COMMISSION OF THE EUROPEAN COMMUNITIES

environment and quality of life

Elaboration of methods for determining the costs and benefits of implementing health protection standards concerning sulphur dioxide and suspended particulates

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R. FRISCHE and R. HACHMANN

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Summary

The aim of this study is to identify adequate methods for estimating the costs and benefits related to the proposed directive on health protection standards for sulphur dioxide and suspended particulates in the atmosphere of densely populated areas.

Many studies on the cost-benefit-estimation of pollution control measures have already been carried out. On the one hand there are many objections to the methods applied and on the other hand none of the existing studies deals with such a comprehensive subject as the present investigation. Due to the regional scope (nine different countries have to be covered) additional problems, mainly concerning the availability of data, have to be solved.

In order to overcome these difficulties the work has been divided into parts, i.e. the methods available are discussed according to the various steps of the cost-benefit estimation procedure. The structure of the study follows these main steps and consists of the following five main parts:

- Survey and selection of polluted areas (Chapter 2)
- Determination of the transmission conditions (Chapter 3)
- Evaluation of the avoidance and reduction measures (Chapter 4)
- Methods of determining costs (Chapter 5)
- Methods of estimating benefits (Chapter 6)

The conclusions which are drawn from the discussions are summarised in Chapter 7 (discussion of methods) and Chapter 8 (proposed further procedure).

Within each chapter the different methods applied are briefly described and their advantages and disadvantages discussed.

The selection of the method which seems to be the most adequate for the study under consideration was based on the following criteria:

- effort for estimating costs and benefits (costs involved)
- possibility of generalizing the results (applying individual results to the EC area as a whole)
- accuracy of statements
- possibility of quantifying the main results

Obviously some of these criteria are conflicting, e.g. minimizing effort and maximizing accuracy. In this case we propose the method which guarantees the desired results with the lowest effort.

In the following, a short survey of the contents of the individual chapters is given. The methods investigated are listed, the selected one underlined and reasons given for selection.

Survey and selection of polluted areas

Methods investigated:

- consideration of all polluted areas
- case study
- classification by polluting groups
- classification

In order to keep the work within acceptable limits and yet achieve sufficiently accurate results, the most suitable procedure seems to be to classify the polluted areas according to their dominant polluting processes.

Determination of transmission conditions

Methods investigated:

- methods of determining the transmission conditions by means of dispersion calculations
  - -- application of dispersion models
  - -- application of estimation methods
- methods of relating emission to concentration without dispersion calculations

The contribution of each polluting process is applied to the g.l. concentration with a simplified dispersion calculation.

Evaluation of the avoidance and reduction measures

The following way is investigated: comprehensive literature is available which can be accomplished by oral interviews. The measures are assessed by the criterion of the environmental and economic efficiency.

Methods of cost determination

Methods investigated:

- examination of the desulphurization costs in one industrial sector (model emitters)
- cost determination in industry (representative questionnaire)
- cost determination on the basis of a comparison of alternative processes
- regional approach to the determination of the cost of flue gas desulphurization
- determination of environmental protection costs in the iron and steel industry

An appropriate method is the combination of comprehensive general inquiry with an intensive investigation of important emitter groups (polluting processes).

Methods of estimating benefits

Methods investigated:

- economic approach (i.e. quantifying in monetary terms)
- ecological approach

The ecological approach seems to fit best to the requirements of the study. The benefit of the air quality standards is expressed in terms of the sensitive receptors (like flora, fauna, buildings) which are affected in a positive sense.

Further procedure

In order to keep the effort within an acceptable range it is proposed to apply the selected methods mentioned above in a study for a pilot area (Phase II). The pilot study would consist of the following main items:

- data collection
- determination of transmission conditions
- assessment of measures
- determination of the costs of the measures
- determination of the benefits of the measures

The procedure is described in Fig. 8.2-1 and 8.2-2.

The data collection should be carried out by an institute of the country concerned in order to minimize costs as well as to utilise specific know-how of the characteristics of the area.

In Phase III one of each type of polluted area (classified according to the dominant polluting processes in that area) should be investigated and the results extrapolated for all areas affacted by the proposed directive. Since this phase can make use of the results and experience of the pilot study the work involved should be acceptable.

1. Introduction

1.1. Background, Objectives and Problems of the Study

The environmental action programme of the European Communities /1/ gives priority to the reduction of the concentration of sulphur oxides and suspended particulates in the atmosphere, because according to the present state of knowledge

- they seriously affect human health and sensitive ecosystems,
- they are assumed to have a long-term toxic effect.

In order to protect the population and the environment, the European Communities therefore consider it necessary to set up suitable health protection standards.

Accordingly, the Commission of the European Communities has submitted a proposal to the Council of the European Communities on 25th February, 1976, for a directive on health protection standards concerning sulphur dioxide and suspended particulates in the atmosphere of densely populated areas (cf. Table 1-1) /2/.

Since measures to improve the environment involve costs /3/, the European Parliament has requested the Commission to submit an estimate of the costs likely to be incurred in the Member States of the European Community in connection with the implementation of the proposed health protection standards for sulphur dioxide and suspended particulates. This request was based among other things on the comments of the Social and Economic Committee of 15th February, 1977 /4/. The cost estimates should be specified for the whole economy and for individual industrial sectors.

This is the background for carrying out the present study to determine the costs as well as the benefits introducing the proposed health protection standards.

Taking consideration of the rudimentary state of the methods so far available for determining the costs and benefits of environmental protection measures the study aims to discuss these methods with particular respect to air quality standards. One or a combination of these methods is then to be selected and further developed.

Implementation of the health protection standards leads to social, economic and ecological benefits due to the reduced potential damage to be expected from the atmospheric pollutants sulphur dioxide and suspended particulate. The benefit consists not only in the reduction and prevention of known or unknown negative effects of these pollutants on man, animals, plants and materials, but also in the reduction of the probability of future damage, which may be caused by changed specific environmental conditions.

In terms of environmental politics the introduction of health protection standards has short- and long-term curative and preventive objectives. If possible, damage to the environment due to atmospheric pollution should be prevented initially rather than being remedied later at a higher cost. To assess the benefit of the introduction of a quality standards for SO_2 and suspended particulates it is therefore necessary to take into account both the curative and the preventive effect.

1.2. Procedure

As neither a uniform approach nor a uniform method exists for determining the costs and benefits of the measures necessary for implementing the health protection standards, the problems to be solved in the study will be divided into several subproblems. For each of these parts

- polluted areas,
- transmission conditions,
- suitable measures,

- costs and
- benefits.

several methodical approaches will be discussed on the basis of the following assessment criteria:

- expense (time, money, materials) of estimating costs and benefits,
- possibility of extending the individual results of the whole area covered by the study (EC countries),
- degree of accuracy of the statements and
- possibility of quantifying the most important results.

After considering the advantages and disadvantages of these approaches a methodical approach is proposed which combines the most suitable solutions of the subproblems in a set of method modules. The resultant method is finally appraised with respect to the effort required for its implementation.

This report is composed of the main points corresponding to the above-mentioned procedure:

- selection of polluted areas
- determination of transmission conditions,
- relation between emission to ground level concentration
- determination of suitable measures
- determination of costs resulting from measures of air pollutant control,
- determination of benefits.

2. Survey and Selection of Polluted Areas

2.1. Identification of Polluted Areas

The atmospheric pollution with sulphur dioxide (resulting mainly from combustion processes) and with suspended particulates often leads to hazardous concentrations particularly in densely populated urban and industrial areas. The proposed health protection standards therefore aim to reduce the concentration in these areas without, however, worsening the air quality in regions with lower original atmospheric pollution /5/.

The study primarily covers areas with sulphur dioxide and suspended particulate concentrations above the proposed limits[1)]. For these areas the costs and benefits of possible reduction measures will be determined.

The 1976 EC report on atmospheric pollution by sulphur components and suspended particulates /6/ provides a general survey of the most important polluted areas in the EC. The criterion for the selection of an area is a pollutant concentration exceeding the health protection standards. To prevent specific areas being omitted as a result of different measurement methods, different sensitivities or measuring inaccuracies, areas are included in which the measured values are up to 25 $\mu g/m^3$ below the limits.

Thus, it may be assumed that these are the major polluted areas where emission reduction measures will have to be taken in order to keep below the proposed limits (cf. Table 2-2) /7/.

The polluted areas can be seen in Fig. 2-1 /8/, as they largely coincide with the emission centres shown in the map. Some additional papers /9, 10, 11, 12, 13, 14/ which provide information about regional centres of pollutant concentrations were

1) in the following called "poluted areas"

used to confirm these results.

2.2. Methods of Selecting Polluted Areas

2.2.1. Consideration of All Polluted Areas

The first possibility of determining the area to be investigated in order to assess the costs and benefits of possible measures is to cover all the polluted areas. However, the investigation of such a great number of areas would require considerable time and effort, especially as the structural characteristics:

- topography,
- climate,
- land use,
- trade and industry structure,
- heating patterns,
- traffic distribution,
- location of the polluted area in relation to other agglomerations.

These characteristics differ from one area to the other and emission inventories do not exist for all the areas. In many cases this drawback would not be balanced by the advantage of more accurate results.

2.2.2. Case Study

Another approach would be to carry out a case study of just one polluted area and to extrapolate the results. To select this area, however, comprehensive preparatory investigations of all the polluted areas would be necessary. In order to select an area that is representative with respect to its general structural characteristics and the existing concentrations of sulphur dioxide and suspended particulates a costly data collection process would be involved.

If, on the other hand, a polluted area is selected simply because suitable data are already available, the results of the extrapolation may be too inaccurate.

This procedure would thus appear either too cost-intensive (if a representative area has first to be selected) or too inaccurate (if the selection procedure is reduced to a minimum).

2.2.3. Classification by Polluting Groups

Another possibility is to classify the polluted areas according to the pollution caused in them by the following main polluting groups:

- households,
- industry,
- power stations,
- traffic,
- and possible combinations of these,

and to then investigate only one or two areas from each of the thus formed classes.

The above mentioned EC report /8/ gives a classification with seven types of polluted areas (industrial, commercial, residential and their four combinations).

The main problem of this method arises as a result of the structural heterogeneity of the various areas for they often consist of several of the above classified types. Considering the widely-dispersed measuring network in most of the polluted areas it would be necessary to collect additional data in order to fill the gaps and to balance the inaccuracies due to different measuring methods.

2.2.4. Classification by Types of Process

A further possibility of classifying the polluted areas would be according to the amount of pollution caused in each area as a result of the following processes[1]:

- fuel combustion proccesses
  - power stations
  - industrial furnaces
  - small-scale consumers
  - traffic

- production processes
  - fuel
  - non-metallic mineral
  - iron/steel
  - chemicals

Polluted areas with a similar structure as regards the amount of pollution caused by the various processes would be grouped in the same class and the investigation could then be concentrated on one or two examples from each class.

In the Federal Republic of Germany there is sufficient data on the quantities emitted as a result of each of these processes. If such data does not exist for all the EC member countries, emission quantities could be estimated using stuitable structural data and emission factors.

Data on the shares of the fuel types

- coal,
- fuel oil and
- gas oil

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1) This classification is taken from a report on air quality control in the Federal Republic of Germany (cf. Table 2-3 /15/).

in the total emission are available for all EC member countries /16/.

The data collection effort would thus be limited to evaluating the statistics of the individual countries. Since sufficient data are available this classification procedure would produce useful results.

3. Methods of Determining the Transmission Conditions

The processes that transform emissions into a ground level concentration field (= immission) are very complex. The immission cannot simply be inferred from an emission in a particular area. As immission-reducing measures are usually taken on the emission side, it is necessary to find adequate methods of determining the transmission conditions. Existing dispersion models and other methods must be studies as to their suitability and, if need be, further developed.

A particular problem arises as a result of the height at which the emissions are released. Sulphur dioxide emissions, for instance, are released in residential areas mainly at building level, while in industrial and commercial areas the emissions take place at greater heights. As a result, the proportion of the total ground level concentration (= g.l. concentration) by households in a polluted area caused is larger than corresponds to their proportion in the total emission. Hence, it can be concluded that reduction of the industrial emissions will probably have a lower effect on the g.l. concentration situation in the agglomeration than relevant measures taken on the part of the households (see 3.2.2) /17/.

3.1. Methods of Determining the Transmission Conditions by Means of Dispersion Calculations

The strong influence of the source level and other parameters on the dispersion processes makes it difficult to establish the relationship between the g.l. concentration in an area and the emission sources without complex analyses. Of the more detailed methods of analysis the various dispersion models are of particular interest. They permit a quantitative determination of the contribution of the various emitters to the overall g.l. concentration.

Relatively reliable information about the overall g.l. concentration in an area and the influences of various emitter groups can be obtained by complex mathematical simulation of the dispersion processes. With this information the measures needed to reduce the g.l. concentration to values below the proposed limits can be worked out.

3.1.1. Application of Detailed Calculations

The application of a dispersion model requires

- the collection of data characterizing the meteorological conditions in the dispersion area, and
- a mathematical description of the transmission process.

A dispersion model suitable for solving the problems covered by the present study would have to meet specific requirements with respect to short- and long-term investigations. The requirements /18/ to be met by the input data of such a model are summarized in Tables 3-1 and 3-2.

Accordingly, the following input data must be available for the dispersion calculations /19/:

- Area under investigation
  - -- Locations of all sources and measuring stations

- Wind
  - -- Average wind speed and direction

- Diffusion
  - -- Stability class, mixing height

- Source
  - -- Emission rate, flue gas volume, velocity and temperature, stack height and diameter, air temperature

The Gaussian models developed on the basis of mathematical statistics give characteristic values to be expected on a multiannual average. One of the most important boundary conditions of these models is that weather situations with no or only light winds cannot be assessed.

Another problem is the lack of long-term data to describe all the above parameters. Because of the annual fluctuations, these parameters should always be described by long-term averages.

If dispersion calculations are to be used for the present study, an emission inventory will have to be established. This requires the collection of comprehensive data. To reduce the mathematical effort, several emitters of the same type can be combined and represented by one fictitious emission source. This approach could be applied not only to individual polluted areas but also to types of polluted areas determined on the basis of identical or similar emission conditions.

The quality of the results depends primarily on the reliability of the data contained in the emission inventory. Usually, they are quite accurate, but collection of the necessary data involves comparatively high cost.

It would therefore appear useful to look for simplified methods which, for example, do not require direct conversion of emissions into g.l. concentrations.

3.1.2. Application of Estimation Methods

In the Federal Republic of Germany a method has been developed to make simple estimations of g.l. sulphur dioxide concentrations / 20/. This method assumes the following factors to be identical for all urban and rural districts:

- the shape of the district,
- the topography,
- the meteorological factors,
- the location of the emission sources within the district, and
- the amount of sulphur dioxide emissions per unit of energy consumed and the emission characteristics (stack height etc.) according to four groups of emitters (traffic, domestic heating, industry and power stations).

The only information that has to be considered separately for each district is the energy consumption of each of the above mentioned groups of emitters.

The reason for distinguishing between these four types of emitters is that each of them has

- specific rates of SO_2 emissions per unit of energy consumption and
- specific emission and dispersion characteristics.

According to this method the g.l. sulphur dioxide concentrations in a particular district is thus assumed to differ from that of another district purely on account of the difference in energy consumption of these four emitter groups (see Fig. 3.1.2-1).

One problem of this method is, therefore, the highly simplified assumption involved which does not allow the peculiarities of particular regions to be taken into consideration. An even more important drawback, however, is the difficulty of applying it to a polluted area that does not necessarily coincide with existing administrative and statistical boundaries.

3.2. Methods of Relating Emissions to G.L. Concentration without Dispersion Calculations

In the case of polluted areas where the emissions are caused predominantly by one processing type, g.l. concentrations exceeding the proposed limits can be attributed to that particular type and reduction measures implemented appropriately. Knowledge of the transmission conditions is not necessary.

If the polluted areas are characterised by the presence of several processing types, the following approach is possible.

It is assumed that the contribution of a specific processing type to the total emission corresponds to its contribution to the total g.l. concentration. In determining measures to reduce the g.l. concentration a safety margin must then be introduced to allow for the unknown specific transmission conditions. This means that the proposed measures (and costs) will usually be more comprehensive than is strictly necessary to achieve the desired reduction in the g.l. concentration. The safety margin can be determined on the basis of expert opinions on the transmission conditions in the polluted area concerned.

In order to take due account of the source height without using dispersion calculations an assessment factor can be applied as, for example, in the Ruhr District /21/.

Sulphur dioxide polluting group	Source height m	Assessment factor
Traffic	2	8.5
Household	20	7.2
Industrial furnace	100	3.4
Sintering plants	200	1.6
Power stations	300	1.0

In a supraregional analysis of sulphur dioxide pollution, an extension of this concept was proposed to enable standardized assessment factors to take account not only of the source height but also of the size of the polluted area.

Most of the emission data required for this approach is readily available. The main drawback is the increased cost of the proposed measures on account of the above mentioned safety margin.

4. Methods of Determining Suitable Measures

A reduction of g.l. concentration to the level specified in the health protection standards can be achieved both by reduction and by prevention of particular emissions. First of all, a catalogue of all possible measures (cf. Table 4-1) must be prepared /22/ and the latest technical developments documented /23/. The measures can then be classified according to one or more of the following criteria:

- emitter groups,
- pollutants,
- technological, organisation and planning measures,
- emission sources (production plants or furnaces),
- fuel types,

depending on the methodical approach selected for the investigation. Suitable measures can then be selected from the catalogue according to their

- environmental effectiveness (in reducing g.l. concentration),
- economic efficiency,
- technical effectiveness (in reducing emissions),
- technical practicability.

It would, of course, be best to select measures which satisfy all four criteria.

Since the primary objective of all measures is to reduce the g.l. concentration to the limits proposed by the health protection standards, the criterion of environmental effetiveness is of maximum importance.

When looking for the most effective measures, the emission producing sectors which have the highest share in the total g.l. concentration should be examined first. Then the sector with the second highest share should be investigated, and so on.

In the Federal Republic of Germany, for example, the energy sector contributes most strongly to the total emission both of sulphur dioxide (95.5 %) and of suspended particulates (74.4 %). The situation is similar in other EC Member States. Further, the emissions caused by the various fuel types (cf. Table 2-4) indicate that the measures should be specifically aimed at the coal, lignite and heavy oil combustion process /24/.

In using this method for the assessment of emission-reduction measures, major uncertainties may occur if the environmental efficiency, expressed by the anticipated reduction of g.l. concentration, has not been sufficiently calculated. There are, however, studies which have already calculated reductions in the pollutant concentration as a result of emission-reduction measures /25/.

The second essential assessment criterion is the economic efficiency, Among several measures having the same environmental efficiency, the one should be selected which involves the lowest cost.

In our opinion the other selection criteria are less important for the selection of measures, in particular because some of them necessitate very detailed data collection.

The problems in the selection of effective measures differ for the various assessment criteria: in the case of economic efficiency, they are to be seen in the field of cost determination. In the case of environmental effectiveness they concern the consideration of the transmission conditions.

It should be noted here that substantial efforts will be necessary to list all the abatement measures used in the European Community and to document the latest technological developments. In this context, the data on the technical effectiveness will have to be collected by comprehensive literature surveys and interviews with experts.

5. Methods of Costs Determining Concerning Air Pollution Control Measures

5.1. The Concept of Cost

Before the problems involved in determining the benefits and costs of measures to reduce g.l. concentration are dealt with in greater detail, certain concepts and categories must be clarified.

The following cost concepts, introduced by the Council of Environmental Quality, are used in literature relating to environmental economics /26/:

- damage costs
- avoidance costs
- transaction costs
- abatement costs.

Damage and avoidance costs refer to the economic costs incurred as a result of the environmental burdens arising from production and consumption. They represent the monetary equivalent of the damage to man, plants, animals and material goods, i.e. the external effects /27/.

In evaluating the costs of measures to maintain a standard air quality, only the transaction and abatement costs are relevant since these are incurred to reduce - or avoid - harmful emissions (cf. Fig. 5-1, visualizing the economic-cost concepts /28/).

Increasing the abatement costs in the field of production and consumption aims to reduce the damage caused, which is equivalent to an alleviating the environmental effects. Thus a benefit to the environment is achieved in the form of reduced or avoided damage, i.e. the damage and/or avoidance costs fall. These economic costs are therefore omitted from cost calculation, but are relevant to the benefit calculation (cf. Section 6.3).

5.2. Cost Determination

According to the preceding concept of costs the main feature of this investigation is the development of methods of determining the abatement costs and significantly lower the transaction costs.

The first question is what proportion of these costs should be allocated to the government, industry or private households. In the case of the government, the main costs in the field of pollution control are transaction costs. Households may be subject to abatement costs, e.g. as a result of the use of vehicles that do not create such large quantities of pollutants in the exhaust gases, or as a result of the conversion of high-emission coal systems to gas. The majority of costs are incurred by industry, which is therefore at the centre of this study. There is no need to deal with the extent to which these costs are passed on to the consumer in the form of higher prices since this is a macroeconomic consideration.

When determining the cost to companies of air pollution control, it is useful to differentiate between

- the level of the individual firm and
- the aggregate level.

5.2.1. Determination of the Cost of Air Pollution Control Measures at the Level of the Individual Firm

Here it is necessary to differentiate between production-related air pollution control measures, which aim to prevent or reduce environmental effects resulting from the production process, and product-related measures, which are incurred in connection with the production of a (new) product, the use of which involves a lower environmental burden (compared to a reference product). This distinction is based mainly on the aims of the different measures taken: whilst the production-related measures aim to reduce production-specific emissions, product-related measures are intended to produce goods which when used or consumed have lower emission rates. Thus the target areas of these two types of measures are different.

The determination of the environmental protection costs incurred in companies must take into account both capital and operating costs. Company accounting represents a suitable basis for the definition and determination of these costs /29/.

However, since the costs incurred for air pollution control are not usually separated or indicated in a companys accounts it is not always possible to determine them directly /30/. In particular, problems arise when multi-purpose equipment is in use, i.e. equipment which serves other purposes, such as worker protection, improvement of the infrastructure or conservation of energy or resources, in addition to pollution control.

It is necessary to determine the proportions of the capital costs that should be allocated for each purpose. This is difficult especially when the environmental protection equipment is an integral part of a larger unit and where there is no reference equipment without the environmental protection facility.

Additional problems are to be expected especially where it is difficult or impossible to separate between costs incurred by the company's environmental protection policy and actual production costs or the cost of labour protection.

In general it is useful to indicate both the absolute capital costs of environmental protection and also these costs as a proportion of the total capital costs of multi-purpose units /31/.

While it is relatively simple to determine the capital costs in the accounting department (apart from the exceptional cases just mentioned), operating costs can often only be estimated within broad limits. The main reason for this is that conventional accounting methods provide for cost categories and cost centres, but not for the goals of investment - in this case environmental protection.

Differentiating between capital and operating costs makes it possible to compare information from various companies or sectors, even if the tax basis or the capital market conditions affecting these costs differ.

In recent years the ratio of annual capital costs to operating costs has constantly progressed in favour of operating costs. For example, the ratio in the chemical industry of the Federal Republic of Germany was 1:1.7 in 1974, 1:2.4 in 1976 and 1:3.5 in 1977 /32/. This development is due to the growing amount of existing environmental protection equipment.

The amount of capital investment required for abatement equipment as a result of regulations of industrial hygiene, as well as the operating costs of running such equipment can be derived from company accounts. The problem will tend to be the profusion of separate pieces of information, rather than the lack of sufficient detail.

To minimize the cost of data collection, information on this emission-reduction equipment may be obtained by means of a special survey - questionnaires or interviews - among potential users /33/ or among producers, planners and engineering firms /34/. Care should be taken to ensure that only those companies that are really relevant are approached. An important criterion is that the companies concerned are in a position to consider abatement measures on the basis of both size and emission structure. Past experience has shown that involving of the relevant industrial associations is indispensable for clarification of this point.

Individual companies do not often specify total environmental protection costs attributable to the separate environmental sectors, so to that point it should be included in the above-mentioned inquiry /35/.

The costs of air pollution control to the individual company is particularly influenced by the following technical and economic factors /36/:

- type of industry concerned,
- size of company,
- production processes,
- intensity of emissions from the relevant processes,
- location,
- waste, e.g. of the flue gas desulphurisation equipment,
- furnace data and
- usual method of operation.

It is not possible to generalize the results for a particular that it can individual for the whole sector concerned.

5.2.2. Determination of the Cost of Air Pollution Control at the Aggregate Level

There are basically two ways to obtain data on operating and capital costs at the aggregate level. One is to carry out a very detailed investigation collecting a lot of data with the individual results combined to obtain an overall picture. The other is to work on the basis of global figures, in which case a loss of information must be accepted. Aggregation of such data permits statements to be made on the total emissions by a specific industry.

In studies available in the literature, the cost of environmental protection measures has been divided according to

- sectors,
- processes,
- products and
- groups of emitters,

sometimes for the whole economy of a country, sometimes for a particular industry.

In the following sub-chapters five cost studies are described briefly, as an example they vary with respect to the subject matter and the methods applied. Some comment is made on the advantages and disadvantages of each method.

5.2.2.1. Examination of the Desulphurisation Costs in the Oil Industry (Model Emitters)

One possible way of aggregating the costs of product-related measures - i.e. reducing the sulphur content of fuels - is as follows / 37/. The refineries of the oil industry are divided into six groups according to the parameters processing capacity and type of crude oil processed. A model refinery is then derived for each of these groups, then the main factors affecting the cost of the desulphurisation equipment are determined, and finally the acutal cost is calculated.

The factors determing the extra cost of desulphurisation are the various types of crude with their different compositions, the respective prices, and the desulphurization capacity.

The desulphurization costs of all refineries are represented by those of the model refinery of the corresponding class. In order to obtain the total costs, the costs of the model refinery are multiplied by the number of refineries in that class and their capacities. Finally, the costs of the individual classes are added together.

In conclusion such a way of proceeding can be evaluated as follows:

- The cost of the assessment depends very much on the availability of the necessary data. In order to build a model, data on structural features are required, and in order to determine the costs, information must be obtained on the leading parameters.

  The advantage of this method is that all individual companies are reduced to specific categories. However, this advantage can only be exploited when the sector under consideration has a relatively homogeneous plant and production structure.

- Data relating to a particular sector obtained in this way can only be applied to polluted areas with homogeneous structures.

- If they are applied to polluted areas of heterogeneous structure - such as exist in the European Community - considerable loss of accuracy and therefore of the weight of the statements may occur.

5.2.2.2. Cost Determination in Industry (Representative Questionnaire)

Another method of determining the cost of future environmental protection measures is to conduct a survey among industrial companies, as has been done in the Federal Republic of Germany /38/. Since it is not possible to conduct a survey of all industrial companies due to the large number involved, the distribution of the questionnaire must be limited to a specific number of companies. The selection criterion is the capital investment: by experience it can be assumed that investment for environmental protection will correlate rather with a company's total investment than with its turnover or the number of its staff. The companies selected should together account for as large a proportion of total industrial investment as possible while at the same time, affecting the environment.

The results of the survey do not, however, permit direct conclusions to be drawn on the expenditure of the whole industry on environmental protection measures. First the results are extrapolated for the selected sample and then for the industry as a whole.

Our assessment of the applicability of this method to the planned investigation is as follows:

- The costs involved are divided between selection of the companies to be included in the survey, and the costs of actually conducting the survey and interpreting the results.

- Using this method in the investigation will pose problems in so far as the health protection standards are not yet specified in a form that can be taken into account in the company's investment planning, i.e. the individual emitters do not yet know by how much they will have to reduce their emissions.

- Since the information is only obtained from those involved, estimations will be purely subjective (e.g. decisions as to the proportion of costs incurred for environmental protection in the case of multi-purpose equipment).

5.2.2.3. Cost Determination on the Basis of a Comparison of Alternative Processes

This approach involves the determination and comparison of the costs of alternative desulphurization processes /34/. Here the costs of hydrodesulphurization of selected atmospheric residues from the distillation of crude oil, these residues having different sulphur, asphalt and metal contents, are calculated for various final sulphur contents.

The majority of the information required relating to processes and costs is obtained by means of questionnaires distributed among those companies that have developed desulphurization processes or which offer their engineering services to others planning or constructing facilities of this type. In addition, specific offers are obtained from these companies for the construction of a flue gas desulphurization facilities in the form of a demonstration plant. The intention behind such binding statements was to make the cost calculations more reliable.

Since the offers only include the "battery limits" rather than the "off sites", 30 percent of the cost of the main plant is allowed for this purpose.

Operating costs are included in the offers, The possibility of marketing the sulphur-containing residual products is not taken into account in the cost calculations.

The aim in this case is to compare the costs incurred per unit product for oil or flue gas desulphurization. Using this as a basis, the total cost incurred in the use of desulphurization processes in the Federal Republic of Germany will then be determined. For this, both the process costs mentioned earlier and the future energy requirement are relevant. The cost considerations are based on the following processes:

- mechanical removal of sulphur from coal,

- mechanical desulphurization of coal combined with flue gas desulphurization in new power stations,
- desulphurisation of heavy fuel oil and
- flue gas desulphurization in existing oil-fired power stations.

The fuel consumption of the Federal Republic of Germany for a previous year and the estimated consumption for a future year are used to derive a mean value which is then combined with the process-specific costs per unit output.

If, in order to evaluate this method, the work involved and the degree of accuracy of the resulting statements are balanced out against each other, the following conclusions can be drawn:

- As described by the authors of this study, the time and effort required to obtain offers for a reference plant are substantial. A major problem is that specific offers can sometimes only be obtained if the suppliers believe that the plant will really be built.

- The accuracy of the results can certainly be regarded as satisfactory for the reference plant.

- There is cause to doubt whether individual results will be able to be applied to other member countries because of the differing technical and economic environments.

5.2.2.4. Regional Approach to the Determination of the Cost of Flue Gas Desulphurization Processes

The aim of this approach is to determine the cost of flue gas desulphurization in a particular region /33/. All major emitters in the region are included.

Alternative assumptions are made with respect to the sulphur content of the fuel for the major emitters. Furthermore, three strategies are formulated for the allocation of furnace conditions and flue gas desulphurization. It is assumed that each emitter will use only one process.

Capital and operating costs are calculated for the various possible solutions on the basis of the alternative assumptions relating to sulphur content, the operating strategies and the possible desulphurization processes. For calculation purposes flue gas desulphurization is subdivided according to the parts of the plant.

The costs are calculated on the basis of a standard plant, corrected to take into account the limiting conditions prevailing in the case of the individual emitter. In contrast to the other methods, this approach incorporates the prospects of finding market gaps or creating new markets for the alternative waste products, e.g. synthetic plaster, elemental sulphur, both quantitatively and qualitatively.

The capical and operating costs of each process are then determined for each emitter. together with credits for alternative waste products or debits for dumping and transport costs.

Summing up the costs of the processes to be used by the major emitters gives an indication of the total capital and operating costs for the area under consideration.

This procedure can be evaluated as follows:

- The cost of data collection is very high due to the alternative assumptions relating to the sulphur content, the various strategies and the possible processes. This cost is increased still further by the fact that the information then relates only to a single region. In the course of the proposed study these detailed surveys would have to be conducted for each polluted area since applying the results from one area to the rest of the Community would be unacceptable on account of the expected inaccuracy.

- Relatively accurate results are obtained for the region under study.

5.2.2.5. Determination of Environmental Protection Costs in the Iron and Steel Industry

In this study /35/ the aim is to determine the cost of environmental protection measures in one sector of industry. The investigation is restricted to the largest and most important companies which represent 64.4 percent of total turnover and 80.2 percent of total production in this sector.

The companies are questioned about the current state-of-the-art of the environmental protection equipment and on the emissions they release into the environment. The individual production methods used also figure in the questions asked, since the emissions are largely determined by the process. The capital investment is assigned to the individual plant section and to the environmental sector (which may be further differentiated into air, water, noise, etc.). Information that is not available is estimated by extrapolation.

In order to work out the capital cost of environmental protection of the total sector, an extrapolation is conducted on the basis of two years.

In addition, an attempt is made to describe the future development of investment for environmental protection purpose by determining the trend of total investment. For this it is necessary to analyse the following influences:

- future requirements laid down by the administration,
- the future state-of-the art- and
- the investment policy of the companies.

Data collection problems make it impossible to use the same procedure to determine the operating costs. Information on operating costs is obtained by individual discussions, but, due to the differences in the technologies, the costs cannot be attributed to single processes. For statistical reasons and for difficulties of definition, the operating costs of the plants examined are not extrapolated to the whole sector, nor is an overall trend extrapolated.

The following points are relevant to the evaluation of this method:

- The effort required for data collection effort is substantial, since detailed company surveys are necessary.

- Since the polluted areas differ significantly with respect to the emitters, a survey to obtain structural data on all sectors in all areas would involve a relatively high expenditure.

- Due to the trend extrapolation, which would have to be extended to cover the polluted areas, the degree of accuracy would probably not be sufficiently high.

6. Assessing Benefits of Environmental Protection Measures

6.1. General Considerations on Measuring Benefits of Environmental Improvements

6.1.1. Benefit Considerations in the Decision-Making Process

In general estimates of the costs and benefits of a measure are regarded as a necessary input for decision-making. This applies also to environmental protection measures. In order to be able to balance disadvantages (costs) and advantages (benefits) both have to be expressed in identical units, preferably in monetary units.

Regarding the environmental benefit, this economic approach is not appropriate since there are types of benefits which cannot be adequately reflected in monetary benefit calculations (see Section 6.1.2). Hence, alternative methods of assessing environmental benefits have to be developed and applied. It should be emphasised that the aim of measuring and quantifying environmental benefits is to justify pollution control measures (or programmes). Thus the method adopted has to meet the following main requirements:

1. comprehensiveness, i.e. it should include all types of benefits
2. transparency
3. flexibility with respect to changes in priorities (e.g. environmental goals vs. economic goals)
4. avoiding controvers, i.e. it should be based on objective data
5. taking into account the characteristics of the environment as a complex resource of great value not only for human beings but also for flora and fauna.

According to these requirements, two alternative approaches of quantifying benefits resulting from environmental improvement are discussed in the following and the further procedure is described.

6.1.2. Discussion of the Economic Approach for Assessing the Benefits of Environmental Protection Measures

The monetary benefits of an improvement in the quality of the environment are defined as the corresponding reductions in the costs associated with environmental damage. According to the definitions of the Council of Environmental Quality (CEQ) the relevant cost categories are: damage costs and avoidance costs (see 5.1.). In an OECD study the costs associated with environmental damage are classified according to the categories "financial losses" and "amenity losses". Examples of financial losses are increased medical spending, value of crops lost, extra painting cost. Whereas it is possible to express these financial losses in monetary terms within a range of certainty it is almost impossible to express the "amenity losses" in monetary values. This is due to the fact that these amenity losses are more or less intangible. One method proposed for estimating these losses is to ask the individuals concerned about the necessary monetary compensation (i.e. avoidance costs). It is quite obvious that this approach can only take into account some aspects of environmental benefits and thus does not meet the requirement of comprehensiveness (see 6.1.1). In addition, the requirements 4 (objective data) and 5 (consideration of flora and fauna) are not satiesfied.

Apart from these arguments one important objection to the monetary approach is the following: it tends to concentrate on short-term physical effects, i.e. it does not reflect future generations' preferences.

As can be shown in several case studies the economic approach tends to underestimate the benefit of an environmental control measure and thus seems to be inadequate for the purpose of this study. As a consequence, in the following section a non-economic approach is discussed.

6.1.3. Discussion of the Ecological Approach for Assessing the Benefits of Environmental Protection Measures

In order to overcome the disadvantages of the economic approach it is necessary to take into consideration

- the seemingly harmless emissions, which may have long-term effects
- accumulation of non-degradable pollution in the natural environment
- the irreversible environmental quality deterioration.

Since knowledge of the dose-effect relationship is scarce and sometimes controversial it seems to be advisable to focus attention on the receptors (man, plants, materials, ecosystems) affected by pollution and thus deriving profit from pollution control measures. Although the result of this so-called ecological framework cannot be balanced with costs estimates for pollution control measures it seems to be an adequate and valuable instrument in justifying pollution control measures. A comparison of the different quantities and types of receptors affected by alternative quantity and kind of pollution facilitates the decision-making process and leads to a more objective argumentation. Looking at the requirements pointed out in 6.1.1 the ecological approach meets all the requirements listed.

As a consequence we propose this approach as the best available method for identifying and describing the benefits of the reduction of SO_2 and particulate g.l. concentration. The procedure proposed is described in the following section.

6.2. Proposed Procedure for the Identification of the Benefits

6.2.1. Sensitivity of Objects and Functions with Respect to Pollutants

Man, animals, plants and materials - and thus sociological, economic and ecological functions - react differently to the atmospheric pollutants sulphur dioxide and suspended particulates.

At present it is not possible to make scientifically confirmed and reliable statements on quantitative relationships between concentration level and effect of SO_2 and suspended particulates. Some laboratory findings on dose-effect relationships are available for single objects, but these cannot be transferred to the environment as a whole because of the complexity of inter-relations involved. It is possible, however, to make qualitative statements on the sensitivity of single objects and functions on the basis of observations in differently polluted areas extending over many years.

To quantify the benefit resulting from the implementation of the standards, it appears useful to select particularly sensitive and valuable receptors and functions and to restrict the following study to these samples. Although this procedure does not permit the overall benefit to be determined, the major part is taken into account.

6.2.2. Determination of Areas with Reduced Pollutant Concentration

As outlined in the description of the transmission conditions, the implementation of the health protection standards leads to the reduction of g.l. concentration not only in the polluted areas themselves but also in the neighbouring areas. A benefit in the above-defined sense results for all areas in which the concentration of pollutants is reduced, i.e. the air quality is improved.

The benefit of the reduction of pollutant emission does not result merely from the reduction of the pollutant concentration at one defined point, it results rather from the change of the concentration values in all areas which are affected by the pollutants emitted in the polluted area. An important factor for the determination of the benefit is, therefore, the identification of those areas in which the pollutant concentration has been definitely reduced. Basis for the determination of the amount of pollutant reduction and the size of the areas affected is the compilation of concentration inventory, or at least an emission inventory.

A rough method of determining the reduction of pollution according to the reduction of g.l. concentration and the size of the affected area without the use of inventories of g.l. concentrations or emissions is the following:

The areas of peak concentration within the above specified polluted areas are assumed to be the more (highly developed) urban areas. The size of these areas should be roughly determined. These areas are expected to be subject to a reduction of g.l. concentration equal to the difference between the highest g.l. concentration value measured in the area and the value specified in the standards. The adjacent areas are expected to be subject to a distant-dependent reduction of g.l. concentration. The lower limit of reduction is a concentration which may be regarded as the basic concentration. The link between g.l. concentration reduction rates and distances is established according to the rules of dispersion calculations.

It should be noted, however, that dispersion calculations are not to be carried out for those areas where the concentration reductions achieved are substantially lower than the basic concentrations. The same applies to those areas where the residual concentrations are very low.

As this procedure yields only very approximate values for the reduction of the pollutant concentration per unit area, the pollution-controlled areas should be grouped in a few (about three or four) classes.

6.2.3. Determination of the Objects and Uses Profiting from the Reduction of Concentration

The probability of damage is dependent on the concentration level. A reduction of concentration therefore also implies a reduction of the probability of injuries to health.

Another decisive criterion of the benefit resulting from the observance of the health protection standards is the number of persons living in the identified areas. The number of persons living in a specific area can be determined with sufficient accuracy from generally accessible statistics and maps.

By analogy, the sensitive objects and uses and the use functions

- residential population,
- forest land,
- agricultural land and
- ecologically significant areas

can be determined for each pollution-controlled area. Agricultural and forestry uses can be indicated both in area units and in yields units. Quantification of increases in yield due to reductions of g.l. concentration are, however, of little use because of the uncertainties with respect to the relationship between g.l. concentration and yield.

Historically valuable buildings also belong to the sensitive and valuable objects. A number of investigations has already been conducted, in particular on the destruction of these buildings by SO_2. It should therefore be considered whether those buildings should be included in the study which are located in the areas where the concentration level has been reduced. The following cirteria can be used for a classification according to value and sensitivity: type (e.g. church, castle, residential building, monument), predominant building material (e.g. sandstone, limestone, marble), age (or architectural style) and number of comparable objects.

7. Discussion of Methods

Of the methods briefly discussed in the foregoing, those which appear best suited for the proposed investigation will be selected. For each of the five main parts of the study

- survey and selection of polluted areas,
- determination of the transmission conditions,
- evaluation of the avoidance and reduction measures,
- determination of the costs and
- assessment of the benefits

methods are to be determined and combined in the form of a set of "method modules".

The methods are evaluated on the basis of the following criteria:

- low effort for estimating costs and benefits,
- possibility of applying individual results to the whole of the survey area (EC countries),
- maximum possible accuracy of statements,
- quantifiability of the major results.

On the basis of these criteria, the suitability of the methods is evaluated as outlined below.

Survey and selection of polluted areas

For the survey and selection of polluted areas, the methods "case study" and "consideration of all polluted areas" can be eliminated since either there is a high degree of accuracy but difficulty in applying the individual results to the whole survey area, or the required degree of accuracy involves too much work.

|In order to keep the necessary effort within acceptable limits|

and yet achieve sufficiently accurate results, the most suitable procedure seems to be to place all po-luted areas into classes according to special characteristics. These classes can be grouped according to the structure of the dominating polluting processes or of the groups of polluter in each area (as described in Chapters 2.2.3 and 2.2.2).

The most suitable of these classification criteria appear to be the polluting processes.

Transmission conditions

To take into account the transmission conditions, the simplified model described in Chapter 3.1.2 can be ruled out. Apart from its numerous assumptions it is based on administrative geographical areas and requires comprehensive data.

Substantial amounts of data are also required for the dispersion calculation so that this method can only be applied when the number of types of polluted areas to be examined is low. The remaining possibility of simply assigning the share of emission to the total g.l. concentration (as described in Chapter 3.2.2) produces less precise results but has the advantage of being easier.

Avoidance and reduction measures

The evaluation of the avoidance and reduction measures appears to involve no problems because comprehensive literature is available. However, it will be necessary to collect some data about potentially suitable processes and their efficiency.

Cost determination methods

The assessment of the cost determination methods is more difficult. Each procedure has its advantages, either with respect to accuracy or to availability of data (see Chapter 5.2). The specific disadvantages are usually a result of the fact that they were all developed for purposes other than the present study.

An appropriate method appears to be the combination of an extensive survey with an investigation according to polluting processes. The other methods are either too specialised for specific plant types or require too many data to be suitable for the EC study.

Methods of evaluating the benefits

The method most suitable for the purpose of the present study is the ecological approach of measuring benefits (see Chapter 6.1.3). The method focusses on the identification and quantification of sensitive receptors (man, flora, fauna, buildings, ecosystems). The main advantages compared with the economic approach can be summarized as follows: comprehensiveness, objective data, flexible with respect to varying preferences.

8. Proposed Further Activities

The objective of the first phase of this investigation was to propose methods suitable for determining the costs and benefits of implementing health protection standards for sulphur dioxide and suspended particulates. The next phases will be concerned with the practical application of these methods.

8.1. Basic Possibilities

The question as to which polluted areas are selected for the investigation is important for the further course of action. The alternatives include:

(a) All polluted areas are investigated individually (single-phase).

(b) The investigation of one polluted area is conducted for each member country.

(c) The study is limited to the consideration of selected types of area, corresponding to classification by polluting processes (single-phase).

(d) A pilot study is conducted for a selected area and the experience gained is then applied to investigations of type (b) or (c) (two-phase).

8.2. Proposed Procedures

8.2.1. Determining the Costs of Implementing Health Protection Standards

The cost determination procedure we propose is described as follows:

In phase two a pilot study should be conducted to estimate the expected costs in a selected polluted area. This would take advantage of the benefits of a case study, especially concerning the detail of the data collected and the accuracy of the results. For the data collection, we recommend a suitable institution in the country concerned.

In phase three one of each type of polluted area (according to the classification by polluting processes) should be investigated and costs estimated, this work being conducted on the basis of the experience and results of the pilot study. It would be useful to select each type of area from a different country in order to take account of the specific features of different countries.

The results of the investigations into the various types of area can then be extrapolated for all the polluted areas.

Fig. 8-1 shows the cost determination procedure recommended for the pilot study.

Some comments on specific problems that need to be solved in phase two should be emphasized:

Evaluation of data

The structural data that have been recognized as essential in the present methodological study (Phase I) should be determined for the pilot area. In addition to obtaining information at the location and drawing on literature and statistics, it is useful to interview experts. If gaps in the available data become evident they should be filled using approriate auxiliary information.

Determining the transmission conditions

The transmission conditions must be determined in order to throw light on the question of which measures should be used to reduce g.l. concentrations and which polluting processes should first be submitted to action.

The polluting processes and their emissions are identified on the basis of structural data. The processes are then ranked according to their shares in the total emission of the area. These shares are then applied to the g.l. concentration by means of a simplified dispersion model.

Assessment of possible measures

As part of the "study of methods" (see Fig. 8-1) a catalogue of possible measures for reducing g.l. concentrations is drawn up. Basically suitable (e.g. technically feasible, safe, acceptable in economic terms) measures are then selected on the basis of literature studies and discussions with experts.

From the resulting list a measure is to be chosen for the polluting process with the highest contribution to the g.l. concentration. It should be chosen according to environmental effectiveness.

Determining the costs of possible measures

The next step is to make sure there are not alternative measures that would offer the same environmental effects but involve lower costs.

Another possibility is to apply a less costly method (despite lower environmental effectiveness) and at the same time to apply auxiliary measures to the second most important polluting process.

This procedure could eventually lead to each of the polluting processes being submitted to action. However, it is advisible to start with the most important process and to continue progressively. The measures should always be considered as regards their environmental effectiveness before being assessed cost-wise.

A final point requiring attention is the possibility of specific local features (e.g. the state of production technology or furnace equipment) affecting the costs and making it necessary to incorporate correction factors into the calculation.

8.2.2. Determining the Benefits of Implementing Health Protection Standards

In order to determine the curative and preventive benefits of environmental protection measures, it is essential to know the change in g.l. concentration related to unit areas. This means that in principle g.l. concentration inventories must be drawn up, at least for the polluted areas and their immediate vicinity.

However, the effort involved in determining the improvement in air quality per unit area is, in our opinion, not justified. This view is reinforced by the fact that the informative value of the results is limited because it is impossible to extrapolate the results for one polluted area sufficiently accurately to obtain the improvement in air quality of all areas. Moreover the objects that are sensitive to the improvement in air quality also differ from area to area and must therefore be separately determined and quantifeid for each polluted area.

For this reason we suggest a determination of the benefits in one single polluted area, as an example, for which the area selected for the pilot study appears particularly suitable.

In doing so the improvement in air quality per unit area is determined as a first step. The reductions in the concentrations of dust and SO_2 are dealt with separately since the objects and uses that are sensitive to these pollutants are not identical. The improvement in air quality per unit area will be given in four categories that have still to be defined and will be determined on the basis of the rules for the dispersion calculation, the results of which will be used to check the adherence to the standards.

The sensitive uses and objects are assigned to the areas of identical pollution. The result can be presented in a table (cf. Table 8-1). We regard it as indispensable that information be given on the number of residents affected, and on woodland, agricultural land and ecologically important areas that benefit from the improvement in air quality.

In our opinion, the problem of data collection and data processing for the minimum of objects and uses stated above is not insurmountable. Other objects and uses could be included depending on the desired degree of accuracy and detail.

8.2.3. Results Relevant to Phase Three

The pilot study of a single area (phase two) can be expected to produce results that are necessary for carrying out phase three. These results relate to the following points:

Availability of data

Effort to collect and process the structural data is reduced since it is known which data are really necessary and - once the data gaps have been discovered - the additional input data can be fixed.

Transmission conditions

When a simplified dispersion calculation has been made for a specific area, it becomes possible to formulate general dispersion rules for groups of emitters in this area. A correction factor must be incorporated to take into account specific climatic conditions, but overall the determination of the g.l. concentration level is simplified.

Assessment of possible measures

The suitability of measures carried over into the more detailed part of the study is critically examined.

Determining the costs of possible measures

When the cost of measures that are basically appropriate has been determined and assigned to the emitter groups in the area, it is possible to apply these results to all areas of similar structures, i.e. of the same classification. The sensitivity of cost to the specifif local features can also be included in the calculation. This simplifies the procedure.

Determining the benefits of implementing health protection standards

The determination of the benefits of measures will not be continued in phase three. Under the proposed procedure it would be necessary to investigate each area individually owing to the large number of area-specific factors. Extrapolation of the results of investigations on individual areas would be impossible as far as benefits are concerned because of the inadequate representativity.

8.2.4. Estimate of the Work Involved

Although the work involved in phase two of the study mainly depends on the desired detail of the results the following rough estimate can be made: for the investigation of the cost of achieving the air quality standard in pilot areas as outlined in Section 8.2.1 at least ten man-months have to be calculated for the Battelle staff. In addition, the effort involved in data collection by a local institute has to be taken into account. This rate of effort cannot be estimated yet since it highly depends on the data situation. Approximately ten man-months effort is assumed for the determination of the benefits resulting from the introduction of the standards (Section 8.2.2).

A P P E N D I X

Table 1-1: Limit values for sulphur dioxide and suspended particulates

	Reference period	Concentration of sulphur dioxide µg/m³		Concentration of suspended particulates plus sulphur dioxide 1) µg/m³	
1.	Year	median of daily means	80	annual median of daily values	> 40
2.	Year	median of daily means	120	annual median of daily values	< 40
3.	Winter (1.10.-31.3.)	median of daily means	130	winter median of daily values	> 60
4.	Winter (1.10.-31.3.)	median of daily means	180	winter median of daily values	< 60
5.	24 hours (98 percentile)	arith-metic mean	250	arithmetic mean	> 100
6.	24 hours (98 percentile)	arith-metic mean	350	arithmetic mean	< 100

	Reference period	Concentrations of suspended particulates alone 1) µg/m³	
1.	Year	median of daily means	80
2.	Winter (1.10.-31.3.)	median of daily mean	130
3.	24 hours (98 percentile)	arith-metic mean	250

1) measured by the black-smoke method; the results of measurements of black smoke taken by the OECD method have been converted into gravimetric units as described by the OECD

Source: Gazette of the European Communities, No. C 63 (dated 19.3.1976) /2/

Table 2-2: Polluted areas in the European Community

- Belgium /9/ -- Brussels -- Antwerpen -- Charleroi -- Gent -- Liege - Denmark -- Copenhagen	- Great Britain -- London -- Manchester -- West Midlands (Birmingham) -- Glasgow -- Merseyside (Liverpool) -- Leeds -- Sheffield -- Tyneside (Newcastle) -- Belfast -- Teeside (Eston) -- Cardiff
- Federal Republic of Germany /10, 11, 12/ -- Rhein-Main (Wiesbaden-Mainz) -- Frankfurt -- Rheinschiene Süd -- Rheinschiene Mitte -- Ruhrgebiet West -- Ruhrgebiet Mitte -- Ruhrgebiet Ost -- Ludwigshafen -- Berlin -- Hamburg -- Saarbrücken/Völklingen	- Republic of Ireland -- Dublin - Italy -- Milano -- Roma -- Genova -- Venezia -- Bolzano -- Pescara -- Torino
- France /13/ -- Marseille -- Bordeaux -- Toulouse -- Strasbourg -- Paris -- Lyon -- Lille-Roubaix-Tourcoing -- Le Havre -- Rouen	- Netherlands /16/ -- Amsterdam -- Rotterdam

Table 2-3: Annual emissions of sulphur dioxide and suspended particulates in the Federal Republic of Germany, by types of polluting processes

Types of polluting processes	SO_2			Suspended Particulates		
	1975		Forecast 1980 %	1975		Forecast 1980 %
	kt/a	%		kt/a	%	
Fuel combustion processes	3,471	95.5	95.3	417	74.4	75.5
Power stations and district heating systems	1,704	46.8	49.6	172	30.7	31.0
Industrial furnaces	1,214	33.4	33.4	154	27.5	29.1
Small-scale consumers	473	13.0	10.8	72	12.8	10.9
Traffic	80	2.2	1.5	19	3.4	4.5
Production processes	163	4.5	4.7	143	25.6	24.5
Fuel	-	-	-	39	7.0	7.5
Non-metallic minerals	-	-	-	36	6.4	5.5
Iron and steel	81	2.2	2.2	53	9.5	8.1
Chemicals	82	2.3	2.5	15	2.7	3.4
Crafts/consumers	-	-	-	-	-	-
Total	3,634	100	100	560	100	100

Source: Materialien zum Immissionsschutzbericht 1977, ed. by Umweltbundesamt, Berlin 1977 /29/

Table 2-4: Annual emissions of sulphur dioxide and suspended particulates in the Federal Republic of Germany, by fuel types

Energy source	SO_2				Suspended particulates			
	1975		1980		1975		1980	
	kt/a	%	kt/a	%	kt/a	%	kt/a	%
Coal	1,219	35.1	1,450	37.0	257	61.8	207	58.5
Lignite	785	22.6	818	20.9	95	22.8	76	21.5
Heating oils	962	27.7	1,201	30.7	36	8.7	37	10.5
Heavy fuel oils	408	11.8	362	9.2	9	2.2	12	3.4
Gas	16.8	0.5	24	0.6	0.4	0.1	0.6	0.2
Gasoline	2.0	0.05	2.3	0.06	-	-	-	-
Diesel fuel oil	78	2.2	59	1.5	18.5	4.4	21.0	5.9
Total	3,470.8	99.9	3,916,3	99.9	415.9	100	353.6	100

Source: Materialien zum Immissionsschutzbericht, ed. by Umweltbundesamt, Berlin 1977 /29/

Table 3-1: Requirements to be met by input data of models for long term studies /18/

Anforderungen an Eingabedaten

	Gaußsches Rauchfahnen-Modell	Gaußsches Puff-Modell	Box-Modell	Grid-Modell	Pic-Modell	Statistisches Modell
Entwicklungsstand des Modelltyps	Geeignet zur Standardisierung (4)	Wurde in Einzelfällen schon eingesetzt (2)	Wurde in Einzelfällen schon eingesetzt (2)	Wird z.Z. noch untersucht (1)	Wird z.Z. noch untersucht (1)	Anwendung ist im Prinzip möglich (0)
Untersuchungsgebiet	max. ca. 30 x 30 km (Stadtgebiete) Rauhigkeit wird durch unterschiedliche Ausbreitungsparameter σ_y, σ_z berücksichtigt.	max. ca. 30 x 30 km (Stadtgebiete) Rauhigkeit wird durch unterschiedliche Ausbreitungsparameter σ_x, σ_y, σ_z berücksichtigt. digitalisierte Höhenlinien, falls komplexes Gelände	Stadtgebiete und Region Höhenlinien zur Anordnung der Boxen Rauhigkeit wird durch ortsabhängige Austauschkoeffizienten k_x, k_y, k_z berücksichtigt	Stadtgebiete digitalisierte Geländedaten bei komplexem Gelände Rauhigkeit wird durch ortsabhängige Austauschkoeffizienten k_x, k_y, k_z berücksichtigt	Stadtgebiete, Region digitalisierte Geländedaten bei komplexem Gelände Rauhigkeit wird durch ortsabhängige Austauschkoeffizienten k_x, k_y, k_z berücksichtigt	Region
Emissionsdaten	Emissionskataster für Punkt-, Flächen- und evtl. Linienquellen mit: Punktquellenangaben - Lage (Koordinaten) - Quellstärke (> 1 kg/h) - Quelldurchmesser - phys. Quellhöhe - Abgastemperatur - Austrittsgeschwindigkeit Flächenquellenangaben - Quellstärke - Rastergröße (500 x 500 m, am Rand 1000 x 1000 m) - Emissionshöhe Berücksichtigung von Monats- und Tagesgang möglich	wie beim Rauchfahnen-Modell; zusätzlich Zeitreihen für Quellstärke und variable Quellparameter erforderlich entsprechend den Intervallen der meteorologischen Daten	Zeitreihen der Emissionsraten bezogen auf Boxvolumen mittlere Emissionshöhe	Raster der Flächenquellen, Emissionshöhe, Emissionsrate (Zeitreihen) Punktquellen: Koordinaten, effektive Quellhöhe, Emissionsrate (Zeitreihen)	Behandlung aller Quellen als Volumenquellen Vorgabe der Anzahl der Partikel Zeitreihen für die Emissionsraten, effektive Quellhöhe	Stationarität der Emissionsbedingungen ist Voraussetzung für Anwendung des Modells
Meteorologie	Stabilitätsklasseneinteilung, Auswahl einer repräsentativen Häufigkeitsverteilung von - Windrichtung - Windgeschwindigkeit - Stabilitätsklasse Koeffizient für vertikales Windprofil für jede Stabilitätsklasse, Monatsgang der Lufttemperatur, Mischungsschichthöhe für jede Stabilitätsklasse, Diffusionsparameter σ_y, σ_z	wie beim Rauchfahnen-Modell, jedoch Zeitreihen für Ein- oder Dreistundenintervalle zusätzlich: Daten von mehreren Windstationen zur Ermittlung der Trajektorien sowie Diffusionsparameter σ_x	Meteorologisches Submodell zur Bestimmung von Zeitreihen für vertikale Wind- und K-Profile, Mischungsschichthöhe, geostrophischer Wind, Rauhigkeitslänge, Höhe der bodennahen Grenzschicht, Wärmefluß	Meteorologisches Submodell zur Bestimmung von Zeitreihen für vertikale Wind- und K-Profile mittlere stündliche Werte der horizontalen Windgeschwindigkeitskomponenten für jeden Gitterpunkt. Windprofilexponent Monin Obuchow-Länge, Schubspannungsgeschwindigkeit, Mischungsschichthöhe Windscherung	Meteorologisches Submodell zur Bestimmung von Zeitreihen für vertikale Wind- und K-Profile, mittlere stündliche Werte der horizontalen Windgeschwindigkeitskomponenten, Windscherung Mischungsweglänge diffusionsklassenabhängiges vertikales Windprofil, Schichtungsparameter	Zeitreihen meteorologischer Daten mehrerer Meßstationen: - Windrichtung - Windgeschwindigkeit - Temperaturgradient - Niederschlag - Mischungsschichthöhe - Stabilität - Bedeckungsgrad - Temperatur
Schadstoffdaten	Abbaurate, falls Abbauterm im Modell enthalten	Abbaurate, falls Abbauterm im Modell enthalten	Absorptionsrate Reaktionsrate Abbaurate	Absorptionsrate Abbaurate	chemische, photochemische Reaktionsraten, radioaktiver Zerfall	
Immissionsdaten	Immissionsmeßwerte zur - Validierung des Modells - Ermittlung der Grundbelastung	Immissionsmeßwerte zur - Validierung des Modells - Ermittlung der Grundbelastung	Background-Konzentration und Grundbelastung	Background-Konzentration und Grundbelastung	Background-Konzentration und Grundbelastung	Zeitreihen von Immissionsmeßwerten von mehreren Meßstationen im Untersuchungsgebiet
Eignung des Modelltyps	Der Modelltyp wurde speziell im Hinblick auf diese Aufgabenstellung entwickelt. Gute Jahresmittelwerte. Befriedigende 95 %-Werte in ebenem Gelände.	Zur Ermittlung von Jahresmittelwerten zu aufwendig. Geeignet für Fallstudien bei Einzelquellen, spez. zur Berechnung von Monatsmittelwerten.	Insbesondere der stationäre Ansatz ist für großräumige Untersuchungen geeignet. Der instationäre Ansatz ist sehr rechenintensiv.	Wegen zu hohem Aufwand kaum geeignet zur Ermittlung von Jahresmittelwerten. Äußerstes sinnvolles Zeitintervall: Monat	Wegen zu hohem Aufwand ungeeignet zur Ermittlung von Jahresmittelwerten.	Wurde noch nicht getestet. Könnte auch dann noch eingesetzt werden, wenn kein Emissionskataster vorliegt. Emissionsschwankungen können nicht berücksichtigt werden.

Table 3-2: Requirements to be met by input data of models for short term studies /18/

Anforderungen an Eingabedaten

	Gaußsches Rauchfahnen-Modell	Gaußsches Puff-Modell	Box-Modell	Grid-Modell	Pic-Modell	Statistisches Modell
Entwicklungsstand des Modelltyps	Wurde in Einzelfällen schon eingesetzt (2)	Wurde in Einzelfällen schon eingesetzt (2)	Bereits erprobt (3)	Wurde in Einzelfällen schon eingesetzt (2)	Wurde in Einzelfällen schon eingesetzt (2)	Wird z.Z. untersucht (1)
Untersuchungsgebiet	max. ca. 30 x 30 km (Stadtgebiete) Rauhigkeit wird durch unterschiedliche Ausbreitungsparameter σ_y, σ_z berücksichtigt	max. ca. 30 x 30 km (Stadtgebiete) Rauhigkeit wird durch unterschiedliche Ausbreitungsparameter $\sigma_x, \sigma_y, \sigma_z$ berücksichtigt ggf. digitalisierte Höhenlinien, falls komplexes Gelände	Stadtgebiet und Region Rauhigkeit wird durch ortsabhängige Austauschkoeffizienten k_x, k_y, k_z berücksichtigt Höhenlinien zur Anordnung der Boxen	Stadtgebiete, Tal, Straßenschlucht, Anlagengruppen Rauhigkeit wird durch ortsabhängige Austauschkoeffizienten k_x, k_y, k_z berücksichtigt digitalisierte Geländedaten	Stadtgebiet, Region, Tal Rauhigkeit wird durch ortsabhängige Austauschkoeffizienten k_x, k_y, k_z berücksichtigt digitalisierte Geländedaten	Region
Emissionsdaten	Emissionskataster für Punkt-, Flächen- und evtl. Linienquellen mit: Punktquellenangaben - Lage (Koordinaten) - Quellstärke (>1 kg/h) - Quelldurchmesser - phys. Quellhöhe - Abgastemperatur - Austrittsgeschwindigkeit Flächenquellenangaben - Quellstärke - Rastergröße (500x500 m) - Emissionshöhe Zeitreihen für variable Quellparameter entsprechend den Intervallen der meteorologischen Daten	wie beim Rauchfahnen-Modell	Zeitreihen der Emissionsraten bezogen auf Boxvolumen	Raster der Flächenquellen Emissionshöhe, Zeitreihen der Emissionsraten Punktquellen: Koordinaten, effektive Quellhöhen, Zeitreihen der Emissionsraten	Behandlung aller Quellen als Volumenquellen, Vorgabe der Anzahl der Partikel Zeitreihen der Emissionsraten, effektive Quellhöhe	Stationarität der Emissionsbedingungen ist Voraussetzung für die Anwendung des Modells
Meteorologie	Zeitreihen für - Windrichtung - Windgeschwindigkeit - Stabilitätsklasse - Mischungsschichthöhe Tagesgang der Lufttemperatur Windprofilexponenten Diffusionsparameter σ_y, σ_z	wie beim Rauchfahnen-Modell Zur Trajektorienermittlung meteorol. Daten mehrerer Stationen Diffusionsparameter σ_x, σ_y, σ_z	Meteorologisches Submodell zur Bestimmung von Zeitreihen für vertikale Wind- und K-Profile: Mischungsschichthöhe, geostrophischer Wind, Rauhigkeitslänge, Höhe der bodennahen Grenzschicht, Wärmefluß	Meteorologisches Submodell zur Bestimmung von Zeitreihen für vertikale Wind- und K-Profile: mittlere stündliche Werte der horizontalen Windgeschwindigkeitskomponenten für jeden Gitterpunkt, Windprofilexponent, Monin-Obuchow-Länge, Schubspannungsgeschwindigkeit, Windscherung	Meteorologisches Submodell zur Bestimmung von Zeitreihen für Wind- und K-Profile: Standardabweichungen σ_i, Windscherung, Mischungsweglänge, diffusionsklassenabhängiges vertikales Windprofil, Schichtungsparameter	Zeitreihen meteor. Daten mehrerer Meßstationen: - Windrichtung - Windgeschwindigkeit - Temperaturgradient - Niederschlag - Mischungsschichthöhe - Stabilität - Bedeckungsgrad - Tageszeit - Temperatur
Schadstoffdaten	Abbaurate, falls Abbauterm im Modell enthalten	Abbaurate, falls Abbauterm im Modell enthalten	Absorptionsrate Reaktionsrate Abbauraten	Absorptionsrate, Abbaurate	Chemische, photochemische Reaktionsraten, radioaktiver Zerfall	
Immissionsdaten	Zeitreihen von Immissionsmeßwerten zur - Validierung des Modells - Ermittlung der Grundbelastung	Zeitreihen von Immissionsmeßwerten zur - Validierung des Modells - Ermittlung der Grundbelastung	Backgroundkonzentration und Grundbelastung	Backgroundkonzentration und Grundbelastung	Backgroundkonzentration und Grundbelastung	Zeitreihen von Immissionsmeßwerten von mehreren Meßstationen im Untersuchungsgebiet
Eignung des Modelltyps	Ungeeignet für Schwachwindsituationen	Geeignet für Fallstudien bei Einzelquellen	Geeignet für großräumige Untersuchungen	Geeignet für Kurzzeitprognosen	Geeignet für komplexe Topographien sowie zur Berücksichtigung von Schadstoffveränderungen durch chemische und photochemische Reaktionen oder radioaktiven Zerfall	Geeignet bei Nichtverfügbarkeit eines Emissionskatasters und bei Verletzung der Randbedingungen für den Einsatz von Diffusionsmodellen.

Table 4-1: Catalogue of measures for reducing or avoiding emissions of sulphur dioxide and suspended particulates in industry and households (traffic is not included in the investigation because of its small contribution to the overall emission values)

1. Sulphur dioxide 1.1. Industry
1.1.1. Reduction of pollutant emission at the source by cleaning the exhaust air - Wet desulphurization processes -- Absorption processes using alkaline absorbents -- Absorption processes using alkaline-earth absorbents -- Absorption processes using other absorbents - Dry processes for the desulphurization exhaust gases -- Adsorption processes -- Reaction processes - Processes for the treatment of SO_2 in exhaust gas -- Catalytic oxidation -- Catalytic reduction
1.1.2. Changes with respect to raw materials and fuels (fuel desulphurization) - Desulphurization of heavy fuel oil (atm. residues) from crude oil distillation - Desulphurization of coal - Production of gas from solid and liquid fuels - Substitution of fuel
1.1.3. Returning air-polluting materials into the same production process (recycling) or into another process (waste/secondary product) in the following form: - Sludges ($CaSO_3/CaSO_4$)

Table 4-1 contd.

	- Plaster - Sulphur - Sulphur dioxide (SO_2-rich gas) - Sodium sulphate - Ammonium sulphate Problems: - Quantities - Quality - Potential applications - Market prospects
1.1.4.	Change of production - Use of a different process - Modification or replacement of equipment - Change of the product
1.1.5.	Modification of the exhaust gas release conditions in order to dilute the emissions by high and/or several stacks
1.1.6.	Limitation of the product range
1.1.7.	Shutdown of the plant (and/or transfer of the plant to less polluted regions)
1.2.	Households
1.2.1.	Fuel desulphurization
1.2.2.	Substitution of electric energy or district heat for sulphur-containing fuels (prerequisite: desulphurization by the fuel supplier)

Table 4-1 contd.

2. Suspended particulates 2.1. Industry
2.1.1. Reduction of pollutant emission at the source by cleaning the exhaust air - Mass force separator dust separation by mass forces (gravitational force, inertial force, centrifugal force) Basic designs for dry dust: -- Inertial force separators -- Centrifugal force separators (cyclones) - Filtering separators dust separation by filtering through porous layers and other materials Basic designs for dry dust: -- Cloth separators -- Packed bed separators - Electrical separators dust separation by electric forces Basic designs for either dry or wet dust: -- Dry electric separators -- Wet electric separators - Wet separators dust separation by bonding the dusts to the washing liquid Basic designs for wet dust: -- Static separators -- Rotating separators
2.1.2. Changes with respect to raw materials and fuels
2.1.3. Change of production Reduction of pollutant emission at the source by process-related changes - Use of a different process - Modification or replacement of equipment

Table 4-1 contd.

	- Change of the product
2.1.4.	Modification of the exhaust gas release conditions - Stack height
2.1.5.	Other possibilities - Limitation of the product range - Shutdown of the plant
2.2.	Households
2.2.1.	Changes of the combustion or design principle and the mode of operation
2.2.2.	Change of fuel

Table 8-1: Example of tabular presentation of benefits

Objects and uses \ Immission reduction (in µg/m³)	>10	10 - 5	5 - 2,5	2,5 - 0,5
Area (km²)	15	30	20	10
Residents (number)	$15 \cdot 10^3$	$18 \cdot 10^3$	$7 \cdot 10^3$	$11 \cdot 10^3$
Woodland (km²)	7	3	15	6
Agricultural land (km²)	5	15	0	3
Ecologically important areas (importance, area (km²))	resting place for migratory birds 0,8			wet area 5

Fig. 2-1: Spatial distribution of 1973 SO_2 emissions (kilotons/a)

Source: Johnson, W.B., Wolf, D.E., Mancuso, R,L.: The European Regional Model of Air Pollution (Eurmap) and its Application to Transfrontier Air Pollution, In: NATO/CCMS Air Pollution Pilot Study 1976 /8/

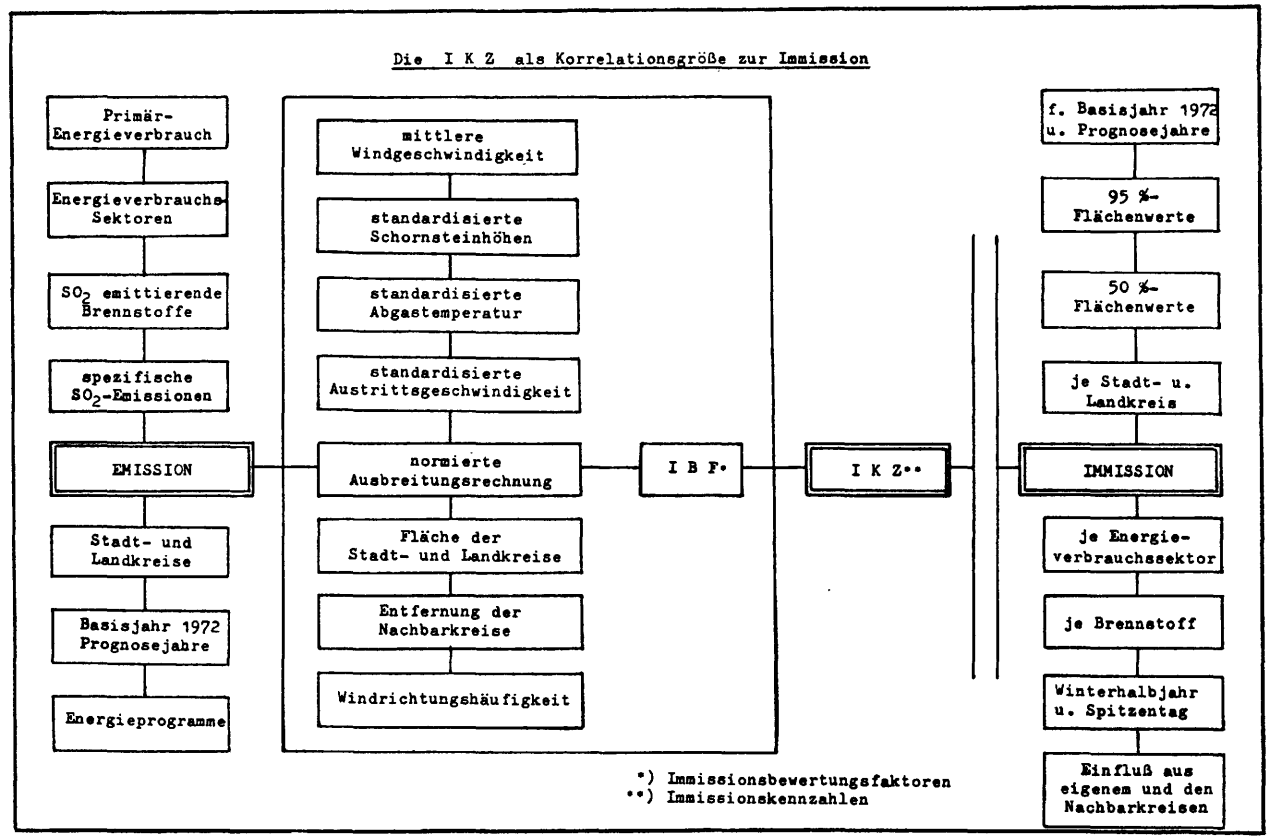
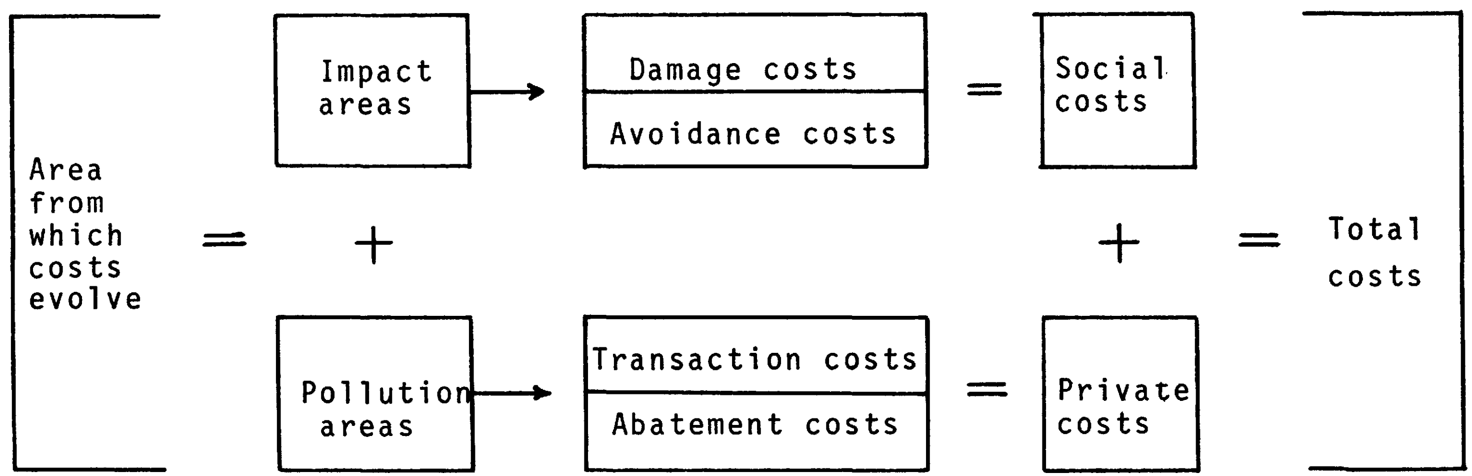


Figure 3-1: The concentration characteristics as a correlation coefficient to concentration



<u>Fig. 5-1:</u> Categories of costs (according to /29/)

Figure 8.2-1: Flow diagram of the pilot study

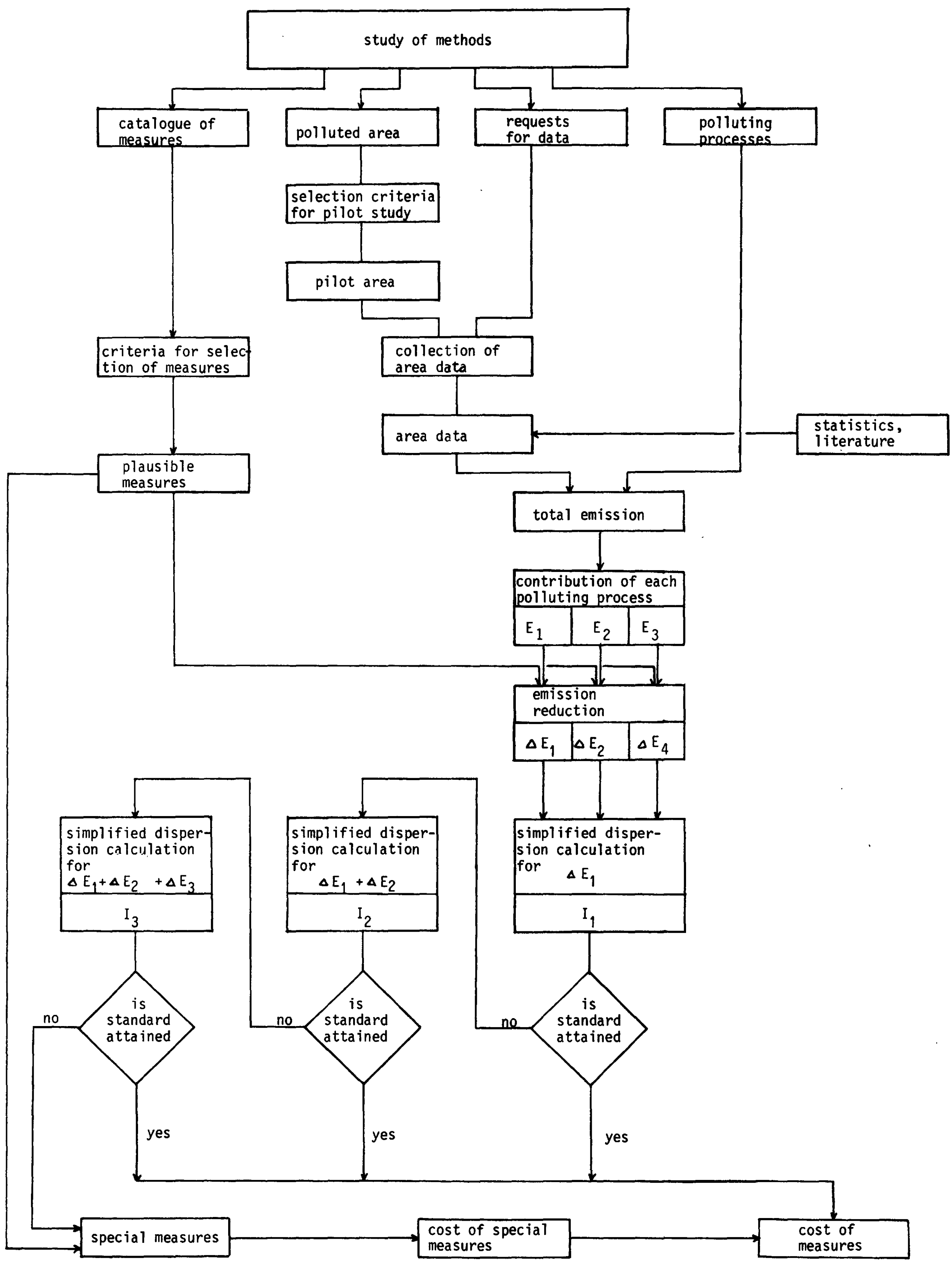
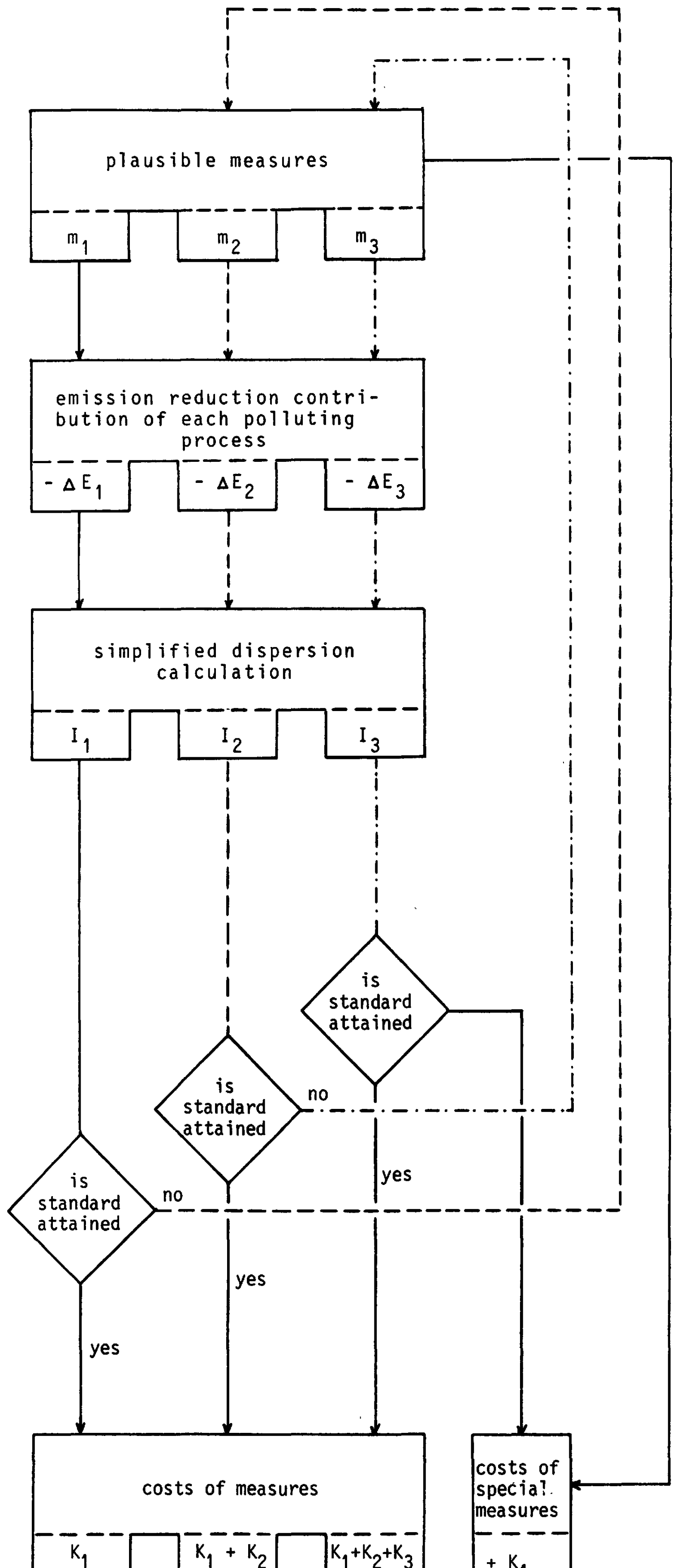


Fig. 8.2-2: More detailed flow diagram of the simplified dispersion calculation



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European Communities — Commission

EUR 6852 — Elaboration of methods for determining the costs and benefits of implementing health protection standards concerning sulphur dioxide and suspended particulates

by R. Frische and R. Hachmann
Battelle-Institut — Frankfurt am Main (FR of Germany)

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This report investigates possible approaches to evaluate the costs and benefits of the observance of health protection standards for sulphur dioxide and suspended particulates in the atmosphere of polluted areas. Today neither standardized approaches nor uniform methods for quantifying the above parameters exist. For this reason, the problem is divided into various partial problems; possible solutions are presented and examined for their suitability.

Two different basic methods are proposed for the determination of costs and benefits. While it appears appropriate to assess the disadvantages (= costs) in monetary units, this does not apply to the advantages. Positive effects of air pollution control measures cannot be expressed by one single parameter. They can be determined, however, by the degree of relief for different objects and functions.

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