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EMISSION SOURCES IN THE SOVIET UNION

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PREFACE

This report represents a compilation of available data concerning the emission of trace elements from the major industrial regions in the USSR. The work was undertaken in order to obtain a basis for evaluation of the transport of air pollution to the Arctic. The often incomplete information available has been supported by estimated emission factors, e.g., as indicated in the text. Because of the limited information available, the users should note that the present survey may contain serious omissions and mistakes. Only experience will show to what extent these data will be of help tracing the origins of atmospheric pollutants.

Several of the scientists at NILU have contributed to this work. The assistance of the library in searching the literature has been of particular value.

B. Ottar
Director

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LIST OF CONTENTS

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1 INTRODUCTION

Many activities within an air quality management system require the development and use of pollutant emission surveys. During the last decade significant progress has been made in emission evaluations. Nation-wide surveys have become available for several pollutants released from a variety sources. (1). Recently, global emissions of sulphur and nitrogen oxides, and trace elements have been reported for both natural and anthropogenic sources (2,3,4,5).

In this report, an attempt is made to assess anthropogenic emissions of 12 atmospheric pollutants, released from 12 emission areas in the Soviet Union. The emission survey has been prepared in order to model long range transport of trace elements to the Arctic.

The data for this report have been based on trace element emission factors calculated in an earlier report (6), and statistical information on the consumption of ores, rocks and fuel, and the production of various types of industrial goods (7).

2 EMISSION REGIONS IN THE SOVIET UNION

The main emission sources in the Soviet Union are coal, oil and gas combustion for electric utilites and in industry, industrial processes, and traffic.

In 1979, electricity production in conventional thermal power plants in the Soviet Union was 1015 TWh (82 per cent of the total electricity production in the country) (8). Hard coal (sub-bituminous and bituminous) - fired power plants have contributed 35 per cent to the electricity production, and lignite- fired power plants 15 per cent. The remaining 50 per

cent of electricity was generated in oil and gas-fired power plants (9, 10, 11, 12, 13, 14). For industrial uses, 130×10^6 tons of hard coal and lignite, and 54×10^6 tons of oil were combusted in industrial boilers (7).

From among a number of industrial processes releasing air pollutants, the following are considered here: non-ferrous metal production, pig iron and steel manufacturing, cement and phosphate fertilizer production, wood processisng and pulp chemicals. Information on emissions from refuse incineration in the Soviet Union is not readily available and is not presented in this report.

In 1978, production of copper, zinc, lead and nickel in the Soviet Union was 1.5×10^6, $0,77 \times 10^6$, 0.52×10^6, and 0.23×10^6 tons, respectively. A major part of the above-mentioned metals was produced in smelters (primary non-ferrous metal production). Of the ferrous metals, 110×10^6 tons of pig iron and 151×10^6 tons of steel were produced in the USSR in 1978 (5). Iron is commonly extracted in a blast furnaces where iron ore, coke and limestone are reacted at high temperatures. The production of 1 unit weight of pig iron requires an average charge of 0.55 unit weight of coke. Coke contains a number of trace elements, which evaporate at the high temperatures in the furnace. Several elements are used for deoxidation, alloying, and graphitizing of steel, e.g., manganese, silicon, chromium and phosporus. During ferro- alloy manufacturing, these element are released into the atmosphere in varying amounts.

Soviet Union cement, phosphate fertilizer, and wood pulp industries produced 127×10^6 tons, 5.9×10^6 tons, ca 8.5×10^6 tons of their products in 1979, respectively (5).

Large amounts of Pb are emitted yearly from vehicular traffic. There are 18 to 20×10^6 cars in the Soviet Union, compared to ca 110×10^6 cars in the USA (15). If Komarov's suggestion (15), that each Soviet automobile poisons its environment almost 4 times as much as an American car is accepted, then the much more numerous cars in the USA pollute the atmosphere only 1.4

times more than cars in the USSR. He suggests, that this may be due to the more intensive use of cars in the USSR, and poorer engine emission control.

In this work, 12 regions in the Soviet Union, judged to have the highest emissions have been chosen. The locations of these regions are presented in Fig. 1.

2.1 The Kola Peninsula (Region 1)

2.1.1 Copper-nickel production

Two large complexes of copper-nickel metallurgy are located in this region. Smelters use ores from the Nikel-Zapoljarnyj and the Monchegorsk mines (16). The yearly Ni and Cu production in this area is 65×10^3 and 75×10^3 tons, respectively.

2.1.2 Fossil fuel combustion

Coal and gas are burned in the two large power plants in the area at Severodvinsk and Arkhangelsk. Bituminous coal is shipped to these plants mainly from the neighbouring Pechora basin.

2.1.3 Steel and iron manufacturing

Iron ore has been mined at Olenegorsk and Kovdor for a long time. The combined output from these mines was estimated to 10×10^6 tons of concentrate in 1976 (16). Recently, a large mining complex was inaugurated at Kostomuksha in subarctic Soviet Karelia, with a yearly production of 3×10^6 tons of iron pellets during first phase of the development (17). This will be followed by two other development phases, which are expected to reach a production capacity of 9×10^6 tons of 66% Fe pellets a year. Coking coal for the complex is transported from the Pechora basin.

2.1.4 Phosphate fertilizer production

The Kola Peninsula contains the world's largest apatite deposits. The current annual capacity of the Apatity mining complex and a mine at Kirovsk is about 15×10^6 tons of concentrates (16,18), providing more than 70 per cent of all raw materials for the production of Soviet phosphate fertilizers.

2.1.5 Wood processing

Almost 40 per cent of total wood pulp production in the Soviet Union comes from in the Kola Peninsula. A giant pulp and paper complex is located in Svetogorsk. Air pollution problems in this area are enhanced by combustion of bituminous coal in the Svetogorsk complex. The production of 1 unit weight of wood pulp and paper requires an average charge of 1 unit weight of bituminous coal. Thus, 3.5×10^6 tons of coal is burned annually in the complex.

2.2 The Pechora basin (Region 2)

2.2.1 Coal mining and combustion

The Pechora basin is centred on Vorkuta and Inta. In 1976, 26×10^6 tons of coal was mined in the area, including 16×10^6 tons of coking coal (16). The area contains 28 mines (not all are producing) including the Vorgashor mine, the largest shaft mine in the European USSR (19).

The major consumers of coal mined in the Pechora basin are the industrial complexes of the Kola Peninsula, and the Cherepovets iron and steel plant (20).

In the Pechora basin, the main users of low- and high-grade bituminous hard coal are thermal power plants in Ukhta and Vorkuta, and industry (wood processing and pulp chemicals production, mineral and fuel extraction and construction materials).

2.2.2 Wood processing

The production of wood pulp in the Pechora basin is estimated to almost 2×10^6 tons of pulp a year, requiring about 2×10^6 tons of bituminous coal annually.

2.3 The Norilsk area (Region 3)

2.3.1 Copper-nickel production

The copper-nickel smelter complex in Norilsk is claimed to be the world's largest copper-nickel smelter. Yearly capacities for the concentrates are 0.55×10^6 tons nickel concentrate, and 0.65×10^6 tons copper concentrate (18). The mining complex in Norilsk consists of more than 20 mines, smelters and rafineries.

The Norilsk smelter utilizes the Outokumpu flash smelting method. In this method the roasting and smelting processes are integrated, whereas conventionally these operations are carried out in separate furnaces (21). Among the advantages of this process, three are particularly important from the air pollutant emission standpoint: low energy consumption, high SO_2 concentration in the flue gas (with a possibility to produce H_2SO_4), and high copper concentration in the mate. Thus, emission of atmospheric pollutants from the Norilsk complex are lower than from other smelters in the USSR.

2.3.2 Fossil fuel combustion

Coal from the Tanguska province has been used as fuel for power at Norilsk. Gradually, it was supplanted by hydroelectric power from the Khantayka River dam, and then by gas from the West Siberian fields (19). Nowadays, the coal is still used as a backup fuel for the nearby Snezhnogorsk hydroplant.

Certain amounts of coal are also burned in a thermal power plan in Norilsk. For purposes of this report it is assumed that 1 per cent of total electricity production in the Soviet Union is generated in the Norilsk area.

2.3.3 Wood processing and pulp chemicals

The production of wood pulp in the area is at the same level as that in the Pechora basin.

2.4 The Urals (Region 4)

2.4.1 Copper-nickel production

Substantial amounts of nickel and copper are produced in smelters located in the southern and central parts of the Urals. The main copper-nickel mining and smelting complexes are centred on Verchnyy Ufaley, Resh, Khalilovo, Orsk, Sverdlovsk, and Chelyabinsk. The annual production in these complexes is 65×10^3 tons of nickel and 350×10^3 tons of copper.

2.4.2 Fossil fuel combustion

Coal, oil and gas are burned in a number of thermal power plants in this region. Additionally coal and oil are used in several industrial processes. Several coal districts are located in the south-western part of the West Siberian basin, along the eastern flank of the Urals (19). The coal is mainly of lignite type. Oil and gas are mainly from the West Siberian basin. The Samotlor oil field in this basin is the largest oil field in the USSR (19). Urengoy in the same basin is the world's largest gas field. It is believed, that Urengoy soon will supply much of the nation's gas, and significantly contribute to the gas consumed in Europe (19).

The largest amounts of fossil fuels in the Urals are consumed

in the following thermal power stations: Reftinskaya, Verhnaya Pyschma, Karmanovo, Jushnouralsk, Troizk, and Iriklinskij. All these have power output of over 1000 MW. It is assumed, that one third of the total coal and a half of oil consumption in Soviet power plants is used in the above electric power stations.

2.4.3 Steel and iron manufacturing

Almost half of pig iron and steel produced in the Soviet Union comes from the factories along the Urals. The main iron foundries and steel mills are located around the following cities: Serov, Nishniy Tagil, Sverdlovsk, Chelyabinsk, Slatoust, Magnitogorsk, Orsk, Kamensk Uralskiy and Rudnyy. Electric arc and open-hearth furnaces are commonly used in the Soviet steel technology.

2.5 The Yakutsk area (Region 5)

2.5.1 Coal combustion

South Yakutia Basin coal fields yield high-grade bituminous coals. This type of coal is used to produce excellent coking coal as well as steam coal. As thick seams of coal lie close to the surface, strip mining is employed in this area (22). This causes additional air pollution problems during the mining of coal.

2.5.2 Wood processing

The 1.7×10^6 tons of wood pulp, produced in the Yakutsk area, consume about the same amount of coal.

2.6 The Moscow area (Region 6)

Fossil fuel combustion is one of the major air pollution sources in the Moscow area. There are 4 large thermal power plants in the region, with a capacity of over 1000 MW each. Lignite, mined around Kaluga, Novomoskovsk and Tula is burned in the plants. Substantial amounts of gas and oil are also fired there. Steel mills in Elektrostal and Tula are also important consumers of coal.

Very high airborne concentrations of lead in Moscow are caused by traffic. The CO quantity on the streets of Moscow are often 20-30 times the maximum permissible concentration (MPC) (15).

2.7 The Donetsk area (Region 7)

2.7.1 Fossil fuel combustion

The Donetsk region is one of the largest coal-producing area in the USSR. Bituminous coal and lignite are burned in a number of thermal power plants. 9 of which have a capacity over 1000 MW each.

2.7.2 Steel and iron manufacturing

Annual production of 49×10^6 tons of steel and 35×10^6 tons of pig iron is estimated to take place in this area. The highest emissions of air pollutants are found in Krivoi Rog, a famous centre of the iron ore industry (15).

Coal consumption during iron manufacturing in the area is about 20 $\times 10^6$ tons as coke per year. Another coal consumer in the area is a giant cement plant on the shores of the Black Sea at Novorossiisk. About 10 tons of coal are used to produce $1 \cdot 10^3$ tons of cement. The plant at Novorossiisk is now equipped with efficient filters and emissions of air pollutants have been reduced.

2.8 The Kuznetsk area (Region 8)

2.8.1 Fossil fuel combustion

The Kuznetsk area is the second largest coal-producing area in the USSR, with 162×10^6 tons mined in 1978 (19). About half of the Kuznetsk mines can be worked from the surface by strip mining. Most of the coal is low-ash, high-rank bituminous coal (15), used as coking coal (40 per cent of production) and steam coal (60 per cent of production).

Lignite is mined in the Kansk-Achinsk basin located in the northeastern part of the Kuznetsk area. Electricity is generated in 8 large thermal power plants with a wet installed capacity of 1000 MW each.

2.8.2 Steel and iron manufacturing

About 15 per cent of total steel production in the Soviet Union comes from Novosibirsk, Gurjevsk, Novokusnetsk and Krasnoyarsk. Iron ore mines are located in the southern part of the region (Temirtau, Taschtangol, Abasa, etc). An amount of 10^7 tons of coal is used for pig iron production in the above plants.

2.8.3 Lead and zinc production

More then half of the lead and zinc production in the USSR comes from the Kuznetsk area (0.3×10^6 tons Pb and 0.5×10^6 tons Zn, yearly). The main factories are located in Salair, Leninogorsk, Ust-Kamenogorsk and Byelousovka. Air control devices installed in these plants are poor, and lead concentrations in Leninogorsk and Ust-Kamenogorsk are often 30-40 and 14 times the MPC, respectively (15).

2.9 The Fergana area (Region 9)

2.9.1 Fossil fuel combustion

Coal, oil and gas are combusted in the Fergana area by electric utilities and in industrial processes. Electricity is produced in 5 large power plants. Non-ferrous metal production is a major consumer of fossil fuel by industry.

2.9.2 Lead and zinc production

The Fergana area is the second largest lead and zinc producing area in the Soviet Union. Almost 0.16×10^6 tons Pb and 0.23×10^6 tons Zn are produced in Kentau, Taschkent (near the city), Almalyk and other places.

2.9.3 Copper production

About 0.7×10^6 tons Cu are yearly produced in the area. The Dzhezkazgan plant is the largest copper smelter in the USSR. Other important factories of copper production are located in Uspenskiy, Kounradskij, Sayak and near Taschkent.

2.10 Caucasus (Region 10)

Oil is the main fuel in power plants and industrial factories in this area. Among industry, copper metallurgy and aluminium production are the main energy consumers. About 0.25×10^6 tons Cu are produced near Erevan and Kafan.

2.11 The Leningrad area (Region 11)

Electricity in this area is generated in two large power plants and a number of smaller units, consuming oil, coal and mazut. Mazut is one of the "dirtiest" fuels, resulting in a high emission of several pollutants. Thermo-electric power and

heating plants are the major fuel consumers. However, substantial quantities of oil, coal and mazut are also used in industry, mainly steel manufacturing and aluminium production.

Vehicular traffic in the area poses serious health hazard. There are ca. 670.000 automobiles in the city. Concentrations of pollutants measured on the main streets exceed significantly the MPC values (15).

2.12 The Baikal area (Region 12)

Subbituminous coal and lignite, together with oil, are the main fossil fuels used in the area. Copper and aluminium production are the two main industries in the Baikal (Irkutsk) area, and are centred near Irkutsk and Angarsk.

3 EMISSION FACTORS OF AIR POLLUTANTS FROM THE SOVIET SOURCES

Of the large number of chemical compounds contained in fuels, ores and rocks only 12 are considered here. These elements are either the most toxic, or have particularly high enrichment factors in ambient aerosols relative to the earth's crust. The emission factors were estimated separately for all the elements analysed, various emission sources and different source locations in the Soviet Union.

3.1 Fossil fuel combustion

The emission factors for air pollutants emitted during coal and oil combustion from electric utilities and industrial processes are listed in Table 1.

Table 1: Emission factors of air pollutants from coal and oil combustion in electric power stations and industrial plants in the USSR.

Chemical compound	Electric utilities(in µg/MJ)			Industrial processes ($g/10^6$ g)	
	Hard coal	Lignite	Oil	Coking coal	Oil*[1]
As	57.2	79.5	32.0	1.7	1.2
Cd	17.6	24.6	15.2	0.5	0.6
Cr	290	403	56.7	12	2.2
Cu	228	317	227	9.8	8.8
Mn	247	343	53.3	11	2.1
Ni	365	507	1340	14.5	52
Pb	207	287	164	7.7	6.4
Sb	34.0	47.2	13.8	1.1	0.5
Se	26.6	37.0	24.2	2.7	0.9
V	203	282	4840	9.7	187
Zn	288	400	116	11.4	4.5

*[1] in $g/10^3$ litres

The emission factors in Table 1 should be regarded as average values for coal and oil from several basins. The following coal basins were considered: Timan-Pechora basin, West Siberian basin, Kuznetsk area, South Yakutia area,. Tanguska basin and Donetsk area. Fully 58 per cent of oil and 32 per cent of gas consumed in the Soviet power plants come from the West Siberian basin alone (19). The list of other oil basins considered in this report is long, and includes the following districts and basins: Baltic, Carpathian, Dnepr - Donetsk, Black Sea, North Caucasus - Mangyshlak, Baku-Chelekan, Volga-Urals, Timan Pechora, North Caspian, Fergana and East Sakhalin. All available information on the ash content of coal the sulphur content of oil and the chemical composition of coal and oil from these basins was used to calculate emissions of air pollutants from fossil fuel combustion in the 12 above-mentined regions of the Soviet Union. Movement of coal and oil in the Soviet Union has also been considered.

In addition to those in Table 1, SO_2 emission factors were calculated to be 28.5 kg/1 tons of coal and 16.6 $kg/10^3$ litres of oil.

3.2 Non-ferrous metal production

The trace metal emission factors for mining operations are listed in Table 2. Information on the chemical composition of ores mined in the Soviet Union is scarse. Thus, the emission factors generally available in the literature were applied to the Soviet mines (23).

Table 2: Emission factors of trace elements from non-ferrous metal mines.

Trace element	Emission factor	Unit
Cd	0.5	g Cd/1 ton of Zn mined
Cu	100	g Cu/1 ton of Cu mined
Mn	90	g Mn/1 ton of Mn mined
Pb	910	g Pb/1 ton of Pb mined
Zn	100	g Zn/1 ton of (Zn+Cu+Pb)mined
Se	8	mg Se/1 ton of Cu mined
	8	mg Se/1 ton of (Cu-Ni) ore mined
	25	mg Se/1 ton of (Cu-Zn) ore mined
	25	mg Se/1 ton of (Pb-Zn) ore mined

The Ni emission factor for Ni ore mining has been included in the Ni emission factor for Ni refining, which is 9 kg/ton of Ni produced. The trace element emission factors for non-ferrous metal production in the USSR are shown in Table 3.

Table 3: Emission factors of trace elements from non-ferrous metal production (in g/ton of metal produced).

Trace element	Copper smelters	Zinc smelters	Lead smelters
As	1000	590	180
Cd	200	500	50
Cu	2500	140	72
Ni	9000*[1]		85
Pb	2950	2540	3000
Sb	100		
Se	113	18	23
Zn	845	16700	110

*[1] in g/ton Ni produced instead of g/ton Cu produced.

The emission factors in Table 3 were calculated for primary non-ferrous metal production in smelters. These values do not include emissions during the metal production by secondary processing (from scrap). The lack of reliable information has made it impossible to assess a part of non-ferrous metals production by secondary processing in the total metal production in the Soviet Union. It is believed, however, that this contribution is small.

SO_2 is also emitted during the non-ferrous metal production. Based on uncontrolled emission factors and, assuming that SO_2 can be reduced by about 90 per cent, the following SO_2 emission factors have been estimated: 62.5 kg/ton of Cu produced, 66.0 kg/ton of Pb produced, and 110 kg/ton of Zn produced.

Trace element and SO_2 emission factors for copper-nickel smelters in Norilsk are lower than the factors for other copper-nickel smelters in the Soviet Union. As mentioned earlier in this report, the Norilsk smelter employs the Outokumpu flash-smelting process. The extraction of copper from the slag takes place either in an electric furnace, or by flotation after cooling and pulverization. This process releases lower trace element concentrations than the conventional processes.

3.3 Pig iron and steel manufacturing

The trace element emission factors for steel manufacturing are given in Table 4.

Table 4: Emission factors of trace elements from steel production in the USSR (in g/ton of steel production).

Trace element	Emission factor	Trace element	Emission factor
Cd	0.4	Ni	2.6
Cr	9.0	Pb	4.1
Cu	1.0	Zn	39
Mn	6.4		

Emission factors for pig iron manufacturing are dependent on the impurities in coking coal, shown in Table 1. The fact that the production of 1 ton of pig iron requires 0.55 tons of coke must be taken into account.

3.4 Phosphate fertilizer and wood pulp production

For this report the trace element emission factors for phosphate fertilizer production by Pacyna (6), shown in Table 5, were adopted.

Table 5: Trace element emission factors for phosphate fertilizer production (in g/ton of product)

Trace element	Emission factor	Trace element	Emission factor
Cd	1.8	Pb	0.4
Cu	5.1	Se	2.5*[1]
Ni	5.1	Zn	15.0

*[1] in mg/ton of product

The trace element emissions from wood pulp production are mainly due to fossil fuel combustion in the process. Based on the literature information (7,24,25), it was found that the production of 1 unit weight of wood pulp and paper requires an average charge of 1 unit weight of coal. Thus, the emission factors from Table 1 for coal combustion in industrial processes can be used, when emissions of air pollutants during wood pulp production are considered.

4 EMISSIONS OF AIR POLLUTANTS IN THE PARTICULAR SOURCE REGIONS

Based on emission factors and statistical information on the consumption of fuel and ores, and the production of industrial goods presented in previous chapters, emissions of air pollutants were calculated for all the source areas considered in this work. The results are shown in Tables 6 and 7.

The contributions of various sources to the total emissions in

particular areas are shown in Table 6. Copper-nickel production seems to be the dominant emission source in the two northerly areas 1 and 3 (Kola Peninsula and Norilsk). Both areas are very important, when the potential contamination of the Arctic is considered. Two other regions in the Soviet North, the Pechora basin (2) and the Yakutsk area (5), are also significant because of their coal mines and power plants. A mixture of emissions from several sources is ascribed to region 4, the Urals. Two large urban agglomora- tions, Moscow and Leningrad, are affected mainly by vehicular traffic. Lead-zinc production appears to be the most important source of atmospheric emissions in the Soviet South, namely in the Kuznetsk and Fergana regions (areas 8 and 9). In the latter region, copper production is of equal significance. Emissions from iron and steel manufacturing appear the most significant in the western region 7 (Donetsk).

The above geographical locations of emission regions in the USSR encourage the selection of certain elemental ratios to serve as indicators or tracers for these regions. The ratios of Cr/As or Mn/As seem to be very convenient for differentiating between the emission sources in areas 2, 5, 7 (coal combustion for electric utilities and industry) and emission sources in regions 1, 3, 9, 10 (copper smelters). Extremely high ratios of Pb/Cd or S/Cd were found in ares 7 and 11 (intensive traffic) when compared to the other regions. Region 3 (the Norilsk area), especially important when contamination of the Alaskan air is considered, can be identified by the ratios of Ni/Mn, Ni/Cr, Ni/Sb, Ni/Se or Ni/Cd. The ratio of Zn/Cr appears to be a good indicator of emissions from lead and zinc smelters in the southern regions of the USSR (areas 8 and 9).

Emissions of air pollutants in a particular regions can be also considered in regard to the size of the region, i.e. per unit area. Such "emission densities" are presented in Table 7. It can be seen, that antimony is the most evenly distributed element, followed by selenium and lead. The ratios of other elements to these three can also indicate emissions from certain region, although the emission sources may be small. As

Table 6: Emissions of air pollutants in the USSR (in t/y except SO_2* in 10^3 t/y).

Region and source	As	Cd	Cu	Cr	Mn	Ni	Pb	SO_2*	Sb	Se	V	Zn
1. The Kola Peninsula (1)												
1.1 Copper-nickel production	154	15	173	2	2	535	412	26	14.0	16.0		61
1.2 Fossil fuel combustion	2	1	10	34	30	40	54	190	2.0	4.0		10
1.3 Steel and iron	3	1	29	47	37	44	13	30	2.3	1.5		19
1.4 Phosphate fertilizer	-	10	21	-	-	21	3	-	-	2.4		80
1.5 Wood processing	6	2	2	39	37	5	26	10	4.8	1.7		10
1.6 Gasoline combustion	-	-	-	-	-	-	237	-	-	-		-
Total 1	165	29	235	122	106	645	745	256	23.1	25.6	122	180
2. The Pechora basin (2)												
2.1 Coal mining and combustion	8.5	2.1	34	60	55	62	27	70	7	17.5	49	40
2.2 Wood processing	3	1	15	21	19	11	13	30	4.8	4.7	17	16
2.3 Gasoline combustion							158					
Total 2	11.5	3.5	49	81	74	73	198	100	11.8	22.2	66	56
3. The Norilsk area (3)												
3.1 Copper-nickel production	242	24	312	3	2.5	900	649	75	22	24.9		235
3.2 Fossil fuel combustion	1	0.5	7	8	7.0	11	27	100	1	3	113	8
3.3 Wood processing	3	1.0	83	20	18.5	24	13	5	2.4	4.7	17	19
3.4 Gasoline combustion							53					
Total 3	246	25.5	402	31	28	935	742	180	25.4	32.6	130	262

Table 6 cont.

Region and source	As	Cd	Cu	Cr	Mn	Ni	Pb	SO_2*	Sb	Se	V	Zn
4. The Urals (4)												
4.1 Copper-nickel production	462	70	910	5	5	585	1224	78	41.5	47		444
4.2 Fossil fuel combustion	42	33	185	151	130	790	173	5050	13.6	57	2733	180
4.3 Steel and iron	47	42	340	1230	998	240	499	498	38.5	76	267	3296
4.4 Gasoline combustion							7630					
Total 4	551	145	1435	1386	1158*[1]	1615	9526	5626	93.6	180	3000	3920
5. The Yakutsk area (5)												
5.1 Coal combustion	3.5	1.0	10	25	23	16	10	143	1.5	4.1		6
5.2 Wood processing	3.0	1.0	10	21	19	14	13	48	2.4	4.7		20
5.3 Gasoline combustion							106					
Total 5	6.5	2.0	20	46	42	30	129	191	3.9	8.8	20	26
6. The Moscow area (6)	16	6	81	66	56	300	3622	1154	6.3	22.3	861	74
7. The Donetsk area (7)												
7.1 Fossil fuel combustion	30	10	166	219	201	265	83	1650	30	59		210
7.2 Steel and iron	33	30	107	832	699	240	349	350	27	53		2310
7.3 Gasoline combustion							2710					
Total 7	63	40	273	1051	1104*[1]	506	3342*[2]	2000	57	112	995	2520

Table 6 cont.

Region and source	As	Cd	Cu	Cr	Mn	Ni	Pb	SO_2*	Sb	Se	V	Zn
8. The Kuznetsk area (8)												
8.1 Fossil fuel combustion	9.5	3	55	44	40	53	50	1021	10.0	20	35	42
8.2 Steel and iron	15.5	14	23	403	327	59	163	164	12.7	25	88	1069
8.3 Lead and zinc prod.	404	245	76	9	8	26	2098	51	1.1	15	17	7723
8.4 Gasoline combustion							1631					
Total 8	429	262	154	456	375	138	3942	1236	23.8	60	158	8834
9. The Fergana area (9)												
9.1 Fossil fuel combustion	6	11	35	8	8	197	36	1506		6		20
9.2 Lead and zinc prod.	204	123	45	7	6	13	1064	36	1	8		3859
9.3 Copper production	770	140	1750	6	6		1813	174	70	79		671
9.4 Gasoline combustion							1631					
Total 9	980	274	1830	21	40*[1]	210	4544	1716	71	93	766	4550
10. Caucasus (10)												
10.1 Fossil fuel combustion	3	4	16	3	2	15	18	750	1	4		24
10.2 Copper combustion	250	50	625	3	3	60	738	62	24	28		242
10.3 Gasoline combustion							1342					
Total 10	253	54	641	6	30*[1]	75	2098	812	25	32	215	266
11. The Leningrad area (11)	4	1.6	13	17	15	80	1088	364	1.7	2.6	233	20
12. The Baikal area (12)	55	14	157	41	39	50	715	510	10.8	17.1	33	88
The total USSR	2780	860	5290	3320	3070	4660	30700	14145	350	610	6730	20800

*[1] The Mn emission from the metal producing plants is included.
*[2] The Pb emission from the cement plant at Novorossiisk is included.

Table 7: Emissions of air pollutants in the USSR per unit area (in $mg/m^2 \times y$ except SO_2* in $g/m^2 y$)

Region	As	Cd	Cu	Cr	Mn	Ni	Pb	SO_2*	Sb	Se	V	Zn
The Kola Peninsula (1)	1.2	0.2	1.8	0.9	0.8	4.8	5.5	1.9	0.2	0.2	0.9	1.3
The Pechora basin (2)	0.25	0.1	1.1	1.8	1.6	1.6	4.4	2.2	0.3	0.5	1.5	1.2
The Norilsk area (3)	5.5	0.6	9.0	0.7	0.6	21	16.7	4.0	0.6	0.7	2.9	5.9
The Urals (4)	3.1	0.8	8.0	7.7	6.5	9.0	53.1	31.4	0.5	1.0	16.7	21.9
The Yakutsk area (5)	0.3	0.1	0.9	0.9	1.8	1.3	5.6	8.3	0.2	0.4	0.9	1.1
The Moscow area (6)	0.2	0.1	0.9	0.7	0.6	3.3	39.8	12.7	0.1	0.25	9.5	0.8
The Donetsk area (7)	0.6	0.4	2.4	9.4	9.8	4.5	29.7	17.8	0.5	1.0	8.9	22.4
The Kuznetsk area (8)	3.7	2.3	1.3	4.0	3.3	1.2	34.3	10.8	0.2	0.5	1.4	77.0
The Fergana area (9)	8.9	2.5	17	0.2	0.4	1.9	41.1	15.5	0.6	0.8	6.9	41.2
Caucasus (10)	3.7	0.8	9.4	0.1	0.5	1.1	30.8	11.9	0.4	0.5	3.2	3.9
The Leningrad area (11)	0.2	0.1	0.6	0.8	0.7	3.6	49.0	16.4	0.1	0.1	10.5	0.9
The Baikal area (12)	2.4	0.4	6.9	1.8	1.7	2.2	31.9	22.4	0.5	0.75	1.5	3.9

Table 8: Emission ratios of individual air pollutants to Sb for the various emission regions in the Soviet.

Compound / Region	As	Cd	Cu	Cr	Mn	Ni	Pb	SO_2 *[1]	Sb	Se	V	Zn
1	7.1	1.3	10.2	5.3	4.6	27.9	32.3	11.1	A	1.1	5.3	7.7
2	1.0	0.30	4.2	6.9	6.3	6.1	16.8	8.5	A	1.9	5.6	4.8
3	9.7	1.0	15.8	1.2	1.1	36.8	29.2	7.1	A	1.3	5.0	10.0
4	5.9	1.6	15.3	14.8	12.4	17.3	102	60.1	A	1.9	32.0	42.0
5	1.7	0.51	5.1	11.8	10.8	7.7	33.1	49.0	A	2.3	5.1	6.7
6	2.5	0.95	12.9	10.5	8.9	47.6	575	183	A	3.5	137	11.8
7	1.1	0.70	4.8	18.4	19.4	8.9	58.6	35.1	A	2.0	17.5	44.2
8	18.0	11.0	6.5	19.2	15.8	5.8	166	51.9	A	2.5	6.6	371
9	13.9	3.9	25.9	0.30	0.57	3.0	64.4	24.3	A	1.3	10.9	64.5
10	10.1	2.2	25.6	0.24	1.2	3.0	83.9	32.5	A	1.3	8.6	10.6
11	2.4	0.94	7.7	10.0	8.8	47.1	640.0	214.0	A	1.5	137.0	11.8
12	5.1	1.3	14.5	3.8	3.6	4.6	67.1	47.2	A	1.6	3.1	8.1

*[1] $\times 10^3$

an example, Table 8 shows the emission ratios of individual air pollutants considered here to Sb for the various emission regions.

5 UNCERTAINTIES OF CALCULATIONS

All emission surveys contain a number of uncertainties, more or less limiting their applicability. The estimates presented here were especially difficult to obtain because of Soviet reluctance to divulge information on the capacity of their industries, emission factors, etc. Nevertheless, the present work seems to be the first attempt to assess the anthropogenic emissions of a large number of air pollutants in the Soviet Union.

From among the various emission sources considered in this report, non-ferrous metal production is probably assessed most accurately. On other hand, a lack of information made it impossible to indclude other important surces, such as, waste incineration, industrial application of several metals, etc. The available information on lead content in gasoline was probably unreliable.

It is difficult to compare the emission estimates arrived at this work with other data, for a simple reason that no such evidence exists in the literature (except for a few evaluations of SO_2 emission). Amble (2) has estimated SO_2 emission from all sources in the European part of the Soviet Union to be 8.1×10^6 ton/y. Total emission of SO_2 from the European regions (1, 2, 4, 6, 7, 10 and 11) of the USSR in the present report was estimated to 10.3×10^6 tons/y. Highton and Chadwick (26) indicate emission of 25.5×10^6 tons S/y from the Soviet sources. The relevant emission found in this report is 14.1×10^6 tons S/y. The emissions in this work include amounts of air pollutants from the 12 regions only. Thus, it can be expected that the total emissions of SO_2 in the Soviet Union are likely to be higher.

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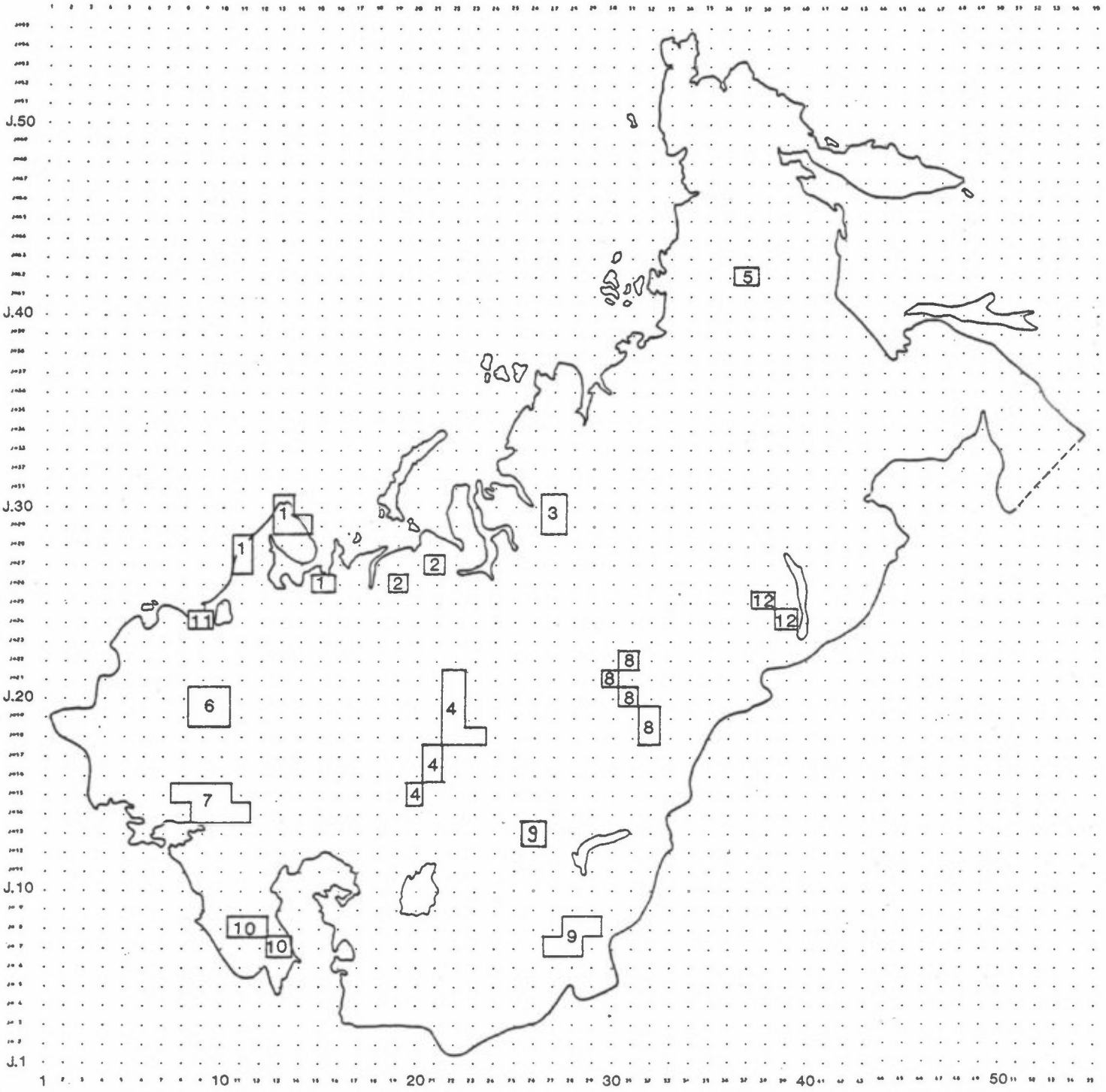
Fig. 1. Location of emission regions considered in this report.

1. The Kola Peninsula
2. The Pechora basin
3. The Norilsk area
4. The Urals
5. The Yakutsk area
6. The Moscow area
7. The Donetsk area
8. The Kuznetsk area
9. The Fergana area
10. Caucasus
11. The Leningrad area
12. The Baikal area



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ABSTRACT (max. 300 characters, 5-10 lines.
An attempt is made to assess anthropogenic emissions of 12 atmospheric pollutants, released from 12 emission areas in the Soviet Union. The data have been based on emission factors, and statistical information on the consumption of ores, rocks and fuel, and the production of various types of industrial goods.
The emission survey has been prepared in order to model long range transport of pollutants to the Arctic.

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