



environment and quality of life

Methods and costs of preventing Cadmium emissions

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COMMISSION OF THE EUROPEAN COMMUNITIES

environment and quality of life

Methods and costs of preventing Cadmium emissions

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A. Rauhut
(Landesgewerbeamt Bayern, Nürnberg)

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SUMMARY

The most common methods of removing cadmium from waste water are neutralisation precipitation, carbonate precipitation, sulphide precipitation, and ion exchanger + neutralisation precipitation.

For the purification of exhaust air electrostatic filters, cloth filters and wet scrubbing are employed. The efficiency of recovery techniques is described and the limiting values obtained are discussed. Costs of waste water and exhaust air purification are presented.

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1 CONVENTIONAL METHODS OF REDUCING EMISSIONS

1,1 Water

Note: The possibility of eliminating cadmium from solutions is based on the decreasing solubility of cadmium with increasing pH value.

Daester and Jolla⁽¹⁾ made a detailed study of the problems of precipitating heavy metals from waste water. Theoretically, the residual concentration of cadmium ions is obtained from the solubility product of cadmium hydroxide at different pH values:

<u>pH value</u>	<u>Residual concentration of Cd²⁺ mg/litre</u>
8	1120
9	11.2
9.5	1.12
10	0.112

The authors emphasize that the calculation is only valid for ideal conditions, which is not the case with present-day conditions of waste water. Neutral salts, which are always present, cause an increase in the residual concentration after hydroxide precipitation, as can be demonstrated by including the activity coefficients in the calculation.

In the purification of metal-containing waste water it is necessary to ensure that the waste water does not contain any complexing agents. In the case of cadmium, particular attention must be paid to ammonium ions (NH_4^+) and cyanide ions (CN^-). As some cadmium-containing waste waters are cyanidic, the CN^- has to be removed from the solution before the actual precipitation by oxidation with NaOCl at pH 11-12.

It was shown in the work of Daester and Jolla⁽¹⁾ that even less than 100 mg/litre NH_4^+ leads to a tenfold increase in the solubility of cadmium hydroxide.

1.1.1 Neutralization precipitation

Neutralization precipitation can be effected with NaOH or Ca(OH)₂.

The reaction is as follows: $\text{Cd}^{2+} + 2(\text{OH})^{-} \longrightarrow \text{Cd}(\text{OH})_2$.

To conduct this neutralization precipitation, the waste water must be adjusted to a pH range which provides the correct conditions for obtaining the desired cadmium concentration after precipitation. After adjusting the pH value with the above-mentioned precipitating compound, the precipitate is filtered or allowed to settle. The most economical method of separating the precipitation residue depends mainly on the amount of water involved. Up to about 50 m³/h it is economical to filter using chamber filter presses. Above 50 m³/h it is usual to employ sedimentation in large settling tanks. If the water which runs off has the prescribed concentrations for sewage it can be discharged into the main drain.

Neutralization precipitation with sodium hydroxide is a particularly simple operation. NaOH is readily soluble and easily measured out; the resulting precipitates can usually be separated or filtered easily.

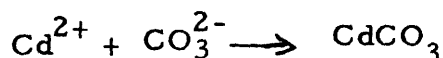
Waste water with a high sulphate content may have disadvantages. If lime precipitation is used in this case it may result in concentration precipitates of CaSO₄·2H₂O (the solubility of gypsum at 20°C is 2 g/litre).

Since certain metals are of an amphoteric nature, the precipitate dissolves with increasing pH, with formation of hydroxo-compounds.

In the presence of complexing agents (e. g. NH₄⁺, CN⁻), precipitation may not occur at all. Organic complexing agents form even more stable complexes with the metal, so that satisfactory precipitation is impossible. The presence of heavy metals favours the precipitation of cadmium owing to their combined effect.

1.1.2 Carbonate precipitation

Precipitation is effected with Na₂CO₃ solution. The precipitation reaction is as follows:



As the precipitate has a crystalline structure, the result is good filterability and a low residual water content in the filter residue.

The reservations which were made regarding hydroxide precipitation also apply to carbonate precipitation. The attainment of high pH values without addition of NaOH requires a large excess of soda.

The above-mentioned neutralization process for precipitation of metal hydroxides or carbonates and the subsequent separation of the solids by gravity sedimentation or filtration should be regarded as the process which meets the accepted technical standards.

The other methods described below for reducing the cadmium content of waste water cannot yet be applied on a large scale, or may only be applied in special cases which cannot be generalised.

1.1.3 Sulphide precipitation

The solubility of cadmium sulphide is so low that the influence of foreign salts does not play a significant role in this method. Even in the presence of complexing agents, sulphide precipitation is possible. Precipitation occurs with a satisfactory degree of separation even under acid conditions. The solubility of CdS is so much lower than $\text{Cd}(\text{OH})_2$ or CdCO_3 that sulphide precipitation should undoubtedly be the most suitable method for removal of Cd^{2+} .

However, the sulphide is highly toxic and has a very low olfactory threshold (< 0.1 ppm). This requires expensive equipment and expert supervision. The air leaving the storage vessels, make-up vessels, precipitation tanks and the filtration equipment must be drawn off and made odourless, e. g. by burning. In the filtrate as well, H_2S must be destroyed quantitatively, e. g. by addition of H_2O_2 . Additional problems may occur if the metal sulphides are produced in colloidal form. In view of its many disadvantages, and in particular the high toxicity of hydrogen sulphide, sulphide precipitation does not appear to be a good proposition.

1.1.4 Ion exchange + neutralization precipitation

As noted in an EEC study (ENV/588/76), the treatment of effluent containing heavy metals by the use of ion exchangers should be regarded as a practical proposition.

The cadmium-containing water is first passed through a cationic exchanger and then through an anionic exchanger. Water purified in this way can be fed back to the works and recycled.

The ion exchanger requires regenerating at intervals involving a process that is the reverse of water purification. The cadmium is at a much higher concentration in the effluent from ion-exchanger regeneration and neutralization precipitation can be effected with little loss of water.

The ion exchanger is chiefly suited to the purification of large amounts of effluent with low metal content, in order to make possible the recycling of process water.

There are particular advantages when the metal solutions are of high purity.

Another possible application of the ion exchanger is selective purification, as a second stage in purification.

1.1.5 Other processes

Reverse osmosis, ion flotation, liquid-liquid extraction, electrolysis and cementation are processes which so far have only played a secondary role in sewage treatment, and are not employed on a large scale.

1.2 Air

The type of equipment used to reduce cadmium emissions varies considerably, depending mainly on the amount of gas to be treated, the type of gases and the dust content of the gas streams to be purified.

1.2.1 Electrostatic filters

In the electrostatic filter, a rectified high voltage is applied between a discharge electrode and a collector electrode. The dust-containing gas flows through the electric field. In this field the dust becomes negatively charged and migrates to the positively-charged electrode on account of the resulting Coulomb force. A small proportion of the dust receives a positive charge under the influence of the corona discharge, and migrates to the discharge electrode. Both systems of electrodes are cleaned periodically by tapping. The dust, in large crust-like agglomerates, is collected in filter hoppers situated below the electrostatic precipitator and is removed continuously. In addition to this dry electrostatic filter system, there is also a wet system in which the water-vapour-saturated crude gas flow is passed through an electric field. Dust and water particles are precipitated together on the electrodes, and are removed periodically by brief spells of rinsing. The dust flows away in waste water and must undergo further treatment by concentrating or treatment of the resultant effluent,

The electrostatic precipitator is currently the usual method of purifying large quantities of gas with a high dust content, in order to achieve high degrees of separation. This system is mainly employed at power stations and refuse burning plants. The proportion of cadmium in the dust contained in the crude gas is so low that the degree of purification achieved by the electrostatic filter also makes it possible to attain the values prescribed for the emission of heavy metals. Purification of gases containing higher concentrations of heavy metals requires other systems.

1.2.2 Cloth filters

Cloth filters, which can be designed as a hose, pocket, bag, mat, rigid tube or moulded article, consist of various materials depending on their application. These include fibre mats, fleece materials, needle felting or wool felt, and porous, ceramic and metallic structures, the elements of which can be arranged both horizontally and vertically.

The filtering effect of the cloth filter does not consist purely of the filtering action of the cloth, but above all, the filtering effect of a layer of the dust being filtered. The cloth filter reaches its optimum purification ability when a filtering layer of dust has formed on the supporting fabric of the filter, since this possesses a much greater filtering effect than the filter fabric itself.

The crude gas flow impinges either on the outside or on the inside of the bag filter. The filter cloth retains the dust particles. The purified gas is discharged on the inside or outside of the filter, depending on its design. These bag filters are cleaned by mechanical shaking of the filter bags, by means of a gas stream flowing in the reverse direction, or by short bursts of compressed air. It is also possible to combine shaking and air 'rinsing'. In all cases the dust falls away from the bag filter and is carried away in a dust collecting channel.

The filter bags, which are made in various lengths and combined in varying numbers, can in this way be adjusted to the gas flow occurring in the particular application. If large quantities of gas need to be purified, the filter units are combined into what are known as filter boxes. Cleaning and replacement of damaged bags can be undertaken in sections, so that continuous operation is possible.

1.2.3 Wet scrubbing

In wet scrubbing by the counterflow principle or in the Venturi scrubber, the gas stream is mixed with a washing liquid, so that the dust particles adhere to particles of liquid. The dust-laden particles of liquid can then be precipitated, to undergo further treatment as sludge. In the course of this treatment, it is generally also necessary to treat the resultant waste water. Energy consumption for intimate mixing, especially in Venturi scrubbers, is very high, so that application is only appropriate under special conditions (small quantities of gas, high cadmium concentration).

1.3 Disposal at dumps

In order to reduce the cadmium content in dumps, either the proportion of cadmium in the refuse, or the amount of refuse itself, must be reduced.

Reduction of the cadmium concentration without changing the amount of refuse would require improvement of the production technology, in order to provide even better extraction of cadmium from cadmium-containing products.

The second case includes, for example, the waste produced in air and sewage purification. It is difficult to alter the cadmium concentration of this waste on the basis of purification techniques and attention should therefore be concentrated on developing processing methods which give rise to less cadmium pollution of the waste air or waste water.

Another possibility for reducing the pollution at dumps would be to produce cadmium-containing products with the aim of recovering the cadmium and returning it to the metal cycle.

Administrative measures, i. e. the threat of fines, seem to be much less effective from this point of view. Methods of creating economic incentives, to make the recovery of cadmium-containing products economic, are preferable.

1.4 Efficiency of existing recovery techniques

1.4.1 Water

The Bavarian Industrial Institute (Landesgewerbeanstalt Bayern) has conducted its own investigations to review the efficiency of neutralization precipitation in pure solutions and industrial effluents.

1. Neutralization precipitation in pure solutions

Cadmium was precipitated with NaOH and with $\text{Ca}(\text{OH})_2$. Precipitation was effected in the pH range 8.5-11.5, the 1 : 10 diluted mother liquor (1 g Cd/l) was left to stand overnight with the

precipitate and the pH was measured again, immediately before and after filtering. It was found that the pH value had already changed before filtration (alkaline constituents = $\text{Cd}(\text{OH})_2$ had settled). After filtration the pH is usually even lower, the difference being smaller the higher the precipitation pH value.

The $\text{Cd}(\text{OH})_2$ deposit is white, gelatinous and readily filtrable.

The precipitate was filtered with a blue band filter. After filtration, the residual concentration of Cd^{2+} ions was measured by flameless atomic absorption spectrometry. The results are given in Fig. 1.

2. Carbonate precipitation in pure solutions

Cadmium was precipitated with Na_2CO_3 solution, as cadmium carbonate or basic cadmium carbonate. Precipitation was effected in the pH range 8-12. It was established that the precipitate is least soluble in the region of pH 10. Then the cadmium content starts to increase again. Cadmium thus displays amphoteric behaviour with respect to carbonate ions. The CdCO_3 precipitate is white, fine-grained and readily filtrable. The solubility of CdCO_3 is lower than that of $\text{Cd}(\text{OH})_2$. The minimum in the precipitation curve lies around pH 9.6 with a residual concentration of 0.03 mg Cd^{2+} /litre. The precipitation curves are shown in Fig. 2.

These values were obtained under laboratory conditions and are therefore not directly applicable to practical conditions. The waste water from a unit producing metals and metallic compounds often contains various other constituents apart from cadmium, and their influence on the ease of precipitation of the cadmium has to be taken into account. In addition to other metals such as copper and zinc, which also have to be precipitated out and separated, the waste water generally also contains carbonate or bicarbonate ions, which originate either from the process or from the carbonate hardness of the water used in the production process. This carbonate-ion content is very desirable with regard to the more complete elimination of cadmium from the waste water. It makes the addition of

Fig. 1.

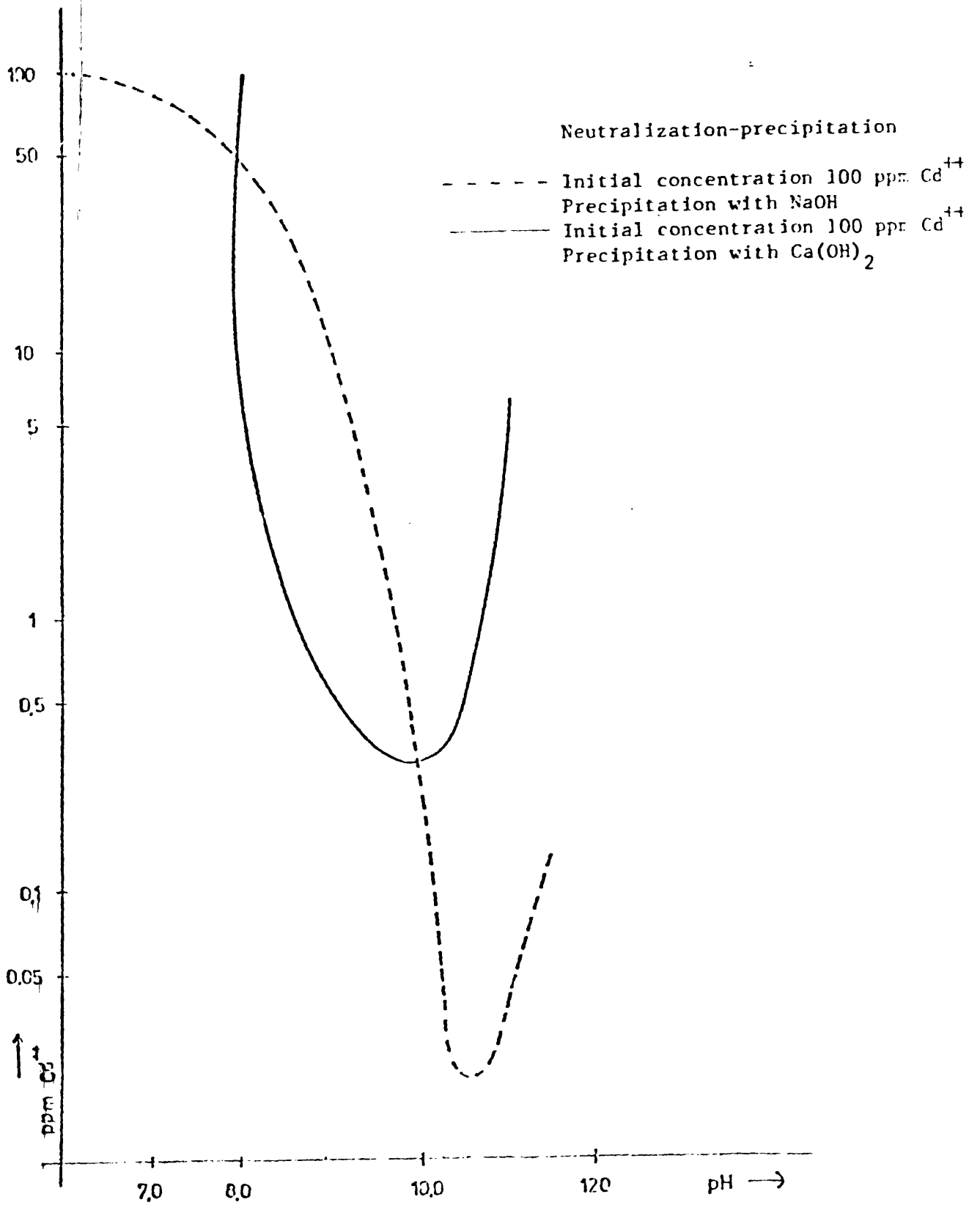
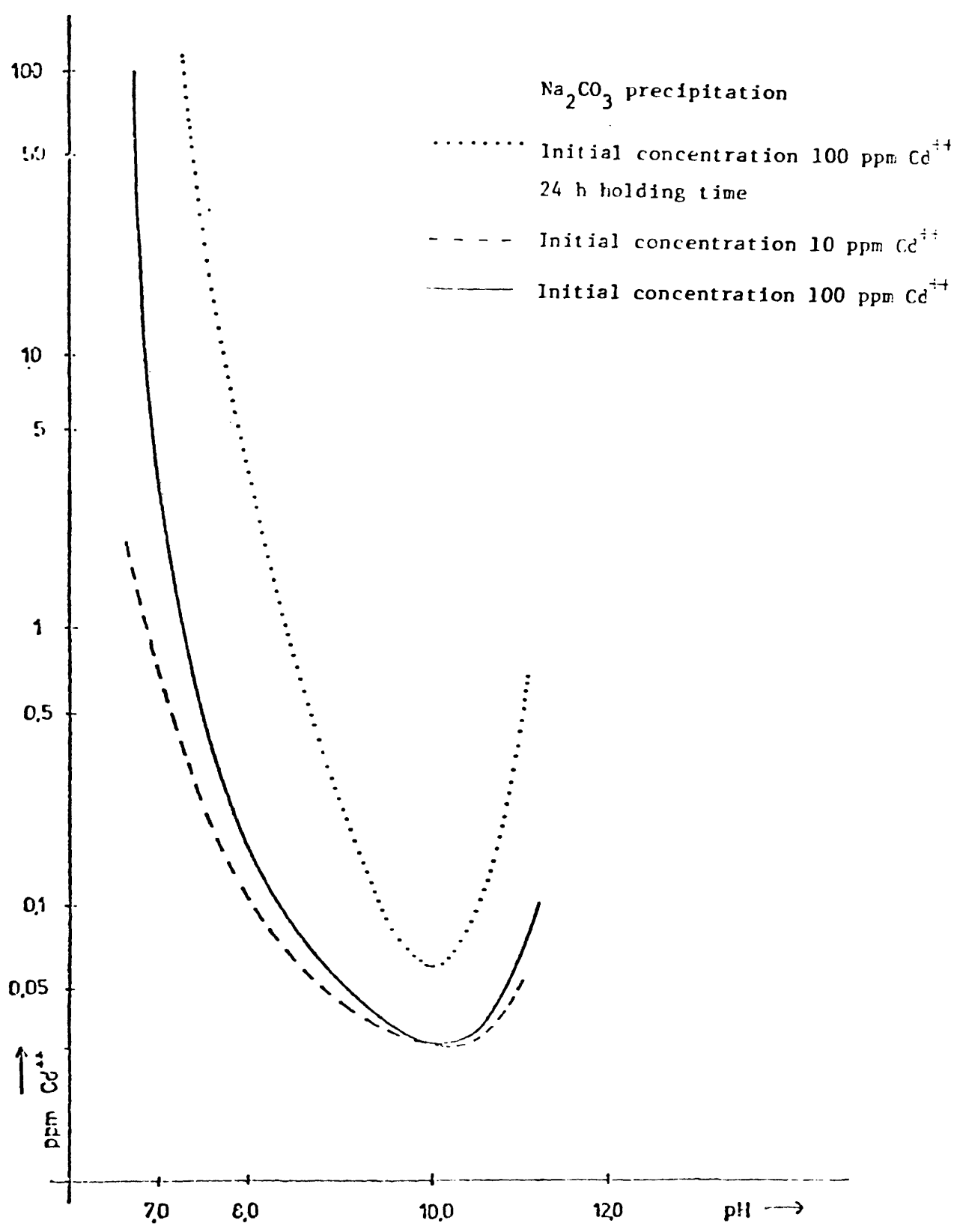


Fig. 2.



soda solution superfluous. However, the favourable effect of the carbonate ions is partly counterbalanced by the simultaneous presence of neutral salts, the presence of which leads to an increase in the residual concentration of all metals, as can also be shown theoretically by including the activity coefficients in the solubility calculation. Complexing agents, e. g. ammonium ions, act in the same manner but much more strongly, and they are present in nearly all industrial effluent. Even at less than 100 mg/litre NH_4^+ there is a considerable increase in the solubility of cadmium hydroxide; other organic or inorganic complexing agents have a similar effect.

3, Effluent samples from electroplating works

Further studies were conducted on effluent samples from two different works.

Samples A and B are from jobbing platers processing cadmium. Samples C and D are from effluent from works specialising in cadmium plating. Results are shown in Figs. 3 and 4. All precipitation series gave a decrease in cadmium concentration. In contrast to the prepared pure solutions, carbonate and hydroxide precipitation led to quite similar results for the effluent samples.

These laboratory precipitation tests on samples of industrial effluents showed that it is possible, with optimal adjustment of pH, to obtain cadmium concentrations of 0.5 mg/litre, or even lower.

The applicability of the adjustment of the optimal pH value to between 9.7 and 10.5 is limited to electroplating operations. Separate treatment of the waste water from electroplating makes it possible to reach as low as 0.5 mg/litre using neutralisation precipitation. This generally applies to work with up to 500 m³ of waste water per day. In other cadmium processing works with quantities of waste water of the order of several thousand m³, such an adjustment to optimal pH can only take place to a limited extent. If a very small lime content makes it possible to adjust the pH to between 9.7 and 10.5, then a limiting value of 1 mg/l would be attainable even with larger quantities of waste water. If higher lime contents are used for precipitation deposits can form on all parts of the machinery so that after a short time impairment of the plant can occur.

Fig. 3.

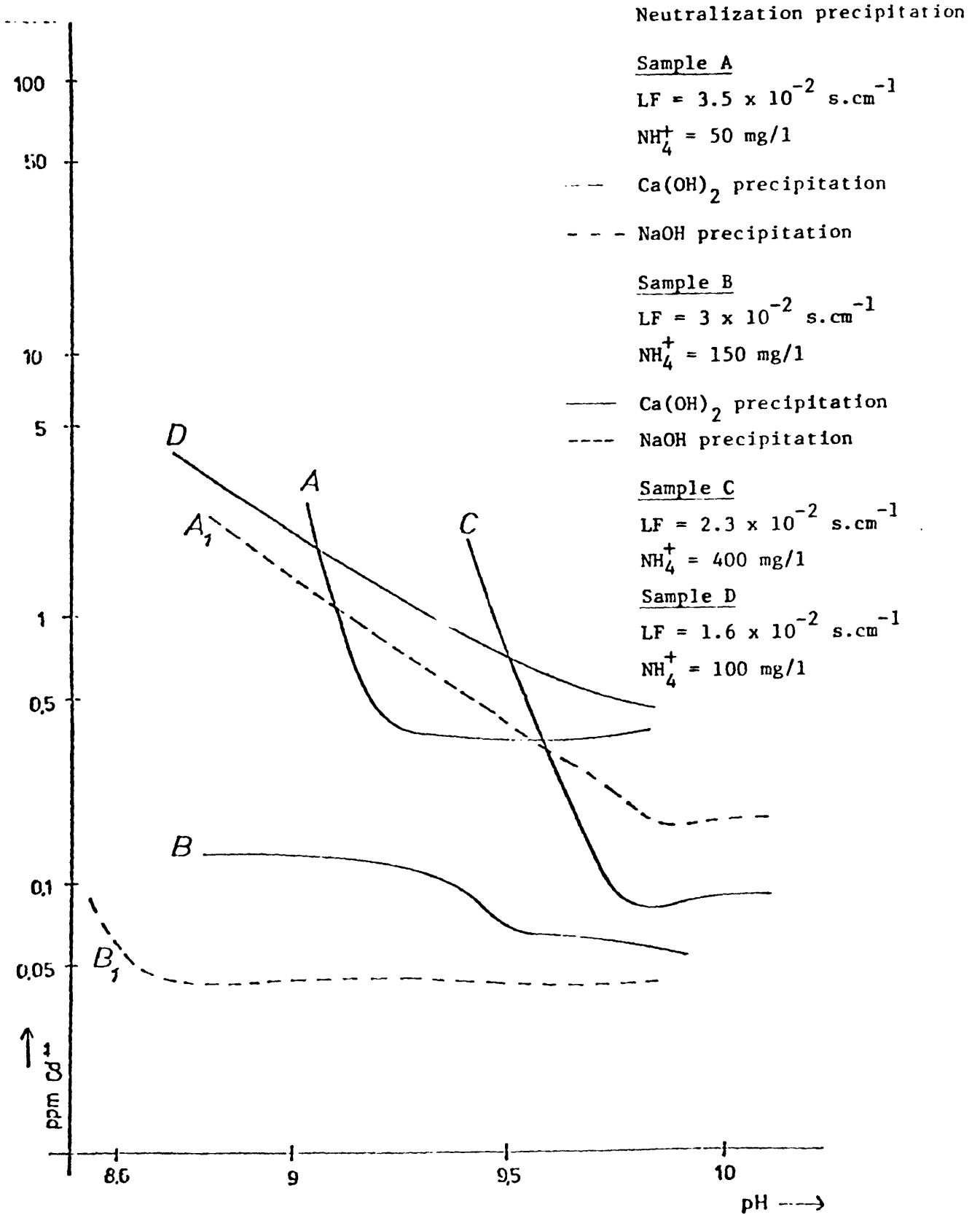
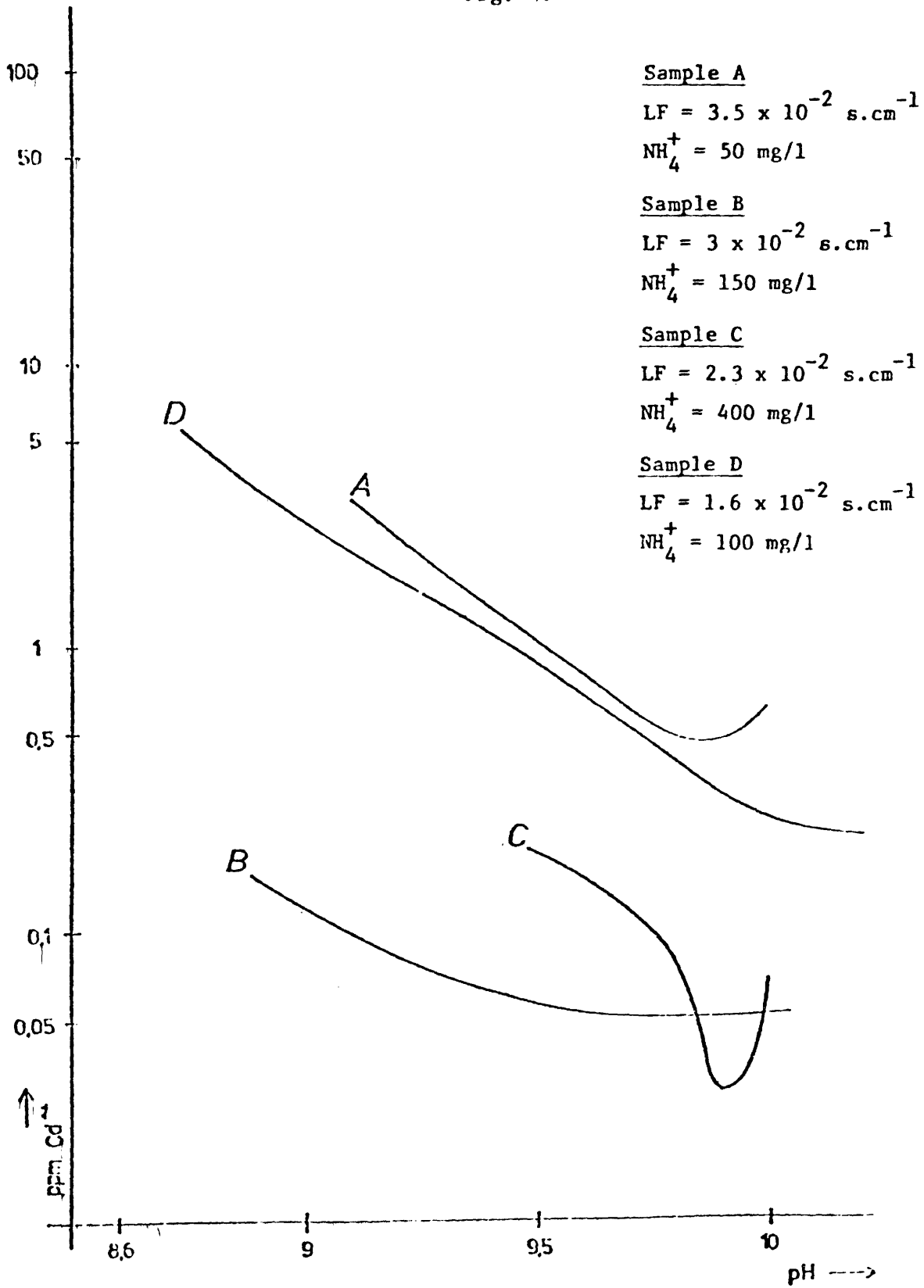


Fig. 4.



This difficulty can be avoided by reducing the pH value to pH 8-9. However, by doing this the precipitation of cadmium becomes less efficient, so that, taking into account standard deviations and a 95% confidence limit, a limiting value of 2.5 - 3.0 mg/l can be obtained for individual samples using existing equipment.

In practice, numerous factors affect the residual concentration of cadmium and other metals, and these must be taken into account. Errors in sampling and analysis, unavoidable disturbances and fluctuations in production and in the operation of the purification plant affect the attainable metal concentration of the discharged effluent.

1.4.2 Air

When highly efficient filter equipment is employed, e.g. electrostatic precipitators, bag filters or Venturi scrubbers, high degrees of separation are achieved for fine particles in the range of 0.2 to 1 μm ; for particles of 1 μm the efficiency is around 98 to 99%. The degrees of separation of these filter systems below 0.1 μm are not known.

Filtration of these extremely fine particles can be accomplished with expensive filtration plant, but this is not yet in large-scale use.

Electrostatic filters are capable of separating particles down to 0.1 μm . Degrees of separation of 95-99% are achieved. These values are dependent on the granulometric composition and conductivity of the dusts. The preconditions are not always present for cadmium, zinc and lead dusts. Therefore electrostatic filters are not usually employed for purification of gases containing a high proportion of these metals. Cloth filter units are generally used in such cases.

The efficiency of cloth filter units depends on the filter surfaces being of sufficient size and on the correct choice of cloth. As a rule the cloth of the filter serves only as a supporting fabric for the build-up of a filtering layer formed by the particles themselves. If the air resistance of this filtering layer becomes too great, it can be cleaned by tapping, shaking or compressed-air 'rinsing'. A filtering layer then reforms and ensures efficient filtration. If the filter has the correct dimensions, the dust

particles are not pulled through the filter, but are trapped in the filtering layer of dust. In time the filter cloth becomes damaged by mechanical stress and the action of extremely fine dust particles. Fine holes develop in the cloth, enabling more dust to pass through. Filtering efficiency then drops. When the filtering efficiency is no longer sufficient to meet the required threshold values, filters must be replaced.

With correct dimensioning of the filter surfaces, it may be assumed that the unit attains values of about 10 mg/Nm^3 after a running-in period.

If the dimensions of the unit are too small, there is a high air load per unit area of filter surface, and as a result more dust particles are pulled through the filter and there is a corresponding drop in the quality of purification. There is also increased filter wear. The initial degrees of separation obtainable with a correctly-dimensioned unit fall with time for the reasons mentioned above. How long a filtration unit can remain installed depends on the prescribed threshold limits. In plants which maintain a threshold limit of 20 mg/Nm^3 , the filters must be replaced sooner than in plants which have to observe threshold limits of 50 mg/Nm^3 . With properly dimensioned load per unit area of the filters, the question of which threshold limits are observed depends essentially on the durability of the filter medium. Therefore a change in the permissible emission limits need not always lead to higher capital costs, but only requires more frequent filter replacement.

With the existing filter equipment it is extremely difficult to meet threshold limits below 10 mg , and all regulations specify the successive installation of different filter media.

1.5 New technical possibilities for reducing environmental pollution

1.5.1 Water

At the present time, neutralization precipitation is chiefly used for the purification of industrial effluents, as it conforms with the present level of technology.

This neutralization precipitation will probably be improved in the future by a supplementary process, which will make possible a greater reduction in the metal concentration. We have in mind the precipitation of iron, aluminium or strontium hydroxides or phosphates, employed in conjunction with chemical precipitation. The collection efficiency thus achieved permits better purification of the liquids than has hitherto been possible using neutralization precipitation alone.

These methods should not yet be regarded as an industrially applicable level of technology. Once it has passed through the prototype stage, this process should give a purification efficiency down to threshold values of 0.5 to 1 mg/litre cadmium. It is expected that this process will find large-scale application in a few years.

At present the use of ion exchangers, in conjunction with neutralization precipitation of reclaimed products, is limited to the electroplating field. However, their use in this field is facilitated by the presence of pure solutions with low contents of alkaline earth elements. For the remainder of the cadmium processing industry, ion-exchange equipment can only be regarded as a technique for subsequent selective purification, even in the future.

Other processes, such as reverse osmosis, liquid-liquid extraction, electrolysis and cementation, do not at present show any development trends which might permit technical realization under suitable economic conditions in the near future.

1.5.2 Air

No basically new technologies for purification of waste air are known at present. The currently-employed methods of electrical gas purification, and the use of cloth filters, are sufficient to maintain concentrations between 10 and 20 mg Cd/Nm³. Whether or not this figure can be achieved then depends solely on adequate dimensioning of the equipment with correspondingly low surface loading of the filters. Maintenance of this

value requires good servicing of the filter media.

The existing filter systems are not able to attain the much lower values of between 5 and 2 mg Cd/Nm³. If such values are to be observed, additional filter units must be fitted. Adhesive-coated once-only filters, which trap most of the residual dust emerging from the main filter, can be used for this purpose. After the cleaning power of this additional filter has been exhausted, a new filter must be inserted, or in the case of a strip filter a new section of filter must be unwound from a roll. High efficiency Venturi scrubbers also attain these values.

2 COSTS OF REDUCING EMISSIONS

2.1 Water

Some costs relating to the neutralization precipitation of cadmium-containing waste water are given below. It was assumed that these costs arise in purifying waste water to a threshold value of 2 mg cadmium per cubic metre.

As with nearly all industrial plants, effluent purification installations exhibit unit cost reductions in larger plants.

The capital costs given in the following table include an addition of 25% for the costs of installing on site and for commissioning.

COSTS OF TREATING WASTE WATER IN NEUTRALISATION UNITS (10 years useful life, 6% interest on capital)

m ³ /h	Capital costs DM	Depreciation DM/m ³	Interest DM/m ³	Costs of chemicals DM/m ³	Staff wages DM/m ³	Total costs DM/m ³
5	40-50,000	0.50	0.15	0.50	0.30	1.45
10	120,000	0.60	0.18	0.50	0.15	1.43
50	250-300,000	0.30	0.09	0.50	0.15	1.04
100	400-500,000	0.25	0.07	0.50	0.15	0.97

Costs for fresh water and sewerage charges are not included in these amounts.

The space required for this single neutralization unit with controls, sludge settling tanks and filter press is as follows:

<u>Capacity, m³/h</u>	<u>Space required, m²</u>
up to 20	100
up to 50	150
100	300

When using an ion-exchange unit + neutralization precipitation as a waste-water purification plant, the costs of purification per cubic metre are increased mainly on account of the higher capital costs of the ion-exchange unit. The capital costs of the unit for treating the regenerated eluate from the ion-exchange unit are lower, on account of the smaller quantities of water, than in a waste-water purification plant for the total volume of waste water purified in the ion exchanger. Nevertheless, the total costs are still higher than for a pure waste-water treatment plant for the number of cubic metres. The costs of purifying 30-50 m³ waste water, using ion-exchange equipment, amount to 2-3 DM per cubic metre of water recycled. About 80% of fresh water can be saved.

2.2 Air

In contrast to the purification of waste water, there are considerable variations in the conditions for purifying cadmium-containing gas streams. The conditions vary so much in the cadmium-processing branches of industry and in the branches of industry where cadmium-containing gas streams are produced that the costs of gas purification show marked differences.

Electrical methods of gas purification are employed in coal-fired power stations and refuse-burning plants. In these fields the cadmium is of no value, as its concentration is very low. The only purpose of the units is to reduce dust emission. Cost analysis of these units in power stations and refuse burning plants does not therefore appear to be meaningful, since cadmium is only present as an unimportant impurity, although it is concentrated to a certain extent in the separated filter dust.

Dry and wet electrical methods of gas purification are employed to a large extent in non-ferrous metal works. They are used to purify the roaster gas, which is then fed to the Contact unit for sulphuric acid. Before this, however, the entrained roaster-gas dust must be removed; this consists of dusts containing zinc, lead and cadmium, which are subsequently reprocessed directly. As these units are usually designed for large quantities of gas, the capital costs and running costs are high. However, these costs cannot be ascribed to individual contents that are separated, but are for all the valuable materials recovered, such as zinc, lead and cadmium, of which cadmium only accounts for a small proportion of the value.

It does not seem appropriate to examine the costs of these units only in terms of reduction of cadmium emission, since they also serve to separate zinc and lead, which greatly predominate in terms of value.

Costs for these units are not considered further.

In all other fields where cadmium is used, cloth filters are the main means of exhaust air purification. Analysis of the type of waste gases from the various fields of application of cadmium has shown that there is no uniform type of dust or volume of gas. It is therefore necessary to adopt the principle that any application of cadmium in which air pollution might occur requires gas purification tailor-made for the particular case. A comparative study of the purification of exhaust air from the manufacture of pigments and of stabilizers has shown that the purification problems are entirely different here, and have corresponding consequences for the size and design of the equipment.

For these reasons it is neither possible nor meaningful to make general statements about the costs of exhaust air purification.

The results of plant comparisons are given below, to give at least an idea of the order of magnitude of the costs and also to elucidate the differences in the solution of the purification problems.

2.2.1 Exhaust air purification in the manufacture of cadmium-barium stabilizers

In the manufacture of cadmium-barium stabilizers, the cadmium-barium compounds are formed by a precipitation process, then filtered off and dried. Dust extractors must be employed during drying and subsequent processing.

Cadmium-barium stabilizers have a soapy consistency in the dry state. This property must be taken into account in the air separation equipment. Cloth filters tend to become clogged by metal soaps with increasing duration of use. The resulting increase in resistance to the air flow can only be eliminated for a certain time by cleaning. If the air resistance becomes too great, the filters must be removed and cleaned. They can be used again after cleaning. Compared with filters for other types of dust, they have longer service lives, since the filtration does not cause damage to the cloth, as is the case with other types of dust.

The following are the annual costs of equipment for purifying approx. 10,000 Nm³:

Capital costs (81,000 DM; 10 years useful life)	8,100 DM
Maintenance costs (one set of filter bags per year)	4,000 DM
Servicing (including staff costs)	20,000 DM
Cost of cleaning bags	2,500 DM
Power	1,000 DM
Interest	4,900 DM
	<hr/>
	40,500 DM

2.2.2 Exhaust air purification in the manufacture of cadmium pigments

Various stages in the manufacture of cadmium pigments, including grinding and bagging, are provided with extractor equipment to prevent contamination of the air in the workplace and to purify the outgoing air. Cadmium pigments are extremely fine-grained (0.4 µm) and are absolutely dry. In the course of time cadmium salts damage the filter cloth, leading to a deterioration in

the efficiency of the filter.

Purification of an exhaust air flow of 2000 Nm³ involves the following annual costs:

Capital costs (35,000 DM; 10 years useful life)	3,500 DM
Maintenance costs (annual replacement of filters)	750 DM
Servicing (including staff costs)	2,100 DM
Power	750 DM
Interest	2,100 DM
	<hr/>
	9,200 DM

The design of both units was based on maximum values of 2-5 mg/m³.

The costs stated assume that the purification equipment can be installed in the building without additional rebuilding. The costs do not include outlay on pipelines from the rooms to be purified to the filter unit.

Furthermore, it was not possible to take into account the costs sometimes required to convert buildings for the installation of exhaust lines. Specific working conditions mean that there can be large fluctuations in this item. In particular, the question of whether a filter unit was allowed for in the original design of the plant, or whether subsequent installation is necessary, has to be taken into account.

3 ANALYSIS OF THE ECONOMIC CONSEQUENCES OF VARYING THRESHOLD LIMITS TO REDUCE ENVIRONMENTAL POLLUTION

The emission situation in individual cadmium-processing concerns in the countries of the EEC is not known. Any lowering of a maximum emission limit, which means additional capital costs or increased maintenance costs for an individual concern, has different effects on that concern according to its economic situation. Economically weak concerns may get into financial difficulties even as a result of small additional charges.

Larger companies can take advantage of the economies of scale associated with larger plant. For these concerns the costs are lower per cubic metre of waste water and air. The result is that smaller firms with smaller plant are at a competitive disadvantage. Foreign investments in countries which impose less stringent requirements on environmental protection have already been stated as an alternative method of avoiding stricter conditions on environmental protection in the EEC or in individual countries. If new user industries were then to develop elsewhere this would mean a transfer of consumption from the Community.

It may be assumed that cadmium and cadmium compounds only find application if alternatives lead to disadvantages which cannot be tolerated. Substitutes for cadmium are being sought all the time, and some have already been found. In many fields there are still no indications that cadmium is likely to be replaced within the next ten years.

At some plants in the main fields of application of cadmium and cadmium compounds (pigments, stabilizers, nickel-cadmium batteries, which together employ about 60% of the total quantity of cadmium processed in the EEC), quite similar processes are employed, so it may certainly be assumed that the standard of the purification processes is comparable. A further lowering of the maximum values for emission to water and air would affect all concerns equally, if the corresponding limits applied uniformly to all concerns. The concerns would try to include the additional costs of environmental protection in the prices of their products, and so pass them on to the consumer. However, the possibility cannot be excluded that these concerns will consider transferring production to subsidiary companies outside the EEC.

A fundamentally different situation would result from lowering the limit for waste water contamination from the use of cadmium in electroplating.

There are considerable variations in the operating structure of cadmium-processing companies. The size of these companies ranges from jobbing

electroplaters using a few kilograms per year, to large enterprises which process 50-80 tonnes of cadmium per year. Lowering the cadmium concentration limit in waste water could necessitate additional capital costs for many firms, and these could only be borne with difficulty especially by smaller concerns. It may be assumed that many concerns in which cadmium plays only a minor role would give up the processing of cadmium. Under certain circumstances they would instead purchase cadmium-plated parts from specially-equipped concerns. Such a change will certainly not affect the economic stability of these concerns. Production in larger plants can even be more cost-effective than in smaller plants, which must first be prepared for cadmium plating, so that components cadmium-plated by large jobbing galvanizers need not be more expensive.

A possible consequence could be the concentration of the use of cadmium in specialized concerns. For such large concerns it is quite feasible to observe even lower threshold limits using equipment that is generally already installed. The existing plants would only require minor changes in certain cases in order to meet the required limits.

The use of cadmium in surface treatments will certainly not decrease with lower effluent limits, as cadmium is already only used when the required properties cannot be achieved with other systems, or when the disadvantages of other systems are too great.

The development of individual branches of industry which currently process cadmium will certainly not be affected. In the case of electroplating works there will presumably be some reorganisation, but this should not result in any closures of works.

One decisive factor for a smooth change-over to new limits is a sufficient transition time to give individual firms the possibility of developing new technology for effluent treatment, which is currently still at the prototype stage, into industrially applicable processes. This prerequisite is of considerable importance not only for the users of cadmium, but also for firms which build plant for purification of waste water and exhaust air.

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