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The Baltic Sea Environmental Programme

The Topical Area Study for Atmospheric Deposition of Pollutants

FINAL TECHNICAL REPORT

J.M. Pacyna

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THE BALTIC SEA ENVIRONMENTAL PROGRAMME

THE TOPICAL AREA STUDY FOR ATMOSPHERIC DEPOSITION OF POLLUTANTS

TECHNICAL REPORT

by

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The Baltic Sea Environmental Programme

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1 INTRODUCTION

1.1 The Norwegian Institute for Air Research (NILU) has been contracted by the European Bank for Reconstruction and Development (EBRD) to provide information and consulting on the impact of air pollution on the contamination of the Baltic Sea.

1.2 The objectives of the study are to: 1) assess source-receptor relationships for air pollutants of concern in the Baltic Sea region with focus on pollution loading from the atmosphere, and 2) recommend reduction scenarios for atmospheric emissions of pollutants of concern and the means of investment in certain regions within the study area in order to meet the reduction goals.

1.3 The study focuses on inputs of nutrients, such as oxidized and reduced forms of nitrogen. Other pollutants of particular interest for the environmental quality of the Baltic Sea will also be studied. They include toxic trace metals, such as mercury, cadmium, copper, lead, zinc, and possible arsenic, chromium and nickel, and persistent organic pollutants, such as, polychlorinated biphenyls (PCBs), hexachlorocyclohexanes (HCHs), and hexachloro benzene (HCB).

1.4 The aim of this report is to provide the Bank with extended information on emissions and deposition fluxes of pollutants in the study area and their future trends as well as with assessment of environmental requirements. A list of priorities is presented with respect to emission and deposition reductions and their strategies. A review of solutions to meet these reductions is included with technical, economic, financial, and institutional issues, following the content of the Synthesis Report. Projected environmental benefits are outlined with focus on the limitation of the Baltic Sea contamination by air pollutants of concern. Finally, technical and financial actions related to the Baltic Sea Environmental Programme are recommended with considerations given to both industrial and human resource requirements and environmental standards in the study area.

2 DESCRIPTION OF THE STUDY AREA

2.1 The study area is the Baltic Sea and source regions with emissions affecting the quality of the Baltic Sea water through the transport of pollutants with air masses and atmospheric deposition.

2.2 Information on deposition of oxidized and reduced nitrogen and lead suggests the study area to be parts of Eastern Europe (CSFR, Poland and Soviet Union) and Western Europe (Belgium, France, Germany, Netherlands and United Kingdom), as well as Northern Europe (Denmark, Finland, Norway and Sweden).

A part of the study area where the actions are proposed in order to reduce atmospheric emissions and deposition to the Baltic Sea of nitrogen compounds, heavy metals, and persistent organic pollutants, is defined here as the proposed action area. This area includes Poland, CSFR, Latvia, Lithuania, Estonia, Leningrad Region, Kaliningrad Region and Karelia.

3 EMISSIONS OF AIR POLLUTANTS OF CONCERN

3.1 NO_x EMISSIONS

NO_x emissions from sources located in the study are presented in Table 1. These estimates were made by national authorities and reported to the UN ECE Convention on Long-range Transboundary Air Pollution (LRTAP). There are two major groups of sources emitting NO_x, namely stationary sources, often referred as high sources (with respect to the source height) and mobile sources, referred as low sources. Information on the source height is important for modellers assessing long range transport of air pollutants and their deposition.

Major stationary source categories include: 1) production of electricity in power stations burning hard (bituminous and sub-bituminous) coals, brown coals including lignites, residual (heavy) and distillate oil, and natural gas, 2) metallurgical coke production, 3) cement production in dry and wet kilns, 4) gas works, 5) steel and iron production, 6) coal combustion in central (district) heating and small residential units, and 7) oil and gas combustion in industrial and residential boilers. Other sources, such as nitric acid production are not significant. Their contribution to NO_x emissions is assumed to be relatively low.

Three major mechanisms are responsible for NO_x formation: 1) "thermal NOx" by fixation of atmospheric nitrogen in the combustion air, 2) "fuel NOx" by conversion of chemically bound nitrogen in the fuel, and 3) "prompt NOx", taking place in the front of the flame. The mechanisms are described in details by various authors (e.g. UN ECE, 1986). The results from the Swedish programme on the influence of coal combustion on human health and the environment (KHM, 1982) indicate that as much as 60% of total NOx formed during coal combustion is due to transformation of the fuel nitrogen.

Emission quantities of NO_x released from stationary combustion sources are dependent of parameters related to fuels, apporatus and operation conditions. Details are available from Pacyna and Joerss (1991). Mobile emissions of NO_x are usually calculated for passenger cars, light duty trucks, heavy duty vehicles, motorcycles, railway locomotives, boats, and agricultural tractors. These emissions depend mostly on type of fuel, cylinder capacity, engine design, control devices, operation conditions, and maintenance of vehicles.

Details on NO_x emissions from major stationary sources in the proposed action area and former German Democratic Republic are presented in Table A-1 of Appendix A.

Spatial distribution of NO_x emissions in Europe in 1989 within the EMEP grid of 150 km x 150 km is presented in Figure 1 in 10^3 tonnes as NO_2, and spatial distribution as an average value for years 1985, 1987, 1988, 1989 and 1990 in $mg/m^2 \cdot year$ as N is given in Figure 2 (Iversen et al., 1991).

3.2 NH_3 EMISSIONS

There are three major source categories of anthropogenic emissions of NH_3: animal wastes, use of fertilizers, and some industrial activities to produce nitric acid, synthetic ammonia and urea. Landfills and sewage treatment also emit NH_3. Only a few countries report officially on their emissions, including Denmark, Finland, Germany, and the Netherlands. These data together with estimates of Buijsman et al. (1987) for other countries in the study area are presented in Table 3.

Emissions from livestock waste contribute the most of the total anthropogenic emissions of NH_3. Percentage contribution of various source categories to the total NH_3 emissions in countries with the proposed action areas and former German Democratic Republic is presented in Table 4.

There are various factors affecting the NH_3 emissions from livestock wastes, including type and number of animals, feed composition, amount and its nitrogen content, retention of nitrogen, type of housing for animals and manure storage system, and NH_3 volatilization during housing and storage manure, after application of manure, and from faeces and urine. More details about this subject are available from Pacyna and Joerss (1991), Klaassen (1990), and Thomas and Erisman (1990).

Spatial distribution of NH_3 emissions from anthropogenic sources in Europe in 1989 within the EMEP grid of 150 km x 150 km is presented in Figure 3, in 10^3 tonnes, while an average value for years 1985, 1987, 1988, 1989 and 1990 in $mg/m^2 \cdot year$ as N is shown in Figure 4. These data are derived mainly from Buijsman's (1987) compilation, with some adjustments by the MSC-W of EMEP. This implies that the numbers are derived from the number of domestic animals and consumption of fertilizers, without detailed consideration of different agricultural practices, such as feeding of animals and manure storage and application.

No major changes of NH_3 emissions in the study area are expected to occur in the near future. Decrease of these emissions during the period from the beginning of the 1980's to present time has been indicated due to decline in cattle breeding and for farming in some countries (Kulmala and Sarkkinen, 1990).

3.3 HEAVY METAL EMISSIONS

High temperature processes, such as coal and oil combustion in electric power stations and industrial plants, roasting and smelting of ores in non-ferrous metal smelters, melting operations in ferrous foundries, refuse incineration, and kiln operations in cement plants emit various volatile heavy metals. The amounts of atmospheric emissions of heavy metals from the above sources are dependent on: 1) the contamination of fossil fuels and other raw materials, 2) the physico-chemical properties of heavy metals affecting their behaviour during the industrial processes, 3) the technology of the industrial processes, and 4) the efficiency of the control equipment (e.g. Pacyna, 1989).

Total emissions of arsenic, cadmium, copper, lead and zinc in countries in the study area are presented in Table 5, while the anthropogenic emissions of various chemical forms of mercury are given in Table 6. Contributions of emissions from major source categories to the total emissions in various European countries are shown in Figures 5-9 for arsenic, cadmium, mercury, lead and zinc, respectively (Axenfeld et al., 1990).

Atmospheric emissions of As, Cd, Hg (total), Pb and Zn from major individual sources in countries with the proposed action areas and the former German Democratic Republic are presented in Table A-2 of Appendix A.

The spatial distribution of As, Cd, Pb and Zn emissions in 1982 from anthropogenic sources in Europe within the EMEP grid of 150 km x 150 km is shown in Figures 10-13, respectively. Similar distribution for total Hg, as well as for elemental Hg in gas phase, oxidized Hg in gas phase and elemental Hg on particles is shown in Figures 14-17, respectively. It is very important to take into account the chemical and physical forms of mercury, as they decide about the chemical and physical behaviour of the element in the environment, as well as on its toxic effects to the individual environmental media.

Two approaches were made by Pacyna et al. (1991) to assess emission trends for heavy metals up to the year 2000. In the first approach, heavy metal emissions for the year 2000 have been obtained on the basis of the 2000/1982 indexes for statistical data and emission factors. The production/consumption index relates the statistical data for the year 2000 as presented in IIASA's model RAINS to the statistical data for 1982. The emission factor indexes were calculated for major source categories, separately. It was assumed, for example, that by the year 2000 all electric power plants in Western Europe will comply with the German regulations concerning the heavy metal emission rates for new plants, while the East European power plants will comply with the regulations for existing plants. Two alternative scenarios were assumed for the use of Pb additives in gasoline in 2000. In the alternative A, 50% of gasoline in Western Europe will be unleaded and the rest will contain 0.15 g Pb/l. In Eastern Europe the content of gasoline will not exceed 0.15 g/l on average. In alternative B, only unleaded gasoline will be available in Western Europe, while 50% of gasoline in Eastern Europe will still contain of 0.15 g Pb/l. There were also assumptions for other industries. The results of calcultations for Pb in Europe in 2000 are given in Table 7. In the second approach, prognosis for atmospheric emissions of As, Cd and Pb in Europe in the 1980's has been prepared on the basis of information on the emission control efficiency of the best available technology (BAT) at present.

The BAT concept assumes the latest stage of development (state of the art) of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting emissions.

Special emphasis was placed on BAT in non-ferrous metal industry. Concerning lead, the prognosis assumes the use of only unleaded gasoline in Europe. The estimates are shown in Table 8. As much as one order of magnitude lower emissions of Pb were calculated assuming the application of BAT and unleaded gasoline in Euorpe. The application of BAT will reduce the As and Cd emissions by factor of 3 and 2, respectively.

3.4 PERSISTENT ORGANIC POLLUTANTS (POPs)

Persistent organic pollutants are emitted to the atmosphere from various point and area sources related to their production and use. Concerning POPs studied in the project, major sources of polychlorinated biphenyls (PCBs) include dumps and landfills, leaks and disposal of industrial fluids, vaporization from plasticized products, and vaporization during open burning of disposed scrap and materials in dump. Of these, only vaporization is regarded as a significant source of emissions to the atmosphere.

Hexachlorocyclohexans (HCHs) are components of pesticides and as such enter the atmosphere mainly by emission during and/or after their application to soil and crops.

Major sources of hexachlorobenzene (HCB) at present include production of tetrachloroethylene, trichloroethylene, and carbon tetrachloride, incineration of municipal wastes, and use of selected pesticides, e.g. quintozene, chlordimethyl, chlorothalonil, and pentachlorophenol.

Emissions of the above POPs in the study are presented in Table 9 (after Axenfeld et al., 1990). No information exists to discuss trends of these emissions in the near future. However, limited use of PCBs, HCHs and HCB in Europe suggests no further increase of their emissions.

3.5 REMARKS ON RELIABILITY OF EMISSION DATA

Reliability of emission data presented in this report varies significantly from one compound to another. Generally, the reliability decreases along the following order:

$$NO_x > Pb > NH_3 > Hg > \text{rest of heavy metals} > \text{POPs}$$

An accuracy of 20 per cent can be assigned to emission data for NO_x and Pb, 50 per cent for NH_3 and Hg, and a factor of 2 for the rest of heavy metals. It is very difficult to assess the accuracy of emission data for POPs due to a lack of these data afterall. There is no doubt, however, that the POP emission data are highly unreliable and should be taken with caution.

4 DEPOSITION TO THE BALTIC SEA

4.1 DEPOSITION ESTIMATES BASED ON MEASUREMENTS

In a view of the growing contamination of the Baltic Sea waters by pollutants from land-based sources, the Baltic Marine Environment Commission - the Helsinki Commission (HELCOM) launched an international monitoring network in 1983 under the supervision of EGAP, the Group of Experts on Air Pollution. The results from the HELCOM/EGAP network form a basic source of information for the proposed study on measured inputs of the pollutants of concern to the Baltic Sea.

At present the HELCOM/EGAP network consists of 26 landbased stations (see Figure 18) measuring the precipitation concentrations of NO_3^-, NH_4^+, Pb, Cd, Cu and Zn as a minimum requirement. The air concentration measurements are carried out at some of these stations on a voluntary basis.

Two methods are used to estimate the atmospheric deposition of nitrogen species to the Baltic Sea. The first, experimental method relies exclusively on measurement data on concentrations and the precipitation recorded at the various coastal stations. The method presupposes that this precipitation is representative also for the open sea and that is a crude approximation. The results of this method must therefore be viewed with some caution.

The second, hybrid estimation method relies on pollution measurements and both observed and calculated precipitation amounts. Model calculations are considered more reliable for estimating precipitation over the open sea than extrapolation of actual coastal measurements.

Average wet deposition values for the years 1986-1990 in different regions of the Baltic Sea calculated by experimental and hybrid methods are presented in Table 10 for nitrogen components and in Table 11 for lead. No data are available for other heavy metals as the measurements started only recently.

The following conclusions can be drawn from these estimates:

- the nitrogen flux decreases from about 1000 kg N/km$^2\cdot$year in the southern parts of the Baltic Sea to 700 kg N/kg$^2\cdot$year in the north. This results in a total N wet deposition to the Baltic Sea of about 300 kt/year on average for 1987-1990, and
- the lead flux was about 2 kg/m$^2\cdot$year resulting in the wet deposition of this metal to be about 600 t/year on average for 1987-1989.

Concerning the concentration trends, the following can be concluded:

- the total nitrogen concentrations in precipitation (a sum of nitrate and ammonium) show a slightly increasing trend during the period from 1986 to 1990 mostly due to increasing concentrations of ammonium,
- the decreasing trend of Pb concentrations in precipitation stopped in 1988, being stable during the last couple of years. As the concentrations of other trace metals in precipitation have been required only since 1990, there is no data to conclude on concentration trends for them, and
- there is a clear tendecy for higher concentrations in the southern parts of the Baltic Sea.

4.2 DEPOSITION ESTIMATES BASED ON LONG-RANGE TRANSPORT MODELS

Both wet and dry depositions are calculated by models as they incorporate concentrations of pollutants in precipitation and air. The model calculations are reliable assuming that the emission data base is complete and transparent.

A one-layer model, developed at the EMEP Meteorological Synthesizing Centre-West (MSC-W), has been used to calculate the NO_x and NH_3 transport and deposition over Europe by the Lagrangian approach. The model is receptor oriented and uses air mass trajectories that are four days long, ending up in a selected set of receptor points every six hours. Detailed description of the model is available from Iversen et al. (1991).

The EMEP model calculates concentrations and depositions of nitrogen compounds with a time resolution of one month in 36 emission and deposition domains representing countries and oceans. The model is able to keep track of the domain in which the pollution was emitted which makes it possible to allocate the deposition on the whole Baltic Sea to relevant emitter countries. The estimates of total dry and wet deposition of nitrogen to the Baltic Sea in the period 1985-1990 are presented in Table 12. It can be noted that the main contribution of 65% comes from the Baltic Sea countries, probably because of their proximity. Other prominent contributors are United Kingdom, France and the Netherlands, which are all upwind of the predominant westerly winds in the Baltic and which are also among the major European emitters. Czechoslovakia is another major contributor.

The nitrogen deposited is divided in the ratio 40/60 per cent among reduced and oxidized nitrogen. Distribution of deposition of oxidized and reduced nitrogen to the Baltic Sea in 1988 on the basis of EMEP model is given in Appendix B. In summary, the following conclusions can be drawn from the three methods for estimating the nitrogen deposition to the Baltic Sea:

> The experimental and hybrid methods probably overestimate the wet deposition of reduced nitrogen.
>
> The model method probably underestimates the same quantity.

For oxidized nitrogen, the deposition estimates are considered fairly realistic even though model also includes the dry deposition processes.

A reasonable estimate for the total deposition of nitrogen to the Baltic Sea in the second half of the 1980's thus seems to be

300 ± 30 kilotons N/yr

Model calculations of heavy metal depositions have been carried out with a trajectory model having similar structure as that of EMEP-MSC-W. The calculations have been restricted to lead for the period from 1980 to 1985 due to limited emission data base. The result is that the total deposition of lead to the Baltic Sea is close to 1400 T Pb/yr. The calculations show that 70% of the input is caused by the countries around the Baltic Sea, and the rest is due to long range atmospheric transport from other areas in Europe. It was also calculated that wet deposition contributed 860 t to the total deposition in 1985 (Grassl et al., 1989).

A similar version of the model was used to calculate mercury deposition to the Baltic Sea (Petersen et al., 1990). Preliminary results indicate that 12 t of mercury was deposited in 1985.

Neither measurements or model calculations are available in order to assess the deposition of POPs to the Baltic Sea. Assuming that this deposition is similar to the deposition of POPs to the North Sea (e.g. Semb and Pacyna, 1988), it can be suggested that the annual PCB and γ-HCH depositions may be of the order of about 40 t each.

4.3 ATMOSPHERIC CONTRIBUTION AS COMPARED WITH OTHER CONTRIBUTION TO THE TOTAL LOAD OF POLLUTANTS OF CONCERN TO THE BALTIC SEA

In order to properly structure the policy of emission and deposition reductions, it is necessary to assess what portion of a given pollutant enters the Baltic Sea from the air, and what portions come through other pathways, namely direct discharges from urban regions and industry, and indirect discharges through transport by rivers. Information presented in previous chapters of this report suggests that only the nitrogen, lead, and mercury emissions and depositions to the Baltic Sea have been extensively studied. Information on emissions on As, Cd, Cu, and Zn also exists but far less data is available of their depositions. It is expected that the HELCOM programme will provide more information on this subject in the near future as the measurements of the above heavy metals started in 1990.

Very limited information can be found which will allow to compare atmospheric loads of nitrogen and selected heavy metals with direct and indirect loads with water bodies. No information was available for POPs.

Information obtained from the HELCOM Task Force (HELCOM, 1991a) suggests that the direct load of nitrogen compounds from urban areas and industrial discharges to the Baltic Sea was in 1987 about 72 kt and 16 kt, respectively. They originated from sources in Denmark, Finland, Germany, Poland, Sweden, and USSR. Indirect load of nitrogen (transport by rivers) was calculated about 760 kt. The above data were provided by National Plans in the respective countries.

A comprehensive report on pollution load to the Baltic Sea was published in 1987 (HELCOM, 1991b). It describes the situation in the early 1980s, and gives an assessment of the conditions of the Baltic Sea and its sub-regions.

Pollution load of nitrogen to the Baltic Sea via different pathways is presented in Table 13. Atmospheric deposition seems to contribute between one quarter and one third to the total load of nitrogen to the Baltic Sea. Transport of nitrogen by rivers is the major contributor, bringing twice as much as the atmospheric transport. A part of nitrogen in rivers originate from the atmosphere. However, the assessment of this value is not within the scope of this report. It can also be suggested, that the nitrogen load through rivers has increased during the 1980s.

Less information is available to directly compare various pathways of Pb, Hg, and other heavy metals to the Baltic Sea. However, very interesting studies have been carried out to assess environmental implications of metal distribution in the Baltic Sea on the basis of the heavy metal content of sediments (Hallberg, 1991). Sediment inventories are ideal for studies of anthropogenic impact of metals on the environment, as they represent geochemical changes of the environment over a long time-span. The regional distribution of metals in the Baltic sediments can be related to atmospheric input and the distribution of organic matter, and for some of the metals (Fe, Mn, and Hg) to the redox conditions. It was concluded that the positive relation found between the metals and organic matter which, according to statistical data, is of significance for the regional distribution, is overshadowed by atmospheric input as an explanation for downcore distribution. The final conclusion has been that the atmospheric input is the most important source of metals to the Baltic area. It was also found that on the average, metal concentrations in sediments of the Baltic Proper have increased fivefold over the past 50 years, and for some heavy metals, such as Cd and Mo there has been an increase by one order of magnitude.

Studies on the input of heavy metals to the North Sea indicate that atmospheric deposition contributed about 60 per cent to the total load of Pb, Cd, and Cu, about 50 per cent for Hg and about 30 per cent for As, Cr, and Zn in the beginning of the

1980s (Norton, 1982, Hill et al., 1984). Recent results from the PARCOM programme on contamination of the North Sea (PARCOM, 1991) indicate that pollution of nitrogen and lead to the North Sea is comparable with that to the Baltic Sea. The comparison is given in Table 14. Higher Pb load to the Baltic Sea can be explained by larger influence of pollution transport from Eastern Europe with mostly leaded gasoline.

Concerning mercury, calculations made by the German modellers at GKSS suggest an amount of about 12 t on annual basis to be deposited to the North Sea (PARCOM, 1991) as well as to the Baltic Sea (Petersen et al., 1990).

A report from Poland (HELCOM, 1991c) indicates wet fluxes of Cd, Cu, and Zn to be 0.47, 1.5, and 8.3 $kg/km^2 \cdot year$, resulting in the annual wet deposition of these metals to be about 140 t Cd, 450 t Cu, and 2500 t Zn. The fluxes reported for the North Sea were 52 t Cd, 524 t Cu, and 3830 t Zn (PARCOM, 1991), thus similar to those suggested for the Baltic Sea except Cd. High Cd fluxes to the Baltic Sea in comparison with fluxes to the North Sea can be explained by higher emissions from primary zinc smelters in Eastern Europe than in Western Europe. This can also explain higher Zn fluxes to the Baltic Sea.

In general, atmospheric pollution loads of nitrogen and heavy metals to the North Sea and the Baltic Sea are comparable. Therefore, it can be suggested that the pathways of heavy metals to the Baltic Sea shall be similar to the pathways of the metals to the North Sea. If so, the atmospheric input is the dominant pathway for heavy metals to the Baltic Sea. Preliminary data collected by HELCOM from the 1987 National Plans of the countries in the study area seem to confirm the above suggestions on atmospheric deposition as a main pathway of heavy metals to the Baltic Sea (HELCOM, 1991a).

Not enough data exists to perform similar analysis for POPs.

5 ENVIRONMENTAL EFFECTS OF POLLUTANTS ON THE BALTIC SEA

Adverse effects of various pollutants on the Baltic Sea environment have been studied by several experts and their results were recently summarized for the HELCOM Task Force meeting in Tallin, 12-15 November, 1991 (HELCOM, 1991a).

Eutrophication of the sea is one of the effects of nutrient content of the water. It was reported that the lower limit of the zone of large algae along the coasts has moved upwards as an effect of a decreased transparency of the water, e.g. bladder wrack (Focus) in southern Bothnian Bay, from 11.5 m to 8.5 m. Transparency (vertical visibility) in water in a control area of the Baltic Sea coast has decreased from 9 m to 5 m, due to effects other than local pollution. Another effect of eutrophication is illustrated by the net catch of the herbivorous cyprinid fishes, which has been more than duplicated during the same period of the two decades. A serious reduction of benthic animals found in some areas of the Baltic coast is also related to an increased production of algae. It can be summarized that strong increase of nutrient concentrations, and mostly nitrogen and phosphorus in the Baltic Sea in the 1970s, although stopped at present, resulted in the increasing biological production and its subsequent sedimentation followed by the microbial destruction of the biogenic organic material and deterioration of the oxygen conditions in the Baltic deep water.

It is difficult to find direct relationship between concentrations and ecological effects of heavy metals, both acute and chronic effects. It has been reported that increased concentrations of various heavy metals can be found in organisms a few hundreds of kilometers from big local sources. An excellent example is found for arsenic. An increased burden of arsenic, believed to be emitted from Rönnskärsverken in the southern Bothnian Bay, has been demonstrated in zooplankton in the whole Gulf of Bothnia some 10 years ago.

There are many measurements of mercury in marine sediments. High values of heavy metal concentrations have been measured for the Baltic sediments obtained in anthropogenically influenced coastal and estuarine waters. Methylmercury was found as one of these metals. This compound is accumulated in the food chain of aquatic ecosystems and is found at comparably high concentrations in certain larger fish, e.g. pike. Fish consumption constitutes the predominant route for human exposure to organic mercury. An extended discussion of effects by the pollutants of concern on the marine environment of the Baltic Sea has been presented in the Baltic Sea Environment Proceedings (HELCOM, 1990).

6 ALTERNATIVES FOR MEASURES TO REDUCE EMISSIONS

Alternative methods to reduce emissions of nitrogen compounds and heavy metals will be discussed here. Incomplete and often confusing information on emissions of POPs in the study area results that discussion on reduction strategies and technical measures for these pollutants is premature at present.

Measures to reduce emissions are highly correspondent to the extent of reduction and major source categories of emission. It is expected that the deposition of several pollutants to the Baltic Sea will be reduced substantially. This would require very effective reduction of emissions of these pollutants in the countries within the study area. An example is given below.

Calculations have been carried out to assess to what extent reductions of NO_x emissions, decleared within the UN ECE "NO_x reduction protocol" (reduction of at least 30% of the 1985 NO_x emissions to be reached in 1998) will decrease the deposition of oxidized nitrogen in Europe. Figure 19 shows the changes in deposition of oxidized nitrogen due to reduced emissions in Austria, Belgium, Denmark, Finland, France, Germany (only former Federal Republic of Germany), Italy, the Netherlands, Norway, Sweden, and Switzerland. The above countries signed the

"NO_x protocol". It can be seen that deposition reduction of up to 25 per cent is achieved in regions where emission reductions will be undertaken. Deposition reductions between 13 and 18 per cent can be expected in the area of the Baltic Sea, but it should be noted that only the Scandinavian countries within the study area have agreed to reduce their NO_x emission (at the time of calculations). In order to achieve a 50 per cent reduction of nitrogen load to the Baltic Sea by 1995, as declared by the HELCOM Ministerial Declaration of 15th February 1988, the emission reductions should be greater than 60 per cent in all countries in the study area. The IIASA study on potential and costs for control of NO_x emissions in Europe (Amann, 1989) concludes, however, that a maximum technically feasible reduction could decrease the European NO_x emissions by some 60 per cent. This chapter of the report reviews the technical options in order to achieve the required emission reduction.

6.1 REDUCTION OF NO_x EMISSIONS

6.1.1 Reduction of NO_x emissions from stationary sources

Major source of NO_x emissions from stationary sources is production of electricity and heat. NO_x is produced during oxidation of fuels with the furnace at a rate governed by the fuel characteristics and the combustion conditions.

Usually coal contains 1 to 2 per cent fixed nitrogen, while commercially available residual oil up to 0.3 per cent by weight. Distillate oils and natural gas are practically free of fixed nitrogen. Therefore, combustion of gas and gas oils generates lower emissions of NO_x than combustion of other types of fuels. Recently the US Environmental Protection Agency has launched the Coalbed Methane Project in Poland with aim to study the possibility of replacing coal in a power plant with methane recovered from the methane-rich coal mines in the Upper Silesia. It is, however, far too early to expect conclusive results of this project now. Generally, the free choice of low nitrogen containing fuels is strongly limited as the utilization of fuels is directly governed by the energy supply structure of a given country. Fuel cleaning with the only purpose of nitrogen removal is uneconomic because of the technically complex requirements. Therefore, only a small NO_x reduction potential is achieved by fuel manipulation.

There are techniques for using gas as a supplemental fuel for emissions control. These methods involve the burning of natural gas with other fuels for emission reduction purposes in stationary applications. In practice there are some operations, such as select gas use, which involve replacing some of the coal and residual oil fired in a boiler. At present, no utility dual-fuel boilers are firing coal and gas, but there are some burning oil and gas that were designed for coal (NAPAP, 1990a). There are also co-firing units in which gas and coal or oil are burned simultaneously in the same boiler.

In practice, the NO_x emission reduction can be obtained either through primary measures related to combustion modification (by suitable manipulation of the stoichiometry/temperature profiles within the boiler) or secondary measures related to exhaust gas treatment. None of the measures is in operation in the heat and electricity plants in the proposed action area. Recently the UN ECE NO_x Task Force has reviewed technologies for controlling NO_x emissions from stationary sources (UN ECE, 1986). The following can be concluded:

Depending on site specific parameters, NO_x reductions of up to 20 per cent can sometimes be achieved by minor modifications of the combustion process, such as operation at lower excess air or by adjusting the fuel/air ratio at selected burners. However, the main area of interest for combustion modifications for NO_x control lies in the use of:

- low NO_x burner (LNB),
- off stoichiometric combustion (overfire air) (OSC), and
- flue gas recirculation (FGR),

all of which can be used either separately or in conjunction with each other. Major changes are sometimes required to implement these latter technologies as retrofits although all are applicable to new units.

LNBs are available for burning coal, oil and gas. For new facilities the NO_x reduction attributable to LNB is about 30-60 per cent.

OSC technique is applicable at new and retrofit systems of all boiler types. Extents of NO_x reduction range from about 10 to 40 per cent depending on fuel and boiler type. A possible negative side effect can be boiler corrosion by reducing atmospheres which might limit retrofittability.

FGR is applicable for new and retrofit installations burning gas and oil, as well as for high temperature coal combustion. NO_x reduction of about 20 per cent for coal, 20 to 40 per cent for oil, and up to 50 per cent for gas can be achieved.

Staged combustion is another NO_x control technology which offers the potential of substantial additional reductions of NO_x. When used in conjuction with other combustion modifications NO_x emissions can be lowered by up to 80 per cent. This technique consists of a second combustion zone in the boiler.

Estimates of removal efficiency and side-effects of combustion modifications for coal (wet and dry bottom type of boilers), oil and gas firing boilers are presented in Table 15 (UN ECE, 1986).

For exising utility boilers the following emission values have been demonstrated for retrofitting low NO_x combustion systems:

(i)	pulverized coal firing (6% O_2)		
	- wet bottom boiler:	1 000 - 1 400 mg/m^3	(350-490 g/GJ)
	- dry bottom boiler:	600 - 800 mg/m^3	(tangential) (210-280 g/GJ)
		600 - 1 100 mg/m^3	(wall-fired) (210-380 g/GJ)
(ii)	oil firing (3% O_2):	200 - 400 mg/m^3	(60-120 g/GJ)
(iii)	gas firing (3% O_2):	100 - 300 mg/m^3	(30-90 g/GJ)

At new facilities in many cases the emissions may be lower than the smaller value of the above mentioned emission ranges.

Post-combustion controls reduce NO_x emissions after the flue gases leave the combustion zone. Commercially available technologies use ammonia or urea to reduce NO_x to nitrogen with or without a catalyst. Higher NO_x reductions are achievable using the selective catalytic-reduction process versus the selective non-catalytic process. Other flue gas treatment processes are under development.

Combustion controls are by far more used than the NO_x scrubber technologies (post-combustion controls). For example, currently all nitrogen oxide control systems in U.S. utility boilers are combustion controls. No NO_x scrubber technologies, such as selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR), are in use (NAPAP, 1990a). In USA some 27 per cent of total boiler capacity and 30 per cent of coal-fired capacity employs some form of low NO_x burner.

Fluidized bed combustion (FBC) is a widespread commercial combustion technique with possibility to limit the NO_x emissions to less than 70 g NO_2/GJ in the circulating fluidized bed (CFBC) and less than 150 g NO_2/GJ in the bubbling bed technique (BFBC). This can be achieved by introducing combustion air at different stages in the fluidized bed. Addition NO reduction may be obtained by ammonia addition in the flue gases (e.g. Hupa and Boström, 1991).

6.1.2 Reduction of NO_x emissions from mobile sources

Approximately two-thirds of total NO_x emissions from mobile sources can be accounted for by gasoline-fuelled engines and one-third from diesel engines. Concerning technologies for gasoline-fuelled cars, the project examined the possibilities for reduction of NO_x emissions with emphasis on technologies lowering NO_x emissions formed in the engine and technologies that reduce NO_x after it has been formed. The former group of technologies includes engine modifications and exhaust gas recirculation (EGR).

The engine modifications to reduce NO_x emissions include the following methods: air/fuel ratio and mixture preparation, delayed ignition timing, increased compresion ratio, combustion chamber design, and electronic control of ignition timing.

Charge dilution of homogeneous charge engines by excess air and by exhaust gas recirculation has been used for many years. These techniques have been used separately and together in order to improve the reduction efficiency. Among several types of EGR systems, the most used are the ones utilizing intake manifold vacuum to control the recirculated gas flow rate.

After-treatment approaches include installation of exhaust after treatment devices, such as catalytic convertors and thermal reactors. Most frequently a combination of oxidation catalyst and EGR is used to reduce the NO_x emissions.

Three-way catalysts have been developed to oxidized hydrocarbons and CO and reduce NO_x simultaneously. In order to work effectively, considerably better control of the air/fuel mixture is required than for oxidation catalyst systems. All catalysts are poisoned by leaded fuel, and require a supply of unleaded fuel to operate at design efficiency.

Estimates of NO_x reduction effects achieved by different technical approaches are presented in Table 16.

Different NO_x reduction concepts have been found to show various impacts on fuel consumption and maintenance cost. The fuel-economy implication of NO_x emission control technology is highly dependent on the technique used and the engine used in the car. Some information on fuel consumption and maintenance impacts is presented in Table 17. Lead-free gasoline enables a closer control of engine parameters and of the fuel metering system. This results in improvements in fuel economy. NO_x emission control systems have also an impact on emissions of hydrocarbons (HC) and CO, as shown in Table 18.

Small diesel-fuelled vehicles emit less NO_x than conventional cars but more than gasoline engines with catalytic emission control. Together with the emission of particulates, NO_x is the major environmental problem associated with diesel-fuelled vehicles. Particulate emissions from a diesel-fuelled car can be 100 times greater than from a comparable gasoline-fuelled car. Reducing both NO_x and particulates presents some special difficulties.

The most common control method for NO_x emissions from diesel engines is EGR, and development of control technologies for this type of fuel has been slower than for gasoline engines. While up to 95 per cent of NO_x emission reduction can be obtained for gasoline engines with 3-way catalysts, reductions of only 20 to 50 per cent are attainable for diesel engines.

6.2 REDUCTION OF NH_3 EMISSIONS

Ammonia emissions from livestock (e.g. from urine) is by far the most important source of atmospheric ammonia. The breakdown of proteins lead to urea, which is further broken down to ammonia and carbon dioxide. Emissions occur in ventilation air of stables, or from manure, which is stored either as a liquid slurry or mixed with straw and litter. In the latter case, composting reactions provide excess temperature and promote ammonia emissions, losses are generally less when the manure is stored as liquid slurry. The storage losses can be reduced even further if the slurry storage tanks are covered. Storage and handling of liquid slurry manure require costly installations, and transport and application in the fields is also expensive. Losses of ammonia during the application of liquid manure can be particularly severe, if the weather is warm and dry, and the manure is not ploughed down or mixed with the soil within a few hours following application.

It is obvious that, if losses from storage have already been avoided, the application step is critical. Another point to be made, is that emissions from cattle (milk cows as well as beef cattle) on pasture are relatively small. Modern dairy farming keep the cattle stabled also during the summer period and feed them newly mown grass. This intensive farming technique will generally increase the economic cost of proper manure storage facilities, and increase the problem of handling manure without losses of ammonia to the air.

The nitrogen balance of the domestic animals need also to be taken into account. Nitrogen is given to the animals in the food, partly converted to products (e.g. meat, milk, eggs), and partly excreted. About half of the excreted amount is urea, the rest is undigested proteins excreted with faeces. By proper feeding, and particularly not overfeeding with proteins, the nitrogen content of the excretions can be kept at a minimum, thereby also minimizing the ammonia emissions.

The following options can be distinguish to control the NH_3 emissions from livestock farming (after Klaassen, 1990):

- changes in the nitrogen content of the fodder,
- adaptations during stable and storage of manure:
  - stable adaptations (such as manure flushing),
  - closed storage, and
  - cleaning of stable air (biofiltration or scrubbing),
- conservative application techniques - often called low nitrogen application (LNA) (e.g. direct ploughing down of manure on arable land, manure injection, sprinkling of manure).

The combinations of various control options as well as reductions in emission coefficients of these options are presented in Table 19 after Klaassen (1990). The combined impact of the control options on emission reductions has been calculated using nitrogen balances (De Winkel, 1988).

6.3 REDUCTION OF HEAVY METAL EMISSIONS

6.3.1 Reduction of Pb emissions from gasoline combustion

The most efficient method to reduce Pb emissions to the atmosphere is to phase out lead additives from the gasoline. The European emissions would then be reduced at least by a factor of 4 as shown in Table 20. The 1982 emissions of Pb in various countries in Europe are presented in this table together with 3 scenarios:

- Scenario 1, presenting Pb emissions in Europe in 1982 assuming that best available technology (BAT) to control industrial emissions is employed,

- Scenario 2, presenting Pb emissions in Europe in 1982 assuming unleaded gasoline only but no BAT available, and

- Scenario 3, presenting Pb emissions in Europe in 1982 assuming unleaded gasoline and BAT available.

It can be observed that the European emissions of lead in 1982 could have been lowered by a factor of 9 if unleaded gasoline and BAT in various industries had been employed. Source contributions to the total Pb emissions in Europe in 1982 are presented in Figures 20 and 21 for scenarios 2 and 3, respectively and source contributions to the Pb emissions in the European countries in 1982 in Figure 22 and 23 for scenarios 2 and 3, respectively (after Axenfeld et al., 1990).

6.3.2 Reduction of heavy metals from various industrial processes employed with BAT

A broad review of the abatement techniques for heavy metal emissions from major industrial categories has been prepared very recently by the Swedish Environmental Protection Agency (SNV) for the UN ECE Task Force on Heavy Metal Emissions (UN ECE, 1991). This section of the report has been prepared on the basis of the above mentioned review.

- Primary iron and steel industry.
  Major sources of heavy metal emissions within primary iron and steel industry include sinter plants, pellet plants, blast furnaces, and steel works with basic oxygen furnace (BOF). SNV suggests to control dust emissions from these sources with fabric filters as BAT or electrostatic precipitators (ESPs) if the flue gas temperature or the physical properties of the dust make fabric filters impossible to use. The following levels of emission factors of dust can be achieved using BAT:

Sinter plants:	40 g/tonne when cleaning the flue gases in fabric filters and 120 g/tonne when using electrostatic precipitators,
Pellet plants:	40 g/tonne,
Blast furnace:	37 g/tonne, and

BOF: 20 g/tonne when cleaning the converter gases in fabric filters and
35 g/tonne when using electrostatic precipitators or scrubbers.

Reductions of heavy metal emissions of the dust can be estimated using the above quantities of dust per 1 tonne of product, and the chemical composition of emitted dust, which may vary substantially.

- Primary non-ferrous metal industry.
  Major sources of heavy metal emissions within primary non-ferrous metal industry include production of lead, copper, zinc and tin. Installation of fabric filters in all non-ferrous metal smelters in order to achieve a dust content in flue gases lower than 10 mg/Nm^3 is recommended as BAT. In most cases of lead, copper and zinc production, all gases can be cleaned in fabric filters to levels lower than 5 mg/Nm^3. Both types of fabric filters: baghouses and membrane type can be considered for installation, taking into account their limitations. A limitation for both types of fabric filters is the temperature of the gases, which should not exceed 280° depending on cloth or membrane material. In addition membrane-type fabric filters are not suitable for cleaning oil-containing dust.

- Secondary non-ferrous metal industry.
  The secondary non-ferrous metal industry generates a significant part of heavy metal emissions to the atmosphere. The predominant sources are melting and refining in connection with recycling of scrap metal. Installation of fabric filters in secondary non-ferrous smelters is recommended in order to reduce the dust emissions below 10 mg/Nm^3. Lead, copper and zinc smelters shall be given priority in this action, as they generate considerable amounts of atmospheric As, Cd, Cu, Pb and Zn.

- Chlor-alkali industry.

  In the chlor-alkali industry, chlorine and caustic soda are mostly produced either in the mercury process or the diaphragm process, both resulting in atmospheric emissions of mercury. The third method, the membrane process is not commonly used. The membrane process is considered as BAT. A conversion of existing chlori-alkali plants (mercury or diaphragm process) to membrane cell operation is possible utilizing some of the existing equipment.

  Some abatement can also be done at existing mercury plants to reduce mercury emissions to air, e.g. process control and technical measures to optimize the cell operation and maintenance, cleaning of cellrooms, and cleaning of limited gas streams.

  According to PARCOM decision 90/3 all existing mercury plants should, at latest in 1996, meet a standard of 2 g Hg/ton Cl_2 for emissions to the atmosphere.

  PARCOM also has recommended that existing mercury cell chlor-alkali plants should be phased out as soon as practicable.

  If comprehensive measures are taken the mercury emission can be reduced below 0.5 g/ton Cl_2.

- Municipal waste incineration.

  Incineration of municipal wastes generates emissions of various volatile metals contained in the wastes. When BAT is used for cleaning the flue gases, e.g. wet scrubbers and ESPs, the concentration of dust can be reduced to at least 10 mg/Nm^3 and the concentration of mercury to at least 50 $\mu g/Nm^3$.

- Power production by fossil fuel combustion.
  Beneficiation, e.g. "washing" of coal prior combustion reduces the content of heavy metals associated with inorganic matter in the coal.

  The major fraction of the heavy metals from electric power plants is emitted on fine particles with diameter lower than 2 µm. At present, electrostatic precipitators are mainly used in large electric power plants to remove particles from flue gases. Removal efficiency of ESP's installed in the area is about 96 per cent for fine particles carrying As, Cd, Cu, Pb, and Zn among other trace elements (e.g. Pacyna and Ottar, 1989).

  In general, a total dust retention of more than 99.75% can be obtained with electrostatic precipitators, as well as with fabric filters. In both cases, careful attention must be paid to the design of the filter so that it is tailored for each specific installation. Good filter surveillance and maintenance are essential. With the exception of mercury, the contents of heavy metals in off-gas can be reduced by at least 95-99%, the lower figure for the more easily volatilized elements.

  Reduction of gaseous mercury content is favoured by a low filter temperature. A number of processes designed for reduction of gaseous mercury content in off-gas from various industry sectors exists.

  Using BAT as described above, a dust content in cleaned gas of less than 20 mg/Nm^3 can be obtained. The total concentration of As, Cd, Pb, Cr, Ni, and Co in the flue gases will be lower than 1.5 mg/Nm^3 as recommended by the German regulations for existing plants.

  Measures aiming at an increase in the energy conversion efficiency of the boiler will contribute to a decrease in heavy metal emissions per output energy unit. Similarly, all measures which reduce energy consumption will also reduce the heavy metal emissions from the combustion of fossil fuels.

7 COST ESTIMATES FOR EMISSION REDUCTION ALTERNATIVES

This chapter discusses economical aspects of emission reductions for nitrogen compounds and heavy metals. The discussion is structured in the same way as presentation of various alternatives for measures to reduce emissions.

For practical reasons it was assumed that 1 European Currency Unit (ECU) equals 1.2 US$ or 2 DM.

7.1 REDUCTION OF NO_x EMISSIONS

7.1.1 Reduction of NO_x emissions from stationary sources

Information presented in this section of the report is based on experience in utilizing various control methods in the United States and summarized for the National Acid Precipitation Assessment Program (NAPAP), and in Europe for the UN ECE NO_x Task Force (NAPAP, 1990a,b; and UN ECE, 1986). In general cost estimates in Europe and North America agree quite well and therefore it was decided here to base discussion on experience in both regions.

The following conclusions can be made on the basis of current experience:

- direct abatement methods related to so-called pre-combustion control, such as switch to or blend with fuels, and coal or oil cleaning are uneconomic when used only with the purpose to remove nitrogen,

- capital cost of primary control measures related to combustion modifications is lower by one order of magnitude than the capital cost of secondary control measures related to exhaust gas treatment, while the reduction potential is only 10 to 20 per cent higher for the secondary measures (e.g. selective catalytic) than for the primary modifications (e.g. gas reburning); an exception is selective non-catalytic reduction method, cost of which is comparable with cost of gas staged combustion and low NO_x burners, and

- operating cost is very low for both primary and secondary measures.

Estimates of capital and annual costs for 200 MW and 500 MW units equipped with various NO_x control methods are presented in Table 21 on the basis of experience gained in USA (NAPAP, 1990a). Annual costs include operating costs and maintenance. The NO_xOUT technique has been selected to represent SNCR technlogies. In this technique a urea-water solution is injected into the furnace. The NO_xOUT and thermal DeNO_x are the two most important SNCR technologies. In addition to the above conclusions, the data in Table 21 indicate that capital cost for smaller utility burners, e.g. 200 MW is about 30 per cent higher than the cost for larger burners, e.g. 500 MW.

Overfire air and low NO_x burners have low capital and maintenance requirements and very low operating costs. These technlogies are favoured in virtually all applications, either alone if they can achieve required NO_x reductions, or in combination with SNCR or SCR.

European estimates of additional investment and operating cost for a 600 MW_{el} new plant, operating during 5700 hrs each year at full load are shown in Table 22 for coal, oil, and natural combustion separately (UN ECE, 1986). The overall conclusion from the European experience is that investment costs for primary measures are fairly low compared with those for secondary flue gas treatment systems. These costs may be negligable for a new plant and can range from 5-15 ECU/MW_{el} for retrofit. Additional operating costs are stated in the majority of cases to be low. The application of gas reburning in combination with low NO_x burners gives the most economical results of NO_x emission reductions.

The primary measures have also been the most widely used methods to control NO_x emissions from industrial process heating furnaces. These techniques include in the first place low-NO_x burners. The SCR methods can remove between 80 and 90 per cent of NO_x from flue gases but the cost is high, reliability low, and catalyst life uncertain at the present stage of development. Internal process modifications are often the most economical approach to emission reduction in industrial processes.

Capital cost of applying low excess air and low NO_x burners for industrial process heating furnaces is comparable with the cost of applying these methods for electric utility furnaces (NAPAP, 1991).

7.1.2 Reduction of NO_x emissions from mobile sources

Different techniques are used to assess the cost of NO_x abatement in North America and Europe. The differences are due to very stringent regulations already in force in North America compared with Europe. Consequently, the use of three-way catalysts is much wider in North America than in Europe. Of course, lower are also the American standards, and removal of additional tonne of NO_x costs much more in North America than in Europe. Therefore, in this work it was accepted to discuss the potential for reduction of NO_x emissions from mobile sources, mainly on the basis of the European experience. The study on potential and costs for control of NO_x emissions in Europe, carried out at the International Institute for Applied Systems Analysis (IIASA) was of special interest to this work (Amann, 1989).

All costs and emission reductions in the IIASA study are summed up over the whole lifecycle of the vehicles. The amount of abated NO_x is estimated on the basis of information on uncontrolled emission factors, requested removal efficiency, average annual fuel consumption and vehicle lifetime. The costs of applying control devices include the additional investments to introduce devices, increased maintenance costs, and the costs of potential replacements of parts of the control systems after its lifetime. The calculations have been carried out for the European countries separately due to differences in the annual energy consumption per vehicle and the fuel prices for the additional energy consumption. The estimates of cost for introducing the US 1991 norms for heavy duty trucks and for 3-way catalysts for gasoline cars are presented in Table 23 for countries in the study area of this project (after Amann, 1989). The estimates of cost of introducing three-way catalysts include results of the evaluation of cost in the case that the credit for simultaneous reduction of VOC and CO is given and with no credit, separately. If no credit is given for simultaneous reduction of VOC and CO, the additional NO_x removals of the three-way system (over the reduction achievable by uncontrolled catalysts) are very expensive. If the credit is given for VOC and CO reductions, this option of reducing NO_x emissions shall be regarded as very cost-efficient. For the purpose of this work the latter version should be relevant.

7.1.3 Comparison of cost of NO_x emission reduction options for stationary and mobile sources

Comparison of cost to remove 1 tonne of NO_x from stationary and mobile sources in the proposed action area, using various techniques is given in Table 24. It should be coutioned that the results presented have been estimated on limited information collected by the ECE NO_x Task Force (UN ECE, 1986) and from IIASA (Amann, 1989). As such, they should be regarded as rough evaluation of cost rather than detailed estimates for direct use.

The results in Table 24 indicate that combination of various combustion modification techniques applied in utility and industrial boilers is the cheapest way to reduce NO_x emissions. They confirm an outcome of earlier discussion in the report that application of secondary methods, such as SCR enhance substantially the reduction cost. It is much more expensive to abate NO_x from mobile than stationary sources.

7.2 REDUCTION OF NH_3 EMISSIONS

Discussion on cost of removing NH_3 is based on the IIASA study on cost functions for controlling NH_3 emissions in Europe (Klaassen, 1990). The IIASA study has used data obtained from the Netherlands, a leading country in research of emissions of ammonia and their control (e.g. Buijsman et al., 1987; Van Horne, 1990).

The algarithm of estimates of investment costs, fixed operating costs and variable operating costs, as well as various cost functions are presented by Klaassen (1990). Concerning two major control techniques, namely low nitrogen feed and adaptations of stable and storage, the following definition of costs can be given:

- the investment cost is defined as a cost of control technology and the investment function describes the investment cost as a function of the number of animals per stable,
- the fixed operating costs include the costs of maintenance, insurance and administrative overhead, and
- the variable operating costs include increase in feed costs per animal due to the higher prices of low nitrogen feed, as well as ordinary operating costs (use of electricity, water, labour, and disposal of wastes).

Concerning the third major technique, which can be used to reduce NH_3 emissions, namely application of manure, its cost estimates include the cost of direct application or ploughing down (both fixed and variable), the cost of sprinking (fixed and variable), and cost savings due to reduction in fertilizer use.

The IIASA study (Klaassen, 1990) has chosen Finland and the Netherlands for cost estimates. Finland was selected because the country is presently collecting data on the costs of controlling ammonia and therefore some verification of the IIASA estimates will be possible. The Netherlands was chosen as most of the data in the IIASA study is based on Dutch experience. The results of the IIASA estimates are presented in Table 25. In Finland, average costs per 1 tonne of NH_3 abated range from 6 ECU (conservative application techniques-LNA, broilers) to more than 67 500 ECU (dairy cows covered storage). The range for the Netherlands extends from 227 ECU (conservative application techniques-LNA broilers) to 28 250 ECU (pigs biofiltration).

Finland belongs to the group of countries within the study area in this work. Therefore, the Finnish case of cost estimates can be extended as to cover estimates for the countries within the proposed action area. In general, relatively cheap options for reducing the NH_3 emissions in this area seem to be conservative application techniques, stripping/absorption of industrial process emissions, and stable adaptations for lying hens and broilers. More expensive are options which include biofiltration for pigs or covering manure storage for cattle.

It should be cautioned again, that the above estimates shall be regarded as rough assessment. There is a lack of practical experience, particularly in the proposed action area, which contribute to the uncertainties of the estimates, particularly cost estimates of stable adaptations for pigs and dairy cows. Cost estimates for conservative application techniques seem to be more certain.

7.3 REDUCTION OF HEAVY METAL EMISSIONS

7.3.1 Cost of Pb emission reduction from gasoline combustion

It requires to use more energy in order to produce low leaded (0.15 g Pb/l) and unleaded gasoline when compared with leaded gasoline (0.4 g Pb/l). The CONCAWE study group, together with other organizations (CONCAWE, 1980) concluded that 1.6 per cent increases in total energy is needed to produce 95 RON (the Optimum Research Octane Number) low leaded gasoline when compared with a base case of 96 RON leaded gasoline. A 92 RON unleaded gasoline requires as much as 5 per cent increase in total energy as compared with a base case.

In 1984, a Working Group set up under the aegis of the European Community's Commission (CEC, 1984) identified the energy and economic costs to the oil industry of reducing lead contents from 0.4 to 0.15 g/l and 0.4 g/l to unleaded gasoline (95 RON) to be:

Lead Content change g/l	Tonnes crude oil per 1000 tonnes gasoline consumed	1000 ECU per 1000 tonnes gasoline consumed
0.40 - 0.15	22	10.0
0.40 - Unleaded	45	15.7

In reality, the above costs will be higher since many countries have introduced super premium unleaded gasoline (98 RON), which is more expensive to make than the 95 RON grade.

Information obtained from the Norwegain Petroleum Institute and Statoil concludes, that costs of producing and distributing unleaded gasoline is about 16.7 ECU per tonne of gasoline consumed higher than cost of low leaded gasoline (98 RON). Thus, this information is in a good agreement with the CEC data.

7.3.2 Reduction of heavy metals from various industrial processes equipped with BAT

Benefication, e.g. "washing" of coal or other cleaning of fuels and ores prior their further application in combustion of fuels or smelting of ores reduces the content of heavy metals in raw materials, but, as in the case of nitrogen is uneconomic.

As mentioned in chapter 6, major part of heavy metals from various industrial processes is emitted on fine particles and high efficiency ESP's, fabric filters and scrubbers need to be used to achieve emission reductions as defined in this chapter. Various attempts have been made to determine estimation procedures for capital and operating costs of the above control equipment (e.g. Halvorsen and Ruby, 1981). The capital cost includes:

1) control equipment purchase cost,
2) installation cost,
3) auxiliary equipment, e.g. exhaust hoods, ducting, pumps, conveyors, stacks pollution-control facilities,
4) freight charges,
5) site preparation,
6) instrumentation,
7) auxiliary buildings, and
8) working capital, ambient monitoring network, and land.

Direct capital costs are enhanced by the expenses on construction, engineering design and supervision, production penalties, and required activities.

The items under the operating cost are the following:

1) operating and maintenance labour,
2) administration,
3) utilities of consumable materials, including water, power, steam, oil or gas, limestone,
4) replacement and maintenance parts and waste disposal,
5) production credits or penalties, and
6) operation and maintenance of ambient monitoring equipment.

A number of empirical functions, relating the cost and the size of particle control installations, have been developed and used in the order-of-magnitude estimate method to calculate capital and operating costs. These were reviewed by Halvorsen and Ruby (1981). An example of estimates of purchase and operating and maintenance costs for different types of control device to remove particles emitted from a 1000 MW hard-coal fired power plant in Poland is presented in Table 26 (after Pacyna, 1987). Although investment cost (e.g. purchase) is fairly low for scrubbers, the operating and maintenance costs are very high compared with ESP's and fabric filters. The high operating cost of wet scrubbers is related to water consumption ranging from 1 to 3 l/m^3 of flue gas, depending mostly on the temperature of flue gas. Therefore, scrubbers can be considered as control technique to remove heavy metals from flue gas only in cases when flue gas contains the most volatile elements, such as Hg an Se, released as vapours or on submicrone particles. Combustion of coal to produce electricity and heat is one of the categories emitting about 95 per cent of Hg and about 60 per cent of Se in gas phase. However, very high temperature of the flue (exhaust) gas in coal-fired power plants results in extremely high demand for water in scrubbers, making this control technique uneconomical.

Another solution to remove volatile heavy metals from flue gas is a combination of particle removal and sulphur removal techniques through the use of an upstream alkali spray into the hot flue gases. This solution, however, is very expensive if employed to control only heavy metal emissions. The experience gained during the NAPAP study (1990a) indicates that the capital cost of both wet flue gas desulphurization (FGD) and lime spray drying techniques employed in utility and industrial boilers to remove up to 95 per cent of SO_2 and up to 60 per cent Hg from flue gas is more than one order of magnitude higher than the cost of primary NO_x controls and at least 2 times as high as the cost of secondary NO_x controls, already concluded as uneconomical for this study. Other SO_2 controls removing also Hg, such as the Wellman-Lord process removing at least 95 per cent of SO_2 and 60 per cent of Hg are even more expensive than the conventional FGD processes.

Concluding the above discussion, ESP's and fabric filters are the most applicable controls for heavy metal emissions considering both the efficiency of controlling fine particle emissions and economy. Based on the NAPAP study for 100 plants (NAPAP, 1990a) major ESP upgrades or new particulate controls can increase the control technology costs by 30 to 100 per cent. This conclusion is in a good agreement with earlier estimates (e.g. Marder, 1977) suggesting that the cost of particulate controls enhances the control cost by about 30 per cent.

Reduction of Hg emission from chlor-alkali plants is probably the only case in this project when switch of production technology can be recommended in order to meet the target. Most of the chlor-alkali companies in the USA, employing mercury-cell technology have considered to switch to the use of membrane-cell technology (information obtained through PARCOM, 1988). It was concluded, however, that economic conditions of the chlor-alkali industry in the 1980s and the cost of switching were a major impediment to replacement at that time. More information is urgently needed on this subject.

8 RECOMMENDED ACTIONS

The following information shall be taken into account when recommending actions within the project:

- contribution of atmospheric deposition of a given compound to its total flux to the Baltic Sea with a view to assess the importance of the atmospheric pathway of the compound,

- physical and chemical forms of a given compound, and particularly heavy metals, with a view to select proper control techniques,

- emissions of a given compound, both total and by major source catetories, with a view to define necessary emission reductions and to select control techniques,

- control methods with a view to reach necessary control efficiency at optimal cost.

Information on the above subjects has been collected for the Baltic Sea region and is presented in Table 27.

All of the studied compounds enter the Baltic Sea from the air and this pathway accounts for between 30 and 50 per cent of total flux, thus is very significant. Actions should then be recommended for all pollutants in Table 27.

The compounds of interest enter the Baltic Sea either as gases (NO_x, NH_3, Hg) or on particles (NO_3^-, NH_4^+, Hg, Pb, other heavy metals and organic compounds). Emission control techniques to reduce releases of both gases and particulate matter need to be recommended.

Among several source categories there are few which can be defined as major emission categories and as such they should be prioritized for recommended actions. They include: combustion of fossil fuels to produce electricity and heat (NO_x, Hg, other heavy metals), mobile sources (NO_x, Pb), production of non-ferrous and ferrous metals (heavy metals) and waste incineration (heavy metals and organic compounds). However, waste incineration is not a common category to be found in the study area. Important source categories, which are specific for individual compounds include livestock wastes (NH_3) and chlor-alkali production (Hg).

Four groups of control technologies have been identified including:

- pre-treatment techniques, such as washing of raw materials and switch of fuels,
- primary control measures, such as combustion modifications,
- secondary control measures, such as selective catalytic reduction methods, flue gas desulphurization, and electrostatic precipitation, and
- specific control measures to reduce emissions of NH_3 from livestock wastes and of Hg from chlor-alkali plants.

It was important to define measures that, as a package, are both feasible and compatible. Results of the cost-effectiveness estimates are also given for each of the control measures, providing a total cost (operating and maintenance) of removal of 1-tonne of NO_x and NH_3 and of 1 kg of mercury, lead, and other heavy metals. Finally, a judgement has been made on the presented methods, indicating best choice of, good solution, or less relevant methods with respect to recommend efficient (high reduction efficiency) and cost-effective way to decrease emissions of studied compounds. The conclusions that can be drawn on the basis of data presented in Table 27 are presented below.

8.1 PRE-TREATMENT METHODS

Pre-treatment methods cannot be recommended due to either low efficiency and high cost for cleaning/benefication of coal or high cost of switch of fuels in the case when only studied compounds are of interest. The situation will change when including cost and benefits of sulphur removal through the above methods. An exception from the above conclusion is of course a switch of leaded to unleaded gasoline, a best method to reduce the atmospheric lead emissions.

Cost-effectiveness for coal cleaning/benefication processes in the United States ranged from 109 to 393 ECU per metric tons of SO_2 removed depending on the technique used and the type of coal cleaned (NAPAP, 1990a). This method is more expensive to decrease SO_2 emissions than switch of fuels. The same cost relation between the two pre-treatment techniques shall apply to mercury removal and other volatile heavy metals. However, no details were available for the project.

A total retrofit cost (including operating and maintenance of altering a coal-fired boiler for seasonal use of natural gas has been conservatively estimated at approximately 15 ECU/kW (NAPAP, 1990a). This is about a tenth of a comparable estimate for installation of scrubbers. The cost of the pipeline must be added to the natural gas retrofit costs, ranging between 62 and 144 ECU/ft in the United States.

Taking into account the production of electricity in Poland (e.g. 25 000 000 kW in both hard coal and lignite-fired power plants), and the amount of mercury to be removed from Polish power plants (11.1 t), the total retrofit cost will be at least 35000 ECU/kg Hg removed. The same simple method can be used to assess cost of 1 tonne of heavy metal abated.

8.2 PRIMARY MEASURES

These measures apply mostly to reduction of NO_x emissions. Combustion modifications seem to be a method to be strongly recommended to remove NO_x from stationary sources, and mostly from electricity and heat producing plants. The methods are less effective for removal of NO_x emissions from mobile sources.

8.3 SECONDARY SOURCES

The SCR method together with primary measures can be very effective and economically acceptable method to remove NO_x from both stationary and mobile sources.

Flue gas desulphurization is an expensive method when applied only with the purpose to reduce NO_x and heavy metals. The method becomes economically acceptable when a package of pollutants is to be removed includes SO_2 (with credit to SO_2). Cost of the Hg and other heavy metal removal from flue gases using FGD was assessed using information on the NO_x removal cost and on concentrations of Hg and other heavy metals in flue gases which are in the Polish coal-fired power plants lower than NO_x emissions by 40000 times for gaseous Hg, 800000 times for Hg on particles, 10000 for As, 20000 for Cd, 3000 for Cu, and 1000 for Cr, Ni, and Zn on the average for subbituminous and bituminous coals, and lignites burned in the country (Pacyna, 1980).

As already indicated, electrostatic precipitators (ESPs) are the most economic, highly efficient instruments to remove particles with heavy metals on them. The cost estimates in Table 27 were performed assuming:

- abatement cost of 1 tonne of fly ash or other dust within flue gases in smelters to be 5 ECU for fly ash in electric power plants and municipal waste incinerators, and flue gas dust in non-ferrous smelters, and 7.5 ECU for flue gas dust in iron and steel plants, and
- concentrations of heavy metals on particles in flue gas from the above mentioned sources located in the proposed action area (e.g. Pacyna, 1980; Pacyna, 1986; Meij, 1989). The heavy metal concentrations in fly ash from coal-fired

power plants ranged from 1 g/t fly ash for Hg to 375 g/t for Cr (Pacyna, 1980). The concentrations in dust within flue gases in Polish copper-lead smelters varied from 300 g/t dust for Cd to 3600 g/t dust for Cu (Pacyna et al., 1980). Finally, the concentrations in dust from iron and steel plants ranged from 1.5 kg/tonne dust for Cd to 150 kg/tonne dust for Cr (Pacyna, 1986).

8.4 SPECIFIC CONTROL MEASURES

Conservative application techniques in combination with stable adaptations are the cheapest and efficient methods to reduce NH_3 emissions from livestock wastes in the proposed action area (Klaassen, 1990).

A change of industrial technology in chlor-alkali production from mercury cell to membrane cell will resolve the problem of air pollution by mercury from this source. The cost of this operation is, however, difficult to assess.

8.5 ACTION RECOMMENDED FOR MAJOR SOURCE CATEGORIES

The following action is recommended:

8.5.1 Public power, cogeneration and district heating plants

- installation of low NO_x burners or combination of low NO_x burners with flue gas recirculation in major power plants (over 1000 MW_{el}) and district heating boilers (over 200 GJ/h capacity),
- installation of high efficiency ESPs in major power plants (over 1000 MW_{el}) and district heating boilers (over 200 GJ/h capacity),

- examination of the possibility to install a combined system of primary measures (low NO_x burners) and SCR,
- introduction of low NO_x techniques of combustion, e.g. fluidized bed combustion (FBC) when planning new plants,
- examination of the possibility to install a FGD system in major existing coal-fired power plants (over 1000 MW_{el}),
- introduction of district heating replacing the production of heat in small commercial and residential burners, and
- increased use of natural gas networks, already existing in the area.

8.5.2 Mobile sources

- introduction of unleaded gasoline at least to the extent as in Western Europe in 1990, namely, 25% of the market on average for countries within the proposed action area; the rest of the gasoline should be low-leaded (0.15 g/l),
- introduction of three way catalysts, and particularly application of closed-loop three way catalysts, and
- introduction of flue gas recirculation (FGR) systems (primary control methods) to diesel-fuelled cars in large cities in the area).

8.5.3 Non-ferrous metal industry

- installation of ESPs or fabric filters as BAT to achieve a dust concentration in flue gases lower than 10 mg/Nm^3. In most cases of non-ferrous metal production, flue gases can be cleaned in ESPs or fabric filters to levels lower than 5 mg/Nm^3, and
- installation of ESPs or fabric filters in major secondary non-ferrous smelters to reach concentration of dust in flue gases below 10 mg/Nm^3.

8.5.4 Chlor-alkali industry

- examination of the possibility to convert existing chlor-alkali plants using mercury or diaphragm process to membrane cell operation for the existing plants, and
- examination of the possibilities to reduce the mercury emissions from existing plants to comply with the PARCOM/ HELCOM recommendations (Hg emissions lower than 2 g Hg/t Cl_2 capacity by the end of 1996) through introduction of methods controlling gaseous Hg emissions, such as Hg absorption methods.

8.5.5 Livestock farming

- introduction of conservative application techniques as a method to reduce NH_3 emissions, and
- examination of the possibilities to introduce LNA together with stable adaptations systems.

9 BENEFITS OF ACTIONS

There are various benefits which can be obtained through implementation of the proposed actions in the area of interest. These benefits can be appreciated in local environment, e.g. around a certain point source of emission, in a given geographical region, or even in a whole country within the proposed action area. The benefits could also be measured on regional or global scale, e.g. the whole study area, or Northern Europe.

9.1 LOCAL BENEFITS

Four groups of benefits can be identified: environmental, health, economic, and social benefits.

9.1.1 Environmental benefits

Major environmental benefit of the proposed action programme is improvement of the quality of environment through the reduction of atmospheric deposition of the studied pollutants. Two scales of the problem can be discussed: reduction of atmospheric deposition around major point sources and reduction of atmospheric deposition within a geographical region or a whole country.

Extended research programmes have been carried out in Poland to assess the impact of emissions from major point sources on the surroundings in the early 1980's. Measurements around 2000 MW_{el} lignite-fired power plants Turow have indicated that about 15 per cent of particulate matter emissions entering the atmosphere through four 150 m high stacks (geometric height) have been deposited in the area with 30 km radius from the plant (Pacyna, 1980). Similar results were obtained from measurements around the biggest copper-lead smelter complex in Eastern Europe-LGOM, located in South-western part of Poland (Pacyna, et al., 1981). Both sources are on a list of sources for actions to be recommended. Reduction of emissions as recommended in this work will substantially reduce the amount of pollution to be deposited in the surroundings. Reduced deposition will result in lowering the pollutant input to soils, plants, and surface water. Concerning the impact of the Turow power station, it was concluded that atmospheric deposition contributed 50 per cent to water contamination by As and Hg, and 90 by Cu, Pb, and Zn (Pacyna, 1980). A migration model developed during this study showed that contamination of leaf-plants through atmospheric deposition was 80 per cent for Cu, 45 for Pb, and about 95 for Zn and Hg, in comparison with low contribution of these elements through soil. Therefore, it can be concluded that reduction in atmospheric deposition of certain pollutants, including heavy metals will decrease their uptake and migration through other environmental media.

As much as one quarter of NO_x emissions in Poland and two thirds of ammonia emissions is deposited in the country, as estimated by the EMEP model (Iversen, et al., 1991). One third of heavy metal emissions in Poland is also deposited in the country (e.g. Bartnicki, 1990). Therefore, the reduction of NO_x and NH_3 emissions as recommended in the proposed action programme will inevitably reduce the amount of atmospheric deposition of the above pollutants in the whole country. The same conclusion applies to the reduction of deposition of heavy metals in a certain geographical region or even a whole country within the proposed action area. Of particular interest is reduction of lead deposition, as major contribution of this element comes from combustion of gasoline, thus, close to the ground source.

Another environmental benefit of the proposed action programme is that not only the emissions of pollutants of interest for this project will be limited but also emissions of other volatile compounds. This applies predominantly to reduction of SO_2 and VOC emissions from stationary sources and of VOC and CO emissions from mobile sources. Installation of control equipment to reduce emissions of heavy metals from major point sources, such as electric and heat power plants, smelters, and incinerators will contribute to emission abatement for metals of interest for this study but also for other metals. Coal contains more than 60 elements as impurities (e.g. Pacyna, 1986) which undergo volatilization during coal combustion and subsequent condensation on particles within flue gases.

Installation of ESPs or improvement of their performance will contribute to the improvement of air visibility in the proposed action area. There is a direct relationship between the air visibility and concentration of aerosols and their gaseous precursors.

9.1.2 Health benefits

Inhalation and ingestion are two major pathways for pollutants to enter human body and result in health effects. Inhalation of acidic aerosols and their gaseous precursors have been studied only recently. More research has been carried out on behaviour of heavy metals. For example, inhaled and ingested lead is absrobed into the blood stream, rapidly reaching equilibrium with the soft tissues. The highest lead concentrations in soft tissues are found in the aorta, liver and kidneys. Most of the lead retained by the body is in the skeleton; some 95 per cent of the lead burden of adults is found in bones. Lead poisoning may result in haematological effects, nervous system effects and kidney injuries. Other metals have other target organs.

A simple quasi-stationary compartment model for transfer of Pb, As, and Cd from air to human body has been developed for the Turow power plant area and the LGOM copper-lead smelter complex in Poland (e.g. Pacyna and Sivertsen, 1981). The micro environment concept has been used together with the concept of exposure commitment and dose-effect and dose-response relationships. It was concluded that ingestion is by far the major pathway for As, Cd, and Pb to human body. Emissions from the Turow power plant, which is defined as one of the most important point sources in the study area, resulted in total dietary intakes of Cd and Pb higher than the WHO/FAO limits. Even higher values were estimated for the LGOM copper-lead smelter complex. It was concluded on the basis of dose-response relationship estimates, that the risk of Pb effects in adults and children in this region was at 10% response level. Reduction of atmospheric emissions from this source, which is also on a list of sources recommended for action, will definitely decrease the intake of trace metals and their ingestion.

Reduction of atmospheric emissions through the implementation of the proposed action programme may result in lowering human intake of studied pollutants, which in some regions has already exceeded the maximum permissible values.

9.1.3 Economical benefits

There are several economical benefits which can be obtained through the implementation of the proposed action programme. They are related to fuel savings and biological recovery of the environment, e.g. increasing the fish population. Fuel savings can be reached in both stationary and mobile combustion. Combustion modifications can result in fuel savings in large point sources recommended for action in the project. Application of closed-loop three way catalysts will not only improve vehicle performance and driveability, and reduce maintenance but is also consistent with improved fuel economy.

Ecological impacts of acid precipitation on both aquatic and terrestrial ecosystem have been studied over two decades. Available information indicates that the effects of acid precipitation on freshwater systems, and especially poorly buffered ones, are greater than on terrestrial systems (e.g. Hutchinson, 1991). Constant features of acidification have been defined with emphasis on nutritional effects, such as leaching of microelements and on mobilization of toxic elements, including those studied in the project. Current measurements indicate a great degree of chemical recovery of some of the watersheds after elimination or reduction of deposition of acidic compounds. Although biological recovery does not seem to follow the chemical recovery to the same degree, it could be concluded that actions recommended in the project are substantial step towards achieving the recovery of the environment in the study area. As a result, an increase of fish population can be expected. Fish market in the study area is an important part of local economy in the study area.

9.1.4 Social benefits

Implementation of the proposed action programme will be one of the biggest environmental investments in the area. As such, the proposed actions will have direct impact on improving people's attitude towards contamination of the environment in the study area. Most of the activity to improve quality of the environment there was limited to sporadic actions to lower emissions in single spots. The internationally coordinated activity as proposed in the actions programme will prove to people living in the area that the only solution to the big environmental problems in the Baltic Sea region is through co-operative efforts of national authorities and international organizations.

Another aspect of social problems related to the contamination of the environment in the Baltic Sea area is a risk of relocation of whole settlements living in highly polluted regions. This has been a long lasting problem for people living in the LGOM copper-lead smelter complex in Poland. Contamination of soil by heavy metals, as well as air pollution has been so high that relocation of whole villages was planned at the end of the 1970's. Implementation of the control programme, as suggested in the proposed actions shall at least diminish the relocation risk.

9.2 REGIONAL/GLOBAL BENEFITS

Major part of pollutants emitted in the proposed action area is deposited outside the emission region and therefore limitation of emissions in the proposed action area will have benefits measured on regional and global scale.

One third of oxidized nitrogen deposition in Scandinavia and one quarter of reduced nitrogen deposition originate in the study area (e.g. Iversen et al., 1990a). One third of lead deposition in Scandinavia is also transported from this region

(Bartnicki, 1990). Based on model calculations by Saltbones et al. (1989) it can be concluded that reductions of emissions of nitrogen and heavy metals in the proposed action area will result in reductions of atmospheric deposition of these pollutants in Scandinavia to the same degree as reductions to the Baltic Sea or slightly lower. Therefore, a 50 per cent reduction of deposition to the Baltic Sea will also mean 40 to 50 per cent of reduction in Scandinavia.

Contribution of emissions from the proposed action area to deposition in Scandinavia is higher than the contribution of Scandinavian emissions for oxidized nitrogen and lead and comparable for reduced nitrogen. Therefore, the pollution abatement strategies in the Scandinavian countries need to be revised against pollution control plans in the proposed action area. The Scandinavian countries will benefit environmentally and economically when reducing the level of emissions in the proposed action area. It can be advisable for the Scandinavian countries to contribute to these emission reductions through e.g. increased supply of natural gas to substitute coal in production of electricity and heat in the proposed action area. A switch from coal to natural gas, although expensive at present, can be economically acceptable if supported by the interested parties. The international co-operation is strongly needed at this point, as none of the market economies have been able to succeed in overcoming an ecological crisis as long as expenditures on environmental protection investment have been hept below 1.5-2.0 per cent (from Memorandum of Poland’s Ministry of Environment, 1991). For long time these expenditures were much lower in the proposed action area.

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Table 1: Total NO_x emissions in the study area during the period 1985-2005 as reported to the ECE [2] (in: 1000 t NO_2).

	1985	1986	1987	1988a	1989a	1990b	1993b	1995b	2000b	2005b
Belgium	281	292	297			300		250		
Byelorussian SSR c/	220	258	287	262	263	271	269	251	187	159
Czechoslovakia	1127	1060	965	950						
Denmark	258	266	262	249		254		224	177	
Finland d/	251	256	270	276				321	226	193
France	1615	1618	1630	1615	1772					
German Dem. Rep.			701	708	705					
Germany Fed. Rep. e/	2930	2990	2940	2860					1980	
Netherlands f/	544	559	559	562	552			422	268	
Norway	203	222	232	227	226				155	
Poland	1500	1590	1590	1550	1480				1345	
Sweden h/	394			390		373		343	341	347
Ukrainian SSR c/	1059	1112	1095	1090	1065	1099	1096	1056	930	885
USSR i/	3369	3330	4218	4201	4418					
United Kingdom	2278	2350	2429	2480		2573	2471	2300	1822	1718

a/ Preliminary data
b/ Projected estimates
c/ Also included under USSR
d/ 2005 = 2010 estimats; 2000 and 2010 projections by Nitrogen Oxide Commission
e/ 2000 = 1998 estimates
f/ 1995 = 1994 estimates; 2000 estimates; according to national environmental policy plan
h/ Projections based on current environmental regulations
i/ European part of USSR within EMEP

Table 2: Stationary vs. mobile source emissions of NO_x in countries with proposed study areas in 1985 (in per cent).

Country	Stationary sources	Mobile sources
CSFR	65	35
German Democratic Republic	79	21
Poland	78	22
European USSR	59	41

Table 3: Emissions of ammonia in the study area as calculated by EMEP (in 1000 t NH_3).

	1988	1989	1990
Belgium	94	94	94
Czechoslovakia	200	200	200
Denmark*1	129	125	125
Finland*1	43	43	43
France	841	841	841
German Dem. Rep.	242	242	242
Fed.Rep. of Germany*1	380	380	380
Netherlands*1	254	254	254
Norway	41	41	41
Poland	478	478	478
Sweden	62	62	62
Soviet Union	3180	3180	3180
United Kingdom	478	478	478

*1 data provided by country.

Table 4: Percentage contribution of various source categories to total anthropogenic emissins of NH_3 in countries with the proposed action areas in 1985.

Country	Livestock wastes	Fertilizers	Industrial sources
CSFR	75	23	2
German Democratic Republic	77	20	3
Poland	78	20	2
European USSR	83	17	n.d.

n.d.= no data available.

Table 5: Total emissions of As, Cd, Cu, Pb, and Zn from anthropogenic sources in the study area in 1982 (in t/y).

Country	As	Cd	Cu*1	Pb	Zn
Belgium	85	12.1	613	2 097	695
Czechoslovakia	94	21.6	323	1 151	756
Denmark	9	6.3	38	653	129
Finland	106	8.0	246	1 123	217
France	144	31.8	450	8 683	3 637
German Dem.Rep.	95	37.1	376	1 750	819
German Fed.Rep.	351	81.1	1 552	5 562	3 699
Netherlands	34	5.5	105	2 206	294
Norway	41	2.1	40	727	117
Poland	591	180.4	1 161	2 956	4 040
Sweden	181	16.4	36	1 035	426
United Kingdom	119	30.7	130	8 615	2 299
USSR (European part)	2 094	308.6	631	30 924	13 160

*1 Data for 1979/1980.

Table 6: Anthropogenic mercury emissions in the study area. Total Hg-emission and emission of Hg species (in t).

Country	No. Sources	Hg (total)	Hg^0 (gas)	Hg^{++} (gas)	Hg (particles)
Belgium	21	8.9	5.3	2.2	1.4
Czechoslovakia	31	15.0	7.8	4.5	2.7
Denmark	21	4.8	2.1	1.9	0.8
Finland	33	4.1	3.1	0.8	0.3
France	59	29.9	15.3	9.0	5.6
German Dem. Rep.	23	330.0	203.0	99.0	28.0
Fed.Rep. of Germany	225	65.0	38.0	20.0	7.0
Netherlands	39	8.2	3.0	3.8	1.4
Norway	9	2.0	1.4	0.4	0.2
Poland	42	44.7	23.3	13.1	8.3
Sweden	34	7.5	5.6	1.4	0.5
Soviet Union	50	87.7	45.0	25.7	17.0
United Kingdom	127	40.0	21.0	14.0	5.0

Table 7: Prognosis for atmospheric lead emissions in Europe in the reference year 2000 (in 10^3 t) based on consumption and emission factor indexes*1.

Source category	1982	2000		2000/1982	
		Variant A*2	Variant B	Variant A	Variant B
1 Power plants:	0.4	0.4	0.4	1.0	1.0
- hard coal	0.4	0.2	0.2	1.0	1.0
- lignite	0.6	0.1	0.1	0.2	0.2
- oil					
2 Industrial, commercial and residential boilers	1.6	1.3	1.3	0.8	0.8
3 Mining of ores	0.8	0.8	0.8	1.0	1.0
4 Primary non-ferrous metal production					
- copper	4.0	3.6	3.6	0.9	0.9
- lead	3.6	3.1	3.1	0.9	0.9
- zinc	4.0	5.2	5.2	1.3	1.3
5 Secondary non-ferrous metal production					
- copper	0.4	0.4	0.4	1.0	1.0
- lead	0.2	0.2	0.2	1.0	1.0
6 Gasoline combustion	68.0	32.4	10.9	0.5	0.2
7 Iron & steel manufacturing					
- iron	2.6	1.5	1.5	0.6	0.6
- steel	1.3	0.8	0.8	0.6	0.6
8 Cement production	0.6	0.6	0.6	1.0	1.0
9 Fuel wood combustion	0.4	0.4	0.4	1.0	1.0
10 Waste-related sources	0.6	1.1	1.1	1.8	1.8
TOTAL	89.5	52.1	30.6	0.6	0.3

*1 Consumption index relates consumption statistics in year 2000 to statistics in 1982, while emission factor index does it for emission factors.

*2 Variants A and B as described in the text.

Table 8: Prognosis for atmospheric emissions of As, Cd and Pb in Europe in the 1990's (in t unless as indicated) assuming best available technology (BAT) in non-ferrous metal smelters and unleaded gasoline.

Source category	As	Cd	Pb x 10^3		
	BAT	BAT	BAT	Unleaded gasoline	BAT + unleaded
1 Power plants	324	149	1.7	1.7	1.7
2 Chemical industry	-	1	-	-	-
3 Steel & iron manufacturing	219	53	3.9	3.9	3.9
4 Non-ferrous metal production	182	365	1.6	13.0	1.6
5 Other industries (incl. cement and industrial application boilers)	340	20	0.7	0.7	0.7
6 Industrial, commercial and residential boilers	408	171	2.1	2.1	2.1
7 Gasoline combustion	-	-	68.3	-	-
TOTAL	1473	759	78.3	21.4	10.0
$\frac{\text{Total}}{\text{1982 emissions}}$	0.3	0.5	0.9	0.25	0.1

Table 9: Emissions of PCBs, HCHs, and HCB in the study area in the mid 1980's.

Country	PCBs in 1000 t	γ-HCH in t	HCB in kg
Belgium	20	1.6	470
Czechoslovakia	31	4.3	950
Denmark	10	1.5	340
Finland	10	0.2	310
France	110	12.8	4 000
German Dem.Rep.	34	6.6	950
Fed.Rep. of Germany	122	36.0	3 300
Netherlands	29	3.1	420
Norway	8	0.5	150
Poland	74	14.5	2 000
Sweden	17	0.4	510
Soviet Union[*1]	350	217.5	23 600
United Kingdom	113	26.7	2 400

[*1] the European part of the country

Table 10: Average annual wet deposition of nitrogen species to the Baltic Sea for the years 1986-1990 (in kt N/y).

Basin	NO_3		NH_4		N Total		$\frac{H}{E}$ Total
	E	H	E	H	E	H	
A1. Gulf of Bothnia	33	37	40	44	73	81	1.11
A2. Gulf of Finland	9	12	11	13	21	25	1.22
A3. Baltic Proper, North	64	58	60	54	124	112	0.90
A4. Baltic Proper, South	26	30	26	31	52	62	1.19
A5. Kattegat and Belts	21	23	24	27	45	50	1.10
Baltic Sea	153	160	161	170	314	330	1.05

E = experimental method
H = hybrid method

Table 11: Average annual wet deposition of lead to the Baltic Sea for the years 1986-1990 (in t/y).

Basin	Experimental method	Hybrid method	$\frac{E}{H}$
A1. Gulf of Bothnia	280	429	1.53
A2. Gulf of Finland	112	203	1.82
A3. Baltic Proper, North	269	261	0.97
A4. Baltic Proper, South	218	275	1.26
A5. Kattegat and Belts	86	117	1.35
Baltic Sea	965	1285	1.33

Table 12: Deposition of oxidized and reduced nitrogen to the Baltic Sea in the period 1985-1990 as calculated by EMEP (in: 100 t N).

Major emitter country	1985			1987			1988			1989			1990 (provisional)		
	Oxidized	Reduced	Total	Oxidized	Reduced	Total	Oxidized	Reduced	Total	Oxidized	Reduced	Total	Oxidized	Reduced	Total
Belgium	28	13	41	21	10	31	29	11	40	29	12	41	34	13	47
Czechoslovakia	83	25	108	56	18	74	66	20	86	59	17	76	45	11	56
Denmark	79	152	231	81	150	231	75	131	206	86	141	227	89	149	238
Finland	60	30	90	62	31	93	58	27	85	48	22	70	57	26	83
France	65	40	105	47	27	74	69	33	102	75	32	107	84	40	124
German Dem. Rep.	123	104	227	134	100	234	143	96	239	138	92	230	133	94	227
Fed.Rep. of Germany	324	99	423	275	86	361	332	95	427	306	86	392	347	101	448
Netherlands	68	55	123	54	44	98	68	51	119	67	47	114	84	60	144
Norway	18	7	25	21	6	27	18	6	24	22	7	29	22	7	29
Poland	157	163	320	164	161	325	188	155	343	156	138	294	127	110	237
Sweden	111	67	178	101	63	164	104	61	165	112	65	177	115	64	179
Soviet Union	129	267	396	155	286	441	128	257	385	67	169	236	83	162	245
United Kingdom	158	42	200	145	37	182	171	38	209	176	37	213	250	53	303
Others	248	193	441	236	174	410	244	180	424	234	172	406	262	181	443
TOTAL	1651	1257	2908	1552	1193	2745	1693	1161	2854	1575	1037	2612	1732	1071	2803

Table 13: Pollution load of nitrogen to the Baltic Sea via different pathways.

Pathways	Unit	1980-85	1987
1. Direct load:	kt	79	88
	%	9	8
- urban areas	kt	68	72
	%	7	6
- industry	kt	11	16
	%	2	2
2. Indirect load (transport by rivers)	kt	532	760
	%	58	66
3. Atmospheric deposition	kt	300[*1]	300[*1]
	%	33	26

[*1] assumed in this report on the basis of HELCOM measurements and EMEP modelling.

Table 14: Comparison of nitrogen and lead loads to the North Sea and the Baltic Sea from the air.

Basin	Area 10^3 km^2	Precipitation mm	Load	
			Nitrogen 1000 tonnes	Lead tonnes
North Sea	525	520	330	1174
Baltic Sea	415	683[*1] 673[*2]	300	1400

[*1] from experimental method
[*2] from hybrid method

Table 15: Estimates of removal efficiency and side-effects of combustion modifications for coal (wet and dry bottom type of boilers), oil and gas-fining boilers (after UN ECE, 1986).

Coal - wet bottom

measure	removal efficiency (%)	applicability new	retrofit	side-effects/restrictions
LNVR	20 - 25	Yes	No	Better fuel flexibility, less slagging and fouling.
LNB	20 - 50	Yes	Yes	Possible increase of CO in flue gas and unburnt carbon in fly ash. Nearly all vendors of burners offer LNBs which can be adjusted to the boiler type.
FGR	up to 15	Yes	site-specific	Influence on the evaporation process of the boiler must be observed. Stability of ignition is a limiting factor. Possible increase of CO in flue gas and near boiler walls causing higher corrosion potential.
OSC	10 - 40	Yes	site-specific	Limited by the potential of corrosion by reducing atmospheres and increase of CO in flue gas and unburnt carbon in fly ash.
Reburning	30 - 50	Yes	site-specific	Not enough full-scale experience using coal as secondary fuel for reburning. Evaporation process of the boiler is influenced. Limited by the potential of corrosion by reducing atmospheres and increase of CO in flue gas and unburnt carbon in fly ash.

Coal - dry bottom

measure	removal efficiency (%)	applicability new	retrofit	side-effects/restrictions
LNB	10 - 30	Yes	Yes	Possible increase of CO in flue gas, unburnt carbon in fly ash. Ash melting must be maintained.
FGR	10 - 25	Yes	site-specific	Influence on the evaporation process of the boiler must be observed. Possible increase of CO in flue gas and corrosion. Flame stability problems at low load operation
OSC	10 - 35	Yes	site-specific	Limited by the potential of fouling and increase of CO in flue gas and unburnt carbon in ash.
Reburning	30 - 50	Yes	site-specific	Development status

Table 15 cont.

Natural gas

measure	removal efficiency (%)	applicability		side-effects/restrictions
		new	retrofit	
LVHR	20 - 25	Yes	No	None
LNB	20 - 40	Yes	Yes	Limited by flame stability at low load operation. Possible increase of CO concentration in flue gas.
FRG	20 - 70	Yes	site-specific	Influence on the evaporation process of the boiler must be observed. At some units derating may occur. Limited by flame stability at low load operation. Possible increase of CO concentration in flue gas.
OSC	10 - 30	Yes	site-specific	Limited by flame stability at low load operation. Possible increase of CO concentration in flue gas and corrosion.
Reburning	30 - 50	Yes	site-specific	Evaporation process of the boiler is influenced. Possible increase of CO concentration in flue gas.

Oil

measure	removal efficiency (%)		applicability		side-effects/restrictions
	light	heavy	new	retrofit	
LVHR	30 - 40	30 - 40	Yes	No	None
LNB	20 - 40	10 - 30	Yes	Yes	Limited by flame stability at low load operation. Possible increase of CO concentration in flue gas. Possible increased smoke/dust emissions may require additional ESP.
FGR	20 - 50	10 - 35	Yes	site-specific	Influence on evaporation process of the boiler must be observed. At some units derating may occur. Limited by flame stability at low load operation. Possible increase of CO concentration in flue gas.
OSC	10 - 30	10 - 40	Yes	site-specific	Limited by flame stability at low load operation. Possible increase of CO concentration in flue gas.
Reburning	30 - 50		Yes	site-specific	Evaporation process of the boiler is influenced. Possible increase of CO concentration in flue gas. Possible increased smoke/dust emissions may require additional ESP.

LVHR - low volumetric rate
LNB - low NO_x burner
FGR - flue gas recirculation
OSC - off-stoichiometric combustion
Reburning - staged combustion

Table 16: Estimates of NO_x reduction effects of different technical approaches for gasoline cars.

No.	Approach	NO_x emission (gNO_x/km)	Emission index	Reduction percentage	Reduction methods
1.	Baseline	2.8	100	0	
2.	Swedish/Norwegian standard	0.62	20-25	75-80	Engine modification or EGR
3.	United States (California) standards	0.40	10-15	85-90	EGR and oxidation catalysts
4.	Lean burn[*1]	0.37	10-25	75-90	Engine modification

[*1] Prototype engines

Table 17: Fuel consumption and maintenance impacts of NO_x emission control technologies (after UN ECE, 1986).

System	Reduction method	Change in fuel consumption a/	Change in maintenance impact
Baseline		0	0
Swedish/Swiss	Engine modifications or EGR	0 to +5	0/+
United States 1983	EGR and oxidation catalysts	-8 to 0	-
Lean burn	Engine modifications	-15 to -5	0/-

a/ Values based on similar fuel octane for all concepts.

Table 18: Effects of NO_x emission control system on emission of HC and CO.

<table>
<tr><th>System</th><th>Effect on HC emission</th><th>Effect on CO emission</th></tr>
<tr><td>Swedish/Swiss</td><td>Some reduction</td><td>Possible reduction</td></tr>
<tr><td>United States 1983</td><td colspan="2">- Reduction of the same order as NO_x -</td></tr>
<tr><td>Lean burn:</td><td></td><td></td></tr>
<tr><td>(i) Without oxidation catalyst</td><td>None</td><td>> 50% reduction</td></tr>
<tr><td>(ii) With oxidation catalyst</td><td colspan="2">- Reduction of at least the same as NO_x -</td></tr>
</table>

Table 19: Combination of NH_3 abatement techniques and calculated emission reductions (after Klaassen, 1990).

COMBINATION OF OPTIONS DAIRY COWS

	Option		Emission Reduction (%)		
			Stable	Application	Meadow
1	Low N-feed	(LNF)	20	20	25
2	Stable adaptation	(SA)	50	-9	0
3	Closed storage	(CS)	10	-1	0
4	Low N-application	(LNA)	0	90	0
5	LNF + SA		60	14	25
6	LNF + CS		28	19	25
7	LNF + LNA		20	92	25
8	SA + LNA		50	89	0
9	CS + LNA		10	90	0
10	LNF + SA + LNA		60	91	25
11	LNF + CS + LNA		28	92	25

Combinations of 2 and 3 are excluded.

COMBINATION OF OPTIONS OTHER CATTLE

	Option		Emission Reduction (%)		
			Stable	Application	Meadow
1	Closed storage	(CS)	10	-1	0
2	Low N-application	(LNA)	0	90	0
3	CS + LNA		10	90	0

COMBINATION OF OPTIONS PIGS

	Option		Emission Reduction (%)		
			Stable	Application	Meadow
1	Low N-feed	(LNF)	15	15	0
2	Stable adaptation	(SA)	65	-9	0
3	Biofiltration	(BF)	90	-16	0
4	Low N-application	(LNA)	0	90	0
5	LNF + SA		70	8	0
6	LNF + BF		92	5	0
7	LNF + LNA		15	91	0
8	SA + LNA		65	89	0
9	BF + LNA		90	88	0
10	LNA + SA + LNA		70	91	0
11	LNF + BF + LNA		92	90	0

Combinations of 2 and 3 are excluded.

Table 19 cont.

COMBINATION OF OPTIONS LAYING HENS					
Option			emission reduction (%)		
			Stable	Application	Meadow
1	Low n-feed	(LNF)	10	10	0
2	Stable adaptation	(SA)	60	-17	0
3	Biofiltration	(BF)	80	-26	0
4	Low N-application	(LNA)	0	90	0
5	LNF + SA		64	-18	0
6	LNF + BF		82	-14	0
7	LNF + LNA		10	91	0
8	SA + LNA		60	88	0
9	BF + LNA		80	88	0
10	LNF + SA + LNA		64	88	0
11	LNF + BF + LNA		82	89	0
Combinations of 2 and 3 are excluded.					

COMBINATION OF OPTIONS BROILERS					
Option			Emission Reduction (%)		
			Stable	Application	Meadow
1	Low n-feed	(LNF)	20	20	0
2	Stable adaptation	(SA)	10	-7	0
3	Biofiltration	(BF)	80	-51	0
4	Low N-application	(LNA)	0	90	0
5	LNF + SA		29	14	0
6	LNF + BF		84	-21	0
7	LNF + LNA		20	92	0
8	SA + LNA		10	89	0
9	BF + LNA		80	85	0
10	LNF + SA + LNA		29	91	0
11	LNF + BF + LNA		84	88	0
Combinations of 2 and 3 are excluded.					

* Conservative application techniques are expressed in the above table as low N-application - LNA.

Table 20: Heavy Metal Emissions in Europe 1982 - (All sources).

Country: Europe Scenario 2/3: NFM.IND_BAT/Unleaded
Gasoline
Source Type: All (Numbers: 1499)

	Emission [t/year]				
Country	Sources	Pb 1982	Pb Sc1	Pb Sc2	Pb Sc3
ALBANIA	14	136.270	115.678	35.270	14.678
AUSTRIA	42	1122.900	1058.660	157.900	93.660
BELGIUM	36	2097.200	1382.464	1021.200	306.464
BULGARIA	27	1569.200	929.880	845.200	205.880
CSSR	55	1151.000	1026.392	467.000	342.392
DENMARK	26	653.300	650.484	70.300	67.484
FINLAND	33	1122.700	767.972	469.700	114.972
FRANCE	94	8682.800	7881.912	1424.800	623.912
GERMANY DEM. R.	39	1749.500	1554.580	482.500	287.580
GERMANY FED. R.	233	5561.800	4460.920	2123.800	1022.920
GREAT BRITAIN	188	8615.270	8090.790	1105.270	580.790
GREECE	14	1393.600	1369.840	86.600	62.840
HUNGARY	49	596.900	587.572	93.900	84.572
ICELAND	2	39.200	39.200	.200	.200
IRELAND	10	437.100	408.060	45.100	16.060
ITALY	125	8591.900	8211.652	990.900	610.652
JUGOSLAVIA	35	1961.900	1207.740	1006.900	252.740
LUXEMBURG	8	165.200	165.200	39.200	39.200
NETHERLANDS	50	2205.800	1874.568	506.800	175.568
NORWAY	20	727.400	551.312	224.400	48.312
POLAND	76	2956.300	1812.300	1750.300	606.300
PORTUGAL	9	381.000	373.432	39.000	31.432
ROMANIA	51	1154.640	943.440	541.640	330.440
SOVIET UNION (EUROPE)	137	30924.400	28283.520	6053.400	3412.520
SPAIN	47	4227.700	3388.708	1261.700	422.708
SWEDEN	49	1034.700	715.612	511.700	192.612
SWITZERLAND	30	450.700	450.700	18.700	18.700
EUROPE	1499	89710.367	78302.594	21373.381	9965.588

Table 21: Estimates of capital cost and annual cost (operating cost and maintenance) for NO_x emission reduction in USA (based on NAPAP, 1990a).

Technology description	Capital cost (ECU/kW)		Annual cost (10^6 ECU/kWh)	
	200 MW	500 MW	200 MW	500 MW
Overfire air (OSC)	3.4	2.0	0.08	0.05
Gas reburning*1	12.8-16.1	9.8-13.0	1.5-3.0	1.4-3.0
Low NO_x burners	14.0	8.1	0.4	0.2
Selective Non-Catalytic Reduction (NO_xOUT)	8.3-10.0	0.8-8.3	1.7-1.8	1.6-1.7
Selective Catalytic Reduction				
- low difficulty (3-7 year catalyst life)	78	65	2.8-3.5	2.5-3.2
- high difficulty (3-7 year catalyst life)	105	87	3.6-4.2	3.1-3.7

*1 Based on 15% gas substitution

Table 22: Estimates of additional investment cost and additional operating cost for combustion modification techniques to reduce NO_x emissions from coal (wet and dry bottom), oil and gas-firing boilers (after UN ECE 1986).

Coal - dry bottom

Combination	expected NO_x emissions % of base case	additional investment ECU/kW $_{el}$	additional operating costs ECU/kW $_{el}$
Base case	100	-	-
LVHR	75 - 80	2.5 - 4.5	-
LVHR + LNB	38 - 64	4.0 - 7.5	-
LVHR + LBN + FGR	33 - 64	8.0 - 12.0	-
LVHR + LBN + OSC	23 - 58	7.5 - 12.5	-
LVHR + LBN + Reburning	19 - 45	12.5 - 15.0	0.05 (gas) *

* gas used as secondary fuel in the reburning process.

Coal - wet bottom

Combination	expected NO_x emissions % of base case	additional investment ECU/kW $_{el}$	additional operating costs ECU/kW $_{el}$
Base case	100	-	-
LNB	70 - 90	4.0 - 7.5	-
LNB + FGR	53 - 81	8.0 - 12.0	-
LNB + OSC	46 - 81	7.5 - 12.5	-
LNB + Reburning	35 - 57	12.5 - 15.0	0.05 (gas) *
LNB + OSC + Reburning	23 - 57	12.5 - 15.0	0.05 (gas) *

* natural gas as secondary fuel

Table 22 cont.

Oil

Combination	expected NO_x emissions % of base case		additional investment ECU/kW $_{el}$	additional operating costs ECU/kW $_{el}$
	light	heavy		
Base case	100	100	-	-
LVHR	60 - 70	60 - 70	2.5 - 4.5	-
LVHR + LNB	36 - 56	42 - 63	4.0 - 7.5	-
LVHR + LNB + FGR	18 - 45	28 - 57	8.0 - 12.0	-
LVHR + LNB + OSC	26 - 51	22 - 57	7.5 - 12.5	-
LVHR + LNB + Reburning	18 - 40	21 - 44	12.5 - 15.0	0.05 (gas) *
LVHR + LNB + FGR + Reburning	9 - 32	14 - 40	15.0 - 25.0	0.05 (gas) *

* gas used as secondary fuel in reburning process

Gas

Combination	expected NO_x emissions % of base case	additional investment ECU/kW $_{el}$	additional operating costs ECU/kW $_{el}$
Base case	100	-	-
LVHR	55 - 65	2.5 - 4.5	-
LVHR + LNB	33 - 52	4.0 - 7.5	-
LVHR + LNB + FGR	10 - 42	8.0 - 12.0	-
LVHR + LNB + OSC	23 - 47	7.5 - 12.5	-
LVHR + LNB + Reburning	17 - 37	12.5 - 15.0	-
LVHR + LNB + FGR + Reburning	4 - 27	15.0 - 25.0	-
LVHR + LNB + OSC + FGR + Reburning	8 - 40	15.0 - 25.0	-

LVHR - Low volumetric heat rate
LNB - Low NO_x burner
FGR - Flue gas recirculation
OSC - Off-stoichiometric combustion
Reburning - Staged combustion

Table 23: Cost estimates for introducing U.S. 1991 norms for heavy duty trucks and for 3-way catalysts for gasoline fueled cars in the study area, in ECU/kg NO_x abated (after Amann, 1989).

Country	U.S. Standard 1991 (6.7 gNO_x/kWh)	3-way catalyst	
		No credit for VOC and CO	Credit for VOC and CO
Belgium	4.55	3.15	0.79
CSFR	8.09	5.29	1.32
Denmark	5.64	3.24	0.81
Finland	4.62	3.15	0.79
France	3.80	4.13	1.03
Germany (as for FRG)	4.46	3.03	0.76
Netherlands	3.74	3.30	0.82
Norway	8.84	3.14	0.79
Poland	9.32	4.51	1.13
Sweden	5.26	2.54	0.64
former USSR	5.58	2.66	0.67
United Kingdom	6.16	2.62	0.66

Table 24: Comparison of cost to remove 1 tonne NO_x from stationary and mobile sources by applying various control techniques in the proposed action area.

Activity sector	Control technique	Removal efficiency in % [*1]	Cost of reduction in ECU
Utility boilers - coal	Combination of combustion modification techniques	60-80	100-150
	Combustion modifications + SCR	90	600-1000
- oil	Combination of combustion modification techniques	60-90	150-200
	Combustion modifications + SCR	90	650-750
- natural gas	Combination of combustion modification techniques	60-90	100-200
	Combustion modifications + SCR	90	650-750
Industrial boilers	Combination of combustion modification techniques	60-80	as for utility boilers
	Combustion modifications + SCR	90	as for utility boilers
Gasoline cars	Three-way catalyst -with credit for VOC & CO -no credit for VOC & CO	 80 80	 350-650 2650-5300
Heavy Duty Trucks (HDT)	Techniques to reach the U.S. 1991 Standards	40	5300-4050

[*1] Only techniques with reduction potential higher than 50 per cent were considered, except for HDT.

Table 25: Average abatement costs for NH_3 estimated for Finland and the Netherlands (in ECU/1 tonne NH_3 abated).

Abatement technique	Cost	
	Finland	The Netherlands
DAIRY COWS		
2 Dairy Stable adaptation (SA)	31141	26256
3 Dairy Covered storage (CS)	68714	26425
4 Dairy Low N-application (LNA)	2314	2200
8 Dairy SA+LNA	7215	6279
9 Dairy CS+LNA	5641	3464
OTHER CATTLE		
1 Cattle Covered storage	54329	13008
2 Cattle Low N-application	1969	1814
3 Cattle CS+LNA	5308	2296
PIGS		
1 Pigs Low N-feed (LNF)	10970	10970
2 Pigs Stable adaptation	19871	19593
3 Pigs biofiltration (BF)	32225	28275
4 Pigs Low N-application	1167	1136
5 Pigs LNF+SA	17345	17174
6 Pigs LNF+BF	25121	22563
7 Pigs LNF+LNA	3718	3691
8 Pigs SA+LNA	5711	5621
9 Pigs BF+LNA	9824	8690
10 Pigs LNF+SA+LNA	7479	7393
11 Pigs LNF+BF+LNA	11420	10311
LAYING HENS		
1 Layhens Low N-feed	2863	2863
2 Layhens Stable adaptation	3191	3191
3 Layhens biofiltration	18592	20361
4 Layhens Low N-application	220	425
5 Layhens LNF+SA	4362	4362
6 Layhens LNF+BF	15190	16549
7 Layhens LNF+LNA	740	746
8 Layhens SA+LNA	966	970
9 Layhens BF+LNA	5438	5947
10 Layhens LNF+SA+LNA	1316	1319
11 Layhens LNF+BF+LNA	5679	6179
BROILERS		
1 Broiler Low N-feed	2092	2092
2 Broiler Stable adaptation	11585	11585
3 Broiler biofiltration	14300	15659
4 Broiler Low N-application	6	177
5 Broiler LNF+SA	2407	2407
6 Broiler LNF+BF	12255	13349
7 Broiler LNF+LNA	1071	1176
8 Broiler SA+LNA	2043	2175
9 Broiler BF+LNA	7925	8728
10 Broiler LNF+SA+LNA	2313	2403
11 Broiler LNF+BF+LNA	8069	8837
INDUSTRIAL EMISSIONS		
1 Stripping/absorption	625	625

* Conservative application techniques are expressed in the above table as low N-application (LNA).

Table 26: Purchase, and operating and maintenance costs for different types of control devices in a 1000 MW coal fired power plant in Poland (in 1000 ECU).

Equipment type	Purchase cost	Operating and maintenance cost
Fabric filters:		
High (95%) efficiency	408	174
Electrostatic precipitator:		
High (99+%) efficiency	1333	136
Medium (98%) efficiency	950	102
Scrubber:		
High energy	467	2833
Medium energy	467	725

Table 27: Technologies and other measures for controlling emissions of target pollutants in the proposed action area: performance, cost, and applicability.

Pollutant	Atmospheric contribution to the total contamination of the Baltic %	Physical and chemical forms of pollutants emitted		Major emission source categories		Control technologies and cost estimate*1 (in ECU/1 tonne abated for nitrogen compounds, in ECU/1 kg abated for other compounds							
		Physical form	Chemical form	Major categories	Contribution %	Pre-treatment		Primary measures such as combustion modification	Secondary measures (related to exhaust gas treatment)			Other measures	
						Washing of raw materials	Switch of fuels		Catalysts e.g. SCR	Flue gas desulphurization (FGD)	Electrostatic precipitators (ESP)	Measures	Remarks
NO_x	30 based on measurements 30-50 based on modelling	gas	NO NO_2	Stationary sources - combustion of coal & oil to produce electricity & heat	60-80		up to 5 000 - 0-50%	100-200 ++ (60-90%)	600-1200 + (90%)	3000-6000 - (70-90%)			
				Mobile sources - gasoline	20-40 67			LOW + (10%)	350-650 ++ (80%)				
				- diesel	33			LOW + (10%)	2800-4050 - (40%)				
NH_3	30	gas	NH_3	Livestock wastes	75-85							a) 5-250++ ? b)1000-7250+ (50-65%)	a)conservative application (LNA) b)stable adaptation + LNA
				Fertilizer use	15-25								
Hg	50	gas	Hg^0 (elemental) (57%)	Combustion of coal	47	? - (10-30%)	at least 35000 - (up to 80%)			240000-480000 - (40-80%)			
				Chlor-alkali production	35					? (40-80%)		? + (100%)	Change to membrane cell
			Hg^{++} (30%)	Combustion of coal	49	? - (10-30%)	at least 35000 - (up to 80%)			480000-1000000 - (40-80%)			
				Chlor-alkali production	26					? (40-80%)		? + (100%)	Change to membrane cell
				Waste incineration	23					480000-1000000 - (40-80%)			
		particle	Hg^0 (elemental) (13%)	Combustion of coal		? - (10-30%)	at least 35000 - (up to 80%)			240000-4800000 - (up to 100%)	5000 ++ (up to 95%)		
				Waste incineration						240000-4800000 - (up to 100%)	at least 5000 ++ (up to 95%)		
Pb	50	particle	Pb elemental, oxides & sulphates	Gasoline combustion	75		10 or 15 ++ (up to 90%)						
				Primary non-ferrous metal production	13					? (up to 100%) -	80 ++ (up to 95%)		
Other heavy metals: As, Cd, Cr, Cu, Ni, Zn	30-50	particle	mostly elemental, oxides, sulphates	Primary non-ferrous metal production	50-85					? (up to 100%) -	1.5 (Cu)-16.5(Cd)++ (up to 95%)		
				Combustion of coal and oil	10-20 (80 for Ni)	? (10-30%)	2500(Zn)- 50000(Cd) - (up to 100%)			3000-12000 - (up to 100%)	15 (Cr)-1650 (Cd) ++ (up to 95%)		
				Iron & steel production	5-30					? - (up to 100%)	5-150 ++ (up to 95%)		
Persistent organic compounds		particles	organic compounds	-Dumps & landfills -Vaporization from plasticized products and during open burning -Waste disposal and incineration -use as pesticides									

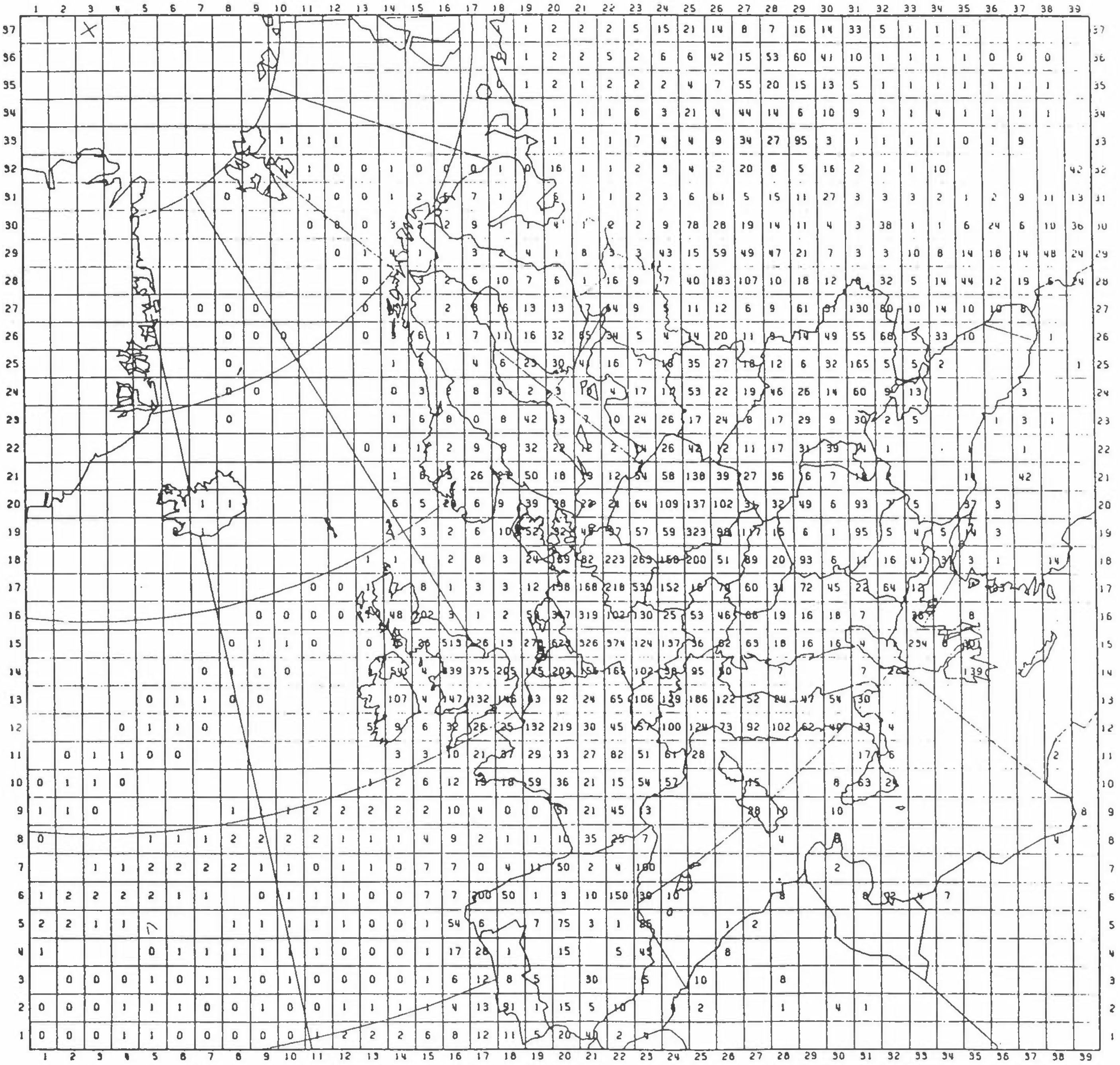
*1 The following is presented.

cost in ECU/1 tonne abated best judgement
(control efficiency in %) for application

for example (1200-2000 ECU/tonne +)
90%

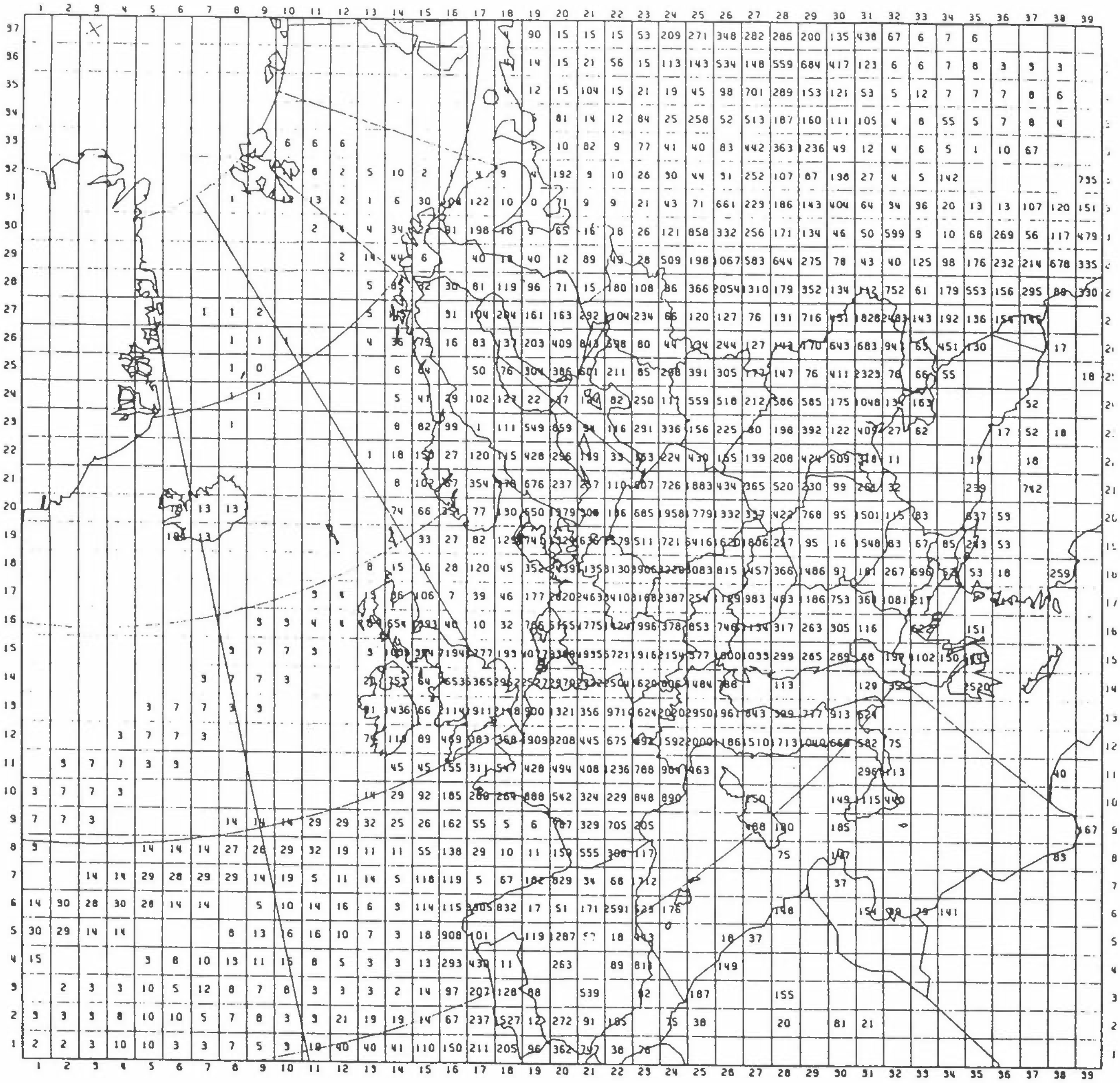
Symbols used.
++ best choice for application in the study area
\+ good solution
\- less relevant because of high cost or low efficiency
NE uneconomical solution

*2 10 ECU/tonne gasoline consumed when reducing lead from 0.4 g/l to 0.15 g/l
15 ECU/tonne gasoline consumed when reducing lead from 0.4 g/l to unleaded



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
37																			1	2	2	2	5	15	21	14	8	7	16	14	33	5	1	1	1				
36																		0	1	2	2	5	2	6	6	42	15	53	60	41	10	1	1	1	1	0	0	0	
35																		0	1	2	1	2	2	2	4	7	55	20	15	13	5	1	1	1	1	1	1	1	
34																				1	1	1	6	3	21	4	44	14	6	10	9	1	1	4	1	1	1	1	
33										1	1	1								1	1	1	7	4	4	9	34	27	95	3	1	1	1	1	0	1	9		
32											1	0	0	1	0	0	0	1	0	16	1	1	2	3	4	2	20	8	5	16	2	1	1	10					42
31								0			1	0	0	1	2	5	7	1		6	1	1	2	3	6	61	5	15	11	27	3	3	3	2	1	2	9	11	13
30											0	0	0	3	2	2	9	1	1	4	1	2	2	9	78	28	19	14	11	4	3	38	1	1	6	24	6	10	36
29												0	1	4	1		3	2	4	1	8	3	3	43	15	59	49	47	21	7	3	3	10	8	14	18	14	48	24
28													0		3	2	6	10	7	6	1	16	9	7	40	183	107	10	18	12	8	32	5	14	44	12	19	6	24
27							0	0	0				0			2	8	16	13	13	7	44	9	5	11	12	6	9	61	31	130	80	10	14	10	10	8		
26								0	0	0			0	3	6	1	7	11	16	32	85	34	5	4	14	20	11	9	14	49	55	68	5	33	10			1	
25								0						1	6		4	6	23	30	41	16	7	18	35	27	18	12	6	32	165	5	5	2					1
24								0	0					0	3	2	8	9	2	3	0	4	17	12	53	22	19	46	26	14	60	9	13				3		
23								0						1	6	8	0	8	42	53	7	10	24	26	17	24	8	17	29	9	30	2	5			1	3	1	
22													0	1	12	2	9	9	32	22	12	2	14	26	42	12	11	17	31	39	14	1			4		1		
21														1	8	3	26	22	50	18	19	12	54	58	138	39	27	36	16	7	14				14		42		
20							1	1						6	5	20	6	9	39	98	22	21	64	109	137	102	31	32	49	6	93	7	5		37	3			
19															3	2	6	10	52	92	48	97	57	59	323	98	117	15	6	1	95	5	4	5	14	3			
18													1	1	1	2	8	3	24	69	82	223	265	160	200	51	89	20	93	6	11	16	41	31	3	1		14	
17											0	0	1		8	1	3	3	12	198	168	218	530	152	16	79	60	31	72	45	22	64	12			33			
16									0	0	0	0	19	48	202	3	1	2	59	347	319	102	130	25	53	46	88	19	16	18	7		36		8				
15								0	1	1	0		0	15	36	513	26	13	278	629	326	374	124	137	36	82	69	18	16	16	4	11	234	8	101				
14							0		1	0				54	4	339	375	205	175	203	156	165	102	38	95	30		7			7	24			139				
13					0	1	1	0	0				7	107	4	147	132	146	63	92	24	65	106	129	186	122	52	24	47	54	30								
12				0	1	1	0						55	9	6	32	26	25	132	219	30	45	57	100	124	73	92	102	62	40	33	4							
11		0	1	1	0	0								3	3	10	21	37	29	33	27	82	51	61	28						17	6						2	
10	0	1	1	0									1	2	6	12	13	18	59	36	21	15	54	57			15			8	63	24							
9	1	1	0					1		1	2	2	2	2	2	10	4	0	0	51	21	45	13				28	10		10									8
8	0				1	1	1	2	2	2	2	1	1	1	4	9	2	1	1	10	35	25	7					4		8								4	
7			1	1	2	2	2	2	1	1	0	1	1	0	7	7	0	4	11	50	2	4	100							2									
6	1	2	2	2	2	1	1		0	1	1	1	0	0	7	7	200	50	1	9	10	150	30	10				8			8	92	4	7					
5	2	2	1	1				1	1	1	1	1	0	0	1	54	6		7	75	3	1	86			1	2												
4	1				0	1	1	1	1	1	1	0	0	0	1	17	28	1		15		5	45			8													
3		0	0	0	1	0	1	1	0	1	0	0	0	0	1	6	12	8	5		30		5		10			8											
2	0	0	0	1	1	1	0	0	1	0	0	1	1	1	1	4	13	91	1	15	5	10		8	2			1		4	1								
1	0	0	0	1	1	0	0	0	0	0	1	2	2	2	6	8	12	11	5	20	40	2	4																

Figure 1: 1989-emissions of Nitrogen Oxides in each grid square of the EMEP/MSC-W grid for calculations.
Unit: 1000 tonnes per annum as NO_2



EMISSION OF NOx IN THE EMEP/MSC-W GRID
YEAR: 1985/87/88/89/90 MG/M2 PER YEAR AS N

Figure 2: Average emissions of NO_x for the years 1985, 1987, 1988, 1989 and 1990 within the EMEP grid of 150 km x 150 km (in mg/m² per year as N).

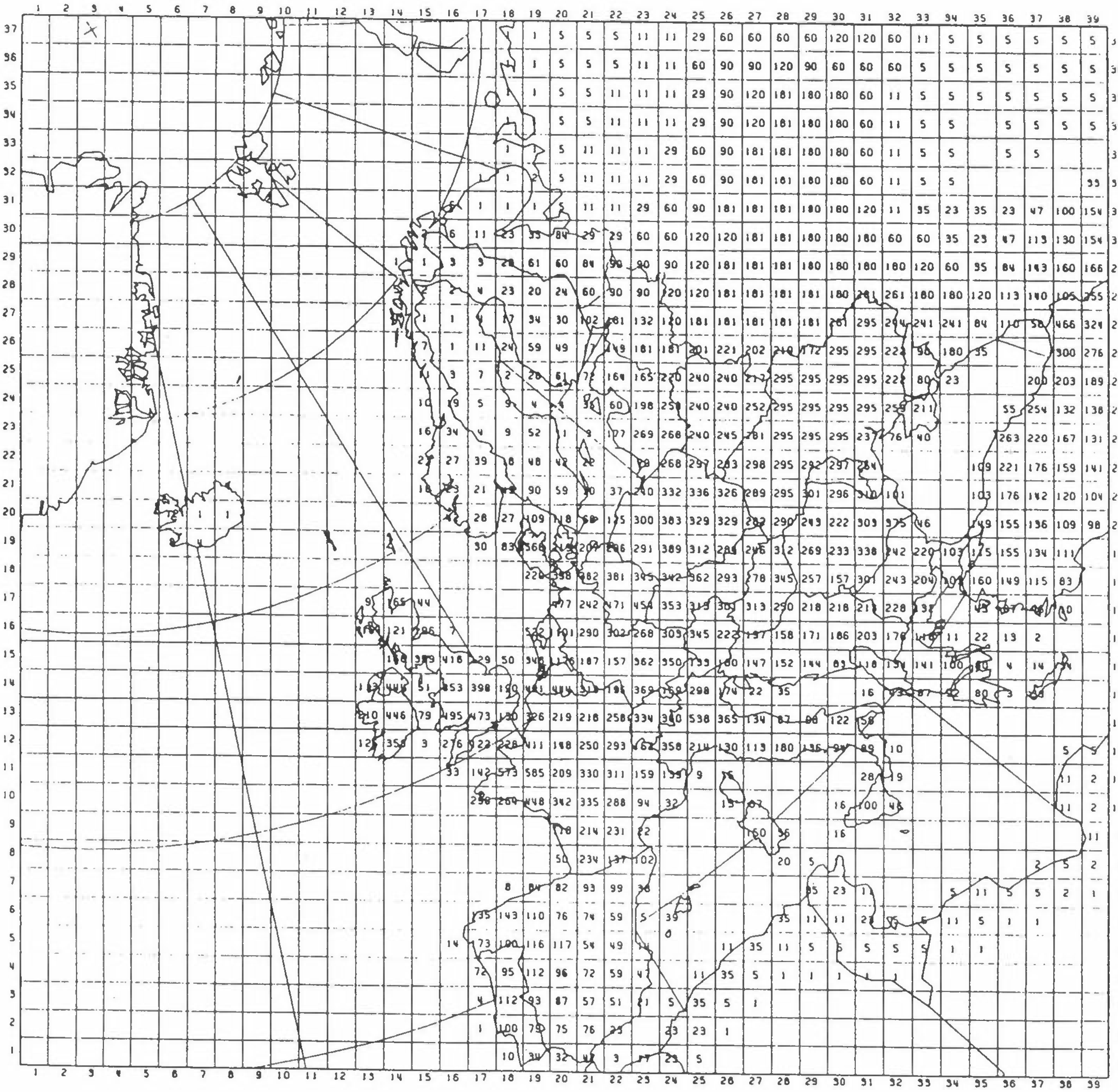


Figure 3: 1989-emissions of Ammonia in each grid square of the EMEP/MSC-W grid for calculations.
Unit: 100 tonnes per annum as NH_3.

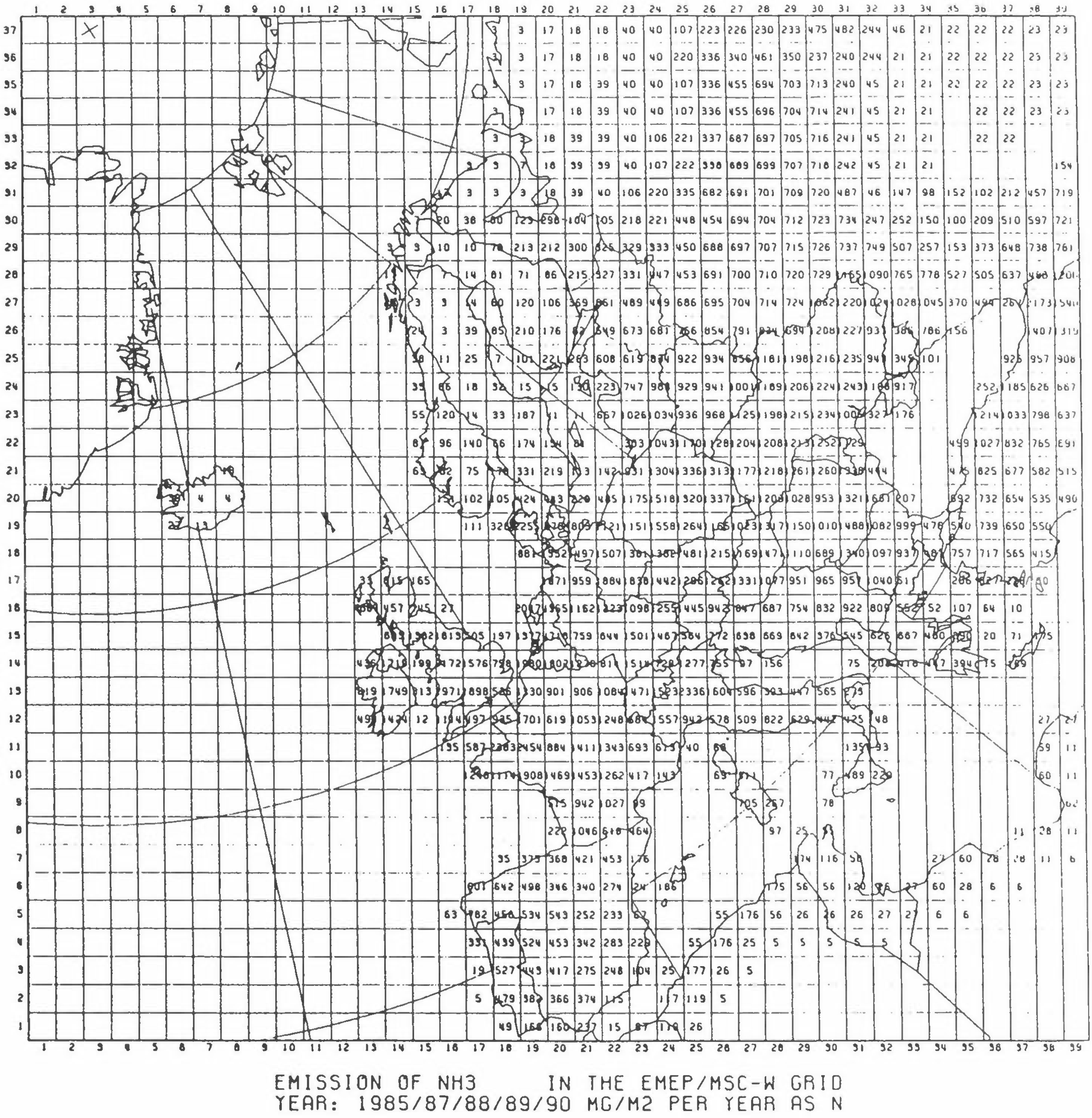


Figure 4: Average emissions of NH_3 for the years 1985, 1987, 1988, 1989 and 1990 within the EMEP grid of 150 km x 150 km (in mg/m^2 per year as N).

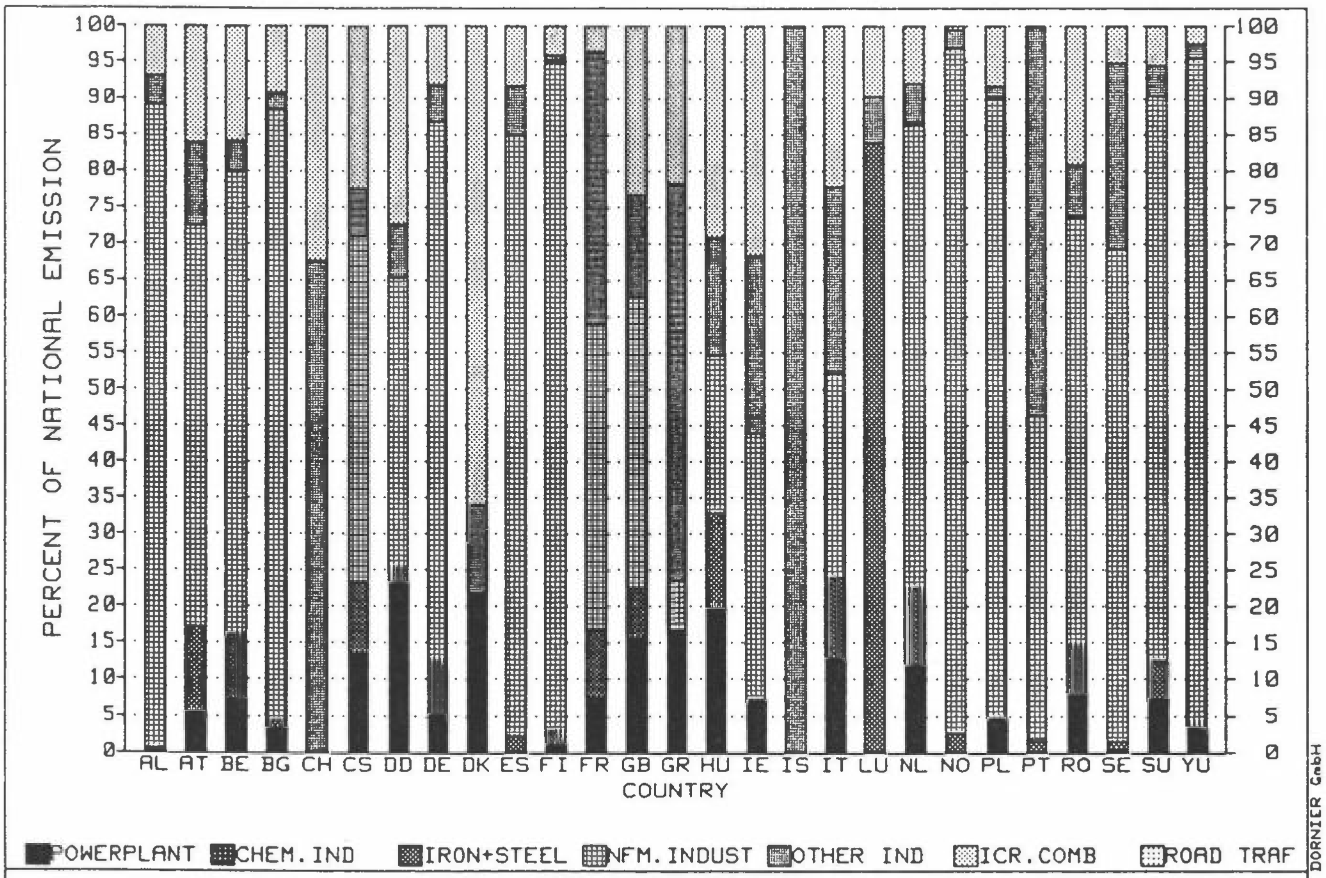


FIGURE 5 : EUROPE - ARSEN EMISSION 1982 (4936.12 T/A)

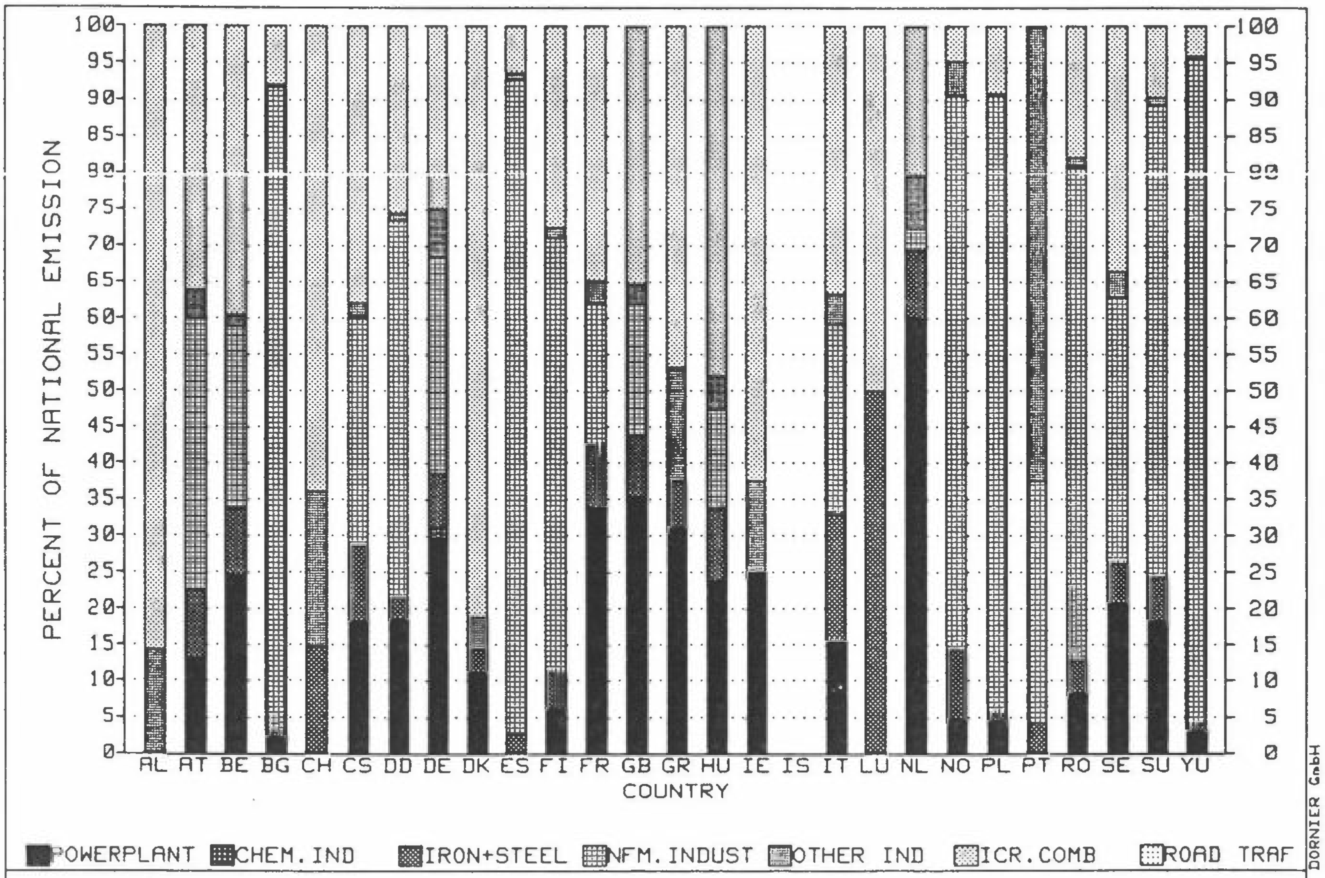


FIGURE 6 : EUROPE - CADMIUM EMISSION 1982 (1123.42 T/A)

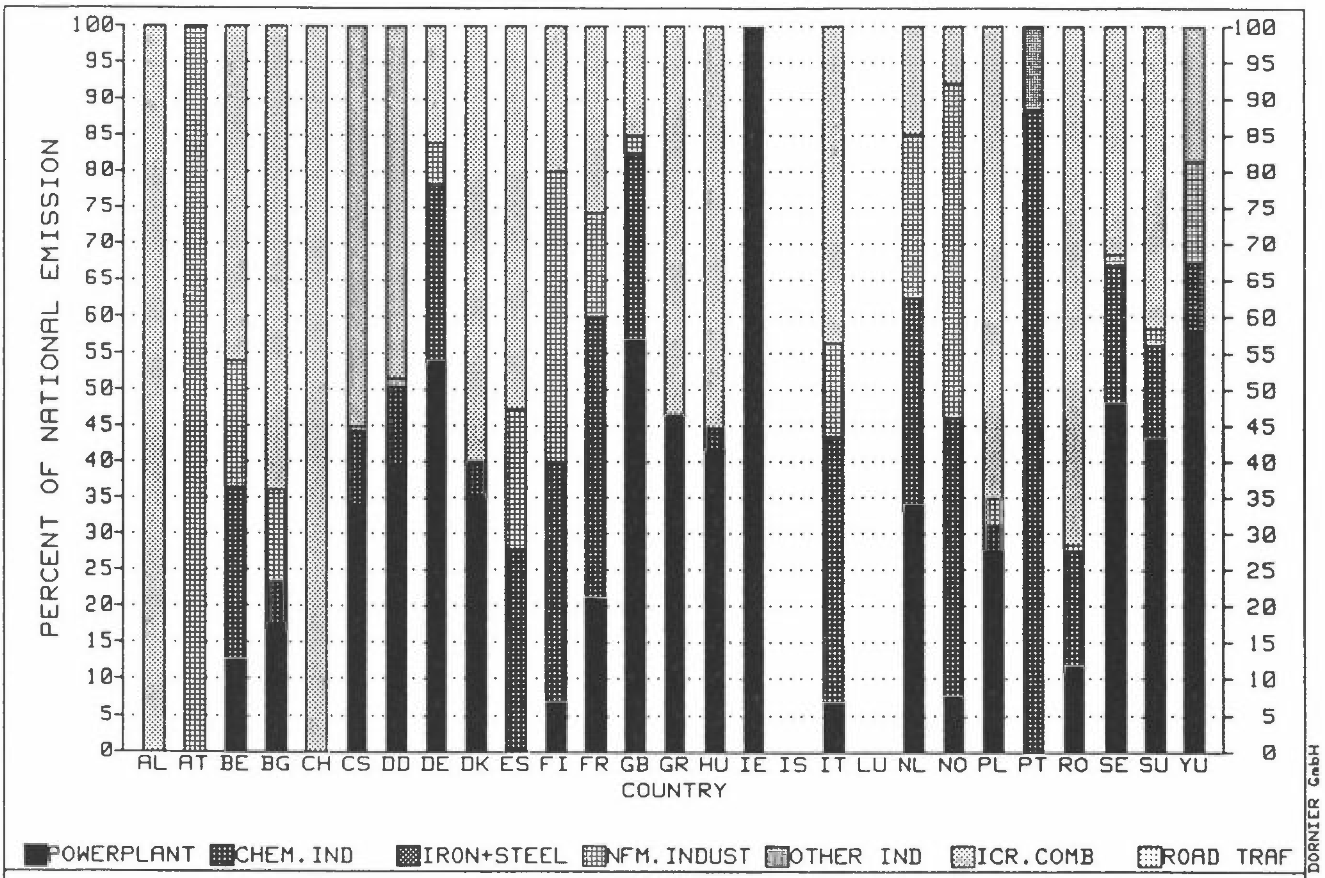


FIGURE 7 : EUROPE – MERCURY EMISSION 1982 (388.9 T/A)

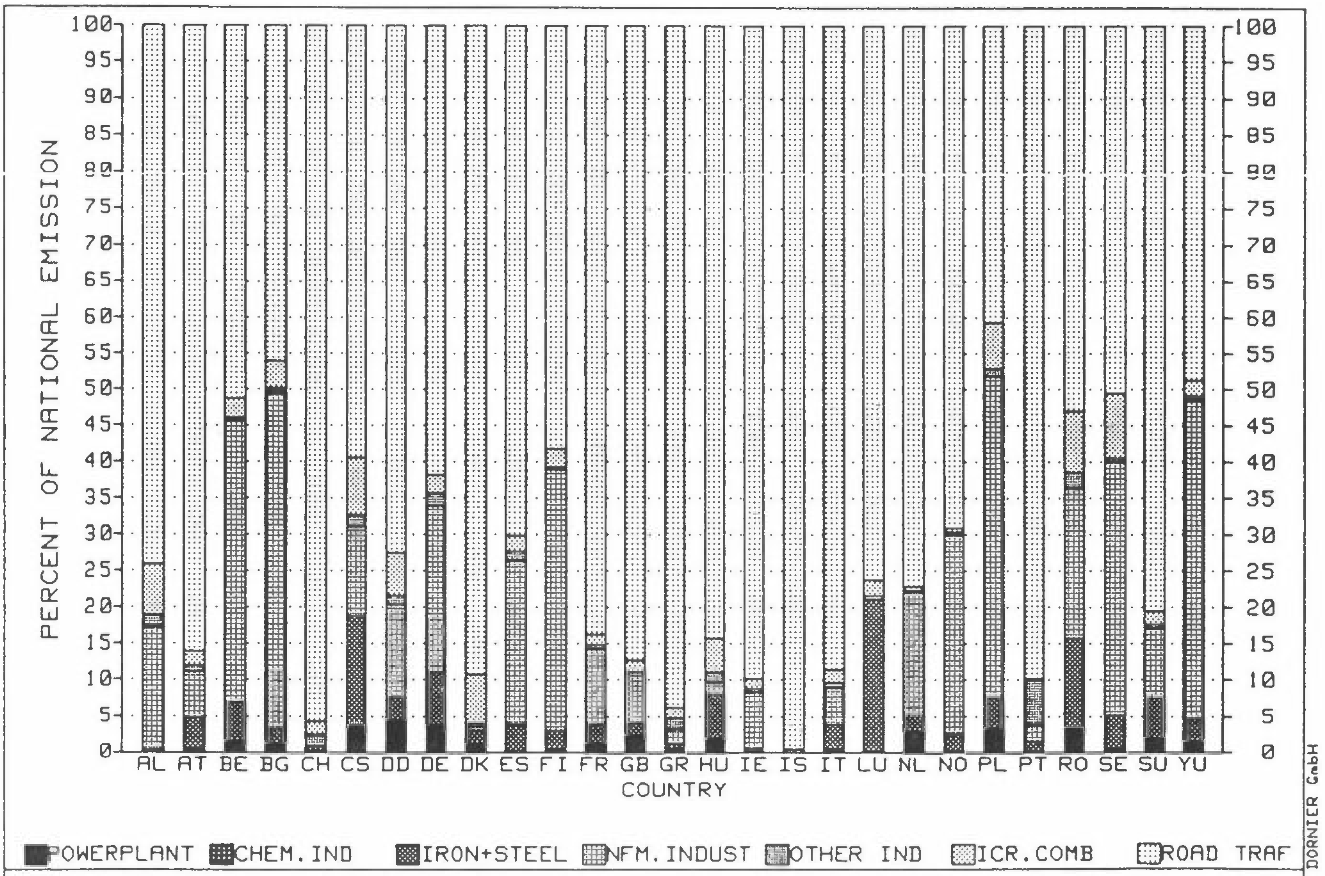


FIGURE 8 : EUROPE – LEAD EMISSION 1982 (89710.38 T/A)

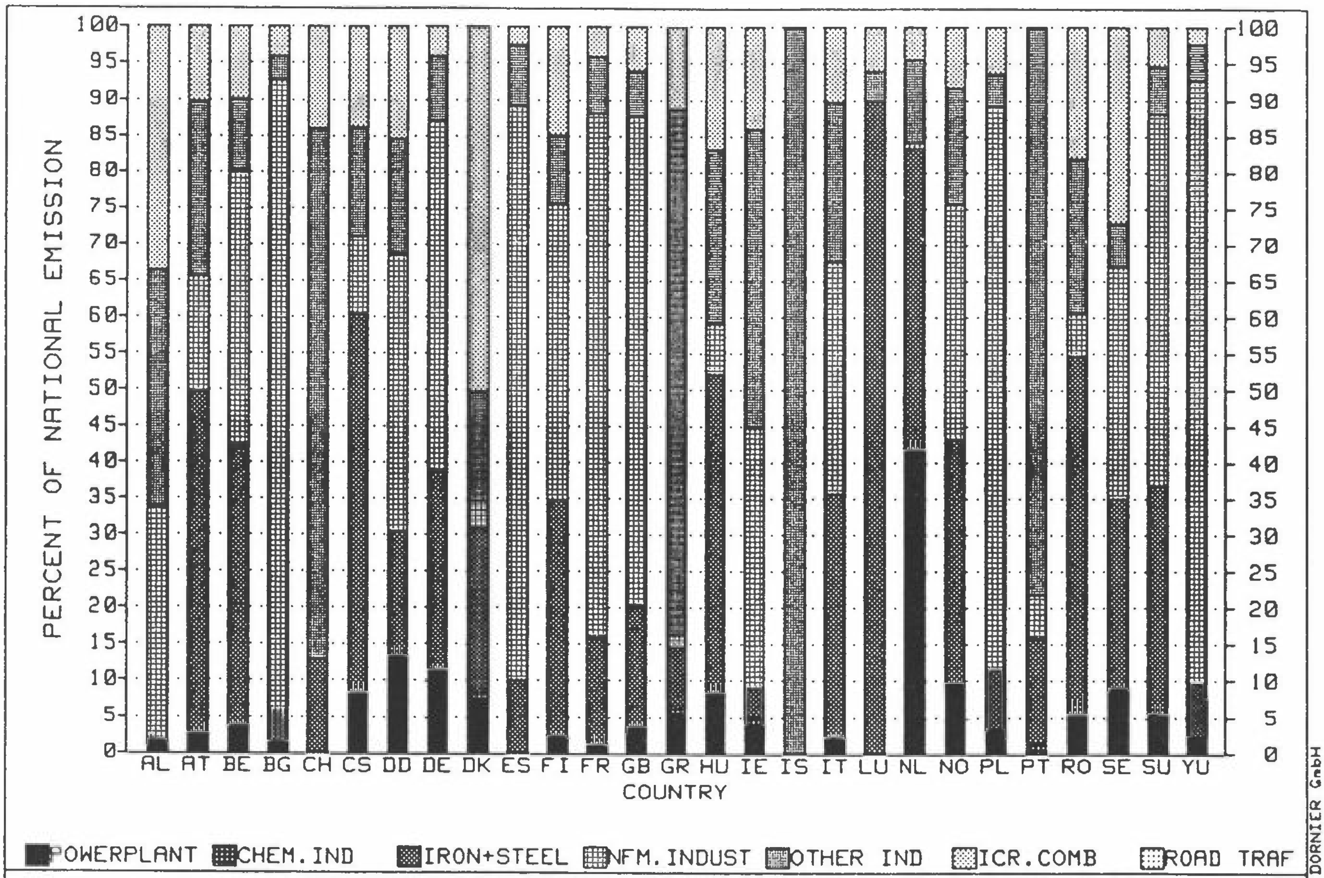


FIGURE 9 : EUROPE - ZINC EMISSION 1982 (41602.48 T/A)

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	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
37														<0.5	2	1	<0.5	<0.5	<0.5	3	156	325	12	333	23	156	165	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
36														<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	8	<0.5	1	1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
35														<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3	<0.5	4	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
34														<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	1	1	1	<0.5	5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
33														<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		
32													<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	1	1	1	<0.5	2	<0.5	<0.5	<0.5	<0.5	<0.5				10
31											<0.5	<0.5	159	<0.5	<0.5	1	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	1	1	6	9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1
30										<0.5	<0.5	<0.5	157	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	6	1	1	1	1	<0.5	2	4	<0.5	<0.5	<0.5	1	<0.5	1	1
29										<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3	1	15	7	5	1	1	<0.5	<0.5	<0.5	<0.5	1	1	1	150	3
28										<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	<0.5	<0.5	1	6	13	3	5	1	1	1	<0.5	<0.5	4	1	52	1	4
27										<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5	1	10	3	<0.5	3	<0.5	1	1	3	6	21	19	1	1	1	<0.5	<0.5		
26										<0.5	30	1	123	16	<0.5	1	2	<0.5	<0.5	<0.5	<0.5	1	3	1	1	5	1	12	<0.5	3	<0.5				
25											1	<0.5	1	<0.5	84	2	2	1	<0.5	<0.5	1	1	1	1	1	1	15	2	3	<0.5					
24											<0.5	<0.5	1	2	<0.5	<0.5	<0.5	<0.5	3	1	8	1	1	2	5	1	12	1	1						
23											<0.5	<0.5	1	2	8	10	<0.5	<0.5	1	2	1	1	1	1	1	1	6	<0.5	<0.5						
22											<0.5	<0.5	<0.5	2	3	3	<0.5		5	1	1	1	1	1	2	2	1	<0.5							
21											<0.5	<0.5	<0.5	1	6	3	1	1	3	3	7	7	5	2	2	3	4	1							
20												8	<0.5	1	5	6	1	1	3	8	7	3	2	27	1	5	3	3	2						
19		<0.5								<0.5		<0.5	<0.5	<0.5	2	3	2	3	3	220	60	7	7	1	31	22	5	3	1	<0.5					
18									<0.5	<0.5					1	70	2	6	27	246	13	43	7	1	3	4	2	54	24	<0.5					
17									<0.5	<0.5	<0.5				<0.5	20	26	36	32	10	5	8	3	1	5	216	1	60	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
16									<0.5	1	2	1			1	7	14	3	5	2	8	3	2	1	2	<0.5	26	8	<0.5	<0.5	1	<0.5		<0.5	
15									<0.5	3	1	11	5	<0.5	8	100	8	9	4	4	2	9	4	1	1	1	13	1	<0.5	3	9		<0.5	<0.5	
14									<0.5	1	<0.5	10	7	6	15	39	13	141	2	1	1	3	<0.5	3	<0.5		1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
13									<0.5	3	<0.5	7	52	9	64	6	4	1	3	6	6	3	1	2	1	3	1	<0.5							
12									<0.5	<0.5	<0.5	1	<0.5	2	5	12	1	2	3	6	6	4	3	3	4	<0.5	2	1							
11									<0.5	<0.5		<0.5	<0.5	1	1	1	1	2	4	1	<0.5	<0.5					2	<0.5							
10													1	1	2	1	1	1	3	3		<0.5	<0.5	<0.5		2	1	2							
9															<0.5	2	1	1	1			<0.5	<0.5	2		<0.5	<0.5								
8																<0.5	1	<0.5	1				27	<0.5											
7														2	<0.5	92	1	<0.5	4	<0.5	<0.5														
6												<0.5	1	17	2	<0.5	2	<0.5	<0.5	<0.5	<0.5														
5												<0.5	2	1	1	4	1	1	4	<0.5															
4													1	1	1	1	<0.5	<0.5	23																
3														2	<0.5	<0.5	13	<0.5	<0.5																
2														8	<0.5	1	1	<0.5																	
1														<0.5	<0.5	86	1																		

EUROPE - AS EMISSION 1982 (EMEP GRID 150•150 KM) (SUM = 4936.119 • 1000 KG/A)

Figure 10: As emissions in Europe in 1982 within the EMEP grid of 150 km x 150 km (in t).

DORNIER GmbH 21 DEC 1988

	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
37														<0.5	40	30	1	1	2	52	747	1654	205	6250	623	740	845	3	<0.5	<0.5	<0.5	1	1	1	1	37
36														<0.5	<0.5	<0.5	1	2	1	4	4	200	3	21	11	12	4	<0.5	<0.5	<0.5	1	1	1	1	1	36
35														<0.5	<0.5	<0.5	1	1	1	3	51	9	64	11	6	5	5	1	1	1	1	1	1	1	1	35
34														<0.5	<0.5	<0.5	1	1	2	2	10	5	11	12	11	7	163	1	1	2	<0.5	1	1	1	<0.5	34
33														<0.5	<0.5	<0.5	1	1	3	4	5	9	33	16	29	7	2	1	1	<0.5	<0.5	<0.5	<0.5			33
32													<0.5	1	<0.5	6	1	1	2	3	132	10	15	11	9	15	4	1	1	9	<0.5				300	32
31											<0.5	6	700	1	<0.5	33	1	1	2	3	7	36	12	15	16	146	316	3	3	2	1	2	5	9	15	31
30										<0.5	<0.5	1	792	1	1	1	1	2	3	167	192	19	13	11	11	6	15	64	1	1	5	15	9	13	10	30
29										<0.5	<0.5	<0.5	2	3	1	1	4	5	3	54	12	364	94	74	15	10	6	6	9	7	10	10	15	772	60	29
28										<0.5	3	3	6	7	7	10	1	16	6	7	21	117	390	20	115	14	14	17	7	9	117	11	5604	17	116	28
27										3	3	5	11	8	11	16	22	501	107	5	106	8	13	16	32	200	2667	449	11	10	13	9	9			27
26										<0.5	151	6	500	30	17	45	33	8	7	6	6	10	20	14	19	57	20	347	6	33	8					26
25											10	2	8	4	499	55	93	10	7	9	17	15	17	21	16	23	324	21	51	<0.5						25
24											<0.5	1	7	22	3	2	1	<0.5	34	13	259	15	11	35	176	10	273	10	10							24
23											<0.5	4	6	26	100	172	3	9	15	71	14	13	16	20	19	15	191	3	7							23
22											<0.5	<0.5	2	20	51	109	5		170	36	43	16	21	27	31	31	10	1								22
21											<0.5	2	15	10	132	37	23	22	80	82	243	103	141	30	63	104	115	46								21
20												4	1	21	81	253	16	30	99	244	191	117	56	453	49	132	93	61	49							20
19										<0.5		<0.5	<0.5	22	161	195	72	100	92	3517	9002	262	176	54	554	2230	165	112	42	1						19
18									<0.5	<0.5					62	806	118	303	779	3766	292	647	105	35	107	145	80	3577	1672	3						18
17									1	15	5				2	370	1963	1376	1442	421	259	235	82	69	1201	3446	44	1006	14	<0.5	2	<0.5	<0.5	2		17
16									1	20	43	29			50	362	434	133	436	106	147	82	54	25	62	19	2302	1123	15	<0.5	22	1		<0.5		16
15									<0.5	86	50	420	140	14	342	1700	603	544	202	267	36	65	132	31	50	31	29	57	12	40	127		3	4		15
14									6	36	4	447	343	150	397	551	293	422	141	62	52	140	3	23	1		30	17	5	19	9	<0.5	4	<0.5		14
13									5	50	34	195	657	302	679	104	95	37	66	109	339	84	43	32	73	69	80	2								13
12									5	11	<0.5	31	43	42	115	527	14	273	90	230	231	192	99	131	150	26	62	16								12
11									<0.5	<0.5		3	6	26	40	24	29	56	51	34	8	3					41	19								11
10													15	16	60	22	17	11	42	316		2	21	<0.5		36	61	50								10
9															1	49	10	37	14			1	20	34		5	3									9
8																12	23	12	23				806	1												8
7														72	13	1845	22	10	110	2	1															7
6												1	21	6925	23	11	62	10	5	10	1															6
5												3	49	25	20	104	10	20	97	1																5
4													26	20	16	10	11	11	2136																	4
3														30	14	12	63	16	9																	3
2														130	9	33	30	16																		2
1														1	7	1397	23																			1
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	

EUROPE - CD EMISSION 1982 (EMEP GRID 150•150 KM) (SUM = 112341.9 • 10 KG/A)

Figure 11: Cd emissions in Europe in 1982 within the EMEP grid of 150 km x 150 km (in 10 kg).

DORNIER GmbH 21 DEC 1988

	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
37														2	10	5	7	7	17	91	266	611	135	760	300	273	326	26	4	4	3	5	7	8	9
36														2	3	2	7	16	7	36	36	197	28	176	89	100	31	4	4	4	5	7	7	7	8
35														1	3	2	8	7	7	28	82	74	195	89	47	42	40	6	6	6	6	6	6	6	8
34														1	2	3	8	8	17	16	86	42	89	103	94	56	45	7	6	21	2	6	6	5	3
33														1	2	3	10	10	26	33	40	70	275	130	244	56	14	7	7	3	<0.5	4	2		
32													4	11	4	53	10	10	16	24	99	88	126	90	72	50	36	7	7	76	3				274
31											<0.5	51	265	12	3	26	10	10	19	26	50	300	104	129	133	223	80	26	22	19	9	16	46	73	125
30										<0.5	1	9	220	9	6	7	9	13	21	79	205	163	113	91	89	40	47	196	10	8	40	130	80	111	154
29										1	1	1	7	10	10	11	34	40	29	109	102	727	209	190	126	85	53	49	72	56	82	149	129	475	161
28										7	4	4	10	22	21	29	5	52	49	55	175	987	344	153	226	114	121	145	58	72	153	94	787	139	145
27										7	5	5	11	25	35	46	70	705	72	44	63	66	110	137	186	192	710	500	91	150	106	79	76		
26										5	62	6	363	290	46	106	67	71	55	52	52	86	159	122	164	321	172	414	55	199	64				
25											20	4	8	5	177	101	130	86	62	73	140	126	146	177	135	192	537	90	82	1					
24											9	8	7	20	3	4	8	2	207	109	260	123	90	294	153	150	299	86	153						
23											11	34	11	24	92	111	1	74	126	186	119	113	133	168	149	120	203	21	58						
22											25	16	47	31	41	40	5		151	39	117	134	180	231	261	260	155	2							
21			5	1							8	19	100	73	67	30	10	10	73	50	131	90	322	255	140	83	153	23							
20		4	1	1								199	32	27	71	187	17	25	75	119	113	94	210	239	44	66	70	62	41						
19		24	3	<0.5						1		1	6	26	170	190	103	93	79	467	900	176	141	76	123	204	126	124	64	1					
18									<0.5	1					65	444	156	402	269	518	268	175	215	60	67	80	91	515	349	24					
17									6	35	35				10	368	667	402	533	282	171	349	118	101	191	509	85	349	111	1	15	1	1	15	
16									10	140	245	50			193	502	427	189	243	123	247	200	85	74	82	54	343	154	131	4	17	13		1	
15									<0.5	256	135	1071	191	80	861	2507	462	447	246	247	118	250	95	41	76	30	67	88	110	100	467		22	34	
14									32	184	31	1406	1000	870	737	975	474	729	255	165	309	311	9	31	3		51	32	46	83	70	3	34	<0.5	
13									40	223	35	450	1273	892	1180	552	103	243	243	617	860	390	224	153	160	303	202	9							
12									19	84	1	130	82	101	204	1140	96	205	215	660	371	412	217	676	677	153	154	30							
11									<0.5	<0.5		20	37	174	196	157	120	371	216	210	45	10					87	111							
10													101	106	221	145	112	80	219	346		15	39	1		140	202	162							
9															6	183	120	100	96			5	89	77		31	16								
8																40	120	65	99				416	8											
7														40	47	434	70	37	354	8	5														
6												2	74	407	47	39	46	37	10	34	3														
5												10	159	67	73	354	46	72	150	4															
4													71	70	30	47	39	41	374																
3														60	46	45	203	57	32																
2														124	28	118	106	40																	
1														4	19	203	83																		

EUROPE - PB EMISSION 1982 (EMEP GRID 150*150 KM) (SUM = 89710.354 * 1000 KG/A)

Figure 12: Pb emissions in Europe in 1982 within the EMEP grid of 150 km x 150 km (in t).

DORNIER GmbH 21 DEC 1988

	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	
37														<0.5	31	3	<0.5	<0.5	<0.5	103	181	750	256	2356	396	181	440	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	37
36														<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	36	1	5	2	3	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	36
35														<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	102	2	105	2	1	1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	35
34														<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	1	2	3	3	2	21	<0.5	<0.5	1	<0.5	<0.5	<0.5	<0.5	<0.5	34
33														<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	2	7	4	7	2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5			33
32													<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5	1	113	2	3	2	2	30	1	<0.5	<0.5	2	<0.5				136	32
31											<0.5	1	302	<0.5	<0.5	3	<0.5	<0.5	1	1	2	8	3	3	4	116	41	1	1	1	<0.5	<0.5	1	2	3	31
30										<0.5	<0.5	<0.5	186	<0.5	<0.5	<0.5	<0.5	<0.5	1	22	27	4	3	2	2	1	30	105	<0.5	<0.5	1	4	2	3	4	30
29										<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	1	1	103	3	198	164	133	3	2	1	1	2	2	2	4	4	186	104	29
28										<0.5	1	1	1	1	1	6	<0.5	30	1	1	5	27	169	32	44	3	3	4	2	2	17	3	2311	4	16	28
27										6	1	1	2	1	2	6	22	260	14	1	14	2	3	4	54	27	1223	373	2	4	3	2	2			27
26										<0.5	26	1	107	9	6	14	40	2	1	1	1	2	33	3	4	65	5	142	1	34	2					26
25											30	<0.5	2	1	95	30	13	2	2	2	4	3	4	5	4	5	358	31	102	<0.5						25
24											<0.5	<0.5	1	4	1	<0.5	22	<0.5	34	3	36	3	2	8	24	4	107	2	4							24
23											<0.5	4	1	12	91	35	<0.5	2	3	11	3	3	4	5	4	3	27	1	2							23
22											<0.5	<0.5	1	4	23	22	1		24	6	7	4	5	6	7	7	4	<0.5								22
21											<0.5	3	10	9	20	7	11	3	23	13	37	106	22	7	11	55	95	6								21
20												8	1	14	40	85	3	5	19	49	42	18	10	20	8	55	15	45	23							20
19		1								<0.5		<0.5	<0.5	3	20	24	10	16	14	201	2951	140	104	9	115	53	65	17	6	<0.5						19
18									<0.5	<0.5					16	230	12	100	186	301	264	88	63	6	54	97	13	1109	442	<0.5						18
17									<0.5	2	1				<0.5	107	1415	190	300	237	64	40	49	71	306	103	6	151	2	<0.5	<0.5	<0.5	<0.5	<0.5		17
16									<0.5	3	10	4			13	141	238	24	150	15	51	65	31	3	30	2	762	351	2	<0.5	3	<0.5		<0.5		16
15									<0.5	80	3	244	119	2	228	1037	180	90	41	45	32	26	66	5	30	8	20	8	2	56	111		<0.5	1		15
14									1	4	1	141	67	62	209	341	368	212	23	20	8	72	<0.5	49	<0.5		4	6	1	9	1	<0.5	1	<0.5		14
13									1	39	<0.5	176	1291	83	2596	53	119	7	51	95	201	53	6	25	61	50	62	<0.5								13
12									1	1	<0.5	3	2	59	77	80	2	4	74	123	154	102	84	40	41	4	27	6								12
11									<0.5	<0.5		<0.5	1	3	5	6	15	10	45	5	1	<0.5					25	3								11
10													2	2	9	5	2	51	45	11		<0.5	2	<0.5		25	9	27								10
9															<0.5	8	2	9	2			<0.5	3	24		1	<0.5									9
8																2	3	1	3				595	<0.5												8
7														76	1	360	2	1	50	<0.5	<0.5															7
6												<0.5	2	2294	37	1	76	1	1	1	<0.5															6
5												<0.5	23	20	2	29	19	2	96	<0.5																5
4													2	2	19	19	1	1	647																	4
3														34	2	2	7	2	1																	3
2														56	2	4	3	5																		2
1														<0.5	1	102	3																			1
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	

EUROPE - ZN EMISSION 1982 (EMEP GRID 150•150 KM) (SUM = 41602.478 • 1000 KG/A)

Figure 13: Zn emissions in Europe in 1982 within the EMEP grid of 150 km x 150 km (in t).

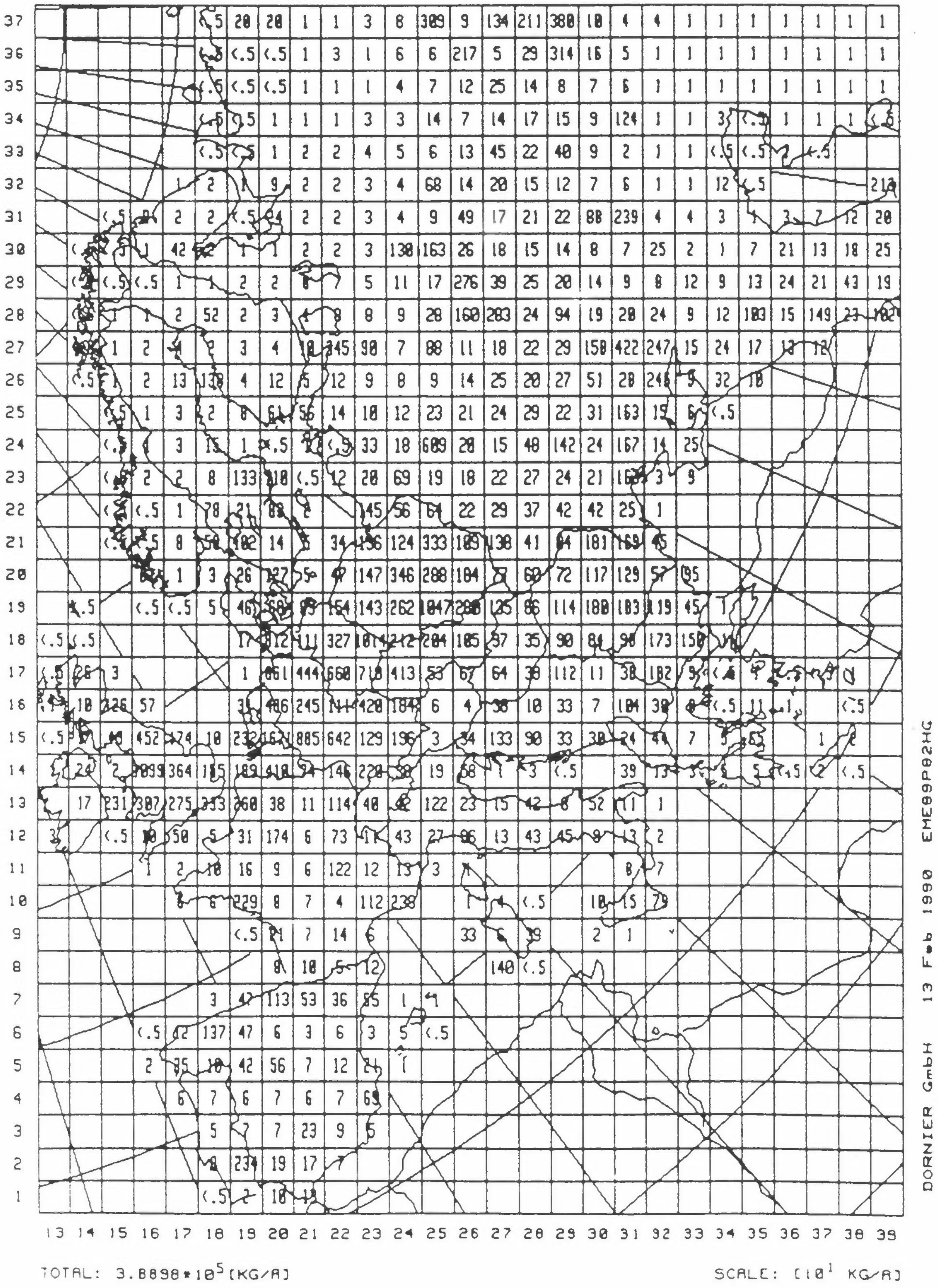


FIG. 14 :EUROPE - HG EMISSION 1982 (EMEP 150*150 KM^2) --- DORNIER / NILU (II. JUNE 88)

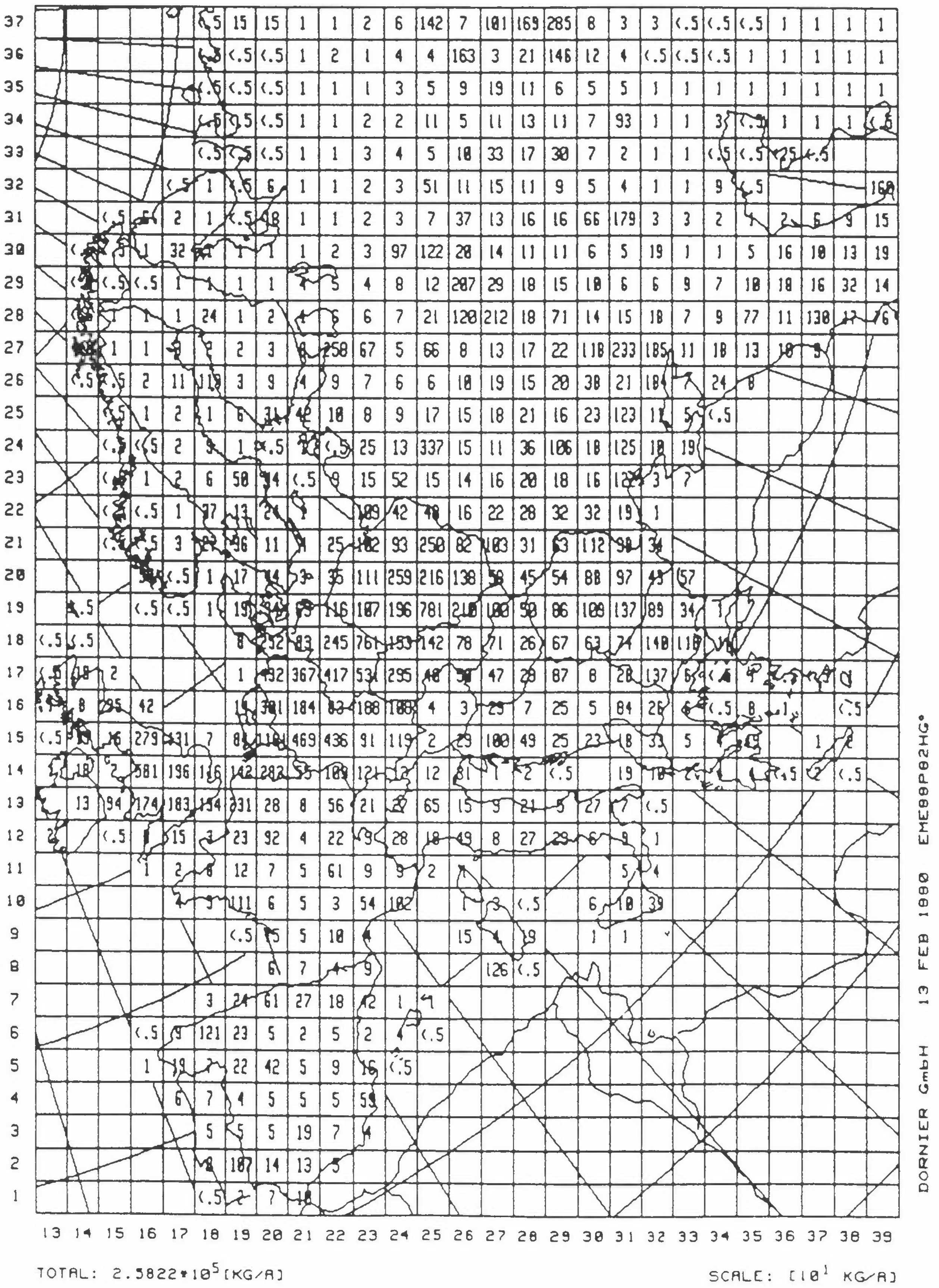


FIG. 15 : EUROPE - HG° EMISSION 1982 (EMEP 150*150 KM^2) --- DORNIER NILU (I. JAN. 90)

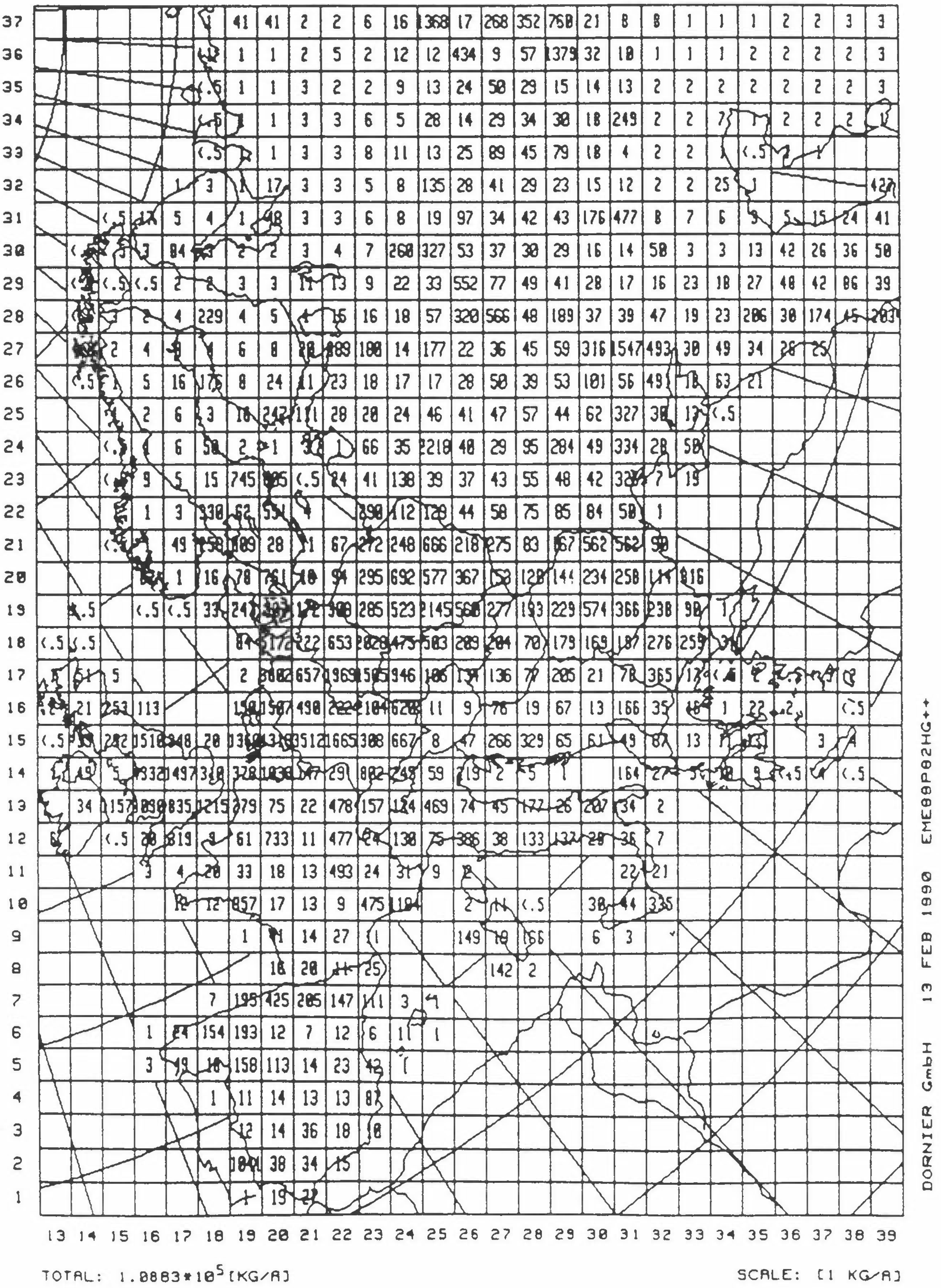
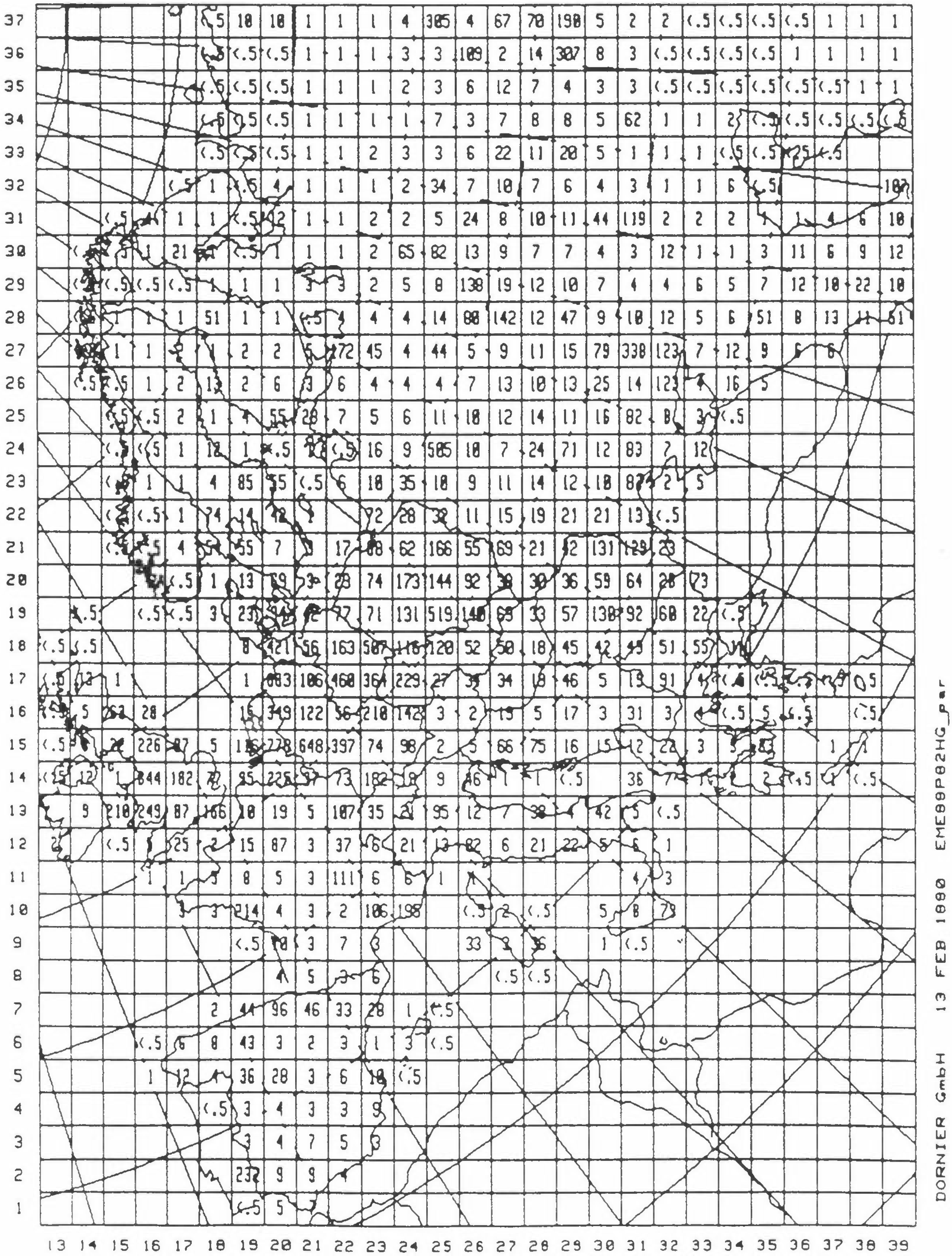


FIG. 16 :EUROPE - HG++ EMISSION 1982 (EMEP 150*150 KM^2) --- DORNIER / NILU (I   TAN 90)



TOTAL: 2.1846*10⁴ [KG/A]

SCALE: [1 KG/A]

FIG. 17 :EUROPE - HG_par EMISSION 1982 (EMEP 150*150 KM^2) - DORNIER / NILU (I,JAN.90)

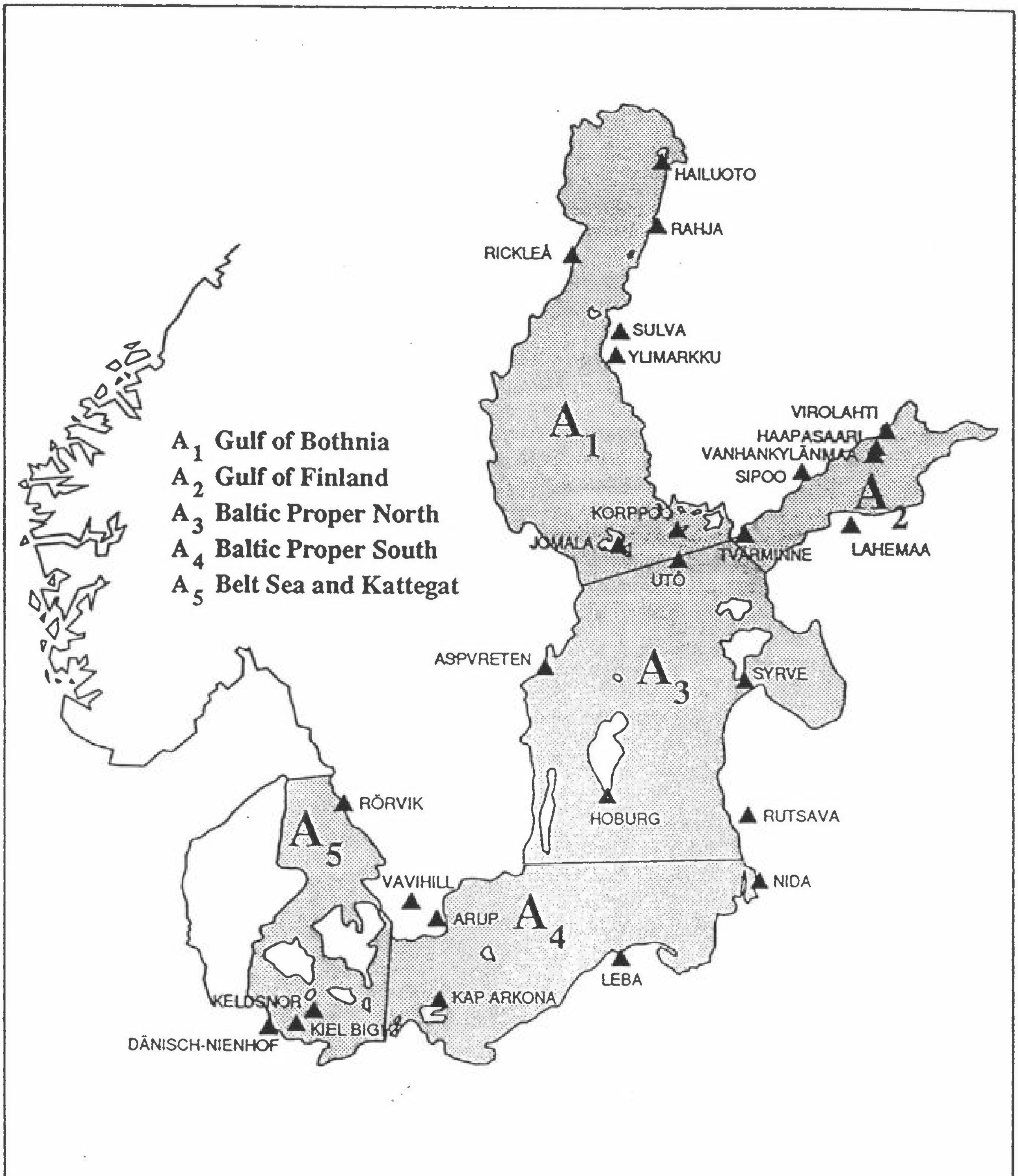
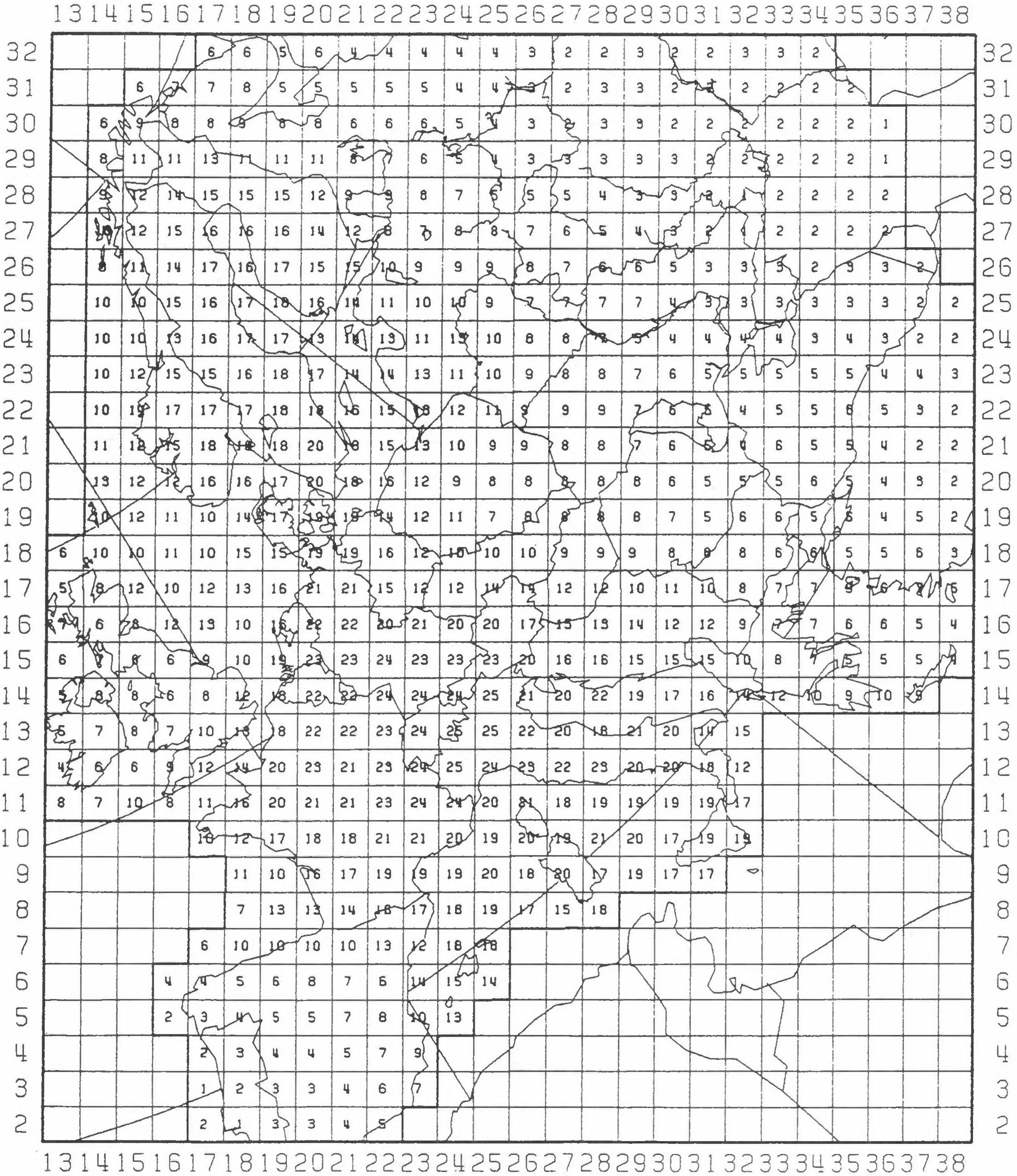


Figure 18: HELCOM/EGAP station network.



	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
32					6	6	5	6	4	4	4	4	4	3	2	2	3	2	2	3	3	2				
31			6	7	7	8	5	5	5	5	5	4	4	3	2	3	3	2	2	2	2	2	2			
30		6	9	8	8	9	8	8	6	6	6	5	4	3	2	3	3	2	2	2	2	2	2	1		
29		8	11	11	13	11	11	11	8	7	6	5	4	3	3	3	3	3	2	2	2	2	2	1		
28		9	12	14	15	15	15	12	9	9	8	7	6	5	5	4	3	3	2	1	2	2	2	2		
27		10	12	15	16	16	16	14	12	8	7	8	8	7	6	5	4	3	2	1	2	2	2	2		
26		8	11	14	17	16	17	15	15	10	9	9	9	8	7	6	6	5	3	3	3	2	3	3	2	
25		10	10	15	16	17	18	16	14	11	10	10	9	7	7	7	7	4	3	3	3	3	3	3	2	2
24		10	10	13	16	17	17	13	14	13	11	13	10	8	8	7	5	4	4	4	4	3	4	3	2	2
23		10	12	15	15	16	18	17	14	14	13	11	10	9	8	8	7	6	5	5	5	5	5	4	4	3
22		10	19	17	17	17	18	18	16	15	13	12	11	9	9	9	7	6	5	4	5	5	6	5	3	2
21		11	12	15	18	18	18	20	18	15	13	10	9	9	8	8	7	6	5	6	6	5	5	4	2	2
20		13	12	12	16	16	17	20	18	16	12	9	8	8	8	8	8	6	5	5	5	6	5	4	3	2
19		10	12	11	10	14	17	19	18	14	12	11	7	8	8	8	8	7	5	6	6	5	6	4	5	2
18	6	10	10	11	10	15	15	19	19	16	12	10	10	10	9	9	9	8	8	8	6	6	5	5	6	3
17	5	8	12	10	12	13	16	21	21	15	12	12	14	14	12	12	10	11	10	8	7	7	9	6	2	6
16	7	6	8	12	13	10	16	22	22	20	21	20	20	17	15	13	14	12	12	9	7	7	6	6	5	4
15	6	7	8	6	9	10	19	23	23	24	23	23	23	20	16	16	15	15	15	10	8	7	5	5	5	4
14	5	8	8	6	8	12	18	22	22	24	24	24	25	21	20	22	19	17	16	14	12	10	9	10	9	
13	5	7	8	7	10	13	18	22	22	23	24	25	25	22	20	18	21	20	14	15						
12	4	6	6	9	12	14	20	23	21	23	24	25	24	23	22	23	20	20	18	12						
11	8	7	10	8	11	16	20	21	21	23	24	24	20	21	18	19	19	19	19	17						
10					10	12	17	18	18	21	21	20	19	20	19	21	20	17	19	19						
9						11	10	16	17	19	19	19	20	18	20	17	19	17	17							
8						7	13	13	14	16	17	18	19	17	15	18										
7					6	10	10	10	10	13	12	18	18													
6				4	4	5	6	8	7	6	14	15	14													
5				2	3	4	5	5	7	8	10	13														
4					2	3	4	4	5	7	9															
3					1	2	3	3	4	6	7															
2					2	1	3	3	4	5																

CHANGES IN DEPOSITION OF OXIDIZED NITROGEN
DUE TO REDUCED EMISSIONS.
(REFERENCE (1985) - SCENARIO 1 (1998))
UNIT : % CHANGES FROM 1985 CONDITIONS

FIGURE 19

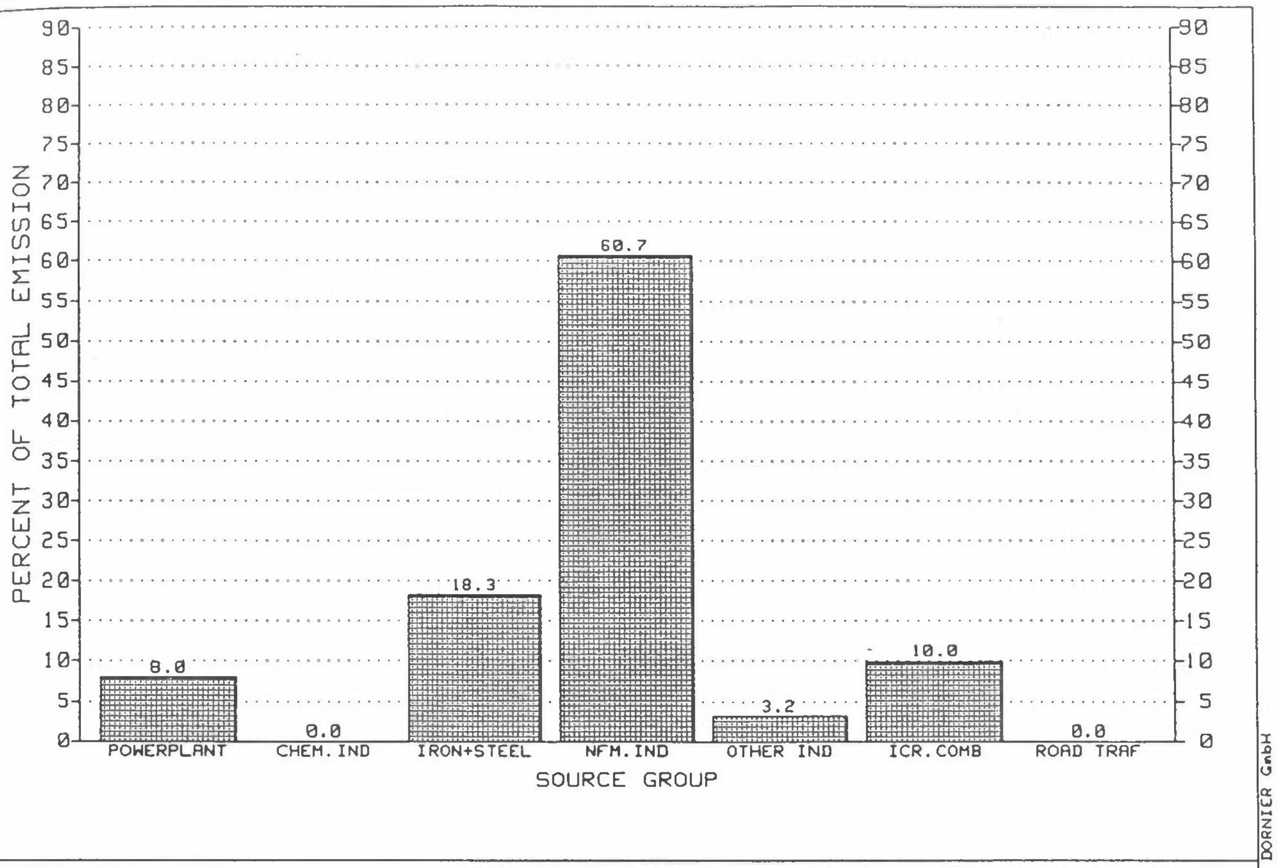


FIGURE 20 : EUROPE - LEAD EMISSION 1982 (21373.38 T/A)
SCENARIO 2 : ROAD TRAFFIC - UNLEADED GASOLINE

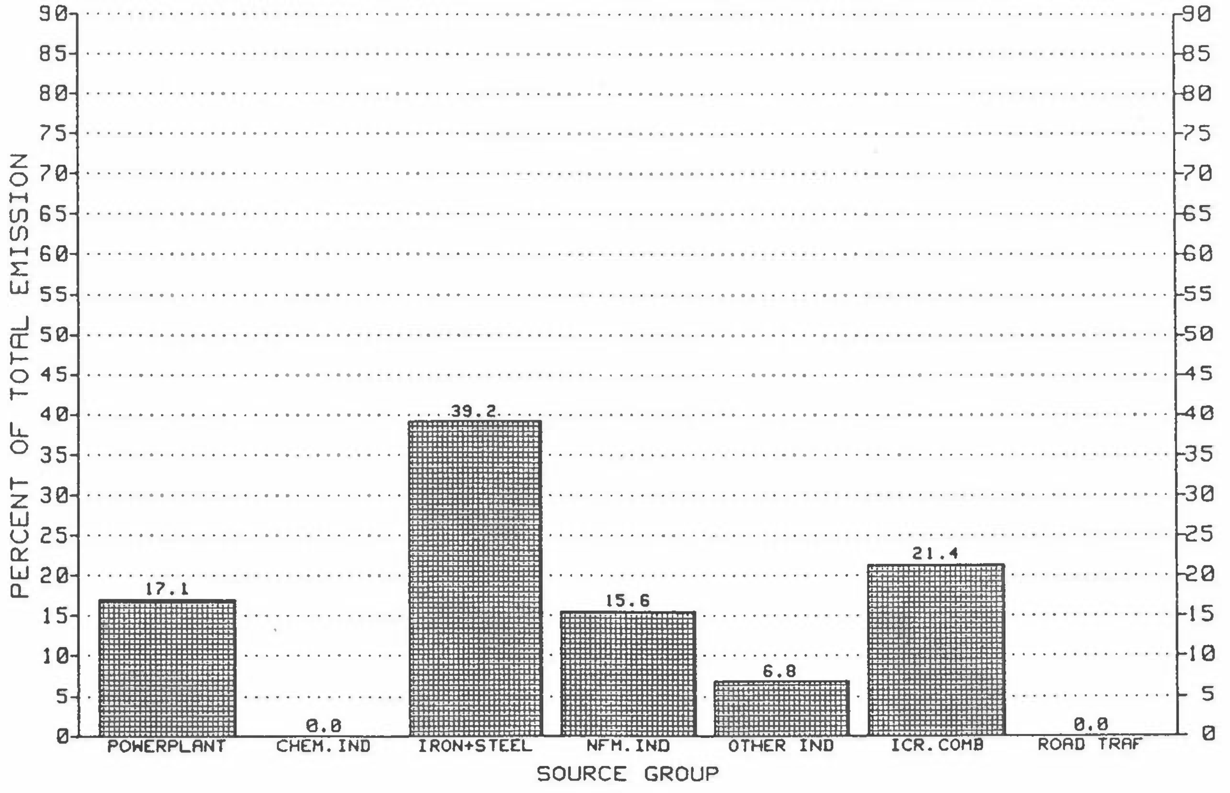


FIGURE 21 : EUROPE - LEAD EMISSION 1982 (9965.59 T/A)
SCENARIO 3 : NFM.IND_BAT + UNLEADED GASOLINE

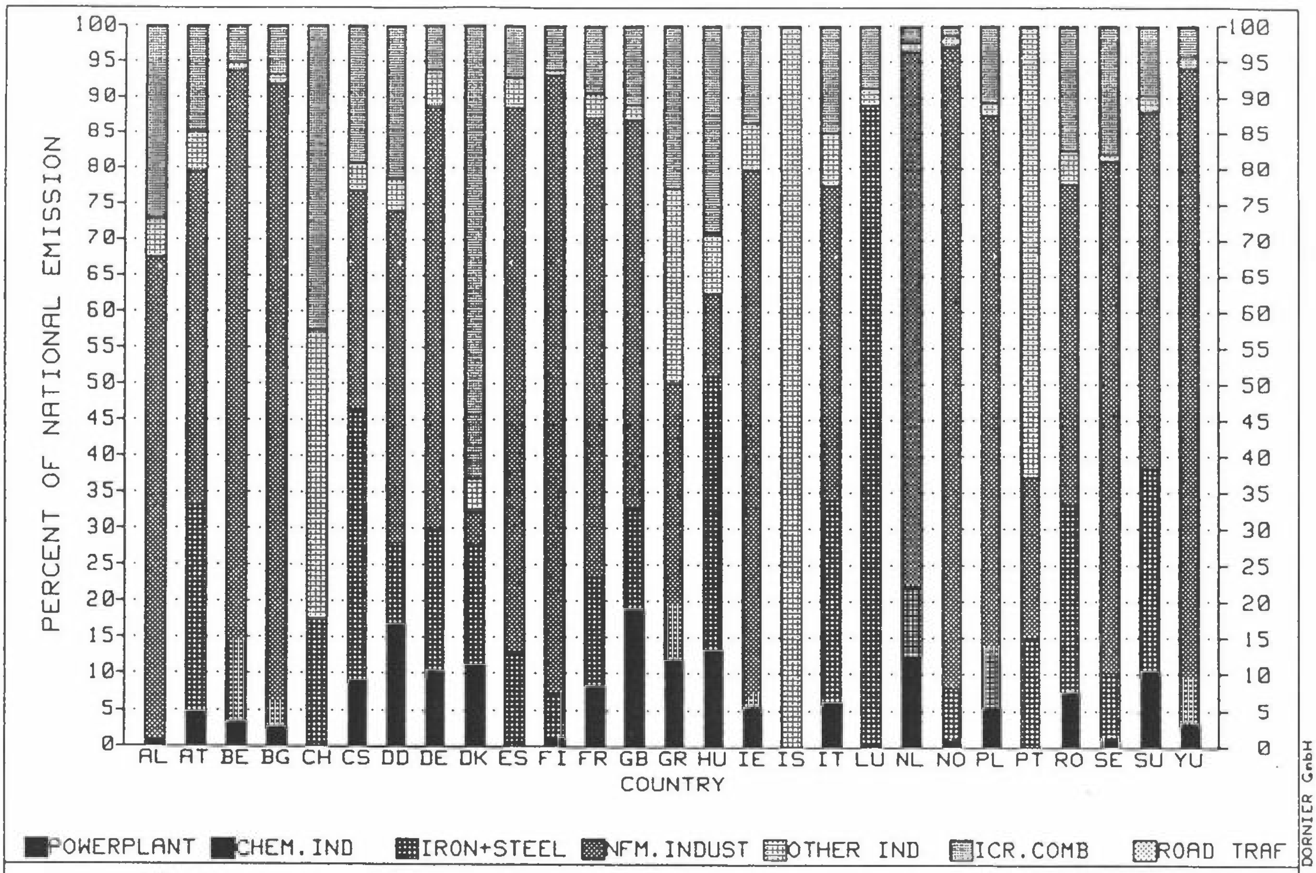


FIGURE 22 : EUROPE - LEAD EMISSION 1982 (21373.38 T/A)
SCENARIO 2 : ROAD TRAFFIC - UNLEADED GASOLINE

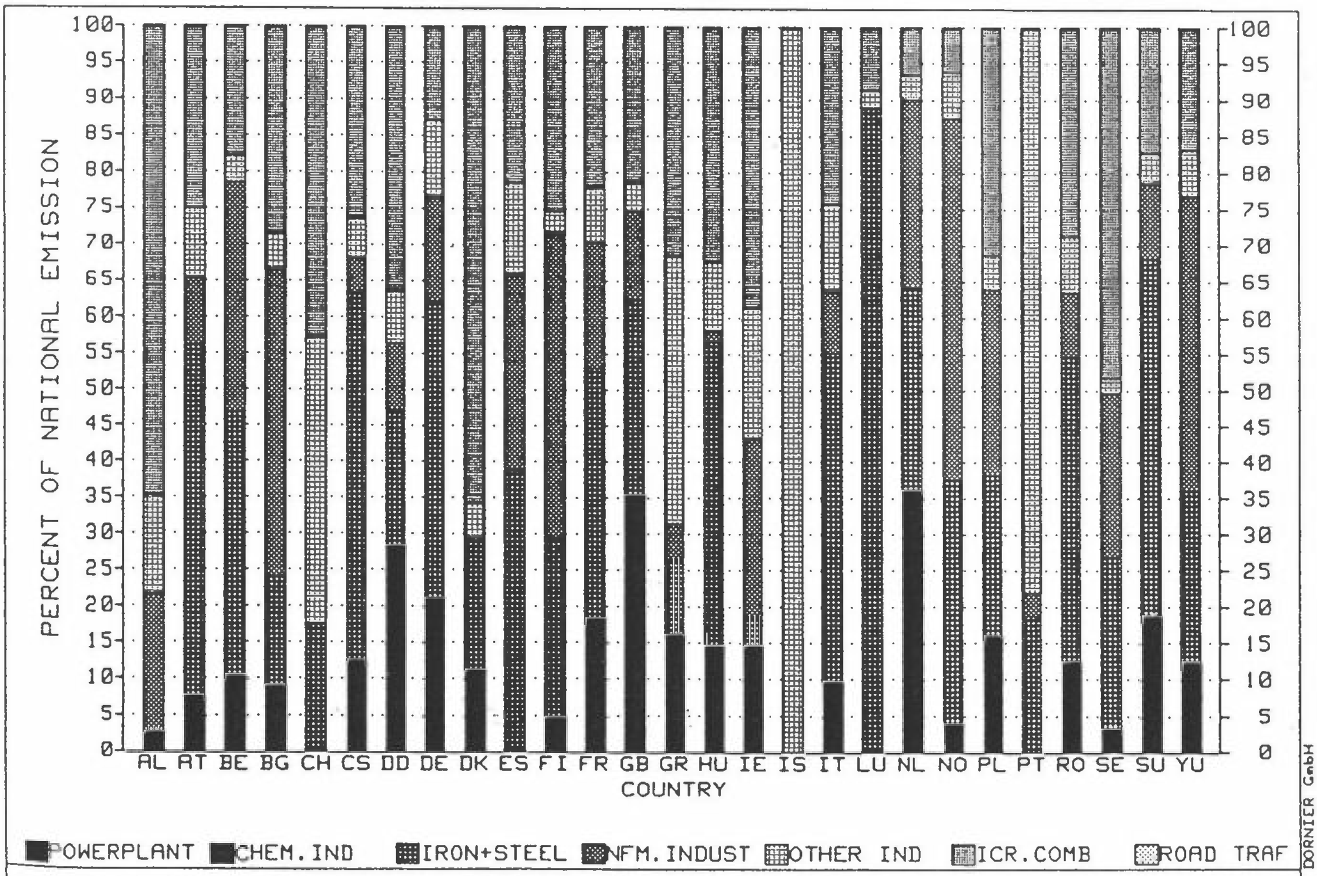


FIGURE 23 : EUROPE - LEAD EMISSION 1982 (9965.59 T/A)
SCENARIO 3 : NFM.IND_BAT + UNLEADED GASOLINE

APPENDIX A

Emissions from individual sources in countries with the proposed action areas and former German Democratic Republic.

Table A-1: NO_x emissions from major stationary sources in the countries with the proposed action areas and former German Democratic Republic in 1985.

Codes:

11	11	Coal fired power plants
61	62	Copper production
61	621	Primary copper production
61	63	Lead production
61	631	Primary lead production
61	64	Zinc production
61	641	Primary zinc production
64	67	Cement plants
50	50	Coke production
50	51	Iron production
50	54	Steel production
32	83	Chlor-alkali production
32	84	N-fertilizer production

COUNTRY CODE: 12 CZECHOSLOVAKIA

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
1	Pocerady	$50^{0} 32'$	$13^{0} 35'$	11	11	16 100
2	Ledvice	50.31	13.33	11	11	9 400
3	Tusimice	50.23	13.20	11	11	18 800
4	Prunerov	50.25	13.16	11	11	24 090
5	Brezova - Tisova	50.16	12.41	11	11	8 050
6	Vresova	50.09	12.38	11	11	4 020
7	Ervenice	50.35	13.40	11	11	1 340
8	Zaluzi	50.33	13.45	11	11	1 340
9	Melnik	50.33	14.25	11	11	16 100
10	Detmarovice	50.20	14.20	11	11	13 400
11	Ostrava	49.50	18.15	11	11	2 680
12	Karvina	49.50	18.30	11	11	1 340
13	Chvaletice	50.07	14.36	11	11	12 040
14	Porici	50.18	14.35	11	11	4 030
15	Hodonin	48.52	17.10	11	11	4 020
16	Novaky	49.39	13.49	11	11	8 050
17	Vojany	48.40	21.10	11	11	10 710
18	Litvinov	50.30	13.30	11	11	2 680
19	Plzen	49.45	13.25	11	11	2 680
20	Kosice	48.44	21.15	11	11	1 340
21	Litvinov	50.30	13.30	11	11	1 340
22	Ruzomberok	49.04	19.15	11	11	1 340
23	Sonstige	49.00	19.10	11	11	1 340
24	Vojany	48.40	21.10	11	11	5 370
25	Chomutov tube works - Chomutov	50.28	13.26	50	54	20
26	Poldi-Snop Kladno	50.10	14.02	50	54	50
27	Nova Huta Klementa Gottwalda - Kunice - Ostrawa	49.50	18.15	50	54	25

CZECHOSLOVAKIA Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
28	EASF Slovak Iron & Steelworks - Kosice	48.44 48.44	21.15 21.15	50 50	54 54	25
29	TZ Trinec/ Ostrawa	49.50	18.15	50	54	170
30	Vitkovice/ Ostrawa	49.50	18.15	50	54	60
31	Skoda/Pilzno	49.45	13.25	50	54	40
32	SZ Podbrezowa	49.45	13.25	50	54	25
33	ZDB Bohumin	49.45	13.25	50	54	25
34	Cement Plant (C.P.) Kraluv Dvur	50.00	14.00	64	67	2 380
35	CP Lochkov	50.00	14.00	64	67	1 510
36	CP Cizkovice	50.10	14.00	64	67	2 160
37	CP Prachovice	50.07	14.25	64	67	1 730
38	CP Cepicne	48.44	19.10	64	67	1 940
39	CP Hranice	49.34	17.45	64	67	1 730
40	CP Rohoznik	48.44	19.10	64	67	1 940
	Gas works					10 970
	Heat production					114 300
	Fuel oil combustion in resid. and ind. boilers					24 200
	Gas combustion					17 780
	[illegible]					352 680

COUNTRY CODE: 07 GDR

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
1	Boxberg	51° 25´	14° 34	11	11	74 080
2	Hagenwerder	51.03	14.47	11	11	31 390
3	Lübbenau	51.57	13.58	11	11	28 880
4	Vetschau	51.48	14.06	11	11	25 110
5	Thierbach	51.10	12.29	11	11	15 070
6	Lippendorf	51.11	12.22	11	11	11 340
7	Vockerode	51.50	12.13	11	11	8 790
8	Jänschwalde	51.51	14.31	11	11	12 560
9	Tratendorf	51.33	14.25	11	11	8 790
10	Hirschfelde	50.57	14.54	11	11	5 040
11	Harbke	52.12	11.07	11	11	2 520
12	Lauta	51.27	14.06	11	11	3 780
13	Zschornewitz	51.43	12.24	11	11	1 260
14	Sonstige	51.20	12.25	11	11	22 490
15	Schwarze Pompe	51.32	14.22	11	11	23 860
16	Espenhain	51.10	12.28	11	11	2 520
17	Regis/Borna	51.06	12.25	11	11	2 520
18	Eisenhüttenstadt	52.20	14.32	50	52	80
19	Unterwellenborn	50.39	11.25	50	52	30
20	Brandenburg	52.25	12.34	50	54	100
21	Riesa	51.18	13.18	50	54	40
22	Henningsdorf	52.38	13.13	50	54	40
23	Thale	51.46	11.02	50	54	10
24	Karsdorf	51.16	11.39	64	67	6 040
25	Rüdersdorf	51.29	13.50	64	67	3 450
26	Bernburg	51.48	11.45	64	67	3 020
27	Deuna	51.48	11.45	64	67	2 580
	Gas works					24 000
	Heat production					313 000
	Fuel oil combustion in resid. and ind. boilers					16 050

COUNTRY CODE: 11 POLAND

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
1	Siekierki - Warszawa	52.15	21.00	11	11	11 200
2	EL Zeran - Warszawa	52.15	21.00	11	11	8 300
3	Zel Bydgoszcz	53.16	17.33	11	11	6 800
4	EL Gorzow	51.01	18.21	11	11	2 500
5	EL Rybnik	50.07	18.30	11	11	33 200
6	EL Halemba - Ruda SL	50.15	18.59	11	11	3 300
7	EL Bytom	50.21	18.51	11	11	2 200
8	EL Zabrze	50.18	18.47	11	11	2 100
9	EL Bedzin	50.15	18.59	11	11	1 900
10	EL Szombierki - Bytom	50.21	18.51	11	11	700
11	EL Leg - Krakow	50.03	19.55	11	11	7 600
12	Z.E.L. Ostroleka	53.05	21.32	11	11	10 900
13	Z.E.L. Lodz	51.49	19.28	11	11	12 900
14	EL Belchatow	51.23	19.20	11	11	93 300
15	EL Konin	52.12	18.12	11	11	17 700
16	EL Patnow-Adamow	52.12	18.12	11	11	32 300
17	EL Turow-Turoszow	51.10	15.00	11	11	20 200
18	EL Jaworzno I	50.13	19.11	11	11	1 900
19	EL Jaworzno II	50.13	19.11	11	11	23 700
20	EL Jaworzno IV	50.13	19.11	11	11	5 300
21	EL Kozienice - Radom	51.26	21.10	11	11	32 100
22	EL Blachownia - Kedzierzyn	50.40	17.56	11	11	6 100
23	EL Dolna Odra - Szczecin	53.25	14.32	11	11	24 000
24	EL Lagisza - Bedzin	50.15	18.59	11	11	14 700
25	EL Polaniec - Tarnow	50.01	20.59	11	11	28 800
26	EL Siersza - Trzebinia	50.03	19.55	11	11	13 000

POLAND Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
27	EL Stalowa Wola	50.15	18.59	11	11	10 000
28	EL Skawina - Krakow	50.03	19.55	11	11	11 000
29	EL Chorzow	50.19	18.56	11	11	2 200
30	EL Laziska - Katowice	50.15	18.59	11	11	18 300
31	EL Pomorzany - Szczecin	53.25	14.32	11	11	2 300
32	EL Czechnice - Wroclaw	51.05	17.00	11	11	1 700
33	Z.E.L. Wroclaw	51.05	17.00	11	11	4 000
34	EL Gdansk	54.22	18.41	11	11	4 400
35	EL Gdynia	54.31	18.30	11	11	1 200
36	EL Szczecin	53.25	14.32	11	11	1 600
37	Huta Labedy Gliwice	50.20	18.40	50	51,54	10
38	Huta Laziska - Katowice	50.15	18.59	50	51,54	40
39	Huta Kosciuszko - Katowice	50.15	18.59	50	51,54	40
40	Huta Bieruta - Czestochowa	50.49	19.07	50	51,54	40
41	Huta Bobrek - Bytom	50.21	18.51	50	51,54	20
42	Huta Dzierzynski - Dabrowa	50.20	18.50	50	51,54	20
43	Huta Florian - Swietochlowice	50.15	18.59	50	51,54	10
44	Huta Katowice - Katowice	50.15	18.59	50	51,54	160
45	Huta Lenina - Krakow	50.03	19.55	50	51,54	210
46	Huta Pokoj - Ruda SL	50.15	18.59	50	51,54	20
47	Huta Zawiercie - Zawiercie	50.30	19.24	50	51,54	10
49	CEM Ozarow	50.40	17.56	64	67	130
50	CEM Strzelce Op.	50.40	17.56	64	67	3 430
51	CEM Malogoszsc - Opole	50.40	17.56	64	67	910

Poland Cont.

No	Source name	Geographical position		Codes		Emission
		Latitude	Longitude	Ind.	Instal.	t/y
52	CEM Kujawy - Bydgoszcz	53.16	17.33	64	67	400
53	CEM Gorazdze - Opole	50.40	17.56	64	67	200
54	CEM Chelm	51.08	23.29	64	67	1 520
55	CEM Rejowiec	51.06	23.18	64	67	1 590
56	CEM Wiek - Ogrodzieniec	51.08	23.29	64	67	3 180
57	CEM Groszowice - Opole	50.40	17.56	64	67	200
58	CEM Wysoka	50.51	20.39	64	67	1 000
59	CEM Wierzbica	51.18	22.31	64	67	3 180
60	CEM Saturn - Bedzin	50.15	18.59	64	67	400
61	CEM Nowa - Huta	50.05	20.02	64	67	400
62	CEM Raciborowice - Legnica	51.12	16.10	64	67	400
63	Z.C.W. Rudniki - Czestochowa	50.49	19.07	64	67	60
64	Z.C.W. Dzialoszyn - Sieradz	51.35	18.41	64	67	1 430
65	Z.C.W. Wojcieszow - Jelena Gora	50.55	15.45	64	67	70
66	Z. Azotowe - Pulawy	51.26	21.59	32	84	15 300
67	Z. Azotowe - Tarnow	50.01	20.59	32	84	12 300
68	Z. Azotowe - Wloclawek	52.39	19.01	32	84	3 800
	Gas works					1 600
	Heat production					449 800
	Fuel oil combustion resid. and ind. boilers					12 170
	Gas combustion					28 740

COUNTRY CODE: 15 SOVIET UNION

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
1	Kolskaya	67°55´	33°01´	11	11	20 080
2	Estonskaya - Tallinn	59.22	24.88	11	11	20 080
3	Wilno	54.40	25.19	11	11	20 080
4	Leningrad	59.55	30.25	11	11	131 940
5	Kirischi	58.30	31.20	11	11	40 160
6	Lukomskaya	53.51	27.30	11	11	91 790
7	Bursztyn	54.40	20.30	11	11	63 100
8	Ladyszinskaya	49.50	24.00	11	11	41 590
9	Kanew	49.46	31.28	11	11	63 100
10	Moscow	55.45	37.42	11	11	91 770
11	Konakowo	58.01	38.52	11	11	63 100
12	Kostroma	57.46	40.59	11	11	63 100
13	Gorki	57.36	45.04	11	11	31 550
14	Nowomoskowsk	54.06	38.15	11	11	63 100
15	Kaszira	54.32	38.13	11	11	63 100
16	Smijew	50.00	37.00	11	11	71 700
17	Nowoworonez	51.15	39.11	11	11	31 550
18	Woloszilograd	51.00	46.40	11	11	123 340
19	Saratow	51.30	45.55	11	11	31 550
20	Nowoczerkassk	47.25	40.05	11	11	100 390
21	Starobeszewskaya	47.05	37.34	11	11	100 390
22	Moldawskaya	46.30	30.46	11	11	63 100
23	Kriwoi Rog	47.55	33.24	11	11	71 700
24	Pridneprowsk	48.29	35.00	11	11	51 630
25	Jerewan	40.10	44.31	11	11	40 160
26	Baku	40.22	49.53	11	11	51 630
27	Ali - Bairamly	39.00	49.50	11	11	40 160
28	Sainsk (Kujbyszew)	53.19	66.55	11	11	40 160
29	Perm	58.01	56.10	11	11	100 390
30	Karmanowo	55.49	34.51	11	11	40 160
31	Sverdlowsk	56.52	60.35	11	11	71 700
32	Czelyabinsk	55.12	61.25	11	11	71 700

SOVIET UNION Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
33	Troizk	54.08	61.33	11	11	63 100
34	Magnitogorsk (Jushno - Uralsk)	53.28	59.06	11	11	80 350
35	Uralsk (Irklinski)	51.19	51.20	11	11	63 100
36	Stawropol	45.03	41.59	11	11	40 160
37	Inta	66.04	60.01	11	11	10 040
38	Vorkuta	67.27	64.00	11	11	8 600
39	Archangelsk	64.35	39.50	11	11	8 600
40	Nizhniy Tagil	58.00	59.58	50	50,54	100
41	Magnitogorsk	53.28	59.06	50	50,54	100
42	Chelyabinsk	55.12	61.25	50	50,54	100
43	Novotroizk	51.11	58.16	50	50,54	100
44	Zlatoust	55.10	59.38	50	50,54	100
45	Alapayevsk	57.55	61.42	50	50,54	100
46	Orsk	51.13	58.35	50	54	100
47	Serov	59.42	60.32	50	54	100
48	Sverdlovsk	56.52	60.35	50	54	100
49	Lysva	58.07	57.49	50	54	100
50	Ascha	54.00	57.00	50	54	100
51	Beloretsk	53.59	58.20	50	54	100
52	Kamensk Uralski	56.29	61.49	50	54	100
53	Cherepovets	59.09	37.50	50	54	100
54	Izhevsk	56.49	53.11	50	54	100
55	Omutnisk	58.35	52.28	50	54	100
56	Leningrad	59.55	30.25	50	54	100
57	Kolpino	59.44	30.39	50	54	100
58	Olenegorsk	68.04	33.15	50	51,54	90
59	Moscow & Noginsk	55.45	37.42	50	54	90
60	Gorki	57.36	45.04	50	54	90
61	Kosaya Gora & Tula	54.08	37.33	50	51,54	90
62	Lipetsk	52.37	39.36	50	54	90
63	Vyksa	54.37	39.43	50	54	90
64	Kriwoi Rog	47.55	33.24	50	50,54	90

SOVIET UNION Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION
		LATITUDE	LONGITUDE	IND.	INSTAL.	t/y
65	Dneprodzerzhinsk	48.30	34.37	50	54	90
66	Dnepropetrovsk	48.29	35.00	50	54	90
67	Zaporozhye	47.50	35.10	50	54	90
68	Kerch	45.22	36.27	50	51,54	90
69	Voroshilovsk	51.08	46.39	50	54	90
70	Yenakiyevo	48.14	38.15	50	54	90
71	Makeyevka	48.01	38.00	50	51,54	90
72	Donetsk	48.00	37.50	50	51,54	90
73	Konstantinovka	48.33	37.45	50	51,54	90
74	Taganrog	47.14	38.55	50	54	90
75	Zhdanov	47.05	37.34	50	54	90
76	Volgograd	48.45	44.30	50	54	90
77	Sestafoni	42.15	42.44	50	54	90
78	Dashkesan	40.29	46.05	50	51,54	90
79	Sumgait	40.35	49.38	50	54	90
80	Volkhov	59.54	32.15	64	67	3 570
81	Kunda	59.30	26.30	64	67	3 570
82	Riga	56.53	24.08	64	67	3 570
83	Belgorod	50.38	36.36	64	67	3 570
84	Volsk	52.04	47.22	64	67	3 570
85	Mikhaylovka	50.05	43.15	64	67	3 570
86	Balakleya	49.27	36.53	64	67	3 570
87	Amvrosiyevka	47.46	38.30	64	67	3 570
88	Tokmak	47.13	35.43	64	67	3 570
89	Moscow	55.45	37.42	64	67	3 560
90	Kolomna	55.05	38.45	64	67	3 560
91	Ryazan	54.37	39.43	64	67	3 560
92	Dobromino	53.00	39.00	64	67	3 560
93	Bryansk	53.15	34.09	64	67	3 560
94	Lipetsk	52.37	39.36	64	67	3 560
95	Voronezh	51.40	39.13	64	67	3 560
96	Kharkov	50.00	36.15	64	67	3 560
97	Kramatorsk	48.43	37.33	64	67	3 560

SOVIET UNION Cont.

No	Source name	Geographical position		Codes		Emission
		Latitude	Longitude	Ind.	Instal.	t/y
98	Dneprodzerzhinsk/ Dnepropetrovsk	48.30	34.37	64	67	3 560
99	Kriwoi Rog	47.55	33.24	64	67	3 560
100	Amayansk	47.50	32.20	64	67	3 560
101	Novorossiysk	44.44	37.46	64	67	3 560
102	Vorkuta	67.27	64.00	64	67	3 560
103	Novo - Pashiysiy	58.00	59.00	64	67	3 560
104	Nizhniy Tabil	58.00	59.58	64	67	3 560
120	Nevyansk	57.34	60.10	64	67	3 560
121	Yemanzhelansk	54.50	61.22	64	67	3 560
122	Katav Ivanovsk	54.45	58.11	64	67	3 560
123	Ufa	55.46	60.08	64	67	3 560
124	Magnitogorsk	53.28	59.06	64	67	3 560
125	Novotroitsk	51.11	58.16	64	67	3 560
126	Orsk	51.13	58.35	64	67	3 560
	Gas works					2 400
	Heat production					1378000
	including:					
	- Baranovicki					344
	- Grodno					2 847
	- Lida					204
	Fuel oil combustion in resid. and ind. boilers					167 500
	Gas combustion					258 400

Table A-2: Emissions of As, Cd, Hg (total), Pb and Zn in 1982 from individual sources in the countries with the proposed action areas and former German Democratic Republic.

Codes:

11	11	Coal fired power plants
61	62	Copper production
61	621	Primary copper production
61	63	Lead production
61	631	Primary lead production
61	64	Zinc production
61	641	Primary zinc production
64	67	Cement plants
50	50	Coke production
50	51	Iron production
50	54	Steel production
32	83	Chlor-alkali production

COUNTRY CODE: 12 CZECHOSLOVAKIA

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
1	Pocerady	50°32´	13°35´	11	11	1.2	0.4	0.5	4.7	6.7
2	Ledvice	50.31	13.33	11	11	0.7	0.2	0.3	2.6	3.7
3	Tusimice	50.23	13.20	11	11	1.4	0.4	0.6	5.0	7.0
4	Prunerov	50.25	13.16	11	11	1.8	0.6	0.8	6.2	8.3
5	Brezova - Tisova	50.16	12.41	11	11	0.6	0.1	0.3	2.1	2.9
6	Vresova	50.09	12.38	11	11	0.3	0.1	0.1	1.0	1.4
7	Ervenice	50.35	13.40	11	11	0.1	0.03	0.03	0.3	0.4
8	Zaluzi	50.33	13.45	11	11	0.1	0.03	0.03	0.3	0.4
9	Melnik	50.33	14.25	11	11	1.2	0.4	0.5	4.8	7.2
10	Detmarovice	50.20	14.20	11	11	1.0	0.3	0.4	1.3	4.9
11	Ostrava	49.50	18.15	11	11	0.2	0.05	0.1	0.3	1.1
12	Karvina	49.50	18.30	11	11	0.1	0.03	0.03	0.3	0.4
13	Chvaletice	50.07	14.36	11	11	0.9	0.3	0.4	3.1	4.2
14	Porici	50.18	14.35	11	11	0.3	0.1	0.1	0.3	1.5
15	Hodonin	48.52	17.10	11	11	0.3	0.1	0.1	1.0	1.4
16	Novaky	49.39	13.49	11	11	0.6	0.2	0.3	2.5	3.6
17	Vojany	48.40	21.10	11	11	0.8	0.2	0.3	1.1	4.2
18	Litvinov	50.30	13.30	11	11	0.2	0.05	0.05	0.6	0.8
19	Plzen	49.45	13.25	11	11	0.2	0.06	0.06	0.6	0.8
20	Kosice	48.44	21.15	11	11	0.1	0.05	0.1	0.2	0.5
21	Litvinov	50.30	13.30	11	11	0.1	0.05	-	0.5	0.4
22	Ruzomberok	49.04	19.15	11	11	0.1	0.05	-	0.5	0.4
23	Sonstige	49.00	19.10	11	11	0.1	0.05	-	0.5	0.4
24	Vojany	48.40	21.10	11	11	0.4	0.15	-	1.9	1.3
25	Krompachy Copper works Banska Stiawnica	48.29	18.50	61	621	38.0	5.2	-	69.9	39.4
26	Olmucz lead works Olmucz n. Brno	49.13	16.40	61	631	3.2	0.1	0.05	33.7	1.2
27	Pribou lead works Pribou n. Prague	49.39	13.49	61	631	3.1	0.1	0.05	33.6	1.1
28	Kamenica remelting works - Jihlawa	49.24	15.34	61	632	0.1	0.7	-	2.2	18.9
29	Velvary remelting works - Velvary	49.24	15.31	61	632	0.1	0.7	-	2.2	18.8

CZECHOSLOVAKIA Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
30	Chomutov tube works - Chomutov	50.28	13.26	50	54	0.4	0.1	-	7.0	18.0
31	Poldi-Snop Kladno	50.10	14.02	50	54	1.1	0.3	-	23.0	51.0
32	Nova Huta Klementa Gottwalda - Kunice - Ostrawa	49.50	18.15	50	54	0.5	0.1	-	10.0	18
33	EASF Slovak Iron & Steelworks - Kosice	48.44	21.15	50	54	0.5	0.1	-	8.0	20
34	TZ Trinec/Ostrawa	49.50	18.15	50	54	3.7	0.9	-	76.0	159
35	Vitkovice/Ostrawa	49.50	18.15	50	54	1.2	0.3	-	21.0	51
36	Skoda/Pilzno	49.45	13.25	50	54	0.8	0.2	-	14.0	34
37	SZ Podbrezowa	49.45	13.25	50	54	0.5	0.1	-	8.0	20
38	ZDB Bohumin	49.45	13.25	50	54	0.5	0.1	-	8.0	18
39	Cement Plant (C.P.) Kraluv Dvur	50.00	14.00	64	67	1.1	0.07		3.8	22
40	CP Lochkov	50.00	14.00	64	67	0.7	0.05	-	2.0	12
41	CP Cizkovice	50.10	14.00	64	67	1.0	0.06	-	3.0	18
42	CP Prachovice	50.07	14.25	64	67	0.8	0.05	-	2.4	14
43	CP Cepicne	48.44	19.10	64	67	0.9	0.06	-	2.0	16
44	CP Hranice	49.34	17.45	64	67	0.8	0.05	-	2.4	14
46	CP Rohoznik	48.44	19.10	64	67	0.9	0.06	-	3.0	18
47	Moravske CZ - Ostrawa	49.50	18.15	32	83	-	-	0.2		-
49	Prerovske CZ - Prerov	49.28	17.30	32	83	-	-	0.2		-
50	Severoceske CZ - Lovocice	50.29	14.02	32	83	-	-	0.2	-	-
51	Spolana - Neratovice	50.17	14.32	32	83	-	-	0.3	-	-
52	Zaluzi CZ - Zaluzi	50.32	13.43	32	83	-	-	0.2	-	-
53	Chemko - Strazske	49.32	15.01	32	83	-	-	0.2	-	-
54	Vychoduceske CZ - Pardubice	50.03	15.45	32	83	-	-	0.2	-	-
	Phosphate fertil. production									5.1
	Ind. comm. resid. combustion					20.5	7.9	8.0	83.4	94.8
	Fuel wood combustion					0.5	0.3	0.2	6.7	9.6
	Gasoline combustion								684.0	
	TOTAL					93.6	21.3	14.9	1129	755

COUNTRY CODE: 07 GDR

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
1	Boxberg	$51^{0}25'$	$14^{0}34$	11	11	5.9	1.8	2.4	21.3	29.0
2	Hagenwerder	51.03	14.47	11	11	2.5	0.8	1.0	9.0	12.5
3	Lübbenau	51.57	13.58	11	11	2.3	0.7	0.9	8.3	11.5
4	Vetschau	51.48	14.06	11	11	2.0	0.6	0.8	7.2	10.0
5	Thierbach	51.10	12.29	11	11	1.2	0.4	0.5	4.3	6.0
6	Lippendorf	51.11	12.22	11	11	0.9	0.3	0.4	3.2	4.5
7	Vockerode	51.50	12.13	11	11	0.7	0.2	0.3	2.5	3.5
8	Jänschwalde	51.51	14.31	11	11	1.0	0.3	0.5	3.6	5.0
9	Tratendorf	51.33	14.25	11	11	0.7	0.2	0.3	2.5	3.5
10	Hirschfelde	50.57	14.54	11	11	0.4	0.1	0.2	1.4	2.0
11	Harbke	52.12	11.07	11	11	0.2	0.06	0.1	0.7	1.0
12	Lauta	51.27	14.06	11	11	0.3	0.1	0.1	1.1	1.5
13	Zschornewitz	51.43	12.24	11	11	0.1	0.03	0.05	0.4	0.5
14	Sonstige	51.20	12.25	11	11	1.8	0.6	0.8	6.5	9.0
15	Schwarze Pompe	51.32	14.22	11	11	1.9	0.6	0.8	6.8	9.5
16	Espenhain	51.10	12.28	11	11	0.2	0.06	0.1	0.7	1.0
17	Regis/Borna	51.06	12.25	11	11	0.2	0.05	0.1	0.7	1.0
18	Eisenhüttenstadt	52.20	14.32	50	52	1.3	0.07		14.0	34.8
19	Unterwellenborn	50.39	11.25	50	52	0.4	0.03		5.0	11.0
20	Brandenburg	52.25	12.34	50	54		0.5		18.0	44.0
21	Riesa	51.18	13.18	50	54		0.25		9.0	22.0
22	Henningsdorf	52.38	13.13	50	54		0.20		8.0	20.0
23	Thale	51.46	11.02	50	54		0.05		1.5	2.0
24	Veb. Kupfer u. Blechwalzwerk m. Niederkirchner - Ilsenburg	51.53	10.41	61	621	2.1	0.9		4.0	4.1
25	Hüttenkombinat Mansfeld - Hettstedt	51.39	11.29	61	621	6.5	3.1		12.0	12.0
26	Hüttenkombinat Mansfeld - Eisleben	51.32	11.31	61	621	6.4	3.1		12.0	12.0

GDR Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
27	Hüttenkombinat Mansfeld - Helbra	51.33	11.28	61	621	6.4	3.1		12.0	13.5
28	V.E.B. Bergbau u. Hütten Kombinat A. Funk - Freiberg	50.55	13.20	61	631,632	15.0	0.5	0.2	150	5.5
29	" "	50.55	13.20	61	641,642	1.7	8.5	0.1	31.5	267
30	Karsdorf	51.16	11.39	64	67	2.8	0.16		8.4	51.6
31	Rüdersdorf	51.29	13.50	64	67	1.6	0.10		5.0	31.0
32	Bernburg	51.48	11.45	64	67	1.4	0.08		4.2	25.8
33	Deuna	51.48	11.45	64	67	1.2	0.06		3.4	20.6
34	V.E.B. Chemische Werke Buna - Schkopau	51.28	11.58	32	83			0.3		
35	V.E.B. Chemiewerk - Bitterfeld	51.37	12.18	32	83			2.3		
36	V.E.B. Chemiewerk - Coswig	51.53	12.25	32	44					2.1
37	V.E.B. Fahlberg - Magdeburg	52.08	11.37	32	44					2.1
	Ind. comm. resid. boilers					25.8	9.4	11.4	101.4	122.7
	Fuel wood combustion					0.2	0.1	0.1	2.9	4.1
	Gasoline combustion								1267	
	TOTAL					95.1	37.1	23.7	1751	818.4

COUNTRY CODE: 11 POLAND

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
1	Siekierki - Warszawa	52.15	21.00	11	11	1.8	0.6	0.6	6.2	9.0
2	EL Zeran - Warszawa	52.15	21.00	11	11	1.3	0.4	0.5	4.7	6.5
3	Zel Bydgoszcz	53.16	17.33	11	11	0.3	0.1	0.1	1.1	1.5
4	EL Gorzow	51.01	18.21	11	11	0.3	0.1	0.1	1.1	1.5
5	EL Rybnik	50.07	18.30	11	11	0.4	0.1	0.2	1.4	2.0
6	EL Halemba - Ruda SL	50.15	18.59	11	11	0.3	0.1	0.1	1.1	1.5
7	EL Bytom	50.21	18.51	11	11	0.4	0.1	0.2	1.4	2.0
8	EL Zabrze	50.18	18.47	11	11	0.4	0.1	0.2	1.4	2.0
9	EL Bedzin	50.15	18.59	11	11	0.2	0.05	0.1	0.7	1.0
10	EL Szombierki - Bytom	50.21	18.51	11	11	0.1	0.03	0.04	0.3	0.5
11	EL Leg - Krakow	50.03	19.55	11	11	0.4	0.1	0.2	1.4	2.0
12	Z.E.L. Ostroleka	53.05	21.32	11	11	0.6	0.15	0.2	2.2	3.0
13	Z.E.L. Lodz	51.49	19.28	11	11	0.9	0.3	0.3	3.0	4.5
14	EL Belchatow	51.23	19.20	11	11	1.4	0.3	0.5	5.0	7.0
15	EL Konin	52.12	18.12	11	11	1.3	0.4	0.6	5.0	6.0
16	EL Patnow-Adamow	52.12	18.12	11	11	1.3	0.4	0.6	4.0	6.0
17	EL Turow-Turoszow	51.10	15.00	11	11	3.9	1.2	1.7	14.6	19.7
18	EL Jaworzno I	50.13	19.11	11	11	0.4	0.1	0.2	1.4	2.0
19	EL Jaworzno II	50.13	19.11	11	11	1.8	0.6	0.6	6.2	9.0
20	EL Jaworzno VI	50.13	19.11	11	11	0.4	0.1	0.2	1.4	2.0
21	EL Kozienice - Radom	51.26	21.10	11	11	1.4	0.4	0.5	5.0	7.0
22	EL Blachownia - Kedzierzyn	50.40	17.56	11	11	0.6	0.15	0.2	2.2	3.0
23	EL Dolna Odra - Szczecin	53.25	14.32	11	11	0.7	0.2	0.3	2.5	3.5
24	EL Lagisza - Bedzin	50.15	18.59	11	11	0.4	0.1	0.2	1.4	2.0
25	EL Polaniec - Tarnow	50.01	20.59	11	11	0.2	0.05	0.1	0.7	1.0
26	EL Siersza - Trzebinia	50.03	19.55	11	11	0.7	0.2	0.3	2.5	3.0
27	EL Stalowa Wola	50.15	18.59	11	11	1.5	0.5	0.6	5.4	6.0
28	EL Skawina - Krakow	50.03	19.55	11	11	0.8	0.3	0.3	2.8	4.0
29	EL Chorzow	50.19	18.56	11	11	0.2	0.05	0.1	0.7	1.0

POLAND Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
30	EL Laziska - Katowice	50.15	18.59	11	11	0.8	0.2	0.3	2.9	4.0
31	EL Pomorzany - Szczecin	53.25	14.32	11	11	0.1	0.03	0.04	0.3	0.5
32	EL Czechnice - Wroclaw	51.05	17.00	11	11	0.9	0.3	0.4	3.2	4.5
33	Z.E.L. Wroclaw	51.05	17.00	11	11	0.9	0.3	0.4	3.2	4.5
34	EL Gdansk	54.22	18.41	11	11	0.1	0.03	0.04	0.3	0.5
35	EL Gdynia	54.31	18.30	11	11	0.1	0.03	0.04	0.3	0.5
36	EL Szczecin	53.25	14.32	11	11	0.1	0.03	0.04	0.3	0.5
37	Huta Labedy Gliwice	50.20	18.40	50	51,54	0.01	0.05		1	3
38	Huta Laziska - Katowice	50.15	18.59	50	51,54	0.07	0.1		10	23
39	Huta Kosciuszko - Katowice	50.15	18.59	50	51,54	0.07	0.1		10	23
40	Huta Bieruta - Czestochowa	50.49	19.07	50	51,54	0.07	0.1		10	25
41	Huta Bobrek - Bytom	50.21	18.51	50	51,54	0.04	0.07		5	13
42	Huta Dzierzynski - Dabrowa	50.20	18.50	50	51,54	0.04	0.07		5	13
43	Huta Florian - Swietochlowice	50.15	18.59	50	51,54	0.02	0.06		2	5
44	Huta Katowice - Katowice	50.15	18.59	50	51,54	0.30	0.5		37	88
45	Huta Lenina - Krakow	50.03	19.55	50	51,54	0.40	0.6		47	114
46	Huta Pokoj - Ruda SL	50.15	18.59	50	51,54	0.06	0.1		6	15
47	Huta Zawiercie - Zawiercie	50.30	19.24	50	51,54	0.02	0.05		1	3
49	CEM Ozarow	50.40	17.56	64	67	0.05			0.2	1.2
50	CEM Strzelce Op.	50.40	17.56	64	67	1.7	0.11		5.1	31.0
51	CEM Malogoszcs - Opole	50.40	17.56	64	67	0.4	0.02		1.2	8.2
52	CEM Kujawy - Bydgoszcz	53.16	17.33	64	67	0.2	0.01		0.6	3.6
53	CEM Gorazdze - Opole	50.40	17.56	64	67	0.1			0.3	1.8
54	CEM Chelm	51.08	23.29	64	67	1.2	0.08		3.6	22.8
55	CEM Rejowiec	51.06	23.18	64	67	0.8	0.05		2.4	14.4
56	CEM Wiek - Ogrodzieniec	51.08	23.29	64	67	1.6	0.10		4.8	28.8

POLAND Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
57	CEM Groszowice - Opole	50.40	17.56	64	67	0.1			0.3	1.8
58	CEM Wysoka	50.51	20.39	64	67	0.5			1.5	9.0
59	CEM Wierzbica	51.18	22.31	64	67	1.6	0.10		4.8	28.8
60	CEM Saturn - Bedzin	50.15	18.59	64	67	0.2	0.01		0.6	3.6
61	CEM Nowa Huta	50.05	20.02	64	67	0.2	0.01	-	0.6	3.6
62	CEM Raciborowice - Legnica	51.12	16.10	64	67	0.2	0.01		0.6	3.6
63	Z.C.W. Rudniki - Czestochowa	50.49	19.07	64	67				0.1	0.6
64	Z.C.W. Dzialoszyn - Sieradz	51.35	18.41	64	67	0.7	0.08		2.1	13.0
65	Z.C.W. Wojcieszow - Jelenia Gora	50.55	15.45	64	67	0.05			0.1	0.6
66	H.M. Glogow I	51.40	16.06	61	621	204.0	30.6		333	233
67	H.M. Glogow II	51.40	16.06	61	621	18.6	2.8		30	21
68	H.M. Legnica	51.12	16.10	61	621	223.0	33.4		365	254
69	KGHM Lubin	51.23	16.10	61	621	18.3	2.8		30	21
70	H.M.N. Szopienice - Katowice	50.15	18.59	61	631,641	12.0	25.0	0.5	164.0	783.0
71	Huta "Miasteczko"	50.15	18.59	61	631,641	12.0	25.0	0.5	162.0	783.0
72	KGH Boleslaw - Olkusz	50.18	19.33	61	631,641	12.0	25.0	0.5	162.0	783.0
73	Huta Cynku Tarnowskie Gory	50.28	18.40	61	641	4.0	8.5		54.0	261.0
74	Oswiecim	50.02	19.11	32	83			1.4		
75	Gdansk	54.22	18.41	32	44					9
	Ind. comm. resid. combustion					48.6	16.3	25.7	179.9	241.9
	Fuel wood combustion					0.7	0.4	0.3	10.2	14.6
	Gasoline combustion								1206	
	TOTAL					597.0	180.4	40.0	3003	4037

COUNTRY CODE: 15 SOVIET UNION

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
1	Kolskaya	67°55´	33°01´	11	11	1.4	0.5	0.4	5.8	6.4
2	Estonskaya - Tallinn	59.22	24.88	11	11	1.4	0.5	0.4	5.8	6.4
3	Wilno	54.40	25.19	11	11	1.4	0.5	0.4	5.8	6.4
4	Leningrad	59.55	30.25	11	11	9.2	3.4	2.5	37.9	42.0
5	Kirischi	58.30	31.20	11	11	2.8	1.0	0.8	11.5	12.8
6	Lukomskaya	53.51	27.30	11	11	6.4	2.3	1.7	26.4	29.2
7	Bursztyn	54.40	20.30	11	11	4.4	1.6	1.2	18.1	20.0
8	Ladyszinskaya	49.50	24.00	11	11	2.9	1.0	0.8	11.5	12.8
9	Kanew	49.46	31.28	11	11	4.4	1.6	1.2	18.1	20.0
10	Moscow	55.45	37.42	11	11	6.4	2.3	1.7	26.4	29.2
11	Konakowo	58.01	38.52	11	11	4.4	1.6	1.2	18.1	20.0
12	Kostroma	57.46	40.59	11	11	4.4	1.6	1.2	18.1	20.0
13	Gorki	57.36	45.04	11	11	2.2	0.8	0.6	9.1	10.5
14	Nowomoskowsk	54.06	38.15	11	11	4.4	1.6	1.2	18.1	20.0
15	Kaszira	54.32	38.13	11	11	4.4	1.6	1.2	18.1	20.0
16	Smijew	50.00	37.00	11	11	5.0	1.8	1.3	20.6	22.8
17	Nowoworonez	51.15	39.11	11	11	2.2	0.8	0.6	9.1	10.0
18	Woloszilograd	51.00	46.40	11	11	8.6	3.1	2.3	35.4	39.2
19	Saratow	51.30	45.55	11	11	2.2	0.8	0.6	9.1	10.0
20	Nowoczerkassk	47.25	40.05	11	11	7.0	2.6	1.9	28.8	31.9
21	Starobeszewskaya	47.05	37.34	11	11	7.0	2.6	1.9	28.8	31.9
22	Moldawskaya	46.30	30.46	11	11	4.4	1.6	1.2	18.1	20.0
23	Kriwoi Rog	47.55	33.24	11	11	5.0	1.8	1.3	20.6	22.8
24	Pridneprowsk	48.29	35.00	11	11	3.6	1.3	1.0	14.8	16.4
25	Jerewan	40.10	44.31	11	11	2.8	1.0	0.8	11.5	12.8
26	Baku	40.22	49.53	11	11	3.6	1.3	1.0	14.8	16.4
27	Ali - Bairamly	39.00	49.50	11	11	2.8	1.0	0.8	11.5	12.8
28	Sainsk (Kujbyszew)	53.19	66.55	11	11	2.8	1.0	0.8	11.5	12.8
29	Perm	58.01	56.10	11	11	7.0	2.6	1.9	28.8	31.9
30	Karmanowo	55.49	34.51	11	11	2.8	1.0	0.8	11.5	12.8
31	Sverdlowsk	56.52	60.35	11	11	5.0	1.8	1.3	20.6	22.8
32	Czelyabinsk	55.12	61.25	11	11	5.0	1.8	1.3	20.6	22.8
33	Troizk	54.08	61.33	11	11	4.4	1.6	1.2	18.1	20.0

SOVIET UNION Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
34	Magnitogorsk (Jushno - Uralsk)	53.28	59.06	11	11	5.6	2.0	1.6	23.1	25.5
35	Uralsk (Irklinski)	51.19	51.20	11	11	4.4	1.6	1.2	18.1	20.0
36	Stawropol	45.03	41.59	11	11	2.8	1.0	0.8	11.5	12.8
37	Inta	66.04	60.01	11	11	0.7	0.3	0.2	2.9	3.2
38	Vorkuta	67.27	64.00	11	11	0.6	0.3	0.2	2.5	2.7
39	Archangelsk	64.35	39.50	11	11	0.6	0.3	0.2	2.5	2.7
40	Ukrzinc lead - zinc plant - Konstantinovka	48.33	37.45	61	631	6.1	0.2	0.06	63.0	12.5
41	Ukrzinc lead - zinc plant - Konstantinovka	48.33	37.45	61	641	5.0	24.9	0.40	92.0	968.0
42	Electrozinc plant - Ordzhonikidze	42.00	43.16	61	631	37.6	1.4	0.34	388.0	77.0
43	Electrozinc plant - Ordzhonikidze	42.00	43.16	61	641	11.0	54.8	0.9	202.0	2129.0
44	Czelyabinsk	55.12	61.25	61	641	8.9	44.8	0.7	166.0	1741.0
45	Alaverdi Copper Smelter & Refinery	41.08	44.40	61	621	156.0	7.4		209.0	179.0
46	Karabashski Gorno - Metallurgical Combine	55.28	60.15	61	621	156.0	7.4		209.0	179.0
47	Kirovgradsk Copper Smelter - Kirovsk	67.37	33.39	61	621	156.0	7.4		209.0	179.0
48	Krasnouralsk Copper Smelter - Krasnouralsk	58.25	60.00	61	621	156.0	7.4		209.0	179.0
49	Kushtym Copper Refinery	55.28	60.15	61	621	156.0	7.4		209.0	179.0
50	Mednogorsk Copper Combine	51.23	57.36	61	621	156.0	7.4		209.0	179.0
51	Pyshma Copper Refinery	57.00	63.10	61	621	156.0	7.4		209.0	179.0
52	Severonickel - Monchegorsk	67.55	33.01	61	621	156.0	7.4		209.0	179.0
53	Sredneuralsk Copper Smelter - Sibai	52.30	57.50	61	621	156.0	7.4		209.0	179.0
54	Verhnaia Pyshma Copper Smelter	57.00	57.00	61	621	156.0	7.4		209.0	179.0
55	Nizhniy Tagil	58.00	59.58	50	50,54	2.7	0.46		42	102
56	Magnitogorsk	53.28	59.06	50	50,54	2.7	0.46		42	102
57	Chelyabinsk	55.12	61.25	50	50,54	2.7	0.46		42	102
58	Novotroizk	51.11	58.16	50	50,54	2.7	0.46		42	102

SOVIET UNION Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
59	Zlatoust	55.10	59.38	50	50,54	2.7	0.46		42	102
60	Alapayevsk	57.55	61.42	50	50,54	2.7	0.46		42	102
61	Orsk	51.13	58.35	50	54	2.7	0.46		42	102
62	Serov	59.42	60.32	50	54	2.7	0.46		42	102
63	Sverdlovsk	56.52	60.35	50	54	2.7	0.46		42	102
64	Lysva	58.07	57.49	50	54	2.7	0.46		42	102
65	Ascha	54.00	57.00	50	54	2.7	0.46		42	102
66	Beloretsk	53.59	58.20	50	54	2.7	0.46		42	102
67	Kamensk Uralski	56.29	61.49	50	54	2.7	0.46		42	102
68	Cherepovets	59.09	37.50	50	54	2.7	0.46		42	101
69	Izhevsk	56.49	53.11	50	54	2.7	0.46		42	101
70	Omutnisk	58.35	52.28	50	54	2.7	0.46		42	101
71	Leningrad	59.55	30.25	50	54	2.7	0.46		42	101
72	Kolpino	59.44	30.39	50	54	2.7	0.46		42	101
73	Olenegorsk	68.04	33.15	50	51,54	2.7	0.46		42	101
74	Moscow & Noginsk	55.45	37.42	50	54	2.7	0.46		42	101
75	Gorki	57.36	45.04	50	54	2.7	0.46		42	101
76	Kosaya Gora & Tula	54.08	37.33	50	51,54	2.7	0.46		42	101
77	Lipetsk	52.37	39.36	50	54	2.7	0.46		42	101
78	Vyksa	54.37	39.43	50	54	2.7	0.46		42	101
79	Kriwoi Rog	47.55	33.24	50	50,54	2.7	0.46		42	101
80	Dneprodzerzhinsk	48.30	34.37	50	54	2.7	0.46		42	101
81	Dnepropetrovsk	48.29	35.00	50	54	2.7	0.46		42	101
82	Zaporozhye	47.50	35.10	50	54	2.6	0.46		42	101
83	Kerch	45.22	36.27	50	51,54	2.6	0.46		42	101
84	Voroshilovsk	51.08	46.39	50	54	2.6	0.46		42	101
85	Yenakiyevo	48.14	38.15	50	54	2.6	0.46		42	101
86	Makeyevka	48.01	38.00	50	51,54	2.6	0.46		42	101
87	Donetsk	48.00	37.50	50	51,54	2.6	0.46		42	101
88	Konstantinovka	48.33	37.45	50	51,54	2.6	0.46		42	101
89	Taganrog	47.14	38.55	50	54	2.6	0.46		42	101
90	Zhdanov	47.05	37.34	50	54	2.6	0.46		42	101
91	Volgograd	48.45	44.30	50	54	2.6	0.46		42	101
92	Sestafoni	42.15	42.44	50	54	2.6	0.46		42	101

SOVIET UNION Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
93	Dashkesan	40.29	46.05	50	51,54	2.6	0.46		42	101
94	Sumgait	40.35	49.38	50	54	2.6	0.46		42	101
95	Volkhov	59.54	32.15	64	67	1.6	0.1		4.7	28.4
96	Kunda	59.30	26.30	64	67	1.6	0.1		4.7	28.4
97	Riga	56.53	24.08	64	67	1.6	0.1		4.7	28.4
98	Belgorod	50.38	36.36	64	67	1.6	0.1		4.7	28.4
99	Volsk	52.04	47.22	64	67	1.6	0.1		4.7	28.4
100	Mikhaylovka	50.05	43.15	64	67	1.6	0.1		4.7	28.4
101	Balakleya	49.27	36.53	64	67	1.6	0.1		4.7	28.4
102	Amvrosiyevka	47.46	38.30	64	67	1.6	0.1		4.7	28.4
103	Tokmak	47.13	35.43	64	67	1.6	0.1		4.7	28.4
104	Moscow	55.45	37.42	64	67	1.6	0.1		4.7	28.4
105	Kolomna	55.05	38.45	64	67	1.6	0.1		4.7	28.4
106	Ryazan	54.37	39.43	64	67	1.6	0.1		4.7	28.4
107	Dobromino	53.00	39.00	64	67	1.6	0.1		4.6	28.4
108	Bryansk	53.15	34.09	64	67	1.6	0.1		4.6	28.4
109	Lipetsk	52.37	39.36	64	67	1.6	0.1		4.6	28.3
110	Voronezh	51.40	39.13	64	67	1.5	0.1		4.6	28.3
111	Kharkov	50.00	36.15	64	67	1.5	0.1		4.6	28.3
112	Kramatorsk	48.43	37.33	64	67	1.5	0.1		4.6	28.3
113	Dneprodzerzhinsk/ Dnepropetrovsk	48.30	34.37	64	67	1.5	0.1		4.6	28.3
114	Kriwoi Rog	47.55	33.24	64	67	1.5	0.1		4.6	28.3
115	Amayansk	47.50	32.20	64	67	1.5	0.1		4.6	28.3
116	Novorossiysk	44.44	37.46	64	67	1.5	0.1		4.6	28.3
117	Vorkuta	67.27	64.00	64	67	1.5	0.1		4.6	28.3
118	Novo - Pashiysiy	58.00	59.00	64	67	1.5	0.1		4.6	28.3
119	Nizhniy Tagil	58.00	59.58	64	67	1.5	0.1		4.6	28.3
120	Nevyansk	57.34	60.10	64	67	1.5	0.1		4.6	28.3
121	Yemanzhelansk	54.50	61.22	64	67	1.5	0.1		4.6	28.3
121	Katav Ivanovsk	54.45	58.11	64	67	1.5	0.1		4.6	28.3
122	Ufa	55.46	60.08	64	67	1.5	0.1		4.6	28.3
123	Magnitogorsk	53.28	59.06	64	67	1.5	0.1		4.6	28.3
124	Novotroitsk	51.11	58.16	64	67	1.5	0.05		4.6	28.3

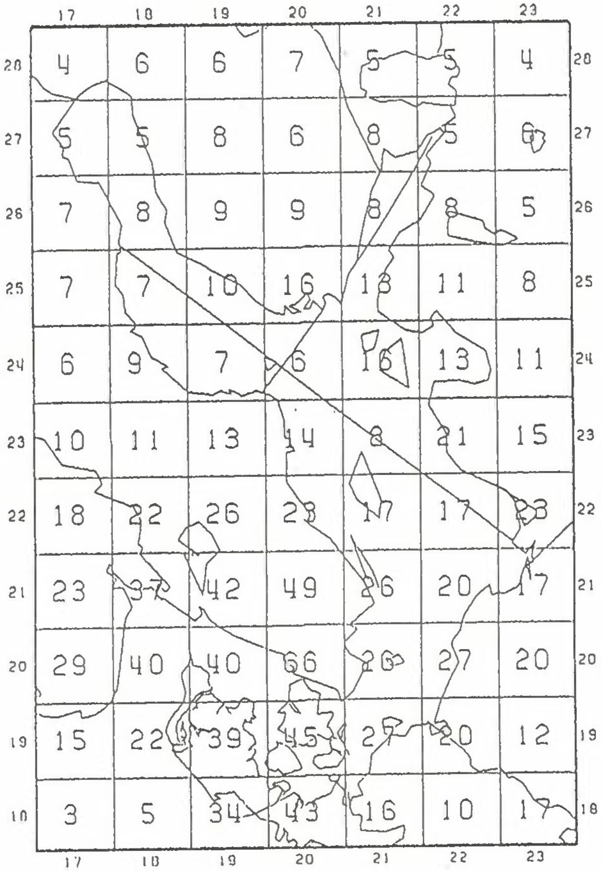
SOVIET UNION Cont.

NO	SOURCE NAME	GEOGRAPHICAL POSITION		CODES		EMISSION, t/y				
		LATITUDE	LONGITUDE	IND.	INSTAL.	As	Cd	Hg	Pb	Zn
125	Orsk	51.13	58.35	64	67	1.5	0.05		4.6	28.3
126	Kirovsk	67.37	33.39	32	44					22.0
127	Kingissepp	58.12	22.30	32	44					22.0
128	Yegoryevsk	55.21	39.01	32	44					22.0
129	Kimovsk	53.58	38.35	32	44					21.0
130	Polpinskaya & Shchigry	51.52	36.54	32	44					21.0
131	Dzerzhinsk	53.40	27.01	32	83			4.0		
132	Lisichansk	48.53	38.25	32	83			3.0		
133	Berezniki	59.26	56.49	32	83			3.0		
134	Sterlitamak	53.40	55.59	32	83			3.0		
	Ind. comm. resid. combustion					101.8	26.8	36.7	426.0	462.7
	Fuel wood combustion					11.3	3.4	4.6	159.0	227.4
	Application of metals					41.6				
	Gasoline combustion								24871.0	
	TOTAL					2098.4	309.3	99.3	30928.0	13191.9

APPENDIX B

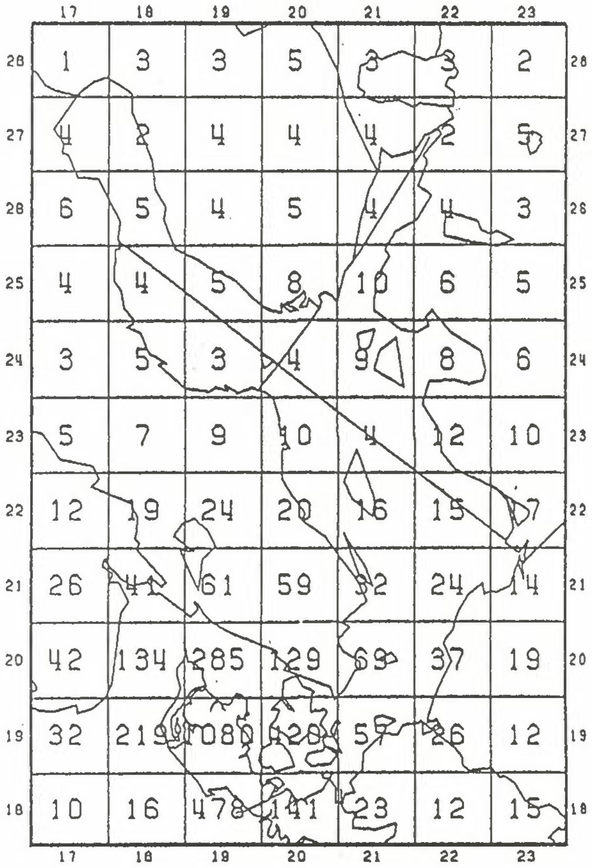
Distribution of Deposition of Oxidized and Reduced Nitrogen to the Baltic Sea in 1988.

Based on MSC-W model calculations.



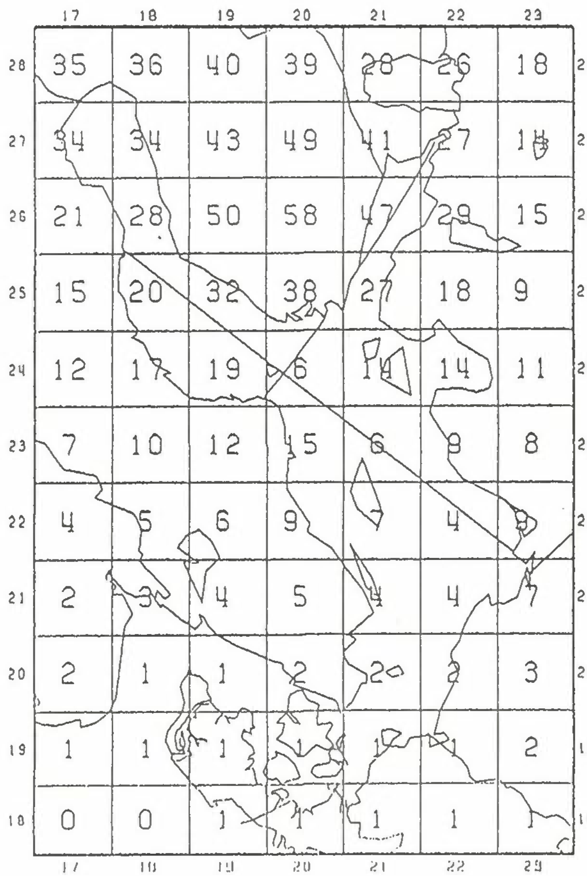
	17	18	19	20	21	22	23	
28	4	6	6	7	5	5	4	28
27	5	5	8	6	8	5	6	27
26	7	8	9	9	8	8	5	26
25	7	7	10	16	13	11	8	25
24	6	9	7	6	16	13	11	24
23	10	11	13	14	8	21	15	23
22	18	22	26	23	17	17	23	22
21	23	37	42	49	26	20	17	21
20	29	40	40	66	26	27	20	20
19	15	22	39	45	27	20	12	19
18	3	5	34	43	16	10	17	18
	17	18	19	20	21	22	23	

TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - DENMARK - DK
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL

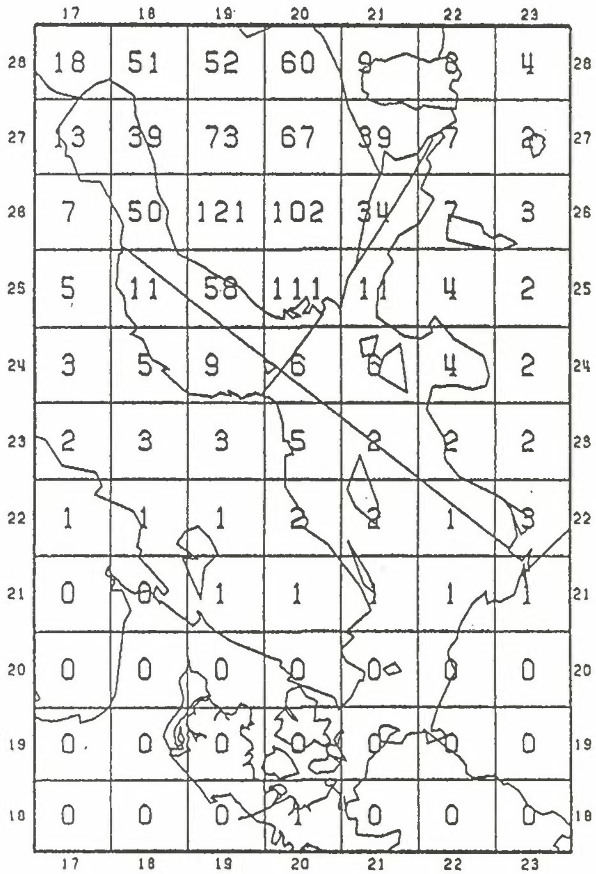


	17	18	19	20	21	22	23	
28	1	3	3	5	3	3	2	28
27	4	2	4	4	4	2	5	27
26	6	5	4	5	4	4	3	26
25	4	4	5	8	10	6	5	25
24	3	5	3	4	9	8	6	24
23	5	7	9	10	4	12	10	23
22	12	19	24	20	16	15	17	22
21	26	41	61	59	32	24	14	21
20	42	134	285	129	69	37	19	20
19	32	219	1080	428	57	26	12	19
18	10	16	478	141	23	12	15	18
	17	18	19	20	21	22	23	

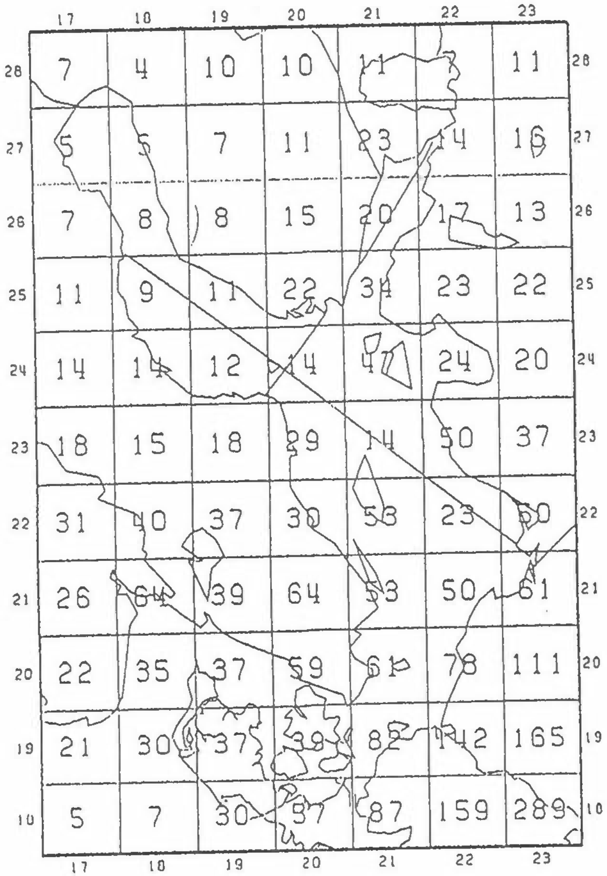
TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - DENMARK - DK
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - FINLAND - FI
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL

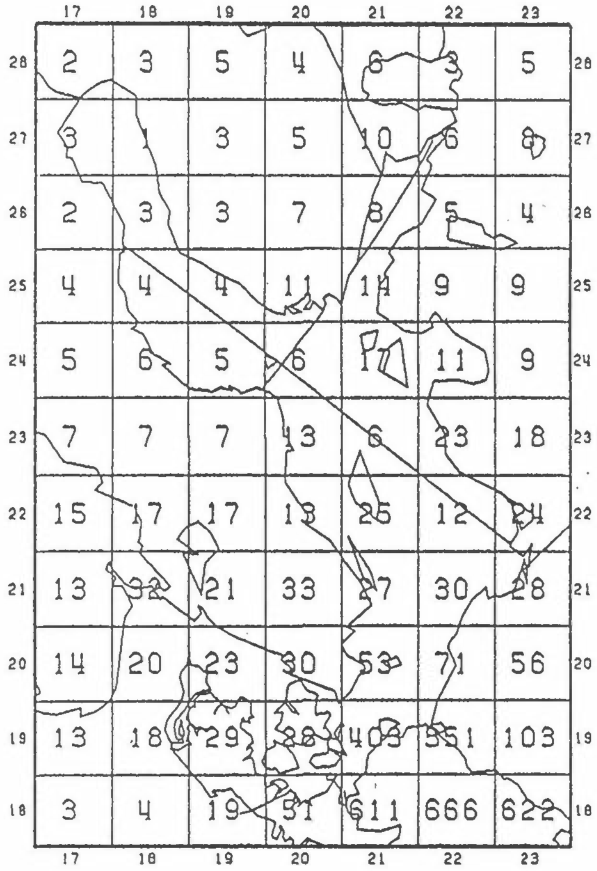


TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - FINLAND - FI
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



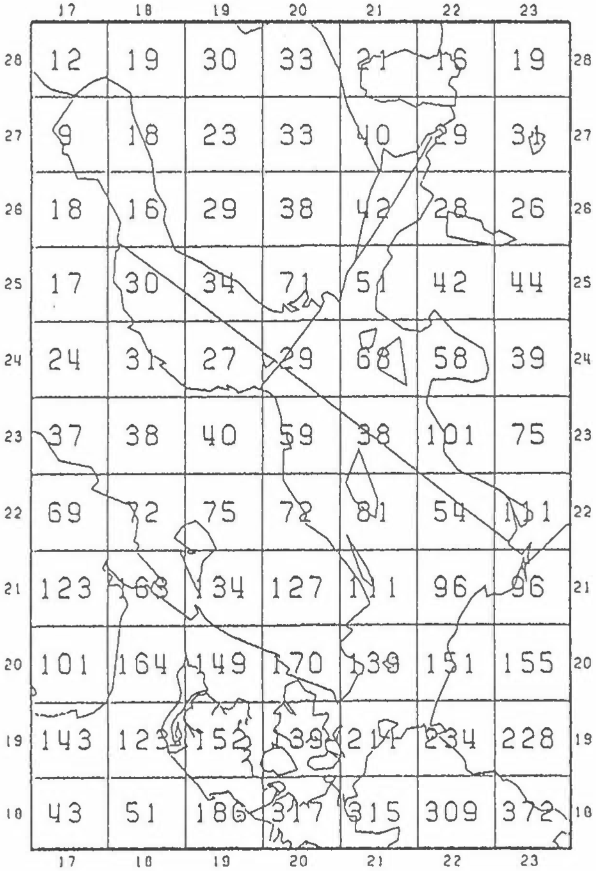
	17	18	19	20	21	22	23	
28	7	4	10	10	11	7	11	28
27	5	5	7	11	23	14	16	27
26	7	8	8	15	20	17	13	26
25	11	9	11	22	34	23	22	25
24	14	14	12	14	47	24	20	24
23	18	15	18	29	14	50	37	23
22	31	40	37	30	53	23	50	22
21	26	64	39	64	53	50	61	21
20	22	35	37	59	61	78	111	20
19	21	30	37	39	82	142	165	19
10	5	7	30	37	87	159	289	10
	17	18	19	20	21	22	23	

TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - GERMAN DEMOCRATIC REP- DD
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



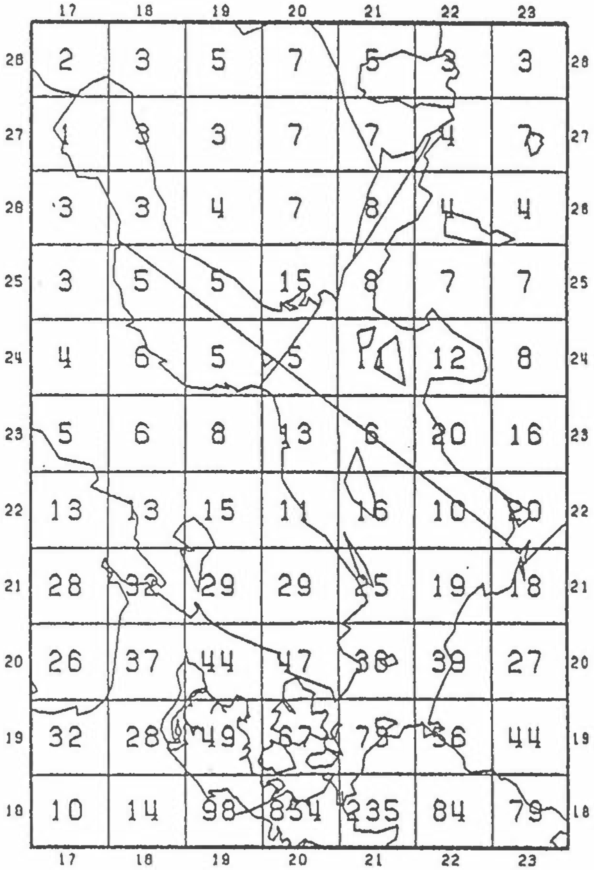
	17	18	19	20	21	22	23	
28	2	3	5	4	6	3	5	28
27	3	1	3	5	10	6	8	27
26	2	3	3	7	8	5	4	26
25	4	4	4	11	14	9	9	25
24	5	6	5	6	17	11	9	24
23	7	7	7	13	6	23	18	23
22	15	17	17	13	25	12	24	22
21	13	32	21	33	27	30	28	21
20	14	20	23	30	53	71	56	20
19	13	18	29	28	403	351	103	19
18	3	4	19	51	611	666	622	18
	17	18	19	20	21	22	23	

TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - GERMAN DEMOCRATIC REP- DD
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



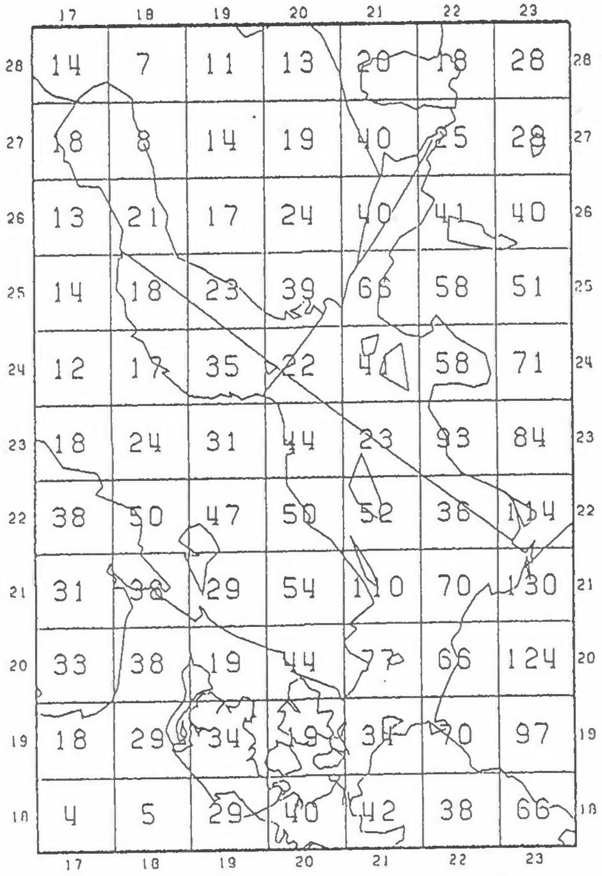
TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - GERMANY, FEDERAL REP.- DE
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL

	17	18	19	20	21	22	23	
28	12	19	30	33	21	16	19	28
27	9	18	23	33	40	29	34	27
26	18	16	29	38	42	28	26	26
25	17	30	34	71	51	42	44	25
24	24	31	27	29	68	58	39	24
23	37	38	40	59	38	101	75	23
22	69	72	75	72	81	54	111	22
21	123	168	134	127	111	96	96	21
20	101	164	149	170	139	151	155	20
19	143	123	152	139	214	234	228	19
18	43	51	186	317	315	309	372	18
	17	18	19	20	21	22	23	

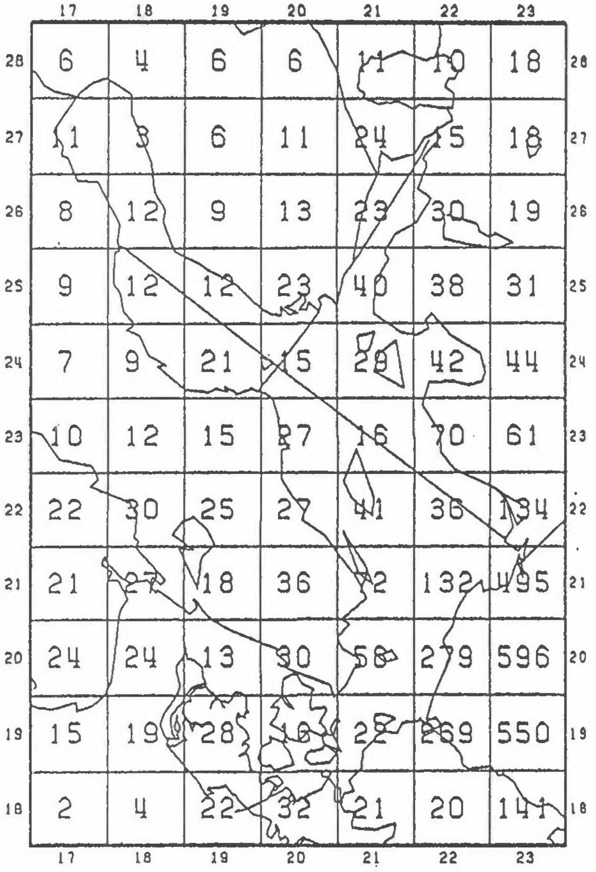


TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - GERMANY, FEDERAL REP.- DE
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL

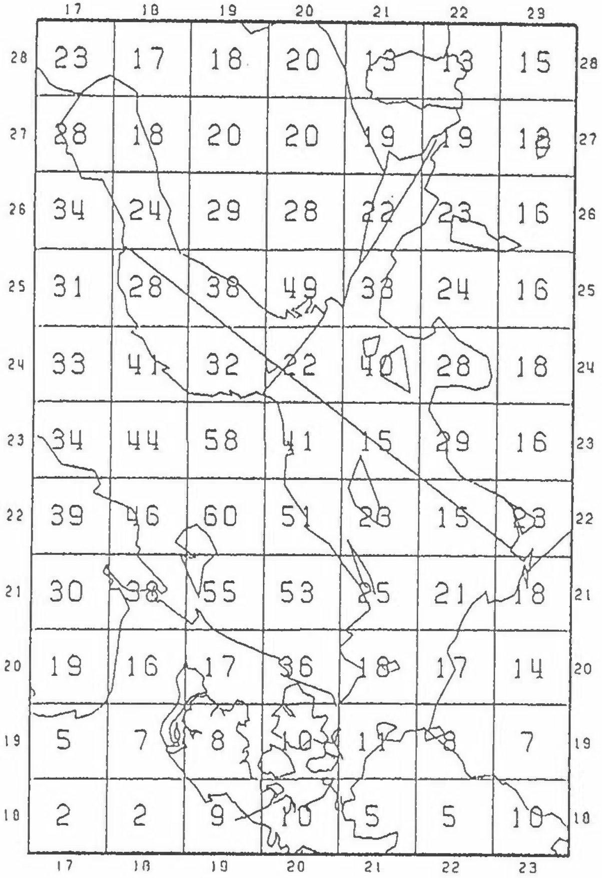
	17	18	19	20	21	22	23	
28	2	3	5	7	5	3	3	28
27	1	3	3	7	7	4	7	27
26	3	3	4	7	8	4	4	26
25	3	5	5	15	8	7	7	25
24	4	6	5	5	11	12	8	24
23	5	6	8	13	6	20	16	23
22	13	13	15	11	16	10	20	22
21	28	32	29	29	25	19	18	21
20	26	37	44	47	38	39	27	20
19	32	28	49	67	78	56	44	19
18	10	14	98	834	235	84	79	18
	17	18	19	20	21	22	23	



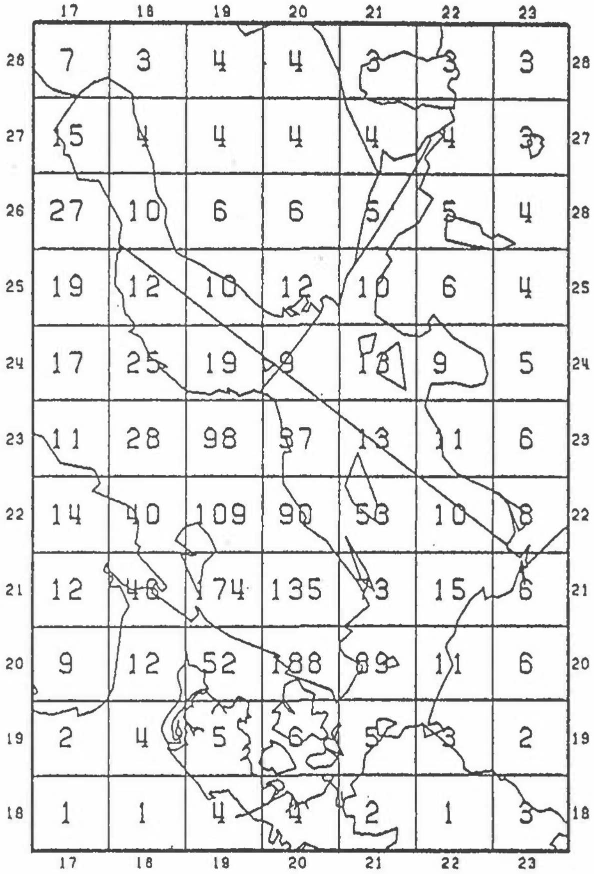
TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - POLAND - PL
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



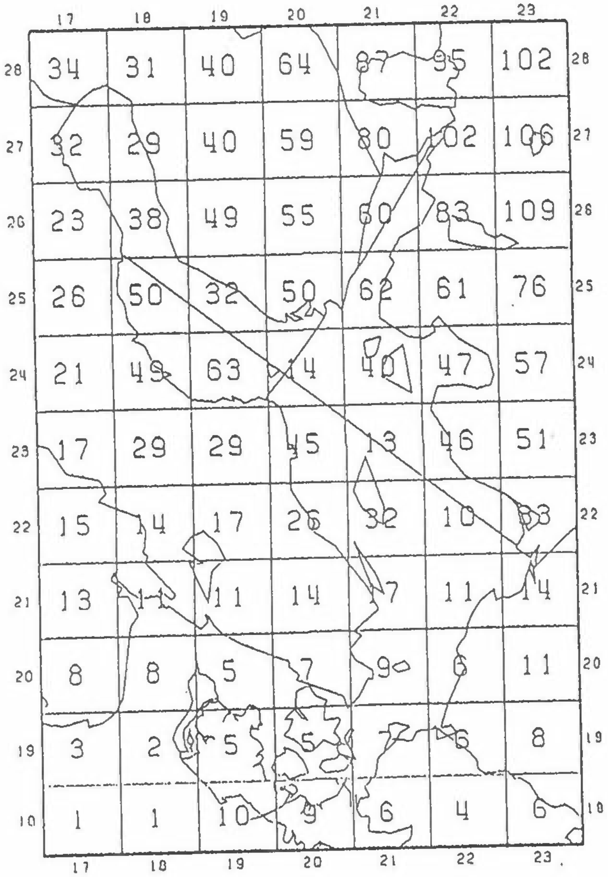
TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - POLAND - PL
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - SWEDEN - SE
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL

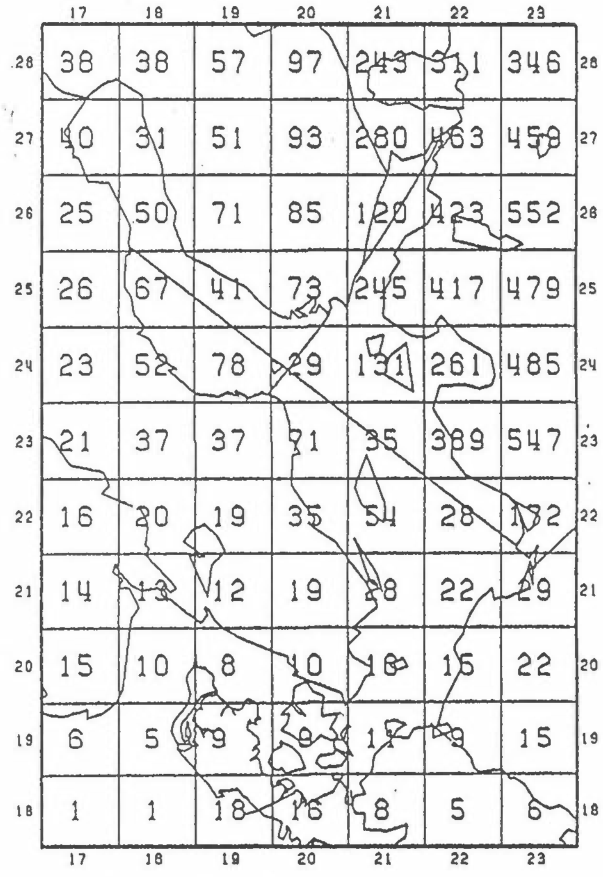


TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - SWEDEN - SE
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



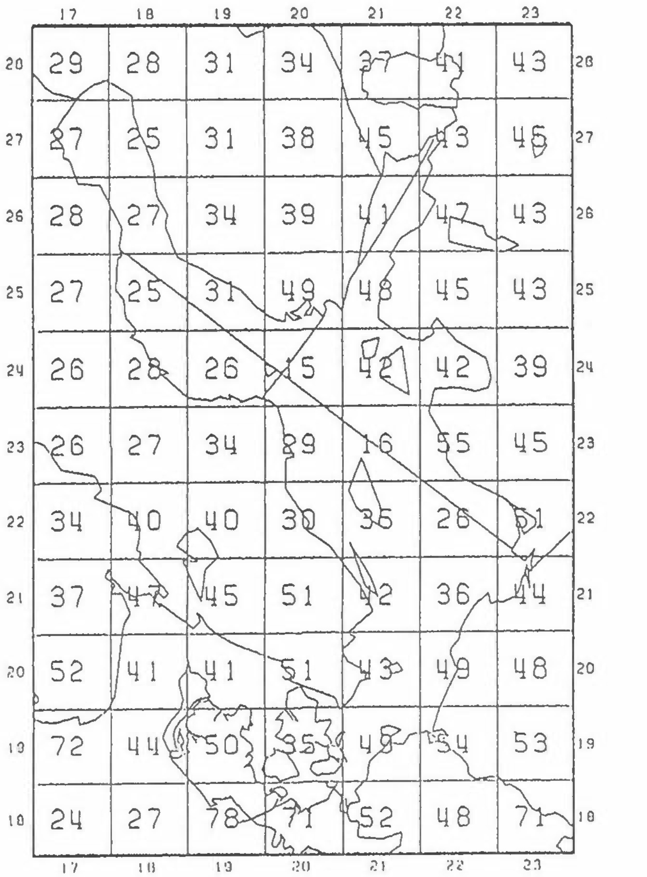
	17	18	19	20	21	22	23
28	34	31	40	64	87	95	102
27	32	29	40	59	80	102	106
26	23	38	49	55	60	83	109
25	26	50	32	50	62	61	76
24	21	49	63	14	40	47	57
23	17	29	29	45	13	46	51
22	15	14	17	26	32	10	83
21	13	11	11	14	7	11	14
20	8	8	5	7	9	6	11
19	3	2	5	5	7	6	8
10	1	1	10	9	6	4	6

TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - USSR (EUROPEAN) - SU
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



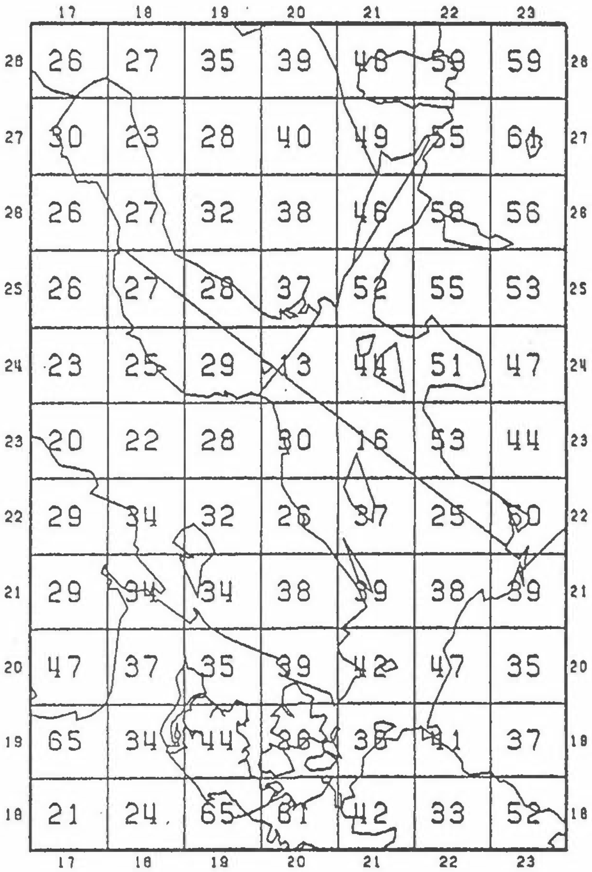
	17	18	19	20	21	22	23
28	38	38	57	97	243	311	346
27	40	31	51	93	280	463	458
26	25	50	71	85	120	423	552
25	26	67	41	73	245	417	479
24	23	52	78	29	131	261	485
23	21	37	37	71	35	389	547
22	16	20	19	35	54	28	172
21	14	13	12	19	28	22	29
20	15	10	8	10	18	15	22
19	6	5	9	9	17	9	15
18	1	1	18	16	8	5	6

TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
CONTRIBUTION FROM - USSR (EUROPEAN) - SU
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



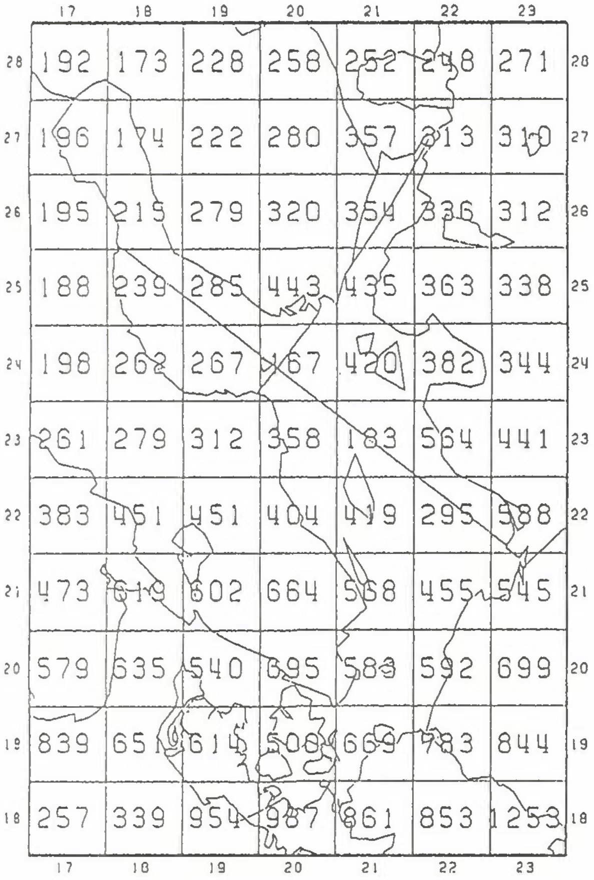
	17	18	19	20	21	22	23
28	29	28	31	34	37	41	43
27	27	25	31	38	45	43	45
26	28	27	34	39	41	47	43
25	27	25	31	49	48	45	43
24	26	28	26	15	42	42	39
23	26	27	34	29	16	55	45
22	34	40	40	30	35	26	51
21	37	47	45	51	42	36	44
20	52	41	41	51	43	49	48
19	72	44	50	35	49	54	53
18	24	27	78	71	52	48	71

TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
INATTRIBUTABLE CONTRIBUTIONS - IND
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



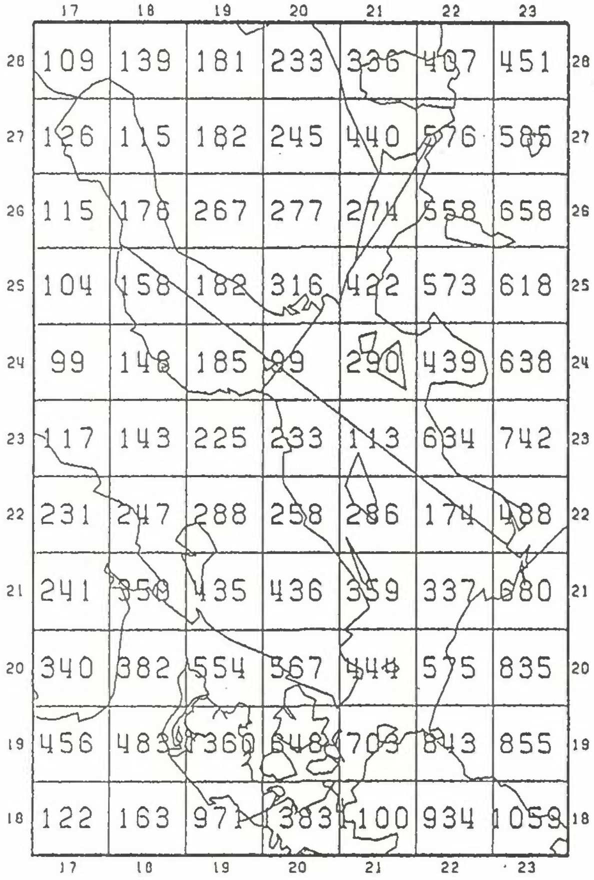
	17	18	19	20	21	22	23
28	26	27	35	39	48	59	59
27	30	23	28	40	49	55	64
26	26	27	32	38	46	58	56
25	26	27	28	37	52	55	53
24	23	25	29	13	44	51	47
23	20	22	28	30	16	53	44
22	29	34	32	26	37	25	50
21	29	34	34	38	39	38	39
20	47	37	35	39	42	47	35
19	65	34	44	36	38	41	37
18	21	24	65	61	42	33	52

TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
INATTRIBUTABLE CONTRIBUTIONS - IND
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



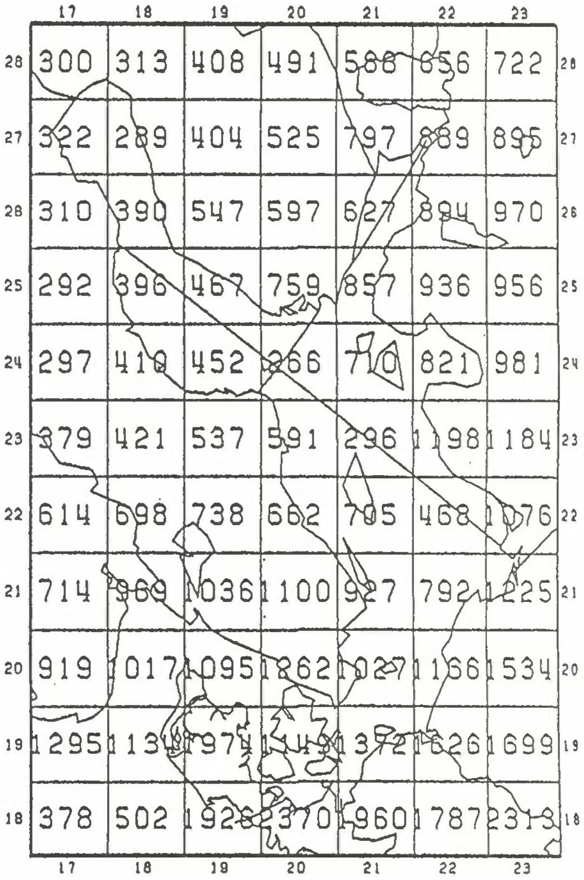
	17	18	19	20	21	22	23	
28	192	173	228	258	252	248	271	28
27	196	174	222	280	357	313	310	27
26	195	215	279	320	354	336	312	26
25	188	239	285	443	435	363	338	25
24	198	262	267	167	420	382	344	24
23	261	279	312	358	183	564	441	23
22	383	451	451	404	419	295	588	22
21	473	619	602	664	568	455	545	21
20	579	635	540	695	583	592	699	20
19	839	651	614	508	669	783	844	19
18	257	339	954	987	861	853	1253	18
	17	18	19	20	21	22	23	

TOTAL DEP. OF OXIDIZED NITROGEN (MG/M2 AS N)
GRAND TOTAL (ALL CONTRIBUTIONS) - TOT
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



	17	18	19	20	21	22	23	
28	109	139	181	233	336	407	451	28
27	126	115	182	245	440	576	585	27
26	115	176	267	277	274	558	658	26
25	104	158	182	316	422	573	618	25
24	99	148	185	99	290	439	638	24
23	117	143	225	233	113	634	742	23
22	231	247	288	258	286	174	488	22
21	241	350	435	436	359	337	680	21
20	340	382	554	567	444	575	835	20
19	456	483	1360	648	703	843	855	19
18	122	163	971	1383	1100	934	1059	18
	17	18	19	20	21	22	23	

TOTAL DEP. OF REDUCED NITROGEN (MG/M2 AS N)
GRAND TOTAL (ALL CONTRIBUTIONS) - TOT
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL



	17	18	19	20	21	22	23	
28	300	313	408	491	588	656	722	28
27	322	289	404	525	797	889	895	27
26	310	390	547	597	627	894	970	26
25	292	396	467	759	857	936	956	25
24	297	410	452	266	710	821	981	24
23	379	421	537	591	296	1198	1184	23
22	614	698	738	662	705	468	1076	22
21	714	969	1036	1100	927	792	1225	21
20	919	1017	1095	1262	1027	1166	1534	20
19	1295	1134	1974	1149	1372	1626	1699	19
18	378	502	1926	2370	1960	1787	2313	18
	17	18	19	20	21	22	23	

TOTAL DEPOSITION OF NITROGEN (MG/M2 AS N)
GRAND TOTAL (ALL CONTRIBUTIONS) - TOT
THE WHOLE YEAR - 1988, EMEP/MSC-W ACID MODEL

APPENDIX C

The following persons have collaborated with the author when preparing this report:

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STIKKORD

Emission	Deposition	Reduction cost

REFERAT

TITLE
The topical area study for atmospheric deposition of pollutants

ABSTRACT
The report provides information on emission and deposition fluxes of pollutants in the Baltic Sea area and their future trends as well as on assessment of environmental requirements. A list of priorities is presented with respect to emission and deposition reductions and their strategies. A review of solutions to meet these reductions is included with technical, economic, financial and institutional issues. Environmental benefits are also presented.

* Kategorier:	Åpen - kan bestilles fra NILU	A
	Må bestilles gjennom oppdragsgiver	B
	Kan ikke utleveres	C