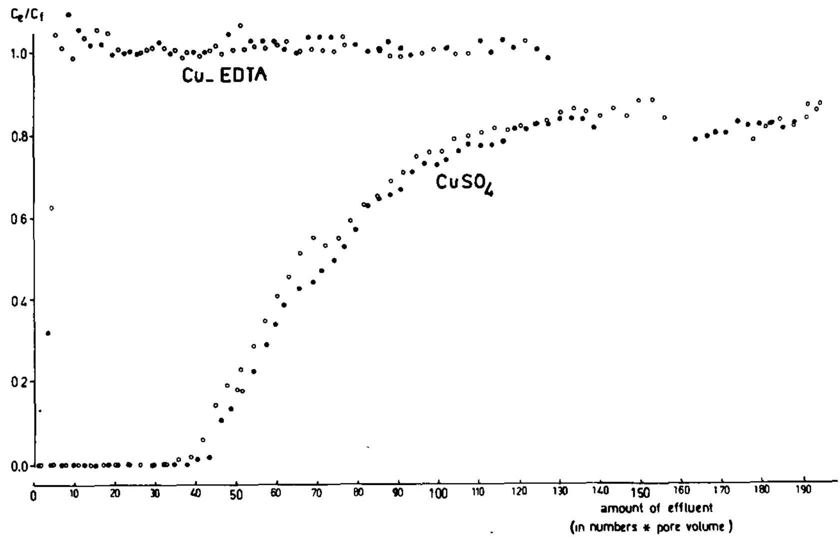


Fig. 2. Breakthrough curves of solutions containing Cu in different forms for a sandy soil (2.5% organic matter).

soil column, such breakthrough was not yet arrived at after percolation of 200 times the pore volume in the case of $CuSO_4$. Moreover, a complete removal of Cu from the $CuSO_4$ solution was measured until an effluent amount of 45 times the pore volume. Although these results are much too preliminary to allow more definite conclusions about the relative contributions of different interaction mechanisms in the Cu bonding, it may be concluded that the Cu originating from $CuSO_4$ probably also forms insoluble compounds in the soil in addition to being bonded on the soil solid phase; this effect exerts itself in the continued removal of Cu from the percolating solution, even following passage of very large amounts of percolate.

Although the method has to be adapted for specific problems met when considering the percolation with solutions containing manure constituents it may nevertheless be concluded that it probably provides a useful tool for the measurement of the mobility in soil of different forms of Cu. As such, it may make a valuable contribution in the evaluation of the effects of increased Cu mobility with respect to leaching through the soil.

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EXAMINATION OF SOIL SAMPLES TAKEN UNDER SILAGE OR MANURE HEAPS AND IN MANURED FIELDS

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INTRODUCTION

For investment and labour saving purposes Danish farmers have to a certain extent utilised temporary storing of farmyard manure (FYM) or silage on bare ground in the field. In most cases, the heaps, particularly of silage, have been covered by sheets of polyethylene to keep out air and precipitation.

Leaching of moisture from such heaps might cause pollution in surface water or groundwater from plant nutrients or organic materials if such materials passed over land or sunk through the soil layers to water courses.

An investigation on the problems of leaching from the heaps was carried out on loamy and sandy areas in the southern part of Jutland, Denmark. Preliminary results from the years 1973/74 and 1974/75 are presented here.

MATERIALS

Soil samples were taken just after removal of the heaps and in some cases also a year later, the area in the meantime being exposed to the weather and cropped normally.

The sampling was carried out at 50 cm intervals down to 400 cm by the use of a sampling tube working inside a casing 10 cm wide. In some localities the sampling was interrupted by water at 100 cm below the surface.

The samples were taken where the heaviest leaching might be expected, mostly near the edge of the former heap. Reference samples were taken in the same field at some distance from the heap.

The soil was examined for ammonium-N and nitrate-N by means of extraction in KCl at pH 1 and titration.

RESULTS

The data obtained were divided according to the type of heap removed and the type of soil in question. The criterion used for a loamy soil was the sum of clay and silt being more than 15%.

The accumulation of N caused by the heap was estimated as the difference between the contents of the experimental sample and the reference sample, (Table 1, A-C).

In general the accumulation of NH_4-N went down to about 200 cm, in some cases in rather large quantities. The large variation between localities showed no significant differences between types of heap or between types of soil.

Apart from one single locality the content of NO_3-N was much smaller than the NH_4-N content but the tendency to accumulation down to 200 cm was the same for both.

As mentioned earlier some of the localities were sampled the following year, 1975.

Table 2 illustrates the effect on the N-accumulation down to 200 cm when the area was exposed one year to weather effects and cultivation.

There was a tendency in the material that soils beneath heaps of silage had a higher content of NH_4-N in 1975 than soils beneath manure heaps.

The figures observed do not give a definite answer to how much nitrogen is lost by leaching. We can only express a warning that if there is an urgent need to store silage or farmyard manure temporarily, then care should be taken. Do not stand

TABLE 1

ACCUMULATION OF MINERALISED N OVER REFERENCE. (N, mg/kg of dry soil, 1974)

	Sandy soil NH_4-N		Sandy soil NO_3-N		Loamy soil NH_4-N		Loamy soil NO_3-N	
A. After farmyard manure								
Depth cm	av. (6)	range	av. (6)	range	av. (5)	range	av. (5)	range
0	110	12-246	6	3-11	190	13-362	13	0-42
50	45	0-145	7	0-24	77	0-282	8	0-35
100	41	1-114	8	0-26	44	0-181	8	0-22
150	23	1-69	6	0-22	27	0-124	5	0-11
200	8	1-15	6	1-22	8	0-29	2	0-6
250	2	0-5	3	0-7	3	0-6	7	0-31
300	2	0-4	1	0-6	3	0-6	4	0-21
350	2	0-5	2	0-5	2	0-3	0	0-0
400	1	0-3	1	0-3	4	2-5	0	0-0
B. After beet top silage								
	av. (6)	range	av. (6)	range	av. (3)	range	av. (3)	range
0	98	25-165	2	0-3	81	5-174	82	9-218
50	44	0-162	1	0-2	22	2-61	2	0-5
100	15	0-49	8	0-44	12	0-30	1	0-2
150	8	0-23	3	0-11	12	0-36	1	0-3
200	6	0-15	5	0-26	11	0-30	1	0-4
250	2	0-13	1	0-4	6	1-11	2	0-3
300	2	0-7	2	0-6	6	1-11	1	0-2
350	7	0-17	1	0-2	1	1-1	0	0-0
400	2	0-3	0	0-0				
C. After grass silage								
	av. (5)	range	av. (5)	range	av. (1)	range	av. (1)	range
0	156	1-308	5	0-12	330	-	6	-
50	36	0-101	5	0-23	53	-	0	-
100	22	0-102	6	0-20	37	-	0	-
150	28	0-106	8	0-30	2	-	0	-
200	6	0-15	5	2-11	0	-	0	-
250	0	0-0	0	0-0	-	-	-	-
300	1	0-0	1	0-2	-	-	-	-

directly over a drain pipe, nor on a slope leading to a stream or a lake, and never use the same locality twice.

TABLE 2

ACCUMULATION OF MINERALISED N OVER REFERENCE 1974 AND 1975 (N, mg/kg of dry soil)

A. After farmyard manure (average of 4)				
Depth cm	NH_4-N 1974	NH_4-N 1975	NO_3-N 1974	NO_3-N 1975
0	170	2	16	7
50	60	0	10	11
100	41	3	9	7
150	21	4	3	3
200	6	6	2	3
250	2	3	2	1
300	3	3	1	0
350	2	0	1	0
400	2	0	0	0
B. After silage (average of 6)				
Depth cm	NH_4-N 1974	NH_4-N 1975	NO_3-N 1974	NO_3-N 1975
0	161	31	41	6
50	78	29	2	1
100	34	13	15	3
150	32	12	8	6
200	14	7	8	2
250	3			

SOIL SAMPLES FROM FIELD EXPERIMENTS

Materials

In field experiments on the effect of moderate and heavy amounts of animal manure, soil samples were taken down to 2 m depth and analysed for the contents of different elements. Yield figures from the experiments are mentioned in the paper presented by Dr. Dam Kofoed to this seminar.

Results

With regard to the soil analyses, preliminary results of contents of ammonium and nitrate nitrogen are presented from an experiment on loam soil.

Manure was applied in 1973 for beet, in 1974 the crop was barley and in 1975 it was grass. Soil samples were taken during the winter after each crop.

Results for the three years are shown in Table 3 for farmyard manure and in Table 4 for slurry. The treatments, respectively 25 and 100 t of manure per ha/year, are compared to 100 and 400 t/ha given in one application every fourth year.

TABLE 3
CONTENT OF MINERALISED NITROGEN IN SOIL SAMPLES AFTER APPLICATION OF FARMYARD MANURE, LOAM SOIL. 1973-75 (N, mg*/kg dry soil).

	NH_4-N			NO_3-N			NH_4-N			NO_3-N		
	73	74	75	73	74	75	73	74	75	73	74	75
	100 t/ha 1973						25 t/ha/year					
0-25	4	4	8	3	7	6	4	6	6	2	2	5
25-50	3	3	4	1	5	0	4	3	6	3	2	2
50-75	1	0	1	0	2	1	2	1	2	1	3	1
75-100	2	0	1	0	0	1	2	2	2	0	3	1
100-125	0	1	1	0	0	1	2	3	2	0	2	1
125-150	2	2	2	0	0	1	1	1	3	0	0	1
150-175	2	1	1	0	0	1	1	0	2	1	1	2
175-200	2	2	4	0	0	1	1	1	1	0	1	1
	400 t/ha 1973						100 t/ha/year					
0-25	4	7	7	4	3	3	5	5	5	4	17	4
25-50	3	3	4	4	6	3	3	5	5	1	13	4
50-75	2	3	4	4	3	3	4	3	4	2	13	3
75-100	1	3	3	3	2	1	4	2	6	2	9	1
100-125	2	2	2	1	4	3	1	3	3	0	12	1
125-150	2	1	3	2	5	3	0	1	1	0	8	1
150-175	1	1	3	1	4	5	0	1	1	0	7	1
175-200	2	2	2	1	7	4	0	1	1	0	9	1

* No deduction of reference values has been performed

When comparing the figures in Tables 3 and 4 with those in Tables 1 and 2, it must be assumed that even 400 t of manure given once in a period of 4 years might give less pollution risks than storing of FYM or silage. Nevertheless, there is a slight tendency for larger amounts of manure to result in larger contents of mineralised N in the soil, a tendency which might serve as a warning against too heavy application.

TABLE 4

CONTENT OF MINERALISED NITROGEN IN SOIL SAMPLES AFTER APPLICATION OF SLURRY, LOAM SOIL. 1973-75. (N, mg*/kg, dry soil)

	NH_4-N			NO_3-N			NH_4-N			NO_3-N		
	73	74	75	73	74	75	73	74	75	73	74	75
	100 t/ha 1973						25 t/ha/year					
0-25	8	6	4	2	5	3	5	4	5	3	3	2
25-50	6	2	6	4	3	3	4	3	3	2	1	2
50-75	7	2	1	4	2	1	3	1	1	1	2	1
75-100	3	2	3	4	1	1	2	1	2	1	1	1
100-125	3	2	1	2	4	1	8	0	1	1	3	1
125-150	4	2	1	6	6	1	5	1	2	2	4	2
150-175	3	1	2	1	3	2	4	0	1	2	5	2
175-200	6	1	1	4	1	2	3	0	1	2	5	1
	400 t/ha 1973						100 t/ha/year					
0-25	5	7	7	12	9	4	4	3	5	1	2	6
25-50	5	4	9	19	3	2	3	1	4	1	2	2
50-75	4	2	4	23	2	1	3	1	2	1	2	2
75-100	3	2	6	15	1	2	3	0	4	2	1	2
100-125	3	3	3	4	4	3	1	0	2	3	1	4
125-150	3	2	2	9	11	4	2	0	2	2	1	4
150-175	2	1	2	6	10	6	3	0	2	1	0	4
175-200	2	0	3	6	7	5	1	0	2	3	0	4

* No deduction of reference values has been performed.

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DISCUSSION

C. Cheverry *(France)*

Dr. Bonciarelli, at the end of your paper you mentioned soil with a bad structure perhaps due to an excess of harmful cations. Have you an estimation of the sodium absorption ratio of your soil solution?

F. Bonciarelli *(Italy)*

I did not determine either the sodium or the cation content. The very poor structure is probably due to the low organic matter content. You have to consider that maize for silage is grown on this soil. All the other ground vegetation is put in silos, thus there is no organic matter return to the soil. You have to remember that cattle and pigs are without bedding material, they are on a slatted floor so there is very little introduction of organic matter. The only organic matter that remains in the soil is the maize roots and the short stalks below cutting level. In these conditions it is impossible to say whether the bad structure is due to the lack of organic matter or to an excessive amount of harmful cations, such as sodium. It is possible that sodium is a contributing factor to bad soil structure. It is a very clayey soil in which the structure is very important for fertility.

H. van Dijk *(The Netherlands)*

Dr. de Haan, you mentioned that 225 ppm copper (or something like that) is added to the feed of the pigs in the form of copper sulphate and that it is almost quantitatively excreted. However, the crucial point is, in what form is it excreted? I expect the main part is as copper sulphide - not as soluble copper organic complex nor as copper sulphate - but as copper sulphide. I know of one experiment where they extracted the faeces, with, I think, hydrochloric acid solution, and there was only a very small amount of copper in the solution.

F.A.M. de Haan *(The Netherlands)*

I fully agree with you that where we indicate these experiments on the mobility of copper sulphate, we do not really expect that that is the form. It is well-known that copper will be excreted in the form of copper sulphide. Now, copper sulphide, in conditions which normally prevail in soil, may relatively easily be oxidated to copper sulphate. That's one point. Then, why do we start to consider the combination and behaviour of copper in connection with chelates? It is because it is pretty sure that there are very many chelates or chelating compounds occurring in manures and they will finally govern completely the mobility of the copper. This is of prime importance, both with respect to leaching but also with respect to uptake. So we presume that there is sufficient possibility for oxidation of copper sulphide, as it is brought on to the soil, to copper sulphate and this will be combined, in one way or another, with a number of organic compounds which we are trying to extract. Dr. Gerritse did some good work on that as he showed this morning. In a comparable way, we are trying to make, by means of gel filtration, a distinction between different sizes of molecule. If you got the impression that we expect copper to be in the manure as copper sulphate, that is wrong. Possibly I gave that impression in my way of presentation ...

H. van Dijk

I know that you know! However, it remains a crucial point because I am not sure that copper sulphide is readily oxidised to copper sulphate in the soil, not even in an aerobic soil. I do not know how much time it will take and I do not know whether it will take place at all on a large scale. This problem needs more attention.

F.A.M. de Haan

Of course, there remains another question which is whether it is really important for the behaviour of copper itself, whether it is present as copper sulphate or copper sulphide. As far as the solubility is concerned, of course, it is important. The question remains as to whether, in combination with chelating agents, the form will make much difference or not. Finally, there is no doubt that you get the considerable part of it as copper sulphate, in my opinion.

<u>L.C.N. de la Lande Cremer</u> *(The Netherlands)*

This has been investigated by Professor Mulder in Wageningen. This transformation from technical sulphide to sulphate is a matter of one, two or three days.

<u>J. Lindhard</u> *(Denmark)*

I would like to make the point that it is not necessary for the copper to come through the animal. We had some examples, we analysed about 150 cattle slurries, they were very high in copper. We investigated the origins of the samples and discovered that in the three farms concerned there were a sort of baths through which the cows had to walk to get into the cowsheds and that was where it came from.

<u>H. Tunney</u> *(Ireland)*

Dr. de Haan, at the breakthrough point with your copper sulphate, when you percolated through your soil column, do you know what level of copper you had in the soil? I would expect perhaps 400 ppm copper.

<u>F.A.M. de Haan</u>

You mean at the point of breakthrough of the copper sulphate? Well, actually I did not figure that out because these data are not used for a correct interpretation of breakthrough curves. They were not designed for that. This was just to try the system. We used the later curves which I showed on the slides for data calculations of absorption, etc. I would make a guess that it was much higher than the 400 ppm mentioned.

<u>H. Tunney</u>

It's academic, of course, because by the time you reach that level in farming practice you have no crops growing. There is another point. It appears that in farming practice copper is very unavailable in the soil. You can have very high levels of copper in the soil and yet the uptake by the plant is very, very small. This suggests to me that it is not in a chelated form which would be readily available to the plant.

F.A.M. de Haan

Yes, that is the reason I mentioned that what we need for phytotoxicity is somewhere about 0.1 ppm in the soil solution. I fully agree with you - and that is what I pointed out - that normally copper is relatively immobile in the soil. It seems to be very immobile, especially in organic soils - peat soils - but the question remains whether the normal organic compounds in soil behave in a comparable way to the specific organic compounds in manures. Of course, we will never hope to arrive at that point in practice.

J.H. Voorburg *(The Netherlands)*

I would like to make some comments on this discussion myself. If you are concerned with soil pollution or ground water pollution, you should consider the longterm effects. However, it is impossible to do research on these longterm effects because, as you have discovered, by the time you have the results it is too late, the soil is polluted, the ground water is polluted. What we must aim for is to be able to predict the effect of an excess of minerals, an excess of manure, after 50 or 100 years. Experiments must be aimed at determining what is happening in the soil. With that information it will be possible to predict what will happen in the future and I think that is very important.

A. Dam Kofoed *(Denmark)*

Dr. de Haan, I find your studies on copper very interesting. As far as leaching and copper are concerned, how many grams per hectare would you have had if you had done these investigations ......

F.A.M. de Haan

I really think that the interpretation of our experiments is wrong in this case because these breakthrough curves have nothing to do with what is actually happening in practice. They are just intended to help us understand the mechanisms which go on in the soil system. I can't answer your question. It is comparable to the question from Dr. Tunney. I do not know exactly at what time this will happen but there will never be a complete breakthrough as we hope, with copper. Nevertheless, there will be a partial breakthrough, and this may be quite a variation in the soil concentration, there is always a certain copper level in the soil. I realise I am not answering your question because it doesn't have anything to do with our experimental approach.

A. Dam Kofoed

It has something to do with the Chairman's comments! That is why I raised the question of leaching of copper to the ground water. As far as our preliminary investigations are concerned, we have roughly 18 g in the drainage water per ha.

J.H. Voorburg

But you can't predict what you will have in the future?

A. Cottenie *(Belgium)*

Mr. Chairman, may I make a comment. We have studied the mobility of copper in soil, in practice. First of all we have to make definitions on what we call soil pollution and soil water pollution. These are two different things. Soil water may not be polluted but the soil may be, for example. I will explain that in a few words. The soil contains 100 000 ppm of aluminium, 100 000 ppm of iron, and no one plant could subsist in such a growth medium. However, at the actual pH of the soil only 3 to 4 ppm of iron are mobile. In the same way, I would not object to a soil containing 1 000 ppm of copper on the condition that it was immobile in just the same way as aluminium or iron are immobile. Now, we speak about organic mineral complexes, copper humate and copper sulphate complexes, and so on. When you study the equilibrium between the liquid phase and the solid phase at different pH values, you see that nearly 100% of the copper present is fixed as insoluble organic copper complexes at pH values below 4.5. From that pH value on, the copper organic mineral complex turns over in another form which is soluble. This explains also that in peat soils, or soils very rich in humic material and acid, there is a deficiency of copper even when such soils are rich in copper. We can make the whole scheme over the pH in which we can keep our soil, say, from 5 up to 7 or 8, and predict the fraction of the total amount present which will be mobile and therefore probably available and toxic for plants. This is not very difficult to do. One of my collaborators made a doctorate thesis last year on that subject, not only for copper but also lead, and so on. So we can predict to a large extent and this is closely related to what Dr. de Haan has told us.

J.H. Voorburg

Thank you very much for this contribution.

F.A.M. de Haan

May I add a few words. Actually, as I pointed out at the end of my presentation, that is the reason that we are now studying the stability constants, not with artificial chelates but with components of the manures. Coming to another point which Dr. Cottenie raised, regarding soil pollution, we all know that earth worms are very sensitive to copper. Now, at what time do we consider the soil is polluted? Is it at the time there is no plant growth, at the time there is harm to the plants, at the time when there is an unacceptably high level of copper (or any other element) in the soil or ground water, or, should we consider other effects, that there are no earth worms in the soil, or only a very small population of earth worms? Are we to consider that as soil pollution? Yes or no? There will be an introduction of new regulations in the course of the next few decades and it is very important to answer these questions and establish just what constitutes pollution.

A. Cottenie

This is the question of whether you take a biological or a chemical criterion. However, there is another biological criterion - that is germination. Germination of seeds is very sensitive to copper toxicity. That may be a better and a more easily handled criterion.

R.G. Gerritse *(The Netherlands)*

I think perhaps I can help over the question raised by Dr. Dam Kofoed on how much copper is transported, or diluted, from the soil. In my results I found that a millilitre of pig slurry contains about 5 micrograms of copper in solid and one microgram in solution. Of this 1 microgram which is in solution, 30% is in high molecular weight compounds. This is .3 micrograms/ml of pig slurry. This is in a DNA complex; DNA is degraded very slowly in the soil, it is fairly stable, so you can assume that if you give high doses of pig slurry this is transported in the soil with the same speed as the soil water moves in the soil. I would offer this as a rough figure that would be transported in the soil and found in the drainage water.

A. Cottenie

Once the soil contains high amounts of some of these elements the problem is not to eliminate the elements but rather to make them insoluble, to fix them, to make them immobile. I cannot yet give results but we are at present working on making secondary minerals in the soil and the most insoluble ones which will be stable for centuries are apatites. Already in the laboratory, when you have soil containing excesses of lead, cadmium, copper, you can make apatites. This is just a question of physical chemistry. If you have conditions there is no reason why normal physical laws should not apply to soil chemistry. Then you can immobilise everything you wish for centuries.

R.G. Gerritse

I would like to say a word of warning in this respect. If you did this with regard to heavy metals you might be creating a chemical bomb. In Europe, with the Ruhr area as a centre, the pH of the rainwater increases from 3 outwards to say, Ireland, with a pH of 6 or 7. This very low pH would attack these apatites and make them soluble. If you had a soil containing a large amount of heavy metals in this form, then, in fact, you would have a sort of chemical bomb in the soil.

A. Cottenie

We have control over the soil pH, I suppose.

H. Laudelout *(Belgium)*

There is something that should not be forgotten. Loss of chemical thermodynamics do not involve time.

A. Cottenie

Well, anyway, we have observed that natural secondary minerals of the type of apatites have existed for a very long time; we know where to find them and we can create them.

H. Laudelout

This is in no way determined by chemical thermodynamics. Chemical kinetics is an entirely different field.

J.H. Voorburg

There seems to be no agreement in this discussion. I think the conclusion should be that we must take care with regard to soil pollution and try to prevent it which means that we must be able to predict what will happen in the long term, what the effect of an excessive amount of slurry will be in the long run.

We will now close this session.

THEME 4

REGIONAL ASPECTS

Chairman: J.H. Voorburg

WATER POLLUTION BY LIVESTOCK EFFLUENTS

R. De Borger and K. Meeus - Verdinne
Ministry of Agriculture, Chemical Research Institute,
Tervuren, Belgium

It is not always easy to discover the real contribution of a well defined branch of human activity to the pollution of a river basin.

Starting from a study of the general situation of a river, we tried to define the part of livestock breeding in the existing pollution. Our choice fell on the River Ijzer and its basin for the reasons that there is little or no industry present, it has a relatively small basin and is thus easy to overlook, etc.

GENERAL SURVEY OF THE POLLUTION OF THE IJZER BASIN

Some 20 years ago the River Ijzer was a healthy river abounding in fish. In the last few years, fish mortality has recurred frequently. Coming from France, where it covers 37 out of the 78 km of its course, the River Ijzer flows slowly through a predominantly agricultural, sparsely populated (180 inhabitants/km^2), poorly industrialised region, the altitude of which does not exceed 5 m.

The river has several tributaries in Belgium. At Nieuwpoort it is separated from the sea by a lock. The flow of the river is very slow and is even at a standstill during some periods of the year.

Near the mouth of the river,waterflow can take place in the two directions influenced by the tide flow and the lock. During rainy periods the flow of the River Ijzer is slowed down by the opening of the lock giving access to the Lovaart, which acts as an overflow, and by the pumping of water which feeds a drinking water reservoir.

TABLE 1

ANALYSIS RESULTS OF SURFACE WATERS - IJZERBASIN - SUMMER 1972. (Nationaal R en D programma, 1973). Mg/l (except dissolved O_2 expressed in % of saturation).

	O_2	COD	Total N	Amm. N	Org. N	NO_3^-	NO_2^-	Total P as PO_4^{3-}
IJZER								
1. Border	82.6	29	3.2	0.5	2.7	0.65	0.45	5.1
2. Downstream Heidebeek	2.2	58	8.2	3.3	4.9	0.21	0.86	10.1
3. Downstream Haringbeek	0	116	22.9	3.5	19.4	0.16	0.11	10
4. Upstream Ieper canal	70.3	57	13.3	6.3	7	0.21	0.27	7.9
5. Downstream Ieper canal	84.6	100	23.5	11.4	12.1	0.68	0.84	14.9
6. Upstream Diksmuide	73.6	61	15.1	4.3	10.8	1.88	0.23	6.2
7. Downstream Handzamevaart	0	103	19.7	13.8	5.9	0	0.11	17.3
8. Upstream Nieuwpoort	162.6	85	13.6	8.3	5.3	0.24	1.65	12
TRIBUTARIES - at the confluence								
a. Heidebeek	0	216	22.6	13	9.6	0.05	0.16	36
b. Haringbeek	27.5	2288	18.7	7.6	11.1	-	0.55	6.1
c. Ieper canal	56	96	24.9	13	12	0.27	0.56	18
d. Handzamevaart	0	100	22.6	0	22.6	-	0.23	18

All these factors make it very difficult to determine the flow pattern of the river. To gain some idea of this flow we should look at the following figures: (Nationaal R en D programma, 1973)

August '72: at the French border: $0.2m^3$/sec
at the estuary : $0.85m^3$/sec
February '73: at the border : $47m^3$/sec
at the estuary : $17m^3$/sec

The flow of the tributaries is much slower.

At its arrival in Belgium the River Ijzer is quite clean,

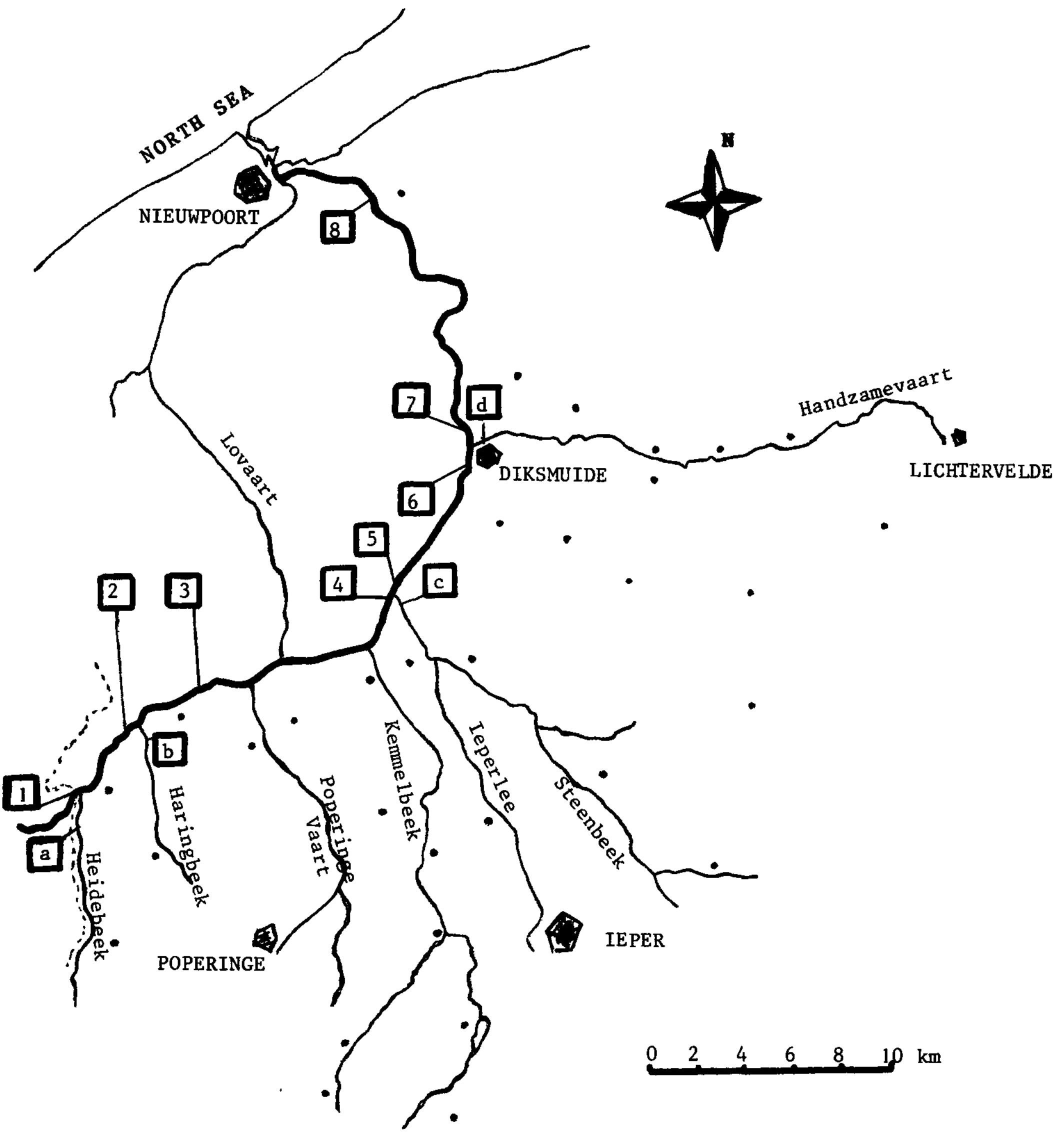

Fig. 1 Ijzer Basin - General Aspect

though it contains many phosphates. The algal growth is not excessive, the nitrate content probably being the limiting factor. The River Ijzer itself does not receive many discharges: they are much more numerous in the tributaries. The analytical data of a summer sampling campaign are given in Table 1. (Nationaal R en D programma, 1973). The sampling sites are indicated in Figure 1. The figures show that we are in the presence of a strongly eutrophicated ecosystem. Hydrobiological analysis confirms this as well (Van Hooren, 1975).

The level of phosphate concentrations is very high. It is accepted that waters containing 3 mg total P as expressed as PO_4---, are heavily loaded. Here the figures are three times higher and in the tributaries up to ten times higher.

With regard to the nitrogen, it is well known that in aerated waters the nitrate levels are much higher than those of ammoniacal nitrogen; the nitrites are absent or only present as traces. In poorly aerated waters the reverse situation occurs, which is the case for the River Ijzer and its tributaries: high amm/NO_3^- N ratios can be found as well as the all-round presence of nitrites. It is interesting to look separately at the different contributions to this strong eutrophication. The following sources of pollution are to be taken into account.

Population

The waste waters of the 125 000 inhabitants of the Ijzer basin are not purified except in the Nieuwpoort area. These waste waters contain principally phosphates from the detergents. The recent installation of tap water distribution in the villages of the Ijzer basin increases this factor. In any case the population cannot be a major source of pollution as the density is rather low.

Industry

There is little industry other than a few dairies, breweries, canning factories, etc. They contribute an important part to the europhication.

Agriculture and livestock breeding

Agricultural activities can engender surface water pollution in two ways:

Indirect pollution - includes leaching and runoff of fertilisers spread on arable land. The cultivated surface represents 42 000 ha, which is 58.5% of the total surface used for agricultural purposes. The main crops are: cereals, 54%, beetroots, 22%, potatoes, 10%.

Direct pollution - direct discharges of livestock effluents in the streams. The livestock is overdeveloped compared to the surface area of this region. There are 140 000 cows and 550 000 pigs.

As a rule, the animal wastes are spread on the soil; the traditional farms have enough arable surface on which to spread the waste products. The only losses are induced by leaching. However, very many cattle breeding farms and especially pig farms, no longer have arable land available to dispose of their waste products. In fact there are more and more of them. We have reason to suppose that this cattle breeding contributes to a great extent to the pollution of surface water.

RESEARCH INTENDED TO DETERMINE THE INFLUENCE OF CATTLE BREEDING ON SURFACE WATER POLLUTION.

In order to study the influence of cattle breeding on the composition of surface water, only a small part of the Ijzer basin was selected, an area situated between Ieper and Diksmuide. It involves the basin of the Kemmelbeek (8 000 ha) and the basin of the Steenbeek-Martjevaart (10 000 ha) (Beernaert, 1971).

The region, with the exception of some dairies, is exclusively agricultural. It is sparsely populated, with rural villages containing 2500-3000 inhabitants each. There is intensive cattle breeding. From the statistics for the year 1973 (Nationaal Instituut voor de Statistiek Landbouwtelling, 1973), we calculated that there was an average production of livestock effluents of 46 tons per hectare per year. One quarter of this waste is pigs' excrement, which is known to be of a strongly polluting nature.

In the course of one year we took samples once a month on twelve sites (see Figure 2). The nitrates, nitrites, ammoniacal nitrogen, the phosphates, the sulphides and the copper contents were determined. The situation of the sampling points can be summarised in the following way:

Points 2 to 6: Kemmelbeek and Robaartbeek - close to the source.

Points 9 to 12: Steenbeek - Martjevaart, downstream, in the direction of the Ijzer river, in the neighbourhood of an artificial water reservoir where the surface water is stocked for drinking purposes.

Point 1: farm water, mainly drainage water - there was probably also a supply from surrounding field drains.

Point 8: stagnant water of field drains in grassland.

The results are represented in Table 2. The figures are mean values of the autumn/winter and the spring/summer campaigns.

TABLE 2

ANALYSIS RESULTS OF SURFACE WATERS - IJZERBASIN - SAMPLING PERIOD 74/75. mg/l

Sampling sites	NO_3^-		NO_2^-		Amm.N		Tot.P as PO_4^{3-}	
	W	S	W	S	W	S	W	S
1. Farm	44.4	27.2	0.06	0.03	0.82	1.63	27.8	12.4
2. Robaartbeek	51	41.5	0.6	0.8	1.6	6.3	14	17.5
3. Robaartbeek near spring	47.5	41	0.24	0.36	1.55	1.63	49.5	14.8
4. Kemmelbeek upper part	-	38	-	0.5	-	1.5	-	11.3
5. Rozenhilbeek	-	39.3	-	0.5	-	0.6	-	9.3
6. Dikkebus water reservoir	-	34.3	-	0.25	-	0.58	-	7.5
7. Kemmelbeek	50.5	27.8	1.1	1.3	2.5	6.4	34.6	14
8. Field-drain in grassland	21.8	19.8	0.11	0.014	1.13	1.25	15.6	16.2
9. Martjevaart	72	30.4	0.94	0.53	8.45	28.9	42.2	28.8
10.Engelendelft	40.8	20	0.28	0.09	1.4	7.14	37.3	22.4
11.Kleibeek	47.8	22	0.23	0.59	0.59	0.39	13.15	13.2
12.Kwabeek	69.4	47.4	1.47	o.73	3.38	16.2	22.7	22.6

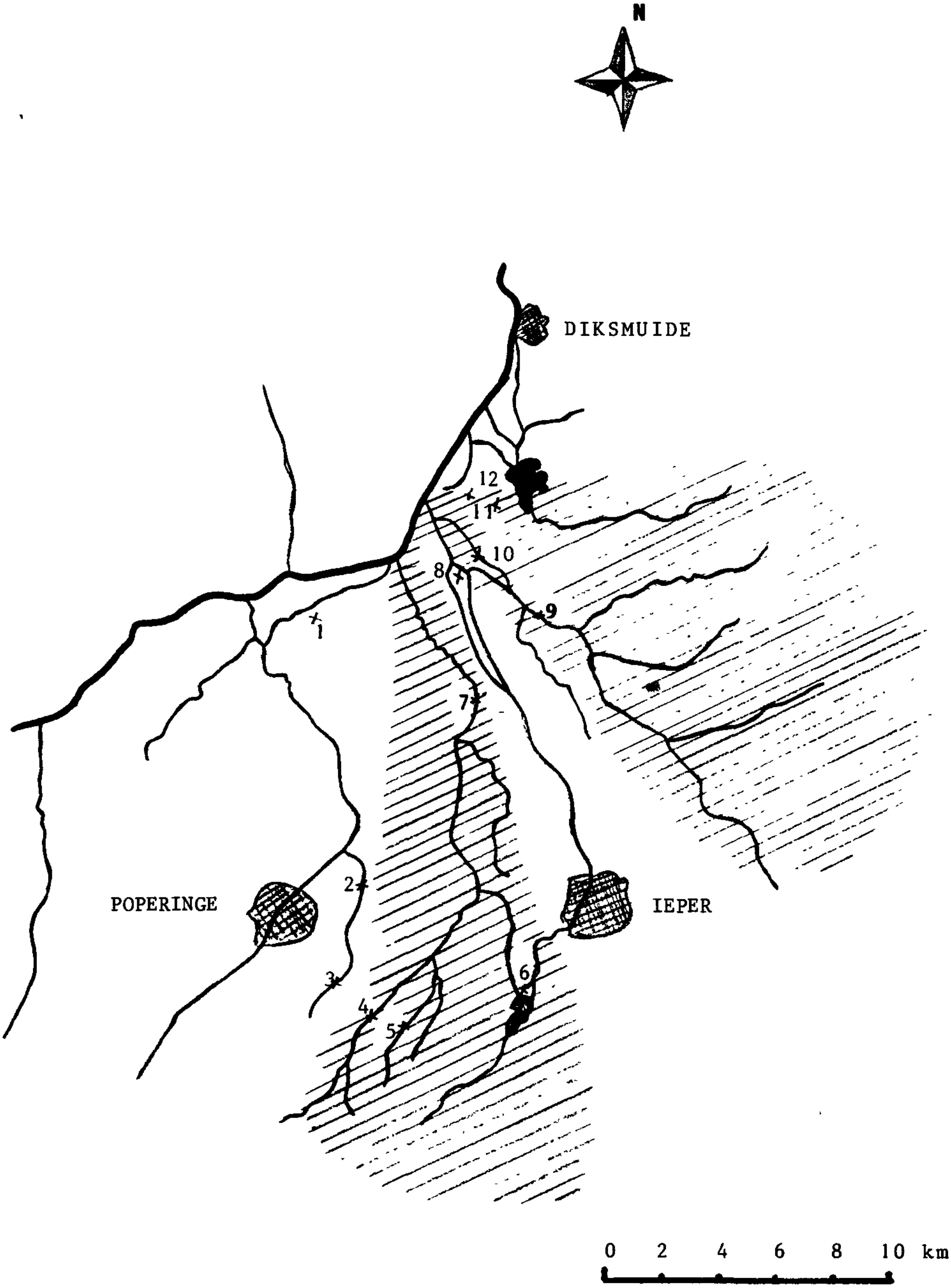

Fig. 2 Ijzer Basin - Sampling points: Kemmelbeek and Steenbeek: Martjevaart

One can see immediately that the levels are very high. As seen in the general study (1973, see first section) it was stated that the water was strongly eutrophicated. There are hardly any differences between the sites, even Points 1 and 8 have high levels, (farmwater and field drain).

The nitrate content is much higher during the winter period than during summer. It is clear that this is due to the drainage water. Experiences in that region showed us that under normally fertilised fields the water of the drainpipes contains an average of 80 ppm NO_3 during the winter period (drainage period).

The nitrite and phosphate levels were nearly the same in the winter and summer periods. The level of the ammoniacal nitrogen is systematically and significantly higher during the summer than during the winter period. The explanation is in the supply of fresh effluents, less dilution and little or no nitrification due to the anaerobic condition. The latter is confirmed by the all-round presence of nitrites and sulphides (0.02 - 0.1 ppm). The whole region is, as it were, impregnated by eutrophicated water. One can readily imagine the problems that arise in the production of drinking water out of such surface water.

In order to gain an idea of the quantities of animal wastes produced in the region under study, we made a detailed survey of the livestock effluents in the villages around the sampling points. Once again we used the livestock statistics (Nationaal Instituut voor de Statistiek Landbouwtelling, 1973) (cows, pigs, poultry) and calculated the quantity of waste products and also their equivalent in NPK (Table 3).

The two river basins under consideration each include about 7 villages. Thus it should be possible to make an evaluation of the wastes produced and the potential pollution in the basins. Unfortunately the limits of the river basin do not coincide with those of the villages, so it is only possible to make an approximate evaluation. When we take these figures into consideration together with the fact that there are no wastewater purification devices in this region, we may assume that a great part of these waste products ends up in the surface waters. The other part is supposedly spread on the land.

Nevertheless, the high nutrient levels in the surface waters are not solely due to cattle breeding but to the population at large and to the nutrients released by the cultivated soil. The latter will have only an appreciable influence during the drainage period (the winter). To illustrate these assertions we have at our disposal, figures collected in the basin of the River Mehaigne (Nationaal R en D programma, 1976)(2 044 ha). It is a small river running through almost exclusively crop growing region with the same population density as the regions referred to above (Figure 3).

The average amount of animal waste produced in this region, again calculated from the statistics (Nationaal R en D programma 1973) amounts to 18 tons per hectare per year and that only from cows. The soil is a heavy loam, thus less permeable than the sandy and sandy loam soils of the part of the Ijzer basin considered above.

The figures are collected in Table 4. The nitrate levels here are five to ten times lower than those noted for the part of the Ijzer basin studied. In the winter they are also significantly higher than in the summer, which can again be ascribed to the drainage water. During the summer period there is a distinct increase of the levels, starting from the source of the River Mehaigne to its confluence with the River Meuse.

The nitrite levels are ten to one hundred times lower than those of the Ijzer basin. There was no sample containing sulphides. The aerobic conditions resulted in a low content of ammoniacal nitrogen in the water. At last the phosphate levels are ten to twenty times lower as well. In fact, the concentrations are higher in summer than in winter, this is certainly caused by a lesser water flow.

There is good evidence that the difference of nitrate and

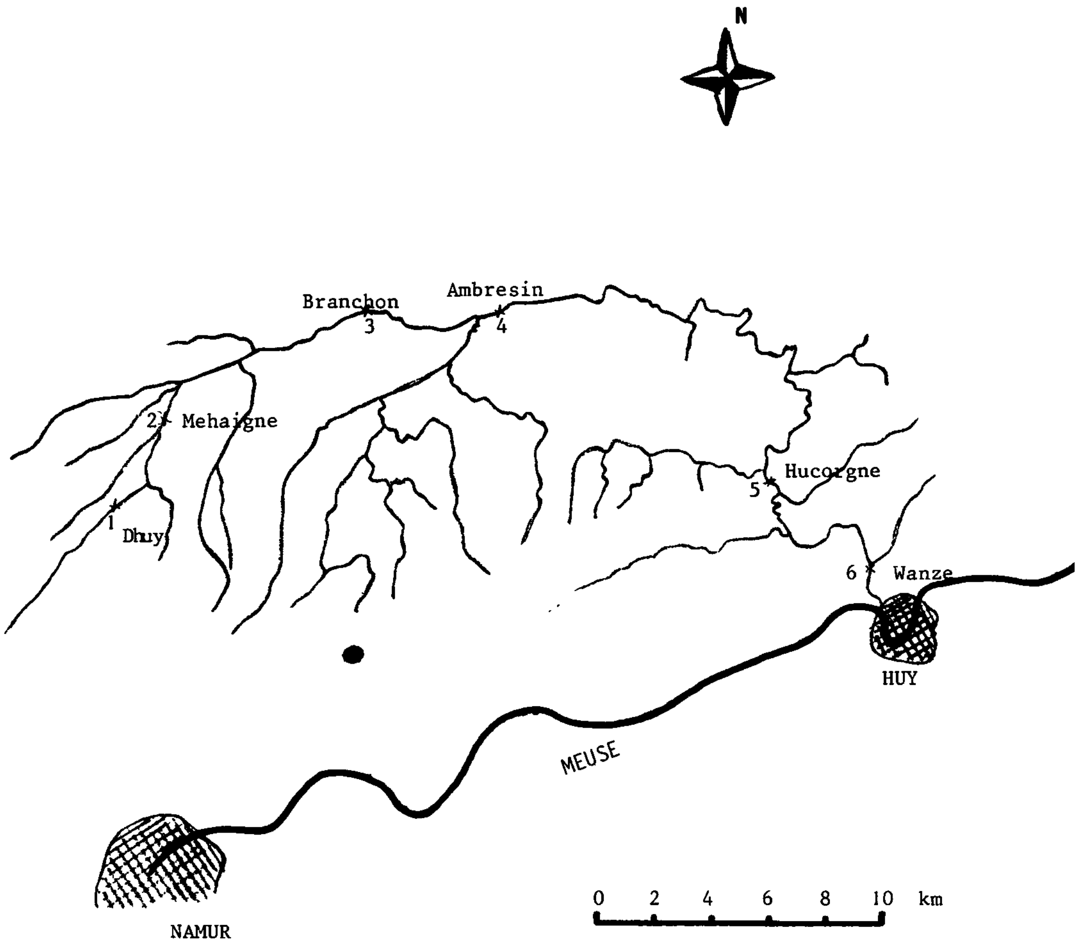

Fig. 3 Mehaigne

TABLE 3

ANIMAL WASTE PRODUCTION IN THE VILLAGES AROUND THE SAMPLING POINTS (1973)
The equivalent value of these wastes as N, P_2O_5 and K_2O was calculated.

	Waste production per year		Fertiliser equivalent					
			N		P_2O_5		K_2O	
	10^3 Ton Total	T/ha	Ton total	Kg/ha	Ton total	Kg/ha	Ton total	Kg/ha
VILLAGES AROUND POINTS 2 - 6								
Reningelst	72	39	423	229	220	119	345	187
Vlamertinge	78	46	439	259	215	127	354	209
Westouter	29	34	153	179	72	84	140	164
Dibbebus	40	47	225	264	109	128	184	216
Kemmel	53	52	319	313	165	162	246	241
Dranouter	37	42	204	232	100	114	174	198
VILLAGES AROUND POINTS 9 - 12								
Langemark	134	46	775	266	393	135	629	216
Houthulst	27	42	143	223	68	106	132	206
Woumen	81	49	451	273	225	136	402	243
Zonnebeke	68	51	396	297	200	150	307	230
Merken	104	49	611	288	318	150	503	237

TABLE 4

ANALYSIS RESULTS OF SURFACE WATERS - MEHAIGNE BASIN - SAMPLING PERIOD 73. mg/l.

Sampling sites	NO_3^-		NO_2^-		Amm.N		Tot.P as PO_4^{3-}	
	W	S	W	S	W	S	W	S
1. Dhuy	10.1	1.2	0.02	0.04	0.13	0	0.21	0.66
2. Mehaigne	9.7	1.9	0.01	0.02	0.09	0.07	0.28	0.73
3. Branchon	8.0	2.5	0.02	0.06	0.15	0	0.43	1.06
4. Ambresin	5.4	2.5	0.16	0.04	0.33	0.13	0.56	0.96
5. Huccorgne	7.3	3.2	0.01	0.01	0.16	0	0.35	0.96
6. Wanze	7.8	12.6	0.01	0.03	0.16	0.06	0.49	1.12

phosphate levels we found between the two regions studied, are due to livestock effluents.

We found further evidence of the discharging of animal waste in surface waters in bacteriological analysis. Indeed, it was stated in general that the fecal flora of the watercoürses of our coastal regions, (and the Ijzer basin is one of them), appear to be predominantly animal origin (Nationaal R en D programma, 1976)

CASE STUDIES

In order to illustrate the possible influence of cattle breeding farms we undertook some case studies.

Water samples were taken upstream and downstream from brooks alongside large farms, and analysed monthly. All these farms are situated in the abovementioned Ijzer basin (Figure 4).

The relative importance of these farms is as follows:

Points 2 - 2': 100 pigs
5 - 5': 600 pigs
7 - 7': 1500 pigs
4 - 4': important - exact number unknown.

The mean values of winter and summer are shown in Table 5. The figures for nitrite, ammoniacal nitrogen and phosphate levels are higher downstream than upstream from the farms. This indicates clearly a supply of "fresh" waste products. In this connection there are indications that copper ions could serve as a tracer. The pig excrements are relatively rich in copper (300 - 500 ppm on dry matter). Nevertheless, it is almost impossible to use water analysis for this diagnosis. Preliminary work shows that the copper is rather fixed on the sediments.

With this we must bear in mind that the monthly analysis figures fluctuate widely around the average. With our samples we can only assess a situation at a moment in time. In fact, we ought to collect samples continuously.

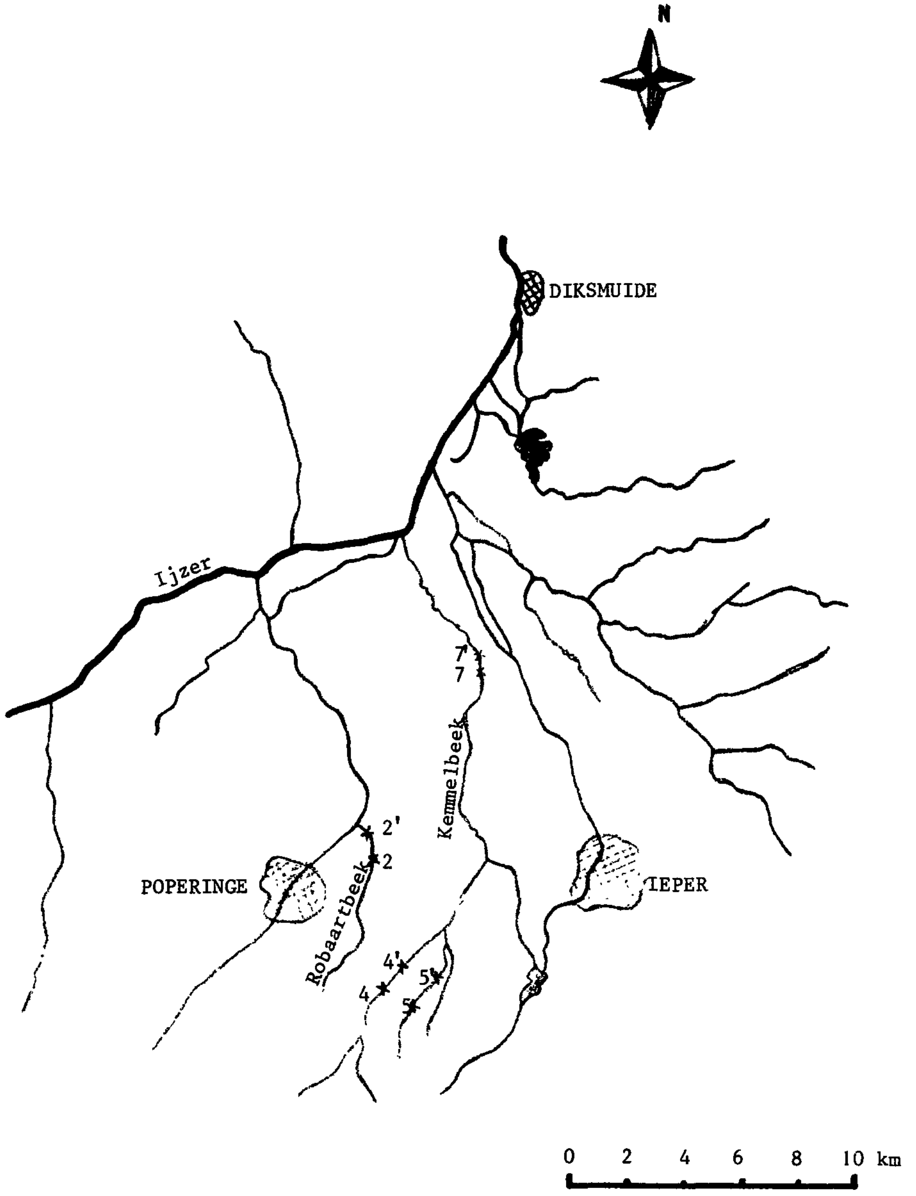

Fig. 4 Ijzer Basin - Case Studies

Moreover in most cases the discharging occurs intermittently as tanks are emptied during the night or during the weekends etc. for the simple reason that discharging such waste products is, in any case, illegal.

These factors also mean that the importance of the pig farms is not reflected in our analysis results.

TABLE 5

ANALYSIS RESULTS OF SURFACE WATERS UPSTREAM AND DOWNSTREAM OF PIG FARMS - SAMPLING PERIOD 74/75. mg/l.

Sampling sites	NO_3^-		NO_2^-		Amm.N		Tot.P as PO_4^{3-}	
	W	S	W	S	W	S	W	S
2. Robaartbeek								
Upstream	51	41.5	0.6	0.8	1.6	6.3	14	17.5
Downstream	50.5	37.3	0.6	1	2.3	11.8	18.5	15.2
4. Upper Kemmelbeek								
Upstream	-	38	-	0.5	-	1.5	-	11.3
Downstream	-	31	-	1	-	1.9	-	14.3
5. Rozenhilbeek								
Upstream	-	39.3	-	0.5	-	0.6	-	9.3
Downstream	-	45.6	-	0.7	-	3.4	-	11.4
7. Kemmelbeek								
Upstream	50.5	27.8	1.1	1.3	2.5	6.4	34.6	14
Downstream	51.5	35	1	1.4	2.6	8.5	45	18.7

DISCUSSION AND CONCLUSIONS

One cannot deny that the discharges of intensive cattle breeding farms have a significant influence on the eutrophication of surface waters. However, one will never be able to determine the exact contribution of livestock breeding to a real existing state of pollution. Too many factors are involved. For example, in the case of the Ijzer basin these factors are:

a) A slight drop and a complicated water-network which make it very difficult to obtain an idea of the water flow.

b) A strongly marked dispersion of the cattle breeding farms that makes a control almost impossible and, to some extent, a lack of collaboration during the inquiry.

c) Interfering sources of pollution.

In general we think that the problem of the eutrophication of the rivers flowing through a mainly agricultural region cannot be solved immediately.

In any case, the direct discharging of livestock effluents in surface waters cannot be allowed, in which case there are two possible solutions:

1) A waste water treatment plant
This immediately raises the problem of where it will be installed. Near the farm means a spreading of the investment and working costs - the latter, especially, will be high because the purification has to be done to the 3rd degree in order to remove the excess of nitrates and phosphates. Furthermore, the efficiency of such a treatment is not what it should be. An alternative solution is a centralisation of the waste water treatment, but then transport becomes the major problem. In any case the treatment will be too expensive. In view of these considerations one can ask if our small scale breeding farms are not doomed to disappear to make room for large industrialised farms, which will be able to absorb the costs of a purification plant.

2) Landspreading of livestock effluents
In the regions where we have an important surplus of animal wastes it seems that the only possible solution is to spread them on the cultivated soil and on the grassland. The direct influence on the soil, the crops and indirectly on the surface water through runoff and infiltration cannot yet be foreseen. Anyhow, it seems to us that there is no general solution for the landspreading of animal wastes. It will always be necessary to examine the local situations such as crops, nature of the soil, rainfall, etc. The data of these case studies could eventually serve to make a mathematical model based on most of the principal parameters.

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TRANSPORT OF MANURE AND THE FUNCTION OF THE 'MANURE BANKS' IN THE NETHERLANDS

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Quite a considerable number of farmers have an income from the so-called intensive livestock production. The technical development in housing systems, manure removal and feeding equipment made it possible to enlarge the number of animals per unit and per man. For the near future it must be expected that the number of animals per farm will increase.

From the point of view of building and labour costs most of the livestock operations in the Netherlands use a slurry system for managing their animal waste. The difference in cost between a housing system with liquid waste handling in comparison with a housing system where the wastes are handled as solids, is considerable.

Nevertheless, disadvantages of handling waste as a liquid can also be mentioned, particularly the offensive odours which develop during storage and spreading, and the transport costs.

Some years ago the problems in the Netherlands were the manure surpluses caused by regional concentration of the livestock operations. These are found mainly in the middle and the south of our country.

MANURE BANKS

Transport of liquid manure to arable farms is one of the possibilities for using the manure of the larger livestock operations. Some years ago there was hardly any interest in using liquid manure on arable farms because of the fact that artificial fertilisers were cheap and could be used without causing bad smells. Under these circumstances the 'manure banks' started their work, which mainly consisted of:

a) Improving liquid manure transport, especially over greater distances

b) Liaising between livestock units and arable farms which were interested in using liquid manure

c) Advising about the correct application of liquid manure.

In three provinces of the Netherlands manure banks are working at present. To stimulate the transport of liquid manure a state aided regulation through the 'Developing Fund for Agriculture' has been made for the 'take-off' of these 'manure pools'.

As stated before, the manure banks are not transporting or handling any slurry themselves, they have only an intermediate and stimulating function. Through the organisation of the manure banks very large quantities of slurry have been transported in recent years. This is demonstrated by the figures given in Table 1.

TABLE 1

THE QUANTITIES OF LIQUID MANURE TRANSPORTED BY MEANS OF THE MANURE BANKS

Manure bank	Quantity of slurry in m^3	
	1974	1975
Gelderland	68 676	215 661
Brabant	24 178	80 939
Limburg*	20 035	119 354

*This manure bank commenced activities in April 1974

These large quantities have mostly been transported to arable farms where they have been used for land application. There are some factors which played an important role in this development, namely:

a) The recent price increase of artificial fertilisers, particularly nitrogen and phosphate

b) The increase of transport capacity which is used for slurry, especially with regard to transport over longer distances

c) The solution found for semi-permanent storage of slurry in the form of a ground pit covered with a plastic sheet.

The manure banks have, until now, had the possibility of giving a certain amount of slurry per m^3, which is mostly used on arable farms.

Depending on the manure bank, about 55 - 75% of the quantities of slurry transported, as given in Table 1, is over distances ranging from 8 - 20 km. The manure banks expect that the livestock operations in their immediate vicinities will not be able to use more than the present rates of slurry in the future. It appeared during the last two years that farmers were prepared to pay 30 - 50% of the fertiliser value of slurry. This fertiliser value, or course, depends largely on the type of slurry which is used (particularly of poultry and pig slurry), the dry matter content and the time of application. The value varies from Dfl 7. to 20.

TRANSPORT OF LIQUID MANURE

The transport of slurry from the livestock production unit to a farm where it is used for land application is a rather costly affair. Two factors are important in this, the road speed of the tanker and its loading capacity. Particularly in the provinces of Limburg and Gelderland an increase in the total transport capacity with the use of quite large tankers, or a combination of tanker and trailer, has taken place. For distances over 25 - 30 km tanker combinations with a capacity of 30 m^3 or more are generally used. As an example, the transport costs are about Dfl 8.50/m^3 for a transport distance of 50 km. The slurry normally brings no money to the livestock enterprise; the arable farmers pay the transport costs to the transport contractor.

It is important for the livestock production units to have enough storage capacity for the slurry. Slurry pits should also be easy to reach with the big tankers. The maximum transport distance between a livestock production unit with a surplus of slurry and an arable farm which can use this slurry for land application, is determined by plotting the fertiliser value of the slurry against the transport costs per m^3 per km.

STORAGE OF SLURRY

In order to obtain good organisation of the transport of slurry over longer distances a semi-permanent or intermittent store is necessary. From the point of view of the periods when land application of slurry on arable land is possible, this storage is attractive too. The filling of such an underground pit is done by a large tanker combination from a central point outside the storage area. This point is connected to the centre of the store by means of a 6" or 8" pipe. The spreading of the slurry stored in the pit takes place when there are no crops on the land, by means of slurry spreaders having a 3 - 8 m^3 loading capacity. Storage and spreading are paid for by the consumer of the slurry.

The investment costs vary, depending on the ground water level and storage capacity, from Dfl 8. to 10. per m^3 of storage. In comparison with the investment needed for concrete or steel storage tanks, the building costs for these ground pits are relatively low. In the Netherlands about 40 of these storage pits with a capacity of 1000 - 2500 m^3 have been built on arable farms.

A combination of good transport equipment, sufficient storage capacity on the livestock production unit and intermittent storage pits on the arable farm, are important factors for the transport of slurry over longer distances.

FUTURE RESEARCH

Some points for future research should be:

a) To develop a practical method for controlling the quality of the slurry in order to reach a more uniform application of the slurry on the land

b) Developing and testing of mixing equipment in the storage pit.

SUMMARY

The manure banks in the Netherlands have an important function in stimulating the land application of slurry on arable farms. In combination with the availability of the right transport equipment and storage capacity on the arable farms, land application has increased very much during the last two years. Slurry is no longer considered as a waste but as a valuable fertiliser.

DEGRADATION AND INCORPORATION OF NUTRIENTS FROM RURAL WASTE WATERS BY PLANT RHIZOSPHERE UNDER LIMNIC CONDITIONS

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The concentration of financial power in urban and industrialised regions as well as the concentrated output of waste waters within a relatively small but densely populated area create conditions for the application of intricate, expensive and effective technologies in waste water treatment. From this point of view the waste water problems in the urban and industrialised districts may be solved much more easily than in rural zones.

Installation and management of modern and effective purification plants cannot be provided for in those areas where the high specific costs of modern, but miniaturised purification plants cannot be met.

Consequently many people all over the world have begun to regard the less crowded rural regions as the most problematic areas as far as waste water pollution is concerned. This might be true not only for countries with a lower standard in industrialisation but also for many regions of highly developed and industrialised countries. Therefore alternative and cheaper technologies have to be investigated and introduced.

The following report describes a model for waste water treatment in a rural district, which has worked sucessfully in Western Germany since January 1974.

The district of Liebenburg (Western Germany) situated near the Harz mountains, was created by an administrative act in 1972. It consists of the district capital, Liebenburg-Othfresen; a dozen little villages; a few hamlets and a lot of isolated houses. 20 000 inhabitants live and work here in an area of about 80 km^2. The district is divided by the Salzgitter Hills into a smaller area of a more urban character and a larger area of about 50 km^2 and 8 000 inhabitants, which is characterised by farms, villages and small-scale industries, e.g. factories for meat and dairy products. There is a modern waste water purification plant on the eastern hillside in the urban area, whereas the waste waters of the western, rural part were being discharged without purification into a small, nearby river, the Innerste. This river and its surroundings are very popular with fishermen, holiday makers and campers and are therefore of some economic importance. The permanent discharge of untreated waste water led to an increasing pollution of the river, by which fishing, swimming and recreation was handicapped severely. Therefore the municipalities began to consider a central junction and a satisfactory purification system for the waste waters from this area.

The district itself has been a centre of mining activities for centuries, especially in the years from 1935 to 1945, when the German ordnance industries were supplied with the very poor iron ores found and enriched here. When the war was over, the import of better ores from foreign countries began again and the mining activities in the district were stopped for economic reasons in consequence.

Many buildings, industrial equipment and workers houses were left from that time and also a series of large, or very large ponds, where the washing waters of the ore concentration process were collected and cleansed of clay, silt and sand particles before they were discharged into the river. In consequence these ponds filled up with sludge very rapidly and were subjected to a rapid process of desiccation, when water discharge ceased. There is no hydrological contact with the environment, and the ponds are not replenished by any water now except rainfall in a range of about 700 mm per year. Moreover, a dense vegetation of reed accelerates the desiccation due to its very high evapotranspiration which normally exceeds 1 100 mm per year. Today the former ponds have very small areas of open water, if any, whereas the margins have been penetrated by plants, which like dry conditions, e.g. *Rosa canina*, *Rubus sp.*, *Hippophae rhamnoides* pines and a lot of annuals and perennials. Within the limnic parts a very rich and interesting fauna and flora has developed and wildlife conservationists consequently became interested in these biotopes. Some of them have been taken under governmental protection.

The intention to keep them as limnic biotopes, might nevertheless be impossible because evapotranspiration exceeds the average rainfall by more than 400 mm per year and therefore the desiccation of the ponds is progressing rapidly.

From this situation the idea has emerged of overcoming the water deficiency of these biotopes by discharge of waste waters into these areas and to purify and polish them here.

The first attempt, a direct discharge into the residual open waters was soon abandoned because the capacity of the lagoons was not sufficient to guarantee a satisfactory process. On the other hand it seemed to be undesirable to discharge the polluted water into the intact centre of the limnic biotope immediately. Ultimately the project was realised in another way by selection of a nearby pond with a total surface of 21 ha. This is situated near National Highway 6 from Salzgitter to Goslar. The shape and state of this pond is represented by Figure 1.

The larger part of the total surface is a terrestrial biotope which tends to dryness, a smaller part is covered densely with *Phragmites vulgaris L.* and may be regarded as a limnic biotope, although very small areas of open water are present. Their areas depend on the abundance of rainfall.

The surface of the pond shows a slight inclination from east to west. This is due to the former discharge of very concentrated sludges; in the same way, two little cones of deposits have been formed on the eastern side.

Saline waters had been used for the transportation of the

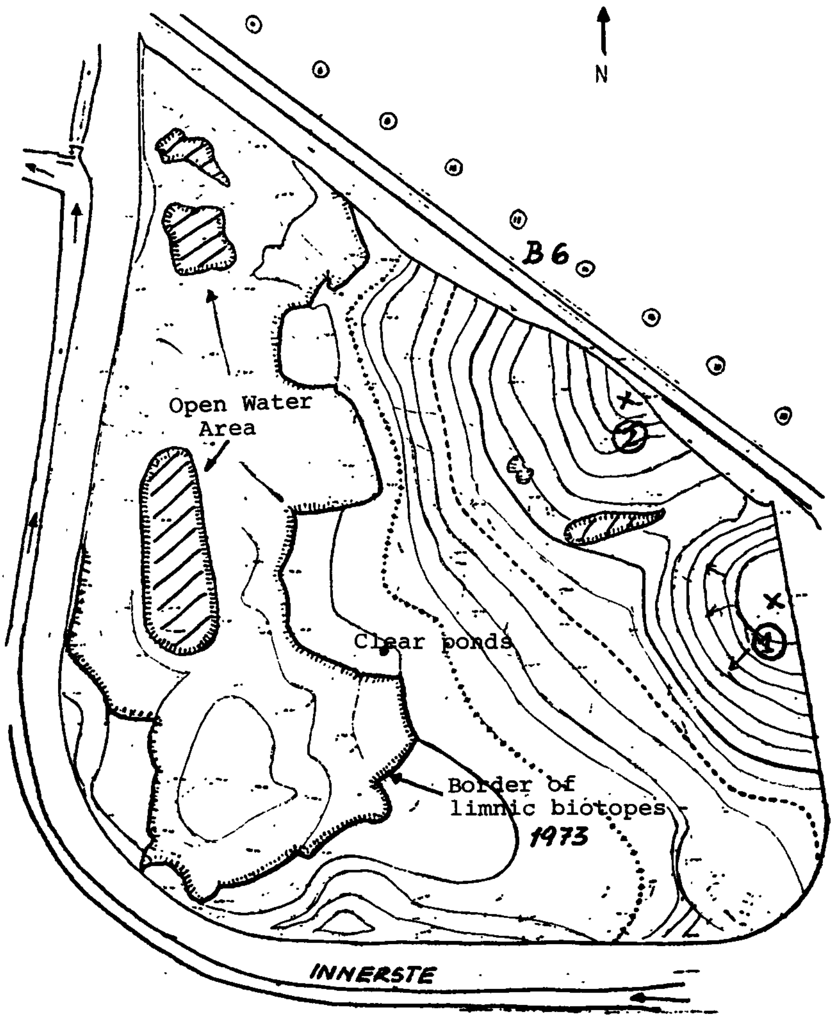

Fig. 1. Purification pond near National Highway 6. State in 1972.

clay and silt. Therefore the very fine material was further dispersed and there was no water percolation from the surface into the deeper soil except in the upper root-zone of the *Phragmitetum*, where the soil is rich in organic matter and made friable by root activity.

These are just the right conditions in which to carry out a very effective waste water purification with much better results than in the most complex purification plant anywhere. The purification process is completely compatible with the ecological situation of the biotope and with the intentions of wild life management. The principle of the process is not the well known elimination of impurities by soil irrigation or infiltration nor the uptake of nutrients and organic material by plants as described by Seidel and others, but it is due to the specific metabolic capacities of rhizosphere organisms associated with the roots of *Phragmites*. This effect was studied by our group for more than fifteen years in laboratory and pilot plants before it was transferred to practice. The action of the rhizosphere, by which the majority of organic compounds, phosphorus (by forming phytines) and nitrogen (by excessive denitrification) are removed, is accompanied by other processes such as:

a) degradation of organic impurities by free living soil and water micro-organisms.

b) ion exchange with humic matter and clay minerals followed by interlayer binding of ammonia and potassium.

c) fixation of phosphates by iron- and alumina-oxides.

d) uptake of nutrients by plants followed by incorporation of nitrogen and phosphorus into humic acids post mortem.

At the present time the waste waters of 3 000 inhabitants are collected by a pipeline, freed from coarse impurities by a rake, pumped over distance of 1.7 km to the pond and discharged from the hills on the eastern border into the root zone of the dry area by means of an infiltration ditch (50 m length). Thus, over a period of 24 hours 300 m^3 of waste waters are discharged intermittently. The disposal waste water from another 5 000 people has been provided for within the next three years. The maximum capacity of the area without creating ecological implications has been calculated at 18 000 persons. On the basis of available capacities for binding in phosphates, ammonia and potassium the area will keep its function for 5 000 years! The present emission of water (about 100 000 m^3) makes up the water loss due to evapotranspiration.

Along a gradient of about 80 m the waste waters are completely freed from all impurities. Effluents, which reach the limnic zone or the open water, could be used as drinking water. Only the sodium and chloride contents are not influenced by rhizosphere processes.

The process and water quality are controlled continuously chemically and biologically by the author's group at Göttingen University and by the Government Water Institute at Braunschweig.

The following figures will reveal some technical and economic details and demonstrate the effectiveness of the procedure, (Tables 1 and 2)

TABLE 1

CONTAMINATED AREA IN RELATION TO MONTH OF DISCHARGE

Contam.	Jan 1974	June 1974	Dec 1974	June 1975	Dec 1975
m^2	0	800	2 500	3 500	4 200
At present (June 1976) the contaminated area covers 4 500 m^2; no further growth can be observed.					

The financial effort has been calculated as 367 000, DM including pipeline, two discharge ditches, soil regulation, fences and a massive building for equipment. Current costs per year for pumping, repairing and supervising amount to about 20 000 DM including the cost of chemical and biological

TABLE 2

ANALYTICAL RESULTS (TYPICAL DATA)

Local.	Total-N	Total-P	BSB_5	Chloride	Potassium
1.7.74	mg/l	mg/l	mg/l	mg/l	mg/l
Start	59.9	19.1	765	104	9.8
70 m 80 m 90 m 100 m	7.1	0.4	23	81	2.3
11.11.74					
Start	53.2	15.0	580	110	7.4
90 m	8.0	0.4	22	85	2.0
7.2.75					
Start	54.1	13.9	455	-	8.9
100 m	0.4	0.18	34	-	1.9
25.6.75					
Start	39.2	15.4	470	-	11.0
100 m	0.3	0.07	12	-	4.1
30.10.75					
Start	71.4	19.26	648	-	15.6
100 m	1.82	0.028	10	-	4.0

The average reaction rates per year and hectare have been calculated as 136 360 kg BSB; 13 600 kg nitrogen and 4 242 kg phosphorus.

investigations.

In less than two and a half years of waste water discharge, the limnic biotope has become revitalised by water and nutrients and has enlarged its area as may be seen fom the following figure.

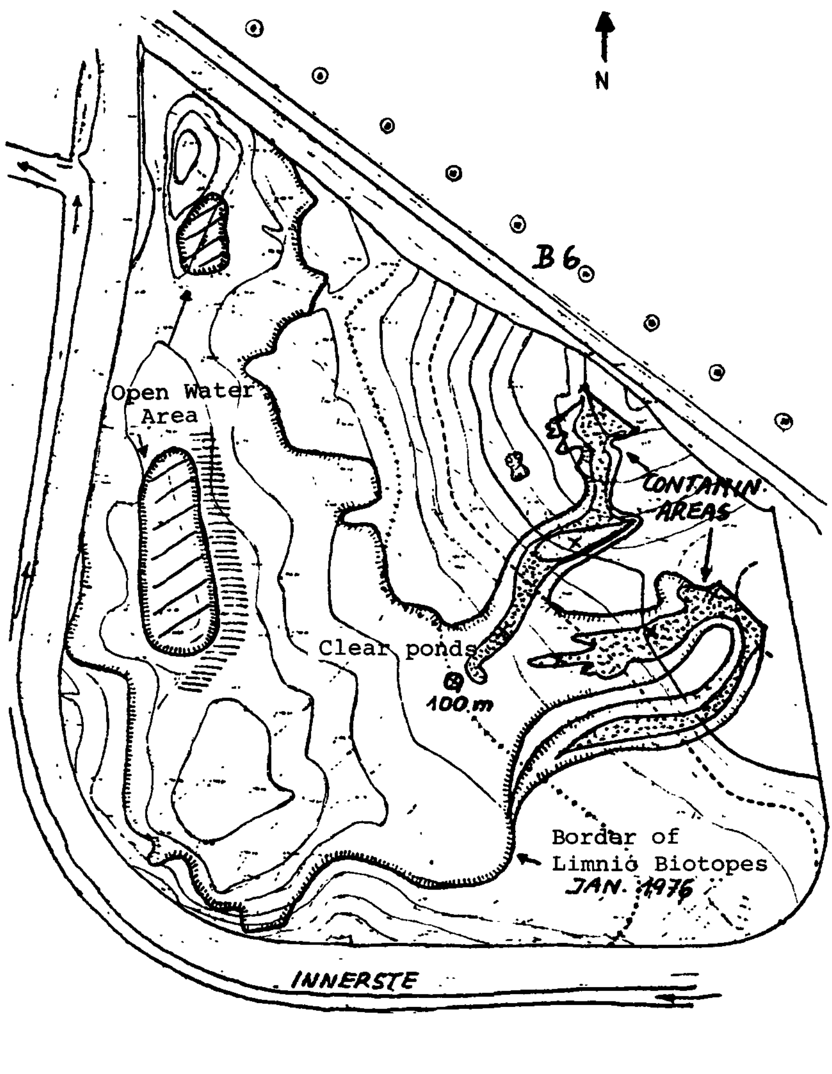

Fig. 2. State of the Purification Pond in December 1975.

DISCUSSION

A.V. Dodd *(Ireland)*

I would like to have some more information from Dr. Jongebreur on the manure bank and then make some comments of my own.

The first thing that struck me was how do you ensure quality control coming both from the livestock producer and to the consumer? On what values of N, P and K and on what application figures do you arrive at this cash value? Do you have any problems with such large capacity tanker wagons in segregation during transport? I thought I observed the secondary storage facilities on the consumers' farms to be based on large open tanks. Do you experience any difficulty with the consumer being dissatisfied with the homogeneity of the manure as spread on the field? In other words, does he have to invest in expensive equipment to agitate this particular shape of tank? Do you build them overground or underground? In either situation do you line them and if so, why?

A.A. Jongebreur *(The Netherlands)*

Your first question refers to one of the problems; the manure banks have now to control the quality of the slurry. Up until now we have no very simple method of quality control. We are doing some research on it and we are also considering the use of Dr. Tunney's hydrometer as a simple method of quality control. We know that at the moment the quality of the slurry varies considerably. The arable farmers do need to have a good quality slurry but as yet we have no simple method of measuring it.

Regarding your question on segregation of the slurry during transport, I can tell you that we have no problems here using the big tank wagon combinations.

Your next question was about agitation of the slurry before use. We have built a lot of large storage pits with a capacity of above 2 500 m^3 and so in future I think it will be necessary to agitate the slurry in order to get homogenised slurry on the land.

The last question was on the building of the storage pits. We dig out the pit and the soil is used as a dyke round the pit; it is piled up at an angle of 45^o and then covered with a plastic sheet. A fence is placed round the ground pit. The pit is built at a maximum of 75 cm below the highest ground water level.

C. Tietjen *(West Germany)*

I have a comment and a question on this topic.

According to your paper you distinguish between pig, cow and chicken slurry with regard to quality and you take account of the DM content. These are already good parameters for quality; the next step would be much more expensive and would endanger the efficiency of this procedure. My question is, how many hectares are now supplied by, or with the help of, the manure banks? Your figures go up to about 500 000 m^3.

A.A. Jongebreur

I don't know this exactly because there is no control on the quantity of slurry which is used per hectare. The manure banks issue recommendations on quantity but they cannot be sure that these recommendations are adhered to by the farmers.

C. Tietjen

Of course this would be the next step in control, when you speak of quality, DM content and quantity applied on the field.

P. Graffin *(EEC)*

Who pays the transportation costs? Also, I understand that the farmers pay a certain price for the manure, on what basis is the cost calculated?

A.A. Jongebreur

The transportation costs are paid by the consumer but the farmer gets a small subsidy from the manure bank for using this slurry. Prices are calculated mostly in relation to average prices for pig, dairy cow and poultry slurry, taking into account the quality of the slurry used. Poultry slurry commands the highest price.

D. Strauch *(West Germany)*

Are there any precautions to avoid the spread of disease through transportation of manure from one part of the country to another?

A.A. Jongebreur

No, there are no such precautions except when there is a question of some highly infectious disease. In that case I think it will be prohibited to transport the manure from the livestock operation unit to arable farmers because the Agriculture Mechanisation Enterprises visit every livestock production unit. In the Netherlands we feel we have no reason to say that there is a risk of spreading disease.

D. Strauch

How about salmonellosis?

A.A. Jongebreur

I don't exactly know.

J.H. Voorburg *(The Netherlands)*

There is a guideline and we are not worried about the risk of spreading disease if we spread the manure on arable land before ploughing. Of course you must prevent losses of manure.

J.S.V. McAllister *(UK)*

Must it be spread on arable land, in fact? Is there anything to stop the consumer putting it on grassland?

A.A. Jongebreur

It is not always spread on arable land, it is also possible to spread it on grassland but it is not done very often.

L. Lecomte *(Belgium)*

May I ask Dr. Kickuth, what do you do with the plant growth in your ponds?

<u>H. van Dijk</u> *(The Netherlands)*

And the phosphate deposits?

<u>L. Lecomte</u>

Another question, maybe this is for the Chairman, could we please have an opportunity to see Dr. Kickuth's slides?

<u>J.H. Voorburg</u>

I can give a positive answer; I was ready for that question. I will ask Dr. Kickuth to show his slides afterwards.

<u>R. Kickuth</u> *(West Germany)*

Really we do nothing with the plants at the moment - and we should not do anything. In former times a concept existed of so-called 'hydro-botanical' steps in purifying water. The basic meaning of this concept is that plants take up phosphorus, nitrogen, and so on, then when they are harvested this material is removed. The role of the plant in taking up nitrogen and phosphorus in this process is a very minor one, about 5% and 2% of the total uptake. The main effect is that of the special micro-organisms in the rhizosphere. There the phosphorus is found primarily as phytates and after that converted to iron phosphates. In the lake I have mentioned there are large amounts of iron oxides from the former mining activities there. Also the phytates are very slowly remobilised under these conditions. We have tried it under experimental conditions in the laboratory but what the plants take directly is very little.

<u>H. Laudelout</u> *(Belgium)*

I understand the whole process very well provided you have a sufficient amount of iron in the silt but what happens with nitrogen in that specific case?

<u>R. Kickuth</u>

As far as we know up to 70% of the nitrogen is lost by denitrification; the rest is built in, half into the organic matrix which is formed in this biotope.

(At this point Dr. Kickuth showed his slides)

R.G. Gerritse *(The Netherlands)*

Dr. Kickuth, I am interested in the phosphorus cycle in the soil. You say that in the rhizosphere the majority of phosphorus is removed in the form of phytates. Have you established this thoroughly? Have you analysed the organic phosphorus and established that it is phytates? This surprises me because in the micro-biological cycle I have studied in pig slurry I have found that the minority of the phosphorus is phytate whilst you find in the rhizosphere that the majority is phytate. How do you explain this?

R. Kickuth

Yes, you are right. This is indeed a peculiarity of the rhizosphere of one plant which we have found up to now. In this rhizosphere most of the soluble phosphorus is transformed to phytates. We have tested it over ten years, we have isolated the phytates and also made constitutional elucidation.

R.G. Gerritse

Have you published a paper on this work?

R. Kickuth

I think we have published one or two papers.

P. Graffin *(EEC)*

What is the composition of the water used, roughly?

R. Kickuth

The composition is between 50 and 100 mg total N/l, between 10 and 25 mg/l total phosphorus. Loading of BOD - between 500 and 1 000 mg/l. In addition there is a loading of potassium of about 50 - 55 mg/l; sodium around 50 mg/l and chlorides about 100 mg/l.

J.H. Voorburg

I think it is shown in your Table 1.

H. van Dijk

I would like to make a remark in connection with what Dr. Jongebreur has said about future research. Homogenisation of the material is a major problem. I think we will have some papers on the subject tomorrow. The solution might be a separation into a homogeneous dry product for compost and a homogeneous liquid, maybe mechanical separation. I would ask this audience here whether anyone has experience with these trade products regarding biological homogenisation of the materials and can tell us that they really do the job claimed in the advertising? Do we get homogeneous material which does not settle?

J.H. Voorburg

Does anyone want to comment on this? I guess tomorrow we will get an account on the separation from Mr. Hawkins.

A.V. Dodd

It occurs to me that rather than spend time on trying to devise a means to homogenise the secondary storage tanks, it might be more prudent to look at the idea of eliminating all secondary storage tanks and provide a central store from which manure could be drawn as required. I am a little uneasy about the idea of these 2 500 m^3 capacity tanks in a situation where one might have 600, 700 or even 900 mm of rainfall per annum. It seems to me difficult to envisage a machine capable of homogenising such volumes under such conditions. After all, the arable farmer, or the consumer, is really only concerned with the cash value of the material he spreads, rather than what he buys.

A.A. Jongebreur

On the point of agitating the slurry, I can tell you that we are doing some research on homogenisation of the slurry to develop some equipment which can be used by contractors and which will agitate the slurry in the ground pits. With regard to your idea of central storage tanks, we have not considered this but I think it would create a problem of organisation.

At present the storage pits are built by the arable farmers and if you relied on a central storage pit I don't think it would cost any less.

A.V. Dodd

That depends on the size and form. I noticed you gave a figure of something like Dfl. 8 - 10 per m^3. I found this remarkably low and certainly a figure unattainable in my experience in Ireland. Perhaps you have some other explanation for it. I looked at the figure for transport; I presume that means Dfl. 8.50 m^3.

A.A. Jongebreur

Yes.

A.V. Dodd

I did find your cost of construction remarkably low.

A.A. Jongebreur

Yes, it is low but I think when you are building a large ground pit it can be done very cheaply. The cost of the plastic sheets is very low, about Dfl. 5 - 6 per m^3. When the ground is dug out by a contractor it is also very cheap.

A. Dam Kofoed *(Denmark)*

Last winter was mild; have you any experience of what would happen in a hard winter?

J.H. Voorburg

No ... we did not have hard winters!

G.J. Kolenbrander *(The Netherlands)*

Dr. Jongebreur, the prices you mentioned for solids and for slurry, are those the prices of the labour only or do they also include the equipment?

A.A. Jongebreur

The difference in yearly cost is made up of the yearly cost of the buildings, the yearly cost of the mechanisation, also the mechanical removal of the slurry and the cost of building the storage facilities of solids. So it is labour and building costs on a yearly basis.

G.J. Kolenbrander

When you speak about solids, does it mean a separate storage of solid manure and liquid manure?

A.A. Jongebreur

Yes.

G.J. Kolenbrander

Following on from that, I wonder if it is right to compare these two systems only on the cost at the farm. I think you should also take into account that perhaps some of this manure has to be transported, not the slurry but the solids. Then the problem is a nitrogen, phosphorus or potassium one. Perhaps a farmer can use liquid manure with nitrogen and potassium on his own fields and transport the solids away. You don't need it in a pit on arable farms. You can transport the manure in big trucks and put it on the fields which need fertilising. This gives a better total cost for slurry than for solids.

A.A. Jongebreur

It is very difficult, you nave to look at it from two angles, from the point of view of the arable farm and the transport costs and from the point of view of the livestock production units. We have to see that the choice between the slurry system or the solid system is made from the point of view of the livestock production units. It is a complex situation.

J.H. Voorburg

I propose that the discussion should continue informally this evening because we have no more time now.

THEME 5

VETERINARY ASPECTS OF LANDSPREADING OF MANURE

Chairman: D. Strauch

VETERINARY-HYGIENIC ASPECTS OF LANDSPREADING AND TRANSPORT OF MANURE

D. Strauch

Institute of Animal Medicine and Animal Hygiene,
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Hygienic problems involved in the application of animal wastes to land must be considered under two aspects:

a) Major problems in epidemiology of infectious diseases.

b) Hygienic problems involved in animal husbandry, in general, many of which are closely associated with environmental hygiene.

INFECTIOUS DISEASES

Epidemiological problems centre upon identification, the utilisation of factors inhibiting infections within the agricultural establishment and the prevention of contributing factors, the protection of rural animal husbandry against the danger of infection resulting from large animal confinement, and the protection of the general public against zoonoses or health hazards due to residues of drugs, active agents, additives as well as therapy-resistant micro-organisms.

Epidemiological problems involved in large animal feedlots are closely associated with those of animal waste disposal. Incidence of latent infections increases when animals of homogeneous populations are concentrated in confined areas. Most infected animals eliminate the pathogenic agent by way of faeces, urine etc., so that germs ultimately come into contact with the floor of the buildings. That many pathogens are excreted is shown by numerous studies; among others, the results of several studies in Romania (Tomescu et al., 1974) in piggeries with a yearly production of 100-150 000 fattening pigs. From seven piggeries 159 samples of effluent and sludge were examined. The total bacterial count varied between 7×10^6 and 3×10^{11}/ml, the total *E. coli* count from 15×10^6 and 6×10^{11}/kg. 142 strains of *E. coli* with pathogenicity for man and animals were isolated and belonged to 23 different sero-groups and -types. 106 strains of salmonella were isolated which belonged to 12 sero-types with the following diminishing frequency: *S. derby, S. anatum, S. münchen, S. heidelberg, S. meleagridis, S. panama, S. senftenberg, S. manhattan, S. enteritidis, S. morbificans, S. panama type Z, S. infantis*. 32 strains of leptospira from the type *L. pomona* and *L. tarassovi* were also isolated. These results show that the raw and partially treated sewage from animal confinements possess a high potential of micro-organisms which are pathogenic for man and animals. These findings could easily be multiplied by the results of other authors all over the world.

CONVENTIONAL WASTE HANDLING

Conventional livestock units where bedding is used do not cause a special epidemiological problem because if proper management procedures are carried out, dung heaps develop such high temperatures as to destroy pathogens that may be present. The safety of this procedure is demonstrated by its being stipulated in many countries in the official provisions of dung disinfection for the control of notifiable infectious diseases, in terms of the so-called dung packing. After three weeks the dung is considered to be disinfected and can be used for agricultural purposes.

LIQUID WASTE HANDLING

Both large animal units and modern rural livestock management have inevitably brought about new housing systems for rational reasons. Straw for bedding is no longer being used. Animal excreta are generally collected jointly in liquid form, the so-called 'liquid manure'. This mixture of urine, dung, forage remains and splashed water is also called slurry. It is either collected and stored within the animal building or it is drained off the building and kept in under- or above-ground reservoirs until it is used. No matter what handling and storing methods are used, spontaneous generation of heat that could entail the destruction of pathogens will not occur in this medium either in summer or in winter.

Self-disinfection

A possible method would consist in awaiting a sort of self-disinfection of the slurry during storage. Pertinent laboratory experiments and others performed in practice in farm liquid manure pits have shown, however, that these expectations are not realised. In fact, salmonella or stable forms of parasites, remain alive in liquid manure both in summer and in winter over many months. Figure 1 shows the findings of laboratory tests which indicate that the viability of salmonella can be nearly one year in winter (8^{o}C) and approximately six months in summer (17^{o}C). Experiments carried out in farm liquid manure pits corroborate these findings. Survival times obtained in practice were slightly reduced to 286 days. The marked differences between summer and winter storage periods in this test were not as distinct as in the laboratory one (Strauch, 1976).

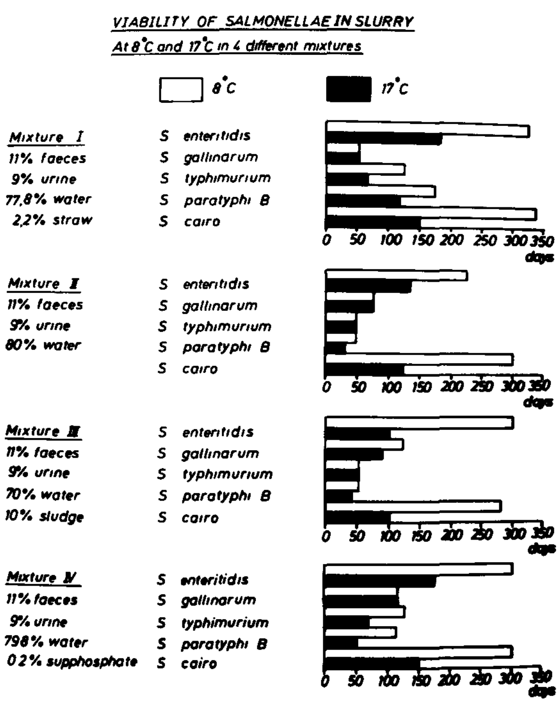

Fig. 1. Viability of Salmonellae in slurry in a laboratory experiment

Other pathogens with a viability of several months' duration in this medium are in part the viruses, especially if they are enclosed in tissue or in faecal segments. Most farms do not have enough storage capacity for slurry over many months. The average storage time for slurry is usually one to three months.

Figure 2 shows that there are seven direct and indirect ways by which animal excreta pass not only to man but also to other animal production units. Successful prevention of infection is only possible if these ways can be blocked efficiently. In view of the many ways of disease transmission shown in Figure 2, a great number of measures would be necessary to block all ways of transmission unless epidemiological measures are launched before germs are released into the environment. This should be done at the animal production facility.

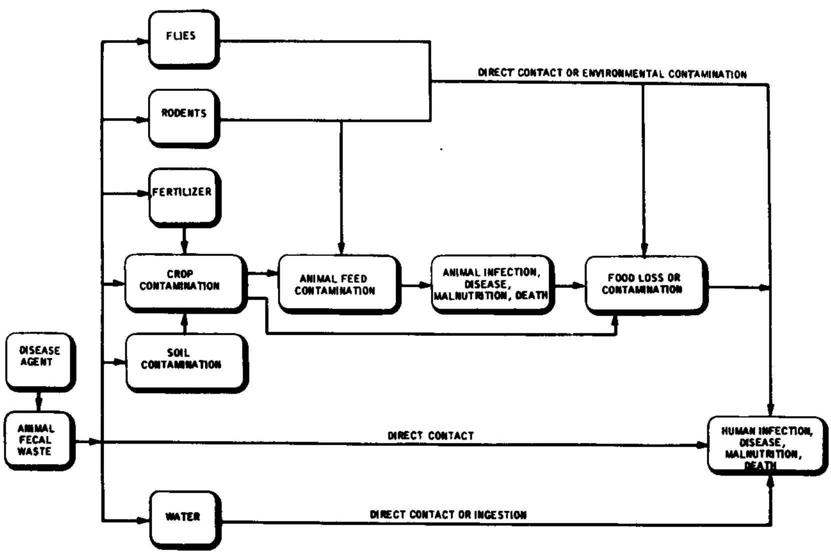

Fig. 2. Animal faecal waste/disease relationships (postulated).

That a hygienic treatment of infected slurry is necessary can be proved by a number of cases in which transmission of infection after spreading of slurry to pastures has been observed.

In Germany a severe salmonella outbreak in a dairy herd with 50 cows was reported (Münker, 1965). 6 sero-types of salmonella were isolated: *S. stanley, S. typhimurium, S. heidelberg, S. braenderup, S. london and S. uganda.* The source of infection was meat meal from a rendering plant. The same salmonella could be found in the three slurry pits as well as on samples of soil and grass of the pastures which were manured with infected slurry during winter two months before the samples were taken. Thus a cycle of infection in this farm was built up. Even after the feeding of meat meal was stopped and all infected animals were eradicated, salmonella could still be isolated from the slurry.

In England, an outbreak of *S. typhimurium* infection in cattle grazing on a pasture which had been irrigated with slurry three weeks before, is described (Jack and Hepper, 1969). *S. typhimurium* was isolated from the slurry system and from four carrier cows after the outbreak.

These observations are in line with investigations in England, Northern Ireland and New Zealand (Taylor and Burrows, 1971, Taylor, 1973, Stewart, 1961, Tannock and Smith, 1972). Slurry, contaminated with either *E. coli* or *S. dublin* , was applied in England to growing pasture under varying climatic conditions. Survival was measured by daily assessment of the number of viable organisms per gram of grass or soil. It was found that under the conditions of the test *E. coli* survived 7 or 8 days. *S. dublin* persisted for 18 days on the lower levels of grass and up to 12 weeks in the soil. When the grass was cropped, however, no recoveries were made after 7 days. An assessment was made of the palatability for calves of slurry-polluted pasture. Calves were allowed to graze a pasture, half of which had been heavily polluted with slurry. For two days they rejected the polluted area but by seven days had grazed it well. Calves that grazed pasture to which 10^6 *S. dublin* /ml of slurry had been applied on the previous day became infected, but no cases resulted when the contamination rate was reduced to 10^3/ml.

In Northern Ireland *S. typhimurium* survived in three different soils for 159 days and in another one 110 days. According to these results salmonella can survive in the surface layers of the soil for over 3 months even when exposed to winter climatic conditions. It is evident from this preliminary work that soils constitute a large potential hazard as vectors of salmonella from animal to animal on the farm.

In New Zealand enumeration of salmonella on inoculated plots containing soil or sheep faeces under various climatic and environmental conditions, suggest that survival is greatest (18 weeks) when the organisms are in contact with organic material. Surprisingly the survival time in the summer period was longer than during winter.

If those cases are added in which animals were infected by sewage and human excretions then it is clear that all infected excretions possess a high infective potential (Bicknell, 1971, Hensel and Frerking, 1964, George et al., 1972).

In one case, *S. aberdeen* was established as the cause of illness in 30 out of a herd of 90 milking cows. The illness was only moderately severe and all animals responded to treatment. The source of infection was human sewage effluent overflowing onto grazing land. In another case a cow aborted caused by *S. paratyphi B* which was transmitted by an infected woman who took care of the cow. In England another case of paratyphoid B infection in cattle is described. *S. paratyphi B* caused generalised subclinical infection of cows and cases of human enteric fever at a dairy farm. The cattle were infected from a stream receiving the sewage effluent of a village in which a chronic carrier lived. At the same time as the farm outbreak a waterborne outbreak of paratyphoid fever occurred in villages several miles away. The water supply was chlorinated and no failure of its treatment had been detected. *S. paratyphi B.* was isolated from the septic tank of a cottage near the water source and from soil over a break in the effluent pipe. Several inhabitants of the cottage worked at the infected dairy farm and one showed serological evidence of the infection.

Another severe case of transmission of salmonella through slurry was reported in Sweden (Hoflund, 1961). In a dairy farm more than 50 out of 96 cows became ill within 3 days during grazing. 20 cows died within 2 days. Bacteriological examination proved *S. choleraesuis* to be the cause of the disease outbreak. The effluent of an infected pig farm *(S. choleraesuis)* had flowed into a dirty pond. From this pond an open ditch had connections with an open ditch system in the pastures of the dairy farm. As a result of heavy rainfall the contents of the pond got into the ditches of the pastures to which the cows had access.

These examples indicate that animal faecal wastes as liquid manure have an epidemiological significance for land disposal which should not be underestimated. That the figures of several experimental studies are also realistic is shown by the fact that as many as 100 000 000 leptospires have been reported to be shed per ml of cattle urine (Gillespie and Ryno, 1963). In acute cases in calves 10 000 000 salmonella organisms per gram of faeces are discharged (Loken, 1967).

In the United States infections with leptospirosis in cattle and swine are common. The most common sero-type infecting cattle is *L. pomona*. Leptospires survive for days to weeks outside the live animal. In recent research leptospires survived up to 138 days in the manure of a field-simulated model of an oxidation ditch (Diesch et al., 1975). These authors also have observed human cases of leptospirosis associated with aerosol-borne transmission from the urine of infected cattle in farmers, veterinarians, packing house workers and hunters. Their quantitative studies indicated that salmonella died (decimal reduction) and leptospires lived or multiplied in the manure slurry environment of the laboratory oxidation ditch. In aerosol studies in the laboratory, leptospires were detected in the air on one occasion and salmonella several times. Leptospires were not transmitted to hamsters by recycled feed that was gathered from the leptospiral-contaminated manure slurry nor were the hamsters infected via aerosols. Salmonella was transmitted to turkey poults by feeding salmonella-contaminated feed and via aerosols. These comprehensive studies are very convincing.

In the United States salmonellosis is one of the major communicable disease problems. There are an estimated 2 million human cases per year. Salmonellosis causes substantial losses to the livestock and the food industry. The cost is estimated at $300 000 000 annually. Salmonellosis is a threat to everyone as a food-borne disease (Diesch et al., 1975).

Summarising, it can be stated that the land disposal of infected animal wastes can result in transmission of pathogenic micro-organisms to man and animals. Therefore it has to be required that spreading of germs via infected slurry must be prevented by on-site treatment of liquid manure by chemical or physical methods.

WATER CONTAMINATION

Even when infected animal slurries are treated by settling out solids, aeration, or sludge drying, pathogens are not eradicated. It is to be expected, therefore, in case of infections of animals in a large feedlot, large numbers of pathogens would be discharged into rivers. It must be added, that in nearly all animal housing, some animals may discharge pathogens without showing signs of infection (Strauch, 1975). Therefore it is expected that feedlot waste waters discharged into river waters will have to be disinfected. Chlorine disinfection is the most common method. When properly applied and controlled, chlorination of waste waters from animal feedlots for disinfection is an effective measure for improving the bacteriological quality of waste water and protecting the human and animal population against transmission of enteric diseases via the water route.

PROBLEMS WITH ANTIBIOTICS

In the early 1950s, the feeding of diets containing low levels of antibiotics was found to increase the growth of farm animals. This was a major breakthrough for commercial animal feedlots. Quite soon, however, it was found that the widespread use of antibiotics for non-therapeutic purposes resulted in the development of micro-organisms which became resistant to antibiotics.

The situation was made worse by the fact that some bacteria became capable of transferring their antibiotic resistance to organisms which had not had contact with these antibiotics.

Although scientists recognise that transmission of drug resistance poses a real threat to disease control in both animals and man, no one seriously recommends that use or production of antibiotics be discontinued. However, transferable resistance cannot be taken lightly. Everybody facing this problem should be aware of the potential hazards of transferable resistance because of the public health implications and because understanding the phenomenon of resistance helps explain why some patients do not respond to the therapy. If transferable resistance proves to be more common than has been shown so far, and there is much evidence that this is so, the discharges of feedlot wastes have to be given special consideration as a massive source of resistant bacterial strains.

Investigations in Czechoslovakia have shown that the surroundings of large animal units show a heavy contamination with all kinds of intestinal micro-organisms and with up to 100% resistant *E. coli* strains. The self-cleaning process of the soil in the surroundings of these farms is considerably retarded so that health hazards to the population living in the vicinity have to be taken into consideration.

It has been feared that the transfer of resistance capability from coliform bacteria to salmonella might be a setback for the control of certain infectious diseases in human medicine. Further tests have shown, however, that transfer in vivo does not occur as frequently as was to be expected according to tests in vitro. In addition, resistant coli bacteria of animal origin have proved not to resist for long the intestinal flora in humans. Therefore it has been inferred that animals cannot be a major source of resistant coli bacteria for man since he is anyway the carrier of antibiotic-resistant coli bacteria of human origin. Only in the personnel of agriculture or slaughterhouses who are professionally in close contact with the animals may resistant strains of coli bacteria of animal origin be found sporadically (Bräuchle, 1971). New substances on the market are reported not to be resorbed, hence will not get into food of animal origin. Manufacturers also claim that these antibiotics do not produce transferable resistance. If this can be confirmed in long-term experiments the problem comes closer to a solution.

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AN APPROACH TO THE PROBLEM OF SLURRY AS A POSSIBLE SOURCE OF PASTURE CONTAMINATION WITH HELMINTH PARASITES OF CATTLE

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INTRODUCTION

The use of slurry as an economic fertiliser is increasing in Ireland and seems likely to expand further. Similarly, an increasing number of cattle are being housed during the winter on slatted floors. This method of housing produces slurry which is applied to swards in the spring, and this may well increase its potential as a source of infection in livestock with helminth parasites. The parasites which might be disseminated by slurry application are gastro-intestinal nematodes (mainly *Ostertagia ostertagi* and *Cooperia oncophora*), the lungworm (*Dictyocaulus viviparus*) and the liverfluke, (*Fasciola hepatica*). The possible role of slurry as a disseminator has so far not been investigated in Ireland and the problem appears to have received relatively little attention in other countries. In Sweden, Persson (1974[1]) cited Nilsson who reported an outbreak of parasitic gastro-enteritis in calves grazing a pasture which had not been contaminated by other cattle, but which had been fertilised with liquid manure. In his own investigations, Persson found that 67% of liquid manure samples collected on farms contained viable trichostrongyle eggs.

SOME APPROACHES TO THE PROBLEM

Slurry as a possible source of helminth infection in cattle can be studied under the following headings:-

a) Survey work to ascertain the occurrence, degree and distribution of contamination/infection in the stored material.

b) Field experiments to determine the capacity of slurry to initiate or augment pasture infection.

c) A study of the viability and persistence of parasites in slurry during storage and following application to land.

d) Investigations of slurry as an infection source in relation to liver fluke, should its use as a fertiliser expand, bringing fluke eggs into snail habitats.

e) An evaluation of sampling procedures.

Should it be found that slurry spreading constitutes a risk of increased parasitic infection, it will be necessary to study ways of overcoming the problem.

PRELIMINARY INVESTIGATIONS MATERIALS AND METHODS

Survey

A limited survey was carried out in March 1976. The survey, mostly of slatted-floor houses, involved ten farms in which one year old cattle (i.e. the previous year's calves) had been producing slurry during the winter. Individual faeces samples were collected from a representative number of these young cattle on each farm. The samples were examined by Parfitt's (1958) method to determine the numbers of 'strongyle' eggs per g of faeces (e.p.g.) On each farm a sample of the slurry derived from these cattle was obtained for parasitological study.

Slurry samples were taken at three depths (c. 30, 90, 170 cm) and from at least five areas of the tank, collecting in all 1 - 2 kg of slurry. On two farms (nos. 1 and 2, Table 2) the samples were taken during the agitating and pumping operations that preceded spreading on the land. The samples from these two farms thus consisted of slurry that had been thoroughly agigated at the time of sampling.

In the laboratory, each slurry sample was mixed by hand and sub-sampled for a strongyloid egg count: a 3 g sub-sample being first examined (Parfitt, 1958) and if this was negative, a 10 g sub-sample was examined by the method of Parfitt (1955). The remainder of the sample was then weighed, mixed with vermiculite and incubated at 27°C for nine days. The larvae were then extracted using the Baermann apparatus.

Grazing trial

An area of pasture 5 acres (2.02 ha) in size was divided into equally-sized plots, A and B. The sward had been used mainly for cutting in the previous year, 1975, and so was expected to have little if any residual infection in the spring of 1976. On April 23, 1976, slurry of known origin (see below) was applied to the whole area of Plot A at the rate of c. 3000 gallons/acre (c. 33 300 kg/ha) Plot B being left untreated as the control. In late May, fifteen calves (late born crossbred Friesian) were put into each plot. On June 1st, further slurry, from the same source as that used in the first application,was applied to half the area of Plot A, this half being held for grazing later in the season. Again, Plot B was not treated with slurry but received nitrogenous fertiliser at a rate which provided the equivalent in nitrogen to that which the slurry supplied to Plot A.

This trial is in progress at the time of writing. Weekly herbage samples are collected from Plots A and B using a transect sampling method. Parfitt's (1955) method is used to recover and enumerate strongyle larvae in these samples. Worm egg counts are carried out at weekly intervals on faeces samples taken from all the calves and the number of *D. viviparus* larvae are determined (Parfitt, 1955) at the same frequency on faeces samples from eight calves in each plot.

To obtain infected slurry for this trial, weanling cattle which were voiding worm eggs were kept in a roofless slatted floor unit during the winter of 1975/76. The slurry from these calves was collected and stored in the underground tank which was situated beneath the slatted floor. In November 1975 there were eighteen weanlings, but the number was increased to twenty-nine over the winter. Faeces samples were collected on five occasions from these animals during the winter for the purpose of assessing their worm egg output (Table 3).

The slurry which these weanlings produced was sampled on three occasions before the first application to Plot A: two samples were collected from the tank using a special instrument, and a third sample was obtained during agitating and pumping on the day of application. The slurry was again sampled before its second application. Using methods already described, estimates were made of viable worm egg concentrations in these samples. In addition, a preliminary attempt was made to determine the relative concentrations of viable eggs in the stored slurry at depths of approximately 30, 90 and 170 cm and to compare egg concentration estimates (a) when undisturbed slurry was sampled with the sampling instrument, and (b) when the sample was obtained following agitation, i.e. as applied to the land.

RESULTS

Survey

As may be seen in Table 1, the majority of the yearling cattle sampled were voiding worm eggs in March, despite the fact that on seven of the ten farms the animals had received at least one anthelmintic dose during the winter. The egg counts were low on average, only 12% of the cattle having counts > 200 e.p.g.

TABLE 1

FARM SURVEY, MARCH 1976: STRONGYLOID EGG COUNTS OF YEARLING CATTLE, PERCENTAGE INCIDENCE, AVERAGE EGG COUNT (e.p.g.) AND PERCENTAGE DISTRIBUTION OF EGG COUNTS

No. farms	No. yearlings sampled	No. yearlings dosed	% positive	Ave. e.p.g.	e.p.g. % frequency		
					<40	40 - 200	>200
10	182	130	94	113	49.5	38.5	12.0

Table 2 shows that 'strongyle' eggs were present in slurry samples from all the farms surveyed, although there was considerable variation between farms. Following incubation all the slurry samples yielded trichostrongyle larvae (l_3) denoting that a proportion at least of the contained eggs were viable in all cases. Few larvae were obtained in the case of Farm 2, despite a relatively high egg count in the slurry. The explanation for this failure to demonstrate viable eggs is that the slurry had been stored for three weeks in a sealed container prior to incubation and that this probably killed the eggs.

An attempt was made to estimate the percentage of eggs in the slurry which were viable. The results are shown in Table 2. It should be noted that these estimates are based on the egg counts: these may not be truly representative since the slurry was merely mixed by hand before sub-sampling for egg counts and this may not have produced a satisfactory distribution of eggs. This bias is presumably exemplified in the sample from Farm 7 in which the egg count seems to have underestimated the true concentration, the number of larvae cultured being greater than the number of eggs counted in the sub-sample.

Grazing trial

Herbage sampling in May/June has shown that, as expected, levels of infection with 'strongyle' larvae were very low at the outset.

Weanlings' egg counts over the winter and slurry sampling procedures

Table 3 shows that the average egg count of the cattle was c 400 e.p.g. on December 11th and that afterwards it declined, remaining at $<$200 e.p.g. from mid-January onwards.

TABLE 2

FARM SURVEY, MARCH 1976. ESTIMATED CONCENTRATIONS OF TOTAL AND VIABLE STRONGYLOID EGGS IN SLURRY SAMPLES COLLECTED FROM TEN FARMS

Farm no.	Slurry storage	Total egg concentration (e.p.kg)	Viable egg concentration (l_3 p. kg)	Percentage eggs viable*
1	Under slats	5 700	574	10.0
2	Under slats	31 500	4	0.01**
3	Under slats	1 900	46	2.4
4	Under slats	71 000	1 575	2.25
5	Under slats	42 000	6 150	14.5
6	Under slats	36 000	2 063	5.7
7	Under slats	1 700	2 950	?
8	Dung-stead	3 100	104	3.4
9	Dung-stead	2 800	1 491	53.0
10	Dung-stead	3 400	2 435	72.0

(NB: l_3 = 3rd stage larvae)

* These estimations are tentative, being based on e.p.g. counts which may be subject to sampling error.

** This sample was stored for three weeks in a sealed container prior to incubation.

TABLE 3

AVERAGE EGG COUNTS (e.p.g.) OF WEANLING CATTLE HELD ON SLATS OVER THE WINTER OF 1975/76 TO PROVIDE SLURRY FOR THE 1976 GRAZING TRIAL

Dec 11		Jan 14		Feb 19		Mar 26		Apr 15	
n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
18	428	16	173	21	149	28	195	25	132

$\bar{x}$ = average e.p.g.

Efforts were then made to ascertain the resulting viable egg concentration in the slurry. For this purpose, and to make preliminary observations on the value of sampling procedures, the slurry was sampled on a number of days as shown in Table 4. The dates of sampling were chosen to give an indication of the slurry's viable egg concentration shortly before it was spread on the pasture used for the grazing trial. Table 4 shows that the estimates of total and viable egg concentrations obtained in samples of undisturbed slurry taken on March 29th were similar to those obtained in the sample of agitated slurry taken on April 26th. Determinations made on samples collected on April 21st indicate that a greater concentration of total and of viable eggs occurred near the top of the slurry as distinct from the lower layers. However, the egg concentrations as estimated from the average numbers for the three depths (April 21st) were considerably higher than those estimated in the samples of undisturbed and of agitated slurry taken on March 29th and April 26th respectively. On the other hand, samples taken on May 10th from slurry that had been agitated and then allowed to resettle, showed a far lower total egg concentration than in previous samples, although the estimate of viable eggs obtained on May 10th were comparable to that found on April 21st when concentration at the three depths was averaged for each occasion.

When slurry was sampled on three occasions during agitation and pumping on June 1st, the counts of total eggs differed widely between the samples: two samples showed very low egg counts and the third showed a fairly high egg count. This result suggests that the similarity in egg counts between the samples of March 29th

TABLE 4

RESULTS OF SAMPLING THE SAME SLURRY ON A NUMBER OF OCCASIONS AND BY DIFFERENT METHODS, TO DETERMINE EGG CONCENTRATIONS IN MATERIAL PRODUCED BY THE OVER-WINTERED WEANLINGS

Slurry samples		Total egg concentration e.p.kg (x 10^3)	Viable egg concentration l_3 p. kg	Viable eggs† %
Date sampled	Type			
29/3/76	Undisturbed* mixture of 3 depths	100	1 275	1.3
21/4/76	Undisturbed*			
	top (30 cm)	500	14 448	2.9
	middle (90 cm)	100	8 227	8.2
	bottom (170 cm)	19	5 850	30.8
	Average	206	9 508	
26/4/76	Agitated/composite**	100	1 938	1.9
10/5/76	Agitated (26/4) and then allowed to resettle			
	top (30 cm)	30	10 689	35.6
	middle (90 cm)	38	2 463	6.5
	bottom (170 cm)	14	3 079	22.0
	Average	27	5 410	
1/6/76	Agitated** Composite sub-sample i	21	-	
	sub-sample ii	11	-	
	sub-sample iii	300	-	
	Average	110		

* Sample obtained with sampling instrument, slurry as it had built up in the tank.

** Agitated/composite denotes sample taken while slurry was being agitated and pumped out of the tank - i.e. as applied to the land.

† These estimations are tentative, being based on e.p.g. counts which may be subject to sampling error.

and April 26th was fortuitous. Unfortunately, incubation of the sample taken on June 1st was not successful and so no estimate is available for its viable egg concentration.

DISCUSSION

The egg counts in faeces samples collected from young cattle during the limited survey in March 1976 were possibly lower than usual due to the severe drought in the summer of 1975, although egg output would in any case have declined by that time of year. The drought may, on the other hand, have resulted in abnormally low egg output by the cattle at the onset of winter. Thus, the concentrations of eggs in slurry on the farms may, in fact, have been less than those occurring after an average wet summer.

Despite the possible effects of the dry summer in 1975 and the fact that most of the cattle had been dosed with anthelmintic during the winter, 94% of them were voiding strongyloid eggs in the faeces. As might be expected, therefore eggs were found in the slurry samples from all ten farms surveyed. The eggs, or a proportion of them, were viable in all the samples. This represents a higher incidence of viable eggs than that found in a larger survey in Sweden by Persson (1974_1) but his incidence (67.2%) was for liquid manure from cattle of all ages, whereas the present survey was confined to slurry derived from susceptible young stock.

The estimates of egg concentrations in the slurry samples showed a wide variation between farms. Part of this variation can be attributed to differences which probably occurred between herds with respect to their egg output - and hence the egg concentration in the slurry - over the winter. Another possible variable was differences between farms in the amount of water used to hose down floors, etc. There seems little doubt too, that considerable sampling errors are likely to occur with slurry.

It is emphasised that the data presented here are the result of preliminary studies. The estimates for egg concentrations and for percentage viability shown in Tables 1 and 4 are only crude approximations. Determination of numbers of viable eggs may have reasonable validity since the volume of material was relatively large (1 - 2 kg) and probably most of the viable eggs presènt would have developed and most of the resulting larvae been extracted. The disadvantage is that the samples themselves may not have been adequately representative.

Clearly, there is a need for improved sampling procedures and for an assessment of the recovery rate of eggs/larvae using slurry to which known numbers of these organisms have been added.

Persson (1974_1) noted that liquid manure when applied to pasture caused far less infection than the contaminated faeces of grazing cattle. In the grazing trial initiated in the present study, an attempt is being made to see if a spring application of slurry on to a relatively 'clean' sward will increase infection on the herbage and in calves grazing thereon. Although viable worm eggs were demonstrated in the slurry used, the cattle that produced it had a low to moderate egg output. While this was probably fairly typical it will be desirable in future pasture experiments to use slurry with higher levels of contamination.

Persson (1974_2) found that under Swedish conditions, eggs and larvae in stored slurry were killed after 11 - 40 days in the summer. Possibly the same would apply under our conditions, but this would need to be ascertained experimentally. Such destruction of larvae would probably not occur in slurry stored during winter and applied to land in the spring.

Persson (1973) described investigations into methods of destroying parasitic contamination/infection in cattle manure, including the addition to it of chemicals and the use of aeration. Should it be found that slurry is an important source of pasture infection, methods along these lines may have to be tried. Dosing cattle in winter will, of course, greatly reduce worm egg output and so limit contamination of slurry.

Up to now, anthelmintics have not been fully effective in this respect, largely because they failed to reduce sufficiently the numbers of 4th stage larvae, in particular those of *O. ostertagi*. Very recently, Duncan et al. (1976) have reported that the new anthelmintic fenbendazole is highly active against these 4th stage larvae. This drug would thus reduce still further the egg contamination of slurry and its use for this purpose would certainly warrant experimental examination.

Lastly, in future work on this it is hoped to include examinations of slurry for the presence of viable *D. viviparus* larvae and *F. hepatica* eggs.

ACKNOWLEDGEMENTS

The authors wish to thank Messrs. A. Baldwin, M. O'Sullivan and J. Farrell for technical assistance.

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POSSIBILITIES OF POULTRY DROPPINGS DECONTAMINATION AS RELATED TO FARM LEVEL MANAGEMENT TECHNIQUES

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Disposal of waste volumes encountered in highly intensive animal production units has become an extremely difficult problem to cope with. This is particularly true of the poultry industry. Farms with poultry production units may still be able to dispose of manure by spreading it on their fields, if an arable area of approximately 60 acres is available for 10 000 laying hens. Large, industrial type production units at times have acute manure disposal problems endangering both the unit itself and neighbouring farm operations.

In Germany, a total of 92 million chickens produces approximately 6 million tons of manure annually. This waste volume must be utilised and/or disposed of in some way or other.

Many suggestions and proposals exist in connection with the search for a solution to the waste problem - not a single one, however, can be regarded as universal and successful. The physical properties and textures of manure from laying houses are well known. There is solid manure mixed with litter material such as straw, peat, wood shavings, also pure droppings from slats, manure pits and cage units. A couple of years ago, water was added for the purpose of liquifying the wastes and slurry resulted. Then heat treatment processes were evolved removing the natural water content in the droppings. Deep pits are a recent development whereby the manure is stored on slats and dried right in the house. However, no one has yet found a solution allowing for the full re-use or recycling of all components contained in poultry manure. It is a generally known fact that poultry manure is a high-value fertiliser because of its high content of essential plant nutrients.

Depending upon the water content, the actual chemical composition of fresh poultry manure is subject to great variation. Assuming an average moisture content of 75%, poultry manure contains the following:

nitrogen, 1.5 - 1.7%

phosphorus, 1.2 - 1.4%

potassium, 0.5 - 0.7%

According to an analysis conducted by Jordan (1966) the following trace elements are present: Fe, Zn, Mn, Cu, Co (iron, zinc, manganese, copper, cobalt).

Poultry wastes are utilised by either applying the manure as fertiliser on company owned or farm owned land or by selling or giving it to other farmers for land application. If this is no longer possible, the only remaining solutions are drying, burning or composting.

For use as fertiliser, only part of the substances are available to the plant. From an epidemiological point of view, manure is of particular importance because of the shedding and spreading of disease agents pathological to animal and man. A great number of infectious and invasive diseases are spread from animal to animal and from animal to man. Animal wastes play an important role in this connection. Poultry manure is always liable to contain pathogens across the entire range of micro-organisms likely to be encountered. Apart from these pathogenic agents the normal poultry litter flora is mostly formed by Coryne bacteria and, to a lesser extent, by Nacardia, Streptomyces, pseudomonas alcaligenes and Achromobacter strains.

The continual increase of salmonella serotypes is of particular concern because all S. strains must be considered potentially pathogenic to both man and animal. Strauch et al. (1968) have conducted extensive research on the persistence of Salmonellae in the manure of caged chickens. Some of the results are surprising as they show far shorter survival times for some S. types than was formerly believed to be the case. In chicken manure stored at 5 to 11°C. killed Salmonellae could already be found after 26 days. This, however, does not preclude the danger of salmonella infections via the manure route. Generally, deep litter is reported to have a salmonellicidal effect in which connection the self-sanitising factor of a rapid increase in pH and ammonia concentration must be mentioned. Apparently, an environment unfavourable to salmonellae growth is thus created.

Studies involving other bacteria show varying results. Laboratory examinations carried out by Platz (1976) helped clarify the persistence of pathogenic bacteria. Dual-walled, heat-insulated PVC containers were used and manure inoculated with different strains of pathogens was left to self-heating. The following agents were involved: *S. typhimurium*, *S. pullorum*, *E. coli*, *Proteus vulgaris*, *P. hemolytica*, *P. multocida*, *β-hem. streptococci*, *List. monocytogenes*, *Clost. perfringens*.

The exothermal metabolic activities of micro-organisms responsible for the self-heating effect led to a rapid rise in temperature up to a maximum of 71^{o}C. which was reached after 11 hours. The pathogens named above were completely killed within 21½ hrs. save for *Listeria monocytogenes* and *Clost. perfringens*.

The effect of pH shift (which may range from pH 5 to pH 9) on the survival rate of the pathogens is still not completely clear.

In poultry farming, tuberculosis is of particular importance. The Tb. bacterium is highly resistant. This fact is the result of the very stable, wax-type coat which encapsulates the bacterium. Persistence studies have shown the Tb. bacterium can still survive after three years of favourable storage conditions. Research is relatively sparse particularly as far as organism behaviour in chicken manure is concerned and more and detailed studies are necessary because tuberculosis is a problem that appears again and again - particularly in smaller poultry production units. The origin of such outbreaks is unknown, however, the high rate of infectivity of mycobacterium tuberculosis avium with respect to cattle and particularly swine, is well known.

Infection of humans is possible, but is certainly not of any significance.

Fungal behaviour has been studied by Burger (1970), Holzinger (1973) and others. The studies mostly involved fresh garbage which contains mesophile fungi, capable of massive further development. High temperatures, acidulation and anaerobic environmental conditions restrict fungal growth in the inner clamps, thus curtailing the activity of thermophile fungi. Preliminary studies have been made to determine the effect of antibiotic fungal action on bacteria elimination. Again, however, this research has been concentrated on trash and garbage so that further research is indicated to determine such activities in poultry manure. It is a well known fact, for example, that certain fungal mould spores can survive which, under faulty storage, can lead to post-drying recontamination.

The chief route of transmission of viral diseases is probably that of animal to animal or animal to human being with faeces acting as the transmission medium. When guidelines for the testing of disinfectants were set up, it became evident that ability to survive differs widely. Coated viruses, such as the ND virus, are very unstable and are inactivated in a short period of time with normal concentrations only. Non coated viruses act differently, some of which still remain alive and reproductive after two hours of high-dosage disinfectant application. Viruses pathogenic to poultry include: the Picorna virus of AE (epidemic tremors). Carlson (1969) studied virus occurrence in effluent sludge and septic tank installations and obtained useful results. At least one virus strain could be identified in each type of effluent - a fact which is, no doubt, worth noting.

Where poultry litter is concerned, no research on coatless viruses is known and it seems to be high time that more information is sought on this subject.

A number of workers have conducted research on the survival of parasites in composted effluent sludge and in the soil. The results show that parasitic survival rates range between three days and six years. Parasitic behaviour in poultry manure (which was modified to dung or litter by various techniques) has not been clearly demonstrated. Research on protozoan (eg coccidia) behaviour in poultry manure and/or litter is also unavailable. Coccidiosis is a disease which is widespread and costly to the poultry industry everywhere. Further spread of this disease should be prevented under all circumstances.

The above clearly shows that our knowledge concerning the survival of micro-organisms in poultry manure and poultry litter, derived therefrom, is quite good but is still not complete. To summarise, the following questions need be answered in the future:

1) How long do tuberculosis bacteria remain viable in poultry manure and litter, and how can they be inactivated early by other means?

2) What is the role of antibiotic fungal activity in the elimination of bacteria?

3) What is the behaviourial pattern of non-coated viruses in poultry manure/litter, what is their survival rate, what other means are available for their inactivation?

Our knowledge concerning the behaviour of parasites and protozoa is incomplete, particularly as regards their invasiveness.

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A STUDY OF THE EFFECTS OF ANIMAL EFFLUENT UTILISATION FOR GRASSLAND PRODUCTION ON LEVELS OF CERTAIN PATHOGENIC BACTERIA IN FOOD ANIMALS AND THEIR CARCASES: PRELIMINARY FINDINGS

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INTRODUCTION

Three groups of cattle, viz. calves in a commercial herd, fattening cattle, and calves at an experimental station, have been repeatedly examined for the presence of *Escherichia coli* which display in vitro resistance to antibacterial agents, or *Salmonella* during the period from February to June 1976. Examination of grass, hay and silage fed to the above cattle for evidence of contamination with these organisms, together with bacteriological examination of faeces and slurry originating from the groups of cattle, have also been conducted. In the case of the fattening cattle, carcases were examined for the presence of R-positive *E. coli* and *Salmonella* which may have arisen a) during life, as indicated by lymph node examination, or b) as a result of carcase contamination during slaughter and dressing out. These latter cattle had been fed silage and were kept in houses with slatted floors until early May at which time they were put out onto grassland which had not been treated with animal slurry during the last four years.

1. MATERIALS AND METHODS

1.1 Animal Groups

1.1.1 Experimental calves: 32 Friesian crossbred calves, purchased on open market at 1 - 3 weeks of age.

1.1.2 Calves in commercial herd: 150 Friesian crossbred calves, among 1300 purchased at 1 - 3 weeks of age and reared at three locations by one producer.

1.1.3 Fattening cattle: 80 Friesian and other crossbred cattle among 4 800 two-year-old cattle kept on slats.

1.2. Materials

1.2.1. Animals: a) Rectal swabs (alginate).
b) Faeces.
c) Carcase swabs (cotton wool) taken after carcase washing
d) Mesenteric lymph nodes.

1.2.2. Feed: a) Grass, 5 x 50 g.
b) Top soil, 5 x 100 g.
c) Silage, 5 x 500 g.
d) Hay, 5 x 500 g.

1.2.3. Effluent: a) Tank slurry, 4 x 250 ml.
b) Lagoon slurry, 4 x 250 ml, taken at a depth of 0.5 m.
c) Pump-out, 4 x 250 ml.

1.3. *E. coli* and *Salmonella*: Isolation procedures

1.3.1. Rectal and carcase swabs, faeces and slurry

a) Surface inoculation onto i) MacConkey Agar, ii) Brilliant Green Agar followed by incubation at 37°C for 24 hours and 48 hours.

b) Following incubation in Selenite broths for 24 hours at 43°C then processed as described in a) above.

1.3.2. Lymph nodes, soil, grass, silage, hay.

a) Following maceration in Selenite broth using a Stomacher, these materials were then processed as described in 1.3.1. a) and b) above.

1.4. *E. coli:* In vitro Antibacterial Sensitivity Studies

1.4.1. Single colonies, as isolated in 1.3. above, were transferred onto the surface of a sensitivity test agar plate onto which paper discs impregnated with the following reagents were then applied: ampicillin (Pn), 25 mcg; chloramphenicol (C), 50 mcg; tetracycline (Te), 50 mcg; neomycin (N), 30 mcg; framycetin (Fy), 100 mcg;streptomycin

(S), 25 mcg and nitrofurazone (Fc), 10 mcg.

1.4.2. After being held for four hours at 4°C, the inoculated plates were then incubated at 37°C for 24 hours. Isolates which displayed a zone of inhibition of 0.5 cm radius or greater around a disc were deemed to be sensitive in vitro to the reagent in the disc.

1.4.3. Isolates which showed in vitro multiple resistance were examined for the presence of Resistance Transfer Factors.

2. RESULTS AND DISCUSSION

2.1. Experimental calves

The calves, which have been kept at the Faculty's Clinical Field Station since purchase, were subject to bacteriological examination on six occasions, excluding an initial sampling at the time of purchase. A total of 408 *E. coli* were isolated and subjected to in vitro antibacterial sensitivity analysis (Tables 1 and 2). During the summer the calves were housed at night and turned out daily to graze on paddocks which have been dressed with farmyard manure annually. During an outbreak of pneumonia which affected the majority of the calves shortly after their arrival, the principal antibacterial agent used was a sulphonamide-trimethroprim preparation. There appears to have been a gradual decline in the prevalence of in vitro resistance to single reagents, as well as to combinations of these reagents, with age. Resistance transfer studies have confirmed the presence of R-factors in a majority of the multi-resistant *E.coli* examined to date.

Salmonella typhimurium was isolated from the environs of one of the calf houses during March. This isolate was sensitive in vitro to each of the reagents tested. No further *Salmonella* isolates have been achieved from this source to date.

2.2. Commercial Calf Rearing Unit

One hundred and fifty calves were randomly selected from 1 300 purchased at under three weeks of age. The selected calves which were distributed throughout the whole population, were examined on three occasions. All the animals were housed in groups of twelve from February to May when they were turned out onto pasture which had been occasionally dressed with farmyard manure during the previous ten years.

The results of the in vitro antibiogram studies are presented in Tables 3 and 4. The persistence of in vitro resistance to tetracycline, ampicillin, chloramphenicol and streptomycin is noted. Resistance transfer studies have confirmed the presence of R-factor in the majority of the multi-resistant *E. coli* examined.

2.3. Commercial Beef Fattening Unit

Earlier this year the unit concerned held up to 4 800 cattle aged from 18 - 24 months in groups of thirty in houses with slatted floors, for 10 - 16 weeks. These cattle received feed which consisted principally of chopped silage prepared from grassland which had been dressed repeatedly during the past five years with slurry and effluent from the above houses. Feeding trials being conducted at the unit include food conversion efficiency trials with flavomycin. During April and May, eighty cattle were identified for examination. These cattle, having since been turned out to pastures which have not been dressed with farmyard manure or with slurry during the past four years, have been followed through to slaughter. The results of in vitro antibiogram studies carried out on *E. coli* isolated from these cattle are presented in Tables 5 and 6. Of thirty-two *E. coli* isolated from rectal swabs taken from thirty cattle which had been receiving 9 g of flavomycin per day in their feed, 9.4% were resistant in vitro to ampicillin and 3.1% to nitrofurazone. In the case of thirty *E. coli* isolated from rectal swabs taken from thirty cattle which had not been receiving dietary flavomycin, no in vitro resistance to any of the seven reagents used was observed. Resistance transfer studies on the isolates are now in progress.

The relative absence of in vitro resistance in the *E. coli* isolated from rectal swabs from the cattle is in direct contrast with the resistance patterns exhibited by the *E. coli* isolated from their mesenteric lymph nodes (Tables 7 and 8). *E. coli* isolated from the mesenteric lymph nodes of other cattle slaughtered immediately before the test animals also displayed a high degree of in vitro antibacterial resistance. Resistant *E. coli* were also recovered from swabbings made from the carcases of the test animals within one hour of having been washed down. A comparison of the patterns of in vitro resistance of *E. coli* isolated from rectal and carcase swabs and from the mesenteric lymphnodes of the test cattle is presented in Table 9. The origin of the carcase contaminants, and the extent of distribution of mult-resistant *E. coli* in the mesenteric lymph nodes of cattle and other animals which may or may not excrete multi-resistant *E. coli* in their faeces, will be the subject of further investigation. The implication that these findings may have for the continuation of the practice of routine lymph node incision during veterinary post mortem inspection will be of particular interest.

The findings relating to *E. coli* isolated from the three groups of animals are summarised in Figures 1 and 2. The persistent and increasing prevalence of in vitro multiple resistance in *E. coli* recovered from the commercial calves, is in contrast with the lower prevalence exhibited by isolates from the other two groups. The continued excretion of multi-resistant *E. coli* by the commercial calves following let-out onto pasture can be explained by the fact that they continued to receive tetracycline in the supplementary feed. Also shown in Figures 1 and 2 is the prevalence of single and multiple in vitro resistance in *E. coli* isolated from slurry, soil, grass and/or silage samples collected at the three units during February and June. The nature and extent of the resistance patterns exhibited by *E. coli* isolated from the animal and other indicated sources appear to be complementary.

An investigation of the possible effects which pH, Aw and storage temperature may have on the presence and persistence of in vitro resistance of *E. coli* present in slurry samples collected at the commercial calf and beef units is now in progress. Preliminary findings suggest that three possibilities at least, must be considered, viz any in vitro resistance present initially may either persist or decline; alternatively, resistant isolates may be recovered for the first time only after several sub-samples have been taken on consecutive days.

TABLE 1

PREVALENCE OF IN VITRO RESISTANCE TO ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM CALVES KEPT AT THE EXPERIMENTAL STATION, FEBRUARY - JUNE 1976.

Sampling Date	No of Samples	No of *E. coli*	Percentage of isolates resistant in vitro to:						
			Pn	C	Te	N	Fy	S	Fc
26.2.76	18	54	24.0	20.3	42.5	31.4	18.5	55.5	O
3.3.76	49	100	43.0	38.0	58.0	36.0	17.0	52.0	2.0
24.3.76	36	78	46.1	34.7	67.9	29.4	3.8	61.5	O
29.4.76	37	102	20.5	15.6	38.2	11.7	9.8	60.0	3.9
20.5.76	36	57	14.0	7.0	26.3	7.0	7.0	50.8	1.7
15.6.76	13	17	5.8	O	11.7	11.7	O	29.4	O

TABLE 2

PREVALENCE OF IN VITRO MULTIPLE RESISTANCE TO THREE OR MORE ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM CALVES KEPT AT THE EXPERIMENTAL FIELD STATION, FEBRUARY - JUNE, 1976.

Date of Sampling	No of *E. coli* examined	Percentage of isolates resistant in vitro to:	
		3 or more reagents	3 or more of Pn, C, Te and S
26.2.76	54	29.6	20.3
3.3.76	100	44.0	34.0
24.3.76	78	50.0	43.5
29.4.76	102	21.5	15.6
20.5.76	57	15.7	10.5
15.6.76	17	11.7	O

TABLE 3

PREVALENCE OF IN VITRO RESISTANCE TO ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM CALVES KEPT AT A COMMERCIAL CALF REARING UNIT, FEBRUARY - JUNE 1976.

Sampling date	No of Samples	No of *E. coli*	Percentage of isolates resistant in vitro to:						
			Pn	C	Te	N	Fy	S	Fc
28.2.76	99	200	45.5	37.5	57.5	15.5	1.5	57.0	0.5
9.4.76	150	286	53.4	34.2	74.4	21.3	8.0	62.5	1.0
9.6.76	63	155	58.0	40.6	92.2	4.5	0	79.3	1.2

TABLE 4

PREVALENCE OF IN VITRO MULTIPLE RESISTANCE TO THREE OR MORE ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM CALVES KEPT IN A COMMERCIAL CALF REARING UNIT, FEBRUARY - JUNE 1976.

Date of Sampling	No of *E. coli* examined	Percentage of isolates resistant in vitro to:	
		3 or more reagents	3 or more of Pn, C, Te and S
28.2.76	200	40.5	39.5
9.4.76	286	48.3	44.4
9.6.76	155	53.5	50.3

TABLE 5

PREVALENCE OF IN VITRO RESISTANCE TO ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM BEEF CATTLE KEPT AT A COMMERCIAL BEEF FATTENING UNIT, FEBRUARY - JUNE 1976.

Sampling date	No of samples	No of *E. coli*	Percentage of isolates resistant in vitro to:						
			Pn	C	Te	N	Fy	S	Fc
21.4.76	45	90	6.6	0	0	0	0	7.7	0
7.5.76	37	43	2.3	0	2.3	4.6	0	2.3	6.9
30.6.76	55	56	1.8	0	0	5.4	0	5.4	1.8

TABLE 6

PREVALENCE OF IN VITRO MULTIPLE RESISTANCE TO THREE OR MORE ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM BEEF CATTLE KEPT AT A COMMERCIAL BEEF FATTENING UNIT, FEBRUARY - JUNE 1976

Date of Sampling	No of *E. coli* examined	Percentage of isolates resistant in vitro to:	
		3 or more reagents	3 or more of Pn, C Te and S
21.4.76	90	0	0
7.5.76	43	0	0
30.6.76	56	0	0

TABLE 7

PREVALENCE OF IN VITRO RESISTANCE TO ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM LYMPH NODES AND RECTAL AND CARCASE SWABS ON THE DAY OF SLAUGHTER.

Type of Sample	No of samples	No of *E. coli*	Percentage of isolates resistant in vitro to:						
			Pn	C	Te	N	Fy	S	Fc
1. Test									
Rectal swab	55	56	1.8	0	0	5.4	0	5.4	1.8
Lymph node	78	80	35.0	7.5	10.0	5.0	1.3	11.3	0
Carcase swab	50	40	22.5	2.5	5.0	0	5.0	10.0	0
2. Other									
Lymph node	23	35	38.3	14.7	29.1	10.2	2.9	29.0	0
Carcase swab	24	10	30.0	0	0	0	0	0	0

TABLE 8

PREVALENCE OF IN VITRO MULTIPLE RESISTANCE TO THREE OR MORE ANTIBACTERIAL REAGENTS IN *E. coli* ISOLATED FROM LYMPH NODES AND CARCASE SWABS ON SLAUGHTER

Type of sample	No of *E. coli*	Percentage of isolates resistant in vitro to:	
		3 or more reagents	3 or more of Pn, C, Te and S
1. Lymph nodes			
Test	80	8.8	8.8
Other	35	25.7	25.7
2. Carcase swab			
Test	40	0	0
Other	10	0	0

TABLE 9

PATTERNS OF IN VITRO RESISTANCE OF *E. coli* ISOLATED FROM RECTAL AND CARCASE SWABS AND MESENTERIC LYMPH NODES TAKEN FROM THE BEEF CATTLE UNDER TEST. JUNE 1976.

Rectal swab isolates	Carcase swab isolates	Lymph node isolates
N (1)		
	Pn (4)	Pn (21)
	S (1)	S (2)
	Fc (1)	
		Te (1)
Pn, S (1)	Pn, S (3)	
	Pn, Te (2)	
N, S (1)		
	C, Fc (1)	
		Pn, Te, S (1)
N, S, Fc (1)		
		Pn, C, Te, S (2)
		Pn, C, Te, N, S, (3)
		Pn, C, Te, N, Fy, S (1)

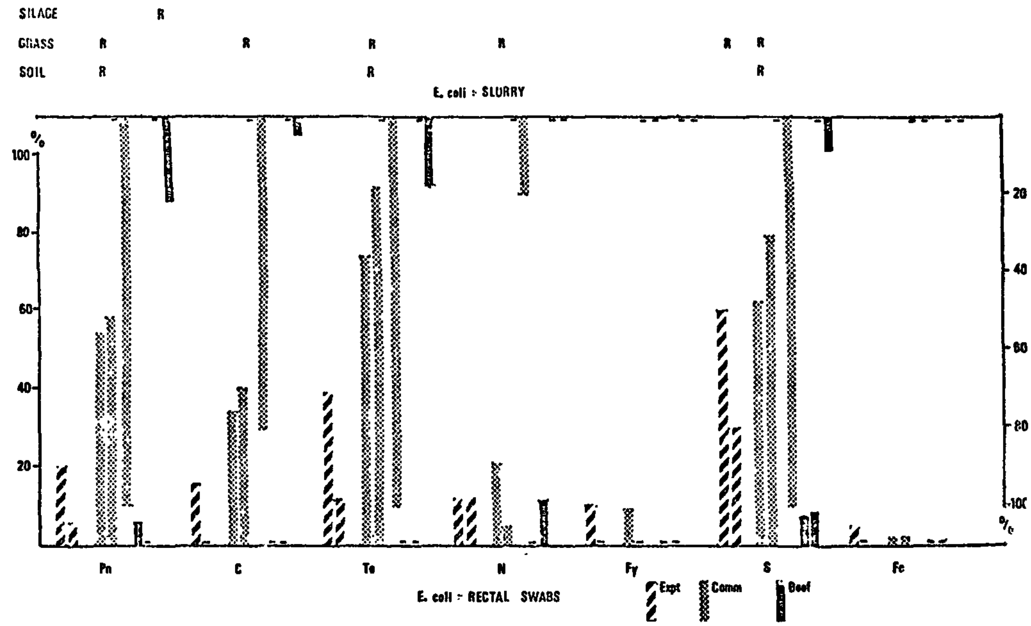

Fig. 1. Prevalence of resistance.

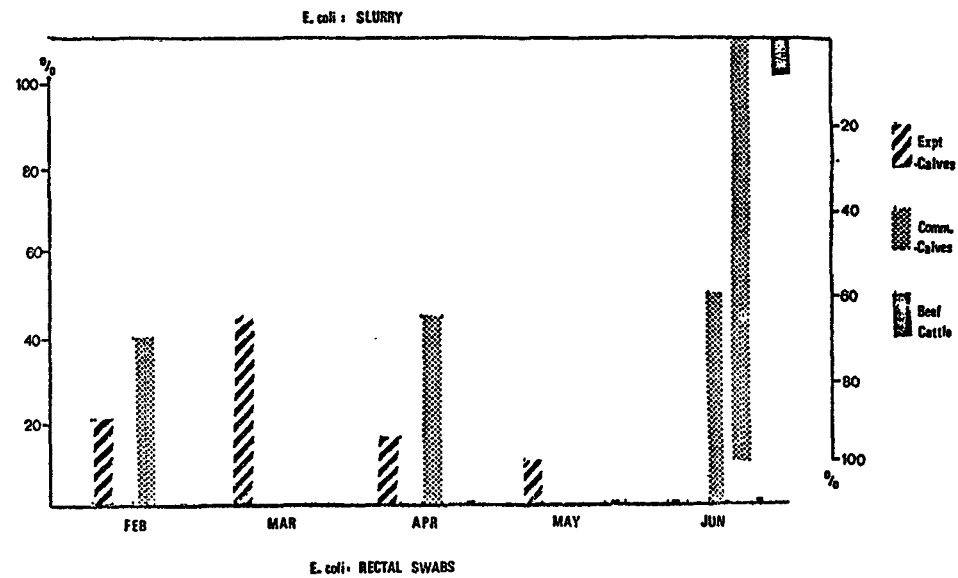

Figure 2 . Prevalence of multiple resistance.

DISCUSSION

D. Strauch *(West Germany)*

The discussion is now open.

R.G. Gerritse *(The Netherlands)*

I have a remark in connection with Dr. Strauch's paper. I have done some calculations on the particle diameter and I have compared this with the diameter of bacteria. To my mind, at field capacity, bacteria will not move in the soil but viruses will. I would like to stress the importance of making further investigations into the problem of viruses and their mobility in the soil.

D. Strauch

Yes, some investigations have been made in Florida on the percolation of viruses into the soil. We discussed this at Rochester at the end of April this year and maybe you can find the results in the Proceedings of that meeting. It was the Animal Waste Management Conference of the University of Cornell at Ithaca.

R.G. Gerritse

You say in your paper that the bacterial count varied between 7×10^6 and 3×10^{11}/ml. If you look at this last value it means that in one ml of slurry 30% of the slurry would be biomass, bacterial mass. This is quite a lot and I wonder if it is possible.

D. Strauch

I quoted these figures from Tomescu's work; I did not re-calculate them.

R.G. Gerritse

I raise the point because the average weight of a bacterium is about 10^{-12}. If you multiply this by the last figure you have .3 g/ml bacterial weight, which is quite a lot.

D. Strauch

Yes, I will have to look at this in Tomescu's paper. I took the figures from his publication but I will have to recalculate them, maybe it is a printing error.

F. Bonciarelli *(Italy)*

I would like to know whether traditional well-made farmyard manures from composts present the same risks as slurries, from the pathological point of view. I am thinking about the Chinese agricultural system where, for centuries, all excreta - animal and human - surely very rich in pathogenic agents, have been used for fertilising fields.

D. Strauch

I will try to answer this question. What you say is quite true but on the other hand the survival of pathogens in concentrated faeces, as we have seen from Dr. Geissler's paper, is different from their viability in liquid material such as slurry. For example, in the faeces of caged birds such as laying hens, the survival time for salmonellae is about 29 days. However, if water is added to this material to make a slurry, the survival time will increase to more than three months. We have found this to be the case in all our investigations over the last five or six years. There is a definite difference between concentrated and diluted material.

W.R. Kelly *(Ireland)*

I would like to add a comment on that. Recently I read a rather interesting report. I think it was by Thungarten in Sweden. His observations were made on slurry and on the traditional farmyard manure system of handling animal waste, cattle waste in particular. He showed quite clearly that the rise in temperature in the heap of farmyard manure, if stored under proper conditions, was sufficient to kill most pathogenic bacteria that might be excreted in the faeces from cattle. He was looking at salmonellae particularly and he found that in liquid slurry salmonellae survived for at least a year; in more concentrated slurry the survival time was reduced by half, whilst in farmyard manure the survival time was a matter of 20 or 30 days.

D. Strauch

When you speak of farmyard manure, do you mean manure containing bedding?

W.R. Kelly

Yes. In fact, the amount of straw in farmyard manure seems to be rather important. I don't know if anybody has determined the exact ratio of straw to faeces that will give the best results.

D. Strauch

In veterinary legislation, one of the methods of disinfecting the manure is to store it for three weeks under certain conditions. There are experiments dating back more than 70 years which show that this three weeks composting is sufficient to kill all pathogens present in farmyard manure.

In addition to what I said to Dr. Bonciarelli, I would add that there is a difference in the viability, at least of salmonellae, in the various types of slurry. They live longest in the cattle slurry; they have a viability lasting about three months in pig slurry but only about three to four weeks in calf slurry. So there is a difference in the behaviour of the salmonellae in the various types of slurry from the various animals.

A. Dam Kofoed *(Denmark)*

This discussion on the viability of salmonellae is very interesting. As far as sewage sludge (not slurry) is concerned, we have noticed a living time of two to three months - not more. It is very important when we consider the disposal method of the sewage sludge, whether it is for grain, vegetables or whatever. I think it is very necessary to have specific information regarding the length of time that salmonellae will survive in varying conditions. I believe you said in your paper, Dr. Strauch, that a type of salmonellae can live 500 days in the field. This shows that there is a very great variation in the survival time and to my mind this is very important. We haven't heard very much about *Ascaris*. Is that a question which should be considered with regard to swine manure?

D. Strauch

Well it is really but I am no parasitologist so I would like to ask Dr. Downey to answer this question.

N.E. Downey *(Ireland)*

I'm afraid we don't have any information on it really because we are dealing with the parasites of cattle in this particular project and, of course, *Ascaris* is a pig parasite. It is possible for *Ascaris* to get into cattle so I think it is really an important question from that point of view. Just to complete the picture with regard to farmyard manure, in general farmyard manure destroys parasites so if there was *Ascaris* in farmyard manure it would be destroyed.

D. Strauch

We did some experiments with *Ascaris* eggs in the context of aerobic treatment of pig slurry by the method which is called rotating aeration, or the Fuchs system. We found that the *Ascaris* eggs are destroyed by this method after 50 hours aeration but I must add for those who are not familiar with this system that it is also called liquid composting because it has the same effect as a compost of farmyard manure. There is a rise of temperature up to 52°, 55° or 60°C within 48 hours, and 50 hours is long enough to destroy the *Ascaris* eggs completely.

A. Dam Kofoed

In experiments on utilising swine manure from a slaughterhouse, we have found viable *Ascaris* eggs after six months and therefore we have to say that the use of swine manure on vegetables cannot be permitted because of this risk.

D. Strauch

Yes, this is quite right. In the first two or three years after the war, at Darmstadt in Germany, we had an epidemic outbreak of *Ascaris* infection in humans through the use of sewage sludge on vegetables.

J.H.A.M. Steenvoorden *(The Netherlands)*

I would like to ask you a question, Dr. Strauch. In Figure 2 in your paper you give the ways in which contamination can occur. One of the ways from animal faecal waste is by use as a fertiliser. I wonder how great the danger is?

D. Strauch

It is as an organic fertiliser.

J.H.A.M. Steenvoorden

Oh, I see, O.K. Then I wonder, as a non-veterinarian, how great the danger is for animal and human health and I wonder what the situation is in the Netherlands because there are a lot of big farms with intensive cattle breeding. Perhaps Dr. Voorburg knows something about the situation there.

J.H. Voorburg *(The Netherlands)*

We are not too worried about these problems. We consider that if the manure is applied on the same farm the risk of infection within the complex of buildings by direct contact is much higher than the risk of disease spreading via the fields. There is a risk when the manure is transported to a neighbouring farm or to a manure bank so care should be taken to prevent loss of manure during transport. In spreading the manure on arable land at the time of sowing or ploughing, there is no risk of transport of diseases. There is a long period between harvest and the application of the manure. It would not be safe to spread manure on vegetables but it is all right on arable land in autumn, winter or early spring. If a farmer buys in manure for a mixed farm he would be well advised to spread it on the arable land rather than on the grassland. If he has grassland he will have cattle and therefore enough manure for that. So, we do not think there is a big problem but, of course, I am talking about manure, not sewage sludge.

D. Strauch

I agree with you that the problem does not arise within a farm, generally speaking. We see the problem arising in the transport of manure. This was the question I raised with Dr. Jongebreur yesterday and I pointed out today that we would like to have a health certificate from a State veterinarian who is responsible for the farm that is selling or giving away the surplus manure. The State veterinarians, at least in our country, have a good knowledge of what is going on in their areas and if they were prepared to give such a certificate there would be nothing against the transport of manure. This is on the assumption that no notifiable diseases are concerned because in all the EEC countries there are strict veterinary regulations in the case of a notifiable disease outbreak. In that case everything is stopped. For instance, if there is an outbreak of foot and mouth disease, in all countries, the manure banks will have to be closed for the duration.

J.H. Voorburg

Yes. I want to make it clear that I was not speaking about disease outbreaks. I am not a veterinarian. All our big units maintain close contact with the veterinary organisations so if there should be an outbreak everything is changed. I was speaking about normal conditions.

A. Cottenie *(Belgium)*

We seem to be accustomed to living with a very important potential source of infections. My question is, is there knowledge, or are there known examples, of transmission of infection to man?

D. Strauch

I cannot answer this question directly because there is no specific organisation to collect the data about these things. Very little is known from the literature but there is some indirect evidence. For example, in Germany, we have had an increase of the notified cases of salmonellosis in humans of 2 000% over the last eight years. In 1975 there were 32 000 notified cases and the human epidemiologists say that this is only 10% of the actual cases. So if we believe these figures it means that there were over 320 000 cases of salmonellosis in Germany in 1975. I must repeat what I have said at other meetings: it is not so much a question of direct danger from the manure to man because the problem of salmonellae is one of quantity rather than quality. For example, if you have an intake of 100 salmonellae in a cup of water nothing will happen to you, but if you swallow 10 000 you will have an infection. So the danger is not so much that the farmer comes into contact with the salmonellae in the manure from his pigs because if he actually put his finger in his mouth he would only take in perhaps 500. The danger lies in the field of food hygiene because the salmonellae are transmitted to all kinds of food in the kitchen. For example, the water from frozen chickens contains salmonellae in about 50% of all cases; the housewives have contact with this melting water and then they are preparing other food which has a high protein content and so the multiplication of salmonellae will take place - within one hour about 100 000 fold!

A. Cottenie

You say 50% of frozen poultry is infected with salmonellae?

D. Strauch

Yes, this is the average. We carried out investigations at Hamburg at the Veterinary Research Institute, with poultry from Holland, Germany and Poland. It varied between 32% and 72% of infected carcases. The highest rate came from Poland. It is a good thing that the meat of chicken is not eaten in the raw state!

T.A. Spillane *(Ireland)*

Dr. Strauch, I would like to ask you about the question of treatment with chlorine to obviate water contamination. You state that a properly applied control is effective in protecting human and animal populations. I just wonder what the dosage is likely to be to achieve this objective. It seems to me to be extraordinarily high to be really effective.

D. Strauch

In my paper I mentioned treated effluent from farms, meaning that the solids are already removed. I don't know any country in which the complete slurry is put into a river - it is not allowed. So in this case we need the same dose before the slurry is put into a river as we need for chlorinating municipal sewage.

W.R. Kelly

I would like to add a comment. I think the problem here is always to determine the amount of organic matter in the water, irrespective of its source. Taking out the solid material would only affect that to a degree, one would still need to know the amount of soluble organic matter in the water. I think the investigations have shown that following treatment, you need to have a residual of 10 to 15 ppm of available chlorine to ensure that the disinfectant action has been effective.

H. Tunney *(Ireland)*

I would like to direct a question to you Dr. Strauch and perhaps to Professor Kelly as well. We know that salmonellae can survive for very long periods in slurry and so can other bacteria, I believe, such as brucella. I think the real question here is for what period are they pathogenic? A lot of work was done in taking bacteria samples and testing in the laboratory to see if they are alive and will grow on agar cultures. Do we know for what period of time these bacteria can cause infection in animals? I think perhaps they are less pathogenic after a month or two in the slurry and they may not be capable of causing infection.

W.R. Kelly

The general assumption which can be proved quite readily by means of biological testing, is that if the organism will grow fairly freely on laboratory media, it is pathogenic. This is a general comment. It is possible that deleterious influences can affect the virulence of the organism and its ability to establish infection. Although we know some of the deleterious influences involved we don't know them all, certainly not in relation to environmental factors.

D. Strauch

Thank you. At breakfast this morning Dr. Geissler told us of a case at his Institute where they had a severe outbreak of salmonellosis in a poultry flock. They isolated the salmonella type and tried an artificial infection of experimental birds at the Institute. They couldn't provoke an infection with this germ which had caused a severe outbreak in a farm under natural conditions. That means that there are other factors playing a certain role in the epidemiology besides the germ itself. It is possible that in the particular flock where the outbreak occurred there were some environmental conditions which were not measured, but which were a contributing factor, for example, a high NH_3 content in the air which depresses resistance to the organism. Salmonellosis is a factorial disease; it is not caused by the micro-organism alone, other contributing factors must be present to cause an outbreak. Is that enough Dr. Tunney? You don't seem satisfied.

H. Tunney

No, not very satisfied.

H. van Dijk *(The Netherlands)*

It is an established fact that plant pathogenic organisms can turn from pathogenic into non-pathogenic.

D. Strauch

This is true for all micro-organisms; they can change their pathogenicity, as Dr. Kelly said. The difficulty in these investigations is that we cannot try each isolate on experimental animals because we would need large numbers of poultry, calves, pigs etc. for experimental purposes. So we have to trust in what Dr. Kelly has said and assume that if it is isolated on an agar medium then it is pathogenic unless proved to the contrary.

H. van Dijk

One other question. The data given this morning regarding storage all refer to anaerobic storage. It would appear from the literature that there is not much difference in the survival of pathogenic organisms in aerobic or anaerobic storage. Have you any experience with this?

D. Strauch

We have made experiments with surface aeration and with oxidation ditches. There is a difference in the survival in aerated slurry and in slurry stored under anaerobic conditions but the aeration itself does not disinfect the slurry. In an oxidation ditch the salmonellae do survive more than 30 days if they are introduced into the slurry artificially. In a naturally infected oxidation ditch it is not possible to kill the salmonellae by aeration; they persist in the slurry for two or three months. Aeration kills the germs a little earlier but it is not such a significant difference that you could say the slurry was free of pathogens after one month, for example. The only effective known method at the present time is rotating aeration which creates high temperatures and thus kills the salmonellae, the *Ascaris* eggs, and so on. However, I would like to stress that it is very important to have a high pH because the viability of most of the micro-organisms is reduced in relation to increased pH level. At a pH of 8.5 with rotating aeration, salmonellae will be killed within a period of 2 - 4 hours. At a pH of 7 - 7.5 it will take about 50 - 60 hours. So there is a direct connection with the pH. The same effect can be achieved by adding lime to slurry - you kill the germs within 24 hours at a pH of 9, 10 or 11.

A.A. Jongebreur *(The Netherlands)*

I would like to make a comment on Dr. Downey's paper. In the Netherlands the infection of young calves with gastro-intestinal nematodes can be reduced by grazing the calves only on pastures which have previously been mown.

N.E. Downey

This raises an interesting point. One of the methods for controlling nematode parasitism and gastro-intestinal parasitism which we adopt and recommend, is to graze calves from mid-July on ungrazed silage aftermath. This relates to the epidemiology of this condition. One of the interesting things here that we ought to look into is that if this silage had been treated with slurry prior to cutting, would it still be safe for grazing?

D. Strauch

Thank you. I have a question for Dr. Kelly. I refer to your Table 1. You said that the calves were not fed with antibiotics as a food additive, but were they, in fact, treated with antibiotics in any way?

W.R. Kelly

These calves were acquired through ordinary commercial sources. They developed pneumonia, I did have serological tests carried out to determine what type it was but the result indicated that at least three viruses were operating. We just put them on to a sulphonamide trimethoprim complex as a form of therapeutic treatment. This is a form of treatment which is stated by the manufacturers of the product not to induce cross resistance to any other antibiotic.

D. Strauch

But they had a considerably high level of resistant coli...

W.R. Kelly

Yes, but the possible explanation of that lies in the fact that the calves had come through a commercial market. If you recall, I said I excluded the first sample from the Table because of the possible obscuring effect this might have on the sensitivity patterns. We recognise that this does occur. If farmers intend to send their calves to market for sale early in life they usually treat them with antibiotics to provide some sort of protection to the calves against *E. coli* infections. The stresses of going to market are well known to be a contributory factor in initiating outbreaks of this disease because calves from different places come into contact, pick up different serotypes of the *E. coli* from the other calves, from which they may not have acquired immunity from the colostrum of their dams.

The other point, following from this, was that as a result of first being in our house environment and then turned out to graze, the percentage of resistance shown by the *E. coli* dropped fairly rapidly. In conjunction with some of our colleagues in the Faculty of Agriculture, we have been carrying out surveys on this particular situation over the past two or three years. A paper is due to be published shortly, if it has not already appeared. Here the groups of calves had their diets supplemented with different types of therapeutic antibiotics during the winter period and then when they were turned out to graze in the summer, the antibiotic medication was stopped. This was done to determine the variation in growth promotion properties of the different antibiotics. However, when the calves were turned out to graze the dietary intake could not be controlled and it was noted that the percentage of antibiotic resistance shown by the *E. coli*(which had been 60 - 70% while the animals were housed) dropped to virtually nothing within a month.

D. Strauch

Thank you. Now we have run out of time and I would like to thank the speakers and all those who participated in the discussion.

THEME 6

MISCELLANEOUS

Chairman: J.R. O'Callaghan

THE EFFECTS OF SEPARATING SLURRY ON ITS STORAGE, HANDLING AND SPREADING ON LAND

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ABSTRACT

Some or all of the extra cost of separating slurry into solid and liquid fractions can be offset by lower storage costs and easier and cheaper ways of emptying stores, especially if they are large lagoons. Handling and application to land can also be easier and cheaper with less risks of water pollution, odour nuisance, and pathogen survival and with a better chance of using the plant nutrients in slurry efficiently.

1. SEPARATION

Manures have often been separated into solid and liquid fractions by gravity, both within the buildings housing animals, and in slurry stores by settlement or through permeable walls of spaced timbers or straw bales. Neither of these methods are reliable nor do they give a solid fraction dry enough to compost into an odourless material or a liquid which is consistently free enough of coarse solids to be handled like water. Such a result can be achieved only by using a mechanical slurry separator of which there are now a number available of three main types, screens, screen presses and centrifuges. Except with pig slurry which is very dilute, that is with less than about 3% dry matter (DM), simple screens (Figure 1) will not produce a solid fraction dry enough to compost or to store without loss of further liquid by drainage. A force higher than gravity is needed for this and is produced by rollers running over the screen in screen presses (Figure 2) or by centrifugal force in centrifuges (Hepherd and Douglas, 1973). A modern efficient slurry separator will produce from undiluted pig or cattle slurry a solid fraction with 20 to 25% DM which can be stacked and a liquid fraction with 2 - 7% DM which can be stored and handled as if it were water.

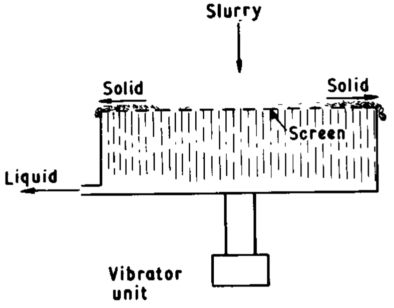


Fig. 1 Vibrating Screen

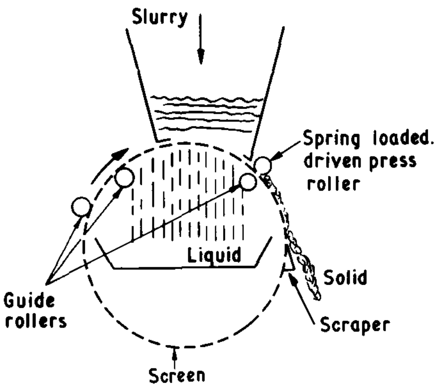
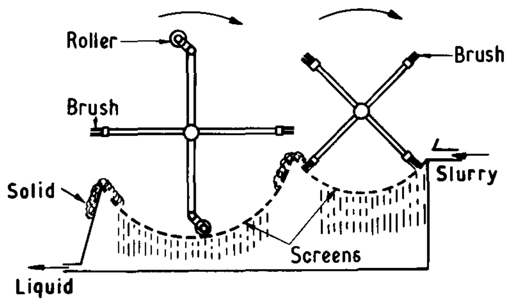


Fig. 2 Rotary Screen with Press Rollers



Combined Brushed Screen and Roller Press

A separator adds to the cost of the equipment needed for handling manure from housed livestock and disposing it on the land. Its purchase and use can be economically justified, therefore, only if there are equivalent returns from savings in slurry storage costs, simpler farm management, a reduction in fertiliser costs or higher crop production. It may also be justified, however, if some of the returns are in the form of reduced risks of water pollution and disease transmission and lower levels of odour around buildings and during land spreading. Both types of benefit from separation are discussed in the following sections, but a conclusion on whether slurry separation is worthwhile for a particular farm can be reached only by considering its own special problems and the benefits on that farm.

2. STORAGE

If slurry is separated, up to 20% by weight of undiluted pig manure and up to 40% of undiluted cattle manure can be stacked as a solid. Since no special structures are necessary to store this material, the smaller tanks needed for the liquid can show a significant saving over the cost of the equivalent store for unseparated slurry. In one case, the liquid fraction has been directed into an existing irrigation water reservoir and so no slurry storage costs have been incurred.

The storage of separated liquid rather than slurry has other advantages. With no crust formation and little sedimentation, stores can be emptied completely without prior mixing. This is particularly important when slurry is stored in shallow excavations or lagoons, in which the contents are very difficult, if not impossible, to mix efficiently in order to facilitate removal. Filled with separated liquid, such lagoons can be emptied completely from outside by tanker or pump. Filled with slurry, it is often necessary to enter them with specialised equipment which is usually owned by contractors, and so the cost of emptying them is much higher. If, for reasons of water pollution, it is necessary to line such lagoons with an impermeable plastic or butyl sheet, they cannot then be entered to remove the slurry without destroying the lining, unless substantial areas of concrete are incorporated in the floor. Even then the linings are likely to be damaged during emptying, and so separation is probably the best solution to the problem of emptying lined lagoons.

3. APPLICATION

The two products of separation are easier to handle than the original slurry. The solid fraction can be loaded, transported and spread with the equipment designed for solid farmyard manure which is on most British farms. It is also very easy to incorporate into the soil even during the later stages of seedbed preparation. The liquid fraction can be removed from storage and distributed as if it were water using either conventional slurry handling or irrigation equipment. When applied to grassland, it will contaminate the herbage less than complete slurry and so is likely to lead to reduced rejection problems. It can also be injected more easily than complete slurry. Smaller pipes can be used on the machines without risk of blockages and thus it is possible to fit narrower tines which cause less soil disturbance and require less power for a given depth of penetration.

Although any conventional irrigation system can be used to apply the liquid fraction of slurry to land, smaller and cheaper equipment has proved adequate experimentally. It consisted of a centrifugal pump driven by 1.5 kW motor and delivering 1.5 ls^{-1} (5.5 m^3h^{-1}) over a distance of 800 m through 38 mm nominal bore PVC pipe against a total head of 30.5 m. The pressure at the pump was 450 kN m^{-2} and about 310 kN m^{-2} at the four conventional irrigation sprinklers with 4.8 mm nozzles used for distribution. The annual cost of slurry spreading using this system, including separation and the application of solids to land, was calculated to be slightly less than that of two others based on tankers and organic irrigation in the ratio of 100 : 107 : 113, (Hawkins, 1972). An even cheaper method, of course, is to direct the liquid fraction from a separator into an existing irrigation reservoir and distribute it with the water when crops are irrigated in the summer.

4. WATER POLLUTION

Where an intensive livestock enterprise does not have quite enough land to accept all the manure produced without risk of pollution, or is to be expanded on an existing area of land which is fully used, separation can often avoid water pollution problems. The ability to stack 20 to 40% of the output of the animals and compost it into an inoffensive and friable material makes it much easier to export to other farms or even to sell in small packs to domestic gardeners. The fibre separated from cattle slurry has also been re-used as bedding for cubicles in the USA , (Dale and Swanson, 1975).

A more important advantage is the ability to apply separated liquid to land in the winter with less risk of run-off or pollution of drainage water than with slurry. If tankers are used for slurry, there are usually problems of traction and damage to soil and crops throughout the winter and it is difficult to apply quantities small enough to avoid water pollution. Whilst organic irrigation avoids the traction and transport problems of tankers, the application rate also has to be high, at about 4.5 ls^{-1} (16.5 m^3h^{-1}), because with the minimum practicable pipe diameter of 75 mm the velocity has to be high enough to prevent sedimentation and hence blockages in the pipes. Further, dilution of manure as produced by the animal is usually required to make reliable pumping possible. Both of these factors contribute to high hydraulic loading of the soil, often of the order of 7.6 mm or more per hour. Separated liquid, however, can be applied through sprinklers at rates very much lower than this: in some cases amounts as low as 2.5 mm h^{-1} have been achieved.

As long as the land is not frozen or it is not raining, there is usually some evaporation from the soil surface in Britain at a wide range of rates depending on the district and the time of year. The least favourable month is December when in Bedfordshire, for example, the mean evaporation over the 10 years 1961-1970 was 1.8 mm or 15.7 m^3ha^{-1}. Taking an example from dairy cows from which 10 volumes of slurry yield about 8 volumes of separated liquid, one hectare would, therefore, accept throughout the year without run-off the liquid fraction from about 15 cows provided that it were applied slowly enough and only in fine weather. In other words, the liquid fraction of the slurry from 100 cows would all go on 7 ha in the least favourable month and, as much more land than this would be available on a dairy farm, the risk of run-off could be made to be very low indeed. (Hawkins, 1972).

However, even if careful application of separated liquid at the right time and at very low rates avoided all risks of water pollution by run-off, its BOD load would remain. Microbiological activity in the soil does not cease at winter temperatures in Britain and would no doubt reduce this load and the seasonal increase in the flow of water through the soil would, by dilution, reduce the level of pollution still further. Research is, however, needed to establish the effects of such very low rates of application of slurry liquids on the quality of the drainage water, on different soils and under a range of conditions.

5. ODOUR

A liquid fraction can be applied to land with less risk of odour nuisance than unseparated slurry, and a solid fraction, if sufficiently dry, will compost to a material which does not have an offensive smell. Because the liquid can be handled through small bore pipes and nozzles, it can be applied to land with low level sprinklers or even trickled on to the surface through perforated pipes. In this way the distance over which droplets and their associated odour are likely to be spread by wind is much less than with conventional tankers or rain guns. Further, the ability to spread slurry liquid at a low rate throughout winter (see Section 4) can allow a policy of a minimum storage period to be adopted. For much of the time, then, only fresh slurry liquid is being spread on land and odour nuisance is thus much reduced.

The liquid fraction of slurry can also give fewer odour problems in storage. There is, for example, some evidence that, with cattle especially, it does not smell so strongly in a shallow store or lagoon as unseparated slurry, although this conclusion needs further confirmation. (Hepherd, 1975). It certainly does not need mixing before removal and so when emptying a store there is far less odour than with an unseparated slurry which has to be mixed before it can be removed. If it is necessary to aerate slurry before spreading in order to reduce odour, separation makes this process easier and cheaper because less energy is required to achieve mixing and hence thorough aeration and the volume to be aerated is reduced by the separation process.

6. PATHOGEN SURVIVAL

Depending on its moisture content, the solid fraction of separated slurry will reach temperatures of 30 to 40°C in about two days. Although no information is available on the fate of pathogenic bacteria during slurry separation, it is probable that bacteria such as salmonellae will die rapidly in the solid fraction during composting. It is also likely that they will have a reduced survival time in the liquid fraction compared with the probable survival time in whole slurry. (Jones, in press).

Finally, separation helps in pathogen control by making it possible to spread slurry in ways which reduce the risk of drift with the wind. Attempts to measure the range of bacterial pollution of herbage downwind from slurry spreading with a raingun have shown that fall-off with distance was rapid in still conditions. In a 56 kmh^{-1} wind, however, gross contamination was detected 8 km downwind at the limit of sampling, (Robertson, 1976) (Figure 3). In such situations separated liquid can be applied close to the ground, in the way described above in Section 3, so avoiding the possibility of the drift of droplets or particles over long distances.

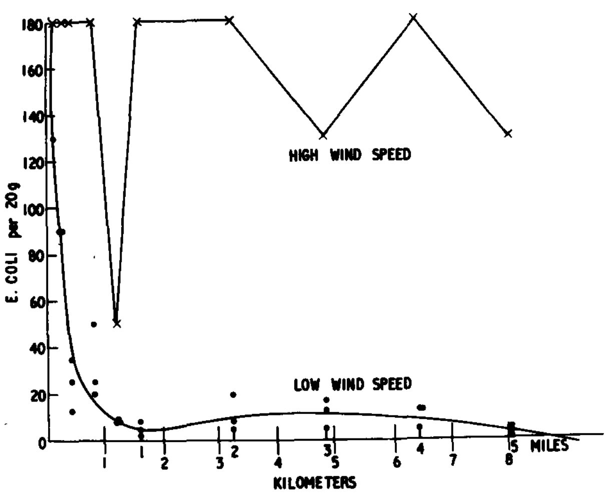


Fig. 3 Bacterial Counts on Grass Samples Downwind from Slurry Raingun - Howsham, Lincolnshire 1973 - 1974.

7. THE USE OF PLANT NUTRIENTS

Separation, because of the resulting advantages for storage described in Section 2 above, makes it cheaper and easier to store slurry for application when crops can use the nutrients in it most efficiently. The advantages of separation from this point of view have been dealt with by Dr. B.F. Pain, (Pain, 1976), The liquid and solid fractions, however, are much easier to use efficiently than slurry because it is possible to make a more accurate estimate of their plant nutrient contents. Being more homogeneous, it is much easier to obtain representative samples for analysis from a stack of solids or a store of liquids than from a store of unseparated slurry. The two fractions can then be used in the correct quantities and balanced when necessary by adding the right amount of inorganic fertilisers.

CONCLUSIONS

a) The extra cost of separating slurry mechanically into solid and liquid fractions may be offset by the resulting economies and benefits.

b) Separation reduces storage costs and makes the mixing and emptying of the contents of stores cheaper and easier.

c) Liquid fractions can be applied to land more cheaply than slurry by means of small pumps and pipelines.

d) Separation can permit higher stocking densities without increasing water pollution risks.

e) A liquid fraction can be applied to land in winter with less risk of run-off than whole slurry.

f) Separation reduces odour nuisance by producing a solid fraction which composts without smell and a liquid fraction which can be handled and spread on land with less smell than slurry.

g) Separation can reduce the chances of pathogen survival in both the solid and liquid fractions.

h) It is easier to use the plant nutrients in slurry efficiently if it is separated before storage.

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AEROBIC TREATMENT IN RELATION TO LAND APPLICATION OF SLURRY

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INTRODUCTION

There is general agreement that excreta from farm animals should be recycled through the land. The development of intensive meat, milk and egg production with associated slurry systems has presented a series of problems, especially in relation to environmental quality.

There is some conflict in obtaining maximum utilisation of the plant nutrients in slurries and maintaining minimum risk to the environment in terms of air, soil and water pollution. Until relatively recently, economic considerations have led farmers to disposal of slurry almost regardless of its value as a fertiliser. This is particularly so of pig and poultry production enterprises with very little agricultural land, but also applies to dairy and beef cattle where grassland management has steadily increased the use of inorganic fertilisers. It is this practice, during a time of public and consequent government interest in environmental control, which has created problems of odour and water pollution. Excessive application of slurry throughout the year may cause organic pollution of streams due to surface run-off or percolation through field drains. Such discharges tend to be high in suspended solids concentration.

Since the control of river pollution based on BOD and SS is well established, emphasis has been placed on avoiding such incidents. More recently, inorganic pollution of water courses has given rise to concern and the extensive use of inorganic fertilisers is regarded as a contributory factor to eutrophication and nitrate toxicity.

RECYCLING OF PLANT NUTRIENTS

These factors and perhaps more significantly, the rapid increase in costs of inorganic fertilisers in terms of money and energy input, have encouraged agriculturalists to re-examine the situation with a view to reducing both the extent of water pollution and the use of inorganic fertilisers by the efficient utilisation of the plant nutrients in slurry. Thus, the twin concept of maximum stocking densities and maximum application rates of slurry have been developed. The utilisation of plant nutrients depends on correct application rates at the appropriate season and therefore requires extended storage facilities. These may be on slurry-producing farms, on land receiving the slurry, or in a 'manure bank'. Minimum dilution of the slurry will reduce the storage capacity required, the hydraulic loading and the cost of transport and application. The proposed stocking densities and application rates will effectively eliminate water pollution except in extreme conditions of topography, soil type and rainfall but certain difficulties remain. Storage conditions must eliminate the risk of ground water pollution and adequate safety measures must be provided. The utilisation of the plant nutrients requires a uniformity of nutrient concentration in the stored slurry and at the time of application. There will be demands for analytical services in order to supplement the slurries with inorganic fertilisers and to prevent excessive application of nitrogen from pigs and poultry, and of potassium from cattle.

The adoption of such a policy will permit maximum recovery of plant nutrients and greatly reduce the risk of water pollution. However, the problem of odour remains and, indeed, may be accentuated by long term storage under uncontrolled anaerobic conditions. Odour is most pronounced on mixing after storage and during spreading. The use of extensive areas of land at some distance from an intensive piggery or egg producing enterprise will disseminate the odour to previously unpolluted areas. Furthermore, long term storage has little effect on the survival of most pathogenic micro-organisms and the risks to animal and human health over enlarged areas cannot be ignored. Serious restraints would apply in conditions of outbreaks of diseases such as foot and mouth, swine vesicular disease and salmonellosis. In the event of animal movement restriction orders it is difficult to imagine the continuation of slurry transport, storage and spreading on land.

ADDITIONAL TREATMENT

These possible constraints demonstrate the need for continued evaluation of methods of handling and treatment, prior to ultimate land application, which will reduce or eliminate odour and facilitate the utilisation of plant nutrients. In particular, the transformation and conservation of nitrogen are of importance. These methods must also be examined in relation to the possible effect on dissemination of pathogens. On order to retain flexibility, the potential of any system in permitting intensive methods of production to continue, by eliminating air, soil and water pollution hazards in situations where land availability does not readily allow a return to non-intensive farming, requires further evaluation.

BIOLOGICAL TREATMENT

The treatment of slurry may be physical, mechanical, chemical or biological. The following discussion attempts to present some of the results obtained at The West of Scotland Agricultural College from largely laboratory-scale experimentation on aerobic treatment of pig slurry. The main findings apply also to slurry from battery hens and from cattle.

Aerobic treatment systems are essentially continuous cultures of micro-organisms. In the presence of an adequate supply of dissolved oxygen, a mixed population of micro-organisms will become established and convert the chemical components of slurry from one form into another, and into microbial cells. Ultimately, aerobic metabolism will result in the production of CO_2, water, inorganic salts, heat energy and microbial cells.

The variety and activity of micro-organisms that establish populations and hence, the degree of biodegradation, depends on a variety of physical and chemical parameters including mean residence time of micro-organisms or sludge residence time (SRT), dissolved oxygen concentration and temperature. These factors are also important in the capital and operating costs of treatment systems.

Variation in operational parameters will affect the end products and the process can therefore be manipulated to meet one or more of the desired objectives of treatment. Primary solids/liquid separation by physical and mechanical techniques must also be considered in conjunction with biological treatment to gain an appreciation of the economic and handling aspects.

SLUDGE RESIDENCE TIME

The substrate loading rate, or food to micro-organism ratio is a useful parameter in controlling the quality and quantity of the end products. Due to the lack of precise information on the substrates present in slurry and to the presence of a large proportion of non-microbial solids in the mixed liquor of aerobic systems treating whole slurries of animal wastes, the substrate loading rate is only an approximation of the food to micro-organism ratio. As the mean residence time of solids in the aeration vessel is increased, the proportion of non-microbial solids is decreased due to biodegradation of solid materials. Thus, in many cases, where there is no recycling of liquids or sludge, it is useful to use SRT in defining operating parameters since it is inversely proportional to the dilution rate of the microflora.

The laboratory treatment systems and the methods used for monitoring and analysis are described by Owens et al. (1973). All analyses quoted are from experiments in steady state conditions. In almost all cases a commissioning period of three complete residence times provided these conditions. In a few cases exceptionally high NO_2^--N concentrations (100 - 1000 $mg.l^{-1}$) occurred. The commissioning period was extended and eventually

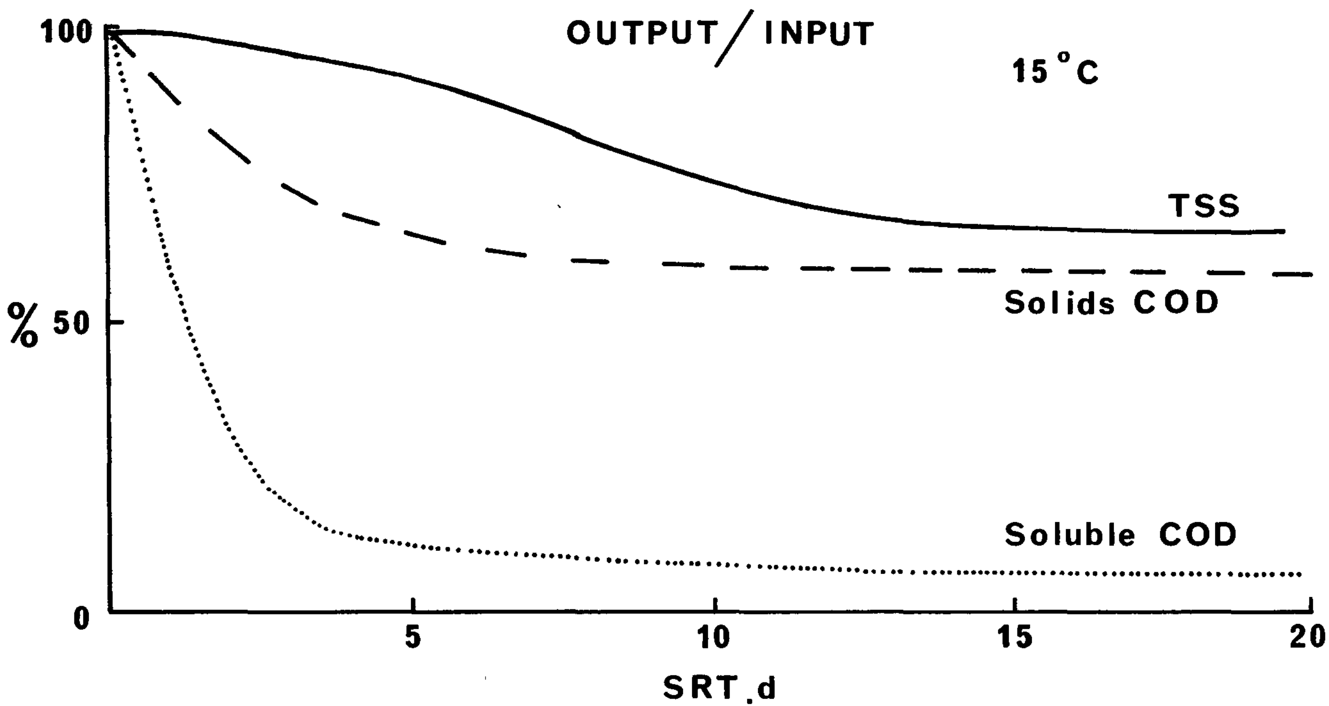

Fig. 1 The percentage output/input of components of piggery slurry from an aerobic continuous treatment unit operated at 15°C and at SRT from 0 - 20 d.

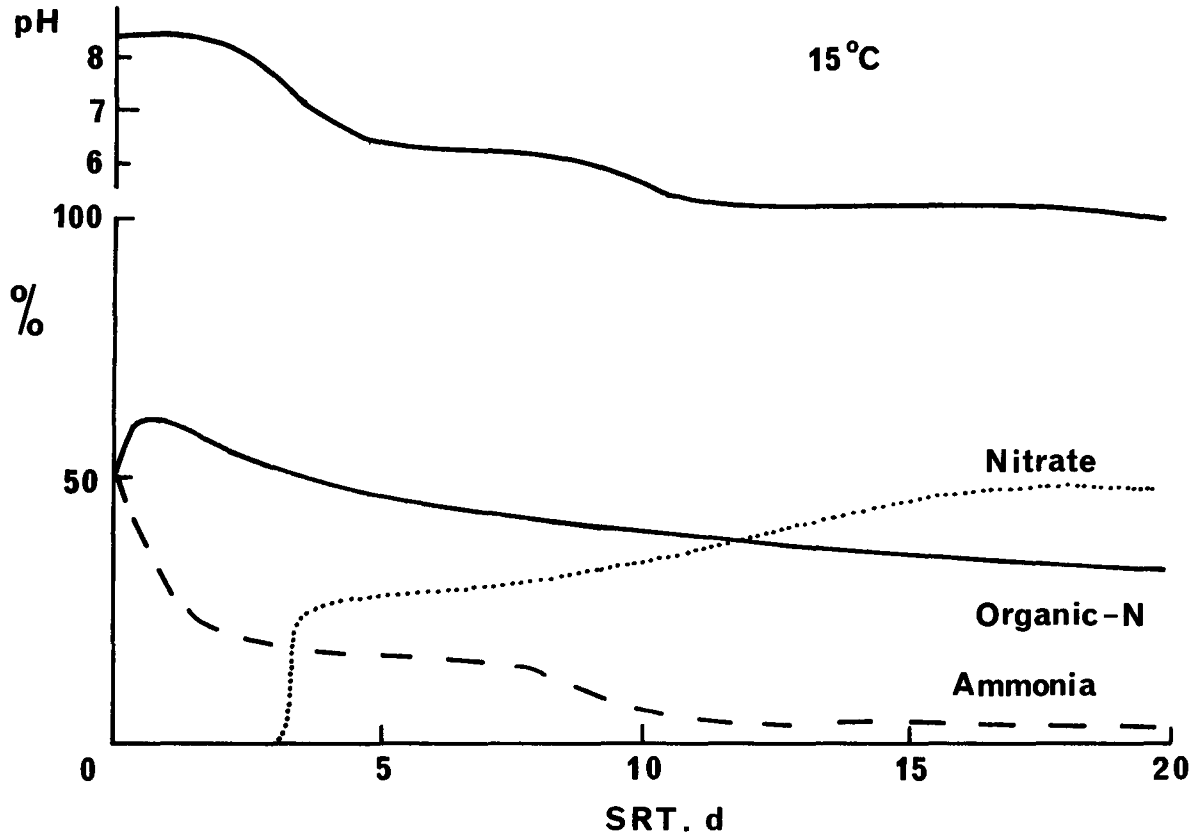

Fig. 2 The pH value and the distribution of nitrogenous compounds expressed as a percentage of total nitrogen in the aerated mixed liquor of a unit treating piggery slurry continuously at 15°C and at SRT from 0 - 20 d.

the NO_2^--N concentration fell and steady state conditions were established.

The effect of SRT on the quality of slurry produced from aerobic treatment of piggery slurry (20 - 25 g TSS.l^{-1}) at 15^oC has been studied over the range 1 - 32 days. Dissolved oxygen was not a limiting factor. The results are illustrated in Figures 1 and 2. The data of soluble COD (Figure 1) have been used to support a substrate model for the continuous treatment of piggery waste by Woods and O'Callaghan (1974). Further design formulae for other parameters such as TSS and COD of solids are being studied.

At a SRT of less than two days some ammoniacal N is assimilated into microbial cells, indicated by an increase in organic N. However, in the SRT range of 0 - 3 d a large proportion of ammoniacal N is lost to the atmosphere. Between 3 and 4 d the specific growth rates of nitrifying bacteria allow the establishment of nitrifying populations in the mixed liquor. About 40% of the total N is oxidised to nitrate, but about 15% remains as ammonia in the range of SRT between 3 and 9 d. From 9 - 14 d there is a gradual increase in nitrate and a gradual reduction in ammonia. At 14 d, about 60% of total N is oxidised to nitrate but beyond 14 d the increase in nitrate appears to be limited by the rate of ammonification of organic N (Figure 2).

The plateaux of oxidised N and ammonia (Figure 2) from 3 - 9 d SRT indicate incomplete nitrification and may be associated with the pH of the mixed liquor. This suggestion is supported by evidence from studies of the effect of dissolved oxygen tension in aerobic systems.

DISSOLVED OXYGEN TENSION

A large proportion of the operating costs and a significant proportion of the capital costs of aerobic treatment are attributable to the requirement for oxygen. It is therefore important to determine the effect of dissolved oxygen tension on the quality of the treated material in order to ensure that the cost of supply is minimal in relation to the desired objectives.

The methods used in controlling and monitoring DO tension will be published elsewhere. The system has been operated over a range of DO from 1 - 99% saturation and there appears to be little effect on the output of TSS, COD of solids and soluble COD at an SRT of 7 d and a temperature of 15°. Oxygen supply therefore becomes limiting to the aerobic microflora responsible for these changes at DO tension levels below 1% at 15°.

However, at DO levels below 12 - 14% there are marked changes in the nitrogen transformations. The concentration of oxidised nitrogen and the output of soluble and total nitrogen in the mixed liquor are directly related to the DO tension. Above 14%, nitrogen output is independent of DO tension. At 7 d SRT and 15° a highly nitrifying mixed liquor is established and 600 - 700 $mg.l^{-1}$ of oxidised nitrogen accumulates. Below the critical DO tension the concentration of oxidised nitrogen decreases and the loss of nitrogen from the system increases. It is concluded that a nitrifying/denitrifying mixed liquor is established and that oxidation of NH_4-N, oxidation of carbonaceous materials and reduction of oxidised N compounds, occur simultaneously under these conditions.

Simultaneous nitrification and denitrification has been suggested in a flocculated mixed liquor (Wuhrmann, 1964) and has been shown to occur in systems where regions of high and low DO occur, e.g. oxidation ditches. (Murray, Parsons and Robinson, 1975). However, it has not been shown to occur in an apparently homogeneous and aerobic mixed liquor. It is possible that, as discussed by Wuhrmann (1964), the microenvironment of the floc may have a very low oxygen tension despite a well aerated mixed liquor. Experiments at shorter SRT have shown that the situation is further complicated by washout of the nitrifying population. The effect of temperature is also being further studied.

TEMPERATURE

The experiments described earlier in this report have been mainly with the objective of evaluating systems operating at ambient temperatures. Temperatures of mixed liquors will normally vary with atmospheric temperatures and it may be expected that metabolic activity will therefore also be related to atmospheric temperature. An increase in the metabolic activity by raising the temperature of the mixed liquor was not originally considered because the entrainment of cool air by traditional aeration methods would entail the input of heat energy, thereby reducing the cost effectiveness of shorter residence times and smaller aeration vessels.

However, the development of aerators such as the plunging jet, being evaluated by Hawkins at the National Institute for Agricultural Engineering (UK) and the 'Licom' systems, currently marketed by De Laval, has suggested that the heat generated by microbial activity and by the conversion of mechanical energy can be conserved in aerobic treatment vessels. Mixed liquor temperatures in excess of 45^{o} have been reported.

It is, therefore, useful to examine the effect of temperature on qualitative and quantitative changes during aerobic treatment. As temperature increases, metabolic activity also increases, but above certain temperatures the components of the microbial population will change. In particular, a marked change can be expected as the temperature enters the thermophilic range. Changes in population will affect the range of substrates utilised and the variety of end products. At present, results of experiments in the continuous systems are not available. The data presented are derived from experiments to show the effect of temperature on the metabolic activity as measured by respiration rate of the microflora in batch systems. Respiration rates have been measured, on aerated slurries inoculated with a seed acclimatised to the appropriate temperature, using a Gilson respirometer and a continuously-recording respirometer. Hissett, Evans and Baines (1975) reported on the biodegradability of whole, and of fractions of pig and poultry

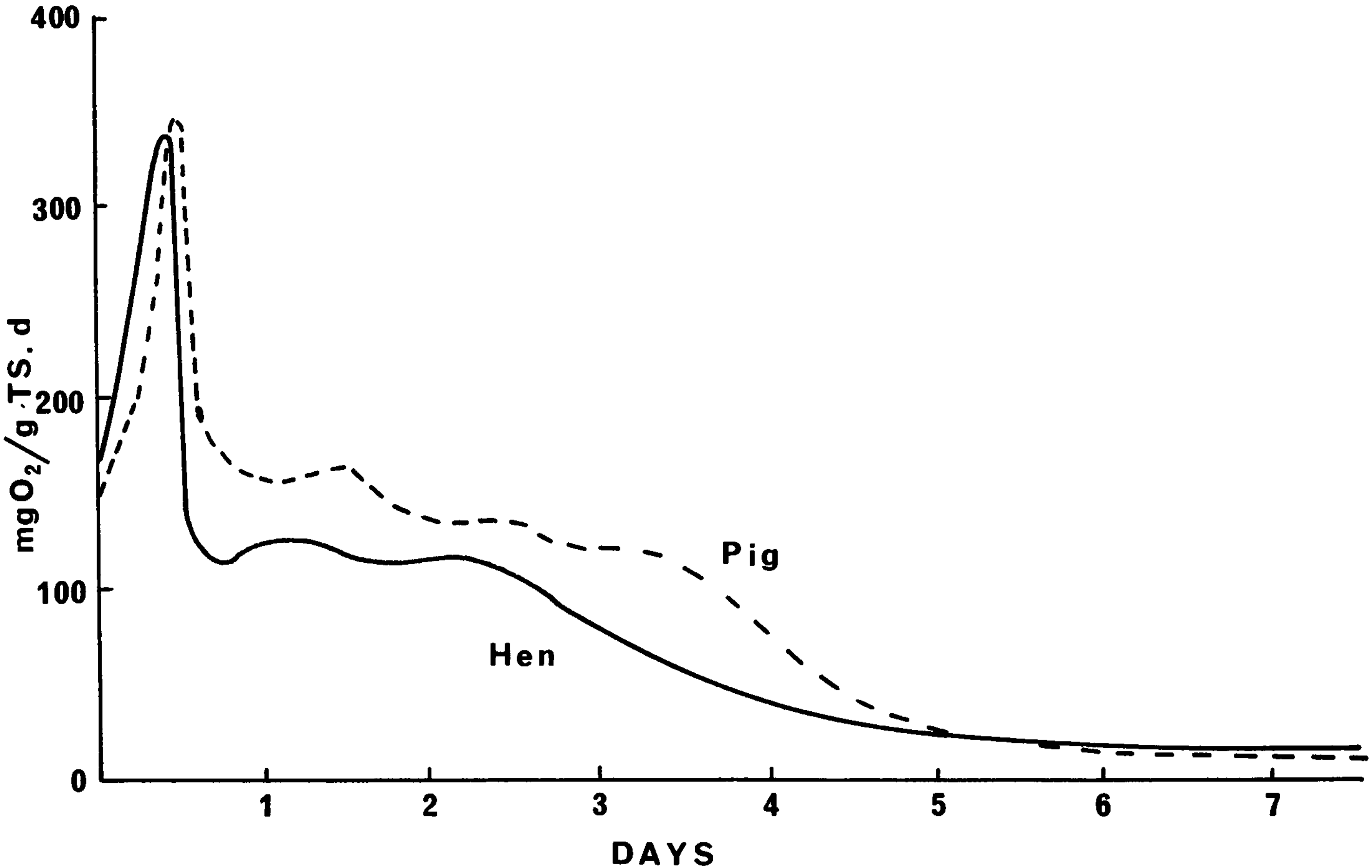

Fig. 3 Oxygen uptake rate during batch aeration of whole pig and hen excreta.

slurry, in batch aerobic treatment at 20°. Data at 10° were presented by Hissett (1974). The respirometric method used in these experiments has been extended to cover the effect of temperature and aerobic treatment of whole slurries over the range 5° - 35° in Gilson and Warburg respirometers. A continuous flow respirometer has been developed and used to study the effects of temperature over the range 30 - 50°. Both methods give similar results at 30° and 35°. The respiration rates of whole pig and poultry slurry at 20° are reproduced in Figure 3. The initial peak is largely due to the degradation of the soluble and fine solids fraction. The plateau is primarily due to respiration of fine solids. Respiration of the coarse solids component which is relatively inert, is responsible for the low respiration rate continuing throughout the experiment. (Hissett, Evans and Baines, 1975). The effect of temperature over the whole range 5 - 50° is shown in Figures 4 and 5. The respiration rate is increased with temperature. The peak of oxygen consumed is higher with increase in temperature and the time at which the peak is reached is progressively shorter. These effects continue up to temperatures of about 40°. At 45° there is a reduction in respiration rate and oxygen consumed and this is followed by a further increase at 50°.

These results are interpreted as being caused by a change from the mesophilic to the thermophilic microflora at 40° to 50°. Thermophilic activity will probably increase at temperatures above 50° but maintenance of these temperatures will be difficult under farm conditions without input energy. The results also indicate that the highest temperatures reached, using the new aerators and insulation, are higher than those required for optimal metabolic activity of the mesophilic aerobic microbial population.

The area under the curves in Figure 3 is equivalent to the BOD and the calculated results of $BOD_{0.5}$, BOD_1 , and BOD_5 over the temperature range used are expressed in Table 1.

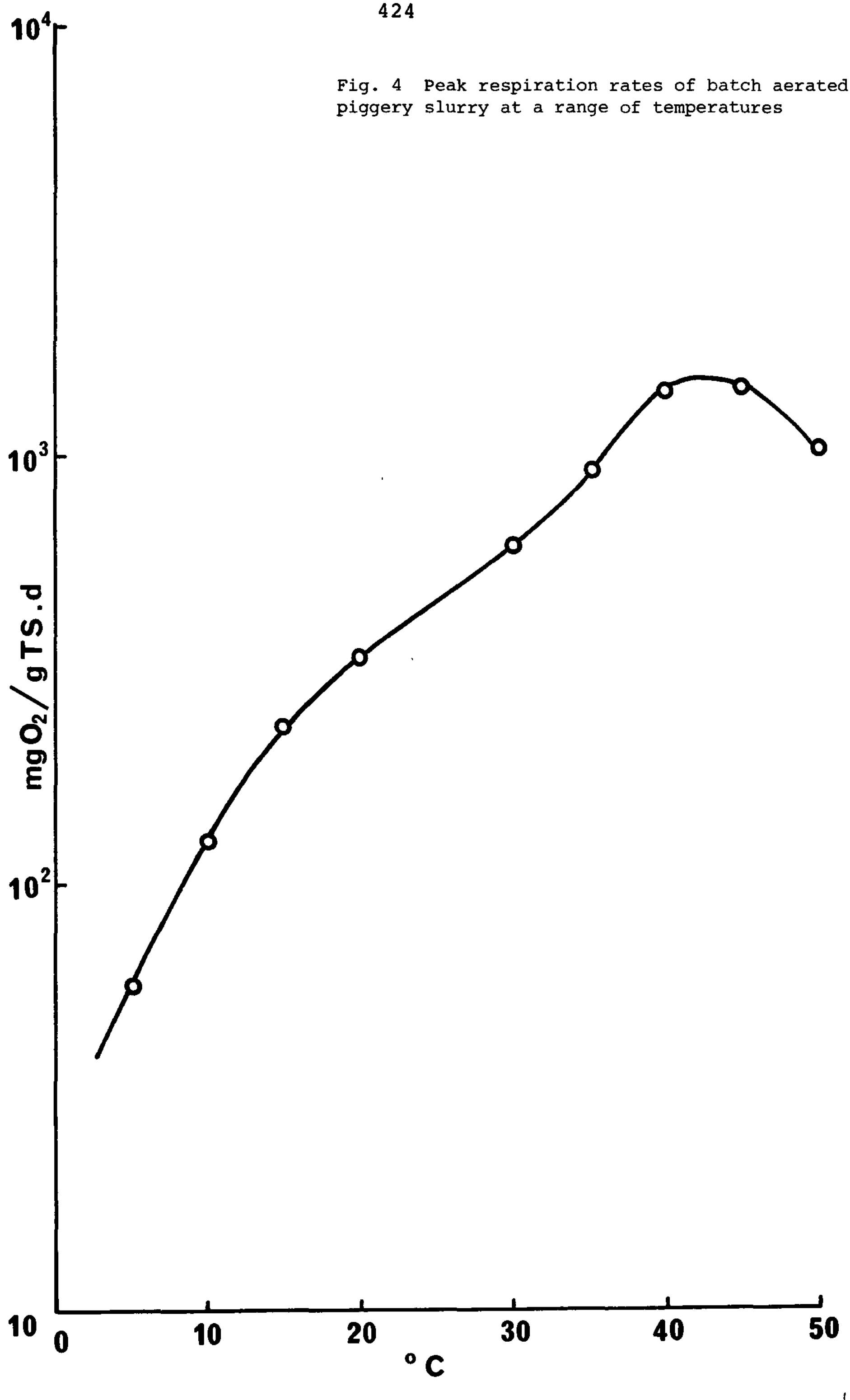

Fig. 4 Peak respiration rates of batch aerated piggery slurry at a range of temperatures

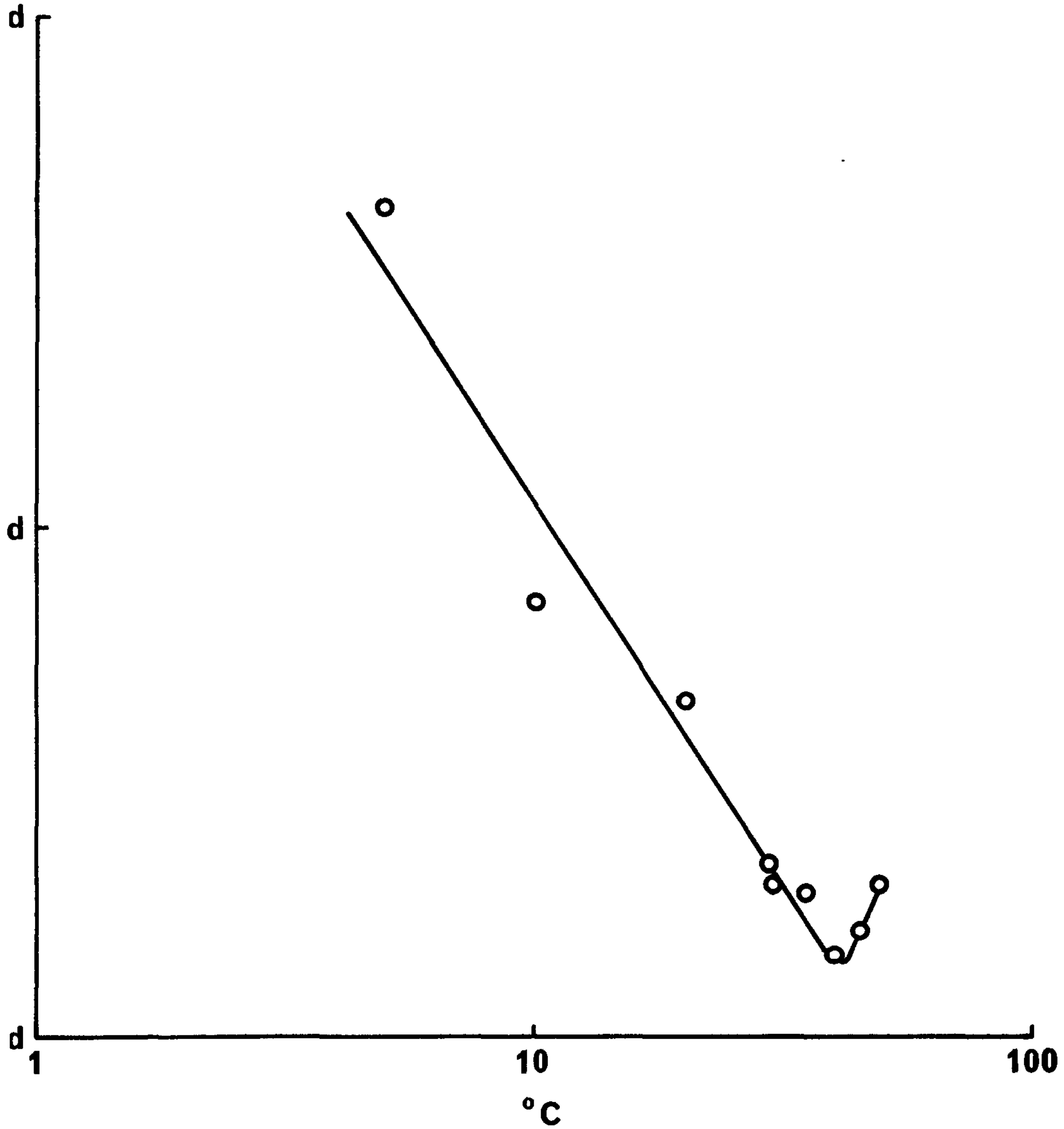

Fig. 5 Time required to reach peak respiration rate during batch aeration of piggery slurry at a range of temperatures

TABLE 1

BATCH AERATION OF WHOLE PIG SLURRY, SEEDED WITH AN ADAPTED POPULATION OF A MIXED MICROFLORA USING A MANOMETRIC AND/OR CONTINUOUS FLOW RESPIROMETER

Temperature $0^{o}C$	Time to reach peak respiration rate h	Peak respiration rate MgO_2/g TS.d	$BOD_{0.5}$ MgO_2/g TS	BOD_1 MgO_2/g TS	BOD_5 MgO_2/g TS
5	102	59	10	17	175
10	17	129	32	72	187
20	11	344	73	147	341
30	5	616	161	247	443
35	5	914	213	276	504
40	4	1411	249	331	-
45	5	1423	235	281	<480
50	5	1017	239	206	<490

APPLICATION TO FARM SYSTEMS

It is apparent from the results presented that aerobic treatment systems can be subjected to manipulation of operational parameters so as to produce a wide variety of end products. In practice, the design and operation will be varied to meet the desired objectives of treatment subject to economic restraints. The application of these design criteria on a pig farm, with about 5 000 whey-fed pigs, has been shown to eliminate odour and greatly reduce water pollution (Evans et al., 1975).

PLANT NUTRIENTS

Nitrogen is the element which is most likely to be converted in form, according to the treatment of slurry from the time it leaves the animal to the time it reaches the land. Long term storage in uncontrolled, largely anaerobic conditions will cause some changes, whereas controlled aerobic treatment can be designed to conserve nitrogen in different proportions of organic N, ammonium N or nitrate N. Alternatively, controlled loss of nitrogen as NH_3 or by denitrification may enable the production of a better balanced fertiliser from pigs and poultry with an increased stocking density and a lower requirement for land.

ODOUR CONTROL

It is widely accepted that maintenance of aerobic conditions in slurry virtually eliminates odour. The odour producing compounds are largely in the soluble components of the slurry and the soluble BOD is most readily supplied in aerobic treatment systems. Residence times for soluble BOD removal are relatively short at ambient temperatures and can be shortened further by increasing temperature. However, the treated slurry cannot be applied to land continuously if the plant nutrients are to be fully utilised. Anaerobic storage of the products of aerobic treatment will rapidly produce odour as more organic material is solubilised and it is necessary, therefore, to consider long term aeration.

It has been suggested that it is possible to remove odour and partially inhibit the formation of odour producing compounds by supplying quantities of oxygen relatively small in relation to those required to develop the aerobic microflora in a fully aerobic system. Oxygen supply has been controlled by maintaining a constant oxidation-reduction potential (Luddington et al., 1967; Bell, 1971; Converse et al., 1971). These authors found an oxygen demand equivalent to 75%, 37% and 27% of the daily BOD_5 input respectively. Hissett, Evans and Baines (1975) demonstrated that odour is confined to the solute fraction of slurry and that at 20^o the oxygen demand of the peak for the solute fraction is equivalent to 27% of the total BOD_5. The oxygen demand of the whole initial respiration peak at 20^o is 59% of the total BOD_5. It appears, therefore, that oxidation-reduction potential control systems satisfy the oxygen demand of only the volatile compounds. Further investigations are in progress in order to determine the minimum oxygen demand required to eliminate odour.

SURVIVAL OF PATHOGENS

Aerobic treatment of slurries will not eliminate pathogens but their survival rate is lower possibly because they continue to respire until specific substrates for maintenance are exhausted. Aeration at elevated temperatures may further shorten the survival time but it remains to be ascertained that multiplication will not occur at these temperatures.

SOLIDS/LIQUID SEPARATION

The evidence presented suggests that it may be possible to control odour and also reduce the pollution risk due to soluble BOD with relatively small amounts of oxygen input. Such systems may also be adapted for control of nitrogen for use as a plant nutrient.

In farm scale plants the energy input to meet the oxygen requirement will be reduced but almost all methods of aeration currently in use rely on a single machine for aeration and mixing. Complete mixing in these systems is important to obtain intimate contact between the microbial flora and the substrate, to maintain steady state operation and to ensure uniformity of nutrient concentration in the treated material. Since it is desirable to have minimum dilution of the slurry the energy demand for agitation may be more than that required for the oxygen supply.

Primary separation and removal of the coarse solids as discussed in another paper by Hawkins should therefore be considered as an adjunct to aerobic treatment.

The solids removed are readily stacked in a sufficiently dry condition to prevent odour and will normally compost. The temperature reached and the storage period will ensure a relatively high death rate of most pathogens. It is also probable that a majority of pathogenic bacteria will be associated with solid particles. Mixing of the liquid fraction can be more readily achieved with lower energy input and at the same time the oxygen requirements can be met. The survival time of some pathogens has been shown to be shorter in lower concentrations of suspended solids when aerated (Evans, 1973; Jones, pers. comm.).

Shallow storage tanks or lagoons may allow adequate aeration without energy input of the stored liquid fraction depending on climatic conditions. Any saving in energy input must be set against the cost of primary separation.

Hissett, Evans and Baines (1975) showed that the coarse solids were resistant to biodegradation and, therefore, their removal may be advantageous in reducing the size of the aeration vessel. Aerobic treatment of the coarse filtrate has been studied in laboratory experiments.

The analyses of the whole and fractions of pig slurry, are shown in Table 2.

TABLE 2

CHARACTERISATION OF WHOLE SLURRY, COARSE SOLIDS AND COARSE FILTRATE

	Whole slurry	Coarse filtrate	Coarse solids
TS	100	46 (46)	54 (54)
Residue	18	14.8 (82)	3.2 (18)
COD	137	67.1 (49)	69.9 (51)
Soluble BOD_5	14	13.3 (95)	0.7 (5)
Total BOD_5	35	29.4 (84)	5.6 (16)
Organic N	3.5	2.7 (76)	0.8 (24)
Ammonia N	3.3	2.9 (89)	0.4 (11)

All values in $g.l^{-1}$. Figures in brackets show the percentage remaining in each fraction.

The TS and COD are almost equally divided between the two fractions. Most of the residue, BOD_5, organic N and ammonia N, are present in the liquid fraction. Further characterisation of the filtrate was achieved by centrifugation and separate analyses of the fine solids and supernatant. The percentage distribution of biochemical parameters is shown in Table 3.

TABLE 3

PERCENTAGE DISTRIBUTION OF BIOCHEMICAL PARAMETERS BETWEEN FINE SOLIDS AND SUPERNATANT FRACTIONS

	Fine solids	Supernatant
TS	66	34
Residue	53	47
COD	64	36
BOD_5	58	42
Organic N	67	33
Ammonia N	14	86

The fine solids fraction contains 66% TS showing that 34% TS are soluble compounds. More BOD_5 and COD are present in the fine solids than in the supernatant. Most of the ammonia is present in the supernatant whereas 67% of the organic N is in the fine solids.

The relationship between SRT and COD, BOD_5 and TSS in the aerobic treatment of coarse filtrate are almost identical to those shown for the treatment of whole slurry (Figures 1 and 2). However, there was no assimilation of inorganic N at short SRT and the concentration of oxidised N did not level off between 3 and 10 d. A SRT of 2.3 d at 15° allowed establishment of a nitrifying population in the aerated mixed liquor. Between 30 and 40% of the total nitrogen is oxidised to nitrate but about 20% of the total N remains as ammonia in the range of SRT between 2.3 and 10 d. As the SRT is increased over this range there is a gradual reduction in ammonia N and a gradual increase in nitrate N.

Similar considerations in the control of plant nutrients and odour therefore apply to treatment of the coarse filtrate as those discussed for whole slurry.

CONCLUSIONS

The data from laboratory experiments, presented and discussed above, provide useful design criteria for the design and operation of aerobic treatment plants to be used in systems where air and water pollution present problems.

Operational criteria are suggested which enable the recovery of plant nutrients as a means of offsetting the cost of pollution control in systems where simple long term storage alone may be inadequate.

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DISCUSSION

J.R. O'Callaghan *(UK)*

We have had two papers which have covered a very wide range. Are there any questions?

F. Bonciarelli *(Italy)*

Could Dr. Baines indicate a figure on the power consumption of such an aerobic plant? For instance, how many kilowatts of electric power per head does a piggery need?

S. Baines *(UK)*

Quite frankly, I cannot answer that question in simple terms. The one I have shown you is already running at the moment with three 7 kilowatt aerators in the main tank and a 17 kilowatt aerator in the secondary tank which may not now be necessary if you can get the material out quickly enough to avoid it becoming anaerobic and starting to smell again. This is a particular case and what we are trying to say is that it depends really on what you want to do. If you want to control odour, and if you take the suggestion of separation, then you can put in a very low level of oxygen with a very small aerator which will keep the contents aerobic enough to control the soluble compounds thereby reducing smell. Obviously, if you wanted to take the material down to Royal Commission standards, the situation would be different. However, we do not think that this is either an economic or, indeed, desirable objective; to convert all the nitrogen into nitrate and throw it into the rivers seems to me a very bad idea. So the situation will vary according to what you are going to do. The problem is not so much the supply of oxygen, as that with a concentrated slurry you need a fair amount of energy for mixing. If you are going to keep the slurry mixed then you will get enough oxygen, at least to control odour. It is the mixing which is the problem and this is where the separation aspect helps tremendously.

D.P. Collins *(Ireland)*

In my country at the moment, farmers are erecting cattle units capable of housing 200 - 300 animals. The system of slurry storage in those houses is an underground tank beneath the slats. I would like to direct a question to Mr. Hawkins. If we were to recommend his system with a machine that would separate the slurry, we would also have to recommend separate storage systems for the liquid and solid fractions, and two systems of distributing them because we would have to use a muck spreader with the solid fraction and possibly a tanker with the liquid fraction. I would like to know whether Mr. Hawkins has done a costing of his system against a system such as ours in terms of the actual storage and cost of distribution?

J.C. Hawkins *(UK)*

The answer is yes and I think you will find the comparative figures in my paper.

J.R. O'Callaghan

I think we can come back to this discussion this afternoon because I believe that Dr. Christensen takes this problem up in his paper.

J.S.V. McAllister *(UK)*

Mr. Hawkins mentioned the injection into the soil of the slurry liquid. I would certainly not be too keen on that because in land where there are piped drains, I think it would greatly increase the possibility of pollutant materials passing through the drains into streams. On the question of ejecting slurry into the atmosphere, again, we have been thinking about this and we are trying to develop a machine that will put the slurry on the surface through trailing pipes much as fertiliser is put onto grassland. I wonder whether anybody else has tried that because injection does seem to be a bad thing.

J.R. O'Callaghan

Any comments? Let us take another question.

H. van Dijk *(The Netherlands)*

Dr. Baines experience is very well in line with our own experience with the biological treatment of animal manure. I am glad that it is much in agreement, corroborating our own results. There is just one question. You mention that you can have incomplete nitrification associated with the pH of the mixed liquid. We add calcium hydroxide solution which solves the pH problem and gives very good nitrification. I think this might also be of advantage with regard to the survival of pathogens.

S. Baines

Yes, I would agree with this. It is mentioned in the paper that when we treated the coarse filtrate only, we did not get this plateau of incomplete nitrification and the pH is different. We have not controlled pH in these materials; we have monitored and, in fact, in these experiments we are settling down to a pH of around 5.4 which we think is getting down to where nitrification would be limited. In the coarse filtrate experiments, for some reason which we have not finally decided, the pH is running at about 6.2, and in this case we do not get the incomplete nitrification. We have not really considered controlling pH because we felt that in a field-scale system this is another added expense and another problem in the field. We are not convinced that it is necessary on the grounds that we do not particularly want, in some cases, complete nitrification.

A.V. Dodd *(Ireland)*

I have some comments on Mr. Hawkins' paper. I assume, on reading his paper, and listening to him this morning, that he is thinking of separating in terms of an aid in handling manure and in overcoming 'crusting', as he refers to it. By this I presume he sees its application primarily in the area of handling cow or beef cattle manure. If it is for pigs, then my own experience has been that there have been few, or no, problems associated with the handling of pig manure. Now, if we are using it to handle cattle manure then one must make the point that the system, assuming it to be technically efficient, does not reduce the nutrients, it merely separates. Thus, in a situation of inadequate land, its success, or its application, depends upon the export of either the liquid, or the solid, or both, as the case may be. My own experience has been that generally with cow and cattle production units there is adequate land. That is the first point I would like to make. The second point is that although there is reference in Mr. Hawkins' paper about the fertiliser value of the liquid fraction, there is no concrete data in Dr. Pain's paper on the results. Nevertheless, I think that it will certainly be easier to spread the liquid fraction but I fear that the use of irrigation pipelines and the spray guns as illustrated may cause other problems particularly in the area of unequal distribution on the sward, especially in windy conditions.

Another point I would like to make is that the figures published for the nutrient characteristics and the solid content, I think depend a great deal on the mesh size of the screen. I have looked at some screens in connection with another problem and I found that you can get quite wide variations in the solid concentrations of the solid fraction depending on what type of mesh is employed as well as the size of the mesh being used. I noticed that Dr. Baines defined 'coarse solids' as something in the region of 200 microns - I think it was .2 m. If one looks at a particle size distribution analysis of the solids in cattle manure, if I remember correctly, something more than 60% are less than 200 microns.

My final point, it's a question really, is that I am not entirely convinced of the cost figures given. I do not think one can isolate the cost of slurry handling from the cost of animal production. One must take into account the building system proposed, but perhaps we can take this point up later. Am I correct in assuming that the figures given in Mr. Hawkins' paper refer to a given system of housing and that having adopted a particular system of housing that one then costs the manure handling and spreading system? I would submit that a more rational approach would be to adopt a housing system which gives the minimum handling cost. From figures which I have worked on for the last two or three years, I am of the opinion that the housing system referred to by my colleague, Dr. Collins, is significantly lower in cost than those systems based on cubicle houses, and can be designed in such a way that the material handling problems are largely eliminated with the use of conventional equipment, and thereby permit the application of the slurry to land in early springtime.

J.R. O'Callaghan

Well, we are very nearly out of time but perhaps Mr. Hawkins would like to tackle those questions somewhat briefly.

J.C. Hawkins

I'll be quick, Mr. Chairman, if I can! I think the separation system does have merit in pig units because if you can stack up and export 20% of the total as solids it is a significant amount of your slurry to handle easily. I know one farmer with cattle who is doing the separation because of the market for the solid fraction. In fact, that farmer is changing from Jersey cows to Friesians because they make more slurry and he has more to sell!

With regard to the uneven distribution, with more modern irrigation equipment, particularly travelling irrigators, this is not a problem, in our experience. It can be if you are careless and if the equipment is old. What Dr. Dodd said about mesh size is, of course, true. If you are prepared to dilute you can use much finer meshes but for the ordinary run of cattle slurries round about 12 - 15% maximum DM, containing the usual amount of stones, odd bits of wood, etc. then the sort of 3 mm mesh size we are using does give the size distribution that Dr. Pain gave. Although you wouldn't expect it there is a sort of blinding effect on the screen that does give the 200 micron maximum size that Dr. Pain quoted. That is a fact of life with that type of machine. Finally, I am in agreement with Dr. Dodd that you could devise systems that might be cheaper if you started from scratch. However, if you are trying to compare ways of handling slurry then you have to start from somewhere and we are comparing dealing with slurry in three ways from the same set of buildings.

If you start to compound this with all possible building variations I do not think you will be able to see the picture quite so clearly, although I do admit that thinking it out from scratch you could make it cheaper. One other point, at the moment the value is very much greater with the separation with dairy cattle than it is with beef animals. With dairy cattle the slurry is produced entirely in the winter and it is more difficult to use it efficiently. With beef cattle you can arrange things to manage the slurry much more easily.

S. Baines

I would like to pick up two points. The first one is on the question of pore size. Ours was an experimental system, experimental separation and fractionisation for our own purposes, but, in fact, we are using .2 mm pore size, and yet our coarse filtrate fraction has 46% of the total solids in it. We do not have this blinding effect - the laboratory situation that Mr. Hawkins was talking about. The second thing is that you will, of course, have a tremendous loss of nitrogen in the separation process because the solids are aerobically treated, they are composted. This is no advantage in cattle where the stocking density is limited by potassium but in pig slurry it might be an advantage.

B.F. Pain *(UK)*

I would agree with Dr. Dodd that there is no concrete evidence in my contribution on the fertiliser value of the separated material. This is because we have only carried out trials for one year and I prefer to repeat them over the next two or three years before I report them fully. The point I was really trying to make is that separating, particularly in the case of cattle slurry, does allow much greater flexibility and accuracy in the rates and in the timing of applications to land.

S. Baines

On the separation question it was mentioned that there was no smell found from the liquid fraction whereas our work would suggest that the smell is in the soluble fraction. When you separate the liquid why doesn't it smell? The answer to this ties up with an earlier question that if you keep the system aerobic then it doesn't smell, and if you have the liquid fraction in fairly shallow lagoons, then you get enough surface aeration to maintain aerobic conditions. You can reduce odour and in the right conditions you may not need to aerate mechanically in order to keep the smell down on a separated liquid fraction.

J.R. O'Callaghan

Thank you very much. It seems to me at the end of this session that one is back on fairly familiar ground and that is that when you have got something, if you are prepared to invest capital, and I think both systems require investment of capital, then you can manipulate the end product resulting from the process and then it becomes a question of trade-offs as mentioned here. Mr. Hawkins seems to be getting to a stage where you could give away the milk and sell the fertiliser! There is the question, therefore, that if you are overstocked it may be possible to trade-off, getting rid of nitrogen for the purposes of using the limited land available to you. There is a third possibility that you can manipulate the availability of the nutrients in the waste, again by investment of capital and control of the process. I do think that it would be extremely difficult to generalise on the economic criteria involved.

Thank you all very much.

THEME 7

MODELS ON LANDSPREADING OF MANURE

Chairman: J.R. O'Callaghan

INVENTIONS AND INNOVATIONS TO REDUCE POLLUTION OF WATER RESOURCES

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PIG SLURRY

For many reasons, the direct landspreading of manure is not always a practical proposition. For example in one area in the North-East Midlands of Ireland in which there is intensive pig production and where the land is hilly and part of a Drumlin Belt (Gleys Soil) the lakes and rivers have been hard-hit by gross pollution and eutrophication of once lovely amenity and fishing lakes has almost reached irreversible levels. The Agricultural Institute Reports No. 1 and 2 of January 1972 and February 1975 respectively, analyse the pollution problem and make certain recommendations as to how the position could be improved. In general, the recommendations provide for storage of the slurry over long periods and only spreading when climatic conditions permit. It is clear that the cost of storage is expensive and the rate of slurry production often exceeds the storage capacity.

As pigs are a very important part of the economy of the area mentioned, a research team of the Agricultural Institute investigated other possible approaches to the problem. The researchers contacted other workers in the UK and Europe, particularly in the field of heat drying, incineration, and biological oxidation etc., but, in the final analysis, it was felt that the cost of such plants would not be a viable proposition in this particular context. Thinking was then directed to chemical methods of treatment and resulted in the patenting of a process (Patent application No. 169/74 O'Shea et al.) based on the production of a urea-form polymer, which encapsulates the nutrients in the slurry. Thus, in obtaining the reduction of pollution in the area, a premium slow release fertiliser, easily packaged and marketed is produced. Methane is obtain-able as a by-product and can be utilised to raise the dry matter content in the end product. Government and commercial financial backing have been obtained and a research and development unit has been constructed and already small-scale production is taking place. Fertiliser trials on selected areas are also planned at the Horticultural Research Centre at Kinsealey.

SILAGE EFFLUENT

In Ireland, as in other countries, where the climatic conditions are not suitable for wilting, the disposal of silage effluent is becoming a larger problem each year as production increases, approximating 8 million tons during 1975. With a yield of effluent of 30-40 gallons per ton, depending on dry matter content, the pollution potential is considerable.

For many years, research workers in the Agricultural Institute have been conscious of this increasing pollution menace. Holding tanks are an expensive and not very satisfactory solution to this sporadic and seasonal problem and our researchers turned their attention to the possibilities of landspreading, concurrent with the production of effluent. The principle by which water power is used to create a negative pressure by passing through a venturi was utilised to extract, by vacuum pressure, effluent from a small capacity trap situated near the silage pit. A water flow rate of 60 gallons* per hour, normally available on most farms, was found to be capable of spreading about 30 gallons per hour of effluent over 50 metres (Spillane and O'Shea, 1968). However, it was obvious that while this system had some merit it would, of necessity, be limited to the small silage producer and that water to create pressure would not always be in adequate supply. With the increasing production of silage, it was considered desirable by researchers to expand the initial system and utilise mechanical instead of water power to achieve the same landspreading of effluent, concurrent with its production. The

* 1 gallon = 4.546 litres

system is described (Spillane and O'Shea, 1973) and is based on a few simple requirements as follows:

a) Directing by channels to a collection of about 50 gallons capacity.
b) A fine screen at ingress to prevent straw and solid matter fouling the pump.
c) A simple centrifugal water pump that will spread the effluent and irrigate the land over some 100 metres.
d) A float-switch that will control the operation of the pump.
e) Neutralisation with lime or limestone if necessary.

With this system about 600 gallons per hour may be spread over a distance of over 100 metres and against a head of about 6 - 8 metres. This rate will cope adequately with the effluent from silos of up to about 2000 tons, even at peak flow periods. It is worth noting that the system is efficient, economical and the land should benefit both from the irrigation and fertiliser aspects. The capacity to spread over a wide area enhances the biological filtration efficiency and the detoxification of effluent by the soil is most effective during the period June to September.

Table 1 shows average results of mineral constituents obtained on a wide variety of silage effluents.

TABLE 1

MEAN ELEMENTAL ANALYSIS OF SILAGE EFFLUENTS

Constituents	Parts per million
Nitrogen	1700
Phosphorus	558
Calcium	1200
Magnesium	220
Sodium	340
Potassium	3400

FARM WATER SUPPLIES

The water sources for most farms in our country are derived from deep or shallow wells, mostly the former, and pose a number of problems. The most important of these are:

a) "Hard" waters causing scale in boiler and heating systems and even blockages in hot-house irrigation systems and nipple-type poultry drinking troughs.

b) Contaminated waters, often from surface drainage water and farm effluents.

c) Ferruginous waters, with iron content that is beyond acceptable limits for farm or domestic use.

d) Waters of a "spa" type with a high hydrogen sulphide content.

Research workers of the Agricultural Institute have had a fair measure of success in alleviating some of these problems. In the case of "hard" or contaminated waters and where the pumps installed were fitted with an air-volume control, it has been found possible to (a) sequester calcium and iron, where the latter content is less than 2 ppm by introduction of polyphosphates through the air-volume control, and (b) similarly inject chlorine solutions to deal with moderately contaminated waters. The process has been patented and fully described (O'Shea et al., Patent Nos. 1488/70 (Ireland) and 7796/72 (UK)).

In the case of excess iron in farm water supplies, this usually occurred in deep-well sources. Soluble iron bicarbonate in water may emerge as a completely colourless solution, but, in the pipe line or under normal storage conditions, eg, house-tank, carbon dioxide is lost and a precipitate, or "floc" of insoluble iron carbonate is formed, leaving rusty deposits and creating a general nuisance value so far as domestic use is concerned. A process which is essentially a scaled down version of standard water works treatment has been satisfactorily developed and includes flocculation with chemicals, sedimentation, filtration and results in complete removal of iron (Spillane and O'Shea, in preparation).

In waters high in H_2S, the process is rather similar to that for iron but in this case, the sedimentation tanks are used for aeration purposes only and so remove the residual H_2S odour.

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MATHEMATICAL MODELLING OF AMMONIUM OXIDATION IN EFFLUENTS

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The mathematical modelling of the processes occurring while the soil solution moves through the profile basically involves solving the continuity equation:

$$\frac{\partial c}{\partial t} = P - D - \mathrm{div}\,\Phi$$

This is the mathematical translation of the fact that in a volume unit, the time change of the amount of a given species ($\partial c/\partial t$) is equal to the chemical balance (P - D) ie what is produced (P) minus what is destroyed (D) per time unit. To this must be added the balance of what is coming into that volume unit minus what is going out ($-\mathrm{div}\ \Phi$). The flux Φ is given by the sum of a diffusive term (- D grad c) and of a convective term (vc).

If one aims at a mechanistic description of the system studied rather than at an empirical-statistical one, it seems necessary that the greatest effort should be spent on obtaining rate laws and experimental parameters for describing nitrogen transformations in soil and water rather than on the diffusion-convection processes which are quantitatively much better known. Unless of course, the experimental method used for studying nitrogen transformations in soil involves the use of soil columns through which the solution containing the nitrogen compounds percolates.

The description of the biochemical balance terms in soils involve mainly mineralisation of organic nitrogen, nitrification, denitrification, ion exchange, volatilisation and plant uptake. Furthermore, during continuous input of organic nitrogen, soil properties determining the rate constants involved in the above processes will vary continuously, due for instance, to quantitative or qualitative changes in biomass, which are determined by composition and quantity of the organic matter supplied to or present in the soil.

There are two ways of approaching the description of such a system: one is to consider it in its full or almost full complexity, the other is to consider only parts of it, build submodels that describe these parts satisfactorily and increase the complexity of the description by fitting submodels together which involves a study of higher level relationships.

A good example of a model of nitrogen transformation in soils involving most of the processes mentioned above is the work of Mehran and Tanji, (Mehran and Tanji, 1974).

The essential weakness of such models seems to be that rate laws are assumed to be first order throughout, disregarding saturation values for an enzyme-catalyzed reaction or the finite exchange capacity in any ion exchange reaction, validation of the model is made by adjusting parameters so that a given set of experimental results is approximated by it.

We have attempted to build a submodel for the nitrification process which would account for the influence of initial population density of nitrifying bacteria, temperature, (Laudelout et al.1974_1), pH, oxygen partial pressure, (Laudelout et al. 1974_2), and, of course, substrate concentration. As shown later a chemical denitrification process could very easily be included in the process.

The relationship which has been used in this study is the hyperbolic equation variously referred to as Michaelis or Monod whether it refers to the influence of substrate concentration on rate of enzyme catalyzed reaction or growth process.

It is rather curious that this type of approach has been used freely by research workers concerned with the problems of sewage treatment, (Lawrence and McCarty, 1970) and much less frequently by soil scientists.

The reason for this was presumably that soil scientists were convinced that substrate concentration would always be much lower than the K_m or C_1 values in the Michaelis or Monod relationships, such an assumption entails first order kinetics but it should be based on facts rather than surmised.

The growth of the population of Nitrosomonas or Nitrobacter is described by a Monod relationship of the type:

$$\frac{dn}{dt} = \frac{k\ n\ C}{C_1 + C}$$

where n is the population level at time t, C is the substrate concentration, k and C_1 are two constants characteristic of each organism. For instance C_1 for Nitrosomonas is 0.17 mM NH_4 and C_1 for Nitrobacter is 0.39 mM NO_2; k is the limiting value of the growth coefficient which is not concentration dependent.

On the other hand, the rate at which the substrate disappears is related to its concentration by an identical relation such as:

$$-\frac{dC}{dt} = \frac{V_m\ C}{K_m + C}$$

where V_m and K_m have their usual significance in a Michaelis relationship. Values of 0.52 mM and 0.56 mM have been found for K_m of Nitrobacter and Nitrosomonas respectively.

It is obvious that the four differential equations mentioned above are not independent not only because the substrate of one reaction is the product of the preceding one but also because the rate of oxidation is related to cell number. The relationship is particularly simple if it is assumed that the molar growth yield Y is constant. If $Y = -dn/dC$ is substituted in the definition of the (cell) specific activity $A = -(dC/dt)/n$, one has: $A = k/Y$ whether k is a constant or given by the Monod relationship

$$k = k_o C/(C_1 + C)$$

It is thus necessary to know 8 parameters before programming the solution of this system of 4-simultaneous differential equations. Furthermore the solution must satisfy the initial conditions namely the 5 values of the initial populations and concentrations.

If it is desired that the solution be valid at all temperatures below the optimum then the influence of temperature on all parameters should be known. One can use the Arrhenius relationship:

$$k = A \exp(-\mu/RT)$$

where k is one of the 8 parameters mentioned above, A a constant, R and T have their usual meaning and μ is the temperature characteristic. Published information on μ value relevant to the parameters mentioned is available: μ values vary from 8.7 to 19.7 kcal/mole.

The validation of such a model requires that its prediction be compared with experimental data, no adjustment of the parameters being made for improving the fit between theory and experiment. Figures 1 and 2 show the comparison between experiments carried out at 30° and 20°C.

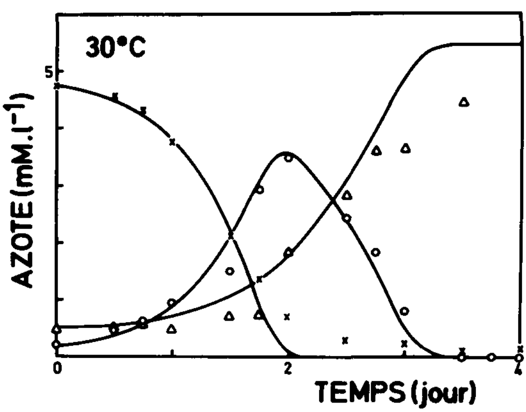

Fig. 1. Nitrification by mixed culture of Nitrosomonas and Nitrobacter at 30°C and in optimum experimental conditions (constant pH 7.8, oxygen in excess) computed curves and measured values (X : NH_4^+ - N, O : NO_2^--N, Δ : NO_3^--N).
Azote = Nitrogen: Temps (jour) = Time (days)

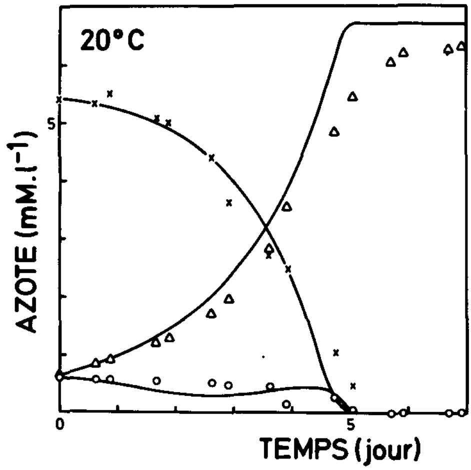

Fig. 2. Nitrification at 20°C and in optimum experimental conditions. Computed curves and measured values (X: NH_4^+-N, O: NO_2^--N, Δ: NO_3^--N).

The agreement seems to be good enough for our purpose and since the apparent result of lowering the temperature was to decrease the transient concentration of nitrite, the model may now be used for simulating the effect of temperature. The results of such a simulation are shown in Figure 3. Apart from the obvious fact that increasing the temperature lowers the time necessary for oxidising a certain amount of ammonium, it is clear that increasing the temperature above 20°C increases the transient concentration of nitrite. As far as we are aware, this fact had not been established previously.

If the possibility exists that side reactions occur in which nitrite may be implicated, leading to nitrogen losses by chemical denitrification, any change in the conditions of ammonium oxidation leading to an increase of the transient nitrite concentration will cause nitrogen losses. Such losses may be advantageous if they lead to a decrease of the nitrogen load of an effluent or detrimental if they cause a decrese of the efficiency of ammonium fertilisers.

The extent of these losses may be easily calculated if the kinetics of the reaction involving nitrite is known. For instance, it has been established long ago that nitrite is decomposed in acid soils. We have shown that a fairly simple rate law accounts for the kinetics of this transformation namely:

$$- \frac{d\ C_{NO_2}}{dt} = k_2 C_{H^+} \cdot C_{NO_2}$$

where C_{H^+} and C_{NO_2} are the concentrations of hydrogen ion and nitrite in the soil solution and k_2 is a second order rate constant, the value of which is 0.0062 $L.mM^{-1}hour^{-1}$ at 30°C with an activation energy of 13.1 kcal/mole.

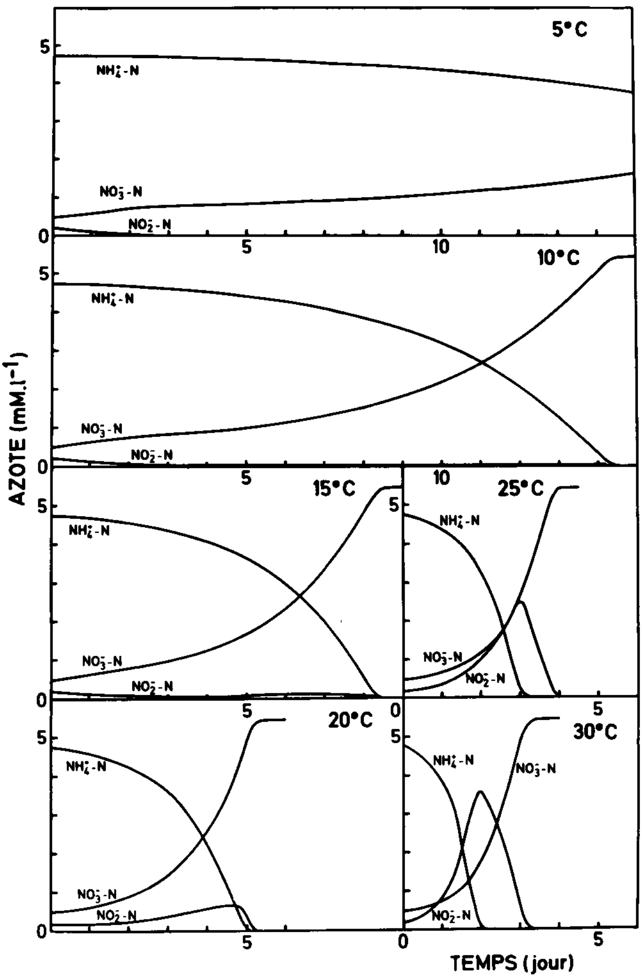

Fig. 3. Effect of temperature on nitrification. Simulated curves.

Introducing and solving this equation in the set of differential equations mentioned above allows one to calculate the extent of the loss of a pulse of ammonium added to the system.

It was found that one third to one half of the added nitrogen could be lost during nitrification under conditions of temperature and acidity prevailing in many tropical soils.

Obviously, a description of the kinetics of nitrification which would involve only temperature and substrate concentration would be far from sufficient. Since the nitrifying bacteria are sensitive to pH change and are strictly aerobic, the next step was to describe quantitatively the effect of pH and oxygen partial pressure on the rate of the process.

Regarding the effect of oxygen concentration, it is known that bacteria will be influenced according to a Michaelis relationship such as:

$$v = \frac{V_m (O_2)}{V_m^{O_2} + (O_2)}$$

where v is the rate of the process, V_m its value when the oxygen concentration (O_2) is much larger than K_m^{O2}. The latter constant is generally very small, nitrifying bacteria being an exception.

The differential equation pertaining to the time change of the oxygen concentration will be:

$$\frac{d(O_2)}{dt} = K\left((O_2)_o - (O_2)\right) + \frac{1}{2}\,\frac{d\,C_{NO_2}}{dt} + \frac{3}{2}\,\frac{d\,C_{NH_4}}{dt}$$

where K is a transfer coefficient and $(O_2)_o$ is the saturation concentration of oxygen, which is temperature dependent.

The influence of pH on the rate of reactions will be calculated by a relationship such as:

$$f\left((H^+)\right) = 1/\left(1 + (H^+)/K_1 + K_2/(H^+)\right)$$

where the constants K_1 and K_2 characteristic of the substrate-enzyme complex appear, a similar relationship is postulated for

TABLE 1

1. Nitrosomonas growth :

$$\frac{dn}{dt} = \frac{k_o.n.C.f_{O_2}}{(C_1+C)(1+(H)/Ka)}$$

2. Ammonium oxidation to nitrite :

$$\frac{dC}{dt} = \frac{V_m.C.f_{O_2}}{(K_m+C)(1+(H)/Kb)}$$

where :

$$f_{O_2} = \frac{(O_2)}{(K_m^{O_2} + (O_2))}$$

3. Nitrobacter growth :

$$\frac{dn'}{dt} = \frac{k'_o.n'.C'.f'_{O_2}}{(C'_1+C')(1+(H)/K'a)}$$

4. Nitrite oxidation to nitrate :

$$\frac{dC'}{dt} = \frac{V'_m.C'.f'_{O_2}}{(K'_m+C')(1+C'(H)/K'b)}$$

where :

$$f'_{O_2} = \frac{(O_2)}{(K'^{O_2}_m+(O_2))}$$

5. Oxygen balance :

$$\frac{d(O_2)}{dt} = K_{1a}((O_2)_o-(O_2)) + \frac{1}{2}.\frac{dC}{dt} + \frac{3}{2}.\frac{dC}{dt}$$

6. H^+ ion production :

$$\frac{d(H)}{dt} = -2\frac{dC}{dt}$$

the growth of the organisms.

The rate of production of hydrogen ion produced will be given by:

$$\frac{dH}{dt} = -2 \frac{d\,C_{NH_4}}{dt}$$

and the effect of the amount of hydrogen ion produced on pH may be calculated from the buffer relationship of the solution.

The validation of the model (Table 1) is provided by the comparison of experimental results obtained either when pH varies because the medium is insufficiently buffered (Figure 4) or when the oxygen concentration is limiting because the aeration is not adequate (Figure 5).

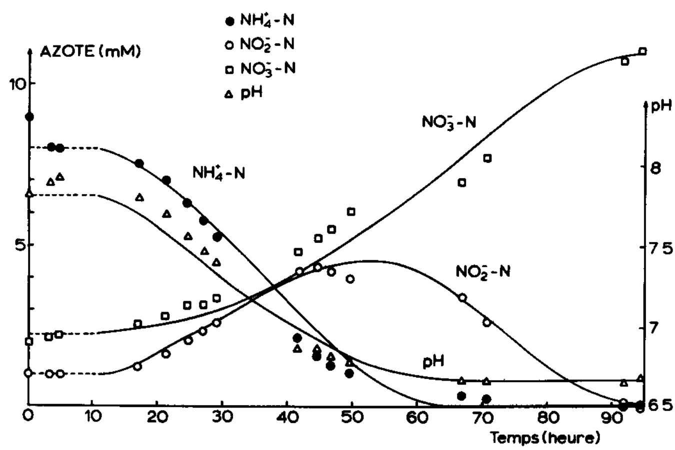

Fig. 4. Nitrification at 30°C in poorly buffered medium and in excess of oxygen. Computed curves shifted by a lag time of 11 h and experimental data.

The agreement is again satisfactory even though no adjustment was made in order to improve the fit.

One interesting result from both of the experiments and the calculations is that a limited supply of oxygen induces a transient accumulation of nitrite.

The results of a simulation of this effect at various temperatures is shown in Figure 6. Again an obvious result is immediately apparent, namely that the BOD for nitrification is less likely to exceed the O_2 supply at the lower temperature. These results make it possible to calculate the temperature at which the BOD will exceed supply since ammonium-nitrogen concentrations in effluents account for most of the BOD in effluents.

Furthermore, the marked shift for nitrite oxidation in conditions of limited oxygen supply is quite evident and this would favour reactions competing with its biological oxidation.

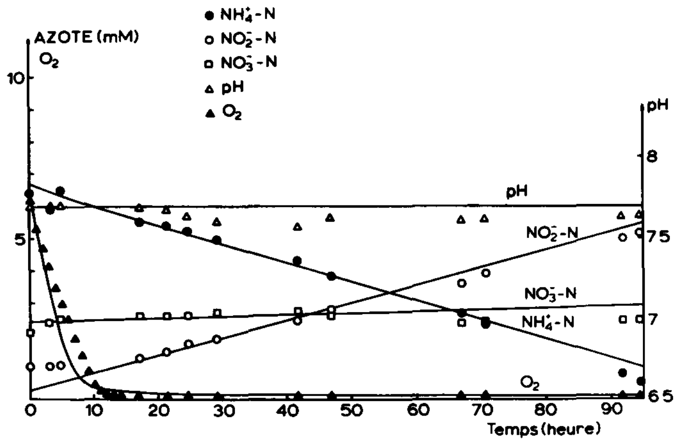

Fig. 5. Nitrification at 30°C in poorly aerated medium and at constant pH 7.7. Computed curves and experimental data.

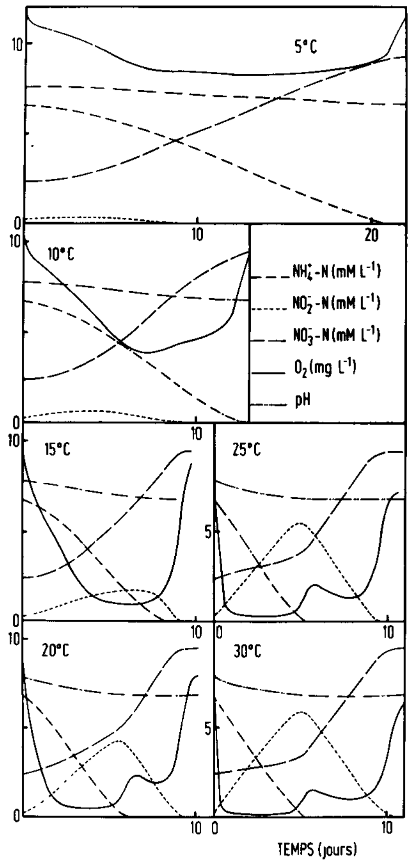

Fig. 6. Effect of temperature, pH and oxygen partial pressure on nitrification of mixed cultures. Simulated curves.

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DISCUSSION

J.R. O'Callaghan *(UK)*

The agreement between the predicted results and the experimental values seems to be extraordinarily good. Now, can we have some questions from those people who have grappled with the nitrogen problems without the aid of mathematical models.

H. van Dijk *(The Netherlands)*

Dr. Laudelout, the ultimate result of the process will undoubtedly depend on the ratio of the populations of nitrobacter and nitrosomonas. I did not see where you brought this in. Secondly, how did you bring in the inhibitory effect of free ammonia on nitrobacter? In the actual process it is very low.

H. Laudelout *(Belgium)*

First of all, I did not tell the whole story as it stands and secondly, a mathematical model never tells the whole story otherwise you might just as well use the real thing. For instance, we limited ourselves to the acid branch section of the pH curve for nitrosomonas thus we did not have to take account of the inhibitory effect of ammonia on nitrogen oxidation. On the other hand, something I did not say was that we did take account of nitrous acid inhibition of nitrobacter. Now, the initial concentration levels are the initial conditions; even if the integration of a set of differential equations is being done, you still have to supply your numerical method with these initial conditions. In this experiment we were working with a pure mixed culture, only nitrosomonas and nitrobacter and so we knew what we started with. We had a ratio of nitrosomonas to nitrobacter which was similar to what is usually found. What we did was to simulate to computer experiments the effect that varying the ratio of nitrosomonas to nitrobacter from 10 : 1 to 1 : 10; would have on the transient peak of nitrite. It was found that this ratio had to go down to values which were unrealistic in respect of what is observed in nature for observing a disappearance of the transient concentration of nitrite. This is for the transient state; it is not for the steady state of ammonium oxidation by a stabilised population; there is no such thing. In fact, the only thing that you can do with a model such as this is to simulate, let's say, 10 days. There are models now, going round, some of them originated in Holland, others in Arizona, that propose to simulate several months. This situation is very much the same as in the Club of Rome model for global prediction. First they said that the end of the world would be in the 26th century; a couple of years later they said there had been some mistake and that it would be in the 45th century!

J.R. O'Callaghan

I think what you are really saying is that it is very difficult to get the initial conditions into the model. I see you had a shift of 11 hours ....

H. Laudelout

If you inoculate pure culture with nitrobacter, for reasons best known to themselves the bacteria will not develop. You know, somebody was talking this morning about salmonellae having a regeneration time of less than one hour. With nitrifying bacteria the regeneration time is between 12 and 24 hours, sometimes more. So you have to be patient and allow for ten hours sometimes when nothing happens at all.

J.R. O'Callagham

But doesn't that worry you about modelling the dynamic situation in the end, that you will have lags .... ?

H. Laudelout

Not at all because while nothing happens the ammonium concentration does not change.

J.R. O'Callaghan

But will you be able to quantify the time during which that lag takes place because otherwise you would get discontinuities in your movement from one situation to another.

H. Laudelout

No, I do not think so. This is the difficult thing in these comprehensive models where people try to picture everything that happens in nature. They start modelling the whole nitrogen cycle. The only thing to do really is to choose what I call a sub-model, for instance, nitrification. Then you start another sub-model, on which we are currently working, on denitrification. You can put them together on a more comprehensive model involving, for instance, leaching of the solution through a soil, however predicting everythinq - that is out of the question.

R.G. Gerritse *(The Netherlands)*

I have a question for Professor Laudelout. In a recent article I found that nitrosamines can also be formed in the soil How would you rate the likelihood of the formation of these compounds in your model?

H. Laudelout

I do not believe that in relation to the total nitrogen balance, the formation of nitrosamines is important. However, suppose it was, the only thing to do would be to quantify definitives of the formation of nitrosamines with respect to pH, nitrite concentration, temperature and organic matter content, and then write one more equation.

R.G. Gerritse

You don't consider it important?

H. Laudelout

It is only important from a health point of view - but more in bacon than in soil.

R.G. Gerritse

I have another question, this time for Dr. Spillane. You say in your paper that with your urea-form polymer you obtained a reduction of pollution. Would this hold for all nutrients? Phosphorus remains phosphorus and maybe organic phosphorus, as

I have described, remains the same. The only thing would be that it is released more slowly but it would cause the same amount of pollution when you add a certain amount of this urea-form product. Would you agree?

J.R. O'Callaghan

May I ask a supplementary question to that? I was rather confused about what the actual process is.

R.G. Gerritse

As I read it, you form a sort of solid matrix within the slurry so as to make a solid product. Is that right?

T.A. Spillane *(Ireland)*

That is correct. For many years the preparation of a urea-form, slow release fertiliser has been well-known. In America there have been many patents which incorporate the encapsulation of domestic refuse and domestic sewage. As far as we know this has not been done in the agricultural field but, as you say, what you do get is a solid product, a urea-form polymer, and this does incorporate whatever is in the slurry. The overall effect is that instead of flush release of nitrogen and phosphorus, and so on, you get a slow release. So one of its advantages which we see is that you have one application in a year as against several, and this is labour saving. You do encapsulate almost all the nutrients in the polymer; it is a solid polymer and the problem at the moment is to get a DM content low enough to make it as completely baggable and exportable as possible.

J.R. O'Callaghan

Is there a separation process before you get to the encapsulation process?

T.A. Spillane

None whatsoever .... you get a coagulation in water treatment. As you know the urea-form polymer is a very involved chemical process. You get long chains, short chains, and so on.

It has been used simply with water as, if you like, the combining agent. In this case what we are doing is actually using the pig slurry as a combining agent.

R.G. Gerritse

You still haven't answered my question. What I can see is that perhaps with nitrogen you would get a reduction in pollution because of the slow release but in the case of phosphorus it wouldn't make any difference because you still get the same phosphorus load.

T.A. Spillane

What we are envisaging is taking the slurry away from the pollution area to a central depot.

R.G. Gerritse

Oh yes, this means transport?

T.A. Spillane

Yes, but in the process there is no doubt that the phosphorus is also encapsulated, I quite agree with you. We are still in the research and development area.

R.G. Gerritse

You do reduce pollution but only for certain elements, not in all cases.

T.A. Spillane

Well, again, one would try to recover phosphorus by using methane. We have been in touch with the Royal Institute on this matter. You could produce methane at the beginning of the process thus getting a higher DM content and thereby also ensure that more phosphorus is held in the final polymer.

R.G. Gerritse

Yes, but in the long run it will be released again.

<u>J.S.V. McAllister</u> *(UK)*

Yes, but there is a big difference in applying phosphorus in slurry to applying a solid phosphorus.

<u>R.G. Gerritse</u>

Yes, but what I mean is that if you have the phosphorus in the solid matrix, it might not affect the organic phosphorus and when the organic phosphorus is released, even slowly, it will move into the soil and you have the same load as when you apply slurry.

<u>J.S.V. McAllister</u>

So long as it stays in the soil we wouldn't be so worried, we would be more worried about it getting into the lakes and into the water.

<u>R.G. Gerritse</u>

Well, if it is in the soil it can eventually come into the lakes.

<u>J.S.V. McAllister</u>

We doubt it.

<u>R.G. Gerritse</u>

I have another small question in connection with the production of the polymer. As far as I recollect, I think that in making these polymers you sometimes use heavy metals to initiate the process. Do you introduce additional elements which might be harmful to the environment?

<u>T.A. Spillane</u>

Not really. The polymer is formed at a pH of about 2 to 3 and sulphuric acid is normally utilised to achieve this end. That's all.

<u>J.S.V. McAllister</u>

Could Dr. Spillane give us some idea of the composition of his product?

T.A. Spillane

I do have some figures. Naturally the urea provides a tremendous amount of the nitrogen. I must stress again that the whole thing is at the research and development stage at the moment - quite a small sum of money was spent on it. I think the nitrogen content is something like 6.4% in the end product. At the moment we have a DM content of only 40%. It is hoped that with further financial backing and in combination with the Royal Institute, we can get methane production to use the heat produced to dry that polymer further. This would, of course, enhance its commercial value.

L. Lecomte *(Belgium)*

I would like to ask Dr. Spillane what is the physical appearance of the end product? You told us that it is encapsulated. Does it take the form of some kind of pill or what?

T.A. Spillane

At the present stage of development it is rather like semi-wet sand, granular. We are using peat moss to increase the DM content. This is relatively cheap in Ireland and so this is an advantage. Limestone to neutralise the product after the polymer is formed is also very cheap. However, in the long term one would hope to use the methane produced at the start of the process. We just did not have enough funds to start with methane but this is what one should do ideally - produce the methane, produce the polymer, and dry it.

J.R. O'Callaghan

We must break now but I do thank the speakers for their contributions.

TWO LEVELS OF MODELLING THE UTILISATION OF ANIMAL MANURES

J.R. O'Callaghan
Department of Agricultural Engineering,
University of Newcastle upon Tyne, England

The principal reason for proposing models of different aspects of the farm manures problem is to provide information for those who must manage the problem. A satisfactory model should provide decision makers with a meaningful summary of the information which is relevant to a clear definition of the issues and alternatives. However, a model is a simplified representation of the actual process and the degree of simplification should be related to the purposes for which the model will be used. In the case of animal manures, the spectrum of understanding required ranges from the simple question, 'Can manure be applied safely to land throughout the year?' to an interpretation, at the micro-level, of the complex way in which plant growth is related to the release of nutrients from animal manures.

The research work of the Newcastle group falls into four distinct stages. Each stage represents a different strategy in dealing with the animal manures problem and spans thinking from the limitations on disposal to the factors which maximise the efficiency of utilisation. In summary, the four stages are:

a) The climatic, soil and cropping factors which constrain the quantity of animal manure that can be applied to land without incurring serious risks of stream pollution.

b) The capacity of the soil to retain, without risk in the long term, the constituents of animal manures;

c) A quantitative description of aerobic treatment as an aid to recycling animal manures;

d) A quantitative description, at the micro-level of the climatic and soil factors which influence the release of plant nutrients from animal manures.

A model must be based on an understanding of the physical and biological components of the processes which take place. An economic evaluation is possible where monetary values can be assigned to the processes. Obviously the smaller the number of variables, the easier it is to handle the model; danger lies in over-simplification so that the model becomes too poor a representation of reality and is worthless as an aid to managing the system.

Stages a) and b) are concerned about returning animal manures to farm land; in stage a) merely for disposal, but in stage b) with the intention of recycling the nutrients in the manure through a crop. In modelling either stage the main information required is that necessary to calculate a mass balance for the process.

Stage c) requires an understanding of the principal factors involved in the aerobic treatment of animal manures and especially measurements of the rate processes in controlled laboratory type experiments. The model relates the rate of growth of microbial population to food supply.

The difficulties in the way of a model of stage d) are formidable in that the processes of transfer of nutrients from manures to plants through the soil are complex and very dependent on changes in soil moisture and temperature, which in turn are related to changes in atmospheric conditions. The steady state approach adopted in modelling stages a) - c) is not likely to be suitable for stage d).

MODEL 1 THE LIMITING ANNUAL CAPACITY OF LAND TO RECEIVE MANURES

Regarding farm land as a sink for receiving animal manures, the possible paths along which slurry could flow when placed on the surface of the soil are shown in Figure 1.

Using the idea of mass balance for the spreading process:

Mass of slurry applied to land	=	(	mass stored in the soil
		(+	" infiltrating to the drains
		(+	" running off the soil surface
		(+	" passing into the atmosphere

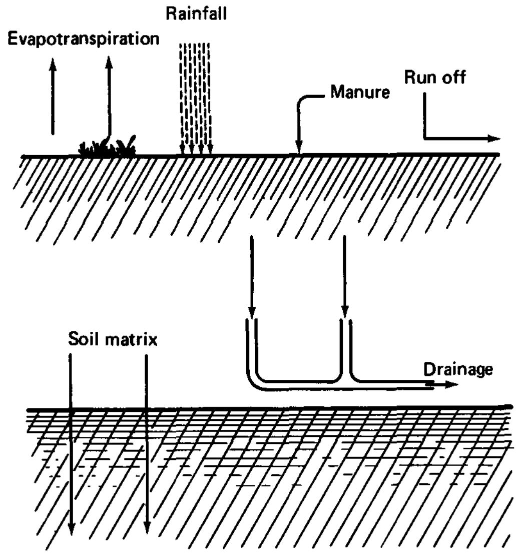


Fig. 1. The possible movement of rainfall and slurry constituents on application to the land

When the soil is at field capacity, the storage term is zero. This condition is most likely to occur during the winter months which is also the time when evapotranspiration is low.

During the growing season, evapotranspiration is likely to exceed rainfall and, as a result, storage capacity is created in the soil profile. Under conditions of a moisture deficit in the soil, the storage capacity may be used to retain animal manures in the soil profile and reduce the risks of the manures either infiltrating to the drains or running off the soil surface into the streams and rivers.

The maximum quantities of slurry which may be spread on land without risk of water pollution can be assessed by comparing evapotranspiration with rainfall figures and allowing the manure applied to make up any resultant soil moisture deficit. O'Callaghan, et al. (1971) have called such maximum rates of application "the permissible hydraulic loading rates" and calculated them for different regions of the UK. The expected potential evapotranspiration may be calculated for each week using the published county averages, derived from Penman's formula (1948). The potential evapotranspiration level is not always attained due to low unsaturated hydraulic conductivity of the soil in the immediate vicinity of the roots. The relative transpiration rate is a function of the potential rate itself so that under high insolation temporary wilting may occur, despite a nominally high soil moisture content.

The soil moisture deficit approach was applied to four different cropping routines, represented by "go/no go" matrices determining in which weeks manure may be spread. The four chosen as examples of existing practice were grassland , grassland that is late in drying out in the spring (e.g. water meadows), cereals, and sacrifice areas. On a sacrifice area, access is permitted in each week, whereas for grassland, cyclical patterns of spreading and conservation have to be established. The comparison of different crops gives an indication of their seasonal hydraulic loading capacity.

The flow diagram of a land spreading programme in Figure 2 indicates the relevant steps in the calculation of the amount of slurry that may be applied. Regional values from national data are required for the potential evapotranspiration figures during the summer. A matrix describing the decrease of evapotranspiration from the potential level is read, followed by the rainfall through the summer months for the last 15 years. The monthly potential evapotranspiration for the given county is read in together with the average county elevation, and the elevation of the farm under consideration. Other farm data required are the total area, the number and area of the fields,

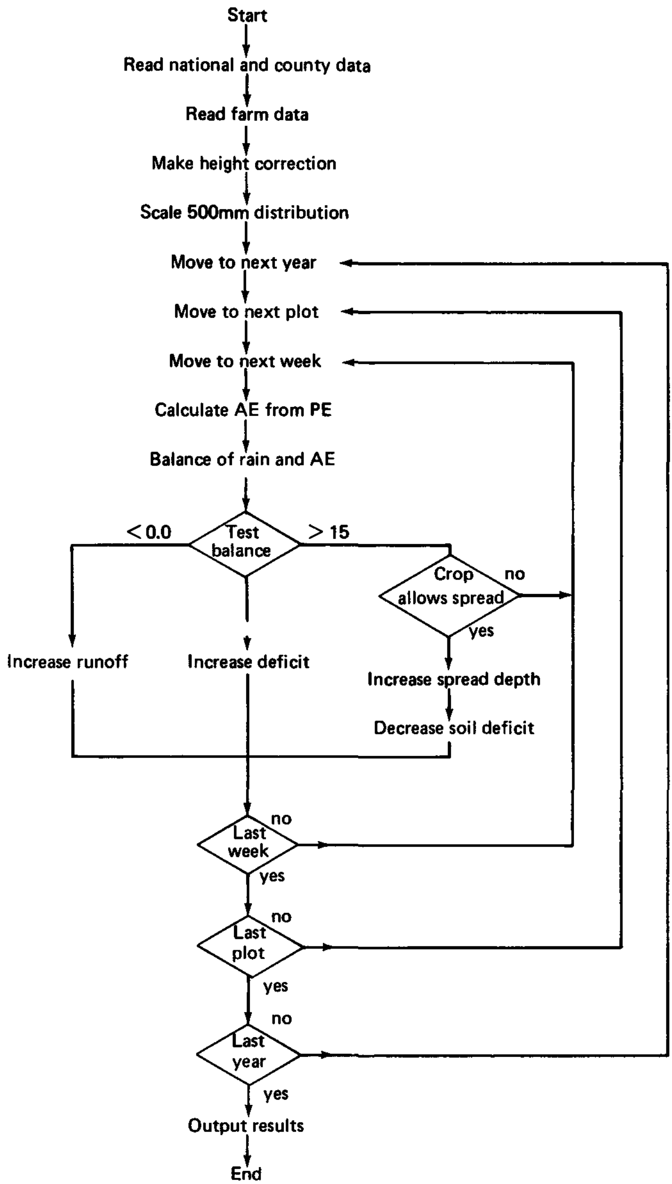


Fig. 2. Simplified flow diagram for landspreading model.

and the cropping pattern on these fields.

In assessing the use of the programme to calculate hydraulic loading in an individual situation, three widely spaced locations in the country were considered, so as to demonstrate the effects of differences in rainfall and insolation. The three rainfall stations were Durham City, Vange Reservoir, Essex and Swyddiffynon, Cardiganshire.

For these three districts, the average maximum potential soil moisture deficits through the year are 36, 173 and 8 mm respectively, so that the extremes of deficit experienced in England and Wales are represented.

The results of the three locations given in Table 1 show that the cereal crop provides least opportunity for spreading in each case. The grassland and late grassland routines are very similar, while the sacrifice area can normally accommodate roughly twice as much slurry.

Essex, as expected, gives the highest demands, and Cardigan values are approximately half as great. Durham gives an intermediate demand, but with a consistently high standard deviation, indicating a greater variability in the summer weather at this location.

A two year field trial, to demonstrate the management implications under actual farming conditions of a hydrological limit on the amount of slurry which could be applied to a grass crop in the growing season, was carried out by the Agricultural Development and Advisory Service and the Department of Agricultural Engineering, University of Newcastle upon Tyne (O'Callaghan and Pollock, 1975). Slurry was spread on grass plots during the growing season and the drainage water was monitored for change in BOD_5, nitrate and ammonium. There was some leakage to the drains following an application of slurry and especially when an application was followed by rain.

TABLE 1

MAXIMUM PERMISSIBLE HYDRAULIC LOADING RATE (t ha^{-1}) FOR FOUR TYPICAL CROPPING SEQUENCES (O'Callaghan et al., 1971)

	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean	SD
Durham City	Late Grassland	99	246	148	123	148	246	148	222	99	222	172	123	74	172	172	161	54
	Cereal	99	271	123	222	148	197	222	99	99	222	0	74	74	99	49	126	71
	Grassland	172	320	172	172	172	246	172	197	74	271	148	148	74	197	148	179	56
	Sacrifice	295	615	369	419	369	517	394	394	246	469	271	246	271	369	345	373	104
Vange Reservoir; Essex	Late Grassland	172	197	123	246	222	222	247	197	222	222	197	246	99	197	246	204	44
	Cereal	148	246	148	124	148	222	172	148	172	74	197	148	25	271	172	166	61
	Grassland	246	271	172	271	197	271	271	246	246	222	246	246	123	271	271	238	43
	Sacrifice	443	542	320	542	443	492	517	443	492	419	394	443	246	542	492	451	83
Swyddffynon; Cardigan	Late Grassland	148	99	74	197	123	197	74	49	74	99	99	49	49	99	49	99	44
	Cereal	123	172	99	148	123	74	25	25	49	0	25	49	0	25	49	66	49
	Grassland	148	172	123	221	148	173	99	74	123	99	99	99	49	74	49	117	49
	Sacrifice	347	320	148	394	246	320	222	148	197	148	197	197	197	172	172	228	79

During the twelve hours immediately following spreading, the drainage water was polluted, but with most measurements returning to background levels within thirty-six hours. However, when the quantity and strength of the drainage water was related to that of the slurry applied to the plot less than one-fiftieth of the slurry was found in the drainage water. The grass crop stood up well to the large applications of slurry (310 t ha^{-1}). Patches of grass were scorched and even killed, particularly in places where considerable amounts of solids were deposited during spreading. In about a month, the grass began to grow and the whole area was covered by the time the grass was harvested. This confirmed that large quantities of slurry, within the hydrological limit, could be applied to soil below field capacity and that the leakage to the drains would be minimal. However, in order to make good use of the nutrients in the slurry and to maximise grass yields, smaller applications which would not scorch grass are advisable.

MODEL 2 LONG TERM MANAGEMENT OF ANIMAL MANURES

Animal manures produced by a livestock production unit may be regarded as a component of an input-output system, the various components of which are shown in Figure 3. The primary input is feedingstuffs, which may in whole, or in part, be imported on to the farm. A pig or poultry enterprise is an example of a unit into which all feedingstuffs may be imported; a beef fattening unit on grass is a unit into which none or only a portion of the feedingstuffs may be imported. Secondary inputs may consist of chemical fertilisers or animal manures. A pig and cattle fattening unit on a grassland farm is an example of the latter; the primary input for the pig unit is imported feedingstuffs, while the manure from both the pig unit and the beef unit may be supplemented with chemical fertilisers to provide nutrients for the grass, which in turn forms the input for the beef unit.

The outputs of the system are animals and animal products such as milk, eggs and animal manures. The manure is usually retained on the farm, but it could be transported off the farm. Alternatively the manures could be spread on land to produce a crop which is taken off the farm e.g. pig manure could be spread on grassland and the conserved grass be sold off the farm.

In a "steady-state" condition, which would need to be the long-term management objective for land spreading, the following conditions must be observed:

a) Manure should be spread during the growing season in order to avoid direct surface runoff and minimise discharge into drains of leached nutrients and organic compounds.

b) Manure should be spread at such rates as to prevent excessive accumulation of nutrients N, P and K in the soil/crop, but to achieve high nutrient utilisation rates.

c) The amount spread even in the growing season should be within the hydraulic loading capacity of the soil.

An advantage in using grass instead of cereals as the crop for the recycling of slurry is that it is feasible to cut grass three, and in some areas four times annually and, if the grass is grazed, further recycling may take place within the season. Each cut may receive applications equivalent to approximately 120 to 150 kg N ha^{-1}, whereas multiple dressings are impracticable with cereals. Grass also matches demand with moisture deficit in a way which would be more difficult to achieve with cereals.

The long term management of animal manures by land spreading must take into account the cropping pattern on the land. The amount of manure applied should be determined on the basis of the nutrient requirements of the crop grown and the permissible hydraulic loading rate, although the latter will probably only be limiting in areas of high rainfall.

A proposal for using the manure from a livestock enterprise to fertilise the grass to be conserved as silage for a cattle unit is calculated in the following examples. Since sufficient nutrients are not produced by a dairy or beef enterprise to meet the fertiliser requirements of the grass necessary to support them during the next winter, it is necessary to supplement the cattle manures with either pig or poultry manure or with inorganic fertilisers. In the calculations it is assumed that all the livestock manures are collected with very small losses into good storage of sufficient capacity to hold all the slurry over a five month winter period, that the pigs and poultry are housed all the year round and cows and beef cattle are on pasture for seven months of the year so that there is no need to spread the manure they produce in that period, and that the application of slurry to grassland is well managed. The following examples, in which figures are rounded, are given to illustrate the principles involved.

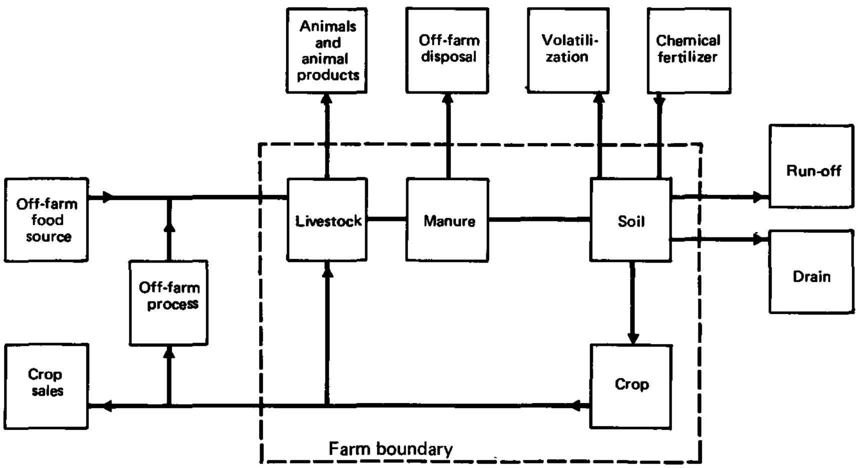


Fig. 3. Diagram showing input and output components of a livestock and or crop production farm.

EXAMPLE 1

Livestock unit

150 cows plus 1 500 fattening pig places
Daily winter feed requirement for cows: 15 kg cow^{-1} for 15 days
Total requirements : 340 t DM

Annual manure data:

(a) From pig unit — 2 500 m^3; Storage tank 1 050 m^3

Nutrients produced

N	15 750 kg
P	4 000 kg
K	4 740 kg

(b) From cow unit — 1 750 m^3 manure; Storage tank 730 m^3

Nutrients in storage tank

N	3 720 kg
P	460 kg
K	3 440 kg

Assume 10% loss of nutrients

Total manure to be spread 3 230 m^3

Nutrients

N	17 520 kg
P	4 000 kg
K	7 340 kg

Assume a low rainfall area, three cuts of grass, a total equivalent N application of 500 kg ha^{-1}, and a DM response of 20 kg N^{-1}.

Conserved area 34 ha
Yield 340 t

Corresponding P application 12 g kg^{-1} of yield DM

Corresponding K application 24 g kg^{-1} of yield DM

Hydraulic load 94.6 m^3 ha^{-1}

Note that in this proposal there will be an accumulation of phosphate.

EXAMPLE 2

Livestock Unit

10 000 laying hens plus 500 beef cattle
Daily winter feed requirements for cattle: 8 kg head^{-1} for 150 days
Total requirements : 600 t DM

Annual manure data

(a) From poultry unit 460 m^3
Storage tank 190 m^3

Nutrients produced

N	6 800 kg
P	2 500 kg
K	1 870 kg

(b) From beef unit 3 340 m^3
Storage tank 1 400 m^3

Nutrients in storage tank

N	7 100 kg
P	830 kg
K	6 530 kg

Assume 10% loss of nutrients

Total manure to be spread 1 860 m^3

Nutrients

N	12 500 kg
P	3 000 kg
K	7 500 kg

Assume a high rainfall area, two cuts of grass, a total equivalent N application of 300 kg ha^{-1}, and a DM response of 20 kg N^{-1}

Conserved area 100 ha

Expected yield of grass form organic N 248 t.

Required yield 600 t

Supplement with approximately 18 t of inorganic N

Corresponding P application 5 g kg^{-1} of yield DM

Corresponding K application 12.5 g kg^{-1} of yield DM

Hydraulic load 18.2 m^3 ha^{-1}

Supplement with 1.5 t fertiliser K to give 15 g kg^{-1} in the crop

EXAMPLE 3

Livestock Unit

1 000 pig places - manure spread on conserved grassland and crop moved off the farm

Annual manure data 1 660 m^3
Storage tank 700 m^3

Nutrients produced assuming 10% loss

N 9 450 kg

P 2 390 kg

K 2 840 kg

Total manure to be spread 1 660 m^3

Spread on land at equivalent N application of 500 kg ha^{-1} - three cuts

Conserved area 19 ha
Yield 190 t

Corresponding P application 12.6 g kg^{-1} of yield DM

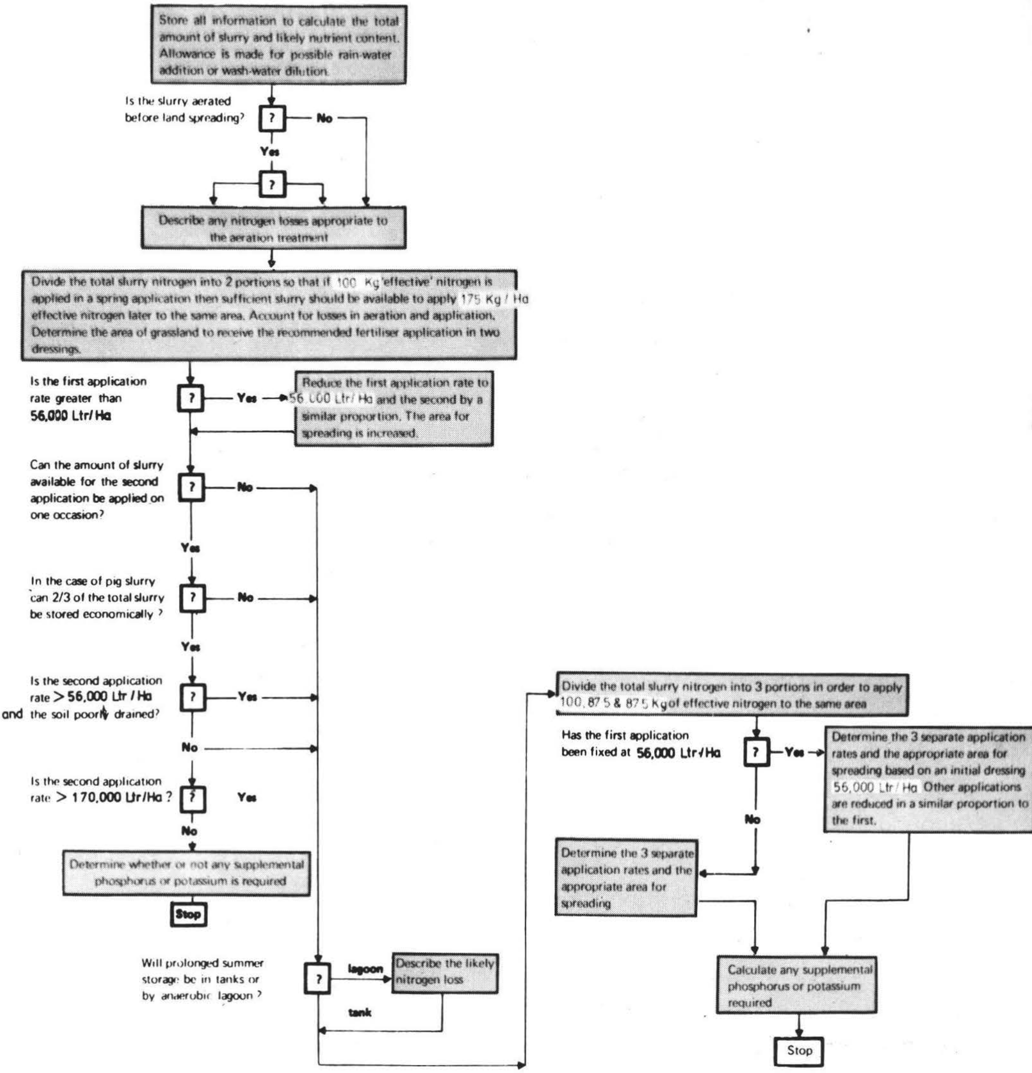
Corresponding K application 15.0 g kg^{-1} of yield DM

Hydraulic load 87.3 m^3 ha^{-1}

Note that in this proposal there will be an accumulation of phosphate.

In the examples given above, a total grass yield of 10 t ha^{-1} dry matter and a storage period of five months have been chosen. These factors will, of course, vary from region to region - colder regions with high rainfall give less yield and a later start to the growing season. Storage will be necessary from October to, say mid-April. Normally at least six weeks should be allowed to elapse between spreading manure and cutting grass, to avoid palatibility problems, as well as to enable the manures to be broken down adequately. This is particularly important for the first cut of grass, normally taken in late May or early June, for which the manure should be spread as early as possible, preferably in March or early April. Cattle slurry should be applied as early as possible for the first cut because, due to its high fibre content, it breaks down slowly.

The approach to management of animal manures contained in Models 1 and 2 has been developed into the decision-making advisory tool shown in Figure 4. From data on the number of animals and the feeding and housing regime, the quantity and nutrient content of the manure may be calculated. The supply of nutrients is matched to the demand from a cropping programme.



Store all information to calculate the total amount of slurry and likely nutrient content. Allowance is made for possible rain-water addition or wash-water dilution.
Is the slurry aerated before land spreading?
?
No
Yes
?
Describe any nitrogen losses appropriate to the aeration treatment
Divide the total slurry nitrogen into 2 portions so that if 100 Kg 'effective' nitrogen is applied in a spring application then sufficient slurry should be available to apply 175 Kg / Ha effective nitrogen later to the same area. Account for losses in aeration and application. Determine the area of grassland to receive the recommended fertiliser application in two dressings.
Is the first application rate greater than 56,000 Ltr/Ha
Yes
Reduce the first application rate to 56,000 Ltr/Ha and the second by a similar proportion. The area for spreading is increased.
Can the amount of slurry available for the second application be applied on one occasion?
No
Yes
In the case of pig slurry can 2/3 of the total slurry be stored economically?
No
Yes
Is the second application rate > 56,000 Ltr / Ha and the soil poorly drained?
Yes
No
Is the second application rate > 170,000 Ltr/Ha?
Yes
No
Determine whether or not any supplemental phosphorus or potassium is required
Stop
Will prolonged summer storage be in tanks or by anaerobic lagoon?
lagoon
Describe the likely nitrogen loss
tank
Divide the total slurry nitrogen into 3 portions in order to apply 100, 87.5 & 87.5 Kg of effective nitrogen to the same area
Has the first application been fixed at 56,000 Ltr/Ha
Yes
Determine the 3 separate application rates and the appropriate area for spreading based on an initial dressing 56,000 Ltr/Ha. Other applications are reduced in a similar proportion to the first.
No
Determine the 3 separate application rates and the appropriate area for spreading
Calculate any supplemental phosphorus or potassium required
Stop

MODEL 3 AEROBIC TREATMENT OF ANIMAL MANURES

Several workers have proposed biological methods for treating farm wastes. Some of the early schemes were designed on rules similar to those for treating domestic wastes. However, animal manures are much stronger than domestic sewage and have a much higher oxygen demand. As a result, conventional design procedures are not directly applicable to plant for animal wastes. In an attempt to provide an understanding of the processes of micro-organism growth in aerobic treatment and correlate experimental results from different workers, a model, which assumes that performance depends on the availability of substrate, has been proposed.

The specific growth rate of micro-organism is defined according to the Monod relation:

$$\mu = \hat{\mu} \left(\frac{S}{K_s + S} \right) \qquad \ldots. \ (1)$$

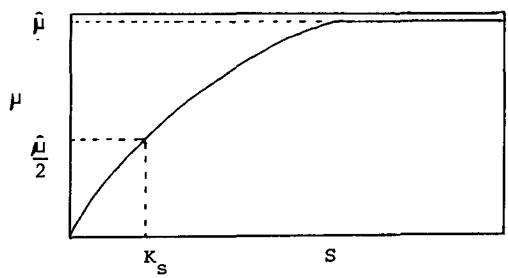


Fig. 5. Specific growth rate as a function of substrate concentration

This relationship is plotted in Figure 5. The maximum value for μ, defined as $\hat{\mu}$, occurs at high limiting substrate concentrations. The growth rate declines with limiting substrate, reaching zero at zero substrate concentration; K_s is the substrate level at which the specific growth rate is a half of the maximum. This expression for μ when substituted into the population growth equation, assuming zero decay rate, gives:

$$\frac{dX}{dt} = \hat{\mu}\ (\frac{S}{K_s + S})X \qquad ....(2)$$

Before this equation can be integrated to describe a batch culture situation, a relationship between X and S is required. The organism-substrate yield equation provides this

$$\frac{dX}{dt} = -y\ \frac{dS}{dt} \qquad ....(3)$$

This assumes that the quantity of organisms produced is proportional to the amount of limiting substrate utilised. In a closed batch culture, with the initial conditions

$$X = X_o \quad \text{and } S = S_o, \text{ at } t = t_o$$

Equation (3) integrates to

$$X = X_o + y(S_o - S) \qquad ....(4)$$

Substituting into Equation (2)

$$\frac{dS}{dt} = \hat{\mu}\ \frac{S}{K_s + S}\left[\frac{X_o}{y} + S_o - S\right] \qquad ....(5)$$

It is useful at this stage to define the parameter E_o, the equivalent substrate:

$$E_o = S + \frac{X}{y} \qquad ....(6)$$

from Equation (4)

$$E_o = S_o + \frac{X_o}{y} \qquad ....(7)$$

demonstrating that the equivalent substrate is constant throughout a batch culture process.
Equation (3) integrates to:

$$\left[1 + \frac{\left(1 - \frac{S}{S_o}\right)}{\frac{X_o}{yS_o}}\right]^{1 + \frac{Ks}{E_o}} \left(\frac{S}{S_o}\right)^{\frac{-Ks}{E_o}} = e^{\hat{\mu}(t - t_o)} \qquad \text{....(8)}$$

Utilising Equation (4), this can be put into the useful form:

$$\left(\frac{X}{X_o}\right)^{1 + \frac{Ks}{E_o}} \left(\frac{S}{S_o}\right)^{\frac{-Ks}{E_o}} = e^{\hat{\mu}(t - t_o)} \qquad \text{....(9)}$$

Physical interpretation

Originally the model was defined in relation to the limiting substrate of a growth process, the hypothesis being that growth would be restricted in the absence of any essential nutrient. The question therefore arises as to whether such parameters as BOD, COD, volatile solids, etc., can be considered as substrate in this model. In waste treatment processes, a very complex situation exists, where a mixed population of micro-organisms feeds upon a variety of substrates. The single substrate hypothesis is obviously not directly applicable; in its place however, the cruder hypothesis might be made that the concentration of the total biodegradable material may control the mixed micro-organism population in the same way. The only true test for this hypothesis is in its application, and from the success already achieved in the waste treatment field, the model does appear to represent the physical situation.

The choice of parameter to measure the substrate available in the feed is crucial. In view of present practice of describing a waste by its BOD_5 and COD these parameters automatically suggest themselves. The BOD determination has the problem of being a treatment process itself and the value of BOD is dependent not only on the period of treatment but on the initial seed. On the other hand the COD value has the problem of incorporating a percentage of non-biodegradable material which is chemically oxidised in the COD test. Neither parameter is ideal, but in the aerobic treatment situation where the change in COD across the system is being measured then the COD seems to have the advantage. The change in COD in this situation is due completely to biodegradation and the non-biological fraction of the COD is eliminated by considering this change across the treatment system. In this way the treatment system itself provides a measure of the BOD for a given retention time:

$$BOD = COD_{in} - COD_{out}$$

As the retention time increases the BOD value approaches BOD_{∞} or the ultimate BOD of the waste. Assuming that the oxygen required is proportional to the food utilised, this biodegradable constituent of the COD, which corresponds to the ultimate BOD, should provide a suitable measure of substrate.

Model parameters

The three properties necessary to define the substrate model are K_s, $\hat{\mu}$ and y. These can be assumed constant only under certain conditions. The substrate level, K_s, is the property characteristic of the "substrate model". As illustrated in Figure 5, the growth rate is a half of the maximum at this substrate level. Therefore K_s is a measure of the availability of the nutrients, indicating the concentration level at which they limit growth. The availability of nutrients is to some extent a function of the agitation which brings them into contact with the micro-organisms, and of the temperature, which affects the absorption process. However, above a certain minimum level of agitation required to achieve a reasonable degree of homgeneity, K_s should be largely a function of the waste, the substrate measure chosen and the treatment temperature.

The maximum growth rate $\hat{\mu}$ is common to many models, and considerable data exists on its value for pure and mixed cultures. The factors affecting $\hat{\mu}$ will be primarily the species present in the mixed culture and the operating temperature. The temperature affects the value of $\hat{\mu}$ in two ways. The rate of chemical reaction increases with temperature, resulting in a corresponding increase in specific growth rate. This is described by the van't Hoff-Arrhenius relationship:

$$K = K_o e^{\frac{E}{r} \frac{T - T_o}{TT_o}} \qquad \text{....(10)}$$

Its other effect is on the dominant species of the micro-organism in the mixed culture, which may increase or decrease the growth rate. For a given waste, at a given temperature, it should therefore be possible to define $\hat{\mu}$ as a constant.

The organism to substrate yield, y is assumed constant; this is not necessarily true as it varies with the availability of nutrients and other factors. However, some limit to the sophistication of the model was necessary to enable solution of the resulting differential equations, and the assumption of a constant yield seemed a reasonable starting point.

Simple straight-through treatment

Consider first the simple straight-through treatment system represented in Figure 6. The waste enters at a flow rate $\dot{v}$ and substrate concentration, S_f. It is assumed that the organism concentration in the feed is negligible compared with that in the treatment vessel. The organism and substrate concentration in the treatment vessel and therefore in the effluent are X and S respectively. In the steady state, for a micro-organism balance on the system, the micro-organism growth in the treatment vessel must be equal to the micro-organisms washed out.

$$\mu X_1 V = \dot{v} X_1 \qquad \text{....(11)}$$

or

$$\mu = \frac{1}{\theta_h} = D \qquad \text{....(12)}$$

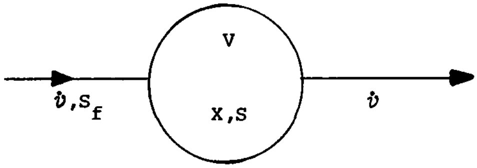


Fig. 6. A straight through continuous treatment system

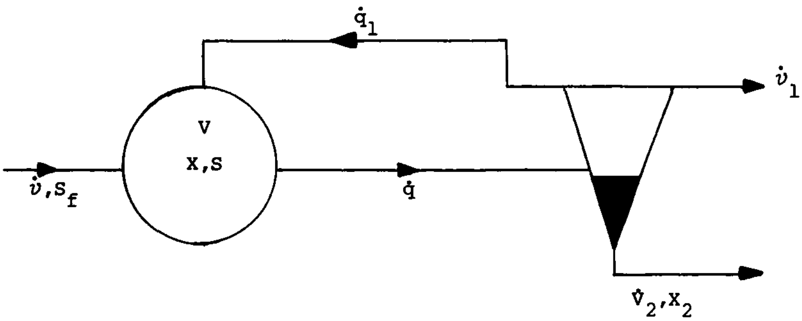


Fig. 7. A continuous treatment system with separation and supernatant recycle.

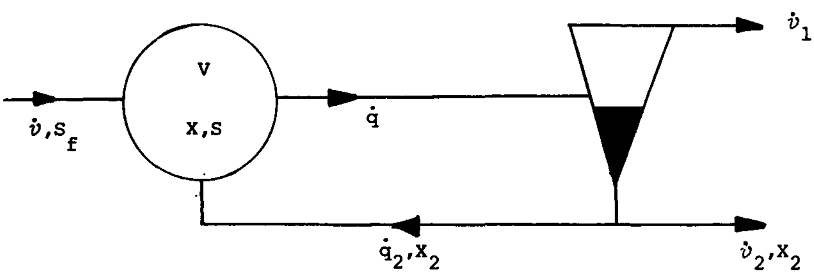


Fig. 8. A continuous treatment system with separation and micro-organism recycle.

where θ_h is the hydraulic retention time and D the dilution rate as defined by:

$$\theta_h = \frac{V}{\dot{v}} \qquad \text{....(13)}$$

$$D = \frac{1}{\theta_h} \qquad \text{....(14)}$$

For the "substrate model" the growth rate is defined by Equation (1) and Equation (12) becomes:

$$\hat{\mu}\frac{S_1}{K_s + S_1} = \frac{1}{\theta_h} \qquad \text{....(15)}$$

rearranging

$$S_1 = \frac{K_s}{\hat{\mu}\theta_h - 1} \qquad \text{....(16)}$$

For a substrate balance on the system the micro-organisms produced by the system must be proportional to the substrate removed thus:

$$\dot{v}X_1 = \dot{v}y(S_f - S_1) \qquad \text{....(17)}$$

$$X_1 = y(S_f - S_1). \qquad \text{....(18)}$$

From Equation (16) an interesting result emerges; the output substrate concentration is independant of the input concentration and varies only with retention time. This result may seem strange until one looks at Equation (18). The output substrate concentration, S_1 is fixed by the retention time, θ_h. The micro-organism concentration in the treatment vessel increases with the substrate feed concentration, adjusting to consume the available substrate. A useful measure of the performance of a treatment system is given by the specific substrate removal rate, $\dot{R}$, where:

$$\dot{R} = \frac{\dot{v}(S_f - S_1)}{V}, \qquad \ldots.(19)$$

$$= \frac{S_f}{\theta_h} - \frac{K_s}{\theta_h(\mu\ \theta_h - 1)}. \qquad \ldots.(20)$$

It can be shown that this has a maximum at

$$\theta_{h_{opt}} = \frac{1}{\mu}\left[1 + \frac{K_s}{S_f}\right]\left[1 + \sqrt{\left\{\frac{K_s}{K_s + S_f}\right\}}\right] \qquad \ldots.(21)$$

Continuous treatment with separation and supernatant recycle

Having dealt with the straight-through system in some detail, the effect of a separation process in the system can be introduced. The operating systems illustrated in Figures 7 and 8, incorporate a solids separation process with a return flow of either of the separated fractions.

In the first system (Figure 7) all of the settled material and the necessary volume of supernatant to maintain the hydraulic balance is removed. The remainder of the supernatant is recycled to the treatment vessel. Assuming that all the micro-organisms are removed by the separator and that the separation has no effect on the substrate, the micro-organism balance becomes:

$$\mu X_1 V = \dot{q} X_1 \qquad \ldots.(22)$$

$$\mu = \frac{1}{\theta_m} \qquad \ldots.(23)$$

where θ_m is the micro-organism retention time given by

$$\theta_m = \frac{V}{\dot{q}} \qquad \ldots.(24)$$

The remaining analysis is identical to the straight-through system with θ_m replacing θ_h in Equations (16) and (20). The relationship between θ_m and θ_h is given by:

$$\theta_m = \frac{\dot{v}}{\dot{q}} \theta_h \qquad \text{....(25)}$$

In this system $\dot{q}$ must be greater than or equal to $\dot{v}$ in order to maintain the hydraulic balance. In practice the volume of liquid, $\dot{q}$, that undergoes separation, or "de-sludging" as it is sometimes called, is often far greater than the volume throughput. This implies that the micro-organism retention. time, θ_m, is far shorter than the hydraulic retention time, θ_h, with a corresponding adverse effect on substrate removal as predicted by Equation (16).

Continuous treatment with separation and solids recycle

The second system (Figure 8) operates by recycling a fraction of the settled material and removing the remainder, together with sufficient supernatant to satisfy the hydraulic balance. Assuming the separation process concentrates the micro-organisms from the level in the treatment vessel X_1 to a concentration, X_2, in the separated material and that the substrate concentration is unaffected by the separation process, then a micro-organism balance gives:

$$\mu X_1 V = \dot{q} X_1 - q_2 X_2 \qquad \text{....(26)}$$

or

$$\mu X_1 V = X_1 (\dot{q} - R_x q_2) \qquad \text{....(27)}$$

where R_x is the micro-organism concentration ratio for the separation process and is given by:

$$R_x = \frac{X_2}{X_1} \qquad \text{....(28)}$$

for this system the micro-organism retention time can be written

$$\theta_m^1 = \frac{V}{\dot{q} - R_x q_2} \qquad \ldots.(29)$$

The analysis now proceeds as before with θ_m^1 replacing θ_h in Equations (16) and (20). Consider the case where all the micro-organisms are recycled:

$$\dot{q} = R_x q_2 \qquad \ldots.(30)$$

and therefore θ_m^1 is infinite. The return flow of micro-organis can be used to increase the micro-organism retention time with the corresponding increase in substrate removal. The recycle system is not frequently encountered in animal waste treatment systems, where the objective of separation is usually solids removal. This analysis does however illustrate the potential benefit to be obtained from micro-organism recycle.

By assuming that the biologically available fraction of the Chemical Oxygen Demand of an organic waste is a measure of the substrate available to the micro-organisms it was possible to use the model as a description of experimental measurements published at two centres. The agreement between the model and experiments is shown in Figure 9.

The substrate model provides a first order interpretation of an aerobic biological treatment system for animal manures. It can be used as a framework for correlating experimental observations and even for planning new observations. Within the limits of accuracy with which the equations describe the processes which are taking place, they offer a convenient method for probing the relations to find the best operating point.

MODEL 4 INFLUENCE OF CLIMATIC AND SOIL FACTORS ON NUTRIENT AVAILABILITY

The main pathway for recycling animal manures is through the soil and plant production. The economic value of the plant

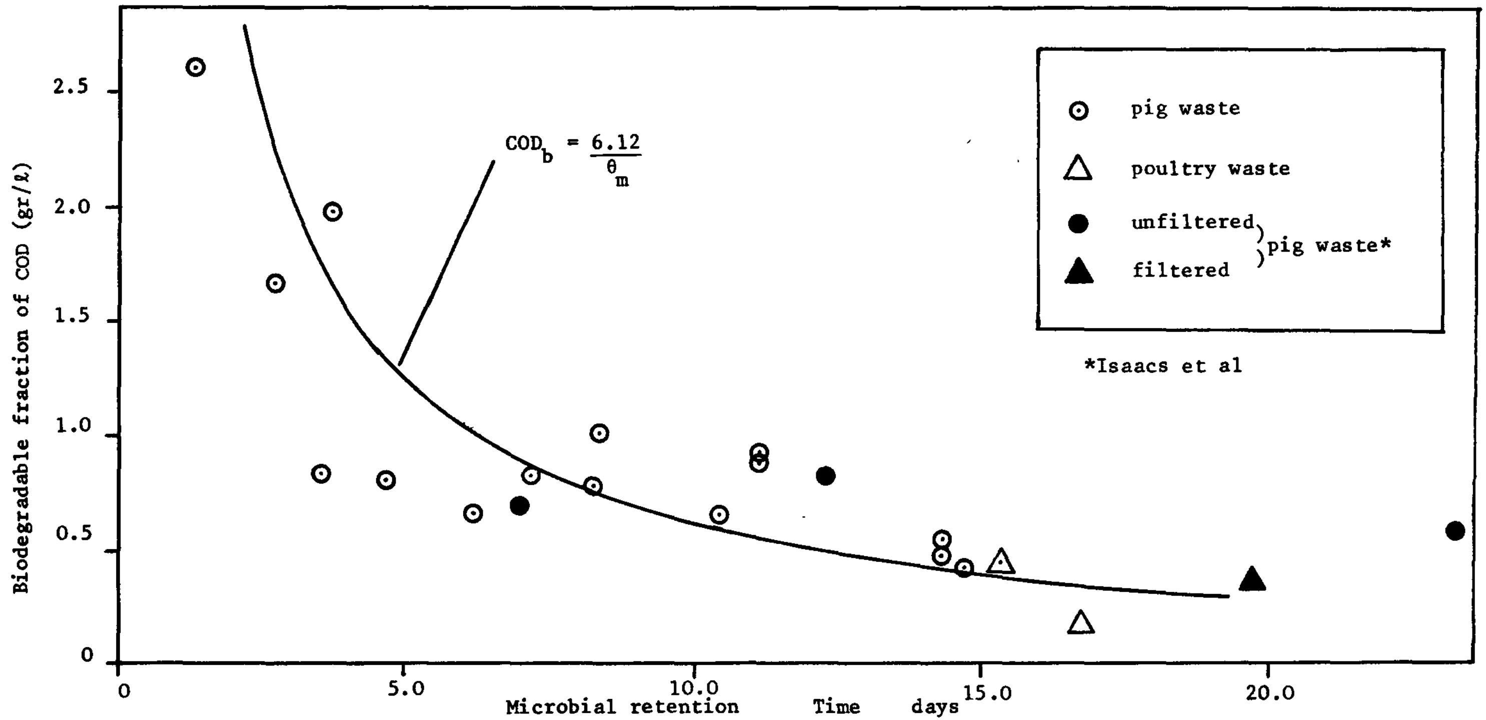


Fig. 9. Comparison between data and theoretical prediction for COD_b.

nutrients in animal manures makes exploitation as a fertiliser worth while. However, it is necessary to improve our understanding of how animal manures are broken-down and the ways in which the chemical components become available for plants. It is also important to match the timing of nutrient release from manures with the demands of the growing plants. There are two preliminary stages in setting up a model of utilisation where it is possible to draw on existing research:

Calculation of the moisture content of the soil,
Calculation of the temperature profile in the soil.

With values for moisture content and temperature, it is possible to begin to characterise the conditions under which chemical changes take place. A diagramatic representation of the model is shown in Figure 10.

Methods for calculating soil moisture profiles range from those using the concept of potential evapotranspiration based on meteorological data to those using equations for unsaturated flow of moisture based on measurements of the physical properties of soil and a model of plant root extraction. The concept of potential evapotranspiration gives the maximum loss of water from the soil under conditions where the supply of soil water is not limiting. The extent to which actual evapotranspiration falls below the potential level is extremely controversial. Some models assume that evapotranspiration continues at near potential level until wilting point; others assume a divergence between potential and actual which is proportional to the remaining soil moisture; while others assume a linear decrease from the potential rate to some arbitrary value.

An intermediate level of complexity, commonly used to predict crop growth, uses the idea of layers of uniform soil, each with a store of available water which is depleted with increasing difficulty as depth increases. During moisture addition each store will fill to its capacity and then overflow to the layer beneath. Such a model uses mean soil physical parameters, root coefficients and meteorological data to describe soil moisture profile changes.

Models based on unsaturated soil moisture flow equations are conceptually closest to reality. Predictions of soil moisture distribution are based on field measurements of soil physical properties and a model of plant root extraction. Where slurry is spread on soil, the infiltration characteristics of the soil are likely to be modified and possibly also the soil physical properties.

The temperature profile in the soil may be calculated from an energy balance at the soil surface based on absorbed radiation, sensible heat loss, heat flow into the soil and evaporative heat loss.

A first stage in proposing a model to represent the moisture and temperature profiles in the soil is a comparison between observed and calculated values based on accurate observations of meteorological, soil and plant conditions. Lysimeter studies have been carried out during two seasons. During the first season, calibration and background measurements were made. During this year, slurry has been applied and the measurements were repeated.

CONCLUSION

Models provide a synthesis of information concerning complex problems. The degree of complexity reflects the detail of understanding which is needed to explore a decision. In modelling the land spreading of animal manures, an approach at the steady state level is adequate in a general advisory situation to help in establishing limits of the rates of application. In order to provide a detailed insight to the utilisation of animal manures by plants, a complex model to reflect dynamic changes in meteorological and soil physical conditions is required.

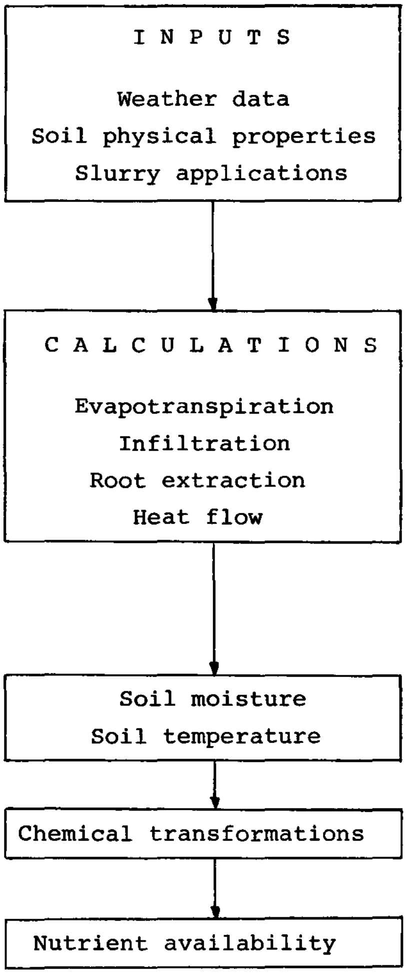


Fig. 10. Flow diagram of slurry-soil-plant model.

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THE SOCIO ECONOMIC ASPECTS OF LAND SPREADING OF MANURES VERSUS OTHER USES - A SYSTEM APPROACH

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In this paper I have tried to show how it is possible, with the technology available, to design processes allowing for an improved use of manure when this problem is seen from a global point of view.

Indeed, with the development of modern agriculture, manure disposal has become a great problem in certain areas where animals, particularly cattle, pigs or poultry are raised in great numbers in a limited space.

In these cases the problem for the producers is, "To dispose of an unwanted by-product as quickly and as easily as possible", as one of them put it. Many techniques and pieces of equipment are available (Pregermain, 1975; Vasseur and Monrocq, 1975). However, frequently they deal with only one aspect of the problem, for example, the odour problem, or if they are satisfactory from a micro-economic standpoint at the level of the farm they are not so from a global environmental point of view. They may, for example, induce losses of useful nutrients, energy costs, pollution of the water table, etc.

My research unit is not specialised in the problems of manure as such. It deals with the socio economics of food and agricultural wastes and by-products, their reduction by the development of so-called clean technologies and the new uses found for by-products. Our main tool is system analysis.

From this point of view land spreading is only one of many possible techniques. It may be used on its own, and this implies a choice between land spreading and other techniques, or it may be included in a more elaborate process. Here a cost/benefit evaluation also has to be made.

The first step in such an analysis is to define as precisely as possible the problem and the corresponding systems.

From a micro-economic point of view, the problem is to dispose of manure at the lowest cost or, if possible, with some profit. The system is the farm; it may or may not include fields. From a global standpoint it is to make the best use of the components of manure considered as an inflow of raw material into a chain of processes. The system is then an agricultural and food system based on a specific area which can range from a region to a whole country. These two objectives may be, and frequently are, quite contradictory.

The following table gives an idea of the importance of manure produced by concentrated intensive farms in France although it is a very rough estimate.

TABLE 1

MANURE PRODUCTION IN FRANCE - ESTIMATES (AVERAGE 1971 - 74)(000 t)

	Total manure	Recycled on traditional farms	Intensive farms (number of head)	Produced on intensive farms ending partly as a pollution	%
Cattle	155 000	94 000	over 50	61 000	39
Horses	3 200	2 200	" 50	1 000	31
Pigs	39 000	19 000	" 100	20 000	51
Poultry	8 500	2 500	" 2 200	6 000	71
Total	205 700	117 700		88 000	43

Source: INRA - Unité de Recherches Nord - IAA

With the pressure of the whole economy towards more and more concentrated and capital intensive agriculture, the proportion of manure produced in great quantities on very limited areas is increasing rapidly.

Some of the many problems related to this trend are:

Odour problems in the surrounding area

Difficulties in finding a large enough area to spread the manure and for a long enough period

Risk of leakage into streams or through the soil into the water table

Risk of crop pollution

Changes of ion distribution in the soil

Time lag between land spreading and cultivation of the field, etc.

Therefore, in order to be successful a project requires long and careful study, including:

A preliminary survey of the area

Trial tests - study of soils, cultures, efficiency control, etc.

Routine checks when the project has been completed.

For small or medium sized farms, such a project is frequently considered too complex and too costly, or is not considered at all, and the actual course of action chosen remains quite unsatisfactory.

Sometimes other techniques such as biological treatment plants are preferred because they are easier to implement and to maintain. In these cases, manure is presented as a mixture of only some of its components, the presentation varying according to the projected use. For example, only NPK is measured if the potential value of the manure as a fertiliser is being considered.

In fact, this raw material is very complex. Many aspects can and should be evaluated: water, fibre (and generally speaking glucides), proteins, enzymes, micro-organisms, fermentation potential, health hazards, odours, minerals - potassium, phosphorus, nitrogen, uric acid, calcium, etc.

The evaluation has to be made in regard to the potential demand for these components. To reach optimum use of manure in each specific case a broad field of potential uses should be considered.

Manure components can be used as animal feed, as a direct or indirect energy source, as the starting point for a food chain, as well as a fertiliser. The economic interest of these uses increases with the evolution of food and agricultural systems considered as a whole. Indeed, the structure of food industries in industrialised countries is becoming more complex. It can best be seen as a double level structure.

The first level, called in our research group, the Intermediate System, is progressively replacing and absorbing traditional industries like flour mills, sugar factories, etc. Many chemical and pharmaceutical firms are investing in it. Its main functions are to supply agriculture with industrial inputs and to extract basic components from its outputs; that is to say proteins, lipids, glucides (ranging from starch to glucose, fructose or saccharose), flavours, colourings, or standardised combinations of some of these.

Strictly speaking the food industry constitutes the second level. Its demand for the intermediate products offered by the first level is growing tremendously in France.

Both agriculture and the food industry are producing an increasing amount of wastes. Manure is just one of them.

It is generally difficult to recycle those wastes directly and economically without transforming them. Most of the time one has to extract valuable products like proteins or transform them into more interesting ones. Many firms within the Intermediate System are developing new techniques and new products in this field.

One of the main results of this evolution is an increasing interaction between markets for raw materials and intermediate products. For example, through their protein content, cereal, soya bean and whey are competing with each other on the animal feed markets. Soya bean is also competing with other sources of fats. This makes the various markets very interdependent and any fluctuation in one affects the others. Moreover, the intermediate products are competing with each other because they can all be partially used as substitutes for others. The case of the sweetener market is a well known example.

It is, therefore, very difficult to analyse these markets and to make a choice between various processes. However, the fact remains that the solutions envisaged to cope with this increasing amount of waste are linked with the development of these intermediate markets and with the technologies produced by the intermediate system or in reaction against its effects. This may be illustrated by a few examples:

1. POULTRY INDUSTRY

As many poultry producers are not primarily interested in obtaining the maximum nutrient value from the manure from their stock but are more interested in disposing of an unwanted by-product, valuable nutrients are frequently lost through heavy dressings (of up to 125 t/ha) or through biological treatment into lagoons.

Manure may also be dried (Dias, 1976). This is a costly operation. As a fertiliser it is economically possible only in the case of large units taking full advantage of economies of scale, and in cases where the final products can be sold in small bags at high prices to market gardeners and domestic outlets.

Better results can be achieved as a feed component if the country's legislation allows it (Blair, 1975). In the UK more than 300 000 t of DPM is being processed annually to be included in feed (Meldrum, 1974). Recently, "Farmers' Weekly" announced that J.B. Eastwood, the principal poultry producer in the UK, is developing a compound cattle feed including DPM. A pilot plant producing 100 t per week has been built. Eastwood could produce 3 500 t per week. The price of the product is related to the price of barley.

Another example is given by a French farmer who is heating his 22 000 chicken plant by burning the manure (Partheney and Fort, 1975). The waste composed of droppings and chips of wood from the litters is heated at about 500°C, producing a gas. 1 kg of the product gives about 2.9 m^3 of gas. At 875°C the combustion of 1 m^3 produces 1 950 kcal. The equipment used has a capacity for 200 000 kcal/hour. It costs 21 500 F H.T. This solution has proven to be satisfactory for this farmer as he has access to a permanent and cheap source of wood chips. In this case manure is competing with the price of fuel.

2. METHANE PRODUCTION

Methane production has often been cited as a potential source of energy. It has also often been presented as uneconomical or uninteresting in Europe because a temperature of 27 to 37°C has to be maintained, which is difficult in our climate.

This is one typical case where a global viewpoint can prove to be useful. In certain areas indeed, thermal pollution from industrial sources is frequent. Waste heat can be trapped to maintain the correct temperature and even to start a food chain. Pr. Persoon from Gent University in Belgium is experimenting with such systems.

Here it is also possible to take advantage of economies of scale. According to Humbert and Espiard (1974) fermentation units costing about 5 M.F. for farms of 5 000 cattle are economically feasible. A fermented manure is produced as a by-product that can be sold.

In the same field, Biomechanics Ltd. in the UK has designed a process with an improved anaerobic fermentation, digesting completely the organic matter and producing enough gas to avoid other sources of energy for running the plant. In certain cases it may produce some excess gas. This latter case is competing with more traditional waste treatment plants. It may be of interest to individual firms but it does not make full use of the original materials.

3. CATTLE FEEDLOTS

A system for recycling manure has been designed by Ceres Land Company in the USA (Lambeth and Secklee, 1975). It has been experimented in France by the SICA Bepy. It is based on the extraction of three fractions, C1, C2 and C3, from manure (Description technique de la station d'engraissement de Noe, 1975; Station d'engraissement de Noe, 1975).

First, manure undergoes an aerobic fermentation to deodorise it and increase the protein fraction. Then solids are separated. They are washed, pressed and stacked in a silo where they ferment naturally. It gives the product C1. The remaining liquid passes through a centrifuge where small particles are separated. They give the product C3 containing a high proportion of minerals. The final liquid is evaporated in a multiple effect evaporator. The product C2 containing the soluble sugars and the protein fraction is dried and granulated. The C1 product competes with corn forage, C2 with corn or soya meal, C3 is a fertiliser. It is the only fraction to be used for land spreading. The plant has a capacity for 40 000 t/year of manure corresponding to about 10 000 head of young cattle.

4. FOOD CHAINS

As I have already stated, it is possible to conceive more or less elaborate food chains based on manure.

In Hungary pig farms have been built over a lake where carp feed on their excrement. More elaborate food chains have also been designed. The well known New Alchemist group in the

USA, as a reaction against the increasing industrialisation of food production summarised above, is doing research on such chains (Fogel, 1976). Using solar energy and wind they can compensate for the thermal problem already mentioned.

Another example is given by a farm in the Tonga archipelago in the Pacific Ocean, where methane is produced from pig manure (Reynolds, 1974). The outflow of water is used to cultivate algae that are used to feed poultry and ducks. The overflow is used to raise shellfish and then goes into a fish pond and finally ends in a vegetable garden! In such cases only part of the minerals and water are landspread, all the other components are used previously, at their optimum level.

The above examples give an idea of the variety of possible processes. More sophisticated techniques than evaporation and less energy consuming ones, like ultrafiltration, reverse osmosis, electrodialysis, can be used. Manure can be mixed with other wastes and fermented to produce single cell proteins. In each case the various steps and products have to be evaluated in comparison with other products, traditional or otherwise, taking into account the demand for intermediate products.

Most frequently only minerals and water are left for land spreading. However, as yet there is no general pattern. Each case is specific for which a system has to be designed, but the above examples show clearly that land spreading must not be designed independently of the environment of the farm.

Frequently contradictions occur between the economic interests of the farms and the socio economic interests of the community. They can lead to accute conflicts between the farms, the neighbourhood, the administrative structures and ecological organisations. In France, the administrative structures are just learning to deal with such conflicts and to adopt the necessary global point of view.

The environmental groups are active and their opposition to the development of intensive industrial food production can lead to useful innovations. The farms in this dynamic process remain the more conservative element.

On the whole the situation is far from being optimum. A great deal of effort and research has to be done to improve it.

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WASTE MANAGEMENT SYSTEMS IN ANIMAL HUSBANDRY APPLICATION OF FARM MODEL STUDIES AND SYSTEM ANALYSIS

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INTRODUCTION

This paper is based on a report concerning an economic and environmental analysis and evaluation of alternative waste management systems on cattle and pig farms (Christensen, 1976). The report is the result of an interdisciplinary research project carried out in 1975/76.

The project was started against the background of some tendencies in the development of agriculture and public opinion.

a) Animal production units are growing and often without a proportional increase in land disposal.

b) The price rise of fertilisers and perhaps a long term shortage of raw materials encourage the best possible use of animal manure in crop production.

c) There is a growing interest in environmental protection and animal manure brings about some problems:

1. Worsening of working conditions.
2. Decrease in state of health and production return caused by equipment and handling of manure in the stable.
3. Risk of dissemination by land spreading.
4. Nuisance of odour from the stable and by land spreading.
5. Pollution of soil as a growing space for plants.
6. Pollution of surface water and ground water.

The intention of the project was to produce an implement which could serve as an aid for the advisory service and form a basis for general discussions concerning animal manure; furthermore, to put the future research work in order of priority.

A selection of findings will be presented here. The economic considerations have been given precedence over those relating to technology and biology in order to avoid overlap of other papers presented at the seminar.

THE MODEL

Figure 1 shows the structure of the model. There are four principal stages in manure handling: gathering and removal from the stable, treatment and storage (internal and/or external), carting out and application in crop production. Different methods and technical plants are connected with each stage and by combination a number of complete manure handling systems can be formed.

It is very important to know the quantity of manure to be managed every year. It depends on the production per animal and the size of the farm unit. Therefore, analyses have been made of a number of farm models and stock sizes.

a) 40 or 80 dairy cows with young cattle in a tie up housing system.

b) 60 or 120 dairy cows with young cattle in a loose housing system with cubicles or permanent litter.

c) 40, 70 or 100 sows with gilts and piglets.

d) 1080, 2160, 3240 or 6480 baconers produced per year - 360, 720, 1080 or 2160 pig places respectively.

The costs are in terms of 1975/76 prices. Investments in stable (floors, slats, channels, dung passage, mechanical scrapers, etc), storage and treatment plants and machinery are included. The capital gain is estimated as an annuity. The rate of interest is 14% and the life of plants and machinery depends on use and quality. Labour requirements concerning bedding, removal, treatment, loading, transport and spreading are fixed at 30 DKr. per hour.

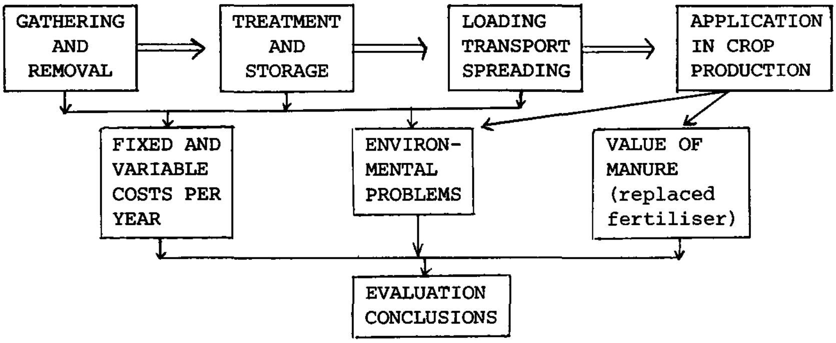

Fig. 1. Structure of model to analyse and evaluate manure handling systems.

The value of manure is considered in the model. The valuation is based on experiments concerning animal manure in crop production compared to inorganic fertiliser.

Environmental problems are often difficult to identify. Only a few comparative experiments have been carried out and the measuring methods are still insufficient.

Both the total costs per year, the value of manure and the different environmental problems enter into the final evaluation. The purpose of this stage is to arrange the manure management systems in order of economic and environmental considerations.

MANURE PRODUCTION

Both cattle and pigs produce considerable quantities of manure depending on age (weight) and feeding. Table 1 shows estimated quantities ex stable in kg per day and t per year.

Normal quantities of bedding, remains of feedstuffs and waste water are included.

TABLE 1

MANURE PRODUCTION, EX STABLE

Unit of animal	Description of manure	Manure quantity		Nutrients kg/t		
		kg/d	t/year	N	P	K
1 dairy cow	Farmyard manure	37.0	13.5	4.8	1.2	2.8
	liquid manure	20.5	7.5	4.0	0	6.5
	Slurry	57.5	21.0	4.5	0.8	4.0
1 young cattle 1 year old on average	Farmyard manure	13.7	5.0	4.4	0.7	2.8
	liquid manure	5.8	2.1	3.6	0	6.5
	Slurry	19.2	7.0	4.0	0.5	3.5
1 sow with gilts and piglets	Farmyard manure	7.9	2.9	7.6	3.0	4.5
	liquid manure	7.1	2.6	4.0	0	2.0
	Slurry	14.3	5.2	6.0	1.6	2.7
10 pigs in the stable, weight 50 kg on average*	Farmyard manure	24.7	9.0	7.6	3.0	4.5
	liquid manure	22.2	8.1	4.0	0	2.0
	Slurry	45.2	16.5	6.0	1.6	2.7

* Equivalent to 30 baconers - produced from 25 to 91 kg.

The Table is divided into types of manure relevant to the fundamental principles of manure handling in practical farming: either farmyard (solid) manure with bedding (straw) and a drained liquid manure or a mixture of slurry practically without bedding.

The content of nitrogen (N) and phosphorus (P) in pig manure exceeds that of cattle manure. There is less potassium (K) in pig slurry than in cattle slurry. Most of the potassium from cattle is in liquid manure and from pigs in solid manure. Normally the content of P in liquid manure is very low and economically of no importance. The content of nutrients in manure from young cattle is lower than in manure from dairy cows.

DISCUSSION OF FINDINGS

In connection with the interpretation of costs and the value of manure it is an advantage to compare with a term of production return. In so doing one receives an impression of the importance of manure handling for the total economy of the farm. This is especially advantageous on application to an international assembly as different exchange rates and production conditions confuse the interpretation.

As a relevant standard of comparison a gross margin, in terms of 1975/76 prices, can be used.

Unit of animal	Standard gross margin SGM
1 dairy cow and 1.1 young cattle for 1 year	4,500 DKr.
1 sow and 0.2 gilt for 1 year, 18 piglets to 25 kg	2,200 DKr
10 baconers produced, from 25 to 91 kg	900

The gross margin is estimated as value of output minus variable costs and indicate the residue to meet the fixed costs in connection with land, buildings, store rooms, equipment, machines and labour.

The stock size influences the costs per unit. However, the findings presented below are selected from those models where advantages of scale have been exhausted.

Manure management systems

As shown in Table 2 the net costs (total costs minus value of manure) of a slurry system are lower than the net costs of a system with farmyard manure and liquid manure. The difference amounts to 14% of the gross margin (SGM) for cows with young cattle and correspondingly 15% for baconers. This difference in costs has led to a considerable interest in slurry systems in practical farming. Costs are saved in all stages of the system from stable to spreading.

TABLE 2

MANURE MANAGEMENT SYSTEMS

System	Dairy cows with young cattle			Baconers		
	Net costs per unit			Net costs per unit		
	Total DKr.	Differ- ence	%/SGM	Total DKr.	Differ- ence	%/SGM
Slurry	1295			525		
		620	14		139	15
Farmyard manure + liquid manure	1915			664		

The estimates imply that the state of health and the production return (gross margin) is independent of different construction of floors, dung channels etc., which is a logical consequence of slurry compared to farmyard manure + liquid manure. However, several studies on diseases and practical experiences show that such an assumption cannot always be upheld.

The estimates for dairy cows in Table 2 concern a tie up housing system partly with slurry channels and grates and partly with manure channels, mechanical scraper and liquid manure drain. Frequency of disease is normally higher in the case of a slurry system but to all appearances the reduction in gross margin does not exceed the advantage of lower costs (620 DKr.).

The report also contains estimations on manure handling in loose housing. Permanent litter is a little more advantageous than cublicles with solid or slatted floors, both as far as costs and frequency of disease are concerned. Methods of manure handling in cubicle houses are either by slatted floors with slurry channels or below house store, or solid floors with tractor scraper or V-shaped mechanical scraper. No differences of costs have been found among these systems and the frequency of disease is also identical, maybe with an advantage to slatted floors because of a constantly dry environment.

In Denmark the experts have reservations about recommending slurry systems in pig production in spite of a considerable advantage in net costs. However, a slurry system precludes the use of straw bedding and due to this more disease, a decrease in growth and an increase in feed consumption has been found. An estimation on the basis of experiments and practical experience shows a decrease in gross margin of about 200 to 250 DKr per 10 baconers produced. That means an all-round lower production return since the advantage in costs was only 139 DKr (Table 2). Therefore, the existing scepticism of slurry systems in pig production is understandable.

Another circumstance in the case of slurry and particularly where below house storage is concerned, is the risk of poisonous gases, especially hydrogen sulphide (H_2S). In Denmark, animals have been poisoned in several cases and now and then so seriously that they died. As far as is known no fatal accident has happened to the staff in pig or cow houses, but there have been cases with symptoms of poisoning. Consequently extreme care must be recommended particularly in connection with the emptying of below house slurry stores. It is also important that research workers and advisers try to reduce the risk in every way possible.

Storage

Generally the manure is stored for a period prior to landspreading. It is impractical to remove it too frequently and the crops can be seriously damaged if the landspreading is not adapted to the growing season and the soil conditions. In addition a reasonable storage capacity is of benefit to the environment. The nuisance of odour can be reduced by spreading once or twice a year instead of several times and the survival of various parasites is drastically reduced by a prolonged period of storage.

Table 3 shows the costs per year of external storage facilities with a capacity of 3, 6 and 12 months. It appears clear that the storage costs of slurry are lower than the storage costs of farmyard manure together with liquid manure.

Of course, costs increase with increased storage capacity.

A higher value of manure is likely because of the possibility of choosing a more suitable time for landspreading. However, it can easily be proved that increase in value cannot meet the increase in costs.

In consideration of practical and environmental circumstances a storage capacity of at least 6 months must be recommended. If the conditions for landspreading are particularly favourable a smaller capacity can be justified, but in no circumstances less than 3 months.

TABLE 3

STORAGE COSTS PER YEAR

			Dairy cows with young cattle, grazing in summer		Baconers	
Manure	Stores	Storage capacity	Costs/ unit, DKr	%/SGM	Costs/ unit, DKr	%/SGM
Farmyard manure + Liquid manure	Open dung yard + Covered liquid manure tank	3 months	155	3.4	42	4.7
		6 months	276	6.1	70	7.8
		12 months	450	10.0	136	15.1
Slurry	Open half below ground slurry tank	3 months	94	2.1	24	2.7
		6 months	162	3.6	37	4.1
		12 months	231	5.1	63	7.0

Treatment

There are various reasons for carrying out a special treatment of animal manure:

a) Reduce the nuisance of odour.

b) Reduce the risk of dissemination.

c) Reduce the quantity in order to cut down the transport cost.

d) Decompose organic matters and other chemical compounds in such a way that residual products can be transferred to surface and ground water or spread on land without risk in a larger quantity than usual.

e) Production of thermal energy or gas (mainly methane).

f) Protein recovery, application as feedstuff.

Several methods for manure treatment exist. To form a general view it is expedient to group the methods according to the basic principles.

a) Chemical treatment.
1. Addition of ammonium persulphate, chlorine, lime, etc

b) Physical treatment.
1. Separation
2. Drying
3. Combustion, pyrolysis

c) Biological treatment.
1. Aerobic
    1.1. Below house oxidation ditch.
    1.2. Liquid composting
    1.3. Solid composting

2. Anaerobic
    2.1. Anaerobic lagoon
    2.2. Anaerobic digester, biogas plant

The methods vary of course both with regard to efficiency and economy. Generally the greatest interest inside research work is in favour of biological treatment. Today none of the methods have been tested to such a degree that a common extension in practical farming can be recommended, at least, not in Denmark.

Four biological methods have been analysed in the report.

a) <u>Below house oxidation ditch</u>: The slurry falls down through a slatted floor in a below house ring channel.

Special rotors aerate the slurry and keep it moving.

b) Liquid composting: Mixed and water diluted slurry is transferred to an insulated tank with a surface aerator/ stirrer. In principle it is the same method as in the below house ditch but the biological decomposition is more effective. The temperature of the slurry rises to about 50°C.

c) Solid composting: The manure is transferred to a compost box with a mat of straw. Air is blown through from the bottom and the mixture of straw and manure is composted for a month. The temperature rises to about 60°C. The liquid part of the manure is gradually evaporated by draining and re-spraying. The residual product (compost) weighs only one third of the original manure and straw.

d) Anaerobic digester, biogas plant: The manure is mixed and diluted with water. The mixture is transferred to a hermetic reactor tank (digester) and heated to a temperature of 35°C. An accelerated fermentation takes place and produces a considerable amount of gas, mainly consisting of methane. Some of the gas is used to maintain the working temperature in the reactor tank.

Table 4 shows the additional costs compared to ordinary storage without a special treatment. All costs from stable to spreading are included and the value of residual products in crop production are deducted. In every case the carting out takes place half yearly. That implies a storage capacity of 6 months.

The additional costs of manure treatment are generally considered rather high. However, the costs vary according to the method. The highest costs are incurred by the below house oxidation ditch and liquid composting. Among other things this is the result of large-scale electricity consumption in running the oxidation and stirring equipment.

TABLE 4

TREATMENT OF ANIMAL MANURE
ADDITIONAL NET COSTS COMPARED TO ORDINARY STORAGE WITHOUT SPECIAL TREATMENT

Method	Dairy cows with young cattle		Baconers	
	DKr. per unit	%/SGM	DKr. per unit	%/SGM
Below house oxidation ditch	-	-	170	19
Liquid composting	1205	27	220	24
Solid composting	810	18	90	10
Anaerobic digester, biogas plant	570	13	80	9

Solid composting and treatment in an anaerobic digester has a lower net energy demand. The surplus of gas, which makes up 70 to 80 per cent of the total production, is not valued and included in the costs above but it could hardly cut down the additional costs already estimated. The calorific value of 2 m^3 of gas is equal to 1 kg of oil. Therefore production and demand of gas must be well correlated in order to save storage tanks. However, this is easier said than done, especially since the largest net gas production takes place during the summer when only a little gas is used in the most obvious field of application, heating of buildings.

With regard to a more favourable environment the methods will probably not be very much different. Odour and the risk of dissemination will be reduced but none of the methods lead to a residual product which can be transferred to surface or ground water. Untimately, landspreading is still the only way to dispose of manure. Solid composting leads to a residual product which is easier to transport. This is an advantage where there is a land shortage near the farm compared to the number of animals

Loading, transport and spreading

To keep down the costs of loading, transport and spreading, it is important that the capacity of machinery fits in with the total quantity of manure. That is apparent from Table 5 which shows the costs per 10 tons of slurry.

The costings are based on the use of typical machinery. Varying distances to the field and total quantities of slurry are taken into account. The total quantity has the greatest influence on the costs per unit.

It can be proved that the costs of carting out liquid and farmyard manure are roughly equivalent.

TABLE 5

LOADING, TRANSPORT AND SPREADING OF SLURRY. COSTS OF MACHINERY AND LABOUR, DKr. PER 10 TONS

Method of spreading	Distance to the field, metres								
	500			1000			1500		
	Quantity of slurry t/year			Quantity of slurry t/year			Quantity of slurry t/year		
	500	1000	2000	500	1000	2000	500	1000	2000
Open	124	75	50	131	82	57	138	89	64
Injection	223	127	79	231	135	87	238	142	94

Two methods of spreading are considered. By open spreading the slurry is spread on the field surface direct from the tank wagon. By injection the slurry does not come into contact with the surroundings. The tank wagon is fitted with an injector unit which transfers the slurry into the ground. By this method the nuisance of odour is very much reduced and a higher value is obtained in crop production, especially as a result of lower ammonia evaporation.

However, injection adds to the costs of land spreading because of more expensive equipment and a high-powered tractor but it is a comparatively cheap step to reduce the odour of slurry. Taking into account the higher manurial value the additional costs amount to roughly 50 DKr per cow with young cattle and 20 DKr per 10 baconers produced. This is far less than in the case of biological treatment according to Table 4.

Application in crop production

The price rises of commercial fertilisers encourage the best possible use of animal manure in crop production. Simultaneously they bring about a more favourable environment since all steps taken to improve the utility value of the manure also have a positive effect on nuisance of odour and pollution of surface and ground water. From an environmental point of view the situation would be more serious if the prices of fertilisers had fallen.

A number of factors influence the value of manure in crop production.

a) Nutrients supply compared to crop requirements.
b) The crop to be manured and the rotation of crops.
c) Season of spreading.
d) Time between ploughing and spreading.
e) The price of N, P and K in commercial fertilisers.

The values of animal manures in Table 6 are based on a typical rotation including roughage crops, and a reasonable supply compared to requirements. The estimations are in terms of 1976 prices of fertiliser nutrients: 3.00 DKr per kg N, 7.75 DKr per kg P and 1.50 DKr per kg K.

TABLE 6

VALUE OF ANIMAL MANURE IN TERMS OF THE VALUE OF REPLACED FERTILISERS

Time between ploughing and spreading	Dairy cows with young cattle		Sows with gilts and piglets		Baconers	
	DKr/unit	%/SGM	DKr/unit	%/SGM	DKr/unit	%/SGM
Immediately	500	11.1	123	5.6	127	14.1
After 1 day	450	10.0	114	5.2	118	13.1
After 4 days	402	8.9	109	5.0	113	12.6

Normally, it is accepted that P and K in animal manure has the same efficiency as P and K in fertilisers. On the contrary many experiments have demonstrated a lower utilisation of N in animal manure and a corresponding adjustment must enter into the evaluation.

The estimations in Table 6 show that the possibility of using manure in crop production is of great importance to the economy of animal production. Of course, the manure adds to the costs of production but most of these costs exist whether the manure is utilised in crop production or not.

In the light of the figures in Table 6 it is perhaps not fair to characterise animal manure as waste. This term is used in the title of the paper and in the basic report. However, the primary initiative of the project was based on environmental points of view. In this context waste is a more exact word.

The value of manure goes up with a rapid ploughing. Simultaneously this reduces the nuisance of odour and the risk of surface water pollution. A rapid ploughing-in is often possible without additional costs. Environmental protection and a higher production return are not necessarily incompatible aims.

CONCLUSIONS

The benefits of the farm model studies and system analyses concerning manure handling have to appear from the extension of the findings in advisory and research work. In this connection it is of great importance that a bringing up to date takes place according to changes in conditions and technology.

A growing interest in animal manure can be expected, partly because of environmental problems - internal as well as external- resulting from the trend towards intensive animal husbandry and partly because of the economic importance of animal manure on the farm. It can be proved that manure handling and its application in crop production influences the total economy on the farm just as much as many other factors and conditions.

REFERENCE

Christensen, J. 1976. Waste management systems in animal husbandry. The Farm Management Committee of the Ministry of Agriculture. Arhus. 143 p. + 62 p. annex (written in Danish).

ELABORATION OF STATISTICS ON MANURE PRODUCTION

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In the actual context of "protection of the environment" it would be erroneous to include the whole quantity of the breeding wastes in the nomenclature of the wastes which are producing a state of pollution. Indeed, in this regard, in breeding waste production, we must distinguish between, on the one hand the quantity of animal waste which can be re-utilised for soil improvement by agriculture and, on the other hand, the surplus produced, which must be disposed of without damaging the environment.

Animal waste is composed of undiluted solid and liquid faeces. The maximum quantity of farmyard manure or semi-liquid manure that the soil is able to receive without damage is limited by several factors such as the specific requirements of the crops, the equilibrium of the nutritive elements of the soil, the nature of the soil, the protection of the surface waters, etc. Too frequent spreading of manure constitutes a potential risk to the environment, to water, the soil and plants.

In the course of breeding cattle, poultry and certainly pigs, in general and in industrial breeding in particular, it frequently happens in certain regions of a country that the production of animal waste widely exceeds the quantity which can be utilised by the soil and, from that time onwards, the surplus of animal waste, which must be disposed of by the producer, becomes harmful particularly to surface water for the same reason as ordinary wastes produced by the community.

Before seeking a solution which would be satisfactory to all the sectors concerned with the problem of the disposal of breeding waste (this situation is alarming in some countries) one must first of all collect exact information concerning the production of the waste, for instance, quantity, origin, geographical distribution, composition for each animal species, etc.

The agricultural and horticultural census performed yearly in Belgium by the National Institute for Statistics supplies information, for instance, on the number of animals of each species classified by age and sex; the information being given for the country, the provinces, the districts and the communes.

These statistics enabled us to evaluate the annual production of animal waste and therefore we applied conversion factors based particularly on infomation found in the literature or supplied by specialists in the problem concerned. This evaluation takes into account (Table 1):

a) Average weight of an animal of each of the groups under consideration and this in relation to age and sex for each species

b) Weight calculated in livestock units (LU)

c) Weight of wastes produced calculated for one LU and this for each species of animal

d) Chemical composition of the waste (%) from a defined species, particularly concerning the amounts of organic matter, total nitrogen, potassium (K_2O), phosphorus (P_2O_5).

All the information collected by us for each species of animal represented on the list drawn up by the National Institute for Statistics (Model 1 Agricultural and Horticultural Census) is approximate but it enables us to make a comparison of the scale of sizes of the values obtained.

Table 1 gives the applied conversion factors:

1. Estimation of weight.

2. Expression of the animal weights in LU.
3. Estimation of the weight of animal waste produced for one LU and for each group of animals in each species.
4. Estimation of the chemical composition of the waste (%) and for each animal species.

Besides the quantities and the composition of the animal waste, other information would be necessary to evaluate the surplus. This information has been collected on:

1. The geographical distribution of the production of animal waste in the different parts of the country and calculated for each commune, district, province, agricultural region, hydrographic drainage basin and for the whole country. The calculation for each farm or breeding unit would be interesting but it is impractical to collect the necessary statistical information.

2. The total local acreage available for the spreading of animal waste in order to enable us to define the real danger of overproduction and the danger level for saturation of the soil. Taking into account the distribution (in %) of the types of crops in a province and the optimal spreading amounts for grassland, cereals, root plants and other crops (Tables 2 and 3), it would be possible, theoretically, to spread the whole quantity of animal waste over the whole country. There would in fact be a deficit of 1.534×10^3t animal waste on the assumption that the production could be distributed geographically. This calculation does not take into account the large amount of mineral fertilisers used in our country. In fact, the high cost of transport absolutely precludes moving the animal waste from one region to another or from one commune to another.

It is certain that the maximum utilisation of breeding wastes could lead to a substantial diminution of the use of mineral fertilisers and especially of the phospho-potassium fertilisers.

3. The number of farms and breeding units together with

their importance in relation to the danger of overproduction of wastes and also the quantities and species of animals which are bred in these places. For this we were obliged to make certain estimations:

a) Expression of the occupation of the ground in relation to the number of total LU bred, and to the agricultural area utilised. (<3, from 3 to 5, >5 LU/ha)

b) The classes of holdings with regard to their surface area (5, from 5 to 20, >20 ha) and the number of bred LU. (<2, from 2 to 50, from 50 to 100, >100)

One must take into account, although it was not possible until now, the way in which the animals are lodged (type of litter) the type of food given, the stabling system, the place of spreading of the animal waste, the nature of the soil, as well as the hydrographical river system, the destination of the waste, its utilisation in relation to the seasons, the animal species, the method of eventual storage of the waste, etc. These details are necessary to obtain more exact information on which depend the solutions of the problems in question.

The values communicated by the National Institute for Statistics, taking into account the conversion factors noted before, are the following:

<u>1st part</u>

a) Number of LU for each animal species and for each category of the same species and the % of each species in relation to the total.

b) Quantities for each animal species of waste produced in t/day and t/year and also of the total amount of waste, organic matter, K_2O , total N, P_2O_5 and the percentage of waste from each species in relation to the total.

c) Number of animals in relation to the surface area, total LU bred in relation to the agricultural area utilised.

d) Waste produced in relation to the surface area in t or kg/ha, total waste, organic matter, K_2O, total N, P_2O_5 and these calculated against the total agricultural area utilised.

2nd part

a) Number of holdings in relation to their area and the number of animals bred on one ha (holdings from 1 to 5 rising to 20 on more than 20 ha). The total number subdivided according to the number of LU bred on one ha. (< 3, from 3 to 5, > 5 LU/ha)

b) Number of holdings where more than 5 LU/ha are bred, subdivided according to the number of animals bred in each holding. (< 2, from 2 to 50, from 50 to 100, > 100 LU)

c) Number of holdings in each subdivision, as mentioned above, where 75% or more poultry, pigs, cattle or animals of other species are bred.

d) Centesimal proportions of holdings where more than 5 LU/ha are bred and where 75% or more of the number of bred LU are poultry, pigs, cattle or animals of other species, in relation to the total number of holdings with more than 5 LU.

One can observe that:

1. The total surface utilised includes the grassland and does not necessarily correspond with the surface utilised for the spreading of animal waste, therefore the estimated rate of occupation in LU/ha or the tonnage of waste/ha must be lower than the actual rates.

2. We have estimated that an occupation of 5 LU/ha results in a potential pollution of the soil.

PRESENTATION OF SOME VALUES

Some of the values noted in the statistics and discussed above are presented in form of maps, tables and histograms. For instance, for each province we have one map, one table and two histograms.

Presentation for each commune of some data extracted from the statistics and recapitulated for the districts, provinces and the whole country (Table 4).

Total weight of the wastes produced in one year.
idem/ha of utilised agricultural surface.
Total weight of organic matter/year/ha of UAS*.
Total weight of N
" " " P_2O_5 /year/ha UAS
" " " K_2O

For the holdings with more than 5 LU/ha UAS:

Total surface
Proportion of this surface against the UAS utilised by all the holdings.
Number of holdings where >5 and <100 LU are bred.
idem for more than 100 LU
idem where more than 75% cattle are bred
idem " " " " pigs " "
idem " " " " poultry " "
idem " " " " of other animal species are bred.

One can point out that we consider >5 LU/ha as a potential pollution, for example 5 cattle of 500 kg.

COMMENTS

If we consider a potential utilisation of 25 t/ha/year as a reasonable utilisation, since the UAS includes the grassland, we would have a surplus of 15 080 x 10^3 t of animal waste over the whole country. (Table 5)

One might also ask, therefore, whether the use of mineral fertilisers in not unnecessarily high. Indeed, from Table 6 we can note an annual cost of about 3 842 Fr/ha. This amounts to a total expenditure of 5 763 000 000 Bfr for 1 500 000 ha for Belgium. Assuming that we could replace some of the mineral fertilisers by animal waste in certain regions of the country we could probably absorb the surplus of animal waste by a judicious landspreading of a supplementary quantity of waste.

* Utilised Agricultural Surface.

This must all be in relation to the nature of the cultivated plants.

As a matter of fact, one can note for the whole country that the total yearly contribution of the nutritive elements present in the total breeding wastes is calculated at the following quantities per ha: 188 kg of N, 92 kg of P_2O_5, 174 kg of K_2O and 4.2 t organic matter.

However, the danger of potential pollution may be less important than suggested due to the fact that on the one hand, a significant part of the waste from the cattle breeding is directly restored to the soil during the grazing period and on the other hand, that the danger of pollution of the environment stems particularly from intensive pig breeding. Consequently it was interesting to note the relative percentages of the wastes produced by the different animal species per province and from the whole country (Table 7).

We thought that it would be interesting to formulate a tentative method of treatment of the very important problem concerning intensive breeding in the matter of the utilisation and the disposal of the wastes. The information collected could eventually be used by the authorities entrusted with the setting up of an overall plan regarding the management and siting of the breeding units, taking into account both their efficiency and the protection of the environment. It would also be interesting to compare between countries, data which are necessary to assure this objective. Eventually, it would be important to increase the range and number of statistical data which must be collected regularly.

With regard to the occupation of the land in LU, one can note that on a total of 1 510 000 ha UAS in Belgium, 1 226 000 ha (81%) are occupied by less than 3 LU/ha, 223 000 ha by between 3 and 5 LU/ha and only 61 000 ha (4%) by more than 4 LU/ha of the total number of 16 352 holdings with more than 5 LU/ha. We can note that 5.5% are breeding in total from 0 to 2 LU, 69%

from 2 to 50 LU, 19% from 50 to 100 LU and only 6.6% more than 100 LU.

Finally, we can note that different maps have been drawn up for each province and district in which the communes are coloured differently in relation to the quantities of animal waste, for example, 0 - 25, 25 - 40, 40 - 55, 55 - 70 and >70 t/ha.

TABLE 1

APPLIED CONVERSION FACTORS

1. Estimation of the average weight of the animals

Poultry	Estimated unit weight (kg)
Laying hens and young non-laying hens	1.8
Chickens	1.3
Ducks, guinea fowl	2.5
Geese, turkeys	8.0
Pigs	
Young pigs - weight less than 20 kg	10
Pigs - weight from 20 kg to < 50 kg	35
Porkers - weight from 50 kg to 110 kg and above	80
Pigs for breeding purposes - weight from 50 kg and above	130
Cattle	
Calves <3 month old	110
Calves from 3 months to 1 year	240
Other males and females	240
Cattle from 1 to < 2 years	
Heifers for breeding	400
Bull-calves kept for breeding purposes	600
Male animals for fattening	600
Female animals for fattening	500
Cattle from 2 years and above	
Bulls for reproduction	900
Heifers for breeding	600
Once-bred for fattening	600
Other animals for fattening	600
Breeding females for milking	600
Breeding females for calf suckling	600

Others

Horses:	
Draught horses used wholly or partly for the holding, or carriage horses, saddle horses or racers	500
Sheep	50
Goats	35
Rabbits	2

2. Expression of the weight of the animals calculated in livestock units.

One livestock unit is equal to 500 kg

	LU
Poultry	
Laying hens and young non-laying hens	0.0036
Chickens	0.0026
Ducks, guinea fowl	0.0050
Geese, turkeys	0.0160
Pigs	
Young pigs - weight < 20kg	0.02
Pigs - weight from 20 kg to < 50 kg	0.07
Porkers - weight from 50 kg to 110 kg and above	0.16
Pigs for breeding purposes - weight from 50 kg and above	0.26
Cattle	
Calves <3 months old	0.22
Calves from 3 months to 1 year	0.48
Other males and females	0.48
Cattle from 1 to < 2 years	
Heifers for breeding	0.80
Bull calves kept for breeding purposes	1.20
Male animals for fattening	1.20
Female animals for fattening	1.00
Cattle from 2 years and above	
Bulls for reproduction	1.80
Heifers for breeding	1.20
Once-bred for fattening	1.20

Other animals for fattening	1.20
Breeding females for milking	1.20
Breeding females for calf suckling	1.20

Others

Horses:	
Draught horses used wholly or partly for the holding, or carriage horses, saddle horses or racers	1.00
Sheep	0.10
Goats	0.07
Rabbits	0.004

3. Estimation of the weight of wastes produced by one LU for the animal species

	kg/day
Poultry	50
Pigs	
Young pigs - weight < 20 kg	50
Pigs - weight from 20 kg to < 50 kg	44
Porkers - weight from 50 kg to 110 kg and above	30
Pigs for breeding purposes - weight from 50 kg and above	23
Cattle	45
Horses	25
Sheep	30
Goats	30
Rabbits	50

4. Estimation in % of the chemical composition of the waste of the animal species

Species	Org. matter	K_2O	Tot. N	P_2O_5
Poultry	25.50	0.60	1.30	1.10
Pigs	7.20	0.26	0.76	0.42
Cattle	12.00	0.52	0.48	0.21
Others	20.00	0.50	0.50	0.20

TABLE 2

% DISTRIBUTION OF THE TYPES OF CULTIVATION

Province	Grassland	Cereals	Root plants	Other cultivations
1	74	10	3	13
2	32	43	13	12
3	42	31	13	14
4	47	31	11	11
5	45	35	12	8
6	65	23	6	6
7	47	31	8	14
8	72	22	1	5
9	54	32	5	9
Country	51	35	9	5

TABLE 3

OPTIMUM AMOUNT OF LANDSPREADING PER HECTARE

"Calculated in relation to the distribution of the cultivations and based on the following landspreading quantities: grassland 25t, cereals 45 t, root plants 60 t, other cultivations 40 t".

Example: Province 1

Grassland:	74%	25t	0.74 x 25 = 18.5 t/ha
Cereals:	10%	45t	0.10 x 45 = 4.50 t/ha
Root plants:	3%	60t	0.03 x 60 = 1.80 t/ha
Other cultivation:	13%	40t	0.13 x 40 = 5.20 t/ha

Province	t/ha	Potential utilisation 10^3 t	Annual Production 10^3 t	Difference 10^3 t
1	30	2 887	5 153	+ 2 266
2	40	6 973	4 293	- 2 680
3	40	9 068	10 614	+ 1 546
4	38	6 502	7 882	+ 1 380
5	37	8 713	6 410	- 2 303
6	33	6 138	6 255	+ 117
7	36	3 245	3 314	+ 69
8	31	4 726	4 621	- 105
9	35	6 239	4 301	- 1 932
Country	36	54 379	52 845	- 1 534

1 ha = 2.47 acres.

TABLE 4

PROVINCE:........................... DISTRICT:...........................

Communes	Breeding wastes yearly						Holdings with more than 5 LU/ha							
	Total		OM	N	P_2O_5	K_2O	Surface		Number of holdings					
	10^3t	t/ha	t/ha	kg/ha	kg/ha	kg/ha	ha	%ha on total UAS	Tot.	>50 <100 LU	>100 LU	>75% LU species		
												Poultry	Pigs	Cattle
-	12	49	5.5	286	143	227	10	4	8	2	0	2	6	0
-	15	23	3.0	175	106	105	17	3	18	2	0	2	10	4
-	15	45	6.0	251	127	232	24	7	25	0	0	12	4	4
-	24	42	5.2	236	116	209	39	7	19	2	1	10	6	2
-	18	85	14.9	801	583	433	68	32	17	1	2	0	5	4

TABLE 5

Province	Breeding wastes yearly 10^3 t	UAS (ha)	Potential utilisation yearly 10^3 t calculated for 25 t/ha	Surplus 10^3 t
1	5 153	96 237	2 406	2 747
2	4 293	174 319	4 358	- 65
3	10 614	226 710	5 668	4 946
4	7 882	171 109	4 279	3 603
5	6 410	235 477	5 887	523
6	6 255	186 013	4 651	1 604
7	3 314	90 142	2 254	1 060
8	4 621	152 436	3 810	811
9	4 301	178 095	4 452	- 151
Country	52 845	1 510 536	37 765	15 080

TABLE 6

CONSUMPTION AND COST OF MINERAL FERTILISERS

Yearly	N	P	K	N	P	K	Total	
	absolute value			relative value			abs. val.	rel. val.
a) Units of fertilisers/ha UAS (1)								
68/69	102	82	112	100	100	100	296	100
73/74	107	107	125	105	130	112	339	115
b) Price in Bfr. of one unit of fertilisers (2)								
68/69	11.65	9.60	4.67	100	100	100		
73/74	15.19	13.35	6.39	130	139	137		
c) Cost (a x b) of the fertilisers in Bfr/ha								
68/69	1188	787	523	100	100	100	2498	100
73/74	1625	1418	799	137	180	153	3842	154

(1) UAS = Utilised Agricultural Surface (including grassland)

(2) Nitrogen fertilisers: ammonium nitrate (26%) represents 55% of the consumption of the nitrogen fertilisers.

Phosphate fertilisers: basic slag and super-phosphates

Potassium fertilisers: chloride 40%

TABLE 7

PERCENTAGE OF WASTES PRODUCED PER ANIMAL SPECIES

Province	Cattle	Pigs	Poultry	Others	Relation in % pigs/cattle
1	77.2	11.3	8.4	3.1	15
2	83.5	9.7	3.3	3.5	12
3	71.0	22.8	4.2	2.0	32
4	78.9	12.6	4.4	4.1	16
5	94.5	3.2	0.9	1.4	3
6	93.4	5.3	0.6	0.7	6
7	72.0	17.5	8.4	2.1	24
8	96.8	2.0	0.2	1.0	2
9	96.2	2.1	0.4	1.3	2
Country	83.7	10.8	3.3	2.2	13

WASTES PRODUCED YEARLY: Tons and %

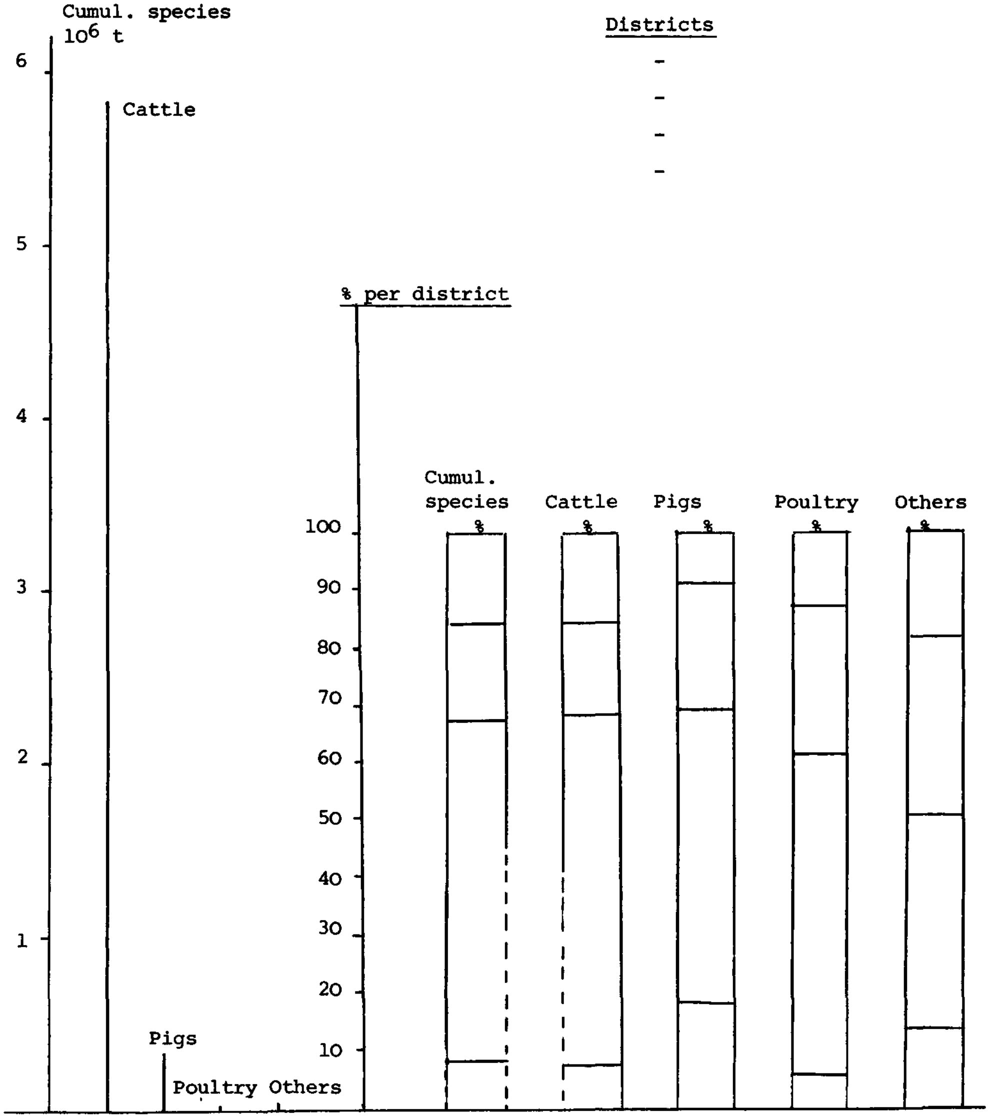
PROVINCE:

DISTRICTS:	10^3 t/ha
-	-
-	-
-	-
-	-
PROVINCE	6 255.1

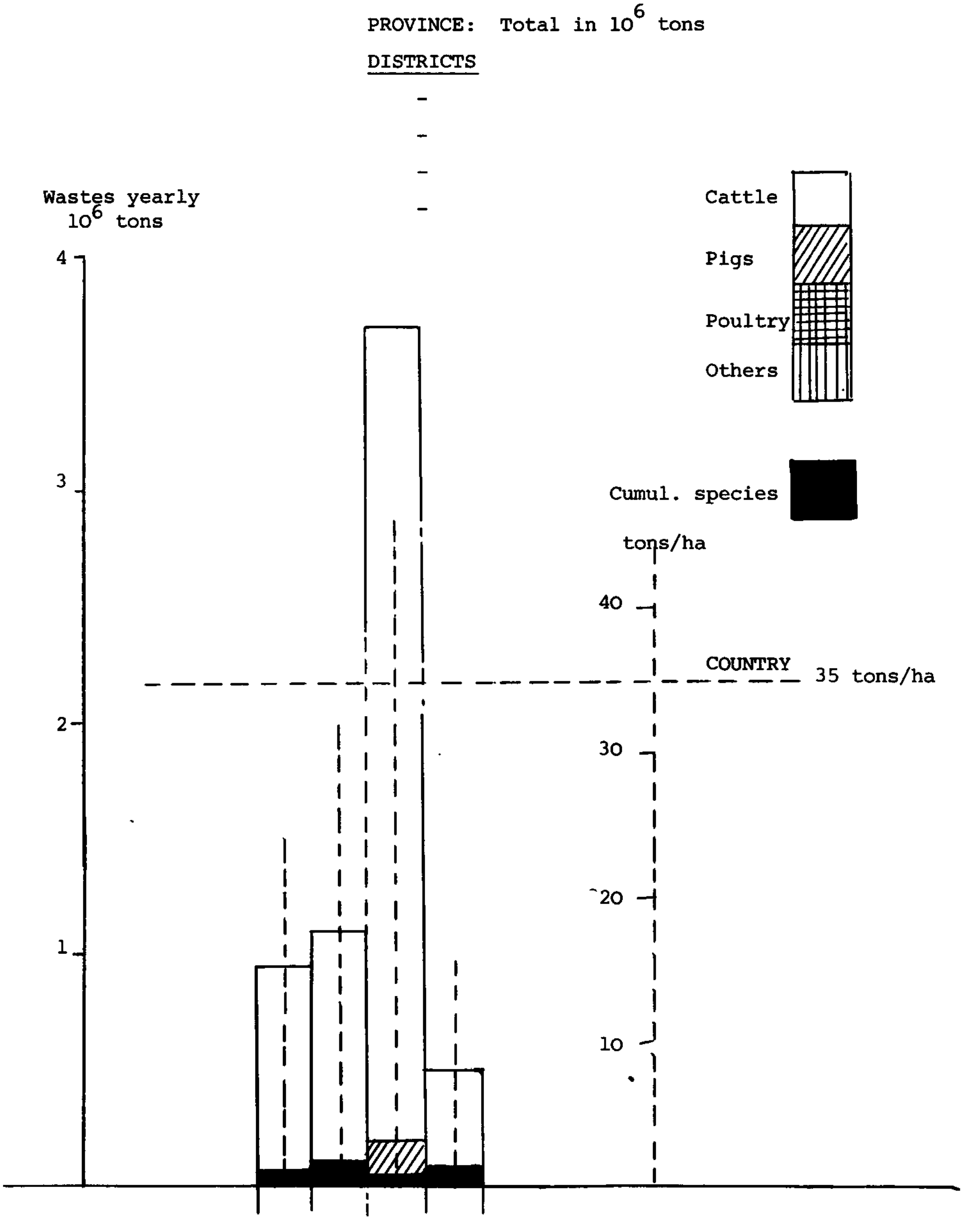
	Cattle		Pigs		Poultry		Others		Total	
	10^3 t	%	10^3 t	%	10^3 t	%	10^3 t	%	10^3 t	%
Tot	5840.8	100	335.2	100	34.9	100	44.2	100	6255.1	100
%	93.4		5.3		0.6		0.7		100	

WASTES - YEARLY PER SPECIES: Tons and %

PROVINCE



WASTES PRODUCED YEARLY IN TONS AND TONS PER HECTARE



SOME ASPECTS OF THE PROBLEM OF MODELLING THE UTILISATION OF ANIMAL MANURES BY LAND SPREADING

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INTRODUCTION

This paper outlines the approach we are taking to the problem of modelling the land spreading of animal manures. To begin with our decision to use an existing model (that of Dutt et al., 1972) as a basis, is discussed. There follows a description of this model. A number of additional factors which may have to be taken into account in the model for the problem under consideration are discussed. Efforts to test the model are outlined. Finally, future developments of the model are considered.

THE DECISION

The decision to use an existing model as a basis was influenced by the following considerations.

1) The desire to proceed as rapidly as possible in view of the size of the task compared to the available time.

2) The existence of a sophisticated computerised model (Dutt et al., 1972) which is reasonably suitable at least in part (Graffin, 1974).

The decision has a major effect on the rest of the project. Normally one would begin with a simple model of one's own conditions. The present approach is different in that one starts with a sophisticated model designed for conditions different from those to which it is to be applied (i.e. semi-arid conditions as against European conditions). To test the agreement of its predictions with European data, a large number of parameters must first be determined. The model with European parameters must then be tested against European data. This is the subject of a later section.

If the predictions of the model are deficient in some areas then one considers what the causes of these deficiencies might be. Possible, (indeed likely) causes of deficiencies are considered later.

THE MODEL

Scope

The model attempts to simulate the soil-water-plant system. Among the factors it takes into account are:

a) Water movement in unsaturated soil allowing for the conduction, diffusion and plant uptake of water.

b) Ion exchange, solubilisation or precipitation of slightly soluble salts and dissociation of soluble ion pairs including Ca-Mg exchange, Ca-Na exchange, Na-NH_4 exchange, solubility and precipitation of gypsum, undissociated Ca and Mg sulphate, dissociated of $CaCO_3$ in water.

c) Reactions involving nitrogenous species including the hydrolysis of urea, the mineralisation - immobilisation of organic-N and NH_4^+-N, nitrification of NH_4^+-N and immobilisation of NO_3^--N.

d) The movement of water soluble species.

e) The uptake of N by the crop.

f) The effect of moisture content and temperature on the above.

STRUCTURE

It is assumed in the model that moisture movement is independent of chemical changes in the soil solution. This allows the computer programme of the model to be divided into two parts; the Moisture Flow Programme and the Biological-Chemical Programme. Output from the Moisture Flow Programme serves as input to the Biological-chemical Programme. A generalised model diagram is shown in Figure 1.

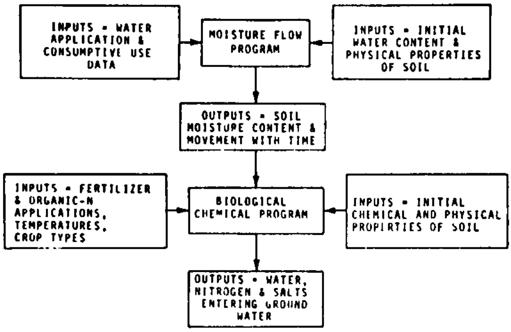

Fig. 1. Generalised Model Diagram

The Moisture Flow Programme

This programme predicts the moisture flow movement in the soil. It assumes one dimensional flow. It is based on the usual equation for unsaturated flow in one dimension:

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial x}\left(D\frac{\partial\theta}{\partial x} - K\right) - S$$

where θ is the volumetric moisture content; D the soil moisture diffusivity and K the unsaturated hydraulic conductivity , are considered to be dependent on moisture content. The user can specify any particular dependence he wishes. S is the moisture removal rate. The user can either specify it by depth for each semi-monthly period of the year, or alternatively, S may be calculated using the Blaney-Criddle formula of experimental constants together with the average root distribution with depth.

The Chemical-Biological Programme

The Chemical-Biological Programme consists of four main sections.

The first section deals with those chemical reactions in base saturated soils which are known to affect the solute composition of the percolating water. Those considered are listed in Figure 2.

It is assumed that the rates of ion exchange, solubilisation

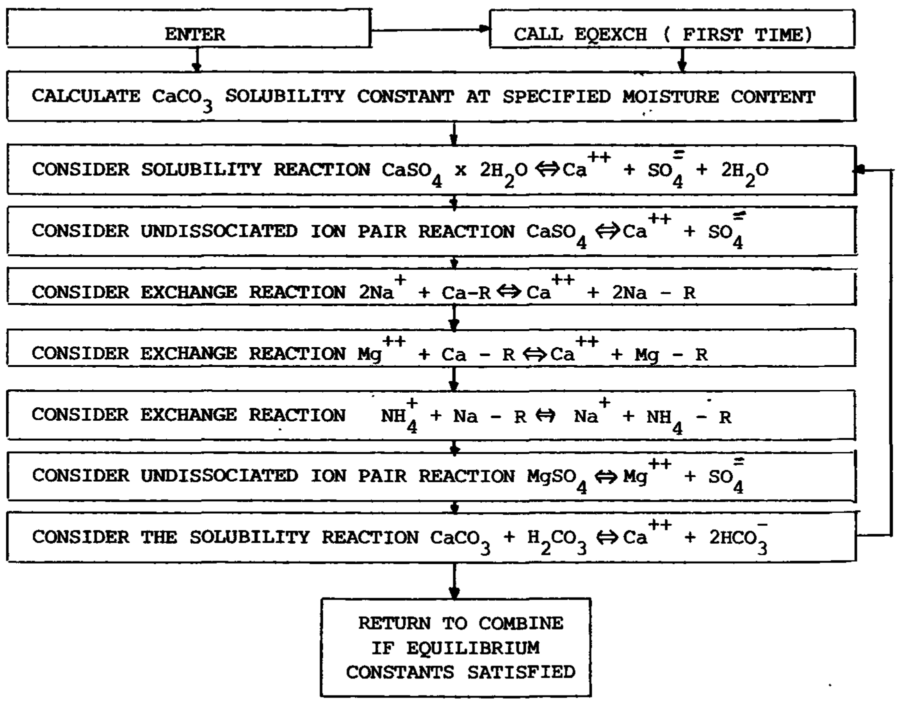

Fig. 2. Generalised Block Diagram of Section One.

or precipitation of slightly soluble salts and dissociation of soluble ion pairs are much greater than the rates of water movement and nitrogen transformation. It is also assumed that the water entering a segment will equilibrate with any remaining solution, the slightly soluble salts, and exchangeable ions on the exchange complex. The equilibrium solution which would result within the segments under these assumptions is predicted.

The second section of the Chemical-Biological Programme deals with the transformation of nitrogen. The biochemical and chemical pathways considered are displayed in Figure 3.

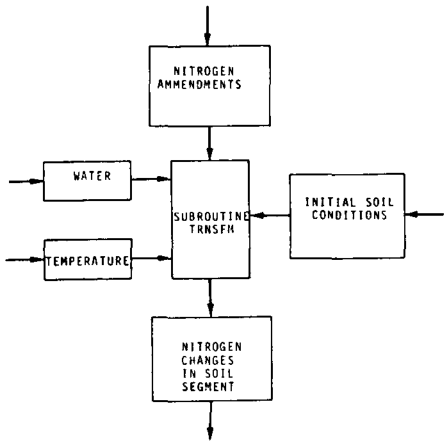

Fig. 3. Biochemical and chemical pathways of section 2.

It was considered that nitrogen transformations take place too slowly to be approximated by the equilibrium relationships. Therefore a kinetic approach was selected to model the pathways. Those variables which it was felt following a literature review would influence the rates of the various transformations were selected and rate equations were calculated using multiple regression.

The following assuptions were also made:

1) Gaseous losses of nitrogen are negligible. This assumption is valid when aerobic conditions exist in the soil, and urea and ammonia fertilisers are not applied on

or near the land surface. The assumption would not hold in cases such as bog soils where restricted aeration exists, or in cases where ammonia is easily lost as a gas.

2) The soil pH remains in the range 7.0 to 8.5. The effect of hydrogen ion activity on soil nitrogen transformations is approximately constant in this interval.

3) Symbiotic and non-symbiotic N fixation and fixation of NH_4^+-N in clay lattices are small in magnitude by comparison with other nitrogen transformations considered in this section.

4) NO_2^--N does not accumulate in the soil beyond trace amounts.

5) Fertilisers and other N additives are applied uniformly and thoroughly mixed with the soil.

6) The microbial populations of different soils are approximately equivalent in their responses to pertinent parameters associated with N transformations.

7) The chemical composition of the soil (other than nitrogen species) has little effect on N transformations.

The third section of the Biochemical Programme deals with the dispersion of soluble chemical species based on water movements calculated by the Moisture Flow Programme. It is assumed that surface fertiliser additions mix completely with water applied to the soil. It is also assumed that only soluble chemical species are capable of being moved with the water. The various soluble species are treated as having the same mobility. It is assumed that each soluble species moves freely with the soil water.

The final section of the Chemical-Biological Programme deals with N uptake. The section calculates the uptake of NO_3^--N and NH_4^+-N at different depths, based on the root distributio (which must be supplied). The user has a choice of two methods.

1) He may assume that N uptake is proportional to consumative use of water. In this case he need only supply the constant

of probability.

2) He can feed in total N uptake and the fraction of this that is NO_3^--N or NH_4^+-N.

It is assumed that root distribution is independent of time.

PROBABLE ADDITIONAL FACTORS

There are a number of hypotheses made in the model which may no longer be so realistic when one is spreading animal manures.

Dutt assumes in his model that the decomposition of organic material takes place in aerobic conditions. This may be reasonable in classical agricultural practice. However, when one is dealing with high levels of application of animal manures it may be necessary to allow for the decomposition of organic material under anaerobic conditions where the supply of oxygen is a controlling factor.

The application of animal manures will also result in additional suspended matter in the soil moisture. The possible effect of the retention of suspended matter in the soil pores on moisture movement may have to be taken into account.

It is felt that the run-off of organic material and the volatisation of NH_4^+-N at the soil surface will require further study.

In addition the inclusion of P, K and Cu in the model is being considered.

TESTING THE MODEL

We are now testing the model under European conditions. To do this it is necessary to obtain the soil and location specific parameters which the model requires. We are at present relying on four sources of data:

1) Irish and English metereological offices for rainfall and temperature data.

2) Lysimeters maintained by An Foras Taluntais (The Agricultural Institute) over a number of years at various metereological stations throughout Ireland for the purpose of determining potential evapotranspiration.

3) Animal manure spreading trials at Lough Sheelin (The Management of AM in the Catchment Area of Lough Sheelin, 1975).

4) Manure spreading trials at Darlington (Joint Land Spreading Trials, 1974).

FUTURE DEVELOPMENTS

We see the model being developed in two ways. As more experimental results become available it should be possible to improve the predictive power of the model. In particular it should be possible to make at least some of the amendments suggested in a previous section. This will lead to an even more detailed model. Such a model is suitable for use in analysing the results of lysimeter work where the soil and crop specific parameters are well known.

However, it is doubtful whether all this detail is relevant when one is trying to predict the results of spreading animal manures over a wide area. The large uncertainties of the soil and crop parameters over the area could render sophistication of the model beyond a certain point superfluous and misleading.

Since we cannot know all about the soil and crop parameters over a wide area the problem becomes one of determining the importance of the different parameters. The model can be used to do this by finding out how sensitive the outputs of the model are to variations in the soil and crop parameters. This allows one to know the degree of uncertainty in the outputs which results from any given degree of uncertainty in the parameters fed into the model. Reactions in the model whose effect is small compared to the expected uncertainties can be discounted.

If one asks questions such as 'What is the best time to spread animal manure in a certain area and how much should be spread?' then one introduces a new major source of uncertainty, i.e. the weather. The method of dealing with this would be to use a much simplified model in a Monte Carlo type simulation. What is meant by'best' will depend on circumstances and could involve one or more of the following:

1) Optimisation of nutrient utilisation.

2) Minimising water pollution.

3) Minimising investment in storage and handling facilities.

4) Minimising land area used for spreading.

It is intended that historical data for rainfall be used as the major variable in the simplified model for a given situation in which soil and crop are specified.

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DISCUSSION

J.R. O'Callaghan *(UK)*

We have a wide basis of discussion. We had the interesting paper from France which looked at the question of how to resolve the conflict of the varying demands of different people on the environment. We have the question of the costings of actual processes from Denmark. We have the national budget for Belgium, looking at that basis. Then there is the paper from Mr. Herlihy. Here I must make a comment insofar as those people who know me well, know that I don't give things away that I could ever use myself! The obvious question you might ask is why do I go to all the trouble to collect more data when I have all this data from Darlington. I think the catch is that the Darlington trial was carried out to check whether the maximum hydraulic loadings were realistic in practice, that what we did over two years was to apply dressings up to the maximum saturation deficit in the soil. I think Mr. Herlihy is right, you can use this as a test with a model, but I would suggest that it isn't actually a complete test because since we held the soil at near saturation all the time, we didn't get the kind of wide variations which one would have during the growing season. This is why I feel I still have to go on struggling to get more data.

However, questions please.

C. Cheverry *(France)*

I have a question about your paper, Dr. O'Callaghan. I refer to Figure 10. In your inputs do you introduce the values of the physical properties of the soil measured before starting landspreading? If so, is the model able to predict the change of those values, the change mentioned on the preceding page of the paper, or do you introduce directly into your model, as inputs, values of the same properties but measured after a lot of landspreading when they are in a steady state?

J.R. O'Callaghan

Well, as I explained, we have not actually got Model 4. We have got Models 1, 2 and 3, and we are getting information ready for Model 4. However, as I see the situation, in Model 4 it will be necessary to measure the soil properties in the particular area concerned. That will be some of the data necessary in order to do the calculations. When you are dealing with soil in the unsaturated condition then the variation between one field and the next becomes so great that one has to measure the soil properties. Having measured them, then I hope we can put this back into all the information which is available on calculation of moisture profiles in soil, dependent on soil properties.

The second point is that there is some indication, though I am not absolutely certain of this, that in fact soil properties will change as a result of applying slurry. I think that over the years there will be changes in the soil characteristics. I am sure my Dutch colleagues have much better information about this than I have, but I feel they will change.

F. Bonciarelli *(Italy)*

I would like to ask Dr. Droeven for some details on his paper. On what basis do you state that 30 t/ha is the maximum which should not be exceeded? What kind of waste are you referring to here? In different wastes organic matter percentage ranges from 7 - 25. Total nitrogen ranges from 0.48 - 1.30%. You state that 5 livestock units/ha, i.e. 5 cows of 500 kg, represent the threshold of potential pollution, but at the indicated daily production of waste, 45 kg per livestock unit, this gives about 80 t/ha, which at 0.48% of total nitrogen makes about 400 kg of nitrogen/ha/year. These figures correspond closely to the quantities of total nitrogen indicated by Dr. O'Callaghan - 500 kg/ha/year of nitrogen in the first example; the same for the third example, 300 kg/ha/year in the second example. I think that 30 t of waste/ha/year is maybe too low.

G. Droeven *(Belgium)*

In addition to the 30 t of manure we also have mineral fertilisers.

<u>J.R. O'Callaghan</u>

Would you care to explain how you reached a figure of 30 t?

<u>G. Droeven</u>

It is an arbitrary figure we use, plus the mineral fertiliser.

<u>L.C.N. de la Lande Cremer</u> *(The Netherlands)*

I agree with Dr. Bonciarelli that your figure is much too low. When you start studies on recycling animal wastes you have to consider the wastes only in the first instance and then when you have a need for a fertiliser you can consider the two things together. We presume that we can recirculate the wastes from about 2.5 to 3 livestock units/ha on grassland, about 7 livestock units on arable land. So, the quantity depends on the proportion between the grassland and arable land. Then you must consider the amount of available nitrogen in the waste. If you are using the waste for up to four years you have a very low efficiency of about 50 - 70%, depending on the type of waste. However, if you have continuous use of wastes year after year on the same plots then you have to use a higher figure. Another point to be considered is the nitrogen efficiency in relation to the time of application. If you are using it only in spring you have a higher efficiency and a lower possibility of using waste than in autumn. In our country, in Germany and Ireland also, animal wastes are used in autumn, winter, spring, and possibly also in summer. You have to make a choice of a mean nutritive efficiency for the nitrogen and I would suggest a figure of 60% for this mean.

<u>J.R. O'Callaghan</u>

One thing I have noticed in the discussions during the week is that people worry about the composition of the wastes, but then almost everybody assumes that the efficiency is going to be 50%. I agree that this must vary quite considerably over the seasons and a lot of our worries on the composition are not reflected in the use of the wastes. We need more information on the efficiencies which is one of the big gaps now in the utilisation.

L.C.N. de la Lande Cremer

Yes, the efficiency of nitrogen does vary with the season of application and also there is a difference in efficiency between poultry, pig and cattle manure. Dr. Tietjen showed in one of the early papers the conditions which determine the efficiency. You can calculate it if you take account of the content of mineral nitrogen in the slurry, in stable manure, in urine, You can make a calculation of the release of nitrogen in the first year from the soluble organic matter and in the following years from the remainder of the organic matter, but the degradation of the latter is much slower. So it is possible to calculate first year and long term effects of the nitrogen taking into account losses in the air and ground water. There is a paper published in Dutch and I think Dr. van Dijk will say something about this on Friday morning.

A. Cottenie *(Belgium)*

We have had three papers today on modelling. I myself have been doing similar work, combining modelling with simulation and we have always found that in order to obtain operational possibilities, simulation was much more reliable than modelling because modelling is always quite theoretical. My question is, how can we now come to an operational stage in the present work, on the basis of models which have been explained and which start from theoretical considerations? What will be the operational value of the models which we see?

J.R. O'Callaghan

Is this a question to me or may I ask for volunteers?

A. Cottenie

It is mainly for you.

J.R. O'Callaghan

I think it would be extremely useful to discuss this. Perhaps you would like to come back at me as we go along.

The first point is that I think there is an enormous gap between what people are doing in the laboratory and how advisers are responding to the questions they are getting in practice. These questions are, of course, very complex. I believe the advisory model I have developed out of just the mass balance does enable the adviser to get simple information and to be able to compound this into a complex answer to a difficult problem. So in advisory work, we can take the information we have at the moment and through a sort of simulation exercise produce an answer which would be more sophisticated than the kind of answers which are provided at present. I see this as the immediate application of a lot of work at the operational level. It is really to raise the level of advice and back up the advisers with the amount of scientific information which is available. The model we have done does take into account the composition of the waste, the problems with regard to dilution, the problems with regard to storage and the consequent losses. All of these are backing up the advice and giving a good result.

Also, at that sort of response at the operational level, we can take into account the conflicts which we have not discussed at this meeting but which do exist. For example, if the rest of the community wants high quality water then we have to take this into account in our advice to the farmers. This is the way in which we can do it.

May I ask whether you agree with that?

A. Cottenie

I would reply with a question, in this sense, have we already one example of real application of a model in the field of action? I have myself made mathematical models for surface water quality and we also started from theoretical considerations. However, we felt that measurements carried out in a laboratory are not the same when you bring them into practical use, to an actual river, an actual waterway. You are working in a very different dimension. The measurements on which these models are based are made in a laboratory on, say, 200 g of soil or 1 kg of soil. When the whole thing is transferred into practice and you are working with maybe 3 or 5 million kg of soil per hectare, what is the effect of the different scale on the parameters, on the operational possibilities of such a model? Unless you have actually done it in practice I don't think you can say that your model is operational. So, I am asking, is there already one example of practical use of our models, in water chemistry or in predicting water quality?

J.R. O'Callaghan

I would like to take up two or three points.

This advisory model has been taken up by ADAS. I believe they use it to some extent although I won't say how much. There is a certain resistance to using models but nonetheless it is operational. We have also done it for one commercial firm. So therefore, to my knowledge, there are two users.

To go on from that, there are two other consequences of what we say. Once the researchers produce the model and it goes out in practice it is still necessary to continue with the simulation and compare this with what people find using it in practice. After all, a model is always a simplification and if the real situation shows that the advice is not sound then you have to look again at the model. There is a need for continual feed-back, to try to get this very wide data, to try to get the big world looked after properly. I think the time has come when models on manure, water and fertiliser could be put into practice but there must be pilot tests so that we can improve in the light of that experience.

Now, if we go back to the model that Laudelout has produced, there is another problem in that he is, in fact, a very long way away from the soil. That gap has to be bridged; there are two possible ways of doing it. One is to try to produce a model of the realistic situation of the soil which will have to be a continuous process. I still think also (though I may have got the argument wrong) that there are troubles in the initial conditions; when you change from one process to another you are not able to take into account the adaptive situation which arises in real life. The other thing which I have at the back of my mind regarding models is that if you build a model of a process, then you want a lot of information and I wonder whether the days of the lone researcher with a small piece of equipment are not over and that what is required is big groups, highly instrumented, collecting a lot of data under very closely controlled conditions, and feeding it back into computers. I find this is the lines along which the younger people are thinking.

A. Cottenie

Going from the laboratory to the field, when you make incubation tests, means going from working at a constant temperature to conditions of extreme variation of temperature, changing from day to day, night to day, and so on. This has to be taken into account. It is not sufficiently buffered to be directly comparable with what is going on in the laboratory stove, for example. There are many other parameters to be considered in practice.

J.R. O'Callaghan

This does not impress me at all! After all, the plants go on growing; they make the adaptations all the time. We can understand that. This is the challenge, to go out and do this. If the plants can make these decisions all the time, we should be able to simulate them!

A.V. Dodd *(Ireland)*

One could apply the same remark to the field experiments. One could get the results of crop production in the three years of this EEC programme and then say, what would happen in 1989; can you predict 10 years further on on the basis of three years results? So I would think the model will only be as good as the data provided by the experimental procedures. I must confess I am not as pessimistic as Professor O'Callaghan is when he talks about the likely changes in the physical characteristics of the soil when one takes into account the actual hydraulic loading. Professor O'Callaghan made it quite clear in his presentation that Model No. 1 was merely an attempt to assess hydraulic loading capacity and that the actual loading in terms of hydraulics will be a fraction of this and will be much more influenced by the chemical characteristics. So if we have consistent characteristics in terms of N, P and K, perhaps copper, zinc and the other elements, and if we can, in the course of the experiment, identify clearly what are the key factors in the soil physical area, for example, K and D, as my colleague Mr. Herlihy pointed out, I think then that the model will be able to predict, if it is a good model. This is the point that Mr. Herlihy put to the audience, that he is dependent on the availability and the generation of the important physical parameters.

In conclusion, I would put it to the research workers engaged in spreading trials that they are dependent on those engaged in modelling to provide the answers which can be predicted and extrapolated from one region of the Community to another.

J.R. O'Callaghan

I agree. I believe that on these Community projects one of the great challenges facing us is how we are going to generalise the results we get, both within the countries in which they are taken, and outside in the other countries of the Community. I think the problem of generalising out from a small basis of information is now more difficult than it was previously.

Well, thank you for a very lively discussion; once again we have run out of time.

THEME 8

SAMPLING AND ANALYSIS

Chairman: H. van Dijk

INTRODUCTION

H. van Dijk
Institute for Soil Fertility, Haren (Gr) The Netherlands

This morning's session is on Sampling and Analysis. Before calling on the first speaker I would like to say a word myself. The majority of papers read at this Seminar have been devoted to the fact that landspreading of manure affects several chemical, physical and biological properties of soil, and as a result, the crop and sometimes water quality. This fact was deduced from and illustrated by analytical data. However, we are confronted by a situation that for each property often numerous analytical methods exist. In some cases results are identical. Then it is a matter of personal preference or available equipment as to which method is used - the choice can be left free because a direct comparison of results is possible. In other cases there is a good correlation between the results obtained with the different methods. When the conversion factors or formulae are known the results are translatable, and thus comparable, although the application of the same methods remains preferable. However, when the correlation is not known the scientists are, as it were, speaking in a different language without an interpreter. The situation frustrates the research programme and is, of course, not acceptable in a common research programme.

Bearing this in mind, it was obviously desirable to place the harmonisation of methods for sampling and analysis on the programme for this meeting. As a first step an inventory was made of the analytical methods in use by those involved in research on effects of landspreading of manures.

At a meeting on 2nd March this year in Brussels, ways and means to achieve the desired harmonisation were discussed and a time schedule was made leading to the presentation of proposals for manures, soils, crops and waters at this Seminar here in Modena.

Yesterday evening when you were still enjoying your cocktails and snacks you may have noticed that a small group of people left early. This was certainly not because this group expected to find more recreational excitement elsewhere but to prepare this morning's session. Two hours of discussion resulted in the following conclusions.

Firstly, it was felt that the schedule adopted in an optimistic mood on 2nd March was too ambitious. It became obvious that there has been insufficient time for you to consult your analytical experts at home. In fact, we concluded that a separate meeting, or meetings, of analytical experts is necessary to draft proposals which will stand a sufficient chance of becoming generally adopted. This is certainly not the fault of the colleagues who undertook the time-consuming and rather unattractive job of preparing the proposals you have received. On the contrary, in my opinion they did an excellent job in accordance with the guidelines they received. Maybe we didn't give good enough guidelines. However, those of you who have ever been involved in normalisation work know that long before the step-by-step policy was introduced by Dr. Kissinger it was already a common procedure in the field of harmonisation of methods. In the light of this, the work done so far can be described as the difficult but important first steps. In view of the situation it was deemed preferable not to include the present proposals in their entirety in the proceedings of this Seminar but to use them as a working document for the analytical experts group to be formed. Now, it is open for discussion as to whether we should make an exception in the case of the proposal for manure because there have been proposals made in other connections for crops, soils and water but, as far as I know, there has not previously been a proposal regarding animal waste, so maybe we will make an exception but we can discuss that later on.

The second conclusion was that in this morning's session the discussion should be centred primarily on (a) the list of parameters - is it complete or incomplete, maybe too long?

(b) the problem of sampling, particularly of manures. It cannot be overstressed that a good sampling technique is essential for the reliability of analytical data. (c) Should we strive for a final standardisation or for an agreement on reference methods? Reference methods may be used alone or alongside other methods; they do not exclude other methods but just serve as a check or control.

The four reporters, Dr. Brogan, Dr. de Borger, Dr. Catroux and Dr. Steffens, are free to enter into some detail with regard to methods of determination but in order to avoid a discussion which would perhaps be rather annoying for many of us, I am asking the audience, in the first instance, to confine comments to point (a) in the list of parameters.

Now I would like to ask Dr. Brogan to address us.

An additional paper by K.W. van der Hoek is included here

SAMPLING TECHNIQUES FOR LIQUID SWINE MANURE

K.W. van der Hoek
Rijks Agrarische Afvalwaterdienst, Arnhem, The Netherlands

INTRODUCTION

The lack of a representative sampling technique for liquid swine manure was considered as a serious handicap for laboratory experiments dealing with liquid manure as well as for interpretation of experiments carried out on a farm scale (eg aerated storage). Liquid manure in a storage pit does not react like a homogeneous mixture, on the contrary, there are three distinct zones: a floating layer, the bulk liquid and a settled layer.

The aim of this paper is to describe the methods and results obtained by sampling an aerated storage basin and a storage pit accommodation for liquid swine manure from fattening pigs.

1. SAMPLING OF AERATED LIQUID SWINE MANURE

There are 3 methods of sampling an aerated storage basin.

1.1.

It is possible to attach a hollow pipe to the frame of the floating aerator, connected with a hose to a little handpump beside the basin. A sample is always obtained at a fixed distance below the liquid level (Figure 1).

1.2.

Another method of taking samples is with a box (volume about one litre) at the end of a steel pipe (Figure 2). Connected to the lid of the box is a second pipe to open or close the box. When the box, with the lid closed, is in position at the desired place and depth it is opened with the aid of the second pipe, and after filling, closed again. In this way there is no mixing with other layers when the box is removed out of the manure.

1.3.

A third method of sampling occurs when the farmer partially empties the basin for landspreading. When the vacuum tanker

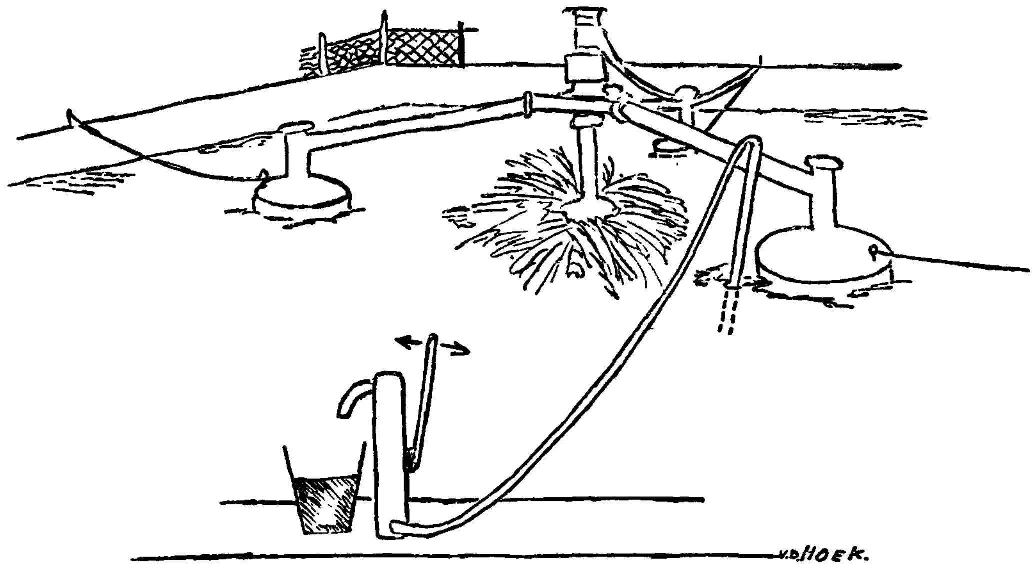

Fig. 1 Sampling device described in 1.1
Design of Institute of Agricultural Engineering, Wageningen.

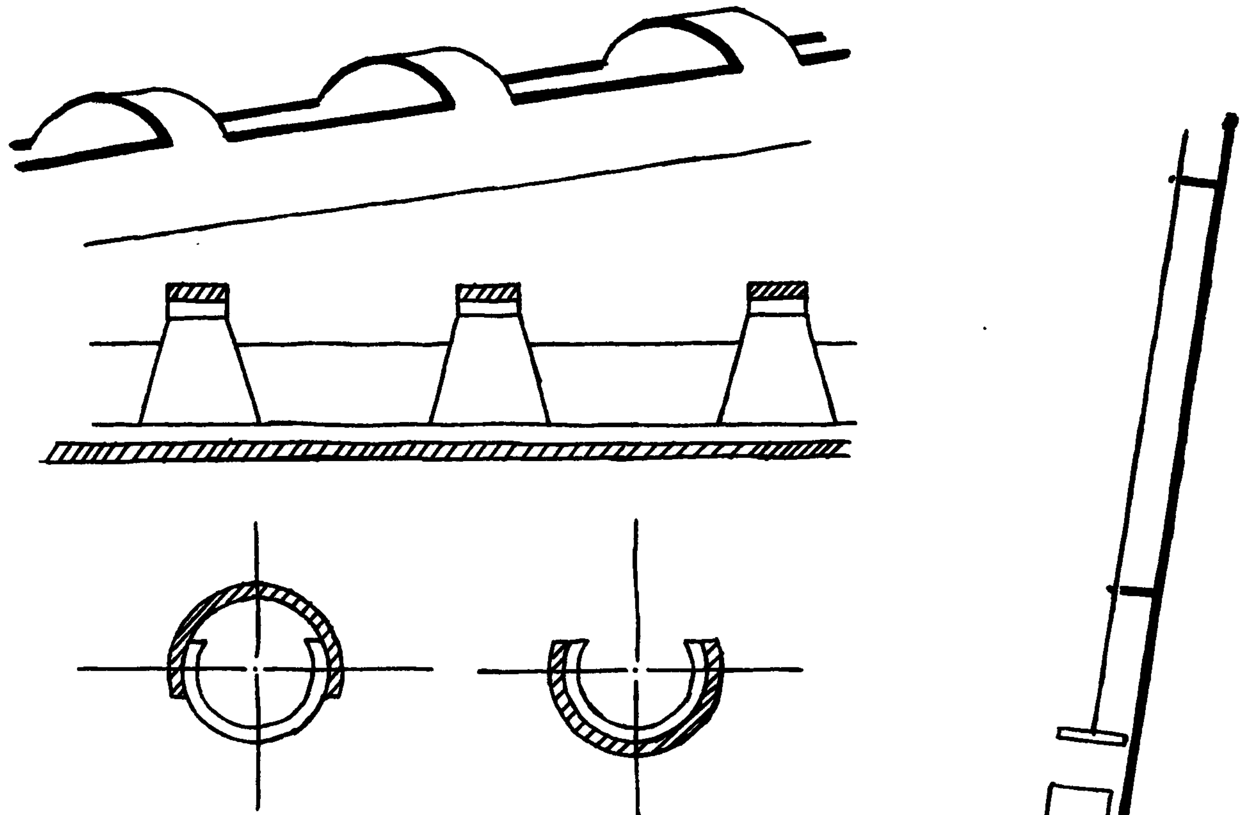

Fig. 2 Sampling devices described in 1.2 and 2.3 (not to scale)
Left side: 2.3 design Manurebank of Limburg
Right side: 1.2 design Institute of Agricultural Engineering, Wageningen.

has been filled, the outlet is immediately opened a little and the desired quantity of manure is collected.

Tables 1 and 2 give an indication of the degree of mixing of an aerated storage basin located in Gendt, Holland

TABLE 1

SAMPLING OF AERATED LIQUID SWINE MANURE, OCTOBER 1975, METHOD 1.2 IS USED. Values in g/l

Sampling place and distance to liquid level		COD	Dry Matter	Ash	N Kjeldahl
A	0.5 metre	46.7	51.2	16.6	3.26
B	"	46.0	51.3	16.7	3.32
C	"	46.9	51.7	16.8	3.19
D	"	49.9	51.4	16.8	3.40
Average		47.4	51.4	16.7	3.29

TABLE 2

SAMPLING OF AERATED LIQUID SWINE MANURE, JUNE 1976, METHOD 1.3 IS USED. Values in g/l

Sequence	Corresponding volume in m^3	COD	Dry Matter	Ash	N Kjeldahl
1	20	65.3	77.9	24.5	5.56
2	19	65.9	78.2	24.7	6.03
3	19	67.2	76.9	24.4	4.88
4	24	67.1	79.6	25.1	5.56
5	19	72.0	76.3	23.6	5.86
Average	101	67.5	77.9	24.5	5.58*

* Of which 51% is ammonia N.

The shape and dimensions of the basin and the applied power of the aerator determine the degree of mixing of an aerated storage basin. Here, the basin has a square shape, the bottom dimensions are 14m x 14m and the dike has a slope of 1 : 1. The applied power is about $9W/m^3$ liquid swine manure.

From Tables 1 and 2 it follows that the degree of mixing is considerable. It is very likely, however, that there is a settled layer on the bottom of the basin.

2. SAMPLING OF LIQUID SWINE MANURE

There are two distinct methods to sample the manure:

- in the storage pit: methods 2.1 - 2.3.
- when the manure is removed: method 2.4.

2.1.

The sampling can be done with the equipment described in 1.2. (Figure 2). Depending on the liquid depth, two or more samples are taken from one vertical column. This has to be repeated at a number of places.

2.2.

Tunney and Molloy (1975) sampled with a hollow pipe. The pipe is inserted into the manure to the desired depth and then, by pulling a rope, the bottom of the pipe is closed with a ball.

2.3.

Dorscheidt of the Manurebank of Limburg, Holland, developed a sampling device consisting of two tubes fitting together (Figure 2). The inside tube is divided into several compartments, the outside tube cuts off the "windows" in the inside tube.

2.4.

When the storage pit is emptied for landspreading, each vacuum tanker can be sampled as described in 1.3. The sampling must take place immediately after filling otherwise there may be settling in the tanker.

If one is interested in the "theoretical composition" of manure, the urine and faeces have to be collected separately in a metabolic crate. For a calculated theoretical composition of liquid swine manure, the reader is referred to the CEC Seminar on Odour Characterisation and Odour Control (1976).

The composition of manure of the farm is influenced by, among others, the amount of cleaning water, spilt drinking water, anaerobic degradation and N volatilisation.

When the storage pit has been fully emptied previously, one of the methods 2.1 to 2.4 can be applied for sampling. Using 2.4, the pit has to be completely emptied because of the settled layer, otherwise no representative sample can be obtained.

If these precautions are not taken (starting with an empty pit and in case of method 2.4 emptying completely) the sample taken is not representative for liquid swine manure. The reason is that when the storage pit has not previously been completely emptied, a part of the settled layer is from a previous fattening period.

It would be possible to mix the contents of a storage pit (eg by pumping to and fro with a vacuum tanker) and then one could take a number of samples. In practice this is not allowed because of the risk of the liberation of poisonous gases such as H_2S and NH_3.

At a farm in Drunen, Holland, two storage pits beneath the partly slatted floor were sampled, using method 2.1. On the same day the pits were completely emptied and each tanker was sampled. The previous time the pits had also been completely emptied. The pig sty consisted of three rows of 9 boxes each for pigs. Table 3 relates to the first row of pigs, Table 4 to the common storage pit of the second and third row. The fattening pigs were fed and watered normally. Usually the pig sty was not cleaned with water.

Table 3 relates to liquid swine manure. The manure in Table 4 has been diluted with discharged water from airwashers.

Table 3 shows that it is possible to take a representative sample with both applied methods (2.1 and 2.4). The manure has a high dry matter content and a corresponding high nitrogen content.

Table 4 shows clearly that the dry matter content of the manure in the succeeding tankers increases, whereas the nitrogen content remains constant.

TABLE 3

SAMPLING OF LIQUID SWINE MANURE, APRIL 1976.METHODS 2.1 AND 2.4 ARE USED. Values in g/l

Description	COD	Dry matter	Ash	N Kjel-dahl	COD/DM	COD/N
Box 2, surface	147.9	127.4	40.4	9.80	1.16	15.1
Box 2, bottom	141.4	134.6	42.5	9.93	1.05	14.2
Box 4, surface	128.3	124.6	39.3	9.59	1.03	13.4
Box 4, bottom	163.3	129.5	41.3	8.55	1.26	19.1
Box 6, surface	85.5	81.5	28.8	7.20	1.05	11.9
Box 6, bottom	151.8	163.0	52.6	9.79	0.93	15.5
Pump pit, surface	35.4	32.5	15.4	6.00	1.09	5.9
Pump pit,middle	121.3	128.9	41.7	9.55	0.94	12.7
Pump pit, bottom	137.1	115.5	37.8	9.33	1.19	14.7
Average, pump pit values counted for 0.67	126.8	118.2	38.5	8.93	1.07	14.2
Tanker 1 - 4 m^3	106.4	101.1	32.8	9.12*	1.05	11.7
Tanker 2 - 2 m^3	140.6	134.9	43.5	9.12**	1.04	15.4
Average tankers	117.8	112.4	36.4	9.12	1.05	12.9

Surface means near the surface of the liquid manure,
Bottom means near the bottom.

* of which 67% ammonia-N. ** of which 70% ammonia-N.

TABLE 4

SAMPLING OF LIQUID SWINE MANURE DILUTED WITH DISCHARGED WATER, APRIL 1976. METHOD 2.4 IS USED. Values in g/l

Description	COD	Dry matter	Ash	N Kjel-dahl	COD/DM	COD/N
Tanker 1	34.4	30.6	10.7	6.29	1.12	5.5
Tanker 2	65.2	61.7	18.8	5.86	1.06	11.1
Tanker 3	99.1	94.0	28.8	6.29	1.05	15.8
Tanker 4	132.2	115.8	35.1	6.77	1.14	19.5
Average	82.7	75.5	23.4	6.30	1.10	13.1

Each tanker contains 4 m^3 manure.

CONCLUSIONS

1. A simple and reliable method to sample a storage pit consists of sampling each tanker, when the manure is removed. All samples can be combined to one sample.

2. To obtain information about representative liquid swine manure the storage pit has to be emptied completely. and the pit will be required to have been emptied completely on the previous occasion as well.

3. The dilution of liquid swine manure with cleaning water and spilt drinking water must be taken into account.

4. Using method 1.2 the reliability of sampling increases when the number of samples in one column and the number of sampling places increases.

5. The composition of the manure in the pump pit is not representative for the total storage area.

4. SUMMARY

Sampling techniques for liquid swine manure in aerated storage basins and storage pits beneath the pig sty are described. A simple and reliable method of sampling the storage pit consists of sampling each tanker, when the manure is removed.

REFERENCES

Tunney, H. and Molloy, S. 1975. Variations between farms in N,P, K, Mg and dry matter composition of cattle, pig and poultry manures. Ir. J. agric. Res. 14, 71-79.

Van der Hoek, K.W. 1976. Odour control of liquid swine manure by aeration. Proc. CEC. Seminar on Odour Characterisation and Odour Control.

METHODS OF ANALYSIS FOR MANURES
COMPARISON BETWEEN COUNTRIES OF THE EEC 2ND APPROXIMATION

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This report incorporates comments and additions suggested by the member countries after circulation of "Methods of Analysis for Manures, 1st Approximation" in May 1976. It is proposed that the following parameters should be measured and reported for animal manures used in EEC projects.

1. pH
2. Dry matter
3. Suspended solids
4. Chemical Oxygen Demand
5. Biochemical Oxygen Demand
6. Kjeldahl nitrogen
7. Ammonium nitrogen
8. Nitrate nitrogen
9. Ash
10. Calcium
11. Magnesium
12. Potassium
13. Copper
14. Phosphorus
15. Chloride

Other parameters may be measured for specialist studies. Standardisation of methods of measurement of the listed parameters is desirable to allow researchers to compare experience across the EEC. This can be approached in two ways. The first method is for every laboratory to adopt the same rigid and detailed standard. This seems the only approach for parameters which are unstable during transport or storage. For parameters which remain constant on storage, samples of manure can be exchanged between laboratories and the separate methods used can be compared. If agreement is not satisfactory, further standardisation can be recommended. The subject is therefore treated here in three sections:

1) Sampling
2) Analysis of unstable parameters
3) Analysis of constant parameters.

1. SAMPLING

1.1. In the field

Sampling to measure rate and quality of material reaching the field was only reported from a small number of stations. Yet some checks should be carried out on the uniformity of spreading Perhaps a special study should be carried out to develop a field sampling method. The following tentative methods are put forward for consideration.

1.1.1. Liquids

A minimum of four rain gauges should be used per plot.

1.1.2. Solids

A minimum of four shallow trays of 1 square metre each should be used per plot.

1.2. From the spreading tanker

Tankers without agitation or recirculation facility should not be used for experimental work. Mix the slurry for two minutes before application. Two buckets, with one hanging on each side of the outlet (Stewart, 1968) are proposed as a convenient method of sampling. Four subsamples per load should be combined and mixed to produce a 2 litre sample for the laboratory.

1.3. From storage tanks

1.3.1. Layered liquids

Special equipment which can be opened or closed underneath the liquid has been described by Netherlands, Ireland and France (Appendix 3). Four subsamples within each tank should be taken and mixed to provide a 2 litre sample for the laboratory.

Van der Hoek, Netherlands, described the use of an open tube attached to a hand pump to take samples from different depths.

1.3.2. Mixed or stirred liquids

Mixing systems are sometimes inadequate so samples should be taken at four different locations in the tank by methods described at 1.3.1. and analysed separately, at least initially as a check on the effectiveness of mixing.

1.3.3. Solids

Four subsamples taken from the heap of solids should be combined and 1 kg taken for the laboratory. The samples should represent the various layers present. A special auger sampler used in the Netherlands seems most appropriate for large compacted heaps. Looser piles could be sampled by a simple grab procedure.

1.4. Storage

Most laboratories favoured storage between 1° - 5°C. Stewart (1968) showed storage at room temperature in screw capped plastic bottles was effective for pH, P, K, soluble and Kjeldahl nitrogen.

1.5. Laboratory division of sample

Standard laboratory practice should be adequate for subsampling slurries. Farm yard manure presents special difficulties. No simple procedure was described for this. Large aliquots for individual analyses will be necessary with farm yard manure.

2. UNSTABLE PARAMETERS

It is proposed that after discussion at Modena one tentative standard method will be selected for each of the unstable parameters. One laboratory from each country will then measure each unstable parameter on four samples of fresh cattle slurry, four samples of fresh pig slurry and four samples of fresh poultry slurry by two methods, one of which would be the "tentative standard" method, and report the results to the co-ordinator. A decision could then be taken whether or not to adopt the tentative method as an official standard.

The following suggestions are made for the guidance of members at Modena Seminar in selecting a tentative standard.

2.1. pH

The sample (10 g) should be diluted 1 plus 2 with distilled water and pH measured by glass electrode.

2.2. Dry Matter

Dry 100 g of fresh material at 105°C (± 3°C) to constant weight. A forced draught oven with vapour exhaust is recommended. The depth of sample should not exceed 1 cm. Quote results as g dry matter per 100 g wet material.

2.3. Suspended solids (in liquid samples)

Stir slurry samples at high speed. Transfer 10 ml to previously dried (105°C) and weighed Whatman GFA. 12.5 cm on buchner funnel. Apply vacuum and continue until 5 minutes after all liquid has drained through. Dry filter and contents for minimum 2 hours at 105°C. Cool and weigh. Quote results as g suspended solids per 100 g wet material.

2.4. Chemical Oxygen Demand

Most laboratories followed the APHA procedure No.220 and diluted the samples where appropriate. Workers at Haren, Netherlands, use stronger reagents to avoid the errors of dilution for samples with COD values in the 25 000 - 60 000 mg/l range. The full procedure is quoted in Appendix 1. Some points of contrast are quoted below:

	APHA	Haren
Sample size	20 ml diluted	10 ml undiluted
Dichromate	10 ml X 0.25 N	25 ml X 2.0 N
Conc H_2SO_4	30 ml	45 ml
Aliquot for titration	total	25 ml out of 325 ml
Mohrs Salt	0.1 N	0.25 N

Some discussion on these points is recommended at Modena. Quote results as: mg O_2 per litre fresh material.

2.5. Biochemical Oxygen Demand

This parameter will require careful study and discussion at Modena if a common standard method is to be agreed by all.

Most reporters accepted the APHA no. 219 as a useful method where the values were low but many considered that the dilution errors were high where concentrated animal manures were being analysed. The oxygen metre or titration is used for measuring dissolved oxygen.

The alternatives suggested were as follows:

a) The Electrolytic respirometer
This is a relatively new method, many laboratories may not have experience of the technique or equipment to carry it out.

b) COD is measured at day 0 and day 5 after incubation and continuous aeration at 20°C. The difference COD_0-COD_5 = BOD_5. Details of method are attached.

c) Gilson Respirometer

d) Warburg Respirometer

e) Sapromat Method

Quote results as mg O_2 per litre fresh material.

2.6. Kjeldahl nitrogen

2.6.1. Take 10 - 20 g fresh material depending on dry matter content. Digest with 20 ml conc. H_2SO_4 160 mg K_2SO_4 40 mg $CuSO_4$ and 4 mg Se until 30 minutes after clearing. Make up to 100 ml, take 10 ml aliquot and distil from NaOH into boric acid. Titrate.

or 2.6.2. Use Zirconium instead of selenium.

or 2.6.3.

Take 250 g fresh material, add 100 ml tartaric acid (20%) dry, grind and mix. Take 1 g of this and measure Kjeldahl nitrogen. Quote results as g nitrogen per 100 g dry matter.

2.7. Ammonium Nitrogen

Extract 10 g fresh material with 0.1 N HCl. Filter and measure ammonium-N in the filtrate using ammonia electrode, (Byrne and Power, 1974). Quote results as mg per kg fresh material.

2.8. Nitrate Nitrogen

Extract 10 g of fresh material with buffer solution (0.025 m aluminium sulphate, 0.05 m boric acid, 0.05 m sulphamic acid, 0.025 m silver sulphate, pH adjusted to 3.0) filter and measure nitrate in the filtrate with specific ion electrode. (Milham et al. 1970)

3. CONSTANT PARAMETERS

These parameters are measured on the dried and ground material and their values are usually constant over weeks or months. Consequently values obtained can be compared by exchange of samples. Moreover, previous studies on plant materials have shown that a number of different methods give essentially the same results for these parameters.

Rigid standards are not proposed for these parameters. Instead twelve slurry samples (4 cattle, 4 pig, 4 poultry) will be dried ground and mixed in bulk and subsamples forwarded to the participating laboratories. Each will then measure the parameters listed by their own method and the results reported to the co-ordinator who will review them for the member countrie

The methods listed below are simply to outline the diversit of methods already in use.

3.1. Ash (Volatile Matter = Dry matter - ash)

Ignite 1 g of dried sample at 550°C to constant weight. Quote g ash per 100 g dry matter.

3.2. Cations (Ca, Mg, K, Cu)

Wet or dry ashing followed by atomic absorption. Quote g element per 100 g dry matter.

3.3. Phosphorus

Dry ashing plus dissolution in HCl or wet ashing are used. Colorimetric procedures included phospho molybdenum blue with a number of reducing reagents or vanadophosphate. Quote as g P per 100 g dry material.

3.4. Chloride

Extract 1 g of dried material with 100 ml of a solution 0.1 N nitric and 10% V/V acetic acid overnight. Filter. Titrate 10 ml of filtrate with silver nitrate solution using automatic titrimeter. Quote as g Cl per 100 g dry matter.

REFERENCES

Byrne, E. and Power, T. 1974. Determination of ammonium nitrogen in animal slurries by the ammonia electrode. Comm. in Soil Science and Plant Analyses, 5, p 51.

Milham, P.J., Awad, A.S., Paull, R.E. and Bull, J.H. 1970. Analysis of Plants, Soils and Waters for Nitrate Using an Ion Selective Electrode. Analyst 95, p 751.

Stewart, T.A. 1968. The collection of slurry samples on a field scale and their subsequent storage for chemical analyses. Record of Agricultural Res. Min. of Agric. Northern Ireland, 17, p 97.

APPENDIX 1

METHOD IN USE IN CENTRAL LABORATORY OF THE INSTITUTE FOR SOIL FERTILITY, HAREN (GR) NETHERLANDS

CHEMICAL OXYGEN DEMAND (COD)

The chemical oxygen demand determination provides a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant.

The following method gives a modified dichromate method: In a flask of 325 ml is placed 10 ml liquid manure, urine or biologically treated manure plus 10 ml water, or 20 ml effluent or 150 mg dry matter plus 20 ml water. 25 ml 2N $K_2Cr_2O_7$ in 3.6 N H_2SO_4 solution is added. Then 45 ml concentrated H_2SO_4 is carefully added with swirling of the flask. The contents of the flask are boiled for two hours under reflux. After cooling and rinsing the reflux condenser with water, more water is added. After further cooling fill up with water to exactly 325 ml, homogenise and allow settling down. Of the clear supernatant 25 ml is placed in a beaker of 100 ml; 20 ml of water is added and excess dichromate is titrated with 0.25N Mohr's salt solution using a phototitrator. 20 ml of water is used as a blank with the reagents added. The resulting COD depends strongly on the concentrations of H_2SO_4 and of $K_2Cr_2O_7$ in the reaction mixture. No more than about half of the dichromate should be used up during oxidation of the sample. The COD also depends strongly on the reaction temperature and time. No catalysts were added to oxidise completely all organic compounds. No $MgSO_4$ was added to eliminate chlorides to react with the dichromate; a correction for that should be made if desirable. If nitrite is present it will be oxidised to nitrate, thus also consuming reagent.

APPENDIX 2

A NEW METHOD OF DETERMINING BIOCHEMICAL OXYGEN DEMAND IN WASTE WATERS

G. Catroux and J.N. Morfaux
translated: K.F. Fforde

REAGENTS

Reagent A:

KH_2PO_4	28.25 g
$Na_2\ HPO_4$, 12 H_2O	149.25 g
water to make up to	1000 ml

Reagent B:

Ca Cl_2, 2 H_2O	3.66 g
NH_4Cl	28.64 g
water to make up to	1000 ml

Reagent C:

Mg SO_4, 7 H_2O	3.06 g
Fe SO_4, 7 H_2O	0.70 g
Zn SO_4, H_2O	1000 ml

Keep the reagents in the refrigerator.

INOCULATION

Use a filtrate of activated sludge from the purification plant or a filtrate of macerated soil in water (10 g soil to 100 ml water).

PROCEDURE

Put one after the other into a 250 ml calibrated flask:
- about 150 ml of the effluent to be analysed, either as it is or diluted to give a COD value in the region of 3000 mg per litre:

10 ml of reagent A, accurately measured;
5 ml of reagent B, accurately measured;
5 ml of reagent C, accurately measured;
5 ml of liquid inoculum.

Make up to 250 ml with effluent to give a mixture containing 225 ml effluent (dilute or not) and 25 ml reagents and inoculum. The precipitate formed does not disrupt the process. Homogenise and check that the pH of the mixture lies between 6.5 and 7.5 and, if necessary, correct the pH with sulphuric acid or with soda.

Determine the initial COD of this mixture (COD_O) according to the AFNOR standard or any other method giving comparable results. Pour the rest of the mixture (200 to 225 ml minimum) into a 500 ml wide-necked flask and put this to incubate for five days at 20°C (using the apparatus shown in 'Sampling techniques for liquid swine manure', Van der Hoek, Figure 1). A glass tube inserted into the mixture injects air, filtered through glass wool and saturated with water vapour (bubbled through at the rate of 250 ml per minute). The air injection tube must first be wiped carefully.

Flasks containing the effluents to be analysed are held at 20°C in a thermostatic water bath.

We use apparatus that includes an air distribution arrangement enabling 6 flasks to be aerated simultaneously.

During incubation regularity of air injection must be ensured to avoid the mixture overflowing. If deposits are produced at the end of the liquid phase they can be brought into suspension by shaking the flasks slightly.

After five days' incubation the mixture looks like a cloudy liquid, sometimes with deposits on the air injection tube. These deposits are re-incorporated into the mixture by scraping and the flask is taken out of the aeration apparatus. The mixture is then shaken vigorously to homogenise it as much as possible, scraping the sides of the flask with a stirring rod with a rubber tip.

COD is determined in this mixture after five days (COD_5) taking the greatest care to ensure that the sample used for analysis is representative of the mixture being studied.

INTERPRETATION OF RESULTS

D is the dilution factor needed to bring the effluent studied to a value of COD 300 mg/l;

COD_o is the COD of the mixture of dilute effluent/reagents/ inoculum at the beginning of incubation (analysis of the raw mixture);

COD_5 is the COD of the mixture after five days' incubation (analysed in the homogenised raw mixture).

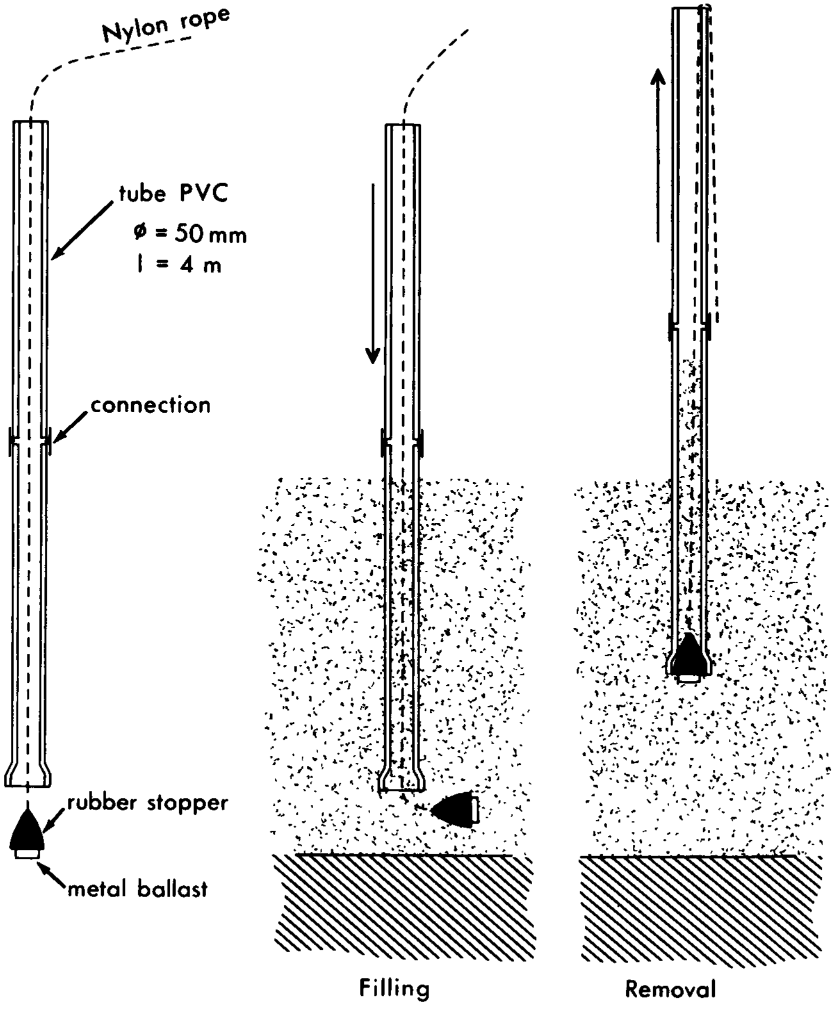
Bearing in mind the fact that the effluent is diluted by nutrients and inoculum, its BOD_5 is:

$$BOD_5 = D \times (COD_o - COD_5) \times \frac{10}{9}$$

It is unnecessary to carry out a control test on the mixture of reagents/liquid inoculum/distilled water, except in the case of effluent with a low BOD_5, since the values found for these control tests vary between 0 and 23 mg BOD_5 per litre - an error that can be ignored in most agricultural and food effluents

Sampling Devices

Probe for slurry samples at present on trial at UCAAB



DISCUSSION

H. van Dijk *(The Netherlands)*

Thank you very much Dr. Brogan. I would like to ask after each report only that question I mentioned. Is the list of parameters shown too long or incomplete? I think it is easiest to do that immediately after each report. Discussion on methods can take place afterwards when there is time left. How about the list of parameters shown on the first page of the report by Dr. Brogan? He himself has already mentioned that maybe zinc and sodium should be added. Are there any suggestions of deletions or additions?

A. Cottenie *(Belgium)*

Mr. Chairman, it seems more useful to me to add zinc. If you have to make a choice up to a limit I would prefer a determination of zinc rather than nitrates. You hardly find any nitrates in such products.

H. van Dijk

That is not quite true; normally not, but in aerated manure you can find nitrate, and aeration is being done.

A. Cottenie

I will express it another way; the nitrate content is often very low in relation to the ammonium content.

H. van Dijk

Again, that depends on the method of aeration. You can carry out an aeration leading to a high nitrate content and an almost complete absence of ammonium. So it is not a determination which should be done in every sample. However, in particular samples the determination of nitrate is important so in my opinion it should not be cancelled from the list. In certain cases it is important to determine.

A. Cottenie

May we add zinc?

H. van Dijk

Yes, I think after the discussions we have already had zinc is No. 16 or maybe No. 13a. The order is not important at the moment although it may become necessary to put an order of priority on the parameters in due course, but I think it is better to leave that to the experts. How about sodium?

A. Dam Kofoed *(Denmark)*

Could we consider the elements alone? I think, in this audience, we should agree to express the real contents as elements, for example, as % potassium and % phosphorus, and not to give the results as % K_2O and % P_2O_5. I am sure this would be a very valuable progress for all of us.

H. van Dijk

This point has been raised several times during this Seminar and I hope it has been duly noted. It is rather self-evident; nevertheless you do sometimes find reports where potassium is mentioned when what is meant is K_2O, and so on. May I ask then that you also turn your attention to the use of the correct terminology. I think you have all received the terminology recommendations of the ASAE from the Proceedings 1971, Livestock Waste Management and Pollution Abatement, Uniform Terminology for Rural Waste Management. As far as I understand everyone has had it.

J.H. Voorburg *(The Netherlands)*

I am not sure whether it has been distributed to all the participants at the moment.

H. van Dijk

Well, it is in the Proceedings of the ASAE Symposium of 1971 - Recommendations of Uniform Terminology for Rural Waste Management. I remember two papers where 'slurry' was mentioned as a mixture of urine and faeces, and 'liquid manure' as urine, but in this terminology the two terms, 'slurry' and 'liquid manure', are more or less synonymous. So that is one form of language pollution we should avoid.

J. Lindhard *(Denmark)*

Regarding urine, wouldn't it be satisfactory to use this term for the liquid taken directly without contact with the floor of the stable? I think this is how we have used it in Denmark.

H. Van Dijk

Indeed, but I just wanted to draw your attention to the question of terminology. I would like now to have some more remarks on the list of parameters. We have added zinc. Should we also add sodium?

L.C.N. de la Lande Cremer *(The Netherlands)*

With the range of elements on the list plus sodium and sulphur you can calculate the effect of manure on the pH of the soil, whether it is a neutral, an alkaline or an acidifying manure.

H. Van Dijk

If that is the only purpose for adding sulphur I would not make it obligatory for every analysis. I have never checked it but do you think the amount of sulphur seriously influences the effect of manure on pH?

L.C.N. de la Lande Cremer

Yes.

J.H.A.M. Steenvoorden *(The Netherlands)*

There was a paper this week devoted to the electrical conductivity in manure on the conductivity in the soil so I am missing electrical conductivity. A second remark: I think phosphorus should be total phosphorus first of all and perhaps secondarily, the soluble part of phosphorus.

F.A.M. de Haan *(The Netherlands)*

I wonder why a distinction is made regarding nitrogen between Kjeldahl, ammonium and nitrate, and not regarding phosphorus, as was suggested here, between ortho, total and organic. The same applies to copper and zinc. I don't know how far you want to bring the discussion at this point on to the refinement of the list of parameters but is there a reason for making much more distinction for nitrogen than for the other elements?

H. van Dijk

Well, the main reason is that the methods are available for nitrogen, are they for copper?

F.A.M. de Haan

Oh yes, sure - well, just using ion specific electrodes.

R. Kickuth *(West Germany)*

From this point of view I can't agree in regarding phosphorus as a stable parameter. If you make an attempt to get fractions of phosphorus, for example, soluble phosphorus, condensed phosphorus, and it is as important as the fluctuating of nitrogen in understanding the processes in soil and water, then phosphorus cannot be a stable parameter because there is a very rapid turnover between the fractions.

H. van Dijk

I think it might well wait until we know more about the effects of the different fractions.

G. Chisci *(Italy)*

I would like to ask whether the determination of iron has been considered. Recently it has been pointed out by some workers that iron may exert a very important role on aggregate stability in soil. I think this parameter may be worth consideration.

A. Cottenie

Mr. Chairman, I would like to recall the intention of the meeting in Brussels. It was rather to reduce the number of determinations, not to increase it. The intention was, and still is I think, to have characterisation of the product - not for real fundamental research but in order to characterise it and to know what the farmer is putting on the soil. It was stated explicitly that in research projects people can add any determination they like in their own laboratory. What we aimed here was just to list the minimum parameters necessary in order to have some idea of the real characteristics of the product. So I would not be in favour of adding more determinations and making more discriminations between phosphorus forms and so on - that is in the field of the fundamental research worker.

R.G. Gerritse *(The Netherlands)*

I agree entirely with the last speaker. On the basis of my research in phosphorus, the phosphorus fractions in a certain slurry, at a certain age, are fairly constant, so the phosphorus as mentioned here is entirely sufficient to get a rough estimate of the various phosphorus fractions. I would like to suggest determining the silt fraction, the particle diameters smaller than one micrometer; also perhaps the viscosity of the slurry, because these factors will affect the permeability of the soil for the slurry.

H. van Dijk

So what you give with one hand, you withdraw with the other!

R.G. Gerritse

Yes, but I only added physical parameters.

H. van Dijk

I think it is the same situation as with phosphorus. For specific research aims, when you want to study the infiltration rate and the transport of the material into the profile, you need physical characterisation of the material you are using, you need to know something about particle size and particle size variation but it is not normally required when you are using manure in practice. It should be done, of course, for research purposes but I do not think it should be on the list of first priorities.

G.J. Kolenbrander *(The Netherlands)*

I agree with Dr. Cottenie. Nitrate nitrogen determination has no sense in slurry because you can have, perhaps, an oxidation of ammonia but the ammonium concentration is so high that it takes a long time before you have a high amount of nitrate. In special laboratory experiments it can be necessary. In that case however, the Kjeldahl procedure does not give total nitrogen because Kjeldahl will yield only 70 to 80% of the nitrate. So in a balance study I can't accept Kjeldahl nitrogen but if you use it only to estimate the total nitrogen then it is acceptable, but you can exclude nitrate nitrogen.

G. Catroux *(France)*

May I ask if BOD_5 is very useful for a research programme?

H. van Dijk

Are you suggesting to cancel it or take BOD_{25}?

G. Catroux

BOD_5 is very useful to make a treatment plant, to make tests for pollutants, but for a research programme I don't know, if you have COD. I don't know - I am asking.

H. van Dijk

I think when you are studying the effect of landspreading, not only on crops but also on environment, on water, then you need a parameter for this and one of the parameters is BOD. It is one which is particularly asked for by the authorities. Maybe we might say it is not so important but the authorities ask for it.

J.C. Brogan *(Ireland)*

I don't think the situation is satisfactory but I think it would be a mistake to eliminate it altogether at this stage.

I think we need to improve and develop it but I think it would be quite wrong just to ignore it because it is not convenient to handle.

S. Baines *(UK)*

The question of BOD_5 is certainly important to the river authorities but why not restrict it to measuring waste water that reaches the water course - the drainage water - rather than measure it very inaccurately on the raw material before the application to land? It is only important as it reaches the water and in that sense it figures in the analysis of waters and effluents to water, not on the fresh material.

J.H. Voorburg

In the Dutch legislation on water pollution we have left out BOD, we only speak about COD. This is also the case in other countries. We can leave it out because it is a very complicated and difficult determination. So maybe we can restrict to COD.

H. van Dijk

Well, I think almost everywhere it is on the list of first priority parameters.

A. Cottenie

Why?

H. van Dijk

Well, it is still there so ...

A. Cottenie

Yes, but because they ignore any other thing. This is made by people in their offices, not in laboratories.

H. van Dijk

Yes, well, I think proving their ignorance via a list of parameters of manure is not the best way ....

<u>F. Bonciarelli</u> *(Italy)*

I think it is a nonsense that the Italian law establishes the same standard for effluents to water and effluents on soil. BOD is important in the aquatic ecosystem where oxygen, because of its lower solubility in water, is the limiting factor for biological growth. On the soil oxygen is not a limiting factor so I think it is stupid to fix such low limits in BOD of effluents to be spread on land areas.

<u>H. van Dijk</u>

It is only very near the surface where you have sufficient oxygen. You can have situations when for rather a long time, when you are giving a high amount of slurry, you have anaerobic conditions in the soil ...

<u>F. Bonciarelli</u>

On the soil surface ...

<u>H. van Dijk</u>

Not on the soil surface but in the soil ...

<u>F. Bonciarelli</u>

There is 20% of oxygen in the atmosphere ...

<u>H. van Dijk</u>

Yes, but in the soil ...

I think we should conclude this discussion on the list. It is somewhat difficult; I am happy that the discussions are on the tape so that the experts can read afterwards what was discussed here. However, it is up to us to decide what is the first priority for research. I have the impression that zinc should be added. I have heard no more votes in favour of sodium but I think zinc should be added in view of the discussion we have already had. Maybe electrical conductivity would also be quite easy. I would stop it there for the first priority parameters.

A. Cottenie

I don't think electrical conductivity has any meaning for a product like this one. It has a meaning for soils being treated but not for manure. Electrical conductivity will always be high and you will always be in a medium which is filled up with all kinds of soluble salts increasing the conductivity. The electrical conductivity for soils is an indication that you will need further analysis eventually but here you need it anyway.

H. van Dijk

Yes, I agree.

F. Bonciarelli

I think sodium is very important, particularly in a clay soil sodium is a fundamental element to foresee the possibility of worsening the physical structure of the soil by the spreading of slurries. Water for irrigation is judged on the basis of sodium absorption ratio, the ratio between sodium and calcium plus magnesium. I think sodium must be determined in slurries. I am very sensitive to this fact because I work on clay soil with a lot of difficulties regarding physical structure.

H. van Dijk

I think it is not an established fact that slurry has a kind of peptising action on a clay soil as you think may be possible. I think it is a matter of research to establish if this is so. I am not aware of a paper on investigations into this subject. I am not sure that slurry is detrimental to the structure of a clay soil because you are not only adding a sodium solution (and there you should also take into account ammonium) but you are also adding divalent cations. I don't know whether the result is deterioration of structure; I think this should be a matter of research first. When it is established as a first priority parameter then it could be included on the list.

G.J. Kolenbrander

I would suggest taking out No.8 nitrate nitrogen, because it doesn't provide important information, and to replace it by the element sulphur. Sulphur provides the means of calculating something about the effect on soil pH and as you have excluded sulphate it is not possible to calculate such things. So I believe the list will be much more valuable if the nitrate is replaced by sulphur.

H. van Dijk

Well, there are more people in favour of adding sulphur because of an estimation of the effect on pH after application of manure. So I think sulphur can be added; zinc will be added. With regard to nitrate, normally you don't need it, only in very special cases when you have highly aerated materials. In that case when you want to know the nitrogen fertiliser value you have to determine nitrate. Nitrate is not a problem; I don't think it will be so controversial to have it. For the time being I would leave it on the list. So, in talking of first priorities, we will add sulphur and zinc. Is that agreed? There are a lot of things which could be second priorities.

J.H. Voorburg

Nitrate could be marked as 'only in aerated manures'.

H. van Dijk

Yes, well I expect that will be picked up by the analytical experts from what is said here.

J.H. Voorburg

What about BOD - is it to be dropped?

H. van Dijk

That is not yet decided.

J.H. Voorburg

I propose to drop it.

H. van Dijk

Although it is still required in legislation to give the BOD?

A. Cottenie

I support Dr. Voorburg. It is in the legislation for effluents, not for such products.

H. van Dijk

Well, I am in favour of it since the 'normal' determination is very inaccurate.

J. Lindhard

What about the suspended solids - is it also for effluents from cities? Is there any big difference between the dry matter and the suspended solids? I understand it has to be dry. Perhaps we could take it off. I would like some information, what is meant by suspended solids?

H. van Dijk

Well, it is in the paper; it is also in the uniform terminology ... oh no, there it is called 'settleable solids' - 'those suspended solids contained in sewage or waste water that will separate by settling when the carrier liquid is held in a quiescent condition for a specified time interval'. When you know what the amount of settleable solids is you have an idea of how quickly you get a de-mixing in your tank.

So, can we cancel BOD, is that agreed?

J.R. O'Callaghan *(UK)*

May I just make a general comment. I am very concerned that we should formulate a minimum set of recommendations to characterise a slurry. As I understand it every experiment would have to carry out these determinations. Therefore I would hope that we can keep the list very small indeed as a minimum set of standards. I think we are tending to make a list of measurements which would make it possible to specify the slurry completely and reproduce it in another experiment; I think that is impractical at this level. So I am very concerned that we may be asking people to carry out too many determinations in every experiment. I would hope that BOD would be absolutely excluded at this minimum level; I hope some other things as well because I think it is much too large a list.

H. van Dijk

One of the aims of this list is that when someone has a research project on landspreading of manure he will give data which although they may not be of vital importance for his specific aims will provide important additional information for his colleagues, so that it is a reasonable characterisation of the slurry.

J.R. O'Callaghan

Yes, but I think it will have to depend on the level of the experimentation and the quantity of material that is being applied, and so on. It is impossible to have just a blanket approach from the precise laboratory experiments to the field experiments. I thought what we were looking for here was the smallest number of things to give a broad characterisation and then to have finer details at other levels.

A. Cottenie

I think this would be possible by sub-dividing the list into first priority and second priority.

C. Tietjen *(West Germany)*

Instead of first and second priority I would suggest '1a' and '1b' - then it is clear.

G.J. Kolenbrander

I suppose there will be a high correlation between COD and BOD if you have the same type of organic matter - I am thinking about slurry - that will not be so different. I generally assume, as I have no information on BOD, that 25% of the COD will be BOD.

H. van Dijk

Yes, well, BOD is already cancelled; nitrate nitrogen - only in special cases; zinc and sulphate is added.

J.H. Voorburg

I propose zinc and copper only if relevant, for example in pig manure.

H. van Dijk

Agreed.

R.G. Gerritse

I would like to make a remark on the question of sulphur and the pH. What is meant, I think, is sulphide not sulphur, because sulphur in manure consists of organic sulphur and sulphide. The effect of sulphide on the pH is understandable but of the other sulphur is not. Also in slurry you have a large amount of carbonate which has an even greater effect on the pH.

H. van Dijk

I am still not sure that the resulting effect of sulphur on pH is very large.

L.C.N. de la Lande Cremer

It is a contribution.

H. van Dijk

Yes, but is it an important contribution? Is the contribution a matter of some percentage of the total? It is a separate determination for sulphur. You can add a list of metals when you are using some modern techniques, it takes hardly any more time, but sulphur is a completely separate determination.

L.C.N. de la Lande Cremer

May I propose to make two lists, one for fertilisation proposals and one for engineering proposals. In the engineering proposals you have to use COD, BOD and so on, and physical properties of slurry. These are not necessary for fertilising ones.

H. van Dijk

Yes, well I would suggest that just as with nitrate nitrogen, we give this a special mark so that the sulphate content should only be given when the pH effect of application of manure is the subject of research.

R.G. Gerritse

Sulphide! In my opinion sulphate and organic sulphur don't influence the pH. It is an unstable parameter.

H. van Dijk

Indeed? I am not quite sure that when you use your manure gun and manure is on the soil you have much sulphide left.

R.G. Gerritse

Well then it is not relevant to determine sulphur.

H. Tunney *(Ireland)*

I would suggest that sulphur can be justified on its fertiliser value, perhaps much more so than on its effect on pH. In some situations where sulphur deficiency may be a problem sulphur is present at about the same level as phosphorus in manure.

H. van Dijk

I am aware of sulphur deficiency reports from Australia but not from western Europe.

H. Tunney

Yes, in western Europe also, perhaps not in industrialised areas but in Ireland response to sulphur is being obtained with concentrated fertilisers with very little sulphur in them.

A. Cottenie

Mr. Chairman, the discussion on sulphur shows already that it is a question of specialists and not a first priority.

H. van Dijk

Yes, and also that the significance of sulphur is somewhat controversial. I wouldn't put sulphur on the list of first priorities. That doesn't mean that it is prohibitive but it just means that we are not asking the group of analysts to start with making harmonisation for sulphur determination. That can wait until later. We are just providing this list requiring immediate harmonised methods.

So, is it agreed? The number is the same because 5 (BOD) is cancelled and zinc is added. Zinc and copper will be marked 'only in pig manure' but that is not an important mark for the analysts because they have to give the method anyway. The same goes for nitrate.

J.C. Brogan

If we want to drop something I would suggest maybe chloride. I think just one laboratory may have asked specially for chloride and I put it in at the end but ...

H. van Dijk

I am in favour of that. Anybody against? .... Chloride is cancelled. It can be brought up again when the analysts have completed their work on the first list.

J.H.A.M. Steenvoorden

Talking about priority, I think if you drop sodium you should also make calcium and magnesium second priorities.

H. van Dijk

Sodium is not dropped but it is not added - it wasn't on the list in the first place.

J.H.A.M. Steenvoorden

I know, but it was first added then dropped again.

H. van Dijk

Calcium, magnesium and potassium are certainly on the list because with manure you add substantial amounts of these nutrients. That is not the case for sodium.

H. Tunney

We could drop calcium because it is not important from a nutritional point of view, in most soils. Magnesium could be retained as a first priority but not calcium.

H. van Dijk

It makes very little difference to the analyst to determine calcium and magnesium as well as potassium because all three can be done by atomic absorption.

F. Bonciarelli

I do not agree with cancelling chloride. For salinity risks chlorides are the most important components so it would be interesting to know the chloride content. I agree with Dr. Tunney that calcium and magnesium could be put on a secondary list together with sodium, but I would like to see chloride included in the list of determinations for evaluating salinity risks. There are a lot of chlorides in slurry.

H. van Dijk

Are you suggesting, let me say for Italy, that you have such a high evapotranspiration that you are running a severe risk of saline soils? In that case it may be important. I don't think it will present problems to the analyst group to add the chloride determination. So chloride is again on the list.

We will have a short break and then Dr. de Borger will address us.

PROPOSITIONS FOR THE METHODS OF WATER ANALYSIS

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PROPOSED METHODS

1. Sampling

The methods of sampling must be discussed at Modena.

It appears that certain factors must be taken into consideration:

- type of bottles used
- frequency of sampling
- technique used for sampling
- conservation technique: t^0 , chemical reagents.

Concerning the type of bottles for instance:
(EEC - potable water - directive 75/440)

- glass bottles : matter in suspension, phosphates, COD, BOD, NH_3 Kjeldahl, copper, zinc.
- glass or plastic bottles: pH, nitrates, conductivity

At present the following propositions are made:

Dk: for each case special sampling method.
Preservation with mercuric-chloride - 4^oC

Ge: glass or plastic bottles - rinsed several times with the water that is to be investigated.

- groundwaters: without disturbing muddy substances
- wells (newly bored or not used) : slow pumping for 20 minutes prior to taking samples.
- lakes, brooks, ditches: at surface or in depth, mixing several samples.
- waste waters: continuous sampling or every 4 - 6 hours
- sewage purification waters: the same water at different stages of the treatment
- muddy waters: sedimentable matter must be included as exactly as possible.

Preservation between 0 and 5°C

If the quantity of undissolved mineral and organic matter needs to be determined, even as dissolved portions, determination must be undertaken separately and special samples must be filtrated immediately.

LIST OF RETAINED PARAMETERS

2. Analysis

2.1. Diverse

pH, conductivity, matter in suspension, sedimentable matter, dry residue at 110°C, dry residue at 550°C

2.2. Nitrogen compounds

Total N, ammoniacal N, mineral N

2.3. Organic compounds

COD, BOD, organic PO_4^{3-}

2.4. Anions

PO_4^{3-} total and ortho

2.5. Cations

K+

2.6. Traces

Cu, Zn.

2.1. Diverse

pH.

Measuring with pH meter, if possible at the moment of sampling (otherwise stipulate).

Conductivity

Conductivity meter at known temperature. The result must be calculated at a 20°C base.

Matter in suspension

Filtration on glass fibre discs, 5.5 cm Whatman G F/C or equivalent (APHA 224C p.537).

For high amounts: centrifugation at 2800 to 3200 g during 15 minutes and decantation (EEC directive 75/440).

In both cases drying at 105°C ± 3.

Sedimentable matter

Sedimentation of 1 litre water in an Imhoff cone. Measuring after 1 and 2 hours. Expressed in ml/l (APHA 224 F p 539)

Dry residue at 110°C

Evaporation on water bath - at least 100 ml, drying at 105°C ± 3 to constant weight.

Residue at 550°C

The dry residue obtained at 110°C is calcinated in an electric furnace at 550°C to constant weight.

2.2 Nitrogen compounds

The EEC Report following the meeting in Brussels of 2nd March, 1976, provides that the sample of water must be analysed without filtration but a sedimentation of one night is necessary and the supernatant should be used for analysis. However, we think that better results may be obtained by operating on the water containing suspended matter using a thoroughly mixed sample. A second analysis can be done on the supernatant water after decantation.

General total N: $\sum$ organic N, mineral N

- Treatment with dilute H_2SO_4 and Na_2SO_3. Mineralisation with H_2SO_4 + $CuSO_4$ and/or Se reaction mixture. Distillation and titration of NH_3
- $\sum$ total Kjeldahl N, NO_3^-, NO_2^-.

Total Kjeldahl N: $\sum$ organic N + NH_3

- For the conservation of the sample, addition of H_2SO_4 up to pH 1.5 - 2
- In principle, the volume of the analysed water depends on the amount of total Kjeldahl N present:

  less than 0.2 mg N/l : 1000 ml
  from 0.2 to 0.5 mg N/l : 500 ml
  more than 0.5 mg N/l : less than 500 ml
- Addition of 10 ml H_2SO_4 and 6 g reaction mixture (100 g K_2SO_4 + 20 g $CuSO_4$ .5 H_2O)

Evaporation until white fumes appear.

- After subsequent mineralisation add distilled water to bring the volume to 300 ml, and 35 ml NaOH (500 g/l).
- Collect 100 ml distillate in H_2SO_4 solution (see NH_3 determination) and titrate or determine spectrophotometrically (NBN - project)

$\underline{NH_3}$

- For the conservation of the sample, addition of H_2SO_4 up to pH 1.5 - 2.
- Distillation method:

When $S^=$ are present, boiling of the sample for 1 minute; when Cl_2 is present treat the sample by $Na_2S_2O_3$ solution.

- Volume of the sample: see above Total Kjeldahl N, but: N expressed as $N\text{-}NH_3$ and if more than 0.5 mg $N\text{-}NH_3 \rightarrow$ aliquot and dilute to 500 ml

Adding of NaOH 0.5 N (or H_2SO_4 0.5 N) up to pH 7.
Distillation (6-10 ml/min) and collection of 100 ml distillate in:
50 ml H_2SO_4 0.02 N for titrimetry
50 ml H_2SO_4 0.5 N for spectrophotometry
Titration with NaOH 0.02 N or spectrophotometry (indophenol blue) at 630 nm (NBN T 91/252)

- Direct spectrophotometry : (indophenol blue)

Applied for low NH_3 amounts if the water is not too coloured.

Total mineral N : $\sum NH_3, NO_3^-, NO_2^-$

$NO_3^- + NO_2^-$:
Reduction of NO_3^- to NO_2^- by Cd-amalgam
Adding HCl up to pH 1.5 - 2, sulfanilamide and N-(1 naphthyl)-ethylene diamine
Spectrophotometry at 545 nm. (APHA 213 B p 458).

$\underline{NO_3^-}$:
Direct photometric determination at 410 nm, after addition of brucine/H_2SO_4. (APHA 213 C p. 461)

$\underline{NO_2^-}$:
Direct photometric determination at 545 nm after addition of sulfanilamide and N-(1 naphthyl)-ethylene diamine (APHA 213 B p 458)

2.3. Organic compounds

COD :

Conservation of sample by addition of 0.2% H_2SO_4.
Oxidation of 20 ml water with $H_2SO_4/K_2Cr_2O_7$. Refluxing 2 hours.
Titration with MOHR salt (APHA 220 p 495)

BOD :

Operating with several dilutions and with a blank. Incubation during 5 days at $20^oC \pm 1^oC$
- noted depression in the bottles which is a measure of the O_2 consumption gives, by calculation, the amount of putrescible organic matter (HACH Chemical Co., Ames, Iowa)
- or : titration of dissolved O_2)APHA 219 p 489).

PO_4^{3-} organic :

Difference between total PO_4^{3-} and total mineral PO_4^{3-}

2.4. Anions

PO_4^{3-} : (priority EEC : total and ortho)

The total mineral PO_4^{3-} includes in fact the ortho phosphate and the meta and polyphosphates.

Total PO_4^{3-} :

Boiling the sample with H_2SO_4 and $K_2S_2O_8$; (APHA 223 C p 524)

Ortho PO_4^{3-} :

Directly on the sample without any treatment; (APHA 223 F p 532)

Total mineral PO_4^{3-} :

Boiling with H_2SO_4 only. (APHA 223 B p 523)

Determination :

For amounts below 2 mg P/l : reduction method

In acid conditions, NH_4 molybdate - K antimonyl tartrate, reduction with ascorbic acid.
Blue complex. Spectrophotometry at 700 nm (APHA 223 F p 532).

For amounts higher than 2 mg P/l : without reduction:

Strongly acid conditions. Addition of NH_4 metavanadate and NH_4 molybdate.
Yellow complex. Spectrophotometry at 430 nm (APHA 223 D p 527).

2.5. Cations

K+ :
Direct flame spectrophotometry

2.6. Traces

Cu :
AA (flame or oven); on the HCl extract of the ash if large amounts organic matter are present.

Zn :
AA (flame); on HCl extract...(id. Cu)

2.7. Microbial Analysis

Propositions see Drs. Kelly and Strauch.

DISCUSSION

H. van Dijk *(The Netherlands)*

Right, we have this list of retained parameters; do you think this is the list on which we should ask the analysts to give us harmonised methods as a first priority? Should anything be added, should anything be deleted?

J.H.A.M. Steenvoorden *(The Netherlands)*

I think before we go into details we should first agree, as with manure, whether it is meant for a rough characterisation of waters or must we add everything. Do we need to distinguish between first and second priorities? Otherwise we will have the same difficulties that we had in the first session. What is the purpose of proposing these analyses?

H. van Dijk

This is a list of what was considered first priority requirements covering partly the data which are being asked for by authorities and covering partly the data which are important for the investigators.

J.H.A.M. Steenvoorden

I get the impression that it is more a collection of the data the different people are looking at than a list of priorities. It is a list of priorities for every researcher in his own small field but not important for every country and every situation. I think we should draw attention to nitrogen, for example, especially nitrate, because it leaches very fast.

H. van Dijk

Nitrate and nitrite are both included.

J.H.A.M. Steenvoorden

Yes, but copper and zinc are not so very mobile; perhaps we should have them in soil sampling but in water sampling, for example, ground water and drainage water, I think copper and zinc are unimportant. So, I can't see that this is a list of priorities.

<u>H. van Dijk</u>

Well, copper and zinc are at the bottom of the list and I think that is what you are asking for. Or do you want them cancelled from the list?

<u>J.H.A.M. Steenvoorden</u>

I would like first to hear a general remark from one of the people involved in setting up this list on what was the intention of it and whether there is any sort of priority in it.

<u>A. Cottenie</u> *(Belgium)*

I can briefly summarise the meaning of the list. It was asked which parameters need to be determined in order to observe eventual pollution of soil water used with animal waste disposal on soils. Which are the elements to determine in order to be able to say whether or not there is pollution of surface water?

<u>L.C.N. de la Lande Cremer</u> *(The Netherlands)*

May I ask what is the importance of potassium in water analysis? It is not a pollutant.

<u>A. Cottenie</u>

I am afraid to touch this point; we have already discussed it at a meeting. Some four or five months ago the EEC published a recommendation stating the characteristics of surface water which is destined to be prepared as drinking water. All the quality factors are listed quantitatively, and we could eventually use that as a reference. Now we have to see in the list stated by the EEC which elements are the ones that will be brought into the surface water after the land treatment of animal manure. Potassium is certainly one of these.

<u>H. van Dijk</u>

I think that is a very good suggestion; it also makes the task for the group of analysts much easier because many of these methods are available.

<u>A. Dam Kofoed</u> *(Denmark)*

I agree with De la Lande Cremer about potassium, it has nothing to do with pollution. However, from Dr. Cottenie I understand we could now follow the EEC recommendation to some extent but if copper is put in here now why not put in cadmium which, in my opinion, is more important as a pollutant than copper. In Denmark, under our conditions, 2 g/ha is leached to the drainpipe. On the other hand, it is not very much. When you speak about the authorities having an interest in this matter, they are interested in cadmium, therefore why not either put in cadmium or leave out copper?

<u>H. van Dijk</u>

I think this question is very easily answered. We closed the discussion on manure without including cadmium so we don't need to include cadmium in water coming from where animal manure is disposed of. Maybe you are making a point but it is for the next session.

<u>F.A.M. de Haan</u> *(The Netherlands)*

I think cadmium is more important than zinc but anyway there is this close relationship between cadmium and zinc which always occurs in the ratio of 1 : 100 or something like that. That would mean that as soon as you determine zinc you have some idea of the level of cadmium - it is almost automatic. So it would be included in the zinc determination.

<u>H. van Dijk</u>

As soon as we have indications that the application of manure gives a selective solubilisation of cadmium and a leaching to the sub-soil then it is another matter, but I have never heard of that.

<u>A. Dam Kofoed</u>

I just mentioned it because it does present certain problems in our country.

H. van Dijk

Yes, but we are not discussing whether or not cadmium is important in general but whether cadmium should be on the list because of its being added in the form of animal manure. It may be on the EEC list for water in general but I know of no reason for extra concern for cadmium after adding animal manure.

R. de Borger *(Belgium)*

I have the EEC list - can we go through it?

H. van Dijk

I don't think it is necessary now. Do you think this list is adequate as far as the effect of manuring on water quality through land is concerned? We are not talking about throwing manure into water.

J.H.A.M. Steenvoorden

I don't know what potassium has to do with water quality demand. I don't know why it has a higher priority than chloride because chloride affects the taste of water and it is in the manure in a very large quantity. It is not bound on the soil, it is just leaching, so I think it is a better parameter than potassium.

H. van Dijk

Is chloride on the list? Well, it is not difficult to add it. Chloride is added; the method is no problem.

A.V. Dodd *(Ireland)*

I would just like to make a comment regarding this aspect. It seems to me that when one is considering parameters for manures one is really concerned with an activity related to agriculture only and the rest of society is not particularly concerned how much a crop grows, although they may be interested in the quality of the crop. However, when we are dealing with the soil water we are dealing with the rest of society, the non-agricultural sector. If I remember rightly the list that was drawn up here was drawn up before the EEC directive to which

Dr. Cottenie referred. I think it would be necessary for the group of chemists who have heard this list to go and check the 'I' and 'G' values that are contained in that EEC directive which, after all, has been accepted by the governments of every member state. Might I make the suggestion, therefore, that the analytical chemists involved in this exercise ensure that the parameters in their own list are in close relationship with at least the 'I' values. I think there are parameters given for 'I' values ('I' meaning imperative values and 'G' being guide values to be attained within so many years). Initially I think the list should include at least all relevant 'I' values, otherwise I feel that the whole programme may be affected in its relationship with, for example, the environmental programme of research and, indeed, with the entire non-agricultural section of society.

H. van Dijk

Your remark is on the tape and is in complete agreement with our discussions of yesterday evening. The same goes for crops because many of the things we want to know regarding crops are in the procedure of harmonisation of cattle feed.

Now I think we can move on to soils and I will ask Dr. Catroux to present his paper.

PROPOSITIONS ON THE HARMONISATION OF CHEMICAL METHODS OF SOILS ANALYSIS IN THE EEC COMMON PROGRAMME ON LANDSPREADING OF ANIMAL MANURE

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INTRODUCTION

In view of the publications of Soil Science and the list of soil analysis methods used by European laboratories engaged in the EEC Common Programme, a need for normalisation in soils analytical methods becomes apparent.

One must remember that the EEC Common Programme goal is to obtain the greatest amount of information so that it may be available for use by all the countries concerned. Therefore, it is necessary that results from different experiments should be compared, in particular, I think, in respect of the utilisation of the analytical data with the mathematical model.

In this sense, the first step was to choose parameters of first priority for the field experiments. These were determined by national experts in a special meeting in Brussels and set out as the minimum necessary determinations to enable comparisons of field experiments.

By the same token and as a second step, in order to obtain comparable results it was considered that the easiest way would be to follow the same methods.

On examination of the list of methods currently in use, it is possible to propose common methods for some parameters; for other parameters, however, I shall propose some recommended methods although these recommendations would not impose their use by all laboratories. It is important, of course, that results obtained on the same sample, whether by recommended or alternative methods should be identical. Therefore it will be necessary to analyse samples of known compostion (synthetic and natural samples + known added quantities).

At this stage it is necessary to distinguish between the different steps: sampling of soil, and, for one parameter, extraction procedure and determination procedure.

The purpose of this report is to make out:

a) The list of methods communicated by the national reporters on the soil chemical analysis (the physical analysis will be reported elsewhere).
b) A list of common methods
c) A list of recommended methods

METHODS COMMUNICATED BY THE NATIONAL REPORTERS ON THE SOIL CHEMICAL ANALYSIS*

1. Diverse

1.1. pH: measurement with pH meter

- aqueous extract:	Soil/water 1/2.5	(I - F - UK - B)
	Soil/water 1/5	(Nl)
	Soil/water 1/2	(Irl)
- KCl extract	Soil/KCl N 1/5	(Nl)
		(B)
- Ca Cl_2 extract	Soil/Ca Cl_2 0.01 M 1/2.5	(FRG - DK)

1.2. Conductivity: measurement with conductimeter at 20°C.

- aqueous extract:	Soil/water 1/2.5	(I - F)
	Soil/water 1/10	(FRG)

1.3. Volatile and mineral matter:

- after measurement of dry matter (105°C overnight F; 95°C - 16 hours Irl; 105°C till constant weight B).
- drying at 550°C till constant weight.

* Some methods not communicated in English are omitted from this list

1.4. <u>Ca Co_3 total</u>:

By measurement of CO_2 evolved after treatment with HCl (I - F - FRG).

2. <u>Nitrogen compounds</u>

2.1. <u>Total Nitrogen</u>

Generally Kjeldahl N distillation of NH_3 and titration after mineralisation by conc. H_2SO_4 with a catalyst; as catalyst

- Se (I - FRG - Nl)
- Na_2 SO_4 + Cu SO_4 + Se (F - B)
- K_2SO_4 + Cu SO_4 + Mg SO_4 (DK)
- Cu SO_4 + Se (UK)
- K_2 SO_4 Hg (UK)

Only <u>total nitrogen</u> with the linkage of N - NO_3^- by pretreatment with salicylic acid (Nl).

2.2. <u>NH_3 + NH_4^+</u> :

Generally extractable or exchangeable N - NH_4^+

- exchangeable with Na Cl pH 2.5 (I)
- exchangeable with K_2SO_4 1% (FRG)
- exchangeable with Na acetate (Irl)
- exchangeable with KCl (F)
- displaceable by Mg O (UK - B - F).

Determination of N - NH_4^+

- by titration after distillation in presence of MgO (UK - F - B).
- by colorimetry:
  - neslerisation (I - Irl)
  - indophenol blue (FRG - F)
- specific electrode (FRG - Irl)

2.3. <u>NO_2^-</u>:

Generally extracted by water (I - FRG) or KCl (UK - F) and colorimetry after reaction with Griess or similar reactant. (Sulfanilamide + naphthylethylene diamine HCl)

2.4. NO_3^-:

Extracted with:

- water and Cu SO_4 (Irl - DK)
- K_2SO_4 1% (FRG)
- KCl (F)

Determination:

- by colorimetry:
  - nitrophenol disulfonic
  - reduction by Cd - Cu and colorimetry as NO_2^-
  - by UV absorption at 210 mn. (FRG)
  - by specific electrode (DK - Irl)

Other determination by reduction until NH_3 by Dewarda alloys, distillation of NH_3 and determination of NH_3 by titration

NO_3^- obtained by difference between (NH_3 + NO_3) - NO_3 (B - F - UK)

3. Organic compounds:

Generally by a mixture of $K_2Cr_2O_7$ and H_2SO_4 (I - F - FRG -Nl Irl - B) conc. H_2SO_4, $K_2Cr_2O_7$, H_3PO_4 (UK)

Determination of Cr3 + by:

- titration:
  Mohr salt (I - Nl)
  Fe SO_4 (B - UK)
- colorimetry (F - FRG - Irl)

4. Anions:

4.1. Total P

After digestion with:

- H_2SO_4, HCl O_4 (I - F)
- H ClO_4 (FRG)
- H_2SO_4, H NO_3 (Nl)
- H_2SO_4, H NO_3, HF (B)

Determination as orthophosphate with colorimetry of phosphomolybdate (all countries)

4.2. Extractable P

Extraction with water (Nl)

Extraction with salts solutions

- NH_4 acetate (B)
- NH_4 oxalate 0.2 N (F)
- Na H CO_3 1% (Irl - UK)
- NH_4 lactate - NH_4 acetate (B)
- acetate buffer (I)
- lactate buffer (FRG)
- lactate - acetate buffer (FRG)

Extraction with acids

- citric acid 2% (Dyer) (F)
- H_2SO_4 N/500 Truog (F)
- H_2SO_4 0.2 N (DK)

Determination by colorimetry as total P.

4.3 SO_4^{2-}:

Extracted with:

- NH_4 acetate (Irl - B - F)
- NaCl (FRG)

Determination:

- by turbidimetry as Ba SO_4 (F - B - Irl)
- by precipitation with Ba CrO_4 and titration of Ba CrO_4 in excess (FRG)

4.4. Cl^-:

Determination on water extract:

Titration with Ag^+, CrO_4^{2-} as indicator (FRG)

5. Cations

5.1. Extractable K^+:

Extraction with:

- NH_4 acetate (F - Irl - DK - B)
- NH_4 acetate and NH_4 lactate (I)
- lactate buffer or acetate buffer (FRG)
- NH_4 NO_3 (UK)

HCl (Nl)

Determination with flame photometry.

5.2. Active lime

Extraction with NH_4 oxalate (I - F - B)

6. Traces

6.1. Total copper

Generally digestion of soils by:

- $HClO_4$ - FH (F)
- $HClO_4$ - NHO_3 (FRG)
- H_2SO_4 - HNO_3 (Nl)
- H_2SO_4 - HF - HCl (B)

Determination by atomic absorption spectrometry.

6.2. Extractable Cu:

Extraction with:

- NH_4 EDTA (I)
- NH_4 acetate (F - B)
- EDTA 2 Na (DK - UK - Irl)
- HNO_3 0.5 N (FRG - Nl)

Determination by atomic absorption spectrometry.

6.3. Total Zn

Digestion of soils and determination as total Cu by AAS.

6.4. Extractable Zn

Extraction with:

- NH_4 EDTA (I)
- HCl O_2N (F)
- HNO_3 0.5 N (FRG - Nl)
- EDTA (Irl - DK)
- Acetic acid (UK)

Determination by atomic absorption spectrometry.

PROPOSED COMMON METHODS FOR CHEMICAL ANALYSIS OF SOILS .

1. Sampling, pretreatment and storage

It is proposed to take core-samples below the soil surface to a depth of at least root penetration of the soil, between 0 and 0.30 to 1 metre, and, if possible, depending on the soil type, to 2 metres (pollution balance). The thickness of each slice may be about 0.15 - 0.20 m depending also on the soil type. It is necessary in a single plot to take several core-samples in order to obtain (after mixing) an average sample. The number of core-samples per plot depend on:

- the surface area of the plot,
- the soil homogeneity of the plot,
- the sampling frequency.

Before investigation, the soil sample is dried, sieved at 2 mn. and stored at room temperature for all the determinations except mineral nitrogen (NO_2^-, NO_3^-, NH_4^+). For these determinations it is best to make the determinations as soon as possible.

2. Proposed common method of analysis

In view of the methods communicated by the national reporters, it is possible to propose common methods for pH, conductivity, volatile and mineral matter, total $CaCO_3$, Kjeldahl and total Nitrogen, organic compounds, active lime.

For these parameters there are only minor differences between methods used by the laboratories and it may be possible to introduce minor adjustments to work with the same methods.

2.1. pH

Water pH

By pH metre on soil water extract ratio 1/2.5

The measurement is made on resuspended soil suspension after an equilibration time of one hour. (There is a Belgian proposal for an equilibration time of very much longer).

KCl pH

Identical but with KCl solution for the suspension.

2.2. Conductivity

By conductimeter at 20°C:

- on filtered soil-water extract ratio 1/2.5 (same extract as pH determination
- and/or on saturation extract.

2.3. Volatile and mineral matter

Determination of humidity on drying at 105°C until constant weight.

Determination of mineral matter by heating at 550°C to constant weight.

2.4. Total $CaCO_3$

By gazometry on CO_2 evolved after treatment with HCl.

2.5. Active lime

Extraction with NH_4 oxalate (Drouineau method).

2.6. Total Nitrogen

It must be differentiated between Kjeldahl Nitrogen and total Nitrogen.

Kjeldahl Nitrogen: When no significant amount of nitrates is present, mineralisation with concentrated H_2SO_4 and Na_2SO_4 (or K_2 SO_4), $CuSO_4$ and Se.

Distillation of NH_3 and determination by titration.

(Alternative: distillation with auto-analyser and colorimetry of NH_3).

Total Nitrogen: When significant amounts of nitrates are present, pretreatment to reduce the nitrates with salicylic acid followed by reduction with Na_2 S_2O_3 and after, same procedure as Kjeldahl Nitrogen.

2.7. Organic compounds

Mineralisation by a mixture of K_2 Cr_2O_7 H_2SO_4 and determination of excess dichromate by titration (Mohr salt) or

Cr^{3+} by colorimetry.
It would be useful to compare the results obtained on glucose and Na acetate (the latter as "recalcitrance indicator").
Alternative method by combustion (with carbograph analyser).

PROPOSITIONS ABOUT RECOMMENDED METHODS

1. $NH_3 + NH_4^+$
   Extraction with KCl N or NaCl N which give simultaneously all forms of inorganic Nitrogen.
   Determination by distillation (MgO) and titration, or colorimetrically (auto-analyser).

2. NO_2^-
   Extraction as NH_4^+.
   Determination by colorimetry with sulfanilamide and naphthylethylene diamine - HCl.

3. NO_3^-
   Extraction as NH_4^+.
   Determination by colorimetry.
   Also determination by reduction *, distillation and titration which give total mineral nitrogen. NO_3^- -N is obtained by subtracting NH_4^+-.

4. Total Phosphorus
   Digestion with H_2SO_4 + $HClO_4$ ** or other method compared with these.
   Determination by colorimetry as orthophosphate.

5. Extractable Phosphorus
   For this parameter there is at least one method for each country (6 currently in use in the Central Soil Analysis Laboratory at Arras, France).

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* There is a Dutch proposition to use Reduction with $FeSO_4$+ Ag_2SO_4 in alkaline medium as a more reliable and rapid reduction method.

** There is a Belgian reticence with the use of $HClO_4$.

Therefore, it is very difficult to propose a recommended method. I propose that this question should be discussed at Modena.

6. SO_4^{2-}

Extraction with NH_4 acetate and determination by turbidimetry as Ba SO_4.

Cl^-

Extraction with water and titration with Ag^+ in presence of Cr O_4^{2-} as indicator.

Extractable K^+

Extraction with NH_4 acetate (as SO_4 and other cations) determination with flame photometry.

Total copper

Digestion of soil with HCl O_4 - HF* .

Determination by atomic absorption spectrometry.

Extractable copper

Extraction with NH_4 acetate** as cations and $SO_4^{=}$) and determination by atomic absorption spectrometry.

Total Zinc

Cf. Total copper.

Extractable Zinc

Extraction with HCl 0.2 N for non-calcareous soils and HCl N for calcareous soils.

Determination by atomic absorption spectrometry.

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* cf. point 4.

** There is a Belgian proposition with extraction by NH_4 Acetate Buffer and EDTA.

DISCUSSION

H. van Dijk

To prevent confusion: on page 7 of the paper under the heading, '2. Proposed common method of analysis', there is a list of parameters but that is not the complete list. On the last two pages several others are added.

It is now open for discussion. Have you the feeling that we have covered here the most important properties that should be determined; are there some missing or can the list be shortened?

J.C. Brogan *(Ireland)*

I would like to make a point about the sampling; I think it is page 7 of the paper. As we are principally interested here in pollution rather than deficiency I think it would be most useful to take very shallow samples - about 5 cm - which would give you much more sensitive methods for picking up high levels of accumulation of any of the parameters, say copper, zinc, potassium, that we might be interested in. If we sample at, say, 30 cm, it may be diluted and unless there are very high levels you would find nothing. So I think it is important, between countries, to establish depth.

H. van Dijk

I think you have made a point there that the depth of sampling should be dependent on what you want to know. Indeed, copper and zinc are very good examples; it is known that they accumulate in the upper cm and when you want to know the copper status of the soil and the danger for animals, you have to take samples from the upper cm.

J.H. Voorburg

That is only for grassland, not for arable land.

H. van Dijk

When the material is added and mixed with the tilth layer then you take samples of the tilth layer and I think that is what was meant here. When it is worked out I think there should be a paragraph on sampling for grassland, for example, in connection with this problem of copper and zinc accumulation. In the final recommendations the number of sub-samples per surface unit and how they are taken, should also be given.

Are you aware of special problems with sampling? We are not discussing general sampling techniques of soil but special problems of sampling after manure has been added to grassland or arable land.

J. Lindhard *(Denmark)*

I would like to make a point that if you are going to have a permanent experiment on manure and you are sampling at 1m, the next year you will have the manure running down in the bore holes. This presents a problem but probably it is not for this forum.

H. van Dijk

Well, the size of your plot should be sufficiently large to ensure that you do not make a sieve in a couple of years.

If there are no more comments we will move on to physical analysis of soil.

PHYSICAL ANALYSIS OF SOIL

Physical analysis is needed primarily for a better understanding and prediction of 'pollution' of soil and water, resulting from landspreading of animal waste. In this respect first priority should be given to sampling methods, the determination of:

Moisture content

Particle size distribution

Particle and bulk density (total porosity)

Pore size distribution, pF curve (from which an estimation of the 'unsaturated permeability' can be derived)

Water (saturated) permeability

<u>Question 1.</u>

Have relevant determinations been overlooked?

For the methods of sampling and determination reference is made to the Collection of Methods used in Western Europe, edited by the West European Working Group on Soil Structure of the Int. Soil Science Society, and issued by the State Faculty of Agricultural Sciences, Ghent, Belgium. (Prof. Dr. M. de Boodt) The most relevant chapters are III, IV and V.

<u>Question 2.</u>

Have certain methods in this collection appeared to you as unsuitable for the study of the effect of landspreading manure on soil properties or, conversely, of the physical properties on the fate of manure (components)?

<u>Question 3.</u>

Should certain methods or modifications, described in this collection be recommended as 'reference methods' because of their particular suitability for our aims?

DISCUSSION

H. van Dijk *(The Netherlands)*

Now, I hope you all have the paper on Physical Analysis of Soil. Can we turn our attention to Question 1 on the paper, Have relevant determinations been overlooked?

C. Cheverry *(France)*

I think other determinations should be added as first priorities. It would be a test of the stability of the structure. Some speakers have mentioned the problem of the structure after landspreading during this session, a test of stability of aggregates.

H. van Dijk

Well there are methods for that. Do you agree, is this a point which should be added? These methods are also mentioned in the Collection of Methods used in Western Europe in Chapter VI.

G.J. Kolenbrander *(The Netherlands)*

If you are using this information in connection with pollution then I believe there is one point missing and that is the level of the soil water table in relation to the pF curve and heaviness of the soil.

H. van Dijk

That is something which you have to determine in the field; it is not a determination to ask from the laboratory. I agree it is important in questions of pollution to know what the water table is.

G. Chisci *(Italy)*

I would add that surface run-off would be very important in this connection too.

H. van Dijk

Again, that is what the investigator making the experiments should measure; it is not a question to the laboratory doing physical soil analysis. It is the same as for the water table. The investigator should also mention the slope.

G. Chisci

What about water infiltration in the field. It is not mentioned here?

H. van Dijk

Yes, it is mentioned in 'unsaturated permeability' and 'saturated permeability'.

G. Chisci

I wouldn't call that water permeability. Maybe in the laboratory it would be better to specify hydraulic conductivity for instance - it would be more specific.

H. van Dijk

I took the terms from the Collection of Methods used in Western Europe where they are trying to get some harmonisation and I didn't try to beat the soil physicists in this respect. I just took what I found there as terms used.

Now, Question 2: Have certain methods in this collection appeared to you as unsuitable for the study of the effect of landspreading manure on soil properties or, conversely, of the physical properties on the fate of manure (components)?

R.G. Gerritse *(The Netherlands)*

I have one remark in connection with the first question. Wouldn't it be useful to have data on oxygen or air diffusion?

H. van Dijk

Don't we have enough when we know the saturated and unsaturated permeability and pore size distribution?

R.G. Gerritse

I don't know; I am just putting the question.

<u>H. van Dijk</u>

Well, I suppose we know enough to have an estimate of the exchange of air.

<u>F. Bonciarelli</u> *(Italy)*

It is very difficult ... someone tried to study oxygen diffusion into soil but they didn't succeed ...

<u>R.G. Gerritse</u>

We have relatively simple methods of determining these parameters at Haren, is that not so?

<u>F.A.M. de Haan</u> *(The Netherlands)*

What, the air permeability?

<u>H. van Dijk</u>

The point is whether unsaturated permeability and pF curve are not enough to estimate air permeability. I think it is enough.

<u>Anon</u>

It is enough.

<u>R.G. Gerritse</u>

O.K. So it's not relevant.

<u>F. Bonciarelli</u>

I agree with Dr. Chisci that field infiltration trials on the infiltration capacity of the soil would be much better than water permeability measured in the laboratory. In the field we can work on undisturbed soil.

<u>H. van Dijk</u>

In Chapters III, IV, V and VI, there are descriptions of measurements in the laboratory. Chapter VII describes field measurements. I cannot say what you should be doing - I am not a soil physicist. All I am saying is that if these parameters are important to establish the effect of manuring on pollution of soil and water, you can find the methods of how to do it in that book.

<u>R. Kickuth</u> *(West Germany)*

The pore size distribution and the determination of saturated and unsaturated flow in the laboratory seems to be insufficient for it depends on the surface tension of the liquid applied. We have found that very, very small amounts of surface active agents, not only artificial but also natural, can lower the surface tension. On the other hand, I refer to the other point of our discussion, that means that instead of measuring the electrical conductivity of water we should determine the surface tension of what we apply. It would be of more advantage from this point of view.

<u>H. van Dijk</u>

What you are asking for, in fact, is an additional parameter for liquid manure - the surface tension. Maybe that is important, anyway it is on the tape. I have never heard that we need a special method for determining the surface tension for the experiments on manuring and the effect of manuring and transport of manuring.

<u>R.G. Gerritse</u>

I would like to remark that surface tension would be a very unstable parameter, it would fluctuate enormously.

<u>H. van Dijk</u>

O.K. It's on the record for those people who are doing this kind of experiment.

Now, Question 3: Should certain methods or modifications, described in this collection, be recommended as 'reference methods' because of their particular suitability for our aims?

<u>F.A.M. de Haan</u> *(The Netherlands)*

I have a suggestion. It doesn't have much to do with the answer to the third question but in my opinion it would be worthwhile to adjust the terminology to that used by the

International Soil Science Society. Three months or so ago they gave a number of indications as to which would be the correct terms to use and I think such an adjustment could easily be made.

<u>H. van Dijk</u>

Agreed. Tomorrow morning there may be time for discussion on whether we should have final standardisation or just ask for reference methods.

PROPOSITIONS FOR THE METHODS OF CROP ANALYSIS

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1. Sampling, preparation
1.1. Sampling
1.2. Washing
1.3. Sub-sampling
1.4. Drying, grinding
2. Chemical analysis
2.1. Moisture
2.2. Volatile and mineral matter
2.3. Nitrogen compounds
2.3.1. Total nitrogen
2.3.2. Nitrate-Nitrogen
2.4. Anions - Total P
2.5. Cations - K+
2.6. Traces - Cu, Zn
3. Methods for characterisation of crop quality
3.1. Cereal grains
3.2. Maize
3.3. Sugar beet
3.4. Grass

1. SAMPLING, PREPARATION

1.1. Sampling

It is the aim of sampling to get a representative average of the original material. Above all, part of plant, stage of development and time of sampling have to be taken into account.

For investigation of the different parameters, the suitable sampling times may vary but it is reasonable to select sampling times in which all interesting parameters can be determined in one sample.

The most important aspects that should be considered are listed in Tables 1 and 2.

TABLE 1

SAMPLING FOR CHEMICAL PLANT ANALYSIS

Type of plant	Part of plant	Stage of development Time of sampling
Cereals	Whole plant above ground	Outset of tilling, after development of 2nd node, plant height up to 40 cm
Maize	Leaves above site of cob	Commencement of blooming
Sugar beet	Leaves without petioles (central leaves)	3 months after sowing, end of June/beginning of July
Grass	Whole plants above ground	Before pasturing or mowing, approximately at commencement of blooming

TABLE 2

SAMPLING FOR CHARACTERISATION OF CROP QUALITY

Type of crop	Time of sampling
Cereal grains, maize corn	After harvesting (dried product)
Sugar beet	Harvest time
Grass silage	Beginning of feeding

1.2. Washing

If the sample is contaminated with soil or other foreign substances it may be necessary to wash it. This procedure should be carried out very quickly to minimise loss of soluble constituents and should be followed by drying with a cloth or paper tissue.

1.3. Sub-sampling

If the sample is large, sub-sampling may be necessary. This step should be carried out quickly. For herbage and foliage the sample is chaffed into short lengths, thoroughly mixed and quartered down to approximately 300 - 500 g. To do this, a flattened heap is formed, the heap is divided in quarters and two diagonally opposite portions are rejected. The remaining material is mixed and the process is repeated. For roots, sugar beet, sub-sample by taking a 10 mm core, or a diagonal slice, approximately 5 mm thick through the root across the shoulder.

1.4. Drying, grinding

The sample is predried at 60 - 70°C in a force-draught oven for 12 - 24 hours. After grinding to pass a 1 mm sieve the material is dried at 105°C (except cereal grains) to constant weight. Cereal grains or corn are dried at 130°C to constant weight.

For special investigations, i.e. the determination of sugars, fresh material, or material that has been dried at 30°C should be used.

2. CHEMICAL ANALYSIS

2.1. Moisture

5 g of the predried and ground sample is dried at 105°C or 130°C according to sample (see 1.4) to constant weight.

2.2. Volatile and mineral matter

Transfer (2 to) 5 g of dried sample into a basin and carefully pre-ash on a hot plate. Complete the combustion in a muffle furnace at 450°C (EEC prop.: 550°). The basin remains there until a white or light grey ash is obtained. If difficulty is experienced in obtaining a carbon-free ash the cold ash may be moistened with some drops of NH_4NO_3 solution (20%). After drying in an oven or on a steam bath the sample is reheated at 450°C.

2.3. Nitrogen compounds

2.3.1. Total Nitrogen (without NO_3^--N)

Transfer 1 g (EEC prop.) of dried sample into a digestion flask. Add 10 g K_2SO_4, approximately 1 g of $CuSO_4 \cdot 5\,H_2O$ and 25 ml conc. H_2SO_4. Heat the flask gently until frothing ceases, more strongly until the solution clears and then for a further 1 hour.

When the sample-digest has cooled, add carefully 100 to 200 ml water. The sulphates should be dissolved completely. Allow the mixture to cool. After addition of 100 ml NaOH solution (40%) distil the liberated NH_3 into a receiver with 0.1 N H_2SO_4 (EEC prop). Titrate the remaining H_2SO_4 with 0.1 N NaOH. If H_3BO_3 (1 - 2%) is used as receiving acid, NH_3 is titrated with 0.1 N H_2SO_4.

Indicator: methyl red alone or in mixture with methylene blue or bromocresol green in ethanolic solution.

A blank determination with 1 g of sucrose in place of sample should be carried out.

The obtained value of nitrogen multiplied by 6.25 gives the (crude) protein content of the sample.

2.3.2. Nitrate-Nitrogen

Shake 2 g of dried and ground sample with 50 ml of water on a shaking machine for 30 min. In the filtered extract determine the NO_3^--concentration by means of a NO_3^--sensitive electrode.

Another proposed way of determination is to reduce the NO_3^- to NH_3 by Devarda's alloy and to titrate NH_3 after steam distillation. Procedure: Pipet an aliquot of filtered extract into a micro - distillation apparatus. Make the extract alkaline by addition of $Mg(OH)_2$-suspension and firstly remove NH_3 by distillation. Then add Devarda's alloy and carry out distillation again. Receiving acid for preference, is H_3BO_3. Titrate with 0.01 N H_2SO_4 (indicator as described in 2.3.1).

2.4. Anions - Total phosphorus

Decompose 2.5 g (EEC prop.) of dried sample at 450°C until the ash is white or grey. Do not disturb small amounts of carbon. Transfer the ash into a beaker and treat it with 10 ml

HCl (d=1.1) on a hot plate or a sand bath. Bring the mixture to a dry state and add 10 ml HNO_3 (d=1.045) to the residue. Heat the liquid to boiling (about 5 min.) and transfer it into a 500 ml graduated flask. Filter the solution after filling up to volume.

Add 10 ml of vanadate-molybdate-reagent (see below) to an aliquot of 10 ml and mix well. Measure the absorbance at 430 nm after at least 10 min. against a mixture of 10 ml of water and 10ml of reagent.

VANADATE-MOLYBDATE-REAGENT (EEC PROP).

a) 100 g $(NH_4)_6Mo_7O_{24}$ .4 H_2O are dissolved in warm water, 10 ml NH_3-solution (d=0.91) are added, and the volume is filled up to 1 l.

b) Dissolve 2.35 g NH_4VO_3 in 400 ml warm water. Add slowly whilst stirring 20 ml diluted HNO_3 (7 ml con. HNO_3 (d=1.4) + 13 ml water) and fill up to 1 l.

c) 200 ml of solution a), 200 ml of solution b) and 135 ml of HNO_3 (d=1.4) are mixed in a 1 l graduated flask. The mixture is diluted to 1 l.

2.5. Cations - K+

Decompose 2 g of dried sample by dry combustion at 450°C (about 3 hours). Transfer the ash with approximately 50 ml of water into a 100 ml graduated flask and add 10 ml of HCl (d=1.12). Heat the mixture and maintain a temperature of approximately 90°C for 2 hours.

After cooling and filling up to volume, filter the solution. Pipet an aliquot of the filtrate (sometimes a preceding dilution may be reasonable) into a 100 ml graduated flask. Add 10 ml of buffer solution (EEC prop : 50 g CsCl and 250 g Al $(NO_3)_3.9\ H_2O$ are dissolved to 1 l. Storage in a plastic bottle) and bring the volume to 100 ml.

Measure the K+-concentration by flame photometry.

2.6. Traces - Cu, Zn

Transfer 2.5 g of dried sample into a beaker. Add 30 ml of digestion acid (mixture of 2 to 4 parts of approximately 70% w/w HNO_3 and 1 part of 60% w/w $HClO_4$, or mixture of $HNO_3/HClO_4/H_2SO_4$ 100 : 10 : 2.5) and keep for several hours or overnight, covered with a watch glass.

Combust cautiously on a hot plate. If the solution darkens (in the case of the $HNO_3/HClO_4$ digestion mixture) remove the beaker from the hot plate, add 1 - 2 ml of HNO_3 and reheat. After volatilisation of all the $HClO_4$ let the residue cool down and add 10 ml of approx. 2 N HCl - if the H_2SO_4 containing digestion mixture is used add 10 ml of water - bring to the boil and simmer gently for approximately 5 min. Transfer the content of the beaker into a 50 ml graduated flask, dilute to 50 ml and filter. Carry out a blank determination.

Measure the concentration of the trace elements by atomic absorption spectrophotometry.

3. METHODS FOR CHARACTERISATION OF CROP QUALITY

3.1. Cereal grains

Fractionating of grain-sizes or determination of thousand seed weight.

3.2. Maize (Corn)

Determination of cobs portion, determination of dry matter in the cobs.

3.3. Sugar Beet

Determination of sugar content.

Procedure: The determination has to be carried out in the fresh material. A certain quantity of beet pulp (in Germany 26 g, depending on the type of saccharimeter) is treated with a certain volume of a diluted lead acetate (basic) solution. After stirring for approx. 5 min. the mixture is filtrated. In the filtrate the angle of optical rotation is measured by means of a "saccharimeter".

3.4. Grass

Determinations of Mg in the case of application of cattle manure with high K+-contents.

Procedure: The ash obtained from 2 g of plant material is dissolved as described for the determination of K+ (see 2.5). After dilution Sr^{2+} is added up to a concentration of 1000 ppm in the final solution.

Measure by means of atomic absorption spectrophotometry.

PROPOSITIONS FOR THE METHODS OF CROP ANALYSIS*

J. Lindhard
Askov Experimental Station, Vejen, Denmark

In the propositions for methods of crop analyses, 1.2 mentions that contaminated samples might be washed: "This procedure should be carried out very quickly to minimise loss of soluble constituents and should be followed by drying with a cloth or paper tissue".

In our work the crops contaminated with soil are beet, swedes and potatoes,together with the tops of beet and swedes.

The experiment presented at Modena by our Director, Dr. Dam Kofoed, includes 192 plots grown to fodder sugar beet every fourth year. From these plots all harvested roots are washed, weighed and subsampled for dry matter estimation of the yield and for chemical analyses.

I cannot really visualise 30 000 roots being quick washed and then dried with a cloth or paper tissue, followed by individual subsampling across the shoulder of the root.

The procedure used here is as follows:
The sample, about 150 roots, is washed in a tumbler washer and passed to a balance where the weight is registered. Afterwards the sample is conveyed to a machine with seven circular saws at intervals of 4 cm which cut the roots in slices. The pulp is used for sampling. Investigations have shown that water left on the roots at the time of weighing and subsampling is of no practical importance to the results of later treatments. Potatoes are washed and chopped, subsamples are taken from the pulp.

With regard to the leaves, no procedure for effective washing of a sample containing 20 - 30 tops has been found.

*This paper has been submitted subsequent to the Seminar.

Instead of washing we chop the sample and weigh subsamples for dry matter estimation into crucibles. After drying and weighing the dry matter is passed on to ashing and the insoluble ash (sand) is calculated and used for correction of the dry matter percentage.

1.4 in the paper mentions: "Drying, grinding The sample is predried at 60 - 70°C in a force-draught oven for 12 - 24 hours. After grinding to pass a 1 mm sieve the material is dried at 105°C .... to constant weight".

Under 2.1 the same is repeated: "5 g of the predried and ground sample is dried at 105°C .... to constant weight".

From my experience samples of root crops dried at 105°C may lose in weight not only the moisture but also some of that volatile matter which is mentioned under 2.2.

The Maillard reaction might be responsible for the loss and anybody who has tried to dry root crops, especially swedes, at temperatures about 100°C knows the burnt smell from the sample.

Drying to constant weight does not seem possible, the probability is to dry to constant loss. An investigation carried out at Askov in 1959 showed the loss from samples dried at temperatures from 60° to 100°C. After drying for 24 hours the dry matter content for different crops was as shown in Table 1.

The dry matter content was estimated after drying for 6 hours and after that every second hour. From 12 hours onwards the loss was constant from period to period.

Statistical analysis proved the results highly significant for all the materials in question.

TABLE 1

DRY MATTER (%) AFTER DIFFERENT TEMPERATURES

	Drying at °C					LSD
	60	70	80	90	100	(95%)
Sugar beet	22.83	22.69	22.61	22.47	22.38	0.16
Fodder sugar beet	18.18	18.05	17.98	17.83	17.71	0.09
" " "	13.64	13.55	13.49	13.41	13.24	0.06
" " "	13.84	13.73	13.56	13.45	13.27	0.09
Mangolds	10.18	10.08	9.90	9.81	9.63	0.10
Potatoes	18.50	18.38	18.00	17.88	17.63	0.21
Swedes	11.47	11.29	11.18	10.75	10.49	0.06
Beet top	12.27	11.57	11.52	11.40	11.30	0.22

A comparison of dry matter percentages obtained after 16 and 24 hours gives differences as shown in Table 2.

TABLE 2

DIFFERENCES IN DRY MATTER (%) BETWEEN 16 AND 24 HOURS

	Drying at °C				
	60	70	80	90	100
Sugar beet	0.07	0.08	0.01	0.00	0.05
Fodder sugar beet	0.04	0.03	0.03	0.03	0.04
" " "	0.03	0.02	0.03	0.03	0.04
" " "	0.04	0.03	0.04	0.06	0.06
Mangolds	0.02	0.02	0.05	0.05	0.06
Potatoes	0.03	0.04	0.05	0.06	0.06
Swedes	0.03	0.04	0.07	0.13	0.08
Beet top	0.06	0.03	0.01	0.04	0.03

In most cases the differences are smaller at temperatures between 70 and 90°C than at 60 and 100°C. Roughly, the loss per hour may be estimated at less than 0.01% (abs.)

Taking into account the risks of thermophilous bacteria invading the samples a temperature of 80°C was chosen as the best compromise, at a drying time of 16 - 20 hours.

On the basis of this investigation and our experience I wish to plead that root crop material is not dried at temperatures higher than 80°C and moreover that alternative methods are given to the paper tissue method for cleaning roots.

DISCUSSION

H. van Dijk *(The Netherlands)*

Now discussion is open on the question of whether the list given in the paper, 'Propositions for the Methods of Crop Analysis' covers the aspects and properties of crops which are affected by manure application.

J. van den Burg *(The Netherlands)*

What is the reason for leaving out magnesium?

H. van Dijk

This relates to the 2nd March meeting so I will refer you again to Dr. Cottenie.

A. Cottenie *(Belgium)*

It is always the same reason; this list is not limitative in the sense that research workers are free to make any supplementary analyses they wish. However because potassium is a very mobile element it will accumulate in plants when there is a large excess due to landspreading of manure.

J. van den Burg

That is why I ask for magnesium, because of the high uptake of potassium.

A. Cottenie

That is the question. In my presentation two days ago I showed a decrease of calcium and magnesium uptake as a consequence of antagonism caused by potassium. But you will have it as soon as your potassium is going so very high due to the landspreading of manure. Anybody can add calcium and magnesium determination for his own information, or we could add them here. The reason why these are not on the list is that potassium is already such a very good indicator for pollution, or for excess. So, once again, we have limited the list rather than extended it.

H. van Dijk

In fact, calcium should be mentioned under crop quality because crop quality depends on calcium content. In that connection also nitrate content is mentioned. I don't know whether you have all read what is given for crop quality: cereal, grain, maize, sugar beet, grass. It is all listed in the paper. Once again, what should be added, what should be left off?

D.P. Collins *(Ireland)*

When you consider crop quality in relation to grass surely you would include the digestibility of the grass?

H. van Dijk

Are there indications that the digestibility of grass is affected by liquid manure other than can be expected on account of the content of nutrients? Do you get a different grass quality with liquid manure than with fertilisers?

D.P. Collins

I don't think we know.

H. van Dijk

We don't know that? Then for the present it does not seem to be a parameter always to be determined. Maybe it will turn up in one of the papers at the next meeting.

B.F. Pain *(UK)*

I would add that we do have limited information that liquid manures do decrease the digestibility of grass. We have some indication that it decreases digestibility a little.

H. van Dijk

Well I don't think it should be included now as a first priority; let's await reports on this point which will perhaps make it more clear and then maybe we will have to ask the analysts to give a reference method. Of course, this is not to stop you from making all the determinations you want; we are just discussing on which methods should there be harmonisation. As long as it is a subject for one investigator he is his own harmoniser - if you understand what I mean.

F. Bonciarelli *(Italy)*

Are nitrates included in the analysis - nitrates in grass?

H. van Dijk

Yes.

J.S.V. McAllister *(UK)*

I was wondering whether there should be a quality characteristic for the potato crop put in; some people have been working on potatoes.

H. van Dijk

Potato crop? You mean the suitability for making chips?

J.S.V. McAllister

I don't know what it would be.

H. van Dijk

Are there indications that it is severely affected by liquid manure?

L.C.N. de la Lande Cremer *(The Netherlands)*

Yes, the DM content or the starch content of starch potatoes.

H. van Dijk

Is that because of the potassium content of manure? When you get the same from an excessive dose of potassium mineral fertiliser it is not a specific effect of manure.

L.C.N. de la Lande Cremer

Most effects of manures are much the same as fertilisers.

H. van Dijk

Perhaps we should restrict ourselves for the moment to discussing the specific, I think that is first priority, otherwise we would be discussing the general topic of plant analysis.

L.C.N. de la Lande Cremer

It is the whole discussion between organic farming and normal farming.

A. Cottenie

Mr. Chairman, at the risk of making the list somewhat longer, in looking to quality judgement of grass we now add magnesium to potassium determination, that is in order to know the ratio potassium to magnesium. I would ask whether it is not more interesting to know the ratio of potassium to magnesium plus calcium, and add the calcium content - for quality. That is the second step of course.

H. van Dijk

So calcium should be added?

A. Cottenie

I think so.

H. van Dijk

In what way? Do you want to determine the sum of magnesium plus calcium, or separately?

A. Cottenie

Finally we will have to consider the sum, of course.

H. van Dijk

O.K. Methodically it is a simple addition for an analyst.

H. Tunney *(Ireland)*

I would like to raise the question of the effect of slurry on silage quality - grass silage. I would say that perhaps 90% of the manure that is applied to grassland should be applied to land that will be cut for silage because it is in that area that you have the highest demand for nutrients. The effect of slurry on silage quality is perhaps one of the most important aspects of quality in grassland and there is a very real distinction here between fertiliser and slurry.

H. van Dijk

Is that not a main effect of nitrate and potassium again?

H. Tunney

I think it might also be an effect on microbial activity and fermentation process.

J.H. Voorburg

It can be the subject of a paper for the next seminar.

H. van Dijk

Accepted. You are giving a paper on that subject at the next seminar Dr. Tunney!

H. Tunney

Yes, but I would like to know what parameters we should measure, perhaps there should be an indication.

H. van Dijk

Well, that's another topic than we are discussing now but on that special question is there someone who can give an answer to Dr. Tunney?

H. Tunney

Well, I would think that the people who were drawing up guidelines for what methods of analysis should be used for crop quality should include parameters that we should measure in silage - that might be influenced by manure.

H. van Dijk

Well, what is included here, in fact, is nitrate, potassium and magnesium, possibly calcium, but nothing else.

<u>T.A. Spillane</u> *(Ireland)*

I am quoting a colleague of ours in Ireland who has done a lot of work on DM digestibility, or DOMD, and it is certainly influenced by birds, by stage of growth, and so on, and I think it is a most valuable parameter. I am supporting my colleagues in Ireland and our colleagues here from Britain. It should definitely be included as a parameter on grass.

<u>H. van Dijk</u>

Yes, but what should be determined then?

<u>T.A. Spillane</u>

DM digestibility. In other words, the utilisation by the animal but done with the help of the in vitro technique.

<u>H. van Dijk</u>

O.K. That should be no problem for the analysts because the method is available. Even an EEC method is available as far as I know on digestibility. It can very easily be included in the list and in the report.

<u>F.A.M. de Haan</u> *(The Netherlands)*

Mr. Chairman, it is not my specific field of research but I know from co-workers of our laboratory that there is tremendous evidence now that the protein formation in plants is considerably influenced by the nitrogen supply whether it is in the form of ammonium or nitrate. This should be brought in in some way or another in relation to manure application to soil in the aspect of plant and crop quality. I really can't find that in the proposals as they are made in the paper.

<u>H. van Dijk</u>

No, it is certainly a matter for research but not yet ripe for harmonisation or standardisation. There is a quality problem with sugar beet where the amino acid content of sugar beet juice is very important for the refining of sugar. Determination of sugar content is asked for with regard to sugar beet. Is there any reason to believe that sugar content is affected more than with mineral fertilisers?

A. Cottenie

Of course. In some parts of our country sugar beets have disappeared due to the fact that the sugar content has become so low and the protein content has risen so much that it is no longer of interest to the factory.

H. van Dijk

I think that is a matter of over manuring with nitrogen and not a specific effect of the nitrogen contained in manure.

A. Cottenie

It is, it is especially that.

H. van Dijk

You don't get it when you are over fertilising with nitrogen?

A. Cottenie

Also then, but not in the same way.

L.C.N. de la Lande Cremer

It is a matter of combination of nitrogen from organic manures and from fertilisers. The mistake made is that the farmers are not reducing the fertiliser consumption when using organic manure.

H. van Dijk

Yes, that is what I have heard also; it is a matter of over manuring, not a specific effect of organic nitrogen compounds contained in manure.

F.A.M. de Haan

Evidently it has been indicated from your own research, at your own Institute, the digestibility, or gainability, or whatever you would call it, from sugar beets, is really decreased if you offer the nitrogen either in the form of waste water, manure, or whatsoever, even if you compare it with nitrogen at the same level from fertiliser.

<u>H. van Dijk</u>

O.K. but that's not on sugar content but on amino acid content which is severely hindering in the refining process.

<u>F.A.M. de Haan</u>

Yes, but then you must say that there is no sense in taking the parameter 'sugar content', if within a few years it will be on refining possibilities.

<u>H. van Dijk</u>

Yes, that is my point. I am asking can't we cancel the determination of sugar content and add the determination of amino acid content?

<u>J.C. Brogan</u> *(Ireland)*

I think it would be inconceivable to harvest sugar beet without measuring the sugar content.

<u>L.C.N. de la Lande Cremer</u>

The use of amino acid content is not practised in the calculation of the payment to the farmer, only the sugar content.

<u>H. van Dijk</u>

Yes. Your point, Dr. Brogan, is that the effect of manuring is normally expressed in yield and sugar - O.K.

<u>F. Bonciarelli</u>

On sugar beet quality an important factor in the sugar technology is not the amino acid content but the noxious nitrogen. Under this term some soluble compounds of nitrogen are indicated. These constitute the noxious nitrogen which trouble manufacturers of sugar, decreasing the percentage of crystallisable sugar. This is important and this noxious nitrogen increases as the nitrogen fertilisation increases. Another thing, regarding cereal grains, I can't see how fractionating cereal grains on the basis of their size is a way of characterisation of their quality. I can't see the usefulness of grading cereals on the basis of 1000 kernels.

One final point, I should like to know what the term 'cob' means. Botanically, cob is the rachis at maturity on which the flowers and grains of corn grow. There is true interest in this part of the corn plant, the cob, or should I understand that cob means the entire ear which may be husks, grain and cob?

B.F. Pain

Ear is a more acceptable term than cob for what we are talking about. It is the rachis plus the grain plus the husk.

F. Bonciarelli

I think the ratio of the ear to the entire plant is determined mainly by the genetic composition; it depends on hybrid type. I can't see why slurry application should modify the ratio between the ear and whole plant. I work on maize much more than on slurry and in my experience the percentage of different parts of the maize plant are quite constant. I am not sure that slurries can consistently modify the ratio between different parts of the plant.

H. van Dijk

Anyway, the determination of cobs (whatever we have to understand by cobs) is not a problem you need an analytical expert for. I think it is the problem of the man who is making the experiment and not of the analyst. Determination of the yield also is not something you need to ask of the analyst. The same goes for your first question. I don't know whether the average grain size is affected by manure in another way as mineral fertilisers. Maybe you get the same yield with mineral fertilisers and slurry but in the case of slurry your grains are perhaps bigger? In that case you have a higher 1000 kernel weight.

F. Lanza *(Italy)*

A different ratio between husks, kernels and cobs.

F. Bonciarelli

I insist. The weight of 1000 kernels is not an important factor of quality in cereals. The specific volume weight is a common quality parameter in evaluating the quality of cereals because it corresponds to a different nil extraction in yields. The 1000 kernel weight has no importance at all - only for seeds.

H. van Dijk

As far as I have heard now, for the analytical experts group we can leave out No.3, Methods for Characterisation of Crop Quality. What we are asking them are methods for the chemical analysis mentioned in 2 whereby 2.5 says: cations- potassium, magnesium and calcium. We add, as 2.7, in vitro digestibility, and, as 2.8, sugar content of sugar beets.

A. Cottenie

One very small remark. It seems to me very odd to read in the paper, 'Total nitrogen without nitrate nitrogen'. This is certainly not total nitrogen. As we are now listing what we are asking from the analysts, I would like to suggest 'protein like' nitrogen.

H. van Dijk

That's crude protein?

A. Cottenie

No, it's more than crude protein.

H. van Dijk

That is total nitrogen minus mineral nitrogen, multiplied by 6.25. I prefer then, 'organic nitrogen' because the word 'protein' suggests it is protein whereas it is only a very crude estimate of protein.

A. Cottenie

It certainly is not total.

H. van Dijk

No, well I have no doubt the analytical experts will observe that and it will be improved.

<u>L.C.N. de la Lande Cremer</u>

I would like to add copper to the grass quality especially for areas used for sheep farming.

<u>H. van Dijk</u>

That's no problem because point 2.6 says, 'Traces copper and zinc'. This is in crops. I suppose the method will not vary for cereals or grass. So the determination is included.

<u>A.V. Dodd</u> *(Ireland)*

I would like to make a general comment, seeking information more than anything else. I noticed that the discussion seems to be entirely related to what analytical chemists want. Now it seems to me that in the area of crops (we have heard Tunney talk about quality of grass silage, Bonciarelli talk about quality of grain) there should be some classification here, perhaps No.4, which should be physical measurements which should be taken. Also, I would like to be assured that the parameters here have been drawn up in consultation with some crop husbandry people. I assume they have been but just in case they haven't been may I suggest that consultations take place. If they have already been consulted why have we not got a section dealing with the physical measurements to be made? For example, crop density, straw/grain ratio, the physical measurements that describe, in my view, part of the quality of the crop.

<u>H. van Dijk</u>

What we were asked for were laboratory determinations, chemical and physical. We are not talking about agricultural or agronomic qualities. The proposals concern chemical, physical, and maybe biological, analysis in the laboratory.

I now have to close this morning session.

HARMONISATION OF METHODS FOR SAMPLING AND FOR CHEMICAL AND PHYSICAL ANALYSIS*

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Prior to the seminar, an inventory was made of methods for sampling and analysis in use by the institutes in the EEC which are involved in research on effects of landspreading of manures on the quality of soils, crops and water.

From the answers received, a survey of methods in use and a proposal for harmonisation was made by:

J.C. Brogan (Ireland) for manures,
P. Herman, G. Neirinckx and R. de Borger (Belgium) for water,
G. Catroux (France) for soils,
A. Klasink and R. Mählhop (Germany) for crops.

From this survey, it is quite obvious that a harmonisation of methods is urgently needed. The question of how far the matter is ripe for decisions was discussed by a group of experts at an evening session preceding the plenary session on this topic in Modena. This resulted in the following conclusions:

1. The adopted schedule has been too ambitious. There has been insufficient time for consultation of experts. Besides, very recently, an EEC recommendation on surface water has appeared which has not been taken into account when making the proposal for water. Further, there is an EEC harmonisation in course of preparation for animal feedstuffs, covering partly the same parameters we want to know for manures and crops.

2. In view of this, the rewriting of proposals for sampling and chemical analysis should be delegated to a small working group of analytical experts to be formed. The plenary session should be devoted primarily to the relevance and priority of the parameters listed and to sampling procedures, particularly of manures.

* This summary has been submitted subsequent to the Seminar

CONCLUSIONS FROM THE DISCUSSION IN THE PLENARY SESSION ON 23RD SEPTEMBER, AM.

Manures

Characteristics of manures used in experiments in which the effects of landspreading on soil, water and crop quality are to be measured should minimally comprise:

dry matter - settable solids (only in case of liquid manures) - Chemical Oxygen Demand (ibid?) - Kjeldahl, ammonium and nitrate nitrogen (the latter only in aerobically stored liquid manures) - pH - ash - potassium - calcium - magnesium - phosphorus - chloride - copper and zinc (the latter two only where pig manure is concerned).

Water

Determinations to be carried out in order to establish whether, and to what extent, ground, drain, or surface water are chemically polluted as a result of landspreading of manure comprise:

pH - conductivity - matter in suspension and/or (?) settable solids - dry matter - ash (or volatile solids) - COD - BOD - total, ammonium, nitrite and nitrate nitrogen - total, ortho and organic phosphorus - chloride - potassium - copper and zinc.

This list should be checked with the list in the EEC recommendation concerning surface water and first priority should be given to the relevant "imperative values" of that list.

Soils

a) Chemical

The list of "first priority" chemical properties of the soil which are possibly affected by manure application and for which the methods of determination therefore should be harmonised, remain unchanged as follows:

pH - conductivity - organic matter - total and active $CaCO_3$ - total, ammonium, nitrite and nitrate nitrogen - total and extractable (?) phosphorus - sulphur - chloride - extractable (?) potassium - total and extractable (?) copper and zinc.

b) Physical

As "first priority" soil physical determinations to be made for the study of the transport of manure components were listed:

moisture content - particle size distribution - particle and bulk density (total porosity) - pore size distribution (pF-curve; "unsaturated permeability") - water saturated permeability.

In these studies, of course, the height of the soil water table also has to be observed.

Methods of sampling and determination are given in the "Collection of Methods used in Western Europe", edited by the West European Working Group on Soil Structure of the ISSS, and issued by the State Faculty of Agricultural Sciences, Ghent, Belgium. There, field measurements are also described as well as methods to determine possible structure deteriorating effects of liquid manures on clay soils (the Italian colleagues were particularly afraid that such effects could occur).

Crops

a) Chemical

As "first priority" parameters for crops to be determined in the laboratory for establishing the effect of manuring were retained:

for all crops : dry matter - ash - organic nitrogen - total phosphorus potassium.

for grass, also: nitrate nitrogen - magnesium and calcium - in vitro digestibility - copper and zinc (where pig manure is concerned).

for sugar beet, also: sugar content (and amino acids?).

for starch potatoes, also: starch content.

b) Other observations and determinations

There was an obvious demand for a common guideline for other relevant observations and determinations as for example, yield, grain (kernel) size, crop density, straw/grain ratio, etc.

GENERAL REMARK

The fact that there has not been much discussion on sampling techniques does not imply that, in this respect, the proposals were accepted. In view of the great importance of sampling technique and sample pretreatment special attention to these subjects is also asked from the experts' group to be formed.

PROPOSAL FOR THE ISOLATION OF SALMONELLAE, THE COLONY COUNT AND DETERMINATION OF COLIFORM GERMS IN ANIMAL EXCRETA AND IN WATER

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LIQUID MANURE, SALMONELLAE

1. Culture

Standard - I - nutrient broth (Merck type No 7882) is inoculated with a pure salmonellae surface culture of brilliant green - phenol red - lactose sucrose - nat. agar (Oxoid type No CM329). After incubation for 18-24 hours at 37°C, a purity test is carried out on the germ suspensions obtained. Subsequently, the colony count per ml is carried out.

2. Colony count in the germ suspension

The colonies are counted by means of the Koch surface method. 1 ml of the salmonellae germ suspension is pipetted into a ten-fold series of dilutions of 9 ml physiological salt solution each. Thus, dilutions of 1/10, 1/100, etc... are obtained.

After each of the individual dilution steps has been thoroughly mixed with a Vortex-Genie mixer (Bender and Hobein, Zürich), 0.1 ml of each dilution is transferred to Standard I nutrient agar (Merck type No 7881) and evenly distributed on the agar surface with a Drigalski spatula.

After 24 hours of incubation at 37°C, two series of dilutions arranged in parallel are counted out with an electric bacteria colony-counting apparatus (Placont model Boskamp) only plates with between 30 and 300 colonies being retained for interpretation. The mean value is obtained from two parallel evaluations.

In order to find the colony count per ml, the mean value obtained is then multiplied by the degree of dilution and by the factor 10.

3. Preparation of germ-holders

Sterile 4 cm^2 - size pieces of silk gauze are placed in the salmonella suspension prepared as in paragraph 1. These pieces of gauze are removed after 30 minutes and spread out separately with sterile tweezers on glass dishes. In order to obtain good adhesion of the salmonellae on the germ-holders, the latter are allowed to begin to dry in the incubator at 37°C for from 30 minutes to a few hours according to the thermal conductivity of the container material employed.

4. Containers

The silk gauze germ-holders are placed in the liquid manure in small cast-aluminium, egg-shaped perforated containers. At the desired intervals single pieces of gauze can be separately removed and tested in the laboratory for surviving germs. For method, see 5.2.

5. Re-isolation of salmonellae

5.1. Qualitatively

5.1.1. Pre-enrichment method

If liquid manure of sewage sludge are tested for the presence of salmonellae a standardised method is followed:

25 g or ml of the material under investigation are pre-enriched for 18 hours at 37°C in 225 ml of buffered peptone water (Oxoid type No CM 9/10 + 9 g disodium hydrogen phosphate + 1.5 g potassium hydrogen phosphate per g of distilled water). Then 10 ml of pre-enriched preparation are added to 100 ml of tetrathionate broth with brilliant-green and gall supplement according to Müller-Kaufmann (Oxoid tetrathionate - broth -mat. basic substrate type No CM 343).

This main enrichment is incubated in a water bath for 15 minutes at 45°C and, subsequently, for 18-24 hours at 43°C. Afterwards, subcultures are applied to brilliant-green phenol-red - lactose - saccharose - mat. agar label (Oxoid type No CM

329) and also to a bromothymol-blue - lacto agar (Merck type No 1639).

If the material is strongly suspected of containing proteus, Prilmannitol-agar can be employed as an additional culture medium.

Composition:

Nutrient agar.

3 g NaCl (Merck type 6400)

2 g $Na_2HPO_4 12\ H_2O$ (Merck type No 6580)

10 g trypsin-digested peptone under the action of trypsin (Merck type 7214)

6.5 g Liebig meat extract

31 agar powder (Merck type No 1614)

1000 ml distilled water

Adjust to a pH of 7.2 and dissolve for 30 minutes in the autoclave.

Add the following to the dissolved agar:

15 g mannitol (Merck type No 5982)

6.25 g water blue dissolved in 619 ml distilled water (Merck type No 1279)

18.75 g metachrome yellow dissolved in 606 ml distilled water (Merck 5998)

40 ml of an aqueous 5% Pril solution

After mixing, autoclave for 30 minutes.

After another incubation lasting 24 hours a second inoculation is carried out on the culture media described above

5.1.2. Direct enrichment

In addition, two 10 ml batches of the substrate to be examined are introduced directly into 100 ml each of Kaufmann's sodium tetrathionate enrichment broth.

Composition:

1) 900 ml nutrient broth consisting of

5 g Liebig meat extract in 1000 ml of water

2.5 g Sörensen sodium phosphate (Merck type No 6580) to 900 ml of nutrient broth

50 g calcium carbonate (Merck type No 2066)

Autoclave for 15 minutes.

2) 100 ml distilled water and dissolve therein:
   50 g sodium thiosulphate (Merck type No 6516)
   Boil in the autoclave for 30 minutes.

3) 20 ml distilled water
   2.5 ml potassium iodide (Merck type No 5043)
   2 g iodine (Merck type No 4761)

Allow to stand for approximately 30 minutes, shake well and dissolve thoroughly. After mixtures 1 and 2 have cooled down, shake the whole together and add thereto 7 ml of 1:1000 alcoholic malachite-green solution. Before using the preparation allow it to stand for two to three days at room temperature.

One of these preparations is incubated at 37°C and the other at 43°C. The inoculation is carried out, after incubation times of 24 and 48 hours, on the culture media described under 5.1.1.

5.2. Quantitatively

5.2.1. Determination of the relative germ density on the germ-holders

The germ-holders (preparation described under 3), impregnated with salmonellae and removed from the liquid manure, are transferred to 50 ml of sterile 0.9% saline solution and shaken vigorously on a shaking apparatus in order to wash out the salmonellae from germ density; determination is as follows:

With 1 ml of this shaken suspension, a series of dilutions from 10^{-1} to 10^{-10} in sterile physiological salt solution is prepared. From each dilution separately 1 ml is pipetted into 9 ml of Kaufmann's sodium tetrathionate enrichment broth. After incubation for 24 hours and 48 hours at 37°C, a loop full of each is spread on brilliant-green phenol-red - lactose - Sucrose mat. agar. This is incubated for 18-24 hours at 37°C. Colonies suspected of comprising salmonellae are transferred to Kigler - Iron - agar (Merck type No 3913). After another 24 hours' incubation at 37°C, a rapid slide agglutination procedure with O and H antisera (Behringwerke) is carried out. If the agglutination is not unmistakeable the suspected colonies are tested for the biochemical behaviour.

5.2.2. Determination of the relative germ density of a salmonella broth added to liquid manure

In this case, 1 ml of the liquid inocculated with salmonella broth is pipetted into series of dilutions of physiological salt solution. Subsequently, the same method as that described under 5.2.1. is employed.

6. Colony count of the liquid manure

The colony count is done by means of the same method described under 2.

7. Determination of coliform germs in the liquid manure

The series of dilutions is prepared in the same way as that described under 2.

0.1 ml of each dilution step is spatulated on to Endo's - fuchin - lactose - agar type C (Merck type No 4044). After incubation for 24 and 48 hours at 37°C, the growing colonies lactose- positive, red, with greenish metallic lustre - fuchin lustre), are counted and designated as the number of coliform germs.

WATER EXAMINATION

1. The colony count for water is carried out as described under 2.
2. Determination of coliform germs by means of the diaphragm filter method

The apparatus employed for this is highgrade steel filtering device supplied by the Sartorius Diaphragm Filter Co. (Type SM 16201) and, in the case of heavily polluted water, it may be equipped with an accessory for preliminary filtering (type SM 16807) and a diaphragm filter (type SM 12500) as a pre-filter. For detecting Escherichia coli, type SM 11406 diaphragm filters are used.

Before use the diaphragm filters are cleansed by boiling in distilled water for 20 minutes.

After the water has been filtered, the diaphragm filter is placed on the surface of the Endo's - fuchin - lactose - agar type C, using sterile tweezers. In this cas as well, the growing colonies lactose-positive, red with fuchin lustre are counted after incubation for 24 and 48 hours at 37°C and the figure obtained is designated as the number of coliform germs.

MICROBIOLOGICAL ANALYSIS OF ANIMAL MANURES WITH PARTICULAR REFERENCE TO THE ISOLATION OF ESCHERICHIA COLI AND SALMONELLA SPECIES AND THE DETERMINATION OF THEIR IN VITRO ANTIMICROBIAL SENSITIVITY

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INTRODUCTION

The application of animal manures can result in the contamination of grasslands with such pathogenic micro-organisms as *Salmonella spp.* and *Escherichia coli*, both of which may be antibiotic-resistant. Along with the animal health problems which may arise therefrom, the extent to which such treatment may give rise to indirect contamination, with these organisms, of sheep and cattle carcases during slaughter is also a matter of concern. The viability of these micro-organisms in animal manures prior to and following application on grassland might in this way present hazards to both animal and human health. Current work in progress to elucidate these matter involves the following procedures and methods:

1. ANIMALS

1.1. Cattle

Cattle kept under 1) commercial and 2) experimental conditions to be examined during either a 2 x 1 year or a 1 x 2 year cycle while on (i) grass, (ii) silage and/or (iii) hay from (a) slurry-treated or (b) untreated grassland.

1.2. Sheep

Sheep kept under 1) commercial and 2) experimental conditions to be examined during a one year cycle while on (i) grass, (ii) silage and/or (iii) hay from (a) slurry-treated or (b) untreated grassland.

The carcases of these animals will be examined at Community approved slaughtering premises.

2. METHODS

2.1. Sampling methods

2.1.1. Slurries from intensive cattle production units

2.1.1.1. Five x 200 ml aliquots of (a) near-surface material and (b) sedimented material to be taken at each of two points from tanks beneath the slatted floors of each house, at monthly intervals.

2.1.1.2. Five x 200 ml aliquots of slurry to be taken from each main slurry tank at each of four points and at depths yielding (a) near-surface material and (b) sedimented material, at monthly intervals.

2.1.1.3. Five x 200 ml aliquots to be collected at the pumping station in each location during the pumping-out operation, at monthly intervals. This material to be regarded as representing agitated slurry.

2.1.1.4. The sampling device described in Appendix 1 to be used for slurry sampling, where appropriate.

2.1.2. Soil and Grassland Samples

2.1.2.1. Five x 200 g aliquots of top-soil to be taken from each of four one-metre square plots at monthly intervals.

2.1.2.2. Five x 200 g aliquots of grass to be taken from each of four five-metre square plots adjacent to top-soil sites referred to at 2.1.2.1. above, at monthly intervals.

2.1.2.3. Silage Samples

A 500 g aliquot of silage to be taken from each of five points at the feeding face of each silage pit, at monthly intervals.

2.1.2.4. <u>Hay Samples</u>

A 500 g aliquot of hay to be taken from each of five points at the open side of each hay store, at monthly intervals.

2.1.3. <u>Materials experimentally inoculated with test organisms</u>

Inoculation procedures and frequency and method of sampling to be finalised following discussions with Professor Dr. Strauch.

2.1.3.1. Slurry experimentally inoculated with *Escherichia coli* and/or *Salmonella spp.*

Five x 100 ml aliquots to be collected from the experimental tanks at daily, weekly or two-weekly intervals.

2.1.3.2. Soil and Grassland samples experimentally inoculated with *Escherichia coli* and/or *Salmonella spp.*

a) 100 g aliquots of top-soil to be taken from each of five 0.5 metre square plots at daily and/or weekly intervals.

b) Five x 50 g aliquots of grass to be taken from each of four one-metre square plots adjacent to the top-soil sites referred to at 2.1.2.1. above, and collected daily and/or at weekly intervals.

c) A 50 g aliquot of silage to be taken from each of five points at the feeding face of each silage pit inoculated previously with *Escherichia coli*, at daily and/or weekly intervals.

d) A 50 g aliquot of hay to be taken from each of five points at the open side of each hay store inoculated previously with *Escherichia coli* , at daily and/or weekly intervals.

2.1.4. <u>Excreta from cattle and sheep</u>

2.1.4.1. <u>Calves</u>

Rectal swabbings using alginate swabs to be carried out at monthly intervals in the case of selected calves kept in integrated finishing systems, and at two-monthly intervals from other calves up to the time of let-out to grass.

2.1.4.2. Store cattle, fattening cattle

Rectal swabbings to be carried out at monthly intervals on selected cattle, and, in the case of other cattle, at the time of weighing and/or medication, or otherwise by collection of representative faecal samples from the floors of the units, at two-monthly intervals.

2.1.4.3. Sheep

Rectal swabbings to be carried out at two-monthly intervals on selected sheep. Representative faecal samples to be collected from the floors of pens holding other sheep, at monthly intervals.

2.1.5. Pre-slaughter and slaughter samples

2.1.5.1. Cattle and sheep under test

Rectal swabs to be taken from these animals at the finishing station prior to loading for slaughter.

2.1.5.2. Other cattle and sheep

Representative faecal samples to be collected from the floors of pens on the day of loading for slaughter.

2.1.5.3. Carcase specimens

a) In the case of selected and other cattle and sheep, up to four intact mesenteric lymphatic nodes to be collected aseptically from each carcase.

b) One rectal swab together with one x 250 ml of caecal contents to be collected from selected and other cattle and sheep following evisceration.

c) Using the template and swab method (Kitchell et al., 1973) samples to be taken at five carcase sites, (perineal, mid-abdominal, neck, mid-back and intra-abdominal sites) using gauze pads and a 25 square centimetre template to obtain a sample from an area of 50 square centimetres at each site, from the left side prior to washing and from the right side after washing, in the case of both the selected and other cattle and sheep. The post-washing samples to be taken within two hours of slaughter.

2.1.5.4. Air samples

Using a slit sampler of the Casella type, air samples to be taken during the dressing-out of selected and other cattle and sheep at a point in close proximity to where the carcase spraying is carried out.

2.2. Analytical methods

2.2.1. Isolation of *Escherichia coli*

(i) All slurry, faecal, caecal content and air specimens to be applied directly to the surfaces of MacConkey agar plates using a surface swabbing procedure, where necessary.

(ii) Each soil, grass, silage and hay samples to be treated with its own volume of selenite brilliant green broth, and macerated in a Seward Stomacher* after which two swabs of the homogenate are to be transferred to the surface of MacConkey agar plates, as above.

(iii) Mesenteric lymph nodes to be exposed aseptically and cut into pieces of 1 cm square or less prior to being suspended in an equal quantity of sterile ¼ strength Ringers solution and macerated in a Seward Stomacher. Two 0.2 ml loopfuls of the homogenate to be transferred to the surfaces of two MacConkey agar plates.

(iv) All carcase swabbings to be transferred by swabbing to the surface of MacConkey agar plates.

Following incubation at 37°C for 24 hours, lactose-fermenting colonies resembling *E. coli* to be removed for further identification (Report, 1969) prior to carrying out in vitro antibiogram studies.

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* Seward Stomacher. Messrs. A.J. Seward & Co. Ltd., PO Box 1, 6, Stamford Street, London, SE1, England

2.2.2. Isolation of Salmonellae

All samples of slurry, faeces, caecal content, top-soil, grass, silage and hay to be treated with five times its volume of selenite brilliant green broth and homogenised in this broth using the Stomacher system, prior to incubation at 43^{o}C for 24 hours and subsequent plating onto brilliant green agar plates which are then to be incubated at 37^{o}C for 24 hours and/or 48 hours. All colonies resembling salmonellae to be removed for further identification (Thatcher and Clarke, 1968).

2.2.3. In vitro studies on sensitivity of *E. coli* and *Salmonella* species to antibacterial agents.

(i) Up to four individual colonies of *E. coli* from each specimen and representative colonies of all salmonellae to be submitted for in vitro antibiogram studies, using the following method:

Each colony to be applied evenly to the surface of a dry sensitivity agar plate by means of a swab. Paper discs with the following reagents to be applied to the surface of each inoculated plate: chloramphenicol, 50 mcg; ampicillin, 25 mcg; neomycin, 30 mcg; framycetin, 100 mcg; nitrofurazone, 100 mcg; streptomycin, 25 mcg; tetracycline, 50 mcg; sulphamethoxazole-trimethoprim, 25 mcg. The plates to be left at 4^{o}C for four hours prior to incubation at 37^{o}C for 24 hours. Organisms to be deemed "sensitive" in vitro to a reagent when the zone of inhibition surrounding the relevant disc exceeds 0.5 cm in radius. Analysis of results to be computerised.

(ii) Selected *E. coli* and *Salmonellae* colonies displaying single or multiple resistance to be submitted for transferable resistance studies (Moorhouse, 1969), using *Escherichia coli* E711 as the recipient strain.

NOTE:

In the case of the slurry and top-soil, grass and silage specimens a number of sub-samples to be examined at intervals of one to three days following storage at ambient temperatures for the presence of *E. coli* and salmonellae. The influence of storage on survival rates and pattern and nature of in vitro resistance to antibacterial agents to be studied using the methods described above.

2.2.4. Physical measurements of slurry and other samples

2.2.4.1. pH measurements

The pH of all slurry, top-soil and silage samples to be taken at the time of collection and at predetermined intervals thereafter using a portable pH meter.

2.2.4.2. Temperature measurements

Temperature measurements to be taken at up to three depths in the main slurry tanks at the time of sampling.

2.2.4.3. Water activity (Aw) measurements

Water activity (Aw) values to be determined* for each slurry, top-soil and silage sample on its arrival at the laboratory and at other predetermined intervals.

* Wert-Messer, Model 5803, Messrs. G. Lufft Metalbarometerfabrik, D-7 Stuttgart 1, Postfach 692, West Germany

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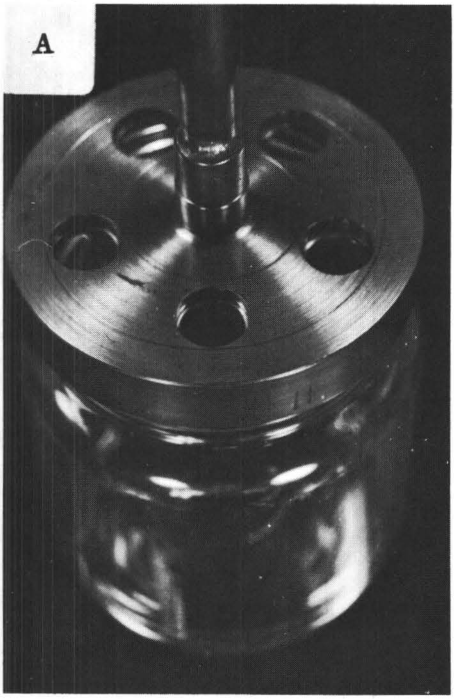


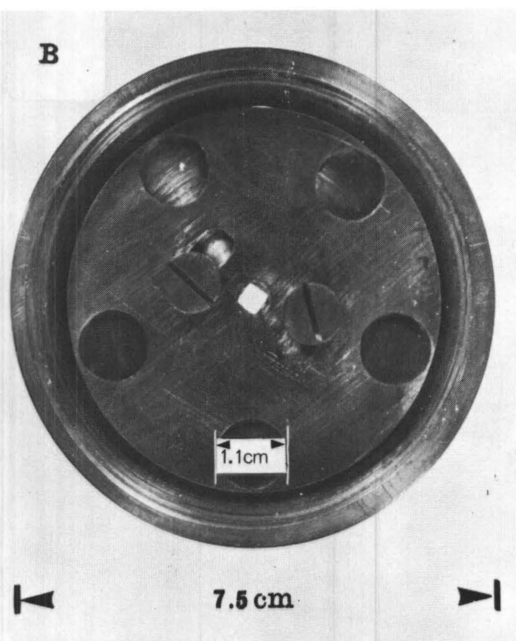
APPENDIX 1

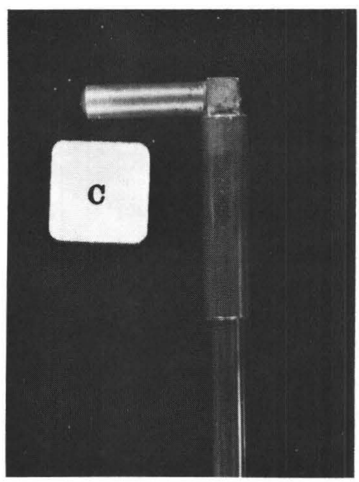
SLURRY SAMPLING DEVICE

Fig. A. Assembled unit showing valves in open position.

Fig. B. View of unit from underneath showing valves in closed position.

Fig. C. Control at end of 1.2. metres long handle.





DISCUSSION

H. van Dijk *(The Netherlands)*

Are there any questions or comments on what Dr. Strauch and Dr. Kelly have said?

N.E. Downey *(Ireland)*

I was interested in Dr. Kelly's device for two reasons. Obviously he has got something which he can put down between slats and take samples but I was amazed in a sense that he could collect slurry with this device because in our experience the top layer of the slurry is extremely hard and it simply won't flow into such a container. The very bottom layer is liquid and slurry would go in from there. Also, of course, from the point of view of parasitology, the sample collected would not be large enough for our purpose because we deal with buckets rather than test tubes, so to speak.

H. van Dijk

Thank you. Any comment Dr. Kelly?

W.R. Kelly *(Ireland)*

No, I don't think there is any comment I can make. As I say, we have had no problems in collecting our samples. We don't collect from too near the surface because of the obvious reason that aerial contamination of the other sources may, to a certain extent, confuse the picture and we want to minimise this to the greatest degree possible.

H. van Dijk

Thank you. The sampling technique is very important and, as I said yesterday, decisive for the result. Do you think that it would be advisable to set up a small working group to discuss the sampling technique and present proposals at the next meeting, or just a proposal that could be distributed via the Bureau in Brussels?

D. Strauch *(West Germany)*

I don't think it is necessary to have a working group. I think we could do it via the Bureau at Brussels but I do think it would be good to compare Dr. Kelly's sampling method with another method in which the samples are taken after the slurry has been stirred, because I have the feeling that by stirring the slurry we may have better and more reliable results than if we take samples, as Dr. Kelly does, from one of the various layers in a slurry pit when the slurry has been in it for three or four months.

H. van Dijk

When I raised this question of sampling I wasn't only thinking of microbiological and parasitological, but also of the chemical analysis.

W.R. Kelly

Mr. Chairman, perhaps I didn't make myself altogether clear. I would say that working groups may be set up within different areas. Perhaps the working group could look at the technology of sampling for a particular purpose - a microbiological purpose. My reason for raising this matter at this juncture was to get some guidelines on what people thought regarding the number of samples required in order to ensure that a valid, statistically acceptable, result was available.

H. van Dijk

I suppose in that connection the same problem exists for chemical analysis. I suppose it is much easier to establish by chemical analysis whether you have an adequate sampling technique than by bacteriological analysis because that is normally much more laborious.

D. Strauch

I would support your proposal for a working group if this covers sampling for all the various purposes. What I have just been saying was in the context of microbiological sampling. I thought it unnecessary to have a working group only on that but as you mean it now I think it is a good proposal to have such a group.

H. van Dijk

Yes, well that's what I thought but from Dr. Kelly's answer I concluded that a different technique would be necessary for bacteriological analysis than for other analyses so that there would be no point in combining .... but maybe I misunderstand you?

W.R. Kelly

It's a moot point. There are so many aspects that overlap; a general working party might be a useful thing to establish to discuss the matter.

J.R. O'Callaghan *(UK)*

Mr. Chairman, I am not clear whether the results of these tests are subjected to statistical analysis because I would have thought that when you come to analyse the experiments statistically this would throw a lot of light on the amount of sampling required. I wonder how much statistics are built into this experimentation.

W.R. Kelly

I am thinking of this in the context of salmonella isolation from food supplies, from bulk food material. We know that within reason the larger the amount of material proportional to the bulk you examine, the more salmonella recoveries you would see. So, obviously, this sort of principle having been established, one must recognise it and react to it in the type of microbiological work we are doing. I don't know if this applies elsewhere or not. As you say, Mr. Chairman, perhaps the question of soil analysis is a more simplified matter. In any event, if statistics come into experimentation at all, one should start off on the basis of a satisfactory statistical base to commence with - rather than bring it in later.

S. Baines *(UK)*

I think there is a difference in the statistical approach in microbiological work in salmonella isolation. In the chemical analysis one is looking, on a statistical basis, for reproducability, whereas in this case, if you find salmonella in one out of fifty samples it is enough; it is quite a different approach in the statistical reasons for the number of samples you take.

What I would like to ask Dr. Kelly, and I think this would be valid, is whether, for example, DM analysis was done on these samples. In our experience certainly, with this type of device, you get the liquid; even if you are working in a mixed solid/ liquid material the liquid drains in through these small pores. I would suspect it is very dilute slurry that you are actually sampling. Again, most types of bacteria including many pathogens tend to be associated more with the solid fraction. I would think that for microbiological analysis you need exactly the sort of sampling devices that have been suggested, in other words the great bucketful. I believe the problem of external contamination raises itself and it is not quite the sort of thing one wants. I do believe it is important to get a uniform sample - this is the essence of it.

H. van Dijk

In many respects the same goes for chemical analysis components adhering to solid particles or in solution. Would you like to comment on that Dr. Kelly?

W.R. Kelly

No, I would accept what has been said by Dr. Baines. The only problem is that we must use sterile collecting vessels. A large vessel, a bucket for instance, would present some problems in sterilisation prior to use. Then again there are certain technical problems in ensuring that you collect the sample at the depth you want. I agree that the type of sample we get is probably rather selective because of the small size of aperture at the top of the vessel. I am very conscious of this myself and have, in fact, asked my technical colleague to devise a new top probably with an aperture covering at least 30% of the top of the jar.

D. Strauch

I think, Dr. Kelly, we have to free ourselves of certain principles of our bacteriological education in handling manure problems. I think it is sufficient if we have a guarantee that the sampling device, whatever it might be, is free from salmonellae and E. coli. It need not be sterile because the slurry itself is such a heavily contaminated material, bacteriologically, that it doesn't make much difference if there are one, two or three germs more or less in the sampling device. The only thing is that it must be free of those germs for which we are looking.

R.G. Gerritse *(The Netherlands)*

Mr. Chairman, I was amazed to hear the phrase, "If we use statistics in sampling". Should it not be that it is a prerequisite to use statistics? We must always use statistics in sampling. To my mind sampling statistics are well-known and can be found in reference books. I think anyone who is involved in sampling should be familiar with these statistics.

H. van Dijk

Yes, I completely agree. Setting up a sampling technique includes statistical consideration of course. As far as I can gather from the discussion there may indeed be reason to ask some people to discuss sampling techniques of manure in more detail and present proposals. Maybe it doesn't have to wait for the next meeting but instead can be circulated by the Bureau in Brussels. I think it is very important for all of us that some document should come out quite soon because I sometimes have the impression that we are fooling around in making analyses in decimals where there are sampling errors in tens or hundreds. So I think it is rather important. If there is general support I would propose that a small group is formed to discuss this problem more thoroughly and present a document. Is that agreed?

I think that concludes the first points.

Now there is one other thing: there will be a group of analytical experts formed to present a proposal on analytical methods. Yesterday I promised that there would be an opportunity for discussion on whether we should have final standardisation or setting up of reference methods. In my opinion there is hardly any discussion necessary because I think the only practical way, at least to start with, to reach something which is generally workable, is to set up reference methods. However, since I promised that there would be an opportunity for discussion I am asking if any of you want to comment.

A. Dam Kofoed *(Denmark)*

Mr. Chairman, I strongly support your suggestion for reference methods because it is most necessary that we know what we read about.

H. van Dijk

Thank you, it is agreed then. We can continue with the programme, Dr. Lecomte's paper.

MECHANISATION OF SOIL SAMPLING UP TO A DEPTH OF I.80M

J. Guiot, R. Lecomte, L. Rixhon and O. Vitlox
Centre de Recherches Agronomiques de Gembloux, Belgium

Soil sampling for the purpose of studying the dynamics of a fertiliser must fulfil two well defined requirements.

a) Respect the volumetric proportion of the sample taken in relation to the horizon considered.

b) Avoid contamination from soil falling from one horizon onto another.

These requirements rule out borings of the drill type and are hardly more consistent with the use of the sledge hammer which generally causes a compaction of the core sample.

Furthermore, in the case of a particular research on mineral nitrogen any disturbance of the soil structure must be avoided so as not to alter the initial content.

We have developed a boring technique and built a borer which provides very good results. This will be illustrated by slides.

In spite of its possibilities, this technique remains very time and labour consuming. Under certain conditions of ground dryness, borings become a very arduous task especially when they reach a relatively important depth (1.80m). Furthermore, whatever precautions may have been taken, the taking of samples from cultivated plots results in trampling of the vegetation and consequently development is disturbed, which ultimately necessitates very large sampling areas.

Our research on the dynamics of nitrogen in general and nitrates in particular, in soils on which liquid manure has been sprinkled requires the taking of a large number of samples (40 000 per year) at a minimum depth of 1.20m.

These requirements are to allow us to establish the time history of the profile of the nitrates and finally to set up a model of the dynamics of this element.

Being confronted with this range of problems, we designed and constructed a vehicle capable of moving without causing damage under all cultivation conditions of experimental plots and taking core samples down to a depth of 1.80m without any change in the soil structure.

The other immediate objectives assigned to this vehicle were; speed, precision, saving of labour and ease of handling.

The machine consists of a self propelling and straddling chassis of which the gauge has been adjusted to that of standard agricultural machinery. A sufficiently spacious platform has been fitted to the chassis to take personnel and sampling equipment.

A 2.50m long slide has been attatched to the back of the platform. Two carriers, each supporting a double action jack with a 70 com stroke can travel on this slide. The down stroke of the piston, locking of the piston on the length of its stroke and the up stroke is performed through a simple push button. The speed of the down or up stroke of the piston can be regulated through a valve on the oil pump.

The pressure exerted on each jack is adjustable to working conditions (hardness of ground, size of the boring). A special safety device provides automatic lifting of the piston if the borer encounters an obstacle. The sideways travel of the carriers on the slide allows sampling on a 2.50m width.

In one day and under normal working conditions, three men can perform over 120 borings down to a depth of 1.20m, which amounts to collecting more than a thousand core samples of a height of 15 cm. It would take nine men two days to accomplish the same work by hand.

Apart from the advantage of being able to use this machine with different types of ground rigs, this device has also allowed us to make very exact compaction measurements with the help of a strain gauge.

As a complete technical description of the machine we have constructed does not fit into this short report, we will now present it through slides.

ANALYTICAL APPROACH TO SILAGE AND SLURRY EFFLUENTS

T.A. Spillane
The Agricultural Institute, Dunsinea Research Centre,
Castleknock, Co. Dublin, Ireland

As in other fields of science, analytical methods for slurries, effluents and general pollutants have changed dramatically and indeed, with the development of new instrumentation, continue to change. In its programme of promoting agricultural research, this Institute also investigates sources and levels of pollution arising from agricultural activities. With these commitments in view, the laboratories concerned sought methods which lend themselves to dealing with relatively large numbers, a wide range of parameters and acceptable control of analytical performance, particularly where precision and accuracy are concerned.

Before summarising the analytical procedures adopted in our laboratories, it might be relevant to interpret briefly the pollution parameters sought. The most important of these are the following:

<u>pH value</u>

An index of measurement indicating the acidity or alkalinity of an effluent. This is an important indicator of the corrosiveness, or otherwise, of a liquid. This is expressed as the logarithm of the reciprocal of the hydrogen ion concentration.

<u>Dissolved oxygen</u>

A water course becomes critically deoxygenated if the pollution load is excessive. The level of dissolved oxygen determines whether fish life can survive.

<u>Biochemical oxygen demand (BOD)</u>

The significance of this parameter is that it indicates the degree to which the oxygen content of a receiving water will be vitiated by the pollutant source. This is a most valuable indicator of pollution but has the disadvantage of requiring a five day incubation period.

Chemical Oxygen Demand (COD)

A test developed to overcome the time disadvantage of the BOD test. Based on measurement of oxidisable matter in an effluent by digestion of the sample with a chemical oxidising agent (potassium dichromate) it is not always reliable in that it fails to include some biodegradable organic compounds. In certain circumstances, it can be relatable to BOD results once a ratio has been established and thus can be substituted for the BOD test.

Permanganate value (PV)

This measures the amount of oxygen absorbed from standard potassium permanganate in four hours at 27°C. It is essentially an empirical method to measure the concentration of chemically oxidisable material and is of more value in controlling sewage works treatment than as a method for measuring the degree of pollution in effluents.

Ammoniacal Nitrogen

An indicator of decay of plant and animal residues and degradation of protein. This is a very useful indicator of pollution; very furl waters normally contain less than 0.4 mg/l.

Nitrate

This results from the bacterial oxidation of ammonia to nitrite and thence to nitrate.

Phosphate (4)

Apart from some natural occurrences (e.g. rocks and sand) its presence in effluent may be derived from the oxidation of phosphorus found in all living tissues; animal and vegetable.

Suspended solids (SS)

If these are essentially of an organic nature, they can be a strong indicator of pollution.

Mineral content

Minerals such as sodium, potassium, calcium, magnesium, chloride, etc., may also indicate degree or source of pollution.

Volatile or organic acids

In silage effluent formic, acetic, butyric, lactic, etc., may be present but unless a source of pollution, may be in too dilute quantities to be detectable.

In this brief review of analytical methods it is not proposed to elaborate in detail the methods in use for the detection of effluent from silage and slurry sources, but only to mention briefly those in use and found satisfactory.

pH

The most preferable is electrometric measurement by a suitable instrument based on the glass and calomel electrodes. These give good discrimination and accuracy and may be attached to a continuous recorder.

Dissolved oxygen and biochemical oxygen demand (DO and BOD)

For years both these methods were based on that of Winkler (1902), but the methods of choice are now based on the principle of polarography. Many firms produce excellent instruments which use a 10 to 100 millivolt potentiometric recorder equipped with a polarographic oxygen sensor. For DO measurement, since the DO contents of pure water at STP are known, the sensor probe measures DO directly. For BOD measurement, as for Winkler (1902), the suspect effluent is diluted appropriately with oxygenated water and its DO content measured. It is incubated for five days at $20^{\circ}C \pm 1^{\circ}C$ and the DO content again measured. It might be of interest to note that in one tropical laboratory where the writer has worked and where the near constant ambient temperature was $28^{\circ}C$, incubation for three days only gave results in good agreement with that of the five days at the lower temperature.

Chemical oxygen demand (COD)

As stated earlier this test is more rapid than the BOD but is essentially a manual chemical method and not, to my knowledge, capable of any degree of instrumentation or automation and hence limited as to numbers examined.

Permanganate Value (PV)

This is a simple chemical test which measures the amount of oxygen absorbed from standard $KMNO_4$ by an effluent in four hours at 27^{o}C.

Ammoniacal Nitrogen

The classical method has been distillation under alkaline conditions and development of a yellow/brown colour with Nessler reagent (a strongly alkaline solution of potassium mercuri-iodide) and colour measured absorptiometrically or by visual comparison with standards. Recently the development of specific ion electrodes has brought a whole new approach to this and other assays. These specific ion electrodes may be used with a good quality pH meter with an expanded scale in the range 100 - 300 MV. However, many firms are now supplying specific ion meters which contain a direct concentration read-out. The reference and specific ion electrode are also combined in these instruments. Recorders may also be attached and these are essential when permanent monitoring of a suspect polluted source is required. It is not possible to dwell at length on the principle of this method except that the measurement of ion concentration is based on measuring the potential across the membrane between the ion in solution and that in the electrode sensing solution. Ranges of measurement usually lie between 10^{-1} and 10^{-6} so that direct measurement without recourse to dilution or concentration are possible.

Nitrate and Nitrite

These ions are preferably measured by selective ion techniques using the appropriate electrodes and since there are about twenty specific electrodes for both cations and anions, this technique is almost a pre-requisite in any modern laboratory for a wide range of tests.

Phosphate

May be measured indirectly by specific ion technique but this laboratory uses the colourimetric technique of Fiske and Subbarow (1925).

Minerals

This laboratory developed a multi-digestion rack (Spillane and O'Leary) and the resulting acid digests from this process are diluted and estimated by atomic absorption spectroscopy for a wide range of minerals that include calcium, magnesium, sodium and potassium.

The interpretation of results is founded on a wide knowledge of pollution and pollutant factors. However, chemical evidence of pollution may fail to identify the source and, in these cases, advice is sought from the Agricultural Adviser and the extent of his local knowledge. Micro-biological examination would also be a useful ancillary test providing additional and valuable information.

For preventative rather than legal purposes, it may be essential to distinguish between pollution from animal or human waste and that from silage effluent. In conclusion I would like to seek suggestions from speakers and colleagues at this meeting whether parameters other than these outlined, would be meaningful in this regard for it is possible that micro-biologists may pin point bacteria present in one source only and not others. You may also consider that there would be merit in seeking evidence of the presence of organic acids or sugars that may only be relevant to silage effluent.

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DISCUSSION

T.A. Spillane *(Ireland)*

Mr. Chairman, I propose to take my paper as read but I would just like to raise some of my own points of difference with what has been said by other speakers.

It has been said, and it is obvious, that there are sampling difficulties in the field but I think that when the sample gets to the laboratory, if it is representative, the sampling technique in the laboratory should be efficient enough to get a representative sample for analysis.

I was surprised that most of the speakers, in describing the sample weight they took, spoke of 2 g, 5 g, and weights of this nature. Most modern laboratory equipment analyses in ppm and most people spoke about atomic absorption spectrophotometry. This, as we all know, measures ppm or fractions of a ppm. It seems to me that in taking large rates of samples one is then faced with a large dilution problem. One has to dilute maybe one or two thousand times. I think that with modern equipment and accurate sampling techniques in the laboratory one should deal with relatively small samples, something in the order of 250/500 mg, or even less. That is the main point of difference I would like to raise.

The other point is with regard to the Kjeldahl nitrogen which several people described, accurately of course, but ended up with the distillation and titration of the sulphuric acid digested product. Again, I think it is clear that the laboratories are going to have large numbers of analyses and large numbers of assays to carry out in the future in this particular field and, of course, in other fields as well. Therefore I suggest that to avoid that distillation and titration the standard Kjeldahl procedure should be avoided and a colorimetric technique, of which there are many, should be adopted instead.

I have one particular slide I would like to show. Where we take 250 mg size of all sorts of materials; slurries, pastures, silage, hay, compounded feeds, biological materials, urine, faeces, and so on, we do this on a very small scale and we have compared results with the national working party laboratories set up many years ago and have found that our results are very much on a par with those of other laboratories who may use much larger sized samples.

The actual sampling technique we use has three tiers of heating elements with controls on each layer. There are 20 test tubes on each layer, that is 60 in all, in quite a small fume cupboard. The sample we are taking, as shown on the slide, is 250 mg. The sulphuric acid is only 5 mills. The usual catalysts are used, of course, and after digestion which takes approximately a half to one hour, these 60 samples are diluted and the tubes (20 cm long x 2.5 cm wide) are calibrated to 50 mills. On those single digests we carry out total nitrogen and all the cations that we need to carry out which is usually 8 or 10.

That is all I have to say Mr. Chairman, thank you.

H. van Dijk

Thank you Dr. Spillane. Are there any questions?

J.C. Hawkins *(UK)*

Could we be told how we go from the field sample to the very small sample used in this technique? I want to know how you can go down from perhaps many litres of slurry to a few milligrams.

T.A. Spillane

If the field sample is representative there are various procedures. For slurry you can use an agitator - a Kenwood mixer type of thing - until you get a perfect homogeny. In that case one would take a catch weight of the sample and do two or three replicates but generally there is no need for a vast number of replicates.

THEME 9

CLOSING SESSION

Chairman: J.H. Voorburg .

THE NITROGEN BALANCE SHEET

G.J. Kolenbrander
Institute for Soil Fertility, Haren (Gr), The Netherlands

ELEMENTS OF THE BALANCE SHEET

Just like a financial balance sheet, the soil nitrogen balance sheet has an input and an output side. The input and output of the nitrogen store in the soil consist of the following elements:

N input

1. Rainfall
2. Seed
3. Biological fixation
   a) non-symbiotic (*Azotobacter, Clostridium butyricum*, blue-green algae)
   b) symbiotic (legumes)
4. Organic manures and fertilisers

N output

1. Removed with harvested crop
2. Leached
3. Volatilised
   a) ammonia
   b) denitrification (N_2O, N_2)

If we write this input and output as a formula we get:

input — output — soil N store

$$(S + R + F + M) - (C + L + V) = N_f - N_s$$

S = seed
R = rainfall
F = biol. fixation
M = manure, fertiliser
C = crop
L = leaching
V = volatilisation
N_f = N_t - store at the end of experiment
N_s = N_t - store at start of experiment

The nitrogen contribution of S, R, M, C, N_f and N_s can be established very exactly by analysing water and soil quantities for their total nitrogen content.

Three elements remain, biological fixation, leaching and volatilisation, the contribution of which directly or indirectly has to be established. Because it is very difficult to get a precise estimation of the amount of nitrogen fixed from the air by biological activity, legumes are generally excluded from the experiments. Such a measure cannot be taken in the case of non-symbiotic fixation, because it would lead to serious interference with the total microbial activity of the soil. Partial sterilisation would affect the nitrogen balance sheet so seriously that the experiment would lose most of its practical value. Nitrogen input via non-symbiotic fixation is estimated at about 7 kg N $ha^{-1}.y^{-1}$. This mechanism will be accepted and included in the balance sheet including its estimation error.

We still have the factors, leaching and volatilisation, of which leaching can be determined in a direct way.

LEACHING

N-leaching can be determined by measuring the amounts of drainage water and the nitrogen concentration of this water. The most exact determination is direct measurement by means of lysimeter constructions, of which two types can be distinguished, viz, "monolith" types (filled with an undisturbed soil profile) and "filled-in" types (soil profile is built up in thin, homogeneous soil layers corresponding to the natural horizons in the profile). Each type has its positive and negative points but the main drawback is the small scale in relation to actual farming.

In artificially drained fields leaching has to be estimated from drainage water production and nitrogen content. However, here the possibility exists that the estimate of the nitrogen concentration of the drainage water will be too low, because of dilution with the ground water layer between and below the drains. In this way the amount of nitrogen discharged to the surface water is estimated, but this does not include the nitrogen from the root zone lost between the drains into the shallow ground water.

A better method, on a practical scale, is sampling the upper layer of the shallow ground water in soils not drained artificially and to estimate the amount of water moved downwards through the profile on the basis of rainfall and actual evaporation.

The quality of the results will depend on the right estimation of sampling depth and amount of "drainage water".

CHECK ON THE NITROGEN BALANCE SHEET

It is clear that volatilisation is determined only indirectly by difference, taking into account input, output and change in soil nitrogen. The consequence of an indirect estimation is that experimental errors are also included. Sometimes, therefore, the term "not accounted for" is used, indicating the sum of loss by volatilisation and experimental errors.

A balance sheet can become positive or negative due to experimental errors alone. It will be necessary, therefore, to verify the N balance sheet by measuring elements which are not lost to the air and which are not fixed from the air, to get an impression of the real value of the N balance sheet. Such an element may be chlorine or total phosphorus.

To prevent systematic errors in weighing of the soil used in a lysimeter experiment, it is necessary to check the weighing instrument used at the start and finish of the experiment by means of official standard weights.

All material which is removed or is supplied to lysimeters during the experiment should be weighed and analysed to prevent systematic errors in the balance sheet.

TYPE OF ANALYSIS

To get a good balance sheet it is necessary to use those methods of analysis which give a real total amount. The method of Kjeldahl does not give the real total nitrogen content because not all nitrate in soil, crop or water is measured. Part of the nitrate will be lost to the air as nitrosyl sulphuric acid.

To prevent such losses the old method of Jodelbauer, or a modified method with salicylic acid, has to be used in nitrogen balance sheet studies. Methods based on chemical extraction will never result in satisfactory balance sheets. This holds true also for the elements used in checking the N balance sheet for experimental errors.

SAMPLING

Soil should be sampled in thin layers and dried at 105^{o}C. After weighing, the dried soil is coarsely ground. The coarse grained material is divided over a number of open boxes via a vibrating gutter. The boxes are placed on a spinning disc each box covering a section of it so that together they occupy the surface of the disc. Such a sampling instrument is called a "laboratory sample splitter". To reduce sample size, the procedure is repeated with one or more of the boxes. Finally, there will be a sample suitably sized for the laboratory. Before it is used there, the sample is ground again in an agate ball mill to get a homogeneous mixture of very fine sand and organic matter which will not settle out differentially in the laboratory.

This way of sampling guarantees that experimental error will be as small as possible and should prevent that much time and money will be wasted.

DURATION OF THE EXPERIMENT

When a balance sheet study is started, the total amount of nitrogen in 20 cm of top soil may be about 5 000 kg $N_t.ha^{-1}$ at 0.2% N_t and a bulk density of about $2.5.10^6$ $kg.ha^{-1}$.

If we apply an amount of 40 $t.ha^{-1}$ cattle slurry containing 200 kg N_t we may expect, based on long term experiments, that about 25% of the total nitrogen, or 50 $kg.ha^{-1}$, will not be available in the year of application. However, this 50 kg $N_t.ha^{-1}$ will increase the original N_t content of 0.2% by 0.002% to 0.202% N_t. It is clear that such an increase cannot be established analytically with the normal equipment used.

From this example it will be evident that N balance sheet studies require experiments of long duration with all the consequences this entails. The duration can be reduced by exceptionally high applications but this will affect the entire nitrogen cycle and will result in abnormal losses which are not applicable to actual farming.

DIRECT DETERMINATION OF N LOSSES BY VOLATILISATION

In the laboratory it is possible to use N_{15} for a direct determination of N losses by volatilisation. However, for field experiments this technique is too expensive. It is also difficult to collect the gaseous products formed without reducing photosynthesis of the crops.

FERTILISATION IN FIELD EXPERIMENTS

If we want to know only the short time effect of residual nitrogen, we can conduct field experiments in which fertiliser and/or organic manure is applied in different, increasing amounts. The first year effect is indicated by an increased dry matter production of the crop. The residual effect in the next year can be found by measuring dry matter production in that year without fertiliser application.

The first year effect and residual effect of organic manures can be measured in the same way and expressed as a percentage of 100 kg $N.ha^{-1}$ applied as fertiliser.

This type of research will never give any information about leaching and denitrification becuase no real balance sheet is made.

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DISCUSSION

J.H. Voorburg *(The Netherlands)*

Thank you very much Dr. Kolenbrander for this splendid explanation. I hope you will be able to produce this for the Proceedings also. Who will take the floor on this?

J.R. O'Callaghan *(UK)*

Mr. Chairman, as one of the people who asked Dr.Kolenbrander to prepare this paper, I would just like to say that I am very sad he has had to spend a day in the hotel to do it but I am sure it is very much appreciated.

A. Dam Kofoed *(Denmark)*

My sentiments are the same, Mr. Chairman. All of us deal with nitrogen balance and there are so many different opinions about how to do it. Dr. Kolenbrander has put it in a very nice way. He mentioned leaching, as far as we are concerned with a heavy isotope N 16, we have found only 3% of the nitrogen given in the springtime was leached in the following autumn and winter. The next year I think it was about ½%. We have compared this with field trials and therefore we are most interested to see the balance set out as a model for us and we can use that in our future discussions.

J.H.A.M. Steenvoorden *(The Netherlands)*

I want just to add something about measuring the leaching. Dr. Kolenbrander mentioned lysimeter catchment and drainage. I think a further possibility in some countries would be to take samples of the upper ground water by bore holes. I presume that by drainage water you mean the water coming from drainage pipes and there you already have the mixing with deeper ground water.

G.J. Kolenbrander *(The Netherlands)*

If you take the concentration in the ground water .... the difficulty is that you have to estimate how much drainage water is produced. If you have a mixing in this layer how is the situation then?

J.H.A.M. Steenvoorden

I think the mixing is a problem in the deeper ground water but in the upper ground water, for example, the upper metre, the margin for error is very small. When you know something about the actual evaporation, the precipitation quantity and the porosity of the soil, you can make a rough estimate of what quantity of ground water you need to sample. This is just an idea.

F. Bonciarelli *(Italy)*

What do you think about the figures Dr. O'Callaghan gave in his model in which he assumed that 500 kg of nitrogen/ha/year could be envisaged? Do you think soil will be able to digest this quantity of nitrogen?

G.J. Kolenbrander

It depends on the type of soil. From experiments on grassland I know that leaching starts about an amount of 350 kg nitrogen. Afterwards it increases. This means that the uptake capacity of the grass is too low for the application. In other words, you have given too much and it will be mineralised in the same year; it has to be lost because it is nitrate and cannot stay in the soil as you have these present conditions in which it is leached. It depends on the type of soil. In the heavy soils, as I see here, I expect most parts of this nitrogen will be denitrified because you have anaerobic conditions in the sub-soil and leaching loss will not be so high. Where you have a sandy soil then you would have a very high amount of nitrogen leached in this way.

F. Bonciarelli

I think it would be interesting to distinguish between organic nitrogen and ammonium nitrogen in slurries. The ammonium nitrogen is dangerous for pollution of ground water so I think we could consider only the fraction of ammonium nitrogen in slurry in establishing how much slurry we can give to the soil. We need not attach too much importance to organic nitrogen. Organic matter will enter in the organic matter cycle, the carbon cycle, in the soil and then maybe that nitrogen will be much less harmful from the pollution point of view than the ammonium nitrogen. Maybe we could agree with Dr. O'Callaghan's figures by establishing that we can apply perhaps 400 kg of nitrogen/ha/year, half of which is under ammonium and the other half in organic matter. The half of 400 is 200 and I think 200 is not very far from the figure you introduced - 150 - as input by fertilisers. So we could avoid the use of mineral fertilisers by using slurry.

G.J. Kolenbrander

I have the opposite view from yours. It is true that ammonia is absorbed in the soil and does not leach very quickly, but it nitrifies very quickly. In the moment that it is nitrified it can be leached or it can be denitrified - and you have a loss. The organic nitrogen will not be lost so quickly but it is mineralised in time. We know from experiments that only the leaching losses from organic matter are high, not from fertiliser, because this mineralisation takes place also after the crop is harvested and you get an increase in leaching loss. In the range of grassland it is very small because grassland is grown to the end of the year; then you get sugar beets and potatoes harvested in September/October and the grains which are harvested in July. However, you still have mineralisation afterwards and if you do not have a crop which can take up this nitrogen it will be lost. (I should not say lost because we could, perhaps, use it in another way). However, I am of the opinion that the organic matter is a more serious source of nitrogen pollution than fertiliser.

J.H. Voorburg

I think you don't agree Dr. Bonciarelli?

F. Bonciarelli

May I try to explain why I don't consider the organic matter of nitrogen very harmful? In the first place may we consider a layer of the top 30 cm of the soil, or 1.3 as volume weight. We have a mass of 4 000 tons; we attribute 2%

of organic matter content, it gives 80 t of organic matter. The soil organic matter has an average content of nitrogen of about 5%. Thus we have in the upper 30 cm layer 4 t less than 4 000 kg of pure nitrogen. This is mineralised at about the rate of 1.5 to 2% every year which produces about 60 - 80 kg nitrogen/ha/year. You state 65 - we are in agreement. I think it is not very important if we add maybe 200 kg of nitrogen every year to this huge quantity of 4 000 kg of nitrogen inorganic matter present in the soil.

G.J. Kolenbrander

Yes, but it is not the total amount of nitrogen you have in the soil. The harmful part we are talking about is the amount that is mineralised from the soil, that is the 65 kg which is mineralised. However the rate of mineralisation depends on the rate of organic matter input that you have. If you have a high rate of input of organic matter such as farmyard manure, then you also get a high rate of mineralisation and that increases with time. If you are looking at the organic matter of your soils over a period of time then you get a steep curve and after 20 - 25 years you have an equilibrium. That means that each input is also totally mineralised from an equilibrium point of view. If you start giving farmyard manures in high amounts for a short time then part will not be mineralised but in 15 years you will have a very high mineralisation level and you can calculate it from the input of nitrogen you have. You do not have to take into account whether or not it will be mineralised during the next year; that part which is not mineralised is compensated by all the parts you have had in the previous years. In this way you can calculate the mineralisation level. If you have a light soil then a large part of this organic matter will be mineralised out of the season. If you have a very heavy soil, such as I have seen here, then it may be that leaching loss will be small. It is a question of economics - whether to denitrify your nitrogen in soil or to use it for crop production.

J.H. Voorburg

We have discussed this earlier in the Seminar; we should distinguish between the short term and the long term effect.

H. van Dijk

There is another error you are making Dr. Bonciarelli. You are assuming that organic nitrogen is organic nitrogen. Organic nitrogen in manure is about half organic nitrogen which is becoming available in the first year. It is not comparable with organic nitrogen stored in the soil; it is much more rapidly mineralised in the first year. Only about half the organic nitrogen in manure is mineralised at a comparable rate with the soil organic matter.

F. Bonciarelli

If there is a good carbon input in the soil a lot of nitrogen could be recombined by micro-organisms. The danger of very rapid mineralisation is present if there is a lack of carbon input as when you burn the straw for instance, or you harvest maize for silage, leaving practically no carbon on the soil. I think if we had a good source of carbon maybe we could obtain a fixation of nitrogen of the slurry in fresh organic matter which will enter in the very slow carbon cycle. Maybe I made a mistake, I am not a soil chemist, but I should like to know if it is possible to give a rather high level of nitrogen to the soil without harmful effects.

H. van Dijk

That's impossible. The average of the whole year shows a net mineralisation and it should do so because when there is no net mineralisation and there is as much carbon source as you want to add to avoid net mineralisation, then your plants will be deficient. Dr. Wassman from the United States once said that the microbes are sitting on the first table and the plants on the second. If you add so much carbon source that you don't have net mineralisation the plants would be deficient. On the average in a year you have net mineralisation. If you have some mineral nitrogen left in the soil in autumn when there is no crop you can add straw and temporarily try to fix that amount but the fixation of nitrogen should be over in the spring when you are sowing the crop. When you calculate the amount of carbon you would need to fix all the nitrogen in the slurry then it is a tremendous amount.

J.H. Voorburg

I am going to stop this discussion on nitrogen balance; something should be left for the next seminar! Thank you very much Dr. Kolenbrander.

I have to tell you that Dr. Gerritse will send copies of his paper on organic phosphates to anyone who is interested.

Now, Mr. L'Hermite has some information about the reporting of the research programme.

P. L'Hermite *(EEC)*

It seems to me that we must get, as soon as possible, the application of conclusions for the CEC research programme on effluents from livestock. I expect to meet soon the group of experts who set up the programme in order to discuss the conclusions of this meeting with regard to its implications on our programme and to make a proposal on the composition of the two expert groups - the analyst group and the group on the technology of sampling. Afterwards I will launch a discussion inviting the scientific leaders of the projects of the common programme to consider the implications of the Seminar conclusions within the scientific context of the programme and to discuss the final composition of the expert groups. This is just to inform you; I will send the relevant documents and invitations in due course. The experts appointed by the national delegations were told of this meeting but the project leaders have not yet been informed. If short notice creates difficulties for some of the leaders of the projects they can be replaced by one of their co-workers.

J.H. Voorburg

Thank you Mr. L'Hermite.

Now I propose we discuss the conclusions. Copies are available here but there has not been time to harmonise them.

THEMES I, 2 AND 3
CHAIRMAN'S DRAFT CONCLUSIONS AS A BASIS FOR DISCUSSION

1. More attention should be paid to the long term effect and to the impact on the environment of excessive amounts of manure. Therefore balances should be produced on input/output and composition of the main nutrients and other relevant minerals.

2. To understand the results of experiments an exact description of the manure applied is necessary. Effort should be made to develop a standardised formula to describe the chemical and physical properties of manure.

3. Research on manure application on grassland should take account of the influence of manure on the sward and on animal behaviour.

4. In regions and on farms with a surplus of manure the amount of dilution water should be minimised in order to reduce transport costs.

5. More information is needed about the role of run-off in the pollution of surface waters.

6. Attention should be paid to the amount of zinc in concentrates and manure and its toxicity for animals and crops.

7. It is necessary that research produces information in order to predict the long term effect of excessive amounts of manure, therefore we should try to understand the mechanism of the composition and transport of minerals in the soil.

THEMES 4 AND 5
CHAIRMEN'S DRAFT CONCLUSIONS AS A BASIS FOR DISCUSSION

1. Various systems of landspreading of slurry should be investigated in respect of their potential for spreading known pathogenic micro-organisms which might cause diseases in animals and man (e.g. aerosol).

2. Investigations on persistence of pathogens on herbage and soil, in top-soil and percolation to greater depths; adverse effects of other micro-organisms on pathogens in soil and varying types of manure.

3. Influence of various slurry treatment methods (physical-chemical-biological) on the persistence of pathogens.

4. Determinations of the virulence of pathogens after varying periods in stored slurry and following its application to pasture and soil.

5. Determination of survival periods of tubercle bacilli, non-coated viruses and coccidiae in poultry manure and deep litter, and methods of their inactivation.

6. Investigations of the occurrence and persistence of *Ascaris suum* in pig slurry in relation to its transmission via land-spreading to ruminants and man.

7. Investigations of sheep manure as a possible means of recycling helminths and other pathogens.

Dr. Downey
Dr. Geissler
Dr. Kelly
Dr. Strauch

THEMES 6 AND 7

CHAIRMAN'S DRAFT CONCLUSIONS AS A BASIS FOR DISCUSSION

1. That we should give attention to generalising results from experiments by the use of models which may be at the levels of research and of extension.

2. A long term policy for landspreading of animal manures should be related to the constraints of general regional policy, for example, recommendations on quality of surface waters.

3. Treatment and separation offer possibilities for modification of slurries which may have a favourable cost/ benefit ratio in some situations.

DISCUSSION

J.H. Voorburg *(The Netherlands)*

I have not had much time to study all the conclusions but as far as I can see there is quite a good agreement between the conclusions of the different chairmen and the group discussions that have taken place in the different hotels. If everyone has a copy of the papers I propose to discuss them in order and I suggest we start with the conclusions of Themes 1, 2 and 3. Is there anybody who wants to comment on these topics?

D.P. Collins *(Ireland)*

With regard to point 3, "Research on manure application on grassland should take account of the influence of manure on the sward and on animal behaviour", we are looking at the sward but since our experiment was only of a few months duration at the time I wrote the report we didn't have any results about sward. However, we will be looking at that in the course of our work and continuing our work on animal behaviour.

J.H. Voorburg

So you agree with this conclusion?

D.P. Collins

Oh yes, I do.

J.H. Voorburg

Anybody else? .... Then we can move on to Themes 4 and 5. They are quite detailed conclusions. The participants who have specialised in this field have signed so they are all in very good agreement but are there any comments from anybody else?

S. Baines *(UK)*

I wonder whether the specialists have given sufficient attention to the throughput of organisms into surface waters through drainage. The concentration is on the herbage and in the soils and perhaps not enough on microbial contamination of surface waters.

<u>J.H. Voorburg</u>

Are you proposing to add this?

<u>S. Baines</u>

I wouldn't want to propose it; I would like the experts to consider whether it is worth including - I think it is important.

<u>A. Dam Kofoed</u> *(Denmark)*

The question of bacilli is put in point 5 and I am sure that is right. What about this stronguli? It plays a very, very important role in my country and, I think, in some others. When bacilli is specified here, quite rightly, why shouldn't we put in that?

<u>D. Strauch</u> *(West Germany)*

Dr. Baines, I think this is covered in point 2 under, "Percolation to greater depths". In our opinion this also covers the ground water.

<u>S. Baines</u>

I mean drainage water ... drainage water going straight out ....

<u>D. Strauch</u>

You mean the run-off?

<u>S. Baines</u>

Either surface run-off or through drainage pipes. In our experience it can happen that within an hour of applying slurry you can have faecal organisms in the stream.

<u>D. Strauch</u>

Thank you, we will consider that. We could follow your proposal, Dr. Dam Kofoed, just by using the term 'helminths' or'parasites' instead of 'coccidiae'.

<u>J.H. Voorburg</u>

So point 5 will read, "Determination of survival periods of tubercle bacilli, non-coated viruses and parasites in poultry manure and deep litter, and methods of their inactivation". Have you a proposal regarding point 2?

H. van Dijk *(The Netherlands)*

I think this can be covered by changing 'percolation' to 'transport'.

S. Baines

'Transport into and out of the soil profile'. 'Out of' is particularly important, it is very rapid indeed.

J.S.V. McAllister *(UK)*

It might be better, Mr. Chairman, to say, 'top-soil and throughout the soil profile and into the ground water'.

S. Baines

It doesn't mean ground water, it means the drainage water.

J.H. Voorburg

O.K. I've got it. Are there any more comments on this paper? ..... Right, the third one is a short one, Themes 6 and 7, does anybody wish to comment on these conclusions? I should tell you that we will discuss the conclusions of the various hotel group discussions afterwards and in due course all the various conclusions will have to be harmonised. Now, are there any comments on the draft conclusions on Themes 6 and 7?

A. Cottenie *(Belgium)*

Mr. Chairman, my comment is not on what is on the paper but rather on what is not on it. Reading these recommendations I had the feeling that we have just accepted the situation as it is. We try to be informed on how the situation automatically evolves. We try to be informed about the harm we do, and so on. I am asking myself whether we should not think about the pressures put on a given region, on a given surface, by the intensive cattle breeding as it is practised in our different countries. Yesterday we visited holdings having 4 000 cattle pieces on 500 acres, or 250 ha. However, we know of examples of quite a large number of cattle on surfaces covering one tenth of that. Is that not also a problem about which we should think and try to give information to the people who are responsible to our law makers, to the people responsible for allowing the creation of new, and the extension of existing, holdings? Through the information that we have now, what is the input of nitrogen, of phosphorus, of potassium? What is the input of bacteria and other harmful elements and organisms per unit of surface and how far can we really go? To me these are very important questions.

J.H. Voorburg

Is this not covered by the very first conclusion, "More attention should be paid to the long term effect and to the impact on the environment of excessive amounts of manure"?

A. Cottenie

This is acceptable amounts of manure; I would go further.

H. van Dijk

Excessive amounts ....

A. Cottenie

Yes, but, I think about acceptable amounts of manure and therefore as a consequence of that, acceptable amounts of cattle per unit of surface.

H. van Dijk

Mr. Chairman, as far as I understand Dr. Cottenie, he is not only asking us to give the consequences of the effects of manuring but he also wants us to act as a kind of pressure group. Maybe that is too strong a term ....

A. Cottenie

Yes, it is.

H. van Dijk

But you were going in that direction and I think that this group is just to study the consequences of what is being done. The conclusions and actions to be taken in view of those consequences are the subject of political decisions and I don't think we should bring that in here. It might even endanger the co-operation within this group.

P. L'Hermite *(EEC)*

No, I regret I do not agree with you Dr. van Dijk. In order to convince politicians it is necessary to have an immediate channel of communication between you as scientists, who know exactly what the problems are and who can supply the information, through the intermediate organisation to the politicians. We must try to bring pressure on the politicians otherwise political decisions will not be made until it is too late to avoid the damaging effects of pollution. Decisions which are contrary to the present economic policy will not be made without pressure. So, if we have recommendations from this Seminar,the Commission can try, through the appropriate channels, to press for at least some small changes. We know that political change will always be subject to economic policy but at least the recommendations must be made; we must try to get any necessary legislation before pollution becomes an accomplished fact making it impossible for people to live in some areas, as has already happened in certain regions in Europe.

J.H. Voorburg

I want to comment on that because I am not in agreement with Mr. L'Hermite. Our task is to find the impact of manure landspreading, in this case, on the environment - on surface water, on ground water, and the effect of accumulation. We should try to predict the short term and especially the long term effects. We should try to find solutions to reduce the bad influence on the environment but it is not our job to make legislation or organise pressure groups. I am not in agreement; if you try to do that then you will never be able to have the kind of open discussion which we have had here.

P. L'Hermite

I think we have a misunderstanding. The problem is not to use you as a political pressure group. The problem is that the purpose of the research within the Commission is to help the common agricultural policy, in its regulations, and especially application to the farms. If you don't accept that the Commission uses the results of your research to do this I can say that you will never have from your Ministers the money for research through the Commission!

J.H. Voorburg

But it is not our job to formulate legislation. Our information is available and we will help you to make optimum use of it, but legislation is not our job.

A.V. Dodd *(Ireland)*

May I make a comment. Personally I feel that the Community has allocated quite a considerable amount of money to carry out research into what was recognised to be an established problem. From some of the surveys that have been reported at this Seminar, in my view it has now been proved to be a problem in many regions. Surely it is the job of this group of people who, after all, are being financed by public funds, in the end to come up with a set of recommendations rather than talk about predicting what will happen. Surely our function is to come up with a set of recommendations to ensure that the animal manures problem may not increase. This may be quite unpalatable to farmer oriented groups in society because it may well involve setting down stock/land ratios for specific regions. However, I feel in the end we must do that, make these recommendations.

T. Leenders *(EEC)*

I should like to support Dr. Cottenie's remarks, Mr. Chairman. I think there has been a misunderstanding between you and Dr. Cottenie, also with Mr. L'Hermite, because when you speak about the long term effects you are, at the same time, indicating measures which are necessary to avoid the harmful long term effects. I would like to see results of work made available more rapidly in view of the long term effects of pollution because we must also consider measures taken by other people, not by agrarian people but by departments of the environment, then we are in a defensive position and the best position is attack. However, when we want to attack we need the information and the figures. Therefore I would suggest that you should .....

J.H. Voorburg

.... find a compromise. Dr. Cottenie, in the conclusions of the discussion group from the Hotel Estense, point 2 a) suggests that more emphasis should be given to the limits of optimum manure application rates with regard to plant compatibility. I suggest we could add, 'and environment'.

A. Cottenie

Mr. Chairman, when I read all these recommendations I am very disappointed, I must say. My disappointment is because all these recommendations are just recommendations for further research. We just recommend that we might continue to do what we have been doing, that we get more money for doing that. Of course, I agree we must go on doing research and gathering information but I feel that we have already got some basic information which would enable us to conclude something now, and we have concluded nothing. That is my feeling. I don't want to be a pressure group; I don't want to take the place of the law makers, but I think we have the duty of supplying information and not only of listing figures but of trying to come to conclusions and to formulate a certain conclusion. So I go half-way to what Mr. L'Hermite says; I would not want us to be a pressure group but I feel that bringing home all these papers I might be able to calculate what is the maximum acceptable pressure for a given type of agricultural holding. I think we could come to such conclusions - not today - but with all the information which we have. That is the thing. As a group I feel that we should not only supply figures but also formulate conclusions even in the sense of a warning. I think that is needed by our law makers and by the Ministers of the European Community - a warning. We are very severe against industrial pollution and we should be equally careful regarding pollution in our own field of activity.

C. Tietjen *(West Germany)*

I agree with Dr. Cottenie but only as far as the topics of this Seminar are concerned. We must realise that this Seminar didn't deal with all those questions which have to be answered before laws are made. We didn't deal with socio/economic problems; we didn't deal with all the problems of social structure - small farm units, large farm units, and so on. The pressure from those groups is much stronger than just the dirty water problem.

H. Tunney *(Ireland)*

I get the feeling during this meeting that perhaps there is one area of almost complete agreement. That is that the rates of manures which should be applied to land (and indeed the rates of fertilisers) should be related in some way to the requirement of the crop. I think this is a reasonably unanimous feeling. Now, it may be that the rate the crop requires is right, or it may be that double the rate can be allowed as a maximum, but I think there is a relationship here. A group of scientists like the one gathered here has a responsibility to communicate this opinion to the politicians who are the people who legislate. It is up to them to decide whether they want to accept or reject this information; it is their responsibility to decide how they are going to legislate in the light of this knowledge.

J.H. Voorburg

It is not easy to come to a conclusion from this discussion. I understood that you wanted to have something like a guideline about amounts of livestock and amounts of manures that are acceptable. However, at this Seminar we have had such an overloaded programme and such a big group that I think it should be prepared in a smaller working group; it should be formulated in more detail and then it could be discussed afterwards. It was not our problem so the conclusion couldn't come out but maybe it can be a proposal to the European Commission to form a small group to prepare a guideline. This guideline should also be studied from other points of view. Do you agree with that conclusion, which I hope is on the tape?

J.S.V. McAllister

I am rather worried about the idea of guidelines. I am also a bit disappointed that much of the research seems to be work that has been done for a long time in certain countries. I am somewhat worried about the legal aspect of guidelines. We are quite an extensive livestock area in Northern Ireland and yet we did a survey during 12 months, about a year ago, of 17 farm streams with different intensities of stocking in the catchment areas and that was done in conjunction with our Department of the Environment. We only found 3 streams that had contamination and every one of those was a point source. At the moment there seems to be far more trouble in contamination from point sources than from intensive stocking, as far as we are concerned anyway, it may be different in other countries.

J.H. Voorburg

Thank you. We must move on now to the conclusions of the discussion groups in the various hotels. It would be better to discuss all three groups together but there has not been an opportunity to harmonise the conclusions although they are quite similar.

D. Strauch

I would just like to note here that in January in Rome there will be a seminar of UNEP together with FAO, on agricultural waste - not only animal waste but on all kinds of waste in agriculture. I think it would be a good idea if one representative of this group could attend this meeting. Perhaps Mr. L'Hermite could note the date, it is from 17th - 21st January 1977, in Rome.

CONCLUSIONS OF DISCUSSION GROUP
HOTEL ESTENSE

1. IMPROVEMENT OF INTERNATIONAL CO-OPERATION IN RESEARCH

a) The suggestion was made that the EEC should establish a documentation and information centre on the handling and utilisation of animal manure in the European Community. An inventory of all projects, whether subvened by the EEC or not, should be made available to all research workers concerned. Also, progress reports, at least of subvened projects, should be distributed.

b) Co-operation and co-ordination in research will also be improved by separate EEC seminars on technological innovations for collecting, storage, handling and treatment of animal waste and on harmonisation of sampling and analysis procedures.

2. IMPROVEMENT OF THE RESEARCH PROGRAMME

More emphasis should be given to projects on:

a) The limits of optimum manure application rates with regard to plant compatability (yield and quality).

b) The optimisation of the collection, storage and handling of manures, particularly from pigs and cattle.

c) Development of simple methods to estimate the fertiliser value of slurry. Development of equipment for accurate dosing of slurry in field trials.

CONCLUSIONS OF DISCUSSION GROUP
HOTEL EUROPA

1. IMPROVEMENT OF INTERNATIONAL CO-OPERATION IN RESEARCH

a) The group agreed that it was too early to judge the effectiveness of the Seminar.

b) It was proposed that a similar Seminar be held in three years time. In the meantime, smaller, more specialised groups should meet annually. These groups could meet under the following headings:

(i) Soil and water
(ii) Engineering
(iii) Disease and veterinary aspects

Group (i) may need to be subdivided into smaller categories.

c) There should be a regular exchange of written material (results, techniques, test reports on machinery, etc.).

2. IMPROVEMENT OF THE RESEARCH PROGRAMME

a) List composition of manures in different countries with reference to type of livestock, feed, storage, management, etc.

b) Standardise terminology.

c) Research required on storage of manures, including losses and changes in composition during storage.

d) Research required on physico-chemical treatment of slurry prior to landspreading.

e) Research required on the effect of nutrient imbalance on the quality of feedstuffs.

f) Research required on the effects of landspreading on ground waters.

g) More intensive studies on fertiliser value and fate of plant nutrients.

h) More research required on health problems.

CONCLUSIONS OF DISCUSSION GROUP
HOTEL ROMA

1. IMPROVEMENT OF INTERNATIONAL CO-OPERATION IN RESEARCH

The present Seminar, being very broad in its terms of reference, forged valuable links between widely disparate aspects of the problem, giving perspective to one's own research and enabling individual workers to view their projects in relation to those of others in the field. It was felt, however, that in the immediate future, some form of grouping would be desirable to enable workers with common objectives and overlapping problems to meet from time to time to exchange their data and ideas.

With this in mind the following proposals were made:

a) That international working groups be formed, such as:

(i) Heavy metals and their soil/water/plant/animal interactions.

(ii) Nitrogen (including methodology)

(iii) Phosphorus (including methodology)

(iv) Transmissible diseases of man and animals

(v) Computer modelling.

b) That the above groups hold two day international seminars (say, annually) in their particular areas, with emphasis on discussion; the proceedings of each group seminar to be forwarded to all other groups; all groups to come together for a comprehensive seminar in two or three years time.

c) National seminars to be held by all workers within each participating country; their proceedings to be circulated internationally.

d) Government regulations governing the use of slurry to be circulated between all workers in participating countries.

e) Circulation of scientific literature: that existing computer services within the Community be used for scanning and retrieval of literature for which programmes already exist.

2. IMPROVEMENT OF THE RESEARCH PROGRAMME

The meeting was unanimous in its opinion that this improvement will be a logical outcome of the foregoing proposals under heading 1. above.

DISCUSSION

<u>J.H. Voorburg</u> *(The Netherlands)*

Has anybody any comments on the conclusions of the discussion group from the Hotel Estense?

<u>C. Tietjen</u> *(West Germany)*

In point 2 b) I would like the last few words to be deleted because the point should relate to all kinds of animals.

<u>J.H. Voorburg</u>

Yes, as was shown for example, by Dr. Tunney. Thank you.

The groups from the Hotel Roma and the Hotel Europa both proposed more restricted seminars so there is quite good agreement that we should have more seminars but with more restricted groups.

<u>A. Dam Kofoed</u> *(Denmark)*

The Hotel Europa group, in point 1. a), state, "The group agreed that it was too early to judge the effectiveness of the Seminar". I wonder if I might just say that in my personal view it has been an extremely well organised and effective Seminar here and I congratulate the Chairman for that.

<u>J.H. Voorburg</u>

Thank you. You propose to scratch point 1. a)? ... It shall be cancelled, thank you.

<u>N.E. Downey</u> *(Ireland)*

Point 1. b) (iii) says, "Disease and veterinary aspects". In a sense they mean much the same thing but they don't include other aspects of animal work which might be done. I would suggest changing this to, "Animal and public health aspects".

<u>J.H. Voorburg</u>

Yes, is that accepted? .... O.K. Is there anything else relating to the Hotel Europa list? ... No. Then we will go on to the last hotel group, the Hotel Roma. There is a proposal about national seminars; I am not sure that the Community will organise national seminars ..

P. L'Hermite *(EEC)*

No, but scientific workshops are allowed.

S. Baines *(UK)*

I think in that point (1. c) the words 'to be' might be eliminated. I think the implication is intended to be that the results of any national seminars which are held anyway should be communicated, rather than that we should ask the EEC to set up national seminars.

J.H. Voorburg

So, you want the stress to be on the proceedings being circulated internationally?

S. Baines

Yes, right.

P. L'Hermite

I can tell you that within the co-ordination of each programme we generally invite participants in our programme to attend national seminars or they can ask us to participate in the expenses for attending national seminars.

A. Dam Kofoed

I had overlooked it until now but I would suggest that a survey of the research programme that goes on in the EEC be added.

J. van den Burg *(The Netherlands)*

Point 1. d), "Government regulations governing the use of slurry to be circulated between all workers in participating countries". I do not quite understand the meaning of it - is it the circulating of slurry?!

J.H. Voorburg

No! It is the information about legislation and guidelines. For example, the paper from Dr. Graffin that was promised. Dr Graffin is making an inventory of the existing legislation and he proposes to send the results to you all.

J. van den Burg

Mr. Chairman, maybe my English is too poor but when I read this I had a strange impression. However, if the English people say the sentence is all right, O.K. I think it is more a problem of language.

A.V. Dodd *(Ireland)*

Perhaps the sentence could be changed to, "Government regulations governing the construction of new animal production units and the management of slurry therefrom, should be circulated". I think both these things go together.

J.H. Voorburg

I hope it is on the tape! Thank you.

J.S.V. McAllister *(UK)*

I am not sure whether it should be regulations or guidelines because some countries have guidelines but not regulations.

J.H. Voorburg

You want them both? O.K. that's agreed. Is there anything else? .... Then we can stop discussing the conclusions and I will welcome Dr. Baracchi who has a short message for us.

P.P. Baracchi *(Italy)*

Mr. Chairman, ladies and gentlemen, I am Dr. Baracchi, a chemist who specialises in the pollution problem and I belong to the Centre for Ecological Defence. The Chairman is kindly allowing me to speak for two minutes.

First, I want to say that it is very good that you have held this Seminar here in Modena. I think that Modena is a great place to hold a Seminar like this one. Secondly, I want to tell you that my colleagues from the anti-pollution centre have been working for many years on the problem of intensive farm slurry in co-operation with the Experimental Institute of Agronomy. Therefore I would like to promise you that all the pollution specialists of Modena will take account of what has been said during this Seminar by the so-eminent participants. Thank you Mr. Chairman, thank you everybody.

J.H. Voorburg

Thank you very much Dr. Baracchi for this short message. You will understand from the discussion we had about our conclusions after the remarks and comments made by Dr. Cottenie, that we are not just doing research for the sake of research, we are very motivated. Thank you very much.

Before closing this Seminar I have to express thanks on behalf of Mr. L'Hermite. As far as I know this Seminar is the first to be organised by two separate organisations. I hope you will understand that initially I had some doubts about this type of set-up. Usually there is a local organiser who is also the Chairman of the seminar. However, this week has proved that we have had a very fruitful co-operation resulting in a very good Seminar, not only from a technical point of view, but there has also been a very pleasant atmosphere. So many things have been organised around the Seminar, not only in the form of cocktail parties, that we have had a very intensive week and not only from the scientific point of view.

Therefore, in the first place I have to express our thanks to Professor Lanza and Dr. Boschi and also to the people who have assisted them. It is very dangerous to mention names so I will not do that but I ask you especially to clap for the Secretariat which has done such a very good job, not only in putting things down on paper but also in organising our hotels, our trains, in fact, everything we have asked them. I would like to single out one person and that is the interpreter. He is the best interpreter I ever met, for example, he translated 'Mr. Voorburg' into 'Professore Voorburg' ...!

Of course, I also add my thanks to Janssen Services, the people who are making the report of the discussions, but perhaps it is too early because we haven't seen their work yet!

Finally, I want to express my thanks to all of you, the participants. I was worried about the numbers; I was afraid that you wouldn't act as a group, but I can see that we became friends, we got to know each other, and we had very open discussions. I would especially stress my thanks to the participants whose mother language is not English, as in my case, not only because you have had to listen to my very bad English but also because I know that many of you have to make a great effort to discuss here in English, to give papers in English, and I am sure this was a very valuable contribution which you made. If we had used simultaneous translation it would have been easier for you but the Seminar would not have been so fruitful as it has been now. We have been able to have much better open discussions, we have had more direct contact, we were a more homogenous group, and we were able to make friends much more easily, which is also important. Thank you very much.

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