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Emissions of Sulphur and Nitrogen Oxides Resulting from the Energetic Utilization of Fuels

The Situation in Poland

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EMISSIONS OF SULPHUR AND NITROGEN OXIDES RESULTING FROM THE ENERGETIC UTILIZATION OF FUELS - THE SITUATION IN POLAND -

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Abstract

This paper contains an estimate of emissions of sulphur and nitrogen oxides from anthropogenous sources in Poland for the year 1982. The spatial distribution of emitters has been taken into account. The following classes of emitters have been distinguished:

industry (including construction), transport and households and others (including agriculture). In the 'industry' sector the so-called large fuel consumers category was analyzed separately (power plants, heating plants and large industrial enterprises), indicating also the emitter heights. In 1982 the total SO_2 emissions were about 3.6 x 10^6 tons, i.e. about 100 kg SO_2 per capita per year. NO_x emissions were considerably lower at 1.1 x 10^6 tons, i.e. about 30 kg NO_x per capita per year. It should be noted that emission volumes calculated in this work are based only in part on statistical data. Some of the parameters used in calculations are mere estimates and not always representative of the whole territory of Poland. Thus, one should bear in mind the relative uncertainty of the results obtained. This is particularly important in the case of emissions of nitrogen oxides, where the data base was quite limited.

SO_2- und NO_x-Emissionen aus der Verbrennung von fossilen Energieträgern in Polen

Zusammenfassung

Dieser Bericht enthält eine Schätzung der Schwefel- und Stickstoffoxydemissionen aus anthropogenen Quellen in Polen für das Jahr 1982. Die räumliche Verteilung der Emittenten wurde berücksichtigt. Es wurde nach den folgenden Emittentenklassen unterschieden:

Industrie (einschließlich Bauwirtschaft), Verkehr und Haushalte (einschließlich Landwirtschaft). Im Bereich Industrie wurde die Kategorie der sogenannten "Großverbraucher" (Kraftwerke, Heizwerke und große Industrieunternehmen) auch im Hinblick auf die Emissionshöhe getrennt analysiert. 1982 lagen die gesamten SO_2-Emissionen bei etwa 3,6 x 10^6 Tonnen. Dies entspricht etwa 100 kg SO_2 pro Kopf und pro Jahr. Mit 1,1 x 10^6 Tonnen, d.h. etwa 30 kg NO_x pro Kopf und pro Jahr, waren die NO_x-Emissionen beträchtlich geringer. Es sollte darauf hingewiesen werden, daß die Emissionsberechnungen in diesem Bericht nur teilweise auf statistischen Daten beruhen. Einige Berechnungsparameter sind lediglich Schätzungen und nicht immer für das gesamte polnische Gebiet repräsentativ. Eine gewisse Unsicherheit sollte bei der Interpretation der Ergebnisse also bedacht werden. Dies trifft insbesondere bei der Emission von Stickoxyden zu, da die Datenlage in diesem Bereich besonders ungünstig ist.

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PREFACE

This paper deals with emissions of sulphur and nitrogen oxides in Poland. It has been prepared by the research workers from the Department of Energy Problems in the Institute of Fundamental Technological Research of the Polish Academy of Sciences in Warsaw (ZPE IPPT-PAN). The Department for Applied Systems Analysis in the Nuclear Research Center Karlsruhe (AFAS, KfK) has maintained scientific contacts with ZPE IPPT-PAN for several years. This work is a product of the co-operation between these two institutions, based on an exchange of experience and information on research work carried out with the objective to determine the influence of various energy system development strategies on the natural environment. Results of this work - being part of the European database on emissions of sulphur and nitrogen oxides - will be used for calculations of the long-range transport of pollutants in Europe which will be performed by AFAS, KFK, within the framework of a project on the regional distribution of acidifying and toxic pollutants. This project is partly financed by the Projekt Europäisches Forschungszentrum für Maßnahmen zur Luftreinhaltung (PEF).

J. Cofala (ZPE IPPT-PAN)
R. Coenen (KfK/AFAS) July 1987

1. Introduction

The rapid increase in world-wide energy consumption is accompanied by growing emissions into the atmosphere of a number of toxic substances originating from fuel burning. Sulphur and nitrogen oxides are the major gaseous components of atmospheric pollution. They create acids and other noxious compounds during transport in the atmosphere which may have detrimental effects on human health, as well as upon the natural environment, and on the economy. Acidification of the environment is currently considered to be one of the major causes of forest dieback.

Sulphur oxides emitted into the atmosphere are transported over long distances which results in the fact that their concentration in a given place depends not only on local emissions but also on emissions from sources which are sometimes hundreds or even thousands of kilometers away. Problems of transfrontier pollution transport are dealt with in mathematical models. Wide international cooperation and information exchange exists in this field. Research for the FRG (Coenen 1985) carried out within the framework of the so-called 'Coal Project' of the Karlsruhe Nuclear Research Centre, using the MESOS model, showed that 53 % of sulphur immissions in West Germany come from emitters situated in other countries. In Poland the same percentage of sulphur deposition also originates from foreign sources (Kozlowski 1984).

The mechanisms of atmospheric transformation of NO_x are not fully understood. Therefore, modelling of long-range transport of nitrogen oxides is not possible, as yet. However, it is known that atmospheric transformation of nitric oxide into the more dangerous nitrogen dioxide is associated with the production of several chemical compounds which, under specific meteorological conditions form the so-called photochemical smog. That is why noxious effects of nitrogen oxides are more pronounced than those of sulphur dioxide.

It is estimated that approximately 50 % of the emissions of sulphur and nitrogen oxides on a global scale come from natural sources (Environment '82 Committee 1982). However, in industrialized countries anthropogenous sources predominate.

The emissions of SO_2 and NO_x [1] in selected European countries in 1980 to 1982 are presented in Table 1. The majority of SO_2 emissions comes from energy intensive industries, first of all from the power industry. In the case of NO_x road transport usually is the largest contributor to total emissions in highly developed countries. The levels and structure of emissions differ among countries due to the varying levels of industrial development and motor-vehicle transport and differences in fuel consumption structure and employed technologies. There are wide discrepancies in per capita emissions for the countries listed in Table 1. Per capita SO_2 emissions for the GDR are six times higher than for Italy. Great differences can also be observed in the case of NO_x emissions, where the maximal values are twice as high as the minimal ones.

It should be pointed out that there are substantial differences in emission levels given by different authors. For example, SO_2 emissions for France in 1980 given in (Halbritter et al. 1985) are approximately 400 thousand tons lower and for the United Kingdom 700 thousand tons lower than according OECD figures (OECD 1984). Similarly NO_x emissions in France published by the ECE [2] (Economic Commission for Europe 1986) are approximately 200 thousand tons higher than the figure reported by the OECD. This reveals the high uncertainty of such estimates.

SO_2 emissions depend nearly exclusively on the sulphur content of the fuels. Therefore, it is relatively simple to estimate emission levels. Prevention of excessive emissions is possible either by means of utilizing clean fuels with a low sulphur content or by desulphurization of flue gases. Estimating NO_x emissions is much more difficult, because the unit emission depends strongly not only on the kind of fuel but also on the combustion process itself (temperature, oxygen concentration, reaction velocity, etc.) Solid fuels produce more NO_x per unit of burned fuel than liquid fuels. Gaseous fuels produce the comparatively lowest emission levels.

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1) The amounts of nitrogen oxides emissions are usually given recalculated to nitrogen dioxide (NO_2). This convention has also been adopted in this paper.

2) Economic Commission for Europe.

The three following mechanisms of NO_x formation during combustion of fossil fuels are known:

1. Formation of 'thermal NO_x' by binding of atmospheric nitrogen with oxygen during combustion.
2. Formation of 'fuel NO_x' through chemical transformation of nitrogen contained in the fuel.
3. Formation of 'prompt NO_x'.

Table 1: Emissions of SO_2 and NO_x in Selected European Countries

No.	Country	Reference Year	Emission			
			10^6 t/a		kg/capita	
			SO_2	NO_x	SO_2	NO_x
1.	FRG	1980	3.2	3.1	52	50
2.	France	1980	3.2[1)]	1.5	59	27
3.	Italy	1980	2.7	1.3	46	22
4.	United Kingdom	1980	4.7	1.9	83	33
5.	Spain	1980	3.8	0.8	100	22
6.	Czechoslovakia[2)]	1982	3.3	0.5	220	33
7.	GDR	1982	4.9	0.6	280	33
8.	Poland	1982	3.6	1.1	100	31

1) - Without process emissions.
2) - Without emissions from the 'transport' sector.

Sources: OECD countries - (OECD 1984), Czechoslovakia - (Melzer et al. 1983), GDR - (Bethkenhagen et al. 1985), Poland - own estimates.

The rate of 'thermal NO_X' formation increases rapidly with temperature. It depends also on oxygen concentration and residence time of reagents in the reaction zone. Formation of 'fuel NO_X' essentially means chemical reactions of nitrogen compounds contained in the fuel into nitric oxide and other nitrogen compounds. 'Prompt NO_X' is formed in the front part of the flame in presence of hydrocarbon radicals. This mechanism is of secondary importance in large industrial furnaces and may be considered to be a special case of the 'fuel NO_X' mechanism (Soete 1981).

Measures aiming at reducing emissions of nitrogen oxides are usually divided into primary and secondary measures. Primary measures consist of modifications of the combustion processes in order to reduce temperature, oxygen concentrations and residence time in the reaction zone. Such measures are comparatively inexpensive (1-3 % investment costs of large boilers). However, their application may sometimes lead to certain operational difficulties. Moreover, primary measures cannot solely ensure fulfillment of the emission standards in force in many countries. Therefore, secondary measures consisting of the construction of denitrification installations for flue gases are required. These secondary measures are very costly.

Development of an optimum strategy for reducing the air pollution of sulphur and nitrogen oxides presupposes an analysis of the structure of emission sources and their spatial distribution. This study has been devoted to that problem under Polish conditions.

2. Scope and Method

An attempt has been made in this work to give an approximate estimate of the overall sulphur and nitrogen oxides emissions in Poland in 1982. The spatial distribution of emission sources has been presented based on a geographical grid of 0.5° latitude by 1° longitude. This network divides Poland into 98 regions - see Fig. 1. Such a subdivision is required for the modelling of pollutant transmission with consideration of trans-boundary transport phenomena. Estimates of emissions have been based on the national consumption of fuel and energy which, in turn, has been split up for each of the regions. Generally available statistical data, published by or sent to international organizations have been used (e.g. United Nations 1984, GUS 1983a, WEC 1986).

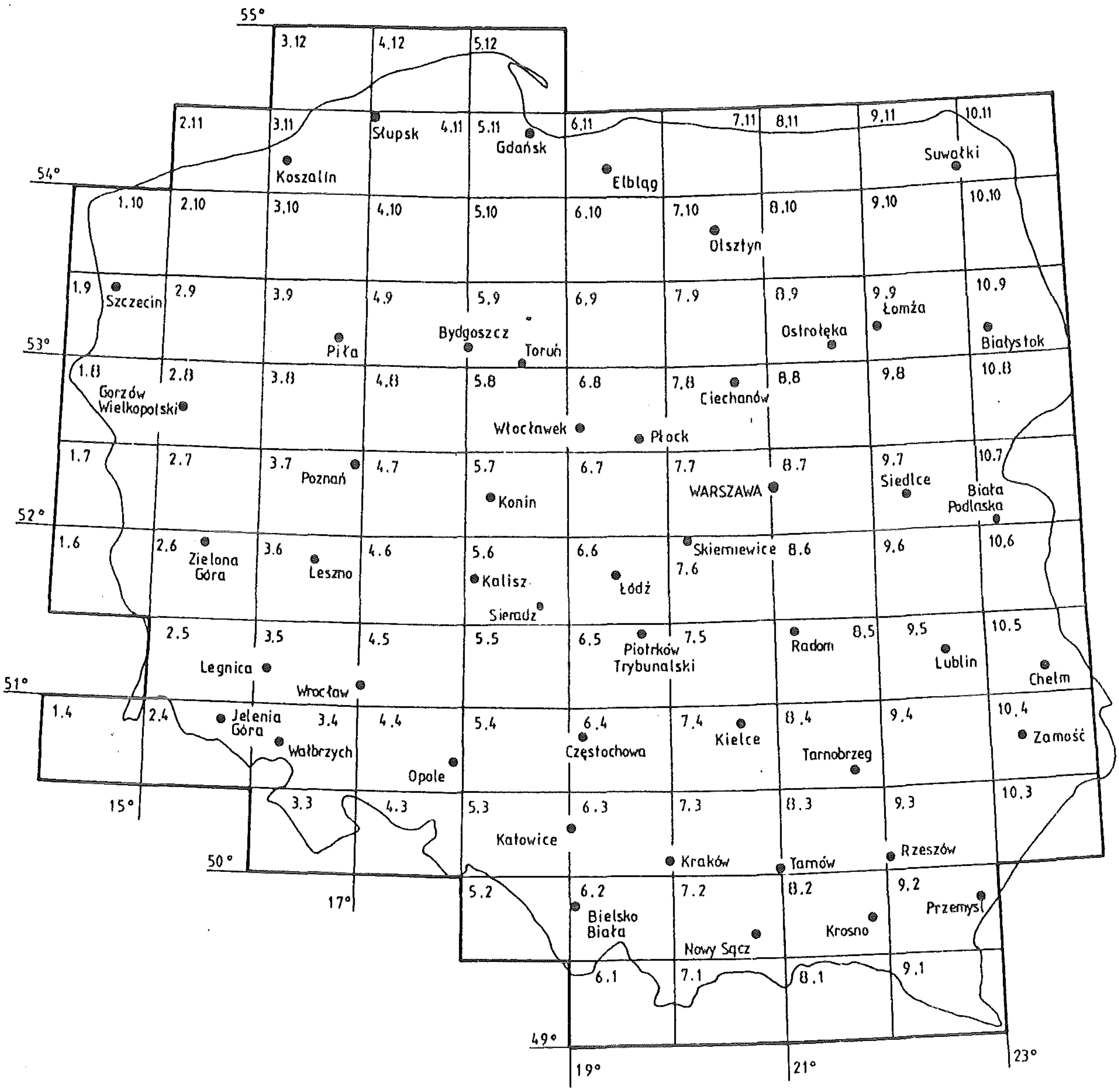

Fig. 1: Division of the Polish Territory with Geographical Grid

SO_2 and NO_x emissions have been estimated separately for the following economic sectors:

- industry (including construction),
- transport,
- households and others (including agriculture).

Industrial emissions have been additionally subdivided into emissions from plants consuming large amounts of fuels and from other industrial users. Emitter heights have been considered for the first group of plants.

Elaborations of the Polish Central Statistical Office (GUS) on environmental protection were the source of data for industry (GUS 1983a). These include, among others, information about air polluting emissions from plants recognized by the local administrative authorities as being specially harmful for the environment. It is estimated that these data add up to about 90 % of all the industrial plant emissions. The data are published subdivided according to the administrative system [3] and separately for about 100 named industrial plants - the greatest emitters of pollutants. The latter data were used to create the set of information on point sources of emissions. Plants with an annual SO_2 emission exceeding 4×10^3 t/a were taken into account. All these plants have furnaces of capacities exceeding 300 MW. Emitter heights and fuel consumption data have been collected for these objects. Besides the GUS data, power industry statistical information (PIIC 1983) and elaborations of the Institute for Environment Formation (Prokopowicz 1984, Warchalowski 1984) were used. Furthermore, data about individual objects were aggregated for a given grid area taking emitter heights into account. Thus, the so-called equivalent emitters have been obtained. For some objects it was possible to separate the so-called process emissions, computed as a difference in value between plant emissions given by GUS and the emissions computed on the basis of fuel consumption. It is estimated that emissions from industrial processes (not connected with energy conversion) are of the order of 150-200 thousand tons of SO_2 annually on the national scale. SO_2 emissions for the group 'other industrial users' have been computed on the basis of information on fuel consumption and on total industrial emissions in voivodships.

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3) The Polish territory is subdivided into 49 districts called voivodships.

Industry consumes the so-called final energy as well as the primary energy. To avoid double accounting, coking coal consumption in coking plants and consumption of coke in blast furnaces have not been accounted for during computations [4].

After having established the fuel consumption and emission values for the different voivodships the data were transformed into the geographical grid pattern. In the case of great fuel consumers such transformation did not pose problems because their geographical location is known. For the group 'other industrial users' it was assumed that their fuel consumption and emissions are distributed over the individual grid areas in the given voivodship proportionally to urban population density [5] for that area. This is because industrial activity, as a rule, is concentrated in towns.

Unfortunately data published by GUS for nitrogen oxides emissions in industry are not adequately reliable in all cases. Therefore, estimates of NO_x emissions have been based totally on fuel consumption. In the case of NO_x the lack of data made it impossible to provide separate figures for 'process emission' (i.e. emissions from industrial processes not related to fuel combustion for energetic purposes). Therefore, it was assumed that the unit nitrogen oxides emissions due to fuel combustion in industrial appliances (in metallurgical works, chemical plants, etc.) are of the same order as for industrial boilers. This assumption does not represent significant errors from the point of view of overall emission, although the differences in the case of individual plants may be significant. Several remarks on this topic have been made in a further part of this report.

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4) Coking coal consumption as charge in coking plants and coke consumption in blast furnaces do not cause direct emissions of SO_2. Only coke-oven gas used for heating coking retorts is an emission source of approximately 25 thousand tons of SO_2 annually on the national scale. This emission has been included as 'process emission' in coking plants or in metallurgic plants because coking plants are often part of metallurgic works.

5) For technical reasons only towns having a population above 20 000 have been considered. There were 200 such towns in Poland in 1982, being 1/4 of all towns in Poland and grouping about 80 % of the total urban population (GUS 1984).

GUS does not register emissions of air pollutants for non-industrial economic sectors i.e. for 'transport' and 'households and others'. Therefore, estimates of SO_2 and NO_x emissions have been based totally on fuel statistics. The national contribution of individual fuel sources has been transposed into fuel consumption on the voivodship level using the regional GUS statistics (GUS 1983b). In some cases (i.e. consumption of gaseous fuels in households) data for voivodships were directly available from regional statistics. In other cases, however, it was necessary to estimate voivodships data on the basis of secondary information (e.g. number and kind of vehicles registered within the territory of a given voivodship, railway line length, share of voivodships in national data etc.). It has been assumed that solid fuel consumption in construction and agriculture is proportional to gross production of these branches in the individual voivodships. Similarly, it has been assumed that petrol consumption is proportional to the number of cars and diesel oil consumption is proportional to the number of trucks registered in a given voivodship. Fuel consumption by railways was split up based on railway line length. Estimates of national fuel consumption by individual groups of consumers not given separately by statistics (e.g. vehicles of a given group) have been obtained from the results of the modelling of domestic energy demand (Cofala 1984).

It should be emphasized that the transport sector comprises diesel oil consumption by tractors in agriculture [6] and liquid fuels consumption by private cars as well as by municipal transport. In official energy statistics these last two categories of fuel users are usually accounted for in the residential - commercial sector (households and others).

Fuel consumption by sea transport (marine bunkering) as well as by air transport has not been taken into account. In principle, emissions resulting from fuel use by ships in sea ports and on the way from the open sea to ports should be taken into consideration. However, investigations carried out for the GDR (Bethkenhagen et al. 1985) have shown that such emissions can be neglected. Emissions of air transport have not been specified because of a lack of data, but according to (Bethkenhagen et al. 1985) this causes minor errors only.

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6) In that case total domestic consumption taken from (Cofala 1984) has been split up among individual voivodships proportionally to the number of tractors.

After the data on fuel consumption for voivodships had been elaborated they were transformed into the geographical grid pattern. Similarly as for 'other industrial consumers', voivodship data were transformed into grid data using population densities within each of the voivodships. However, overall population density data were used here. An exception was made for gaseous fuels where the distribution of urban population was employed because the contribution of rural gas users is low (below 10 % - see GUS 1984).

3. Emission Coefficients

3.1 Unit SO_2 Emissions

The emission coefficients for sulphur dioxide depend in principle on the type of fuel, i.e. calorific value and sulphur content of the fuel. The main information indispensable for estimating emission coefficients will be given below. Emission coefficients applied in this study have been collected in Table 2.

3.1.1 Hard Coal

Sulphur content in coal for big power plants is quite varied and amounts to 0.9 - 2.6 % at the net calorific value (NCV) 15 - 22 GJ/t. Therefore, the dispersion of emission coefficients is large (0.7 - 2.9 kg SO_2/GJ). In smaller plants (public power plants with cogeneration, heating plants or industrial power plants) coal of better quality with a sulphur content of 0.7 - 1.2 % and NCV of 20 - 24 GJ/t is normally used. Unit emissions are of the order 0.6 - 1.0 kg/GJ. Information necessary for computing emission coefficients for individual power plants is available in statistics of the power industry (PIIC 1983). Emission coefficients for great fuel consumers (after aggregation within each individual grid area) are to be found in Table A-1 in the Appendix. The dispersion of coefficients in Table A-1 is, of course, smaller than given above because of the aggregation effect.

For the category 'other industrial users', a sulphur content of 1.0 % and NCV of approximately 25.2 GJ/t were assumed leading to the emission coefficient of 0.794 kg SO_2/GJ. For the above categories of coal users it was assumed that sulphur contained in coal is completely transformed into SO_2 and is exhausted into the atmosphere.

Table 2: SO_2 and NO_x Emission Coefficients for Various Fuels and Economic Sectors

No	Sector / Energy Source	Emission Coefficient, kg / GJ	
		SO_2	NO_x
1	2	3	4
A.	Industry (Including Construction)		
1.	- Great Consumers - Furnaces > 300 MW		
1.1	- Hard Coal	1.228	0.29
1.2	- Brown Coal	1.217	0.18
1.3	- Fuel Oil	1.008 [1)]	0.24
2.	- Others		
2.1	- Hard Coal	0.794	0.19
2.2	- Brown Coal	1.012	0.18
2.3	- Coke	0.578	0.12
2.4	- Fuel Oil	1.234	0.17
2.5	- Gaseous Fuels	-	0.10
B.	Transport		
1.	- Hard Coal	0.682	0.051
2.	- Petrol	-	0.65
3.	- Diesel Oil	0.279	1.54
C.	Households and Others (incl. Agriculture)		
1.	- Hard Coal	0.682	0.051
2.	- Coke	0.520	0.051
3.	- Gaseous Fuels	-	0.034

1) See note to Table A-1 in the Appendix.

Analogous assumptions for 'transport' and 'households and others' are: 1.0 % S, NCV = 26.4 GJ/t, 90 % of S are transformed and emitted (the rest is fixed by ash); unit emission 0.682 SO_2/GJ.

3.1.2 Brown Coal

Sulphur content in brown coal amounts to 0.4 - 1.1 % at NCV 7.6 - 8.6 GJ/t. Emission coefficients depend on the type of coal because in some deposits up to 40% of S is fixed by ash during combustion (PIIC 1983). Emission coefficients for large power plants (1.1 - 1.4 kg SO_2/GJ) are given in Table A-1.

Amounts of brown coal used outside large power plants are very small. The emission coefficient for this category of brown coal users (industrial power plants, heating plants) can be assumed at approximately 1.01 kg SO_2/GJ.

3.1.3 Domestic Coke

Sulphur content in domestic coke is approximately 0.8 % and NCV can be assumed at 27.7 GJ/t. The emission coefficient for 'other industrial users' is 0.578 kg SO_2/GJ. In the household sector it was assumed that up to 10 % of S is fixed by ash. Therefore, the emission coefficient is 0.520 kg SO_2/GJ.

3.1.4 Liquid Fuels

In Poland fuel oil is used in industry as an auxiliary boiler fuel or as a furnace fuel. It is nearly exclusively heavy fuel oil. At a sulphur content of 2.5 % in heavy fuel oil, the emission coefficient may be assumed to be 1.234 kg SO_2/GJ. In some cases fuel oil with a higher sulphur content (i.e. 3 %) is burned up. Then, the emission coefficient is 1.481 kg SO_2/GJ. Emission resulting from fuel oil burning in industrial processes (outside power boilers) has been included as 'process emission' (see Table A-1). Therefore, the emission coefficient given in Table 2 for 'great consumers' is lower than the above values.

Fuel oil is not used in the household sector in Poland. Amounts of light fuel oil used in agriculture for heating and drying are negligible. Sulphur content in diesel oil may be assumed to be 0.6 % [7] and the emission coefficient is 0.279 kg SO_2/GJ. Sulphur content in petrol has been neglected.

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7) Acc. to (Michalowska 1983).

3.1.5 Gaseous Fuels

In the case of gaseous fuels the sulphur content is usually very small and can be neglected. Coke-oven gas used for heating coking retorts is the only exception here. Emission from such sources has been included as process emission. [8)]

3.2 Unit NO_x Emissions

The level of unit nitrogen oxides emissions resulting from the energetic utilization of fuels depends on a variety of factors, such as:

- type of fuel,
- nitrogen content of the fuel,
- combustion process temperature,
- organization of combustion (excess air, flue gas cooling rate, etc.).

The range of these parameters is quite high depending on the type of appliance, duration of operation and load. Therefore, calculations of NO_x emission coefficients are not possible, as yet. One must, in principle, rely on adequately representative emission measurements for given types of appliances under typical operation conditions. A range of emission coefficients for nitrogen oxides is usually given in the relevant literature instead of specific values, and maximum values are typically 3 - 5 times higher than minimum values (see. e.g. ECE 1986). This points to the approximate character of such information.

The data in Poland are similarly uncertain. As yet there are no systematic NO_x concentration measurements for flue gases, neither in power plants, nor in any other industrial appliances. Selective measurements which are adequately representative have not been made either. Presently available estimates of global nitrogen oxides emission in Poland (e.g. Nowicki 1985) were based mainly on emission coefficients taken from foreign, mostly American, references. This transposition to Polish conditions is not always adequate due to the different type of equipment used, different fuel and organization of the combustion process.

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8) In coking plants or in metallurgical plants because coking plants are often part of metallurgical works.

The measurements made up to now in Poland (see Cieslinski, Baranowski 1986, Sadowska-Janusz 1986), although carried out in many plants, cannot be considered to be fully representative. Because of a lack of other, more reliable data sources emission coefficients have to be estimated on the basis of this existing information. Such measurements have shown that NO_x emissions from coal-fired boilers in the power industry are typically lower than those given in Western literature. The reasons are as follows (Wroblewska, Dabrawska 1984):

- the Polish power industry uses mostly hard coal having a low calorific value and high ash content (often above 25 %), which lowers the combustion temperature,
- the boilers with wet bottom furnace (liquid slag disposal) are not popular in Poland (see: Orlowski et al. 1979); all boilers in public as well as in industrial power plants are of the dry bottom type,
- lower unit heat loads for furnaces are typical due to the slagging properties of Polish coal as compared with analogous foreign designs. This favours lower NO_x emissions,
- a majority of large power boilers have tangential type furnaces characterized by relatively low emission coefficients,
- stream burners with top and bottom air flow are commonly used; thus, having effects similar to those operating acording to OFA (overfire air) principles,
- industrial power plants use large numbers of grate firing boilers (PIIC 1981); grate type boilers have considerably lower unit emissions than powdered coal boilers.

Coal combustion in plants of large industrial consumers takes place usually in large powdered coal boilers at a furnace capacity above 300 MW. The emission coefficients were derived adopting upper NO_x concentrations observed during runtime conditions, i.e. at about 0.29 kg NO_x/GJ (Cieslinski, Baranowski 1986, Sadowska-Janusz 1986). NO_x concentrations in flue gases from brown coal-fired boilers are lower and the emission coefficient has been assumed to be about 0.18 kg NO_x/GJ being consistent with the value for the FRG (Löblich 1986). Emission coefficients for each category of consumers and types of fuels have been compiled in Table 2.

Within the category of 'other industrial consumers' most of the hard coal consumed is used in boilers, including powdered coal boilers at capacities of 100 - 300 MW and a considerable number of grate boilers at capacities below 100 MW. Output of grate boilers amounts to some 40 % of boiler output in industry outside the public power plants (PIIC 1981). The emission coefficient for powdered coal boilers in this group has been taken to be about 20 % lower than for large power boilers, i.e. at about 0.24 kg/GJ. For grate boilers, an emission coefficient of 0.12 kg/GJ was assumed. After consideration of different capacity factors for boilers with differing outputs the average emission coefficient has been estimated at 0.19 kg/GJ. A slightly lower coefficient has been adopted for brown coal. Emission coefficients for coke have been taken to be the same as for grate boilers. Emission coefficients for fuel oil and gas have been assumed to be the same as for medium-sized users in the FRG (Coenen 1985).

Emission coefficients for the sector 'households and others' have been taken to be the same as in the FRG (Coenen 1985). Light fuel oil is practically not used for heating purposes in Poland. Therefore, Table 2 does not specify a unit emission coefficient for that type of fuel.

Coal is used in transport for operating a number of steam locomotives and for space heating. Emission coefficients for furnaces of these types have been taken to be similar to those in the household sector.

There are significant difficulties in determining emission coefficients of nitrogen oxides for liquid fuels used in transport. Emissions of motor vehicle engines depend highly on the type of engine and, particularly in the case of petrol engines, on traffic conditions (city or road traffic). Unit NO_x emission coefficients for four-stroke spark ignition engines vary from 0.35 to 0.45 kg/GJ in city traffic and from 0.65 to 1.38 kg/GJ in road traffic outside cities (Bernhardt et al. 1982) [8]. Measurements of NO_x emissions for two-stroke ignition engines have not been performed in Poland, as yet. According to data for the GDR (Bethkenhagen et al. 1985) the emissions are approximately lower by an order of magnitude than those for four-stroke engines. Emissions of compression ignition engines (Diesel engines) are much less dependent on traffic conditions.

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8) Values from test runs for typical cars in Poland according to ECE regulations.

In Table 3 a rough estimate of average unit emissions for cars equipped with petrol engines has been performed. Fuel consumption by specified groups of cars has been computed on the basis of data taken from (Czajkowski et al. 1984). It has been assumed that about 50 % of the fuel is used in city traffic. Emission coefficients given in (Bernhardt et al. 1982) for selected groups of vehicles allow to estimate the average unit emission at about 0.65 kg NO_x/GJ.

Table 3: Shares in Fuel Consumption and Unit NO_x Emissions for Selected Groups of Cars with Spark Ignition Engines

No.	Type of Engine	Share in Fuel Consumption, %	Unit Emission, kg NO_x/GJ		
			City Traffic	Road Traffic	Mean
1	4-stroke, < 0.9 l	15	0.45	0.65	0.55
2	4-stroke, 0.9 - 2.0 l	53	0.35	1.38	0.86
3	4-stroke, > 2.0 l (Delivery Vans)	18	0.38	0.75	0.57
4	2-stroke, (Cars and Motorcycles)	14	-	-	0.08
				Average	0.65

The coefficient for Diesel engines has been adopted from (Bernhardt et al. 1986) at 1.54 kg NO_x/GJ. Similar values of coefficients have been obtained from investigations carried out in Czechoslovakia. The relatively high emission coefficient for Diesel engines results from the dominance of vehicles equipped with direct injection engines (Januszewski et al. 1980) having higher unit emissions (compare: Bethkenhagen et al. 1985, UBA 1981).

4. Results of Calculations and Discussion

4.1 Emissions of Sulphur Dioxide

The SO_2 emissions for selected sectors of the economy estimated according to the assumptions discussed above have been collected in Table 4. Table A-1 in the Appendix presents emissions of the so-called large emitters in industry taking into account their spatial distribution and (stack) height. In Table A-2 emissions for the sector 'other industrial users' are described in more detail. SO_2 emissions for individual grid segments according to the type of fuel consumed have been listed. Similar data for 'transport' and 'households and others' are presented in Table A-3. Table A-4 summarizes the spatial distribution of emissions from the following sectors: industry (including construction), transport and households (including agriculture). Spatial distribution of emissions in individual grid areas is also shown in Fig. 2.

The total emission of sulphur dioxide in 1982 calculated on the basis of the above assumptions amounted to 3.6 x 10^6 t, 77 % of which have been caused by industrial users, with 56 % being the so-called large emitters (first of all, public and industrial power plants). The household sector is responsible for about 20 % of the emission volume. The share of the transport sector is the smallest at about 3% of all SO_2 emissions. Data from Table A-1 have been used in Table 4 to indicate emission volumes by emitter heights. It was assumed that emissions from transport and household sectors take place at a height of up to 20 m and the ones from 'other industrial users' at a height of approximately 50 m. It is estimated that about 77 % of SO_2 emissions take place at a height exceeding 50 m and about 26 % at a height exceeding 200 m.

The above value of total SO_2 emissions corresponds to the estimate performed by (Nowicki 1985), who gives a value of 3.5 - 4.0 x 10^6 t of SO_2 emission in Poland annually in the period 1982/83. An earlier expert report of the Committee of the Polish Academy of Sciences 'Man and Environment' (Juda et al. 1980) establishes a value of 4.3 x 10^6 t of SO_2 emissions for the year 1978. Data from this report are cited in a report of the International Institute for Environment and Society IIUG (Schreiber 1984). The expert report was one of the first attempts at estimating total emission of air pollutants in Poland. Higher values can be explained as follows:

Table 4: SO_2 Emissions in 1982 for Economic Sectors and Emitter Heights

No	Sector / Energy Source	Fuel Consumption 1) PJ	Emission Coefficient t/TJ	Emission 10^3 t/a	Emission %
1	2	3	4	5	6
A.	Industry (Including Construction)	2944.2	0.944	2780.7	76.8
1.	- Great Consumers	1532.7	1.314	2013.8	55.6
1.1	- Hard Coal	1167.8	1.228	1434.2	39.6
1.2	- Brown Coal	277.0	1.217	337.0	9.3
1.3	- Fuel Oil	87.8	1.008 2)	88.5	2.4
1.4	- Process Emissions	-	-	154.1	4.3
2.	- Others	1411.4	0.543	766.9	21.2
2.1	- Hard Coal	806.1	0.794	639.8	17.7
2.2	- Brown Coal	10.5	1.012	10.6	0.3
2.3	- Coke	98.6	0.578	56.9	1.6
2.4	- Fuel Oil	30.4	1.234	37.5	1.0
2.5	- Process Emissions	-	-	22.0	0.6
B.	Transport	421.6	0.269	113.6	3.1
1.	- Hard Coal	78.7	0.682	53.6	1.5
2.	- Diesel Oil	215.0	0.279	60.0	1.6
C.	Households and Others (Including Agriculture)	1215.6	0.600	729.5	20.1
1.	- Hard Coal	942.2	0.682	642.5	17.7
2.	- Coke	167.3	0.520	87.0	2.4
D.	Total for the Country	4581.4	0.791	3623.8	100.0
E.	Emission Volumes by Emitter Heights				
1.	- 20 m and less	-	-	843.1	23.3
2.	- 50 - 150 m	-	-	1855.5	51.2
3.	- 200 m and more	-	-	925.2	25.5

1) Partly primary, partly final energy; consumption of gaseous fuels and petrol included at a sector level.
2) See note to Table A-1 in the Appendix.

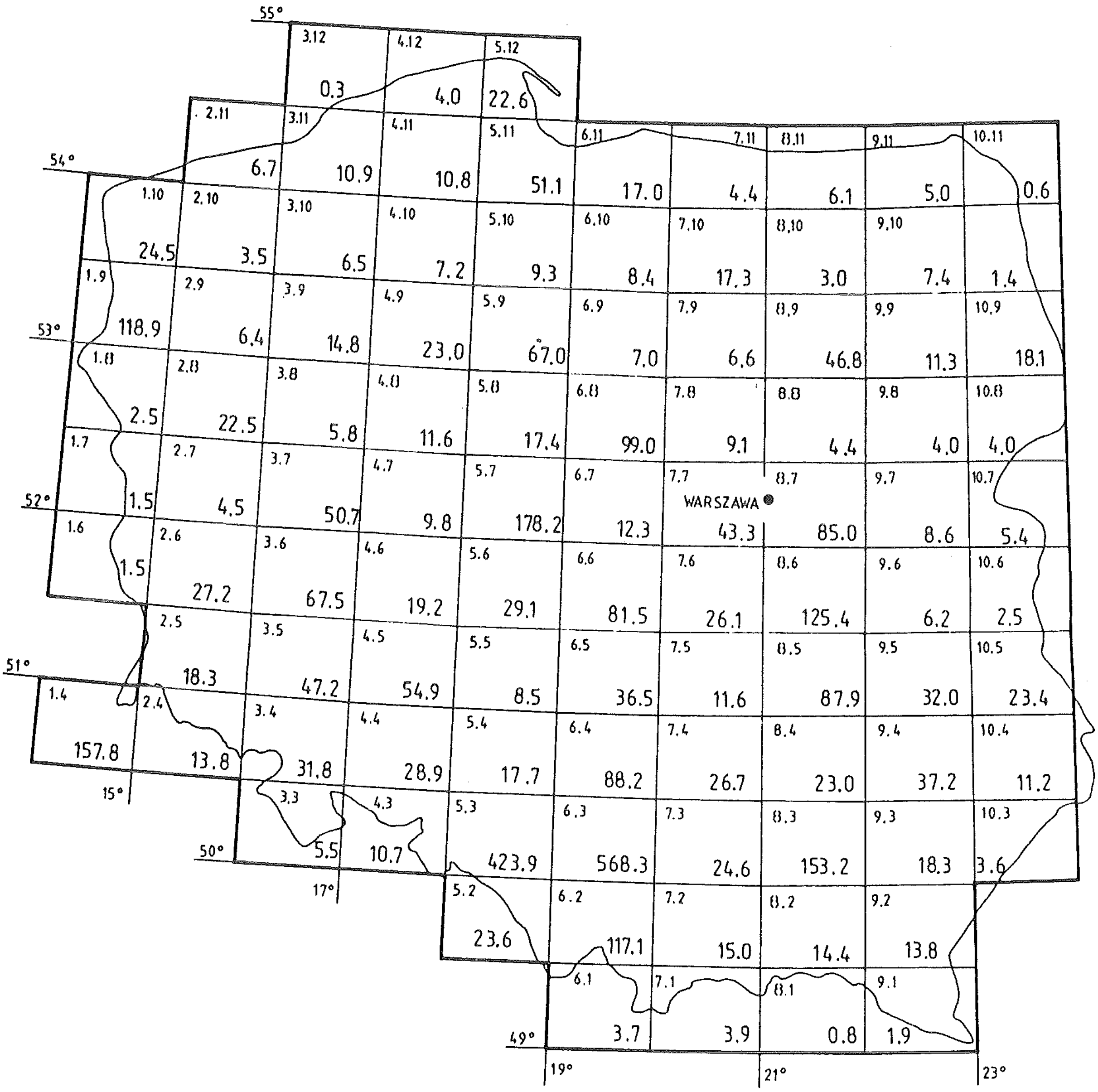

Fig. 2: SO_2 Emissions in Individual Grid Elements in 1982, 10^3 t Values Rounded

- in the report emissions have been estimated on the basis of fuel consumption statistics and sulphur content in fuels without detailed analysis of processes of fuel utilization. The fact that in some processes emissions are actually much lower than the emissions calculated for the sulphur content of fuels has not been taken into account. It refers first of all to coking plants, where 75 - 80 % of the sulphur remain in the coke and coking gas is cleaned for technological reasons. Similarly, in blast furnaces sulphur contained in coke is fixed to a great extent by slag. It is estimated that the real values of SO_2 emissions lie approximately 350 x 10^3 t below the values given in the report;
- in the period 1978 to 1982 a substantial reduction of fuel consumption took place in Poland because of the socio-economic crisis (see WEC 1986). Reduction of SO_2 emissions in 1982 compared with 1978 is estimated at more than 300 x 10^3 t because of lower economic activities.

Taking into account the two factors mentioned above, total SO_2 emissions computed in this work seem to be compatible with the emission data from (Juda et al. 1980).

It is worth explaining the differences between the value of total SO_2 emissions given in this study and that reported in the so-called environmental statistics of the Polish Central Statistical Office (GUS 1983a). The GUS data have not been properly interpreted in the above mentioned report of WZB / IIUG (Schreiber 1984). Information collected by GUS refers only to industrial plants recognized to be especially harmful for the environment. According to GUS estimates these statistics comprise about 90 % of all industrial plant emissions. Computations performed within the framework of this study based upon fuel consumption statistics in industry have confirmed the correctness of this estimate. In order to obtain total (domestic) emissions it is necessary to add to the GUS data emissions from industrial plants not included in the statistics, as well as emissions from the sectors 'transport' and 'households and others'.

Distributions of SO_2 emissions shown in this study are based, by nature, on many estimations and assumptions. Nevertheless it seems that absolute values for 1982 as well as their spatial distribution are fairly realistic.

It should be stressed that in the period 1982 to 1985 industrial SO_2 emissions have increased by about 220 thousand tons (GUS 1986), as a result of the economic recovery after the crisis years 1981 and 1982. Emissions from other sectors have not changed.

4.2 Emissions of Nitrogen Oxides

Table 5 presents NO_x emissions for the different economic sectors. Total emission is about 1.1 x 10^6 t NO_x annually, 56 % of which stem from industrial sources, 38% from the sector 'transport' and 6 % from 'households and others'. Spatial distribution of emissions of great fuel consumers is given in Table A-5. Tables A-6 and A-7 characterize emissions of the sectors 'other industrial users', 'transport' and 'households and others'. Finally, in Table A-8, emissions of individual economic sectors in grid areas have been summed up. Spatial distribution of emissions is also shown in Fig. 3.

NO_x emissions given in this study have been calculated assuming that emission coefficients associated with the use of fuels in industrial processes are the same as in the case of combustion in power boilers. These coefficients may differ significantly from those in the power industry in some cases. This is particularly true of nitrogen fertilizer plants, where the production of nitric acid makes a significant contribution to NO_x emissions at about 25 - 30 thousand tons of NO_x per year (Bistron 1986). However, while these emissions may be locally detrimental, they are insignificant on the national scale. This topic still requires investigation.

The industrial emissions of nitrogen oxides in 1982, calculated on the basis of the above assumptions (about 620 x 10^3 t), are higher than data cited by GUS (GUS 1986). GUS gives emissions of 610 x 10^3 t of N_2O_5 per year in 1982 - 83, which corresponds to 520 x 10^3 t of NO_2 per year. GUS statistics do not include all industrial plants, but only those which state administration authorities consider to be detrimental to the natural environment. For some of these plants information on nitrogen oxides emissions is not available because of a lack of data. Therefore, the higher values of the present calculations are justified. GUS data are not sufficient in the case of NO_x emissions and should be considered with caution.

Table 5: NO_x Emissions in 1982 for Economic Sectors and Emitter Heights

No	Sector / Energy Source	Fuel Consumption PJ	Emission Coefficient t/TJ	Emission 10^3 t/a	Emission %
1	2	3	4	5	6
A.	Industry (Including Construction)	2944.2	0.210	618.2	56.4
1.	- Great Consumers	1532.8	0.267	409.6	37.4
1.1	- Hard Coal	1167.8	0.29	338.7	30.9
1.2	- Brown Coal	277.0	0.18	49.9	4.6
1.3	- Fuel Oil	87.8	0.24	21.0	1.9
2.	- Others	1411.4	0.148	208.6	19.0
2.1	- Hard Coal	806.1	0.19	153.1	13.9
2.2	- Brown Coal	10.5	0.18	1.9	0.2
2.3	- Coke	98.6	0.12	11.8	1.1
2.4	- Fuel Oil	30.4	0.17	5.2	0.5
2.5	- Gaseous Fuels	365.8	0.10	36.6	3.5
B.	Transport	421.6	1.008	418.2	38.1
1.	- Hard Coal	78.7	0.051	4.0	0.4
2.	- Petrol	127.9	0.65	83.1	7.5
3.	- Diesel Oil	215.0	1.54	331.1	30.2
C.	Households and Others (Including Agriculture)	1215.6	0.0495	60.2	5.5
1.	- Hard Coal	942.2	0.051	48.1	4.4
2.	- Coke	167.3	0.051	8.5	0.8
3.	- Gaseous Fuels	106.1	0.034	3.6	0.3
D.	Total for the Country	4581.4	0.246	1096.6	100.0
E.	Emission Volumes by Emitter Heights				
1.	- 20 m and less	-	-	478.2	43.6
2.	- 50 - 150 m	-	-	423.3	38.6
3.	- 200 m and more	-	-	195.1	17.8

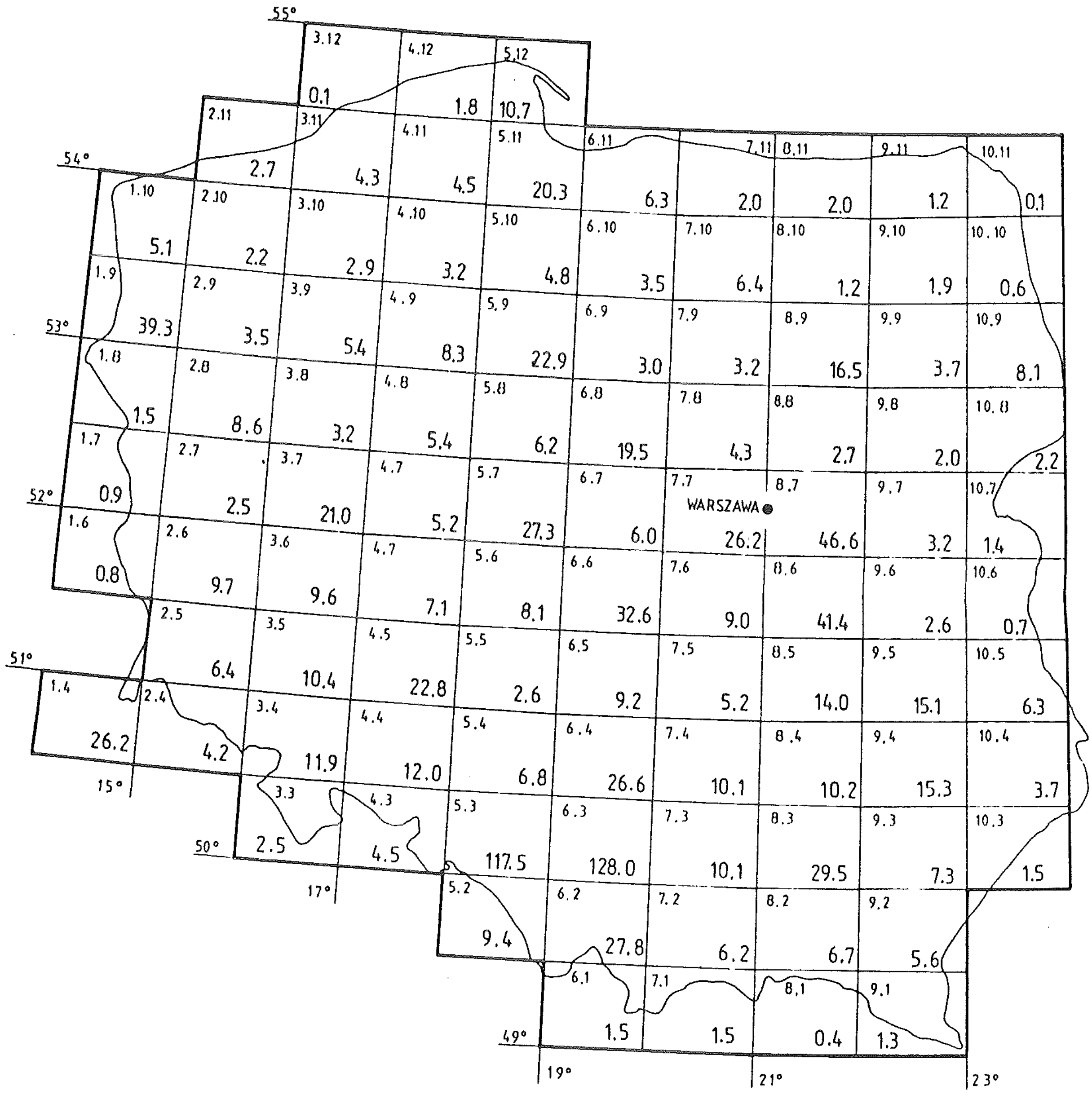

Fig. 3: NO_x Emissions in Individual Grid Elements in 1982, 10^3 t Values rounded

Total NO_x emissions in Poland calculated in this work are similar to the data given in (Bistron 1986), where emissions of NO_x in Poland in 1985 are estimated at about 1.2×10^6 t at a correspondingly higher use of fuels. Other estimates (see e.g. Nowicki 1985) based partially on the use of emission coefficients from foreign sources give higher values exceeding 1.5×10^6 t NO_x per year. It has already been mentioned in Section 3 that transposing foreign conditions to Poland does not always lead to satisfactory results.

The above considerations indicate a high uncertainty of NO_x emission level estimates in Poland and show the need of verifying the estimates by measurements. Such measurements are planned on a wider scale for the near future (Cieslinski, Baranowski 1986).

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Appendix Spatial Distribution of SO_2 and NO_x Emissions

Table A-1: SO_2 Emissions from Large Industrial Objects (Great Fuel Consumers) in 1982

No	Area No	Emitter Height Class	Emission from: Hard Coal		Brown Coal		Fuel Oil		Process Emissions	Total	Type of Emitters
			kg/GJ	10^3 t/a	kg/GJ	10^3 t/a	kg/GJ	10^3 t/a	10^3 t/a	10^3 t/a	
1	2	3	4	5	6	7	8	9	10	11	12
1	1.4	M	-	-	1.09	156.65	1.234	0.95	-	157.6	PPP
2	1.9	M	0.97	88.10	-	-	1.234	1.00	-	89.1	PPP
3	1.9	L	0.81	10.90	-	-	-	-	-	10.9	PPP
4	1.10	H	1.09	7.50	-	-	-	-	11.2	18.7	CHW with IPP
5	2.8	M	0.82	6.80	-	-	-	-	-	6.8	PPP
6	3.5	M	1.64	6.90	-	-	-	-	-	6.9	IPP
7	3.5	L	0.93	3.70	-	-	1.234	1.00	14.3	19.0	MEW with IPP
8	3.6	H	0.93	5.60	-	-	1.234	1.50	40.5	47.6	MEW with IPP
9	3.7	M	-	-	-	-	1.481	5.60	-	5.6	PHP
10	4.4	L	0.96	5.10	-	-	-	-	-	5.1	PHP
11	4.5	M	1.01	15.40	-	-	-	-	-	15.4	PPP
12	5.3	M	0.92	87.86	-	-	0.165 1)	0.54	19.8	108.2	PPP, IPP, CP, MEW
13	5.3	H	1.35	199.14	-	-	1.234	1.76	-	200.9	PPP
14	5.7	M	1.33	1.60	1.37	160.95	1.234	2.55	-	165.1	PPP
15	5.8	M	1.20	4.90	-	-	-	-	-	4.9	PPP
16	5.9	L	0.66	12.90	-	-	-	-	-	12.9	PPP
17	5.9	M	1.08	8.21	-	-	1.234	3.99	-	12.2	IPP
18	5.11	M	1.03	13.33	-	-	1.234	7.37	5.2	25.9	PPP, REF with IPP
19	5.12	M	0.93	9.40	-	-	-	-	-	9.4	PPP
20	6.2	M	1.64	81.89	-	-	1.234	1.11	-	83.0	PPP
21	6.3	H	1.78	269.83	-	-	0.145 1)	2.27	6.5	278.6	PPP, IPP, MEW with IPP
22	6.3	M	1.62	156.17	-	-	0.243 1)	1.13	23.4	180.7	PPP, IPP, MEW with IPP
23	6.4	M	0.96	9.20	-	-	0.000 1)	0.00	5.0	14.2	MEW with IPP
24	6.5	H	-	-	1.21	19.41	1.234	1.19	-	20.6	PPP
25	6.6	M	1.08	35.05	-	-	1.234	0.95	-	36.0	PPP
26	6.6	H	0.73	6.60	-	-	-	-	-	6.6	PPP
27	6.8	M	-	-	-	-	1.481	42.40	28.2	70.6	REF with IPP
28	7.3	M	1.07	6.60	-	-	-	-	-	6.6	IPP
29	7.6	M	1.38	11.90	-	-	-	-	-	11.9	IPP
30	7.7	L	-	-	-	-	1.481	6.80	-	6.8	PHP
31	8.3	H	1.93	126.36	-	-	1.234	1.34	-	127.7	PPP
32	8.4	M	1.12	5.80	-	-	-	-	-	5.8	IPP
33	8.5	M	1.26	11.20	-	-	-	-	-	11.2	IPP
34	8.6	H	0.90	117.11	-	-	1.234	2.39	-	119.5	PPP
35	8.7	M	0.69	29.78	-	-	1.234	1.22	-	31.0	PPP

Table A-1 continued:

No	Area No	Emitter Height Class	Emission from:						Process Emissions	Total	Type of Emitters
			Hard Coal		Brown Coal		Fuel Oil				
			kg/GJ	10^3 t/a	kg/GJ	10^3 t/a	kg/GJ	10^3 t/a	10^3 t/a	10^3 t/a	
1	2	3	4	5	6	7	8	9	10	11	12
36	8.7	H	0.69	15.27	-	-	1.234	0.63	-	15.9	PPP
37	8.9	M	0.87	36.60	-	-	1.234	0.80	-	37.4	PPP
38	9.4	L	0.85	7.00	-	-	-	-	-	7.0	PPP
39	9.4	M	0.85	15.50	-	-	-	-	-	15.5	PPP
40	10.9	M	0.68	5.00	-	-	-	-	-	5.0	PPP
	Total		1.228	1434.20	1.217	337.01	1.008 [1)]	88.49	154.1	2013.8	

Abbreviations:

PPP - public power plant(s); PHP - public heating plant(s); IPP - industrial power plant(s);
CHW - chemical works; MEW - metallurgical works; REF - refinery(s); CP - coking plant(s).

Emitter height classes:

L - low ≈ 50 m
M - medium 100 - 150 m
H - high ≧ 200 m

1) Coefficient refers to total consumption of fuel oil in a given area. Emissions resulting from fuel oil burning in industrial processes outside power boilers have been included in the column 'process emission'.

Table A-2: SO_2 Emissions in the Sector 'Other Industrial Users' /Industry without Great Consumers/ in Individual Grid Areas in 1982

No	Area Designation	SO_2 Emission, 10^3 t SO_2/a from:					
		Hard Coal	Brown Coal	Coke	Fuel Oil	Process Emissions	Total
1	2	3	4	5	6	7	8
1	1.4	-	-	-	-	-	-
2	1.6	-	-	-	-	-	-
3	1.7	-	-	-	-	-	-
4	1.8	-	-	-	-	-	-
5	1.9	2.79	-	2.47	1.10	1.25	7.61
6	1.10	0.56	-	0.49	0.22	0.25	1.52
7	2.4	4.93	3.76	0.48	-	-	9.17
8	2.5	5.40	4.12	0.52	-	-	10.04
9	2.6	13.80	1.79	0.64	1.00	-	17.23
10	2.7	-	-	-	-	-	-
11	2.8	9.00	-	-	-	-	9.00
12	2.9	0.45	-	0.40	0.18	0.20	1.23
13	2.10	-	-	-	-	-	-
14	2.11	2.82	-	0.05	0.32	-	3.19
15	3.3	0.69	-	0.09	0.12	0.31	1.21
16	3.4	9.18	0.96	1.15	1.38	3.59	16.26
17	3.5	2.35	-	3.18	-	6.84	12.37
18	3.6	4.94	-	1.25	-	2.46	8.65
19	3.7	20.80	-	0.98	-	-	21.78
20	3.8	-	-	-	-	-	-
21	3.9	6.66	-	0.52	-	-	7.18
22	3.10	1.64	-	0.03	0.19	-	1.86
23	3.11	4.35	-	0.08	0.49	-	4.92
24	3.12	-	-	-	-	-	-
25	4.3	2.51	-	1.44	-	-	3.95
26	4.4	6.75	-	3.47	0.13	-	10.35
27	4.5	17.02	-	0.92	2.86	-	20.80
28	4.6	6.05	-	0.17	-	-	6.22
29	4.7	1.57	-	0.08	-	-	1.65

Table A-2 continued

1	2	3	4	5	6	7	8
30	4.8	3.68	-	0.23	-	-	3.91
31	4.9	11.74	-	1.13	0.40	-	13.27
32	4.10	2.03	-	0.19	0.07	-	2.29
33	4.11	4.32	-	0.01	0.01	-	4.34
34	4.12	1.37	-	-	-	-	1.37
35	5.2	9.69	-	1.17	0.86	0.25	11.97
36	5.3	48.71	-	6.58	5.01	1.58	61.88
37	5.4	6.40	-	1.21	-	-	7.61
38	5.5	-	-	-	-	-	-
39	5.6	14.15	-	0.15	0.50	-	14.80
40	5.7	4.00	-	-	-	-	4.00
41	5.8	4.08	-	0.39	0.14	-	4.61
42	5.9	22.32	-	1.45	0.40	-	24.17
43	5.10	3.13	-	0.02	0.03	-	3.18
44	5.11	8.62	-	0.29	0.30	-	9.21
45	5.12	4.80	-	0.16	0.16	-	5.12
46	6.1	1.04	-	0.06	-	-	1.10
47	6.2	15.17	-	2.45	0.37	-	17.99
48	6.3	43.27	-	7.63	3.77	1.17	55.84
49	6.4	55.87	-	2.95	-	-	58.82
50	6.5	4.82	-	0.46	-	-	5.28
51	6.6	16.60	-	2.56	-	-	19.16
52	6.7	3.61	-	0.14	-	-	3.75
53	6.8	13.39	-	0.34	1.50	-	15.23
54	6.9	0.83	-	0.02	-	-	0.85
55	6.10	2.62	-	0.07	0.51	-	3.20
56	6.11	10.95	-	-	-	-	10.95
57	7.1	1.04	-	0.06	-	-	1.10
58	7.2	4.87	-	0.14	-	-	5.01
59	7.3	7.37	-	-	-	-	7.37
60	7.4	10.33	-	2.93	1.34	-	14.60
61	7.5	2.40	-	0.68	0.31	-	3.39
62	7.6	4.33	-	0.19	-	-	4.52
63	7.7	14.85	-	0.27	0.85	-	15.97
64	7.8	2.28	-	-	-	-	2.28
65	7.9	1.52	-	-	-	-	1.52

Table A-2 continued

1	2	3	4	5	6	7	8
66	7.10	7.88	-	0.20	1.54	-	9.62
67	7.11	1.01	-	0.03	0.20	-	1.24
68	8.1	-	-	-	-	-	-
69	8.2	5.49	-	0.06	1.04	-	6.59
70	8.3	13.98	-	0.09	-	-	14.07
71	8.4	5.48	-	1.12	0.48	0.86	7.94
72	8.5	10.65	-	1.22	0.58	2.40	14.85
73	8.6	-	-	-	-	-	-
74	8.7	14.67	-	0.37	1.15	-	16.19
75	8.8	-	-	-	-	-	-
76	8.9	4.80	-	-	-	-	4.80
77	8.10	-	-	-	-	-	-
78	8.11	2.48	-	0.03	0.35	-	2.86
79	9.1	-	-	-	-	-	-
80	9.2	5.28	-	-	2.02	-	7.30
81	9.3	7.73	-	0.07	0.94	-	8.74
82	9.4	5.51	-	0.15	0.16	0.84	6.66
83	9.5	18.05	-	0.78	1.62	-	20.45
84	9.6	0.94	-	-	-	-	0.94
85	9.7	2.18	-	-	-	-	2.18
86	9.8	-	-	-	-	-	-
87	9.9	4.20	-	-	2.50	-	6.70
88	9.10	3.07	-	-	0.24	-	3.31
89	9.11	2.13	-	-	0.17	-	2.30
90	10.3	-	-	-	-	-	-
91	10.4	4.58	-	-	-	-	4.58
92	10.5	18.60	-	-	-	-	18.60
93	10.6	-	-	-	-	-	-
94	10.7	2.40	-	0.48	-	-	2.88
95	10.8	1.27	-	-	-	-	1.27
96	10.9	6.93	-	-	-	-	6.93
97	10.10	-	-	-	-	-	-
98	10.11	-	-	-	-	-	-
99	Total	639.77	10.63	56.94	37.51	22.00	766.85

Table A-3: SO_2 Emissions for the Sectors 'Transport' and 'Households and Others' (including Agriculture) in Individual Grid Areas in 1982

No	Area Designation	Transport			Households and Others		
		Emission, 10^3 t SO_2/a from:			Emission, 10^3 t SO_2/a from:		
		Hard Coal	Diesel Oil	Total	Hard Coal	Coke	Total
1	2	3	4	5	6	7	8
1	1.4	0.03	0.01	0.04	0.13	0.04	0.17
2	1.6	0.22	0.11	0.33	1.00	0.18	1.18
3	1.7	0.22	0.11	0.33	1.00	0.17	1.17
4	1.8	0.32	0.21	0.53	1.63	0.34	1.97
5	1.9	0.93	0.99	1.92	6.98	2.38	9.36
6	1.10	0.35	0.38	0.73	2.65	0.90	3.55
7	2.4	0.55	0.27	0.82	2.96	0.82	3.78
8	2.5	0.99	0.52	1.51	5.39	1.35	6.74
9	2.6	1.44	0.74	2.18	6.61	1.16	7.77
10	2.7	0.67	0.34	1.01	2.99	0.50	3.49
11	2.8	1.02	0.54	1.56	4.47	0.65	5.12
12	2.9	0.53	0.44	0.97	3.32	0.85	4.17
13	2.10	0.30	0.29	0.59	2.28	0.63	2.91
14	2.11	0.30	0.26	0.56	2.46	0.48	2.94
15	3.3	0.29	0.27	0.56	3.04	0.69	3.73
16	3.4	1.09	1.02	2.11	10.85	2.55	13.40
17	3.5	0.94	0.77	1.71	6.02	1.21	7.23
18	3.6	1.06	0.70	1.76	8.41	1.08	9.49
19	3.7	1.48	1.81	3.29	17.17	2.85	20.02
20	3.8	0.51	0.40	0.91	4.33	0.56	4.89
21	3.9	0.86	0.46	1.32	5.70	0.56	6.26
22	3.10	0.42	0.34	0.76	3.32	0.60	3.92
23	3.11	0.54	0.43	0.97	4.18	0.80	4.98
24	3.12	0.03	0.01	0.04	0.19	0.05	0.24
25	4.3	0.53	0.36	0.89	5.15	0.73	5.88
26	4.4	1.05	0.80	1.85	10.01	1.63	11.64
27	4.5	1.30	1.73	3.03	12.35	3.27	15.62
28	4.6	0.63	0.69	1.32	10.78	0.84	11.62
29	4.7	0.44	0.59	1.03	6.27	0.83	7.10
30	4.8	0.64	0.55	1.19	5.71	0.82	6.53
31	4.9	0.98	0.63	1.61	7.20	0.93	8.13
32	4.10	0.49	0.32	0.81	3.52	0.59	4.11
33	4.11	0.63	0.45	1.08	4.38	0.96	5.34
34	4.12	0.26	0.18	0.44	1.80	0.40	2.20

Table A-3 continued:

1	2	3	4	5	6	7	8
35	5.2	0.43	0.67	1.10	9.65	0.90	10.55
36	5.3	1.92	3.01	4.93	44.25	3.73	47.98
37	5.4	0.69	0.54	1.23	7.94	0.89	8.83
38	5.5	0.42	0.28	0.70	7.23	0.56	7.79
39	5.6	0.62	0.50	1.12	12.33	0.82	13.15
40	5.7	0.32	0.54	0.86	7.95	0.29	8.24
41	5.8	0.54	0.48	1.02	6.22	0.68	6.90
42	5.9	1.65	1.02	2.67	13.35	1.67	15.02
43	5.10	0.52	0.52	1.04	4.33	0.71	5.04
44	5.11	1.10	1.71	2.81	11.10	2.05	13.15
45	5.12	0.55	0.87	1.42	5.63	1.04	6.67
46	6.1	0.14	0.14	0.28	1.95	0.38	2.33
47	6.2	0.75	0.99	1.74	12.70	1.71	14.41
48	6.3	1.66	3.60	5.26	43.49	4.43	47.92
49	6.4	0.91	0.82	1.73	12.34	1.07	13.41
50	6.5	0.50	0.55	1.05	8.84	0.77	9.61
51	6.6	0.57	1.97	2.54	14.43	2.73	17.16
52	6.7	0.39	0.70	1.09	6.97	0.44	7.41
53	6.8	0.47	0.93	1.40	11.07	0.70	11.77
54	6.9	0.44	0.35	0.79	4.84	0.50	5.34
55	6.10	0.55	0.37	0.92	3.70	0.57	4.27
56	6.11	0.64	0.43	1.07	4.29	0.69	4.98
57	7.1	0.15	0.15	0.30	2.03	0.44	2.47
58	7.2	0.41	0.56	0.97	7.82	1.20	9.02
59	7.3	0.38	0.72	1.10	8.72	0.83	9.55
60	7.4	0.57	0.87	1.44	9.70	0.92	10.62
61	7.5	0.37	0.58	0.95	6.64	0.58	7.22
62	7.6	0.48	0.72	1.20	7.74	0.76	8.50
63	7.7	0.80	2.55	3.35	13.66	3.53	17.19
64	7.8	0.32	0.50	0.82	5.62	0.42	6.04
65	7.9	0.34	0.38	0.72	3.95	0.39	4.34
66	7.10	0.83	0.56	1.39	5.47	0.85	6.32
67	7.11	0.34	0.23	0.57	2.25	0.35	2.60

Table A-3 continued:

1	2	3	4	5	6	7	8
68	8.1	0.05	0.06	0.11	0.58	0.10	0.68
69	8.2	0.43	0.56	0.99	6.10	0.72	6.82
70	8.3	0.46	0.77	1.23	9.50	0.69	10.19
71	8.4	0.69	0.71	1.40	7.28	0.61	7.89
72	8.5	0.56	1.11	1.67	11.03	0.98	12.01
73	8.6	0.30	0.44	0.74	4.69	0.42	5.11
74	8.7	0.86	2.74	3.60	14.32	3.94	18.26
75	8.8	0.30	0.37	0.67	3.37	0.31	3.68
76	8.9	0.30	0.40	0.70	3.57	0.35	3.92
77	8.10	0.32	0.14	0.46	2.23	0.32	2.55
78	8.11	0.35	0.16	0.51	2.40	0.35	2.75
79	9.1	0.16	0.18	0.34	1.38	0.17	1.55
80	9.2	0.34	0.45	0.79	5.16	0.55	5.71
81	9.3	0.46	0.67	1.13	7.75	0.66	8.41
82	9.4	0.57	0.58	1.15	6.36	0.54	6.90
83	9.5	0.37	1.06	1.43	8.95	1.17	10.12
84	9.6	0.33	0.28	0.61	4.27	0.41	4.68
85	9.7	0.47	0.32	0.79	5.18	0.41	5.59
86	9.8	0.25	0.26	0.51	3.19	0.31	3.50
87	9.9	0.24	0.30	0.54	3.64	0.37	4.01
88	9.10	0.39	0.09	0.48	3.21	0.39	3.60
89	9.11	0.30	0.03	0.33	2.13	0.28	2.41
90	10.3	0.19	0.20	0.39	2.92	0.26	3.18
91	10.4	0.41	0.33	0.74	5.43	0.43	5.86
92	10.5	0.30	0.21	0.51	3.81	0.49	4.30
93	10.6	0.18	0.06	0.24	2.04	0.22	2.26
94	10.7	0.20	0.06	0.26	2.01	0.22	2.23
95	10.8	0.26	0.26	0.52	1.86	0.34	2.20
96	10.9	0.58	0.59	1.17	4.18	0.78	4.96
97	10.10	0.14	0.07	0.21	1.01	0.16	1.17
98	10.11	0.06	0.01	0.07	0.47	0.06	0.53
99	Total	53.63	60.00	113.63	642.47	87.01	729.48

Table A-4: SO_2 Emissions in Individual Grid Areas in 1982, 10^3 t

No	Area Designation	Industry (including Construction)			Trans-port	Households and Others (including Agriculture)	Total
		Total	in this				
			Great Consumers	Others			
1	2	3	4	5	6	7	8
1	1.4	157.60	157.60	-	0.04	0.17	157.81
2	1.6	-	-	-	0.33	1.18	1.51
3	1.7	-	-	-	0.33	1.17	1.50
4	1.8	-	-	-	0.53	1.97	2.50
5	1.9	107.61	100.00	7.61	1.92	9.36	118.89
6	1.10	20.22	18.70	1.52	0.73	3.55	24.50
7	2.4	9.17	-	9.17	0.82	3.78	13.77
8	2.5	10.04	-	10.04	1.51	6.74	18.29
9	2.6	17.23	-	17.23	2.18	7.77	27.18
10	2.7	-	-	-	1.01	3.49	4.50
11	2.8	15.80	6.80	9.00	1.56	5.12	22.48
12	2.9	1.23	-	1.23	0.97	4.17	6.37
13	2.10	-	-	-	0.59	2.91	3.50
14	2.11	3.19	-	3.19	0.56	2.94	6.69
15	3.3	1.21	-	1.21	0.56	3.73	5.50
16	3.4	16.26	-	16.26	2.11	13.40	31.77
17	3.5	38.27	25.90	12.37	1.71	7.23	47.21
18	3.6	56.25	47.60	8.65	1.76	9.49	67.50
19	3.7	27.38	5.60	21.78	3.29	20.02	50.69
20	3.8	-	-	-	0.91	4.89	5.80
21	3.9	7.18	-	7.18	1.32	6.26	14.76
22	3.10	1.86	-	1.86	0.76	3.92	6.54
23	3.11	4.92	-	4.92	0.97	4.98	10.87
24	3.12	-	-	-	0.04	0.24	0.28
25	4.3	3.95	-	3.95	0.89	5.88	10.72
26	4.4	15.45	5.10	10.35	1.85	11.64	28.94
27	4.5	36.20	15.40	20.80	3.03	15.62	54.85
28	4.6	6.22	-	6.22	1.32	11.62	19.16
29	4.7	1.65	-	1.65	1.03	7.10	9.78
30	4.8	3.91	-	3.91	1.19	6.53	11.63
31	4.9	13.27	-	13.27	1.61	8.13	23.01
32	4.10	2.29	-	2.29	0.81	4.11	7.21
33	4.11	4.34	-	4.34	1.08	5.34	10.76
34	4.12	1.37	-	1.37	0.44	2.20	4.01

Table A-4 continued

1	2	3	4	5	6	7	8
35	5.2	11.97	-	11.97	1.10	10.55	23.62
36	5.3	370.98	309.10	61.88	4.93	47.98	423.89
37	5.4	7.61	-	7.61	1.23	8.83	17.67
38	5.5	-	-	-	0.70	7.79	8.49
39	5.6	14.80	-	14.80	1.12	13.15	29.07
40	5.7	169.10	165.10	4.00	0.86	8.24	178.20
41	5.8	9.51	4.90	4.61	1.02	6.90	17.43
42	5.9	49.27	25.10	24.17	2.67	15.02	66.96
43	5.10	3.18	-	3.18	1.04	5.04	9.26
44	5.11	35.11	25.90	9.21	2.81	13.15	51.07
45	5.12	14.52	9.40	5.12	1.42	6.67	22.61
46	6.1	1.10	-	1.10	0.28	2.33	3.71
47	6.2	100.99	83.00	17.99	1.74	14.41	117.14
48	6.3	515.14	459.30	55.84	5.26	47.92	568.32
49	6.4	73.02	14.20	58.82	1.73	13.41	88.16
50	6.5	25.88	20.60	5.28	1.05	9.61	36.54
51	6.6	61.76	42.60	19.16	2.54	17.16	81.46
52	6.7	3.75	-	3.75	1.09	7.41	12.25
53	6.8	85.83	70.60	15.23	1.40	11.77	99.00
54	6.9	0.85	-	0.85	0.79	5.34	6.98
55	6.10	3.20	-	3.20	0.92	4.27	8.39
56	6.11	10.95	-	10.95	1.07	4.98	17.00
57	7.1	1.10	-	1.10	0.30	2.47	3.87
58	7.2	5.01	-	5.01	0.97	9.02	15.00
59	7.3	13.97	6.60	7.37	1.10	9.55	24.62
60	7.4	14.60	-	14.60	1.44	10.62	25.66
61	7.5	3.39	-	3.39	0.95	7.22	11.56
62	7.6	16.42	11.90	4.52	1.20	8.50	26.12
63	7.7	22.77	6.80	15.97	3.35	17.19	43.31
64	7.8	2.28	-	2.28	0.82	6.04	9.14
65	7.9	1.52	-	1.52	0.72	4.34	6.58
66	7.10	9.62	-	9.62	1.39	6.32	17.33
67	7.11	1.24	-	1.24	0.57	2.60	4.41

Table A-4 continued

1	2	3	4	5	6	7	8
68	8.1	-	-	-	0.11	0.68	0.79
69	8.2	6.59	-	6.59	0.99	6.82	14.40
70	8.3	141.77	127.70	14.07	1.23	10.19	153.19
71	8.4	13.74	5.80	7.94	1.40	7.89	23.03
72	8.5	26.05	11.20	14.85	1.67	12.01	39.73
73	8.6	119.50	119.50	-	0.74	5.11	125.35
74	8.7	63.09	46.90	16.19	3.60	18.26	84.95
75	8.8	-	-	-	0.67	3.68	4.35
76	8.9	42.20	37.40	4.80	0.70	3.92	46.82
77	8.10	-	-	-	0.46	2.55	3.01
78	8.11	2.86	-	2.86	0.51	2.75	6.12
79	9.1	-	-	-	0.34	1.55	1.89
80	9.2	7.30	-	7.30	0.79	5.71	13.80
81	9.3	8.74	-	8.74	1.13	8.41	18.28
82	9.4	29.16	22.50	6.66	1.15	6.90	37.21
83	9.5	20.45	-	20.45	1.43	10.12	32.00
84	9.6	0.94	-	0.94	0.61	4.68	6.23
85	9.7	2.18	-	2.18	0.79	5.59	8.56
86	9.8	-	-	-	0.51	3.50	4.01
87	9.9	6.70	-	6.70	0.54	4.01	11.25
88	9.10	3.31	-	3.31	0.48	3.60	7.39
89	9.11	2.30	-	2.30	0.33	2.41	5.04
90	10.3	-	-	-	0.39	3.18	3.57
91	10.4	4.58	-	4.58	0.74	5.86	11.18
92	10.5	18.60	-	18.60	0.51	4.30	23.41
93	10.6	-	-	-	0.24	2.26	2.50
94	10.7	2.88	-	2.88	0.26	2.23	5.37
95	10.8	1.27	-	1.27	0.52	2.20	3.99
96	10.9	11.93	5.00	6.93	1.17	4.96	18.06
97	10.10	-	-	-	0.21	1.17	1.38
98	10.11	-	-	-	0.07	0.53	0.60
99	Total	2780.65	2013.80	766.85	113.63	729.48	3623.76

Table A-5: NO_x Emissions from Large Industrial Objects (Great Fuel Consumers) in 1982

No	Area No	Emitter Height Class	Emission, 10^3 t NO_x/a from:				Sort of Emitters
			Hard Coal	Brown Coal	Fuel Oil	Total	
1	2	3	4	5	6	7	8
1	1.4	M	-	25.90	0.18	26.08	PPP
2	1.9	M	26.28	-	0.19	26.47	PPP
3	1.9	L	3.89	-	-	3.89	PPP
4	1.10	H	2.00	-	-	2.00	CHW with IPP
5	2.8	M	2.39	-	-	2.39	PPP
6	3.5	M	1.22	-	-	1.22	IPP
7	3.5	L	1.16	-	0.19	1.35	MEW with IPP
8	3.6	H	1.74	-	0.29	2.03	MEW with IPP
9	3.7	M	-	-	0.90	0.90	PHP
10	4.4	L	1.54	-	-	1.54	PHP
11	4.5	M	4.43	-	-	4.43	PPP
12	5.3	M	27.68	-	0.79	28.47	PPP, IPP, CP, MEW
13	5.3	H	42.87	-	0.34	43.21	PPP
14	5.7	M	0.35	21.07	0.50	21.92	PPP
15	5.8	M	1.19	-	-	1.19	PPP
16	5.9	L	5.71	-	-	5.71	PPP
17	5.9	M	2.21	-	0.78	2.99	IPP
18	5.11	M	3.74	-	1.44	5.18	PPP, REF with IPP
19	5.12	M	2.93	-	-	2.93	PPP
20	6.2	M	14.50	-	0.22	14.72	PPP
21	6.3	H	44.01	-	3.76	47.77	PPP, IPP, MEW with IPP
22	6.3	M	27.95	-	1.13	29.08	PPP, IPP, MEW with IPP
23	6.4	M	2.78	-	0.70	3.48	MEW with IPP
24	6.5	H	-	2.90	0.23	3.13	PPP
25	6.6	M	9.42	-	0.19	9.61	PPP
26	6.6	H	2.61	-	-	2.61	PPP
27	6.8	M	-	-	6.88	6.88	REF with IPP
28	7.3	M	1.80	-	-	1.80	IPP
29	7.6	M	2.49	-	-	2.49	IPP

Table A-5 continued

1	2	3	4	5	6	7	8
30	7.7	L	-	-	1.11	1.11	PHP
31	8.3	H	18.97	-	0.26	19.23	PPP
32	8.4	M	1.51	-	-	1.51	IPP
33	8.5	M	2.58	-	-	2.58	IPP
34	8.6	H	37.65	-	0.46	38.11	PPP
35	8.7	M	12.52	-	0.24	12.76	PPP
36	8.7	H	6.42	-	0.12	6.54	PPP
37	8.9	M	12.27	-	0.16	12.43	PPP
38	9.4	L	2.40	-	-	2.40	PPP
39	9.4	M	5.31	-	-	5.31	PPP
40	10.9	M	2.15	-	-	2.15	PPP
		Total	338.67	49.87	21.06	409.60	

Abbreviations:

PPP - Public Power Plant(s); PHP - Public Heating Plant(s); IPP - Industrial Power Plant(s); CHW - Chemical Works; MEW - Metallurgical Works; REF - Refinery(s); CP - Coking Plant (s).

Emitter Height Classes:

L - low ≈ 50 m
M - medium 100 - 150 m
H - high ≧ 200 m

Table A-6: NO_x Emissions for the Sector 'Other Industrial Users' (Industry without Great Consumers) in Individual Grid Areas in 1982

No	Area Designation	Emission, 10^3 t NO_x/a from:					
		Hard Coal	Brown Coal	Coke	Fuel Oil	Gaseous Fuels	Total
1	2	3	4	5	6	7	8
1	1.4	-	-	-	-	-	-
2	1.6	-	-	-	-	-	-
3	1.7	-	-	-	-	-	-
4	1.8	-	-	-	-	-	-
5	1.9	0.67	-	0.51	0.15	0.03	1.36
6	1.10	0.13	-	0.10	0.03	0.01	0.27
7	2.4	1.18	0.67	0.10	-	0.07	2.02
8	2.5	1.30	0.73	0.11	-	0.08	2.22
9	2.6	3.30	0.32	0.13	0.14	0.20	4.09
10	2.7	-	-	-	-	-	-
11	2.8	2.15	-	-	-	0.03	2.18
12	2.9	0.11	-	0.08	0.03	0.00	0.22
13	2.10	-	-	-	-	-	-
14	2.11	0.68	-	0.01	0.04	0.01	0.74
15	3.3	0.17	-	0.02	0.02	0.08	0.29
16	3.4	2.20	0.17	0.24	0.19	0.99	3.79
17	3.5	0.56	-	0.66	-	0.62	1.84
18	3.6	1.18	-	0.26	-	0.35	1.79
19	3.7	4.98	-	0.21	-	0.13	5.32
20	3.8	-	-	-	-	-	-
21	3.9	1.59	-	0.11	-	0.16	1.86
22	3.10	0.39	-	0.01	0.03	-	0.43
23	3.11	1.04	-	0.02	0.07	0.02	1.15
24	3.12	-	-	-	-	-	-
25	4.3	0.60	-	0.30	-	0.67	1.57
26	4.4	1.62	-	0.72	0.02	1.59	3.95
27	4.5	4.07	-	0.19	0.39	0.21	4.86
28	4.6	1.45	-	0.03	-	0.05	1.53
29	4.7	0.38	-	0.02	-	-	0.40

Table A-6 continued

1	2	3	4	5	6	7	8
30	4.8	0.88	-	0.05	-	0.05	0.98
31	4.9	2.81	-	0.24	0.05	0.03	3.13
32	4.10	0.49	-	0.04	0.01	-	0.54
33	4.11	1.04	-	-	-	-	1.04
34	4.12	0.33	-	-	-	-	0.33
35	5.2	2.32	-	0.24	0.12	0.88	3.56
36	5.3	11.66	-	1.37	0.69	5.86	19.58
37	5.4	1.53	-	0.25	-	0.56	2.34
38	5.5	-	-	-	-	-	-
39	5.6	3.39	-	0.03	0.07	0.05	3.54
40	5.7	0.96	-	-	-	-	0.96
41	5.8	0.98	-	0.08	0.02	0.01	1.09
42	5.9	5.35	-	0.30	0.05	0.05	5.75
43	5.10	0.75	-	-	-	0.02	0.77
44	5.11	2.07	-	0.06	0.04	0.14	2.31
45	5.12	1.15	-	0.03	0.02	0.08	1.28
46	6.1	0.25	-	0.01	-	0.03	0.29
47	6.2	3.63	-	0.51	0.05	0.51	4.70
48	6.3	10.36	-	1.59	0.52	7.89	20.36
49	6.4	13.38	-	0.61	-	1.39	15.38
50	6.5	1.16	-	0.09	-	0.23	1.48
51	6.6	3.98	-	0.53	-	0.08	4.59
52	6.7	0.86	-	0.03	-	-	0.89
53	6.8	3.20	-	0.07	0.21	1.27	4.75
54	6.9	0.20	-	-	-	-	0.20
55	6.10	0.63	-	0.01	0.07	-	0.71
56	6.11	2.62	-	-	-	0.02	2.64
57	7.1	0.25	-	0.01	-	0.03	0.29
58	7.2	1.17	-	0.03	-	0.33	1.53
59	7.3	1.77	-	-	-	0.76	2.53
60	7.4	2.47	-	0.61	0.19	0.33	3.60
61	7.5	0.57	-	0.14	0.04	0.08	0.83
62	7.6	1.04	-	0.04	-	0.10	1.18
63	7.7	3.55	-	0.06	0.12	0.72	4.45
64	7.8	0.55	-	-	-	0.00	0.55
65	7.9	0.36	-	-	-	0.00	0.36

Table A-6 continued

1	2	3	4	5	6	7	8
66	7.10	1.89	-	0.04	0.21	0.01	2.15
67	7.11	0.24	-	-	0.03	0.00	0.27
68	8.1	-	-	-	-	-	-
69	8.2	1.31	-	0.01	0.14	0.83	2.29
70	8.3	3.35	-	0.02	-	0.76	4.13
71	8.4	1.31	-	0.23	0.07	1.79	3.40
72	8.5	2.55	-	0.25	0.07	0.45	3.32
73	8.6	-	-	-	-	-	-
74	8.7	3.51	-	0.08	0.16	0.99	4.74
75	8.8	-	-	-	-	-	-
76	8.9	1.15	-	-	-	-	1.15
77	8.10	-	-	-	-	-	-
78	8.11	0.59	-	0.01	0.05	-	0.65
79	9.1	-	-	-	-	-	-
80	9.2	1.26	-	-	0.28	0.56	2.10
81	9.3	1.85	-	0.01	0.13	0.18	2.17
82	9.4	1.32	-	0.03	0.02	1.86	3.23
83	9.5	4.32	-	0.16	0.22	2.29	6.99
84	9.6	0.22	-	-	-	0.02	0.24
85	9.7	0.52	-	-	-	0.04	0.56
86	9.8	-	-	-	-	-	-
87	9.9	1.00	-	-	0.35	-	1.35
88	9.10	0.73	-	-	0.03	-	0.76
89	9.11	0.51	-	-	0.02	-	0.53
90	10.3	-	-	-	-	-	-
91	10.4	1.10	-	-	-	-	1.10
92	10.5	4.45	-	-	-	-	4.45
93	10.6	-	-	-	-	-	-
94	10.7	0.57	-	0.10	-	-	0.67
95	10.8	0.30	-	-	-	-	0.30
96	10.9	1.66	-	-	-	0.02	1.68
97	10.10	-	-	-	-	-	-
98	10.11	-	-	-	-	-	-
99	Total	153.17	1.89	11.80	5.16	36.60	208.62

Table A-7: NO_x Emissions for the Sectors 'Transport' and 'Households and Others' (including Agriculture) in Individual Graticule Areas in 1982

No	Area Designation	Transport				Households and Others			
		Emission, 10^3 t NO_x/a from:				Emission, 10^3 t NO_x/a from:			
		Hard Coal	Petrol	Diesel Oil	Total	Hard Coal	Coke	Gaseous Fuels	Total
1	2	3	4	5	6	7	8	9	10
1	1.4	-	0.01	0.06	0.07	0.1	-	-	0.01
2	1.6	0.02	0.10	0.62	0.74	0.7	0.2	-	0.09
3	1.7	0.02	0.10	0.65	0.77	0.7	0.2	-	0.09
4	1.8	0.02	0.21	1.14	1.37	0.12	0.03	-	0.15
5	1.9	0.07	1.17	5.47	6.71	0.52	0.23	0.08	0.83
6	1.10	0.03	0.44	2.08	2.55	0.20	0.09	0.02	0.31
7	2.4	0.04	0.33	1.51	1.88	0.22	0.08	0.03	0.33
8	2.5	0.07	0.63	2.90	3.60	0.40	0.13	0.03	0.56
9	2.6	0.11	0.72	4.11	4.94	0.50	0.11	0.04	0.65
10	2.7	0.05	0.32	1.89	2.26	0.22	0.05	-	0.27
11	2.8	0.08	0.48	2.99	3.55	0.33	0.06	0.04	0.43
12	2.9	0.04	0.46	2.40	2.90	0.25	0.08	0.01	0.34
13	2.10	0.02	0.31	1.60	1.93	0.17	0.06	-	0.23
14	2.11	0.02	0.22	1.46	1.70	0.18	0.05	0.01	0.24
15	3.3	0.02	0.33	1.51	1.86	0.23	0.07	0.01	0.31
16	3.4	0.08	1.23	5.64	6.95	0.81	0.25	0.08	1.14
17	3.5	0.07	1.08	4.24	5.39	0.45	0.12	0.03	0.60
18	3.6	0.08	1.05	3.85	4.98	0.63	0.11	0.03	0.77
19	3.7	0.11	3.05	9.95	13.11	1.28	0.28	0.11	1.67
20	3.8	0.04	0.56	2.22	2.82	0.32	0.06	-	0.38
21	3.9	0.06	0.46	2.53	3.05	0.43	0.05	0.02	0.50
22	3.10	0.03	0.27	1.86	2.16	0.25	0.06	0.01	0.32
23	3.11	0.04	0.34	2.34	2.72	0.31	0.08	0.02	0.41
24	3.12	-	0.02	0.09	0.11	0.01	-	-	0.01
25	4.3	0.04	0.46	1.97	2.47	0.39	0.07	0.01	0.47
26	4.4	0.08	1.05	4.40	5.53	0.75	0.16	0.04	0.95
27	4.5	0.10	2.54	9.55	12.19	0.92	0.32	0.10	1.34
28	4.6	0.05	0.81	3.80	4.66	0.81	0.08	0.02	0.91
29	4.7	0.03	0.96	3.25	4.24	0.47	0.08	0.01	0.56
30	4.8	0.05	0.86	3.02	3.93	0.43	0.08	0.02	0.53
31	4.9	0.07	0.98	3.45	4.50	0.54	0.09	0.03	0.66
32	4.10	0.04	0.47	1.79	2.30	0.26	0.06	-	0.32
33	4.11	0.05	0.48	2.51	3.04	0.33	0.09	0.02	0.44
34	4.12	0.02	0.20	1.03	1.25	0.13	0.04	0.01	0.18

Table A-7 continued

1	2	3	4	5	6	7	8	9	10
35	5.2	0.03	1.20	3.70	4.93	0.72	0.09	0.06	0.87
36	5.3	0.14	5.53	16.60	22.27	3.31	0.37	0.30	3.98
37	5.4	0.05	0.71	2.96	3.72	0.59	0.09	0.01	0.69
38	5.5	0.03	0.47	1.51	2.01	0.54	0.05	-	0.59
39	5.6	0.05	0.76	2.74	3.55	0.92	0.08	0.02	1.02
40	5.7	0.02	0.74	2.99	3.75	0.59	0.03	0.01	0.63
41	5.8	0.04	0.63	2.65	3.32	0.47	0.07	0.01	0.55
42	5.9	0.12	1.52	5.62	7.26	1.00	0.16	0.07	1.23
43	5.10	0.04	0.70	2.91	3.65	0.32	0.07	0.01	0.40
44	5.11	0.08	2.16	9.41	11.65	0.83	0.20	0.08	1.11
45	5.12	0.04	1.11	4.80	5.95	0.42	0.10	0.04	0.56
46	6.1	0.01	0.18	0.79	0.98	0.15	0.04	0.01	0.20
47	6.2	0.06	1.57	5.48	7.11	0.95	0.17	0.11	1.23
48	6.3	0.12	6.60	19.90	26.62	3.25	0.43	0.49	4.17
49	6.4	0.07	1.07	4.51	5.65	0.92	0.11	0.05	1.08
50	6.5	0.04	0.75	3.05	3.84	0.66	0.08	0.02	0.76
51	6.6	0.04	3.35	10.89	14.28	1.08	0.27	0.11	1.46
52	6.7	0.03	0.58	3.88	4.49	0.52	0.04	0.01	0.57
53	6.8	0.04	0.74	5.14	5.92	0.83	0.07	0.02	0.92
54	6.9	0.03	0.42	1.99	2.39	0.36	0.05	-	0.41
55	6.10	0.04	0.42	2.02	2.48	0.28	0.06	0.01	0.35
56	6.11	0.05	0.51	2.37	2.93	0.32	0.07	0.03	0.42
57	7.1	0.01	0.18	0.82	1.01	0.15	0.04	0.01	0.20
58	7.2	0.03	0.83	3.08	3.94	0.58	0.11	0.04	0.73
59	7.3	0.03	1.01	3.97	5.01	0.65	0.08	0.04	0.77
60	7.4	0.04	0.77	4.80	5.61	0.73	0.09	0.05	0.87
61	7.5	0.03	0.53	3.22	3.78	0.50	0.06	0.01	0.57
62	7.6	0.04	0.72	3.96	4.72	0.58	0.07	0.01	0.66
63	7.7	0.06	4.95	14.06	19.07	1.02	0.35	0.19	1.56
64	7.8	0.02	0.50	2.77	3.29	0.42	0.04	0.01	0.47
65	7.9	0.02	0.38	2.09	2.49	0.30	0.04	-	0.34
66	7.10	0.06	0.60	3.08	3.74	0.41	0.08	0.03	0.52
67	7.11	0.03	0.25	1.26	1.54	0.17	0.03	-	0.20

Table A-7 continued

1	2	3	4	5	6	7	8	9	10
68	8.1	-	0.06	0.32	0.38	0.04	0.01	-	0.05
69	8.2	0.03	0.63	3.06	3.72	0.46	0.07	0.12	0.65
70	8.3	0.03	0.95	4.25	5.23	0.71	0.07	0.10	0.88
71	8.4	0.05	0.63	3.93	4.61	0.54	0.06	0.04	0.64
72	8.5	0.04	0.97	6.13	7.14	0.82	0.10	0.08	1.00
73	8.6	0.02	0.45	2.42	2.89	0.35	0.04	-	0.39
74	8.7	0.06	5.69	15.12	20.87	1.07	0.39	0.25	1.71
75	8.8	0.02	0.31	2.06	2.39	0.25	0.03	-	0.28
76	8.9	0.02	0.35	2.20	2.57	0.27	0.03	-	0.30
77	8.10	0.02	0.24	0.75	1.01	0.17	0.03	-	0.20
78	8.11	0.03	0.26	0.86	1.15	0.18	0.03	0.01	0.22
79	9.1	0.01	0.17	0.99	1.17	0.10	0.02	-	0.12
80	9.2	0.03	0.49	2.46	2.98	0.39	0.05	0.08	0.52
81	9.3	0.03	0.70	3.71	4.44	0.58	0.07	0.06	0.71
82	9.4	0.04	0.57	3.22	3.83	0.48	0.05	0.03	0.56
83	9.5	0.03	1.35	5.85	7.23	0.67	0.12	0.07	0.86
84	9.6	0.02	0.42	1.54	1.98	0.32	0.04	-	0.36
85	9.7	0.03	0.40	1.76	2.19	0.39	0.04	0.01	0.44
86	9.8	0.02	0.29	1.45	1.76	0.24	0.03	-	0.27
87	9.9	0.02	0.34	1.65	2.01	0.27	0.04	-	0.31
88	9.10	0.03	0.34	0.51	0.88	0.24	0.04	0.01	0.29
89	9.11	0.02	0.23	0.18	0.43	0.16	0.03	0.01	0.20
90	10.3	0.01	0.20	1.06	1.27	0.22	0.03	-	0.25
91	10.4	0.03	0.32	1.83	2.18	0.41	0.04	-	0.45
92	10.5	0.02	0.26	1.20	1.48	0.28	0.05	-	0.33
93	10.6	0.01	0.19	0.31	0.51	0.15	0.02	-	0.17
94	10.7	0.01	0.21	0.35	0.57	0.15	0.02	-	0.17
95	10.8	0.02	0.27	1.43	1.72	0.14	0.03		0.17
96	10.9	0.04	0.61	3.22	3.87	0.31	0.08	0.02	0.41
97	10.10	0.01	0.13	0.37	0.51	0.08	0.02	-	0.10
98	10.11	0.01	0.05	0.05	0.11	0.04	-	-	0.04
99	Total	3.95	83.22	331.09	418.26	48.03	8.53	3.58	60.14

Table A-8: NO_x Emissions in Individual Grid Areas in 1982, 10^3 t

No	Area Designation	Industry (including Construction)		Transport	Households and Others (including Agriculture)	Total
		Great Consumers	Others			
1	2	3	4	5	6	7
1	1.4	26.08	-	0.07	0.01	26.16
2	1.6	-	-	0.74	0.09	0.83
3	1.7	-	-	0.77	0.09	0.86
4	1.8	-	-	1.37	0.15	1.52
5	1.9	30.36	1.36	6.71	0.83	39.26
6	1.10	2.00	0.27	2.55	0.31	5.13
7	2.4	-	2.02	1.88	0.33	4.23
8	2.5	-	2.22	3.60	0.56	6.38
9	2.6	-	4.09	4.94	0.65	9.68
10	2.7	-	-	2.26	0.27	2.53
11	2.8	2.39	2.18	3.55	0.43	8.55
12	2.9	-	0.22	2.90	0.34	3.46
13	2.10	-	-	1.93	0.23	2.16
14	2.11	-	0.74	1.70	0.24	2.68
15	3.3	-	0.29	1.86	0.31	2.46
16	3.4	-	3.79	6.95	1.14	11.88
17	3.5	2.57	1.84	5.39	0.60	10.40
18	3.6	2.03	1.79	4.98	0.77	9.57
19	3.7	0.90	5.32	13.11	1.67	21.00
20	3.8	-	-	2.82	0.38	3.20
21	3.9	-	1.86	3.05	0.50	5.41
22	3.10	-	0.43	2.16	0.32	2.91
23	3.11	-	1.15	2.72	0.41	4.28
24	3.12	-	-	0.11	0.01	0.12
25	4.3	-	1.57	2.47	0.47	4.51
26	4.4	1.54	3.95	5.53	0.95	11.97
27	4.5	4.43	4.86	12.19	1.34	22.82
28	4.6	-	1.53	4.66	0.91	7.10
29	4.7	-	0.40	4.24	0.56	5.20
30	4.8	-	0.98	3.93	0.53	5.44
31	4.9	-	3.13	4.50	0.66	8.29
32	4.10	-	0.54	2.30	0.32	3.16
33	4.11	-	1.04	3.04	0.44	4.52
34	4.12	-	0.33	1.25	0.18	1.76

Table A-8 continued

1	2	3	4	5	6	7
35	5.2	-	3.56	4.93	0.87	9.36
36	5.3	71.68	19.58	22.27	3.98	117.51
37	5.4	-	2.34	3.72	0.69	6.75
38	5.5	-	-	2.01	0.59	2.60
39	5.6	-	3.54	3.55	1.02	8.11
40	5.7	21.92	0.96	3.75	0.63	27.26
41	5.8	1.19	1.09	3.32	0.55	6.15
42	5.9	8.70	5.75	7.26	1.23	22.94
43	5.10	-	0.77	3.65	0.40	4.82
44	5.11	5.18	2.31	11.65	1.11	20.25
45	5.12	2.93	1.28	5.95	0.56	10.72
46	6.1	-	0.29	0.98	0.20	1.47
47	6.2	14.72	4.70	7.11	1.23	27.76
48	6.3	76.85	20.36	26.62	4.17	128.00
49	6.4	3.48	15.38	5.65	1.08	25.59
50	6.5	3.13	1.48	3.84	0.76	9.21
51	6.6	12.22	4.59	14.28	1.46	32.55
52	6.7	-	0.89	4.49	0.57	5.95
53	6.8	6.88	4.75	5.92	0.92	18.47
54	6.9	-	0.20	2.39	0.41	3.00
55	6.10	-	0.71	2.48	0.35	3.54
56	6.11	-	2.64	2.93	0.42	5.99
57	7.1	-	0.29	1.01	0.20	1.50
58	7.2	-	1.53	3.94	0.73	6.20
59	7.3	1.80	2.53	5.01	0.77	10.11
60	7.4	-	3.60	5.61	0.87	10.08
61	7.5	-	0.83	3.78	0.57	5.18
62	7.6	2.49	1.18	4.72	0.66	9.05
63	7.7	1.11	4.45	19.07	1.56	26.19
64	7.8	-	0.55	3.29	0.47	4.31
65	7.9	-	0.36	2.49	0.34	3.19
66	7.10	-	2.15	3.74	0.52	6.41
67	7.11	-	0.27	1.54	0.20	2.01

Table A-8 continued

1	2	3	4	5	6	7
68	8.1	-	-	0.38	0.05	0.43
69	8.2	-	2.29	3.72	0.65	6.66
70	8.3	19.23	4.13	5.23	0.88	29.47
71	8.4	1.51	3.40	4.61	0.64	10.16
72	8.5	2.58	3.32	7.14	1.00	14.04
73	8.6	38.11	-	2.89	0.39	41.39
74	8.7	19.30	4.74	20.87	1.71	46.62
75	8.8	-	-	2.39	0.28	2.67
76	8.9	12.43	1.15	2.57	0.30	16.45
77	8.10	-	-	1.01	0.20	1.21
78	8.11	-	0.65	1.15	0.22	2.02
79	9.1	-	-	1.17	0.12	1.29
80	9.2	-	2.10	2.98	0.52	5.60
81	9.3	-	2.17	4.44	0.71	7.32
82	9.4	7.71	3.23	3.83	0.56	15.33
83	9.5	-	6.99	7.23	0.86	15.08
84	9.6	-	0.24	1.98	0.36	2.58
85	9.7	-	0.56	2.19	0.44	3.19
86	9.8	-	-	1.76	0.27	2.03
87	9.9	-	1.35	2.01	0.31	3.67
88	9.10	-	0.76	0.88	0.29	1.93
89	9.11	-	0.53	0.43	0.20	1.16
90	10.3	-	-	1.27	0.25	1.52
91	10.4	-	1.10	2.18	0.45	3.73
92	10.5	-	4.45	1.48	0.33	6.26
93	10.6	-	-	0.51	0.17	0.68
94	10.7	-	0.67	0.57	0.17	1.41
95	10.8	-	0.30	1.72	0.17	2.19
96	10.9	2.15	1.68	3.87	0.41	8.11
97	10.10	-	-	0.51	0.10	0.61
98	10.11	-	-	0.11	0.04	0.15
99	Total	409.60	208.62	418.26	60.14	1096.62