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JOZEF M. PACYNA

NILU

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1 INTRODUCTION

In this report an attempt is made to estimate the emission of trace elements to the atmosphere from various sources in the European contries. Because of their toxic nature, many trace elements have created serious environmental damage in areas exposed to relatively high concentrations. In order to estimate the significance of man-made emissions relative to natural sources, extensive emission inventories of these pollutants are required. This will be a first step in any attempt to reduce their high levels in particular environmental media.

The data provided in this report have been obtained on the basis of trace emission factors calculated in an earlier report [1], and statistical information on the consumption of ores, rocks, and fuel and the production of various types of industrial goods [2,3,4]. Available information on types of fuel, ores and rocks and differences in manufacturing techniques used in the European countries, have been taken into account. Different types of dust removal installations and their effectiveness have also been considered, as well as import-export relations of fuels and ores between particular countries [5].

2 EMISSION OF TRACE ELEMENTS FROM DIFFERENT SOURCES

In this section the emissions of trace elements to the atmosphere from various sources in particular countries are estimated. The trace element emission factors used are presented in Appendix A. Appendix B contains statistical data on fuel and ore consumption and on the production of industrial goods.

From among a number of trace elements contained in fuels, ores and rocks, only 16 are considered in this report. These elements are

either the most toxic, or have particularly high enrichment factors in ambient aerosols relative to the earth's crust.

The following emission sources have been considered:

- conventional thermal power plants
- industrial and commercial combustion of coal and oil
- wood combustion
- gasoline and diesel oil combustion
- mining
- primary non-ferrous metal production: copper-nickel, zinc-cadmium, and lead
- secondary non-ferrous metal production: copper, zinc, and lead
- iron, steel making, and ferroalloys manufacturing
- refuse incineration
- phosphate fertilizers
- cement production
- industrial application of metals

The results of the trace element emission calculations for different sources are presented in Tables 1-15.

2.1 Fuel combustion

Conventional thermal power plants include coal- and oil-fired plants. Gas-fired power plants have not been considered because of the very slight emissions of particles from these sources.

The amount of trace metals depends on the combustion conditions, the quantity and type of fuel consumed, and the trace metal content of the fuel. In the case of coal-fired power plants, the combustion conditions affecting the trace element emission include the type of furnace and the stack-gas cleaning equipment. Two major types of coal furnaces are commonly used in Europe: the cyclone furnace and pulverized coal-fired furnace. The emission of trace elements from the first type is somewhat larger than from the second. The differences depend on the physical and chemical properties of particular metal.

Among the different types of fly ash control systems, electrostratic precipitators and wet scrubbers are the most widely used installations in coal-fired power plants. Comparing the efficiency of both installations, only Cr and Se emissions from wet scrubbers exceed emissions from electrostatic precipitators [7]. Three sorts of coal are commonly burned in power plants: bituminous coals, sub-bituminous coals and lignite. The largest emission of trace elements comes from lignite combustion. This is mainly due to the larger quantities of lignite that must be burned to equal the energy output of other types of coal, and the high concentrations of particular metals in lignite.

In the case of oil, the particulate loading of stack gases depends primarily upon the efficiency of combustion and the build-up of boiler deposits. The emission of trace elements from tangential and horizontal furnaces working under similar conditions are comparable. The amount of trace elements emitted from heavy fuels is roughly proportional to their asphalt and ash content. Fly ash removal equipment is not generally required, although such equipment is used at some oil-burning plants in Europe [6].

Considering the chemical composition of the fuels, coal-fired power plants emit large amounts of nickel, chromium, zinc and manganese, while vanadium and nickel are mainly emitted from oil-fired power plants.

Emissions from coal- and oil-fired industrial, commercial and residential boilers are affected by the same factors as discussed above. The effluents parallel those from electric-utility sources, assuming the same chemical composition of the fuels. Some differences in composition and particle size of stack dust will occur because of the differences in boiler types. Emission control equipment is generally not used on commercial and residential furnaces.

Wood is no longer regarded as a primary source of heat and energy. However, there are still certain industries where wood is a desirable fuel. Small wood stoves are used primarily as domestic space heaters to supplement conventional heating systems. Considering the trace element emission in Europe, wood combustion appears to be an important source of copper and zinc emission in some areas.

A major source of lead emission is the internal combustion engine in both mobile and stationary applications. Tetraethyl and tetramethyl lead are used to increase the octane ratings of all grades of gasoline; particularly in the high-grade petrol used in small engines with a high compression ratio. Generally, 35 per cent of the lead contained in the gasoline is emitted as very fine particles and 40 per cent ends up in the larger size range. A certain emission of manganese also takes place from motor vehicles powered by petrol that contains manganese additives.

Motor vehicles using diesel oil emit nickel and cadmium, but the amounts released are small compared to other sources of emission for these metals.

2.2 Non-ferrous metal production

Primary non-ferrous metal production involves conversion of an ore concentrate to a relatively pure metal. Five primary metal production processes - copper, nickel, lead, zinc and cadmium are responsible for significant atmospheric emissions of the metals mentioned above.

There are three main sources of emission for trace elements from primary metal production: the roasters, smelting furnaces, and converters. Most of the European plants use electrostatic precipitators to control particulate emissions from these sources. There are two main factors which contribute to the large emissions of many elements in the plume of a smelter. First, the sulphide-associated elements are enriched in the concentrate relative to the ore. Second, the high temperatures involved in the smelting process along with the fact that many elements are volatile will allow these elements to be released during the process.

High efficiency control devices are employed at the majority of non-ferrous metal smelters. Roaster facilities and sintering processes are controlled with fabric filters and electrostatic precipitators. Still, copper-nickel smelters emit huge amounts of arsenic, copper and lead. The quantities of cadmium and zinc are also significant. Zinc-cadmium smelters emit chiefly iznc, lead, cadmium and arsenic. Lead smelters release huge amounts of lead to the atmosphere.

Secondary smelting processes include the recycling of zinc, copper and lead scrap. The major emissions of trace elements are ascribed to three processes: (1) the melting og scrap in a convertor; (2) the oxidation of impurities in the scrap in a convertor; (3) the refining of metal. The amounts of trace elements emitted from secondary non-ferrous metal production in European countries are, however, small compared to those from primary non-ferrous metal production.

2.3 Iron, steel and ferroalloy manufacturing

The iron and steel industry emits relatively large amounts of trace elements to the atmosphere. These emissions are the result of iron and steel production in five main types of plants: the sintering strand, the blast furnace, the open hearth, the basic oxygen furnace, and the electric arc. Sintering operations are the major area of application for electrostatic precipitators in the iron and steel industry. In the European countries the blast furnaces, being the last stage of the iron making, are normally equipped with a multi-stage cleaning system, often employing wet electrostatic precipitators.

The emission of trace elements during steel making is a function of the ceanliness and composition of the scrap metal charge, the refining procedure used with or without oxygen lancing, and the refining time. The higher atmospheric emission factors for electric arc steel making (EAS) compared with basic oxygen steel making (BOS) reflect the differences in the charge materials used in the two processes, which are the most commonly used in Europe. Electric arc furnaces generally receive a charge consisting entirely of steel scrap, while oxygen furnaces have a low scrap loading, the charge consisting mainly of iron. The emission of trace elements also depends on the type and efficiency of the particulate control devices. In European factories, the most commonly used dedusting installations are venturi scrubbers with an efficiency of 98 per cent, bag filters with an efficiency of 99 per cent and electrostatic precipitators with an efficiency of 99 per cent.

In addition to the three main processes for steel making described above, there is also scarfing, which is a method of surface preparation of semi-finished steel. However, the electrostatic precipitators used with this process are so efficient that the trace element emission from this source is neglegible, however.

Ferroalloys are used for deoxidation, alloying, and graphitization of steel. Manganese is the most widely used element in ferroalloys, followed by silicon, chromium and phosphorous. Others include

molybdenum, tungsten, titanium, zirconium, vanadium, boron and niobium. The emission of trace elements during ferroalloy manufacture depends on (1) type of alloy produced, (2) process (i.e., continuous or batch), (3) choice of raw materials, (4) operating techniques, and (5) maintenance. Open furnaces are mostly equipped with fabric filters and closed furnaces have wet venturi scrubbers.

Of the trace elements emitted from iron, steel and ferroalloy plants, chromium, lead, zinc, and manganese appear to be the most important ones with respect to amounts emitted and toxicity.

Large quantities of coke are produced for use in the iron and steel industries, but the emission of trace elements from this process is considered separately in Section 2.1 under industrial use of coal.

2.4 Refuce incineration

Incineration is a combustion process, and like all combustion processes it will cause air pollution unless carefully controlled. The sources considered in this report are municipal incineration and sewage sludge incineration. The particle emission from municipal incinerators is a function of many variables: (1) undergrate air velocity; (2) refuse ash content; (3) burning rate or combustion quality; (4) grate agitation on a continuous feed incinerator; (5) size, method, and frequency of feeding for batch units, and (6) combustion chamber clensing. (1). The contribution of total suspended particulates from this emission is small, however, the particles contain such high concentrations of trace elements, that incinerators are important sources of airborne cadmium, zinc, antimony and probably tungsten, silver and arsenic in many cases(1). The emission of trace elements from municipal incinerators depends on the combustible portion of the refuse input, the noncombustible sources in the refuse input, the chemical composition of the refuse input, the chamber design (combustion temperature) and the efficiency of dedusting installations. Municipal incinerators are

usually equipped for removal of particles from the flue gases (i.e. spray chambers or electrostatic precipitators).

Sewage sludge is a by-product of sewage treatment processes. By incineration the sludge is freed for moisture prior to combustion. The main particulate emission source is the furnace. The plants in Europe are well equipped with control devices. Efficiences of these installations range from 90 to greater than 98 per cent.

2.5 Phosphate fertilizers

The term "phosphate fertilizers" used in this report includes phosphate rock preparation and phosphate fertilizer production. Phosphate rock preparation involves benefication to remove impurities, drying to remove moisture, and grinding to improve reactivity. Emissions from these processes consist primarily of fine rock dust and vary due to phosphate rock composition and properties as well as the efficiency of dedusting installations. To calculate the emission of trace elements from European plants, efficiencies of 95 per cent for drying and 97 per cent for grinding have been assumed as average values.

To obtain a plant-available form of phosphorus, the rocks are converted either by acidification or by a thermal process. The main sources of particulate emission from the conversion are the granulators, dryers, coolers, and screens. Zinc, cadmium, copper, and nickel are emitted in significant amounts from these sources.

2.6 Cement production

The largest source of emissions within a cement plant is the kiln operation (1), which may be considered to have three units: the feed system, the fuel-firing system, and the clinker-cooling and handling system. Other sources of dust emissions are raw material storage piles, conveyers, storage silos, and loading/unloading facilities. The most commonly used control equipments are multicyclones, electrostatic precipitators, and fabric filters.

From among the elements entering the atmosphere from cement factories the most important are lead, chromium, and cadmium.

2.7 Industrial applications of metals

Industrial applications of metals regarded as a source of airborne trace elements is considered for each element in Section 3.

3 EMISSION INVENTORY OF INDIVIDUAL TRACE ELEMENTS

Data for the trace element emission in the European countries in 1979 are given in Tables 16-44.

3.1 Arsen

The total anthropogenic emission of arsenic in Europe in 1979 was calculated to 6,500 tonnes. The most important source of airborne arsenic are primary copper-nickel plants (smelters) which are responsible for 68 per cent of the total emission. As can be seen from Table 6, the countries releasing more than 200 t/year are the following: the USSR, the Federal Republic of Germany, Poland, Belgium and Spain. In the case of Belgium, the data are overestimated because alloys and processing of refined copper imported from Zaire have also been taken into account.

Of the arsenic emitted in Europe 14 per cent comes from primary zinc-cadmium smelters. Emissions higher than 100 t of As/year have been calculated for the USSR and the Federal Republic of Germany (Table 7).

Industrial, commercial and residential combustion of fuels appears to be third source contributing 6 per cent of the arsenic emission. Lead smelters contribute 5 per cent, conventional thermal power plants 4 per cent, wood combustion 1 per cent and refuse incineration 0.2 per cent. The rest of the arsenic entering the atmosphere comes from industrial applications of this metal. The largest amounts

of arsenic are used in steel and iron making, in agriculture (herbicides, insecticides, feed additives), and in wood preservatives. It is estimated, that about 10 per cent of the arsenic used to produce pesticides may be volatilized to the atmsophere by aerobic and anaerobic microbal activity.
Among the main arsenic pesticide producing countries are Sweden, France and the USSR (12).

An important source of arsenic emission is the cotton ginning process, which removes the seeds from raw cotton. The highest amounts of arsenic from this source have been calculated for Sweden, the USSR, and France (Table 14).

3.2 Beryllium

The total anthropogenic emission of beryllium in Europe in 1979 is estimated to 50 tonnes. This quantity chiefly arises from coal combustion. The combustion of oil also contributes to the release of beryllium, but much less than coal combustion. The largest amounts of this metal are released in countries, where coal is a predominant source of energy.

The second source of emission is beryllium extraction plants, releasing about 5 g of Be per 1 tonne of Be processed. The principal uses of beryllium and its compounds are 25 per cent in electrical switches; 30 per cent in computers, radio, and television applications, 10 per cent in missiles and space vehicles, and the remainder in welding, aircraft engines, and precision instruments. The emissions of beryllium from all these sources as well as from the rocket propellant industry and ceramic plants, are very small comparing to those from fuel combustion and can be neglected.

3.3 Cadmium

An amount of 2,700 tonnes of cadmium is yearly emitted from anthropogenic sources in Europe. The largest contribution being 59 per cent from primary zinc-cadmium smelters located mostly in

the USSR, the Federal Republic of Germany, France, Belgium and Poland (Table 7).

Primary copper-nickel smelters result in 23 per cent of the cadmium emission. Much less of the cadmium is emitted from primary lead smelters (only 0.3 per cent).

The third source of cadmium in Europe is industrial, commercial and residential combustion of coal and oil, contributing 6 per cent to the total anthropogenic emission of cadmium. The rest of airborne cadmium emission comes from power plants (4 per cent), refuse incinerators (3 per cent), iron, steel and alloy manufacturing (1 per cent), gasoline combustion (1 per cent), wood combustion (1 per cent), phosphate fertilizers (1 per cent), and cement production, secondary non-ferrous metal production, as well as mining and industrial applications of cadmium. Industrially cadmium is used in plating of other metals (iron, steel and copper), as pigments in plastic, and stabilizers (PVC), in pigments for glass and paint, in nuclear reactors as a neutron absorber, and in insecticide production. The manufacture of aluminium solder, dental amalgams, incandenscent lamps, smoke bombs, small-arms ammunition and storage batteries provide an additional opportunity for cadmium emissions. However, all these industrial applications cause very small emissions and contribute much less than 1 per cent of the total cadmium emission from anthropogenic sources in Europe.

3.4 Cobalt

The anthropogenic emission of cobalt in Europe is estimated to 2000 tonnes per year. Almost all this amount is emitted from the combustion of fuels. The highest values have been calculated for the USSR and Italy, (more than 70 tonnes of Co per year in each of these countries) in the case of power plants, and for the USSR, Poland, the Federal Republic of Germany, the United Kingdom, France and Italy in the case of industrial, commercial and residential combustion of coal and oil. Small amounts of cobalt are emitted from waste incinerators and industrial applications of the metal. Cobalt

is used in high-temperature alloys and in permanent magnets. Its salts are used in paint driers, as catalysts, and in the production of numerous pigments. The emissions of cobalt from these sources are negligible.

3.5 Chromium

More than 18,900 tonnes of chromium are yearly emitted in Europe. About 82 per cent of the chromium emission is estimated to be derived from ferrochrome production, especially in the USSR, the Federal Republic of Germany, Italy, the United Kingdom, France and Poland, (Table 11). Almost 15 per cent of the chromium is released from the combustion of fuels, chiefly coals. Cement production appears to be the third largest source of emission. Relatively small quantities of chromium are emitted from refuse incineration and industrial applications of metal. The later sources include: the production of chromium pigments, the use of chromium salts as a tanning agent for leather, wood preservatives, fungicide, anticorrosion products in cooling systems and boilers and the use of asbestos.

3.6 Copper

The yearly emission of copper from anthropogenic sources in Europe was calculated to 15,500 tonnes. Of this amount 50 per cent is emitted from primary copper-nickel production, mostly in the USSR, the Federal Republic of Germany and Poland. Combustion of fuels accounts for 22 per cent of the total copper emission.
The third largest source of copper in Europe is iron, steel and alloy-making, contributing 11 per cent of the total emission. This source is followed by wood combustion (10 per cent) and primary zinc-cadmium and lead production (4 per cent). Other emissions contributing 3 per cent of total emission, including refuse incineration, mining, secondary non-ferrous metal production, phosphate fertilizers and industrial application of the metal. The last source includes chiefly copper sulphate used as a fungicide and copper salts used as food additives.

3.7 Mercury

The emissions of mercury are given with some reservations. The data listed in the tables give the mercury emission with dust particles. However, high-temperature processes emit mercury mostly in the vapor form (95 per cent of the total emission of mercury from these processes enter the atmosphere as a vapor). Also for other processes, the emission of mercury depends on the temperature of flue gases in the stack. This temperatures depend on the technology used, type of burner, etc. Counting only the emission of mercury in particles, a total amount of 48 tonnes of metallic mercury was estimated for the anthropogenic emission in the European countries. The three most important sources are: refuse incineration (40 per cent), primary zinc-cadmium factories (27 per cent) and fuel combustion (24 per cent).

In addition to the mercury emissions listed in tables 1-15, the emissions from industrial application of mercury have to be considered. The chloralkali industry is the largest consumer of mercury, followed by the electrical and paint industries, measuring instruments, agriculture, dentistry and the chemical industry. Chlor-alkali plants producing chlorine, caustic soda, sodium hypochlorite and hydrochloric acid, release about 5 g of Hg per tonne of chlorine produced [1]. Organic compounds of mercury are employed as preservatives in aqueous emulsion paints to avoid spoilage in the can and increase the resistance of the paint film to mildew attack. Emission factors from 23.5 to 440 g of Hg per tonne of aqueous emulsion paints produced, have been estimated [1]. Organo-mercury compounds are widely used as seed dressings for the control of seed and soil-borne diseases in cereals. To prevent spoilage of grain by fungous growth, a method of treating seed grain is used. The dry spray is supplemented by a liquid solution of alkyl mercury.
A mercury emission factor of 0.17 kg of Hg per 1 kg of mercury used, has been calculated for fungicide production. In the paper industry, mercury protects wood pulp stored for processing from becoming mouldy. The metal is also employed in cleansing the paper-making machinery of the slimy fungous material that adheres to it. When paper is burned mercury becomes airborne.

3.8 Manganese

The anthropogenic emission of manganese in Europe was estimated to 17,700 tonnes per year. The most important source of this emission is iron, steel and ferroalloy production, releasing 84 per cent of total amount. Another 13 per cent of the total emission arises from fuel combustion, mostly from coal-fired boilers. The emission of manganese from coal combustion in Europe is more than four times as high as from oil combustion. The remainder of the manganese emission in Europe comes from mining, refuse incinerators, gasoline combustion and manganese applications in industry. Manganese and its compounds are used to produce dry-cell batteries, electrical coils, ceramics, matches, glass, welding rods, and as oxidizing agents, and animal food additives. The primary uses in medicine are as antiseptics and germicides. Emissions from industrial application sources are very small and can be neglected.

3.9 Molybdenum

Molybdenum is emitted mostly from coal and oil combustion in power plants and industrial, commercial and residential boilers. An emission of 850 tonnes per year has been estimated for this source in Europe. The industrial uses of molybdenum include the manufacture of high temperature steel alloys for use in gas turbines and jet air craft engines, production of catalysts, lubricants, and dyes. This emission is far smaller than the emission of molybdenum from the combustion of fuel.

3.10 Nickel

The total emission of nickel from antropogenic sources in Europe was estimated to 16,000 tonnes per year. Oil combustion in power plants and industrial, commercial and residential boilers contribute 60 per cent to this emission, while coal combustion releases another 17 per cent of the total emission of nickel. The next two sources emitting comparable amounts of nickel are mining and refining and gasoline combustion (at a level of 9 per cent of total

emission from each source). Other sources include wood combustion, production of nickel and copper-nickel alloys, primary lead manufacturing, phosphate fertilizers, refuse incineration and industrial applications of the metal. Nickel from industrial sources is emitted during the production of Ni-Cd batteries, electronic devices, and commercial chemicals.

The highest emissions of nickel in Europe have been estimated for the USSR, Italy, France, the Federal Republic of Germany and the United Kingdom (Table 15).

3.11 Lead

Of all the trace elements examined, lead is emitted in the largest quantities. A total at almost 123,000 tonnes of this metal is emitted from the different European sources. The most important source is gasoline combustion, which contributes 60 per cent of the total.

Iron, steel and alloy production release 12 per cent of the lead emission, primary lead production 8 per cent, primary copper-nickel and zinc-cadmium production 14 per cent and fuel combustion in thermal power plants and industrial, commercial and residential boilers 2 per cent. The rest of lead emission comes from mining, refuse incineration, cement production, wood combustion, secondary non-ferrous metal production and industrial applications of the metal. The last source includes the lead alkyl manufacture, storage battery production, production of can solder, ammunition, cable covering, etc. The brass and bronze ingot production and the lead uses for ceramics also contribute to the total emission. All the above-mentioned industrial processes yield 1.4 per cent of the total lead emission from anthropogenic sources in Europe. Detailed calculations can be made using the emission factors in [1]. The highest lead emission values were obtained for the USSR, France and the United Kingdom (more than 10.000 tonnes per year in each country).

3.12 Antimony

The total emission of antimony from different sources in Europe was calculated to 380 tonnes/year. Nearly all this comes from combustion of coal in power plants and industrial, commercial and residential boilers (74 per cent) and refuse incineration (25 per cent). A small amount of antimony is released from secondary copper production and industrial uses of the metal in lead alloy production, storage battery grids, ceramics, paint production and textiles. The highest emissions of antimony are estimated for countries where coal is the predominant source of energy.

3.13 Selenium

Selenium from high-temperature sources such as power plants is partly emitted as a vapor. The numbers in this report represent the particulate selenium emission. With this limitation, the yearly emission of selenium in Europe was estimated to almost 420 tonnes, emitted chiefly from the combustion of coal and oil in power plants, industrial, commercial and residential furnaces. Some small emission from refuse incineration, primary zinc-cadmium production and industrial sources were also included. Selenium is used in the electronics inidustry for rectifiers, photo cells, and solar batteries, in glass and ceramic manufacturing, as a vulcanizing agent for rubber, in fungicides, insecticides and insect repellants. The emission from these sources is negligible.

3.14 Vanadium

The majority of 34,500 tonnes of vanadium, yearly emitted from the anthropogenic sources in Europe, comes from oil combustion in power plants and in industrial, residential and commercial boilers. The highest values of emission are estimated for countries, where oil is the most important source of energy. Small quantities of vanadium are also emitted from refuse incinerators and industries producing the metal and its compounds, industries engaged in refining crude oil, and industries producing vanadium alloys.

3.15 Zinc

The total emission of zinc in Europe was estimated to 80,000 tonnes per year. The largest source of emission is primary zinc-cadmium production, releasing more than 61 per cent of the total.

Iron, steel and alloy manufacturing emit 13 per cent , refuce incineration 7 per cent, wood combustion 6 per cent, coal and oil combustion 4 per cent and secondary zinc manufacturing and primary copper-nickel production 3 per cent each. The rest of the zinc entering the atmosphere, is released from mining, secondary copper and lead production, primary lead manufacturing, phosphate fertilizer production, and industrial applications of zinc. The last source includes the manufacture of galvanized iron, bronze, white paint, rubber, glass, enamel, and paper, and agricultural uses of zinc in a wood preservative for its fungicidal action. The highest emissions of zinc in Europe were calculated for the USSR, the Federal Republic of Germany, France, Poland, Belgium, Italy and Austria (more than 4,000 tonnes/year in each of these countries).

3.16 Zirconium

The emission of zirconium in Europe in 1979 (1,700 tonnes per year) was calculated from the combustion of coal. Other sources, including applications of zirconium in industry, have emissions far less than the emission from coal firing. In this case, countries where combustion of coal is the main source of energy, contribute most to the total anthropogenic emission. Industrial applications of the metal include uses of zirconium in the nuclear industry as a shielding material, in metal alloys, as a catalyst in organic reactions, in the manufacture of water-repellant textiles, in dyes, in pigments on ceramics, in abrasives, and cigarette lighter flints.

4 COMPARISON OF TRACE ELEMENT EMISSIONS IN DIFFERENT EUROPEAN COUNTRIES

It is very difficult to find a suitable criterion which can serve to compare the emission of trace elements from particular sources in

Europe. In this paper, the ratios of emission values to population have been used. Data for the European countries are listed in Table 45, which shows that there is no simple relationship between population and emission. The higher emissions ratios clearly depend on the occurrance of particular sources. Thus, Luxemburg, with its small population shows a relatively high industrial activity, which results in the highest emission of chromium, copper, manganese, lead and antomony per capita. The iron and steel industries are chiefly responsible for such large emissions of these trace elements (Table B-8, Appendix B).

The spatial distribution of the trace element emissions in Europe are presented in Figs 1-14. For Be, Co, Mo, Ni, Sb, Se, V and Zr data are present in the EMEP grid (150 km) [9]. The main source of emission for these elements is coal and oil combustion. Accordingly, the distribution of the emissions of these elements show the same pattern as that from coal and oil power plants presented in an earlier report [9], and the pattern is similar to that of sulphur (13,14). The square marks in the figures show places with emissions between 50 and 75 per cent of the maximum emission. The circles mark grid elements with an emission of more than 75 per cent of the maximum value.

For As, Cd, Cr, Cu, Mn and Zn, only areas with the highest emissions are indicated on the major.

5 UNCERTAINTIES

The present survey seems to be the first attempt to assess the anthropogenic emission of trace elements in Europe. The results have been obtained by using emission factors for the trace elements emitted from different sources. A number of uncertainties that emerged during the calculations of these factors have already been discussed in previous reports by the author (1, 6, 7, 8).

The uncertainties include the content of trace element in fuels

and raw materials, the efficiencies of control devices used in power plants, smelters and other industries, the uses of different technologies to produce industrial goods, etc. The further uncertainties mainly concern the data used for the consumption of fuels and raw materials and the production of industrial goods. Most of the results have been obtained using data from 1979. Since this time, consumption and production may have changed in some countries.

The iron and steel production contributes significantly to the emission of arsenic. However, the arsenic emission factor for this source is not known. This source is therefore not included.

The lead content in gasoline presented in Table B-5 (Appendix B) is not always representative.

Insufficient data exist to quantify the flow of trace elements from waste incineration. For many countries information on quantities of refuse incinerated are not available, especially for sewage slugde.

A lack of data on the emission of trace elements from industrial applications of metals also creates problems.

The further uncertainties are directly mentioned in Appendixes A and B where the trace element emission factors and the fuel and ore consumption and production of goods are presented.

Many of the assumptions used in estimating the national emissions of trace elements in Europe may well be improved. This would require further information to be collected from the particular countries.

6 CONCLUDING REMARKS

From these results the following conclusions can be made:

1. Beryllium, cobalt, molybdenum, antimony, selenium, nickel, vanadium and zirconium are mostly emitted from the combustion of

coal and oil in power plants, and industrial, commercial and residential boilers. From among these elements nickel and vanadium are chiefly released from oil-fired furnaces. Considering the low contribution of natural sources to the total emission of vanadium and nickel, both elements can serve as good indicators of oil-fired power plants and oil combustion sources in industry. Beryllium, antimony, selenium and zirconium are chiefly emitted from coal combustion. These elements therefore can be suggested as indicators of coal-fired power plants and other sources burning coal.

2. Primary non-ferrous metal production is the most important source of arsenic, cadmium, copper and zinc emission. Copper-nickel smelters release the largest quantities of arsenic and copper. Cadmium and zinc mostly arise from zinc-cadmium smelters.

3. The largest amounts of chromium and manganese are emitted from iron, steel and alloy manufacturing; especially chromium could be regarded as an indicator of emissions from the iron and steel industry.

4. The large emissions of lead are the result of gasoline combustion. About 60 per cent of the total anthropogenic emission of lead comes from this source, and estimation of the lead content in gasoline is of primary importance for this emission.

5. Trace elements can well serve as indicators of large area sources of emission. In this case, the natural sources of the same trace elements have been taken into account. This particularly applies to the emission from natural sources of arsenic, mercury and selenium. It should be noted that it is extremely difficult to ascertain unambiguously what proportion of the trace elements come from anthropogenic and natural emissions.

6. Trace elements can also be used as indicators of origin for aerosols in remote areas (e.g. the Arctic aerosols). As an example, the ratio of manganese to vanadium is sometimes used.

It should be stressed taht one of the major parameters governing the significance of the trace element emissions for this purpose is particle size. Hence, metals associated with particles larger than 3 μm aerodynamic equivalent diameter are minimally effective in atmosphere interactions and have a short residence time in the atmosphere.

7. The present study indicates that when the ratio between different trace elements is used as an indicator of origin, it may be useful to examine the ratio between trace elements from different types of sources.

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Table 1: Emission of trace elements from conventional thermal power plants in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg*[1]	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania	0.1	v.s.	v.s.	0.1	0.5	0.3	2.0	0.4	0.1	0.5	0.3	0.1	0.1	1	0.4	0.3
Austria	1.4	v.s.	0.6	6.2	3.7	9.0	7.4	3.2	1.6	47.2	6.7	0.2	1.0	165	5.6	1.2
Belgium	6.3	0.3	2.6	23.4	21.1	36.5	57.6	18.2	7.5	166.9	28.0	1.6	4.0	554	26.8	10.5
Bulgaria	4.1	0.3	1.4	10.9	17.9	19.4	72.6	15.4	5.2	59.2	16.4	1.9	2.2	152	19.5	11.2
Czechoslovakia	14.1	1.4	4.4	26.6	71.4	56.2	319.1	60.8	18.3	89.8	50.9	8.4	6.6	50	70.9	49.1
Denmark	2.7	0.1	1.1	10.4	8.8	16	27.7	7.6	3.2	74.8	12.2	0.6	1.7	251	11.4	4.2
Finland	2.3	0.1	0.9	7.7	8.2	12.5	24.5	7.0	2.7	53.2	9.7	0.7	1.4	171	10.0	4.5
France	7.0	0.5	2.5	18.5	30.6	34.2	106.1	25.7	8.4	113.2	27.7	3.0	3.8	317	32.5	19.3
German Dem.Rep.	22.1	2.3	6.8	41.6	111.9	88.0	499.9	95.3	28.7	140.7	79.8	13.1	10.3	78	110.1	77.0
German Fed.Rep.	22.1	2.0	7.5	45.1	109.0	96.1	431.2	90.7	26.6	228.6	81.0	11.5	11.0	469	106.8	73.0
Greece	2.5	0.2	0.9	6.2	11.3	11.8	42.9	9.4	3.0	36.7	9.7	1.1	1.3	98	11.7	7.1
Hungary	4.3	0.3	1.5	11.3	18.4	20.0	74.0	3.4	5.4	61.3	16.9	2.0	2.3	157	20.1	11.5
Iceland*[1]	3.4	-	1.6	18.1	6.1	24.3	-	5.7	3.9	142.9	17.6	-	2.6	518	14.4	-
Ireland	0.5	-	0.2	2.7	0.9	3.6	0.2	0.9	0.6	20.9	2.6	-	0.4	76	1.8	v.s.
Italy	14.3	0.1	6.6	71.9	29.0	98.5	22.1	26.6	16.5	560.6	71.8	0.6	10.5	2012	53.3	3.8
Netherlands	5.8	0.1	2.7	28.9	12.2	39.8	13.1	11.1	6.7	224.8	29.1	0.3	4.3	805	21.9	2.0
Norway*[1]	9.5	1.0	3.1	15.2	50.8	37.7	0.2	42.0	11.5	57.9	32.9	5.6	4.4	35	47.4	36.1
Poland	26.8	2.8	8.3	50.6	136.0	107.0	576.2	115.9	34.9	171.1	96.9	15.9	12.5	95	135.0	93.6
Portugal	0.5	-	0.2	2.4	1.0	3.3	1.2	0.9	0.6	18.7	2.4	v.s.	0.3	67	1.8	0.2
Romania	4.5	0.1	1.8	16.8	14.8	25.5	46.6	12.9	5.5	114.9	20.0	1.2	2.8	376	19.2	7.2
Spain	5.8	0.4	2.2	16.7	23.6	29.3	87.9	19.9	6.8	107.6	23.4	2.2	3.3	321	26.0	14.1
Sweden	2.1	-	1.0	11.1	3.7	15.0	0.1	3.5	2.4	87.8	10.8	-	1.6	318	7.7	v.s.
Switzerland	0.1	-	v.s.	0.3	0.1	0.5	0.1	0.1	0.1	2.6	0.3	-	0.1	10	0.2	v.s.
Turkey	2.4	0.2	0.8	5.7	11.3	10.7	47.6	9.7	3.1	26.7	9.3	1.3	1.2	55	11.8	7.4
USSR	104.4	7.2	38.0	316.5	413.6	525.9	1496	357.7	130.5	1908.2	431.0	41.2	58.8	5559	476.2	241.6
United Kingd.	20.5	1.9	6.9	42.2	100.5	89.4	373.8	83.6	24.6	216.3	75.2	10.6	10.3	451	98.7	68.1
Yugoslavia	7.2	0.7	2.2	13.6	36.5	28.7	162.9	31.1	9.4	45.9	26.0	4.3	3.2	26	36.2	25.1
Total	284	21	101	787	1196	1377	4493	1011	352	4580	1138	122	155	12600	1316	732

*[1] in kg/year

v.s.- very small

Table 2: Emission of trace elements from coal and oil in industrial, commercial and residential boilers in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania	0.8	0.1	0.3	2.4	3.1	4.0	0.02	0.7	1.0	14.5	3.3	0.3	0.4	42	3.6	1.8
Austria	3.8	0.1	1.7	15.6	11.8	23.9	0.02	10.8	4.6	114.4	17.9	0.8	2.2	387	16.3	5.4
Belgium	13.3	0.2	4.7	31.9	62.5	61.2	0.30	54.3	17.1	160.1	52.0	6.8	6.4	355	65.7	41.9
Bulgaria	13.0	1.1	4.9	36.1	54.7	62.5	0.28	47.3	16.3	203.5	52.1	5.6	7.1	549	60.8	33.5
Czechoslovakia	20.5	1.7	7.9	59.5	83.7	101.1	0.42	72.6	25.6	348.9	83.4	8.4	11.4	893	94.8	50.1
Denmark	2.6	0.1	1.3	12.7	5.9	17.7	0.01	5.4	3.1	97.4	13.0	0.2	1.9	345	10.1	1.1
Finland	3.3	0.1	1.6	15.0	9.2	22.1	0.01	8.5	4.0	113.4	16.3	0.5	2.1	394	13.9	3.9
France	21.0	0.9	9.4	84.0	66.1	127.8	0.17	59.6	25.4	602.7	97.2	5.0	12.8	2022	90.0	32.1
German Dem.Rep.	25.8	2.4	9.4	66.8	113.3	119.9	0.60	97.8	32.6	355.4	101.4	12.0	13.7	886	122.7	71.4
German Fed.Rep.	27.2	1.9	10.7	88.9	103.9	145.7	0.43	91.4	33.8	570.0	116.4	9.7	15.4	1742	123.9	59.9
Greece	2.7	v.s.	1.2	11.1	7.6	16.2	0.03	6.8	3.2	80.2	12.3	0.5	1.8	273	10.8	3.1
Hungary	3.9	0.3	1.6	12.4	15.0	20.2	0.07	13.0	4.8	77.2	16.4	1.4	2.3	232	17.7	8.5
Iceland*[1]	0.1	-	0.1	0.4	0.1	0.5	-	0.1	0.1	2.9	0.3	-	0.1	10	0.2	-
Ireland	1.3	0.1	0.5	5.1	4.6	8.4	-	4.1	1.6	37.4	6.2	0.4	0.6	124	6.0	2.9
Italy	18.5	0.7	8.5	78.0	52.1	113.6	0.17	46.7	22.0	566.9	86.2	3.4	12.2	1940	75.6	20.7
Netherlands	2.7	0.2	1.1	8.9	10.3	14.4	0.05	9.0	3.4	56.6	11.5	1.0	1.6	173	12.3	5.8
Norway*[1]	1.4	0.4	0.6	6.1	3.5	8.7	0.01	3.1	1.6	45.8	6.5	0.2	0.9	150	5.4	1.1
Poland	48.6	5.4	16.3	100.8	238.1	202.9	1.35	204.2	62.5	408.2	179.9	27.0	23.6	577	241.9	160.5
Portugal	1.5	v.s.	0.8	7.4	3.4	10.2	0.01	3.1	1.8	56.7	7.5	0.1	1.1	201	5.8	0.7
Romania	21.0	2.3	7.1	44.4	105.3	88.5	0.58	87.7	27.0	184.8	78.2	11.5	10.3	284	104.4	68.6
Spain	11.0	0.5	4.9	43.9	34.0	66.1	0.11	30.4	13.3	313.5	50.5	2.5	6.9	1052	46.6	15.8
Sweden	4.5	0.1	2.6	25.2	11.6	35.0	0.02	10.7	6.1	193.0	25.8	0.4	3.8	685	20.1	2.5
Switzerland	0.9	v.s.	0.4	4.3	1.7	5.9	-	1.5	1.0	33.4	4.3	v.s.	0.6	120	3.2	0.2
Turkey	9.2	0.9	3.4	24.8	44.3	48.0	0.14	39.5	12.1	142.2	38.9	4.7	3.9	364	47.6	31.2
USSR	101.8	7.7	40.2	314.6	397.0	519.2	1.93	345.5	126.1	1929.6	422.6	38.5	58.2	5703	462.7	229.2
United Kingd.	27.6	2.3	10.8	86.0	121.8	155.6	0.30	109.8	35.8	551.6	122.3	12.0	12.4	1612	138.1	82.2
Yugoslavia	5.7	0.1	2.8	26.4	14.3	37.3	0.04	13.0	6.8	197.8	27.8	0.7	4.0	692	22.8	4.4
Luxemburg	0.3	v.s.	0.1	1.3	1.0	1.9	-	0.9	0.4	9.0	1.5	0.1	0.2	30	1.4	0.5
Total	394	29	155	1214	1580	2038	7.1	1378	493	7467	1652	154	218	21800	1824	939

*[1] in kg/year

v.s. - very small

Table 3: Emission of trace elements from wood combustion in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg*[1]	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania	0.4		0.3			16.5	8.8			4.1	6.2				50.0	
Austria	0.3		0.2			9.8	5.2			2.5	3.7				30.1	
Belgium	0.1		0.1			2.5	1.3			0.6	0.9				7.5	
Bulgaria	0.3		0.2			10.2	5.4			2.5	3.8				31.2	
Czechoslovakia	0.4		0.2			15.4	8.2			3.8	5.8				47.0	
Denmark	v.s.		v.s.			0.9	0.5			0.2	0.3				2.6	
Finland	1.1		0.7			43.0	22.9			10.7	16.1				131.7	
France	0.8		0.5			28.7	15.3			7.2	10.7				87.8	
German Dem.Rep.	0.1		0.1			5.2	2.8			1.3	1.9				19.6	
German Fed.Rep.	0.3		0.2			12.2	6.5			3.0	4.6				37.3	
Greece	0.5		0.3			20.3	10.8			5.1	7.6				62.1	
Hungary	0.8		0.5			30.2	16.1			7.5	11.3				92.5	
Iceland	-		-			-	-			-	-				-	
Ireland	v.s.		v.s.			0.1	v.s.			v.s.	v.s.				0.2	
Italy	0.8		0.5			30.7	16.4			7.7	11.5				94.1	
Netherlands	v.s.		v.s.			0.3	0.2			0.1	0.1				1.0	
Norway	0.1		0.1			4.8	2.5			1.2	1.8				14.6	
Poland	0.4		0.2			15.4	8.2			3.8	5.8				47.0	
Portugal	0.1		0.1			5.3	2.8			1.3	2.0				16.3	
Romania	1.3		0.8			50.2	26.7			12.5	18.8				153.6	
Spain	0.3		0.2			12.0	6.4			3.0	4.5				36.9	
Sweden	0.8		0.5			30.7	16.4			7.7	11.5				94.1	
Switzerland	0.2		0.1			8.3	4.4			2.1	3.1				25.5	
Turkey	7.6		4.7			286.7	152.9			71.7	107.5				877.9	
USSR	21.8		13.5			819.0	436.8			204.9	307.1				2508.2	
United Kingd.	0.1		0.0			1.5	0.8			0.4	0.5				4.5	
Yugoslavia	1.0		0.6			38.9	20.8			9.7	14.6				119.2	
Luxemburg	v.s.		v.s.			0.2	0.1			0.1	0.1				0.5	
Total	40		25			1500	800			375	562				4590	

*[1] in kg/year

v.s. - very small

Table 4: Emission of trace elements from gasoline and diesel oil combustion in Europe in 1979. (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg*[1]	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania			v.s.					0.1		1	63					
Austria			0.3					1.2		15	965					
Belgium			0.6					1.6		27	1420					
Bulgaria			0.3					0.9		11	730					
Czechoslovakia			0.3					0.9		12	740					
Denmark			0.2					0.8		10	650					
Finland			0.4					0.7		17	970					
France			3.3					9.5		140	7740					
German Dem.Rep.			0.4					1.5		16	1180					
German Fed.Rep.			3.6					11.6		153	3510					
Greece			0.3					0.6		13	1060					
Hungary			0.3					0.8		11	630					
Iceland			v.s.					v.s.		1	36					
Ireland			0.1					0.5		6	400					
Italy			3.2					5.8		136	7410					
Netherlands			0.7					2.0		30	1610					
Norway			0.2					0.7		8	550					
Poland			0.4					1.7		16	1340					
Portugal			0.6					0.4		19	480					
Romania			0.3					1.1		11	920					
Spain			1.6					2.9		70	3480					
Sweden			0.5					1.8		23	1470					
Switzerland			0.2					1.3		8	1040					
Turkey			0.8					1.0		33	810					
USSR			10.0					32.5		430	26300					
United Kingd.			2.2					9.3		96	7570					
Yugoslavia			0.8					1.3		16	1060					
Luxemburg			v.s.					0.1		2	110					
Total			31					92		1330	74300					

*[1] in kg/year

v.s. - very small

Table 5: Emission of trace elements from mining in Europe in 1979.

Element	As	Be	Cd kg/year	Co	Cr	Cu t/year	Hg*[1]	Mn t/year	Mo	Ni t/year	Pb t/year	Sb	Se kg/year	V	Zn t/year	Zr
Country																
Albania						1.1				72.0			0.5		1.1	
Austria			12								5.0		1.2		3.0	
Belgium																
Bulgaria			44			6.0		1.0			106.5		8.8		26.5	
Czechoslovakia						0.9					13.9		0.7		2.4	
Denmark																
Finland			27			4.7				39.6	0.7		4.4		10.1	
France			20			v.s.					29.6		2.5		7.3	
German Dem.Rep.						1.6				24.3			0.7		1.6	
German Fed.Rep.			44			0.1					20.4		4.7		11.2	
Greece			11					0.4		134.1	15.6		1.5		4.0	
Hungary			1			0.2		2.5			0.9		0.2		0.4	
Iceland																
Ireland			88			0.5					43.5		9.1		22.9	
Italy			31			0.1		0.2			20.1		3.3		8.5	
Netherlands																
Norway			14			2.8				9.0	2.9		2.5		6.0	
Poland			114			31.6				25.2	45.1		23.8		5.0	
Portugal						0.3							0.1		0.3	
Romania						4.0		2.5			36.4		2.4		8.0	
Spain			73			3.2					68.5		9.2		25.1	
Sweden			61			4.2					74.5		10.7		28.7	
Switzerland																
Turkey			21			3.3		2.6			13.5		3.5		8.9	
USSR			385			114		265		1332.0	473.2		93.0		243.0	
United Kingd.			1								4.2		0.2		0.7	
Yugoslavia			52			12.3		0.9			113.2		12.2		35.1	
Total			1000			192		275		1640	1090		195		460	

*[1] in kg/year

v.s. - very small

Table 6: Trace metal emission from primary copper-nickel production in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg*[1]	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania	29		0.4			49					60				17	
Austria	19		2.5			31					39				11	
Belgium	243		32.4			405					501				137	
Bulgaria	94		12.5			156					193				52	
Czechoslovakia	46		5.2			77					96				26	
Denmark																
Finland	80		10.6			132					164				45	
France	62		8.3			103					128				35	
German Dem.Rep.	73		9.8			122					151				41	
German Fed.Rep.	605		80.7			1008					1246				341	
Greece																
Hungary	25		3.3			417					52				14	
Iceland																
Ireland																
Italy																
Netherlands																
Norway	13		1.8			22					27				8	
Poland	498		66.4			830					1026				281	
Portugal	5		0.6			7					9				3	
Romania																
Spain	220		29.4			367					454				124	
Sweden	75		10.1			126					156				43	
Switzerland																
Turkey	42		5.6			70					87				24	
USSR	2220		296.0			3700					4573				1250	
United Kingd.	69		9.2			115					143				39	
Yugoslavia	70		9.4			117					145				40	
Total	4490		595			7850					9250				2500	

*[1] in kg/year

v.s. - very small

Table 7: Trace metal emission from primary zinc-cadmium production in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania																
Austria	77		131			37	1.1				664		1.0		4112	
Belgium	75		126			35	1.1				642		1.0		3971	
Bulgaria	18		46			13	0.4				234		0.4		1446	
Czechoslovakia	1		1			0.3	v.s.				5		v.s.		33	
Denmark																
Finland	41		69			19	0.6				353		0.6		2184	
France	74		124			35	1.0				632		1.0		3914	
German Dem.Rep.	5		8			2	0.1				41		0.1		252	
German Fed.Rep.	105		178			50	1.5				903		1.5		5588	
Greece																
Hungary																
Iceland																
Ireland																
Italy	53		89			25	0.7				451		0.7		2792	
Netherlands	46		77			22	0.6				391		0.6		2419	
Norway	21		36			10	0.3				181		0.3		1121	
Poland	65		111			31	0.9				564		0.9		3490	
Portugal																
Romania																
Spain	49		84			23	0.7				425		0.7		2633	
Sweden																
Switzerland																
Turkey																
USSR	228		385			108	3.2				1956		3.2		12104	
United Kingd.	23		38			11	0.3				197		0.3		1217	
Yugoslavia	28		48			13	0.4				242		0.4		1497	
Total	910		1550			440	13				7880		13		48800	

v.s. - very small

Table 8: Trace metal emission from primary lead production in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg*[1] kg/y	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania																
Austria	1.3		v.s.			0.5	14			0.6	46				0.8	
Belgium	22.7		0.6			9.0	244			10.6	795				13.7	
Bulgaria	22.7		0.6			9.0	244			10.6	795				13.7	
Czechoslovakia	3.5		0.1			1.4	37			1.6	121				2.1	
Denmark																
Finland																
France	22.9		0.6			9.1	246			10.7	801				13.8	
German Dem.Rep.	6.9		0.2			2.7	74			3.2	242				4.2	
German Fed.Rep.	19.1		0.5			7.6	205			8.9	669				11.6	
Greece	3.8		0.1			1.5	41			1.8	134				2.3	
Hungary	0.1		v.s.			v.s.	1			v.s.	1				v.s.	
Iceland																
Ireland																
Italy	5.7		0.2			2.2	61			2.6	198				3.4	
Netherlands	3.3		0.1			1.3	35			1.5	116				2.0	
Norway																
Poland	15.8		0.4			6.2	169			7.4	551				9.5	
Portugal	0.1		v.s.			v.s.	1			v.s.	3				v.s.	
Romania	7.8		0.2			3.1	83			3.6	272				4.7	
Spain	15.1		0.4			6.0	161			7.0	527				9.1	
Sweden	9.4		0.3			3.7	101			4.4	330				5.7	
Switzerland																
Turkey	0.5		v.s.			0.2	6			0.3	19				0.3	
USSR	94.6		2.6			37.4	1014			44.2	3307				57.2	
United Kingd.	22.3		0.6			8.8	239			10.4	781				13.5	
Yugoslavia	21.2		0.6			8.4	228			9.9	742				12.8	
Total	300		8.2			120	3200			140	10500				180	

*[1] in kg/year
v.s. - very small

Table 9: Trace metal emission from secondary copper production in Europe in 1979 (t/year).

Element	As	Be	Cd *1	Co	Cr	Cu	Hg*1	Mn	Mo	Ni	Pb	Sb*1	Se	V	Zn	Zr
Country																
Albania																
Austria			63.6			2.4					2.1	48			26	
Belgium																
Bulgaria																
Czechoslovakia																
Denmark																
Finland																
France			2.4			10.1					0.1	2			1	
German Dem.Rep.																
German Fed.Rep.			580.0			21.7					19.4	435			233	
Greece																
Hungary			52.4			2.0					1.8	39			21	
Iceland																
Ireland																
Italy			70.0			2.6					2.3	52			28	
Netherlands																
Norway			22.4			0.8					0.7	17			9	
Poland																
Portugal																
Romania																
Spain			88.0			3.3					2.9	66			35	
Sweden			56.0			2.1					1.9	42			23	
Switzerland																
Turkey																
USSR																
United Kingd.			317.6			11.9					10.6	238			128	
Yugoslavia			380.8			14.3					12.8	286			153	
Total			1630			61					55	1200			660	

*1 in kg/year

Table 10: Trace metal emission from secondary zinc and lead metal production.

Element	As	Be	Cd*1 kg/year	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb*1 t/year	Sb	Se	V	Zn*1 t/year	Zn*2 t/year
Country																
Albania																
Austria			21.7								6.7				2.6	25.2
Belgium																
Bulgaria																
Czechoslovakia																
Denmark			19.0								5.8				2.3	8.1
Finland																
France			142.7								44.0				17.1	-
German Dem.Rep.																
German Fed.Rep.			499.5								153.8				59.9	2339.1
Greece																
Hungary			4.0								1.2				0.5	5.4
Iceland																
Ireland																
Italy			212.7								65.5				25.5	-
Netherlands																
Norway			0.7								0.2				0.1	-
Poland																
Portugal																
Romania																
Spain																
Sweden			43.5								13.4				5.2	-
Switzerland																
Turkey																
USSR																
United Kingd.			311.2								95.9				37.3	255.6
Yugoslavia																
Total			1255								387				150	2630

*1 Emission from secondary lead production

*2 Emission from secondary zinc production

Table 11: Trace element emission from iron, steel and ferroalloy production in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mn*[1]	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania																
Austria			0.4		175	19		120	47	3.9	167				117	
Belgium			1.4		547	61		373	164	12.1	520				364	
Bulgaria			0.2		100	11		130	23	2.2	95				67	
Czechoslovakia			1.5		619	69		423	154	13.8	589				413	
Denmark			0.5		28	3		19	-	0.6	27				19	
Finland			0.2		94	10		64	28	2.1	90				63	
France			6.3		948	105		794	295	21.1	901				632	
German Dem.Rep.			0.7		283	31		193	45	6.3	269				188	
German Fed.Rep.			10.7		1863	207		1272	536	41.4	1771				1242	
Greece			0.1		40	5		28	-	0.9	38				27	
Hungary			0.4		157	17		105	36	3.5	149				105	
Iceland			-		-	-		-	-	-	-				-	
Ireland			v.s.		3	0		2	-	0.1	3				2	
Italy			7.7		980	108		669	172	21.8	932				653	
Netherlands			0.5		223	25		152	73	4.9	212				148	
Norway			0.1		33	4		22	19	0.7	31				22	
Poland			1.9		752	84		513	174	16.7	715				501	
Portugal			0.1		15	2		10	6	0.3	14				10	
Romania			1.2		477	53		326	124	10.6	454				318	
Spain			1.1		466	52		318	101	10.4	443				311	
Sweden			0.4		176	20		120	36	3.9	167				117	
Switzerland			0.1		32	4		22	1	0.7	30				21	
Turkey			0.2		66	7		45	28	1.5	63				19	
USSR			15.1		6134	682		4188	1685	136.3	5831				4089	
United Kingd.			5.9		871	97		594	196	19.3	828				580	
Yugoslavia			0.3		140	16		95	35	3.1	133				93	
Luxemburg			0.7		194	22		133	58	4.3	185				130	
Total			58		15400	1710		10700	4050	340	14660				10250	

*[1] The manganese emission from pig iron manufacturing.

v.s. - very small

Table 12: Emission of trace elements from refuse incineration (including sewage sludge) in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania																
Austria																
Belgium	0.3		1.2	0.01	0.6	2.0	0.2	0.8		0.2	9.5	2.5	v.s.		141	
Bulgaria																
Czechoslovakia																
Denmark	1.3		5.6	0.03	2.6	9.2	1.0	3.9		0.8	43.9	11.4	0.2		651	
Finland																
France	2.5		11.0	0.05	5.2	18.0	1.9	7.7		1.6	86.1	22.3	0.4		1276	
German Dem.Rep.																
German Fed.Rep.	2.8		32.2	2.09	22.2	118.9	8.1	52.2		3.5	331.0	27.8	16.9	10.54	1583	
Greece																
Hungary																
Iceland*[1]																
Ireland																
Italy	1.3		5.8	0.03	2.8	9.6	1.0	4.1		0.9	45.7	11.8	0.2		677	
Netherlands	0.9		5.4	0.18	3.1	14.2	1.1	6.2		0.7	48.9	8.0	1.5	0.85	457	
Norway*[1]																
Poland																
Portugal																
Romania																
Spain																
Sweden																
Switzerland																
Turkey																
USSR																
United Kingd.	1.7		22.5	0.03	16.0	87.6	5.8	38.5		2.4	236.8	17.0	12.9	8.06	969	
Yugoslavia																
Luxemburg	0.1		0.2	v.s.	0.1	0.4	0.1	0.2		v.s.	1.8	0.5	0.0		26	
Total	11		84	4.0	53	260	19	114		10	804	100	32	19.5	5880	

*[1] in kg/year

v.s. - very small

Table 13: Emission of trace elements from phosphate fertilizer production in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg*[1]	Mn	Mo	Ni	Pb	Sb	Se*[1]	V	Zn	Zr
Country																
Albania			0.1			0.1				0.1	v.s.		0.1		0.2	
Austria			0.2			0.5				0.5	0.1		0.2		1.5	
Belgium *[2]			1.1			3.1				3.1	0.3		1.5		9.4	
Bulgaria			0.5			1.4				1.4	0.1		0.7		4.3	
Czechoslovakia			0.6			1.8				1.8	0.2		0.9		5.5	
Denmark			0.2			0.6				0.6	0.1		0.3		1.7	
Finland			0.3			0.9				0.9	0.1		0.5		2.8	
France			2.4			6.9				6.9	0.6		3.4		20.8	
German Dem.Rep.			0.7			2.1				2.1	0.2		1.0		6.3	
German Fed.Rep.			1.3			3.7				3.7	0.3		1.8		11.2	
Greece			0.3			1.0				1.0	0.1		0.5		2.9	
Hungary			0.4			1.1				1.1	0.1		0.5		3.4	
Iceland																
Ireland			0.1			0.2				0.2	v.s.		0.1		0.6	
Italy			1.1			3.2				3.2	0.3		1.6		9.5	
Netherlands			0.6			1.8				1.8	0.2		0.9		5.5	
Norway			0.3			0.7				0.7	0.1		0.4		2.2	
Poland			1.7			4.7				4.7	0.4		2.3		14.2	
Portugal			0.2			0.6				0.6	0.1		0.3		1.7	
Romania			1.3			3.6				3.6	0.3		1.8		10.8	
Spain			0.8			2.4				2.4	0.2		1.2		7.3	
Sweden			0.2			0.6				0.6	0.1		0.3		2.0	
Switzerland			v.s.			v.s.				v.s.	v.s.		v.s.		v.s.	
Turkey			0.5			1.4				1.4	0.1		0.7		4.3	
USSR			10.6			30.1				30.1	2.5		14.8		90.4	
United Kingd.			0.8			2.4				2.4	0.2		1.2		7.2	
Yugoslavia			0.5			1.4				1.4	0.1		0.7		4.1	
Luxemburg*[2]																
Total			27			77				77	6.3		38		230	

*[1] in kg/year

v.s. - very small

*[2] the emission of trace elements during phosphate fertilizer production in Belgium and Luxemburg has been calculated together and listed in Table 13 for Belgium.

Table 14: Trace element emission from cement manufacture in Europe in 1978 (t/year). The figures for arsenic are for 1979.

Element	As*1	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania	0.03		v.s.		1.3						1.4					
Austria			0.2		9.2						10.3					
Belgium			0.3		12.1						13.6					
Bulgaria	0.02		0.2		8.2						9.3					
Czechoslovakia			0.4		16.3						18.4					
Denmark			0.1		4.2						4.7					
Finland			0.1		2.9						3.2					
France	38.50		1.0		45.1						50.7					
German Dem.Rep.			0.5		20.0						22.5					
German Fed.Rep.			1.3		54.3						61.1					
Greece	0.38		0.4		18.3						20.6					
Hungary			0.2		7.6						8.6					
Iceland			v.s.		0.2						0.2					
Ireland			0.1		2.9						3.2					
Italy			1.4		61.2						68.8					
Netherlands			0.1		6.3						7.1					
Norway			0.1		3.7						4.2					
Poland			0.8		34.6						39.0					
Portugal			0.2		7.4						8.4					
Romania			0.5		22.2						25.0					
Spain	0.15		1.1		46.9						52.8					
Sweden	55.00		0.1		3.8						4.3					
Switzerland			0.1		5.9						6.9					
Turkey			0.6		25.0						28.2					
USSR	41.56		4.7		203.1						228.5					
United Kingd.			0.3		25.5						28.6					
Yugoslavia			0.3		13.9						15.7					
Luxemburg			v.s.		0.5						0.6					
Total	136		15		663						746					

*1 Emission of arsenic from industrial applications.

Table 15: Emission of trace elements from all sources in Europe in 1979 (t/year).

Element	As	Be	Cd	Co	Cr	Cu	Hg*[1]	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
Country																
Albania	31	0.1	1	3	5	71	31	1	1	92	134	0.4	0.5	43	72	2
Austria	103	0.2	137	22	200	134	1145	182	6	184	1933	1.1	4.5	552	4370	7
Belgium	360	0.5	171	55	642	613	1874	613	25	381	3986	10.9	11.4	908	4736	52
Bulgaria	152	1.4	67	47	181	288	988	218	22	291	2234	7.5	9.7	701	1722	45
Czechoslovakia	86	3.1	23	86	791	323	793	712	44	472	1726	16.8	18.0	943	635	99
Denmark	7	0.1	9	23	50	38	1118	37	6	185	753	12.2	3.8	596	706	5
Finland	127	0.2	84	23	115	246	641	109	7	237	1621	1.2	4.1	565	2460	8
France	228	1.4	170	103	1095	450	3492	1192	34	903	10545	30.3	18.0	2338	6127	51
German Dem.Rep.	133	4.7	37	108	528	376	1244	432	61	549	2084	25.1	24.1	965	746	148
German Fed.Rep.	782	3.9	328	136	2153	1552	4676	2054	60	1013	9308	49.5	46.6	2222	11689	133
Greece	10	0.2	4	17	77	55	125	45	6	273	1303	1.6	3.1	372	121	10
Hungary	34	0.6	8	24	198	509	160	160	10	162	888	3.4	4.6	389	280	20
Iceland*[1]	73	-	81	378	336	514	-	-	84	4130	36300	-	53	10900	264	-
Ireland	2	0.1	1	8	11	13	0.2	8	2	65	456	0.4	1	199	33	3
Italy	93	0.8	124	150	1055	385	2025	925	38	1300	9365	16	24	3952	4420	25
Netherlands	58	0.3	88	38	255	105	1405	253	10	321	2427	9.3	7.9	979	3067	8
Norway	36	v.s.	39	6	40	56	312	45	2	66	803	0.2	1.2	160	1188	1
Poland	656	8.2	207	151	1161	1313	3036	1009	97	653	4568	43.0	37.0	672	4725	254
Portugal	7	v.s.	3	10	27	29	16	20	2	97	525	0.1	1.4	268	39	1
Romania	35	2.4	13	61	619	228	737	554	33	338	1827	12.7	13.1	660	614	76
Spain	302	0.9	126	61	571	565	1069	472	20	510	5534	4.8	10.9	1373	3255	30
Sweden	147	0.1	16	36	195	237	138	172	9	323	2270	0.4	5.4	1003	346	3
Switzerland	1	v.s.	1	5	40	18	4	25	1	51	1083	0.03	0.6	130	50	0.2
Turkey	62	1.1	17	30	147	427	346	126	15	277	1180	6.0	5.1	419	994	39
USSR	2812	15.0	816	631	7147	6535	8111	6874	257	6014	43842	80.0	120.0	11262	21281	471
United Kingd.	164	4	99	130	1134	580	2489	1032	60	899	10098	40.0	36.0	2074	3488	150
Yugoslavia	134	0.8	65	40	205	287	851	177	16	284	2423	5.3	7.6	718	2013	29
Luxemburg	0.4	v.s.	1.1	1.3	196	24	49	192	0.4	15	301	0.6	0.2	30	158	0.5
Total	6500	50	2700	2000	18900	15500	48000	17700	850	16000	123000	380	420	34500	80000	1700

*[1] in kg/year

v.s. - very small

Table 16 : Emission of trace elements in Albania in 1979 (in t/year).

ALBANIA	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	0.1	v.s.	v.s.	0.1	0.5	0.3	2	0.4	0.1	0.5	0.1	0.1	0.1	1	0.4	0.3
2. Indust.comm. comb.	0.8	0.1	0.3	2.4	3.1	4.0	20	0.7	1.0	14.5	3.3	0.3	0.4	42	3.6	1.8
3. Wood combustion	0.4	-	0.3	-	-	16.5	8.8	-	-	4.1	6.2	-	-	-	50.0	-
4. Gasoline comb.	-	-	v.s.	-	-	-	-	0.1	-	1.0	63.0	-	-	-	-	-
5. Mining	-	-	-	-	-	1.1	-	-	-	72.0			v.s.		1.1	
6. Primary u-f metal																
6.1 Copper-nickel	29.2			0.4		48.8					60.3				16.5	
6.2 Zinc-cadm.																
6.3 Lead																
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.																
9. Refuse incin.																
10. Phosphate fer.		v.s.				0.1				0.1	v.s.		v.s.		0.3	
11. Cement prod.		v.s.			1.3						1.4					
12. Industr.applic.	v.s.															
13. TOTAL	31	0.1	1	3	5	71	31	1	1	92	134	0.4	0.5	43	72	2

v.s. - very small

Table 17: Emission of trace elements in Austria in 1979 (in t/year).

AUSTRIA	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	1.4	v.s.	0.6	6.2	3.7	9.0	7	3.2	1.6	47.2	6.7	0.2	1.0	165	5.6	1.2
2. Indust.comm. comb.	3.8	0.2	1.7	15.6	11.8	23.9	20	10.8	4.6	114.4	17.9	0.8	2.2	387	16.3	5.4
3. Wood combustion	0.3		0.2			9.8	5			2.5	3.7				30.1	
4. Gasoline comb.			0.3					1.2		14.8	964.8					
5. Mining			v.s.								5.0		v.s.		3.0	
6. Primary u-f metal																
6.1 Copper-nickel	18.9		2.5			31.5					38.9				10.6	
6.2 Zinc-cadm.	77.3		130.8			36.6	1099				664.5		1.1		1412.3	
6.3 Lead	1.3		v.s.			0.5	14			0.6	45.8				0.8	
7. Second u-f metal																
7.1 Copper			0.1			2.4					2.1	0.1			25.6	
7.2 Zinc															25.2	
7.3 Lead			v.s.								6.7				2.6	
8. Iron,steel met.			0.4		175.4	19.5		167		3.9	166.7				116.9	
9. Refuse incin.																
10. Phosphate fer.			0.2			0.5				0.5	v.s.		0.2		1.5	
11. Cement prod.			0.2		9.2						10.3					
12. Industr.applic.																
13. TOTAL	103	0.2	137	22	200	134	1145	182	6	184	1933	1.1	4.5	5592	4370	7

v.s. - very small

Table 18: Emission of trace elements in Belgium in 1979 (in t/year).

BELGIUM	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	6.3	0.3	2.5	23.4	21.1	36.5	58	18.2	7.5	166.9	28.0	1.6	4.0	554	26.8	10.5
2. Indust:comm. comb.	13.3	0.2	4.7	31.9	62.5	61.2	300	54.3	17.1	160.1	52.0	6.8	6.4	355	65.7	41.9
3. Wood combustion	0.1		v.s.			2.5	1			0.6	0.3				7.5	
4. Gasoline comb.			0.6					1.6		27.4	1424.9					
5. Mining																
6. Primary u-f metal																
6.1 Copper-nickel	243.0		32.4			405.0					500.6				136.9	
6.2 Zinc-cadm.	74.6		126.3			35.4	1061				641.6		1.0		3970.9	
6.3 Lead	22.7		0.6			9.0	244			10.6	795.0				13.7	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			1.4		546.8	60.7		537.7		12.1	519.7				364.5	
9. Refuse incin.	0.3		1.2	v.s.	0.6	2.0	210	0.8		0.2	9.5	2.5	v.s.		140.6	
10. Phosphate fer.			1.1			3.1				3.1	0.3		v.s.		9.4	
11. Cement prod.			0.3		12.1						13.6					
12. Industr.applic.																
13. TOTAL	360	0.5	171	55	642	613	1874	613	25	381	3986	10.9	11.4	908	4736	52

v.s.-Very small

Table 19 : Emission of trace elements in Bulgaria in 1979 (in t/year).

BULGARIA	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se kg/y	V	Zn	Zr
1. Conv.therm.p.pl.	4.1	0.3	1.4	10.9	17.9	19.4	73	15.4	5.2	59.2	16.4	1.9	2.2	152	19.5	11.2
2. Indust.comm. comb.	13.0	1.1	4.9	36.1	54.7	62.5	280	47.3	16.3	203.5	52.1	5.6	7.1	549	60.8	33.5
3. Wood combustion	0.3		0.2			10.2	5			2.5	3.8				31.2	
4. Gasoline comb.			0.3					0.9		11.1	729.6		v.s.			
5. Mining			v.s.			6.0		1.0			106.5		v.s.		26.5	
6. Primary u-f metal																
6.1 Copper-nickel	93.6		12.5			156.0					192.8				52.7	
6.2 Zinc-cadm.	18.4		46.0			12.9	386				233.7		0.4		1446.2	
6.3 Lead	22.7		0.6			9.0	244			10.6	795.0				13.7	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.2		100.0	11.1		153.4		2.2	95.1				66.7	
9. Refuse incin.																
10. Phosphate fer.			0.5			1.4				1.4	0.1		v.s.		4.3	
11. Cement prod.			0.2		8.2						9.3					
12. Industr.applic.	v.s.															
13. TOTAL	152	1.4	67	47	181	288	988	218	22	291	2234	7.5	9.7	701	1722	45

v.s.- Very small

Table 20: Emission of trace elements in Czechoslovakia in 1979 (in t/year).

CZECHOSLOVAKIA	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	14.1	1.4	4.4	26.6	71.4	56.2	319	60.8	18.3	89.9	50.9	8.4	6.6	50	70.9	49.1
2. Indust.comm. comb.	20.5	1.7	7.9	59.5	83.7	101.1	420	72.6	25.6	348.9	83.4	8.4	11.4	893	94.8	50.1
3. Wood combustion	0.4		0.2			15.4	8			3.8	5.8				47.0	
4. Gasoline comb.			0.3					0.9		12.1	743.1					
5. Mining						0.9					13.9		v.s.		2.4	
6. Primary u-f metal																
6.1 Copper-nickel	46.5		6.2			77.5					95.8				26.2	
6.2 Zinc-cadm.	0.6		1.0			0.3	9				5.3		v.s.		33.0	
6.3 Lead	3.5		0.1			1.4	37			1.6	120.8				2.1	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			1.5		619.2	68.8		577.3		13.8	588.7				412.8	
9. Refuse incin.																
10. Phosphate fer.			0.6			1.8				1.8	0.1		v.s.		5.5	
11. Cement prod.			0.4		16.3						18.4					
12. Industr.applic.																
13. TOTAL	86	3.1	23	86	791	323	793	712	44	472	1726	16.8	18.0	943	695	99

v.s. - Very small

Table 21: Emission of trace elements in Denmark in 1979 (in t/year).

DENMARK	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	2.7	0.1	1.1	10.4	8.8	15.9	28	7.6	3.2	74.8	12.2	0.6	1.7	251	11.4	4.2
2. Indust.comm. comb.	2.6	v.s.	1.3	12.7	5.9	17.7	10	5.4	3.1	97.4	13.0	0.2	1.9	346	10.1	1.1
3. Wood combustion	v.s.		v.s.			0.9	1			0.2	0.3				2.6	
4. Gasoline comb.			0.2					0.8		10.2	646.2					
5. Mining																
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.																
6.3 Lead																
7. Second u-f metal																
7.1 Copper																
7.2 Zinc															8.1	
7.3 Lead			v.s.								5.8				2.3	
8. Iron,steel met.			0.5		28.3	3.1		19.4		0.6	26.9				18.9	
9. Refuse incin.	1.3		5.6	v.s.	2.6	9.2	980	3.9		0.8	43.9	11.4	0.2		651.0	
10. Phosphate fer.			0.2			0.5				0.6	0.1		v.s.		1.7	
11. Cement prod.			0.1		4.2						4.7					
12. Industr.applic.																
13. TOTAL	7	0.1	9	23	50	38	1118	37	6	185	753	12.2	3.8	596	706	5

v.s. - Very small

Table 22: Emission of trace elements in Finland in 1979 (in t/year).

FINLAND	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	2.3	0.1	0.9	7.7	8.2	12.5	25	7.0	2.7	52.2	9.7	0.7	1.4	171	9.9	4.5
2. Indust.comm. comb.	3.3	0.1	1.5	15.0	9.2	22.1	10	8.5	4.0	113.4	16.3	0.5	2.1	394	13.9	3.9
3. Wood combustion	1.1		0.7			43.0	23			10.7	16.1				131.7	
4. Gasoline comb.			0.4					0.7		16.6	968.6					
5. Mining			v.s.			4.7				39.6	0.7		v.s.		10.1	
6. Primary u-f metal																
6.1 Copper-nickel	79.6		10.6			132.7					164.1				44.9	
6.2 Zinc-cadm.	41.0		69.4			19.4	583				352.8		0.6		2183.5	
6.3 Lead																
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.2		94.4	10.5		92.7		2.1	89.7				62.9	
9. Refuse incin.																
10. Phosphate fer.			0.3			0.9				0.9	0.1		v.s.		2.8	
11. Cement prod.			0.1		2.9						3.2					
12. Industr.applic.																
13. TOTAL	127	0.2	84	23	115	246	641	109	7	237	1621	1.2	4.1	565	2460	8

v.s. - Very small

Table 23 : Emission of trace elements in France in 1979 (in t/year).

FRANCE	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	7.0	0.5	2.5	18.5	30.6	34.2	106	25.7	8.4	113.2	27.7	3.0	3.8	317	32.5	19.3
2. Indust.comm. comb.	20.9	0.9	9.4	84.0	66.1	127.8	170	59.6	25.4	602.7	97.2	5.0	12.8	2022	90.0	32.1
3. Wood combustion	0.8		0.5			28.7	15			7.2	10.7				87.8	
4. Gasoline comb.			3.3					9.5		139.6	7737.0					
5. Mining			v.s.			v.s.					29.6		v.s.		7.3	
6. Primary u-f metal																
6.1 Copper-nickel	61.9		8.3			103.2					127.6				34.9	
6.2 Zinc-cadm.	73.6		124.5			34.9	1046				632.5		1.0		3914.3	
6.3 Lead	22.9		0.6			9.1	246			10.7	800.7				13.8	
7. Second u-f metal																
7.1 Copper			0			0.1					0.1	0			1.0	
7.2 Zinc																
7.3 Lead			0.1								44.0				17.1	
8. Iron,steel met.			6.3		947.7	105.3		1089.8		21.1	900.9				631.8	
9. Refuse incin.	2.5		11.0	0.1	5.2	18.0	1910	7.7		1.6	86.1	22.3	0.4		1276.0	
10. Phosphate fer.			2.4			6.9				6.9	0.6		v.s.		20.8	
11. Cement prod.			1.0		45.1						50.7					
12. Industr.applic.	38.5															
13. TOTAL	228	1.4	170	103	1095	450	3493	1192	34	903	10545	30.3	18.0	2338	6127	51

v.s. - Very small

Table 24: Emission of trace elements in the German Democratic Republic in 1979 (t/year).

GER. DEM. REP.	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	22.1	2.3	6.8	41.6	111.9	88.0	500	95.3	28.7	140.7	79.8	13.1	10.3	78	110.1	77.0
2. Indust:comm. comb.	25.8	2.4	9.4	66.8	113.3	119.9	600	97.8	32.6	355.4	101.4	12.0	13.7	886	122.7	71.4
3. Wood combustion	0.1		0.1			5.2	3			1.3	1.9				19.6	
4. Gasoline comb.			0.4					1.4		15.9	1175.7					
5. Mining						1.6				24.3			v.s.		1.6	
6. Primary u-f metal																
6.1 Copper-nickel	73.5		9.8			122.5					151.4				41.4	
6.2 Zinc-cadm.	4.7		8.0			2.2	67				40.6		0.1		251.5	
6.3 Lead	6.9		0.2			2.7	74			3.2	241.7				4.2	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.7	-	282.7	31.4		238.1		6.3	268.7				188.5	
9. Refuse incin.																
10. Phosphate fer.			0.7			2.1				2.1	0.2		v.s.		6.3	
11. Cement prod.			0.5		20.0						22.5					
12. Industr.applic.																
13. TOTAL	133	4.7	37	108	528	376	1244	433	61	549	2084	25.1	24.1	965	746	148

v.s - Very small

Table 25: Emission of trace elements in the Federal Republic of Germany in 1979 (t/year).

GER. FED. REP.	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
							kg/year									
1. Conv.therm.p.pl.	22.1	2.0	7.5	45.1	109.0	96.1	431	90.7	26.5	228.6	81.0	11.5	11.0	469	106.8	73.0
2. Indust.comm. comb.	27.2	1.9	10.7	88.9	103.9	145.7	430	91.4	33.8	570.0	116.4	9.7	15.4	1742	123.9	59.9
3. Wood combustion	0.3		0.2			12.2	6			3.0	4.6				37.3	
4. Gasoline comb.			3.6					11.6		153.3	3514.4					
5. Mining			v.s.			0.1					20.4		v.s.		11.2	
6. Primary u-f metal																
6.1 Copper-nickel	605.1		80.7			1008.5					1246.5				340.9	
6.2 Zinc-cadm.	105.0		177.5			49.8	1493				903.0		1.5		5588.5	
6.3 Lead	19.1		0.5			7.6	205			8.9	669.1				11.6	
7. Second u-f metal																
7.1 Copper			0.6			21.7					19.4	0.4			233.4	
7.2 Zinc															2339.1	
7.3 Lead			0.5								153.8				59.9	
8. Iron,steel met.			10.7		1863.0	207.0		1808.0		41.4	1771.0				1242.0	
9. Refuse incin.	2.8		32.2	2.1	22.2	119.0	8060	52.2		3.5	331.0	27.8	16.9	11	1583.3	
10. Phosphate fer.			1.3			3.7				3.7	0.3		1.8		11.2	
11. Cement prod.			1.3		54.3						61.1					
12. Industr.applic.																
13. TOTAL	782	3.9	328	136	2153	1552	4676	2054	60	1013	9308	49.5	46.6	2222	11689	133

v.s. - Very small

Table 26: Emission of trace elements in Greece in 1979 (in t/year).

GREECE	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se kg/y	V	Zn	Zr
1. Conv.therm.p.pl.	2.5	0.2	0.9	6.2	11.3	11.8	43	9.4	3.0	36.7	9.7	1.1	1.3	98	11.7	7.1
2. Indust.comm. comb.	2.7	v.s.	1.2	11.1	7.6	16.2	30	6.8	3.2	80.2	12.3	0.5	1.8	274	10.9	3.1
3. Wood combustion	0.5		0.3			20.3	11			5.1	7.6				62.1	
4. Gasoline comb.			0.3					0.6		13.2	1064.1					
5. Mining			v.s.					0.4		134.1	15.6		v.s.		4.0	
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.																
6.3 Lead	3.8		0.1			1.5	41			1.8	134.2				2.3	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.1		40.2	4.5		27.6		0.9	38.5				27.0	
9. Refuse incin.																
10. Phosphate fer.			0.3			1.0				1.0	0.1		v.s.		2.9	
11. Cement prod.			0.4		18.3						20.6					
12. Industr.applic.	0.4															
13. TOTAL	10	0.2	4	17	77	55	125	45	6	273	1303	1.6	3.1	372	121	10

v.s.- Very small

Table 27: Emission of trace elements in Hungary in 1979 (in t/year).

HUNGARY	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	4.3	0.3	1.5	11.3	18.4	20.0	74	3.4	5.4	61.3	16.9	2.0	2.3	157	20.1	11.5
2. Indust.comm. comb.	3.9	0.3	1.5	12.4	15.0	20.2	70	13.0	4.8	77.2	16.4	1.4	2.3	232	17.7	8.5
3. Wood combustion	0.8		0.5			30.2	16			7.6	11.3				92.5	
4. Gasoline comb.			0.3					0.8		11.1	630.3					
5. Mining			0			0.2		2.5			0.9		v.s.		0.4	
6. Primary u-f metal																
6.1 Copper-nickel	25.0		3.3			417.5					51.6				14.1	
6.2 Zinc-cadm.																
6.3 Lead	v.s.		0			v.s.	v.s.			v.s.	1.3				v.s.	
7. Second u-f metal																
7.1 Copper			0.1			2.0					1.8	v.s.			21.1	
7.2 Zinc															5.4	
7.3 Lead			0								1.2				0.5	
8. Iron,steel met.			0.4		154.1	17.5		140.7		3.5	149.4				104.8	
9. Refuse incin.																
10. Phosphate fer.			0.4			1.4				1.1	0.1		v.s.		3.4	
11. Cement prod.			0.2		7.6						8.6					
12. Industr.applic.																
13. TOTAL	34	0.6	8	24	198	509	160	160	10	162	888	3.4	4.6	389	280	20

v.s. - Very small

Table 28: Emission of trace elements in Iceland in 1979 (in kg/year).

ICELAND	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
							kg/year									
1. Conv.therm.p.pl.	3.4	-	1.6	18.1	6.1	24.3	-	5.7	3.9	143	18	-	2.6	518	14.4	-
2. Indust:comm. comb.	70.0	-	40.0	360.0	120.0	490.0	-	110.0	80.0	2860	350	-	50.0	10370	250.0	
3. Wood combustion																
4. Gasoline comb.			29.7					44.0		1128	35700					
5. Mining																
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.																
6.3 Lead																
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.																
9. Refuse incin.																
10. Phosphate fer.																
11. Cement prod.			10.0		210.0						240					
12. Industr.applic.																
13. TOTAL	73	-	81	378	336	514	-	160	84	4130	36300	-	53	10900	264	-

Table 29: Emission of trace elements in Ireland in 1979 (in t/year).

IRELAND	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	0.5	-	0.2	2.7	0.9	3.6	0.2	0.9	0.6	20.9	2.6	-	0.4	75	1.8	v.s.
2. Indust.comm. comb.	1.3	0.1	0.6	5.1	4.6	8.4	-	4.4	1.6	37.4	6.2	0.4	0.6	121	6.0	2.9
3. Wood combustion	0	0	0			0.1	v.s.			v.s.	v.s.				0.2	
4. Gasoline comb.			0.1					0.5		5.9	397.8					
5. Mining			0.1			0.5					43.5		v.s.		22.9	
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.																
6.3 Lead																
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			v.s.		2.8	0.3		1.9		0.1	3.7				1.9	
9. Refuse incin.																
10. Phosphate fer.			0.1			0.2				0.2	v.s.				0.6	
11. Cement prod.			0.1		2.9						3.2					
12. Industr.applic.																
13. TOTAL	2	0.1	1	8	11	13	0.2	8	2	65	456	0.4	1	199	33	3

v.s. - Very small

Table 30: Emission of trace elements in Italy in 1979 (in t/year).

ITALY	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	14.3	0.1	6.6	71.9	29.0	98.5	22	26.6	16.5	560.6	71.8	0.6	10.5	2012	53.3	3.8
2. Indust.comm. comb.	18.5	0.7	8.5	78.0	52.1	113.6	170	46.7	22.0	566.9	86.2	3.4	12.3	1940	75.6	20.7
3. Wood combustion	0.8		0.5			30.7	16			7.3	11.5				94.1	
4. Gasoline comb.			3.2					5.8		136.5	7411.9					
5. Mining			v.s.			0.1		0.2			20.1		v.s.		8.5	
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.	52.5		88.8			24.9	745				451.1		0.7		2791.9	
6.3 Lead	5.7		0.2			2.2	61			2.6	197.8				3.4	
7. Second u-f metal																
7.1 Copper			0.1			2.6					2.3	0.1			28.2	
7.2 Zinc																
7.3 Lead			0.2								65.5				25.5	
8. Iron,steel met.			7.7		980.1	108.9		841.2		21.8	931.5				653.4	
9. Refuse incin.	1.3		5.6	v.s.	2.8	9.6	1010	4.1		0.9	45.7	11.8	0.2		677.0	
10. Phosphate fer.			1.1			3.2				3.2	0.3		v.s.		9.5	
11. Cement prod.			1.4		61.2						68.8					
12. Industr.applic.																
13. TOTAL	93	0.8	124	150	1055	385	2025	925	38	1300	9365	16	24	3952	4420	25

v.s. - Very small

Table 31: Emission of trace elements in the Netherlands in 1979 (in t/year).

NETHERLANDS	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	5.8	0.1	2.7	28.9	12.2	39.8	13	11.1	6.7	224.8	29.1	0.3	4.3	805	21.9	2.0
2. Indust.comm. comb.	2.7	0.2	1.1	8.9	10.3	14.4	50	9.0	3.4	56.6	11.6	1.0	1.6	173	12.3	5.8
3. Wood combustion	v.s.		v.s.			0.3	v.s.			0.1	0.1				1.0	
4. Gasoline comb.			0.7					2.0		30.2	1612.2					
5. Mining																
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.	45.5		76.9			21.5	646				390.9		0.6		2419.3	
6.3 Lead	3.3		0.4			1.3	35			1.5	115.7				2.0	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.5		222.7	24.7		225.2		4.9	211.7				148.5	
9. Refuse incin.	0.9		5.4	0.2	3.1	14.2	1140	6.2		0.7	48.9	8.0	1.5	v.s.	457.0	
10. Phosphate fer.			0.6			1.8				1.8	0.2		v.s.		5.5	
11. Cement prod.			0.1		6.3						7.0					
12. Industr.applic.																
13. TOTAL	58	0.3	88	38	255	105	1405	253	10	321	2427	9.3	7.9	979	3067	8

v.s. -Very small

Table 32: Emission of trace elements in Norway in 1979 (in t/year).

NORWAY	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
							kg/year									
1. Conv.therm.p.pl.	v.s.	v.s.	v.s.	v.s.	0.1	v.s.	0.2	v.s.	v.s.	0.1	v.s.	v.s.	v.s.	v.s.	0.1	v.s.
2. Indust.comm. comb.	1.4	v.s.	0.6	6.1	3.5	8.7	10.0	3.1	1.6	45.8	6.5	0.2	0.9	160	5.4	1.1
3. Wood combustion	0.1		0.1			4.8	3.5			1.2	1.8				14.6	
4. Gasoline comb.			0.2					0.7		8.2	547.2					
5. Mining			v.s.			2.8				9.0	2.9		v.s.		6.0	
6. Primary u-f metal																
6.1 Copper-nickel	13.2		1.8			22.2					27.5				7.5	
6.2 Zinc-cadm.	21.1		35.6			10.0	299.5				181.1		0.3		1120.8	
6.3 Lead																
7. Second u-f metal																
7.1 Copper			v.s.			0.8					0.7	v.s.			9.0	
7.2 Zinc																
7.3 Lead			v.s.								0.2				0.1	
8. Iron,steel met.			0.1		32.8	3.6		41.6		0.7	31.2				21.9	
9. Refuse incin.																
10. Phosphate fer.			0.3			0.7				0.7	0.1		v.s.		2.2	
11. Cement prod.			0.1		3.7						4.2					
12. Industr.applic.																
13. TOTAL	36	v.s.	39	6.1	40	56	312	45	2	66	803	0.2	1.2	160	1188	1

v.s.- Very small

Table 33: Emission of trace elements in Poland in 1979 (in t/year).

POLAND	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	26.8	2.8	8.2	50.6	136.1	107.0	576	115.9	34.9	171.1	96.9	15.9	12.5	95	135.0	93.6
2. Indust.comm. comb.	48.6	5.4	16.3	100.8	238.2	202.9	1350	204.2	62.5	408.2	179.9	27.0	23.6	577	241.9	160.5
3. Wood combustion	0.4		0.2			15.4	8			3.8	5.8				47.0	
4. Gasoline comb.			0.4					1.7		15.9	1344.0					
5. Mining			0.1			31.6				25.2	45.1		v.s.		5.0	
6. Primary u-f metal																
6.1 Copper-nickel	498.3		66.4			830.5					1026.5				280.7	
6.2 Zinc-cadm.	65.6		111.0			31.1	932				563.9		0.9		3489.8	
6.3 Lead	15.8		0.4			6.2	169			7.4	551.4				9.5	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			1.9		752.1	83.6		687.2		16.7	714.9				501.4	
9. Refuse incin.																
10. Phosphate fer.			1.7			4.7				4.7	0.4		v.s.		14.2	
11. Cement prod.			0.8		34.6						39.0					
12. Industr.applic.																
13. TOTAL	656	8.2	207	151	1161	1313	3036	1010	97	653	4568	43	37	672	4725	254

v.s.-Very small

Table 34: Emission of trace elements in Portugal in 1979 (in t/year).

PORTUGAL	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	0.5	-	0.2	2.4	1.0	3.3	2	0.9	0.6	18.7	2.4	v.s.	0.3	67	1.8	0.2
2. Indust:comm. comb.	1.5	v.s.	0.8	7.4	3.4	10.2	10	3.1	1.8	56.7	7.5	0.1	1.1	201	5.8	0.7
3. Wood combustion	0.1		0.1			5.3	3			1.3	2.0				16.3	
4. Gasoline comb.			0.4					0.4		19.3	478.6					
5. Mining																
6. Primary u-f metal						0.3							v.s.		0.3	
6.1 Copper-nickel	4.5		0.6			7.5					9.3				2.5	
6.2 Zinc-cadm.																
6.3 Lead	0.1		v.s.			v.s.*	1			v.s.	2.5				v.s.	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			v.s.		15.0	1.7		15.8		0.3	14.2				10.0	
9. Refuse incin.																
10. Phosphate fer.			v.s.			0.5				0.6	0.1		v.s.		1.7	
11. Cement prod.			0.2		7.4						8.4					
12. Industr.applic.																
13. TOTAL	7	v.s.	3	10	27	29	16	20	2	97	525	0.1	1.4	268	39	1

v.s. - Very small

Table 35 : Emission of trace elements in Romania in 1979 (in t/year).

ROMANIA	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	4.5	0.1	1.8	16.8	14.8	25.5	47	12.9	5.5	114.9	20.0	1.2	2.8	376	19.2	7.2
2. Indust.comm. comb.	21.0	2.3	7.1	44.4	105.3	88.5	580	87.7	27.0	184.8	78.2	11.5	10.3	284	104.4	68.6
3. Wood combustion	1.3		0.8			50.2	27			12.5	18.8				153.6	
4. Gasoline comb.			0.3					1.1		11.1	922.2					
5. Mining						4.0		2.5			36.4		v.s.		8.0	
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.																
6.3 Lead	7.8		0.2			3.1	83			3.6	272.2				4.7	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			1.2		477.1	53.0		449.8		10.6	453.5				318.1	
9. Refuse incin.																
10. Phosphate fer.			1.3			3.6				3.6	0.3		v.s.		10.8	
11. Cement prod.			0.5		22.2						25.0					
12. Industr.applic.																
13. TOTAL	35	2.4	13	61	619	228	737	554	33	338	1827	12.7	13.1	660	614	76

v.s.- Very small

Table 36 : Emission of trace elements in Spain in 1979 (in t/year).

SPAIN	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
							kg/year									
1. Conv.therm.p.pl.	5.8	0.4	2.2	16.7	23.6	29.3	88	19.9	6.8	107.6	23.4	2.2	3.3	321	26.0	14.1
2. Indust.comm. comb.	11.0	0.5	4.9	43.9	34.0	66.1	110	30.4	13.3	313.5	50.5	2.5	6.9	1052	46.6	15.8
3. Wood combustion	0.3		0.2			12.0	6			3.0	4.5				36.9	
4. Gasoline comb.			1.6					2.9		70.0	3482.1					
5. Mining			0.1			3.2					68.5		v.s.		25.1	
6. Primary u-f metal																
6.1 Copper-nickel	220.5		29.4			367.5					454.2				124.2	
6.2 Zinc-cadm.	49.5		83.7			23.4	703				4425.4		0.7		2633.1	
6.3 Lead	15.1		0.4			6.0	161			7.0	526.6				9.1	
7. Second u-f metal																
7.1 Copper			0.1			3.3					2.9	0.1			35.4	
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			1.1		466.2	51.8		419.1		10.4	443.1				310.8	
9. Refuse incin.																
10. Phosphate fer.			0.8			2.4				2.4	0.2		v.s.		7.3	
11. Cement prod.			1.1		46.9						52.7					
12. Industr.applic.																
13. TOTAL	302	0.9	126	61	571	565	1069	472	20	510	5534	4.8	10.9	1373	3255	30

v.s.- Very small

Table 37: Emission of trace elements in Sweden in 1979 (in t/year).

SWEDEN	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	2.1	-	1.0	11.1	3.7	15.0	v.s.	3.5	2.4	87.8	10.8	-	1.6	318	7.7	v.s.
2. Indust:comm. comb.	4.5	0.1	2.6	25.2	11.6	35.0	20	10.7	6.1	193.0	25.8	0.4	3.8	685	20.1	2.5
3. Wood combustion	0.8		0.5			30.7	16			7.7	11.5				94.1	
4. Gasoline comb.			0.5					1.8		23.0	1474.2					
5. Mining			0.1			4.2					74.5		v.s.		28.7	
6. Primary u-f metal																
6.1 Copper-nickel	75.6		10.1			126.0					155.7				42.6	
6.2 Zinc-cadm.																
6.3 Lead	9.4		0.3			3.7	102			4.4	330.1				5.7	
7. Second u-f metal																
7.1 Copper			0.1			2.1					1.9	v.s.			22.5	
7.2 Zinc																
7.3 Lead			v.s.								13.4				5.2	
8. Iron,steel met.			0.4		176.2	19.6		156.2		3.9	167.5				117.4	
9. Refuse incin.																
10. Phosphate fer.			0.2			0.6				0.6	0.1		v.s.		2.0	
11. Cement prod.			0.1		3.8						4.3					
12. Industr.applic.	55.0															
13. TOTAL	147	0.1	16	36	195	237	138	172	9	323	2270	0.4	5.4	1003	346	3

v.s. - Very small

Table 38: Emission of trace elements in Switzerland in 1979 (in t/year).

SWITZERLAND	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	0.1	-	v.s.	0.3	0.1	0.5	v.s.	0.1	0.1	2.6	0.3	-	v.s.	10	0.2	v.s.
2. Indust.comm. comb.	0.9	v.s.	0.4	4.3	1.7	5.9	-	1.6	1.0	33.4	4.3	0.03	0.6	120	3.2	0.2
3. Wood combustion	0.2		0.1			8.3	4			2.1	3.1				25.5	
4. Gasoline comb.			0.2					1.3		8.0	1038.0					
5. Mining																
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.																
6.3 Lead																
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.1		31.7	3.5		22.2		0.7	30.2				21.2	
9. Refuse incin.			0.1													
10. Phosphate fer.			v.s.			v.s.				v.s.	v.s.		v.s.		0.1	
11. Cement prod.			0.1		5.9						6.6					
12. Industr.applic.																
13. TOTAL	1	v.s.	1	5	40	18	4	25	1	51	1083	0.03	0.6	130	50	0.2

v.s.- Very small

Table 39: Emission of trace elements in Turkey in 1979 (in t/year).

TURKEY	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	2.4	0.2	0.8	5.7	11.3	10.7	48	9.7	3.1	26.7	9.3	1.3	1.2	55	11.8	7.4
2. Indust.comm. comb.	9.2	0.9	3.4	24.8	44.3	48.0	140	39.5	12.1	142.2	38.9	4.7	3.9	364	47.6	31.2
3. Wood combustion	7.6		4.7			286.7	153			71.7	107.5				877.9	
4. Gasoline comb.			0.8					1.0		33.4	813.1					
5. Mining			v.s.			3.3		2.6			13.5		v.s.		8.9	
6. Primary u-f metal																
6.1 Copper-nickel	42.3		5.6			70.5					87.1				23.8	
6.2 Zinc-cadm.																
6.3 Lead	0.5		v.s.			0.2	6			0.3	19.1				0.3	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.2		66.0			72.9		1.5	62.8				19.3	
9. Refuse incin.																
10. Phosphate fer.			0.5			1.4				1.4	119.8		v.s.		4.3	
11. Cement prod.			0.6		25.0						28.2					
12. Industr.applic.																
13. TOTAL	62	1.1	17	30	147	427	346	126	15	277	1180	6.0	5.1	419	994	39

v.s.-Very small

Table 40: Emission of trace elements in the USSR in 1979 (The European part of USSR) (in t/year).

USSR	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	104.4	7.2	38.0	316.5	413.5	525.3	1496	357.7	130.5	1908.2	431.0	41.2	58.8	5558	476.2	241.6
2. Indust.comm. comb.	101.8	7.7	40.2	314.6	397.0	519.2	1930	345.5	126.1	1929.6	422.6	38.5	58.2	5703	462.7	229.2
3. Wood combustion	21.8		13.5			819.0	437			204.9	307.1				2508.2	
4. Gasoline comb.			10.0					32.4			26310.0					
5. Mining			0.4			114.0		265.0		1332.0	473.2		0.1		243.0	
6. Primary u-f metal																
6.1 Copper-nickel	2220.0		296.0			3700.0					4573.2				1250.6	
6.2 Zinc-cadm.	227.5		385.0			107.8	3234				1955.8		3.2		12104.4	
6.3 Lead	94.6		2.6			37.4	1014			44.2	3307.2				57.2	
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			15.1		6133.7	681.5		5873.0		136.3	5830.8				4089.1	
9. Refuse incin.																
10. Phosphate fer.			10.6			30.1				30.1	2.5		v.s.		90.4	
11. Cement prod.			4.7		203.1						228.5					
12. Industr.applic.	41.6															
13. TOTAL	2812	15	816	631	7147	6535	8111	6874	257	6014	43842	80	120	11262	21281	471

v.s.- Very small

Table 41: Emission of trace elements in the United Kingdom in 1979 (in t/year).

UNITED KINGDOM	As	Be	Cd	Co	Cr	Cu	Hg kg/year	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	20.5	1.9	6.9	42.2	100.5	89.4	374	83.6	24.6	216.3	75.2	10.6	10.3	454	98.7	68.1
2. Indust.comm. comb.	27.6	2.3	10.8	86.0	121.8	155.6	300	109.8	35.8	551.6	122.3	12.0	12.4	1612	138.1	82.3
3. Wood combustion	v.s.		v.s.			1.5	1			0.4	0.5				4.5	
4. Gasoline comb.			2.2					9.3		96.2	7575.0					
5. Mining			0								4.2		v.s.		0.7	
6. Primary u-f metal																
6.1 Copper-nickel	69.3		9.2			115.5					142.8				39.0	
6.2 Zinc-cadm.	22.9		38.7			10.8	325				196.6		0.3		1216.7	
6.3 Lead	23.3		0.6			8.8	239			10.4	781.0				13.5	
7. Second u-f metal																
7.1 Copper			0.3			11.9					10.6	0.2			127.8	
7.2 Zinc															255.6	
7.3 Lead			0.3								95.9				37.3	
8. Iron,steel met.			5.9		870.7	96.7		790.9		19.3	827.7				580.5	
9. Refuse incin.	1.7		22.5	1.6	16.0	87.6	1250	38.5		2.4	236.8	17.0	12.9	8	968.7	
10. Phosphate fer.			0.8			2.4				2.4	0.2		v.s.		7.2	
11. Cement prod.			0.6		25.5						28.6					
12. Industr.applic.																
13. TOTAL	164	4	99	130	1134	580	2489	1032	60	899	10098	40	36	2074	3488	150

v.s.- Very small

Table 42: Emission of trace elements in Yugoslavia in 1979 (in t/year).

YUGOSLAVIA	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
							kg/year									
1. Conv.therm.p.pl.	7.2	0.7	2.2	13.6	36.5	28.7	162.9	31.1	9.4	45.9	26.0	4.3	3.2	26	36.2	25.1
2. Indust:comm. comb.	5.7	0.1	2.8	26.4	14.3	37.3	40.0	13.0	6.8	197.8	27.8	0.7	4.0	692	22.8	4.4
3. Wood combustion	1.0		0.6			38.9	20.8			9.7	14.7				119.2	
4. Gasoline comb.			0.4					1.3		15.9	1059.6					
5. Mining			0.1			12.3		0.9			113.2		v.s.		35.1	
6. Primary u-f metal																
6.1 Copper-nickel	70.3		9.4			117.2					144.9				39.6	
6.2 Zinc-cadm.	28.1		47.6			13.3	399.8				241.8		0.4		1496.5	
6.3 Lead	21.2		0.6			8.4	227.6			9.9	742.2				12.8	
7. Second u-f metal																
7.1 Copper			0.4			14.3					12.8	0.3			153.3	
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.3		139.7	15.5		130.5		3.1	132.8				93.1	
9. Refuse incin.																
10. Phosphate fer.			0.5			1.4				1.4	0.1		v.s.		4.1	
11. Cement prod.			0.3		13.9						15.7					
12. Industr.applic.																
13. TOTAL	134	0.8	65	40	205	287	851	177	16	284	2423	5.3	7.6	718	2013	29

v.s. - Very small

Table 43: Emission of trace elements in Luxemburg in 1979 (in t/year).

	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
							kg/year									
1. Conv.therm.p.pl.																
2. Indust.comm. comb.	0.3	v.s.	0.1	1.3	1.0	1.9	-	0.9	0.4	9.0	1.5	0.1	0.2	30	1.4	0.5
3. Wood combustion	v.s.		v.s.			0.2	9			v.s.	0.1				0.5	
4. Gasoline comb.			0.1					0.1		1.6	111.9					
5. Mining																
6. Primary u-f metal																
6.1 Copper-nickel																
6.2 Zinc-cadm.																
6.3 Lead																
7. Second u-f metal																
7.1 Copper																
7.2 Zinc																
7.3 Lead																
8. Iron,steel met.			0.7		194.5	21.6		196.6		4.3	184.8				129.6	
9. Refuse incin.	0.1		0.2	v.s.	0.1	0.4	40	0.2		v.s.	1.8	0.5	v.s.		26.0	
10. Phosphate fer.																
11. Cement prod.			v.s.		0.1						0.6					
12. Industr.applic.																
13. TOTAL	9.4	v.s.	1.1	1.3	196	24	49	192	0.4	15	301	0.6	0.2	30	158	0.5

v.s. - Very small

Table 44: Emission of trace elements in Europe in 1979 (in t/year).

EUROPE	As	Be	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sb	Se	V	Zn	Zr
1. Conv.therm.p.pl.	284	21	101	787	1196	1377	4.5	1011	352	4580	1138	122	155	12600	1316	732
2. Indust:comm. comb.	394	29	155	1214	1580	2038	7.1	1378	493	7467	1652	154	218	21800	1824	939
3. Wood combustion	40		25			1500	0.8			375	562				4590	
4. Gasoline comb.			31					92		1330	74300					
5. Mining			1			192		275		1640	1090		0.2		460	
6. Primary u-f metal																
6.1 Copper-nickel	4490		595			7850					9250				2500	
6.2 Zinc-cadm.	910		1550			440	13.0				7880		13		48800	
6.3 Lead	300		8			120	3.2			140	10450				180	
7. Second u-f metal																
7.1 Copper			2			61					55	1			660	
7.2 Zinc															2630	
7.3 Lead			1								387				150	
8. Iron,steel met.			58		15400	1710		14770		340	14660				10250	
9. Refuse incin.	11		84	4	53	260	19	114		10	804	100	32	19	5880	
10. Phosphate fer.			27			77				77	6		v.s.		230	
11. Cement prod.			15		663						746					
12. Industr.applic.	136															
13. TOTAL	6500	50	2700	2000	18900	15500	48	17600	850	16000	123000	380	420	34500	80000	1700

Table 45: Emission of trace elements from all sources in Europe in 1979 calculated per person.

1 - g/y·person
2 - mg/y·person

Element	As [1]	Be [2]	Cd [1]	Co [1]	Cr [1]	Cu [1]	Hg [2]	Mn [1]	Mo [1]	Ni [1]	Pb [1]	Sb [1]	Se [1]	V [1]	Zn [1]	Zr [1]
Country																
Albania	11.5	26.2	0.4	0.9	1.8	26.5	11.5	0.4	0.4	34.5	50.0	0.1	0.2	15.9	26.9	0.8
Austria	13.7	24.0	18.3	2.9	26.6	17.8	152.6	24.2	0.8	24.5	258.0	0.2	0.6	73.5	582.3	0.9
Belgium	36.6	164.5	17.4	5.6	65.2	62.3	209.3	62.2	2.5	38.7	404.8	1.1	1.2	92.2	480.9	5.3
Bulgaria	17.0	163.1	7.5	5.3	20.2	32.2	110.4	24.4	2.4	32.5	249.6	0.8	1.1	78.3	192.3	5.0
Czechoslovakia	5.6	205.3	1.5	5.6	51.9	21.2	52.0	46.7	2.9	30.9	113.2	1.1	1.2	61.8	45.6	6.5
Denmark	1.3	29.3	1.8	4.5	9.7	7.5	218.5	7.3	1.2	36.1	147.2	2.4	0.7	116.5	138.0	1.0
Finland	26.8	44.1	17.7	4.8	24.1	51.6	134.5	22.9	1.4	49.7	340.4	0.3	0.8	118.6	516.3	1.7
France	4.3	27.5	3.2	1.9	20.5	8.4	65.4	22.3	0.6	16.9	197.2	0.6	0.3	43.7	114.6	1.0
German Dem.Rep.	7.9	279.5	2.2	6.5	31.5	22.4	74.3	25.8	3.7	32.8	124.5	1.5	1.5	57.6	44.5	8.9
German Fed.Rep.	12.7	63.6	5.3	2.2	35.1	25.3	82.2	33.5	1.0	16.5	151.7	0.8	0.7	36.2	190.6	2.2
Greece	1.1	30.7	0.4	1.8	8.2	5.9	13.2	4.8	0.6	28.9	138.0	0.2	0.4	39.3	12.8	1.1
Hungary	3.2	58.9	0.8	2.2	18.5	47.5	15.0	15.0	1.0	15.1	83.0	0.3	0.4	36.4	26.2	1.9
Iceland	0.3	-	0.3	1.7	1.5	2.3	-	-	0.3	18.8	159.2	-	0.2	47.8	1.1	-
Ireland	0.6	17.8	0.3	2.3	3.3	3.9	0.1	2.3	0.6	19.1	135.4	0.1	0.3	59.2	9.9	0.9
Italy	1.6	13.9	2.2	2.6	18.5	6.8	35.6	16.3	0.7	22.8	164.5	0.3	0.4	69.4	77.7	0.4
Netherlands	4.2	17.1	6.3	2.7	18.1	7.5	100.2	18.1	0.7	22.9	173.0	0.7	0.6	69.8	218.6	0.5
Norway	9.0	9.8	9.5	1.5	9.8	13.8	76.7	11.2	0.4	16.1	197.3	0.5	0.3	39.2	291.6	0.3
Poland	18.6	232.8	5.9	4.3	33.0	37.3	86.2	28.6	2.8	18.5	129.1	1.2	1.0	19.1	134.1	7.2
Portugal	0.7	2.0	0.3	1.0	2.7	2.9	1.5	2.1	0.2	9.8	53.2	0.0	0.1	27.2	3.9	0.1
Romania	1.6	110.1	0.6	2.8	28.1	10.3	33.4	25.1	1.5	15.3	82.8	0.6	0.6	29.9	27.8	3.4
Spain	8.1	23.4	3.4	1.6	15.3	15.2	28.8	17.7	0.5	13.7	148.8	0.1	0.3	36.9	87.5	0.8
Sweden	11.2	9.6	1.9	4.4	23.5	28.6	16.6	20.8	1.0	39.0	273.7	0.1	0.6	121.0	41.7	0.3
Switzerland	0.2	1.6	0.2	0.7	6.2	2.9	0.7	4.0	0.2	8.1	171.2	-	0.1	20.4	7.9	0.1
Turkey	1.4	24.6	0.4	0.7	3.3	9.6	7.8	2.8	0.3	6.3	26.7	0.1	0.1	9.5	22.5	0.9
USSR	14.7	78.1	4.3	3.3	37.4	34.2	42.4	35.9	1.3	31.5	229.3	0.4	0.6	58.9	111.3	2.5
United Kingd.	2.9	72.5	1.8	2.3	20.3	10.4	44.5	18.5	1.1	16.1	180.7	0.7	0.6	37.1	62.4	2.7
Yugoslavia	6.1	40.2	2.9	1.8	9.2	13.0	38.4	8.0	0.7	12.8	109.3	0.2	0.3	32.4	90.8	1.3
Luxemburg	1.1	55.1	3.1	3.5	540.3	66.3	135.0	528.3	1.1	41.2	828.0	1.5	0.6	82.7	432.5	1.3
Average	9.1	71.8	3.7	2.8	26.3	21.9	51.4	24.6	1.2	22.2	172.0	0.5	0.6	48.1	110.7	2.3

APPENDIX A

THE TRACE ELEMENT EMISSION FACTORS CALCULATED FOR VARIOUS SOURCES OF EMISSION IN EUROPEAN COUNTRIES

The trace element emission factors have been calculated in the way presented in previous reports (1, 6, 7]. The results are listed in Tables below.

1 CONVENTIONAL THERMAL POWER PLANTS

Table A-1: Emission factors of trace elements for coal-fired power plants (µg/MJ).

Element	Bituminous			Subbituminous			Lignite		
	Cyclone	Stoker	Pulve-rized	Cyclone	Stoker	Pulve-rized	Cyclone	Stoker	Pulve-rized
As	24	28	16	28	34	19.2	40	47	27
Be	2.5	3.7	1.6	3	4.5	2.0	4.1	6.2	2.7
Cd	7.3	8.7	5.1	8.8	10.5	6.1	12.3	14.7	8.5
Co	44	51	25	54	62	31	75	86	43
Cr	120	200	85	145	242	103	201	337	143
Cu	94	164	63	114	198	76	158	276	106
Hg	0.5	1.0	0.4	0.6	1.3	0.4	0.9	1.8	0.6
Mn	102	186	70	123	226	85	172	314	118
Mo	31	42	19	37	51	23	52	71	32
Ni	150	243	96	182	294	117	253	409	163
Pb	85	128	55	103	156	66	144	217	92
Sb	15	23	9.3	17	28	11.3	24	39	15.7
Se	11	18.7	7.3	13	23	8.9	18.5	31	12.4
V	84	162	58	101	197	71	141	274	98
Zn	119	191	79	144	231	96	200	321	133
Zr	82	179	60	100	217	73	139	301	99

Data presented in Table A-1 are average values, derived for different boilers, and coal-types burning a weighted "average" of coals in power plants with electrostatic precipitators. Efficiency of fly ash removal was assumed to be 99 per cent at an ash content of 10 per cent. For different efficiences of dust removal and ash contents, similar results can be easily obtained by simply multiplications, as it was shown in earlier publications (6, 7).

It has to be considered for Hg and Se calculations, that the emission factors of Hg and Se presented in Table A-1 are only 5 and 40 per cent of the total Hg and Se emission factors, respectively. It is due to volatile nature of both metals. To obtain the total Hg and Se emission factors one must multiply those figures by 20 and 2.5, respectively.

The emission factors used for estimating the trace metal emission from oil-fired power plants are presented in Table A-2.

Table A-2: Emission factors of trace elements for oil-fired power plants (μg/MJ).

Element	Emission factor	Element	Emission factor
As	24.4	Mo	28
Cd	11.6	Ni	1020
Co	129	Pb	126
Cr	43	Se	18.5
Cu	174	V	3700
Mn	41	Zn	89

Data in Table A-2 were calculated for power plant, burning oil with 1 per cent of sulphur. In this case, the particulate emission factor calculated from equation (1) is equal 1.63 kg of dust/10^3 liters of oil.

$$e_p = 1.25 \cdot S + 0.38 \qquad (1)$$

where:

e_p = the particulate emission factor, kg of dust/10^3 liters

S = the percentage by weight of sulphur in the crude oil

For different sulphur (or ash) contents similar data can be estimated, using equation (1).

2 INDUSTRIAL, COMMERCIAL AND RESIDENTIAL COMBUSTION OF COAL AND OIL

Table A-3 presents the trace element emission factors for coal combustion in industrial, comercial and residential units.

Table A-3: Emission factors of trace elements from coal-fired industrial, commercial and residential units (g of trace element/tonne of coal burned).

Element	Industrial boilers			Commercial and residential units
	Cyclone	Stoker	Pulverized	
As	0.34	1.68	1.32	0.59
Be	0.04	0.22	0.13	0.08
Cd	0.11	0.52	0.42	0.18
Co	0.64	3.07	2.09	1.08
Cr	1.73	12.00	7.02	4.22
Cu	1.36	9.80	5.21	3.46
Hg	0.01	0.06	0.03	-
Mn	1.48	11.15	5.81	3.93
Mo	0.44	2.54	1.59	0.90
Ni	2.18	14.54	8.00	5.12
Pb	1.23	7.70	4.54	2.71
Sb	0.20	1.37	0.77	0.49
Se	0.16	1.12	0.61	-
V	1.21	9.73	4.84	3.43
Zn	1.72	11.42	6.54	4.03
Zr	1.19	10.70	4.99	3.77

The factors of mercury and selenium have been calculated with the same assumptions as factors from Table A-1.

Table A-4: Emission factors of trace elements from oil-fired industrial, commercial and residential units (g of trace element/10^3 liters of oil).

Element	Industrial	Boiler Commercial and residential
As	1.24	0.65
Cd	0.65	0.34
Co	6.56	3.42
Cr	2.19	1.14
Cu	8.81	4.60
Mn	2.06	1.08
Mo	1.42	0.74
Ni	51.7	27.0
Pb	6.37	3.32
Se	0.34	0.49
V	187	97.8
Zn	4.50	2.35

3 WOOD COMBUSTION

Table A-5: Emission factors of trace elements from wood combustion (g of trace element/tonne of wood).

Element	Emission factor	Element	Emission factor
As	0.5	Hg	0.01
Cd	0.3	Ni	4.7
Cu	18.7	Pb	7.0
		Zn	58.0

4 GASOLINE AND DIESEL OIL COMBUSTION

Gasoline and diesel oil combustion is considered as a emission source of lead, manganese, nickel and cadmium. The emission factor of lead from gasoline-powered motor vehicles is 0.7 kg of lead/kg of anti-knock additives. The amounts of lead added to gasoline in particular countries are listed in Table A-6.

Table A-6: Anti-knock additives in the European countries (g of lead/1 liter of gasoline).

Country	g/l	Country	g/l	Country	g/l
Albania	0.4	Greece	0.84	Spain	0.6
Austria	0.4	Hugary	0.4	Sweden	0.4
Belgium	0.45	Iceland	0.4	Switzerland	0.4
Bulgaria	0.4	Ireland	0.4	Turkey	0.4
Czechoslovakia	0.4	Italy	0.635	USSR	0.4
Denmark	0.4	Netherlands	0.4	United Kingdom	0.4
Finland	0.7	Norway	0.4	Yugoslavia	0.4
France	0.4	Poland	0.4	Luxemburg	0.4
German Dem.R.	0.4	Portugal	0.635		
German Fed.R.	0.15	Romania	0.4		

For other trace elements the emission factors are following: 0.37 g of Mn/10^3 liters of gasoline, 0.35 g of Cd/10^3 liters of diesel oil and 15 g of Ni/10^3 liters of diesel oil.

5 MINING

Table A-7: Emission factors of trace elements from non-ferrous metal mines.

Element	Emission factor	Unit
Cd	0.5	g of Cd/1 tonne of Zn mined
Cu	100	g of Cu/1 tonne of Cu mined
Mn	90	g of Mn/1 tonne of Mn mined
Ni	9000	g of Ni/1 tonne of Ni mined
Pb	910	g of Pb/1 tonne of Pb mined
Zn	100	g of Zn/1 tonne of (Zn+Cu+Pb) mined
Se	8	mg of Se/1 tonne of Cu mined
	8	mg of Se/1 tonne of (Cu-Ni) ore mined
	25	mg of Se/1 tonne of (Cu-Zn) ore mined
	20	mg of Se/1 tonne of (Pb-Zn) ore mined

6 NON-FERROUS METAL PRODUCTION

Table A-8: Emission factors of trace elements from non-ferrous metal production (g of trace element/1 tonne of metal produced).

Element	Primary n-f metal production			Secondary n-f metal production	
	Copper-nickel	Zinc-cadmium	Lead	Copper	Lead
As	3000	591	364		
Cd	200	500	5	4	2.5
Cu	2500	140	72	150	
Hg		4.2	2.0		
Ni	9000		85		
Pb	3090	2540	6360	134	770
Sb				3	
Se		4.1			
Zn	845	15720	110	1610	300

The zinc emission factor for secondary zinc production was calculated to 9000 g of Zn/1 tonne of zinc produced.

7 IRON, STEEL AND FERROALLOYS PRODUCTION

Table A-9: Emission factors of trace elements from iron, steel and ferroalloys production.

Element	Emission factor	Unit
Cd	0.1	g of Cd/1 tonne of steel produced
	0.08	g of Cd/1 tonne of sinter produced
Cr	40.5	g of Cr/1 tonne of steel and alloy produced
Cu	4.5	g of Cu/1 tonne of steel produced
Mn	15.2	g of Mn/1 tonne of pig iron produced
	27.6	g of Mn/1 tonne of steel produced
Ni	0.9	g of Ni/1 tonne of steel produced
Pb	38.5	g of Pb/1 tonne of steel produced
Zn	27.0	g of Zn/1 tonne of steel produced

The trace element emission factors for steelmaking vary greatly depending on type of operations. The basic oxygen furnace and the electric arc furnace are the most commonly used in European countries, much more than the open-hearth furnace. Considering this fact, the trace element emission factors for the former furnaces have been taken into calculations.

8 REFUSE INCINERATION

Table A-10: Emission factors of trace elements from refuse incineration.

Element	Municipal incinerators g of trace element 1/tonne of refuse burned	Sewage slugde incinerators µg of trace element/1 tonne of sludge incinerated
As	0.52	
Cd	2.25	11.8
Co	0.01	1.2
Cr	1.06	9.7
Cu	3.68	58.3
Hg	0.39	3.5
Mn	1.58	2.57
Ni	0.33	1.0
Pb	17.57	138.9
Sb	4.55	1.9
Se	0.08	9.7
V	24.96	6.2
Zn	260.40	104.2

9 PHOSPHATE FERTILIZERS

Table A-11: Trace element emission factors for phosphate fertilizer manufacture (mg of trace element/ 1 tonne of product).

Element	Emission factor	Element	Emission factor
Cd	1,780	Pb	420
Cu	5,085	Se	2.5
Ni	5,085	Zn	15,250

10 CEMENT PRODUCTION

Table A-12: Trace element emission factors for cement production (g of trace element/1 tonne of product).

Element	Emission factor
Cd	0.037
Cr	1.6
Pb	1.8

The arsenic emission from cotton ginning and other industrial applications has been calculated using the arsenic emission factors 3.3 g of As/1 tonne of cotton processed and 50 g of As/ 1 tonne of arsenic applied.

APPENDIX B

FUEL AND ORE CONSUMPTION AND AND PRODUCTION OF GOODS IN EUROPEAN COUNTRIES

1 ELECTRICITY PRODUCTION

Table B-1: Distribution of electricity production in several types of conventional thermal power plants in 1979 [9].
(10^9 MJ/year).

Country	Total	Type of power plant		
		Hard-coal fired	Lignite-fired	Oil-fired
Albania	1.9	0	1.9	0
Austria	40.6	0.6	15.9	24.1
Belgium	123.8	44.3	0	79.5
Bulgaria	82.8	0	53.8	29.0
Czechoslovakia	221.6	0	221.6	0
Denmark	80.3	52.3	0	28.0
Finland	73.9	49.4	0	24.5
France	465.4	234.6	7.0	223.8
German Dem.Rep.	322.9	0	322.9	0
German Fed.Rep.	920.3	304.7	534.8	80.8
Greece	69.2	0	55.8	13.4
Hungary	87.7	8.4	49.2	30.1
Iceland	0.2	0	0	0.2
Ireland	37.7	0.4	0	32.3
Italy	428.3	24.4	10.3	393.6
Luxemburg	0	0	0	0
Netherlands	142.6	24.5	0	118.1
Norway	0.5	0.5	0	0
Poland	414.0	331.2	82.8	0
Portugal	17.6	1.9	0	15.7
Romania	97.6	0	29.3	68.3
Spain	184.0	55.9	51.2	76.9
Sweden	47.1	0.3	0	46.8
Switzerland	7.2	0.1	0	7.1
Turkey	49.6	7.7	26.3	15.6
USSR	2183.9	767.6	319.5	1096.8
United Kingdom	914.0	747.7	0	166.3
Yugoslavia	102.3	0	102.3	0

2 INDUSTRIAL AND COMMERCIAL COMBUSTION OF HARD COAL AND LIGNITE

Table B-2: Hard coal and lignite consumption in industrial and commercial boilers in European countries in 1979 (8) (10^6 tonnes/year).

Country	Industrial boilers	Commercial boilers	Country	Industrial boilers	Commercial boilers
Albania	0.9		Italy	11.9	0.3
Austria	2.6	0.9	Luxemburg	0.4	v.small
Belgium	9.3	1.6	Netherlands	3.4	0.1
Bulgaria	18.8		Norway	0.8	v.small
Czechoslovakia	26.3		Poland	62.7	
Denmark	0.7	0.05	Portugal	0.4	v.small
Finland	0.7	0.8	Romania	32.6	
France	16.1	3.0	Spain	6.4	0.9
German Dem.Rep.	60.0		Sweden	2.0	v.small
German Fed.Rep.	44.2	2.2	Switzerland	0.1	v.small
Greece	2.0	v.small	Turkey	8.1	3.9
Hungary	4.8		USSR	128.4	
Iceland	-	-	United Kingdom	23.7	12.5
Ireland	-	0.8	Yugoslavia	2.1	

Industrial consumption of coal includes the consumption of coal in coke ovens. Commercial consumption of coal includes both commercial and residential requirements of coal. For the following countries: Albania, Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania and the USSR data for industrial boilers present total consumption of coal in industrial, commercial and residential boilers.

3 FUELWOOD CONSUMPTION

Table B-3: Consumption of fuelwood in Europe in 1979 (5) (10^6 tonnes/year).

Country	Consumption of fuelwood	Country	Consumption of fuelwood
Albania	0.9	Italy	1.6
Austria	0.5	Luxemburg	v.small
Belgium	0.1	Netherlands	v.small
Bulgaria	0.5	Norway	0.3
Czechoslovakia	0.8	Poland	0.8
Denmark	v.small	Portugal	0.3
Finland	2.3	Romania	2.7
France	1.5	Spain	0.6
Greman Dem.Rep.	0.3	Sweden	1.6
German Fed.Rep.	0.6	Switzerland	0.4
Greece	1.1	Turkey	15.3
Hungary	1.6	USSR	43.7
Iceland	-	United Kingdom	0.1
Ireland	v.small	Yugoslavia	2.1

Data from Table B-3 have been calculated on the basis of (5), assuming the weight of 1 m^3 of fuelwood to 546. kg.

4 LIQUID FUEL CONSUMPTION

Table B-4: Consumption of fuel oil in industrial and residual boilers in 1979 (5) (10^6 tonnes/year).

Country	Boiler		Country	Boiler	
	Industrial	Residential		Industrial	Residential
Albania	0.4		Italy	14.8	4.2
Austria	1.9	1.9	Luxemburg	0.3	v.small
Belgium	2.5	0.6	Netherlands	1.4	0.3
Bulgaria	5.1		Norway	1.5	0.1
Czechoslovakia	9.2		Poland	4.1	
Denmark	1.3	2.1	Portugal	1.8	0.2
Finland	2.2	1.6	Romania	2.2	
France	17.0	2.7	Spain	10.6	0.4
Greman Dem.Rep.	8.1		Sweden	4.2	2.6
German Fed.Rep.	14.3	2.4	Switzerland	1.0	0.2
Greece	2.6	0.1	Turkey	2.2	1.1
Hungary	2.2		USSR	54.3	
Iceland	-	0.1	United Kingdom	12.1	3.1
Ireland	1.1	0.1	Yugoslavia	6.8	

Data presented consumption of oil in industrial boilers in Albania, Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, the USSR, and Yugoslavia include consumption of oil in residential units.

Table B-5: Consumption of gasoline and diesl oil in Europe in 1979 (10^9 liters/year).

Country	Consumption of fuel Gasoline	Diesel oil	Country	Consumption of fuel Gasoline	Diesel oil
Albania	0.2	0.1	Italy	15.6	9.1
Austria	3.2	1.0	Luxemburg	0.4	0.1
Belgium	4.2	1.8	Netherlands	5.4	2.0
Bulgaria	2.4	0.7	Norway	1.8	0.6
Czechoslovakia	2.5	0.8	Poland	4.5	1.1
Denmark	2.2	0.7	Portugal	1.0	1.3
Finland	1.8	1.1	Romania	3.1	0.7
France	25.8	9.3	Spain	7.7	4.7
German Dem.Rep.	3.9	1.1	Sweden	4.9	1.5
German Fed.Rep.	31.2	10.2	Switzerland	3.5	0.5
Greece	1.7	0.9	Turkey	2.7	2.2
Hungary	2.1	0.7	USSR	87.7	28.6
Iceland	0.1	0.1	United Kingdom	25.3	6.4
Ireland	1.3	0.4	Yugoslavia	3.5	1.1

Data in Table B-2 come from (5). Density of gasoline was assumed to 0.74 kg/liter and density of diesel oil to 0.944 kg/liter (10). Consumption of diesel oil in Albania, Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, the USSR and Yugoslavia, has been assessed using data on motor vehicles in use (8).

5 MINING

Table B-6: Mining of zinc, copper, lead, nickel, chromium, and manganese ores in Europe in 1979 (8) (10^3 tonnes/year).

Country	Ore					
	Zinc	Copper	Lead	Nickel	Manganse	Chromium
Albania	-	11	-	8	-	390
Austria	25	-	5	-	-	-
Bulgaria	90	60	120	-	11	
Czechoslovakia	-	9	15	-	-	-
Denmark (Greenland)	90	-	36	-	-	-
Finland	53	47	1	4	-	190
France	40	0.2	32	-	-	-
German Dem.Rep.	-	16	-	3	-	-
German Fed.Rep.	89	0.8	22	-	-	-
Greece	22	-	17	15	4	16
Hungary	3	0.2	1	-	28	-
Ireland	180	5	48	-	-	-
Italy	62	0.5	22	-	2	-
Norway	28	28	3	1	-	-
Poland	220	320	50	3	-	-
Portugal	-	3	-	-	-	-
Romania	-	40	40	-	28	-
Spain	140	32	75	-	-	-
Sweden	160	42	82	-	-	-
Turkey	42	33	15	-	28	260
USSR	770	1140	520	150	3000	960
United Kingdom	3	-	5	-	-	-
Yugoslavia	100	120	120	-	10	0.3

6 NON-FERROUS METAL PRODUCTION

Table B-7: Non-ferrous metal production in Europe in 1978 (8, 11). (10^3 tonnes/year).

Country	Copper		Zinc		Lead	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
Albania	19	-	-	-	-	-
Austria	13	16	260	4	7	9
Belgium	162	-	250	-	125	-
Bulgaria	62	-	92	-	125	-
Czechoslovakia	31	-	2	-	19	-
Denmark	-	-	-	0.9	-	8
Finland	53	-	140	-	-	-
France	41	0.6	250	-	130	57
German Dem.Rep.	49	-	16	-	38	-
German Fed.Rep.	400	145	360	260	105	200
Greece	-	-	-	-	21	-
Hungary	17	13	-	0.6	0.2	16
Italy	-	17	180	-	31	85
Netherlands	-	-	150	-	18	-
Norway	9	6	71	-	-	0.3
Poland	330	-	220	-	87	-
Portugal	3	-	-	-	0.4	-
Romania	-	-	-	-	43	-
Spain	150	22	170	-	83	-
Sweden	50	14	-	-	52	17
Turkey	28	-	-	-	3	-
USSR	1500	-	770	-	520	-
United Kingdom	46	80	77	28	120	125
Yugoslavia	47	104	95	-	120	-

Production of zinc in Bulgaria, Czechoslovakia, Finland, the German Democratic Republic, Poland, and the USSR is regarded as a total production of zinc from primary and secondary manufactories. The same is valid for lead produced in Belgium, Bulgaria, Czechoslovakai, the German Democratic Republic, Greece, Netherlands, Poland, Romania, Turkey, the USSR, and Yugoslavia.

7 IRON, STEEL MAKING AND FERROALLOYS MANUFACTURING

Table B-8: Production of pig iron, steel and alloys in Europe in 1978 (8,11) (in 10^6 tonnes/year).

Country	Production			Country	Production		
	Pig iron and alloys	Steel	Sinter		Pig iron and alloys	Steel	Sinter
Albania	-	-	-	Italy	11.3	24.2	14.8
Austria	3.1	4.3	-	Luxemburg	3.8	4.8	7.4
Belgium	10.8	13.5	11.4	Netherlands	4.8	5.5	2.9
Bulgaria	1.5	2.5	-	Norway	1.3	0.8	-
Czechoslovakia	10.2	15.3	-	Poland	11.4	18.6	-
Denmark	-	0.7	-	Portugal	0.4	0.4	-
Finland	1.9	2.3	-	Romania	8.1	11.8	-
France	19.4	23.4	33.7	Spain	6.6	11.5	-
German Dem.Rep.	3.0	7.0	-	Sweden	2.4	4.3	-
German Fed.Rep.	35.2	46.0	36.0	Switzerland	v.small	0.8	-
Greece	-	1.0	-	Turkey	1.8	1.6	-
Hungary	2.3	3.9	-	USSR	110.0	151.0	-
Iceland	-	-	-	United Kingdom	12.9	21.5	17.6
Ireland	-	0.1	-	Yugoslavia	2.3	3.4	-

8. REFUSE INCINERATION

Table B-9: Quantity of refuse incinerated in Europe for 1977 (10^6 tonnes/year).

Country	Refuse incineration		Country	Refuse incineration	
	Municipal	Sewage sludge		Municipal	Sewage sludge
Belgium	0.5	-	Italy	2.6	
Denmark	2.5	-	Luxemburg	0.1	
France	4.9	-	Netherlands	1.7	0.1
German Fed.Rep.	5.4	1.7	United Kingdom	3.2	1.3

For other countries data on quantity of refuse are not available. Quantities of sewage sludge generated in the German Federal Republic and the Netherlands come from 1974, and data for the United Kingdom

are from 1979.

9. PHOSPHATE FERTILIZER PRODUCTION

Table B-10: Phosphate fertilizer production in Europe in 1979 (10^6 tonnes/year).

Country	Production	Country	Production	Country	Production
Albania	v.small	Greece	0.2	Portugal	0.1
Austria	0.1	Hungary	0.2	Romania	0.7
Belgium	0.6	Iceland	-	Spain	0.5
Bulgaria	0.3	Ireland	v.small	Sweden	0.1
Czechoslovakia	0.4	Italy	0.6	Switzerland	v.small
Denmark	0.1			Turkey	0.3
Finland	0.2	Netherlands	0.4	USSR	5.9
France	1.4	Norway	0.1	United Kingdom	0.5
German Dem.Rep.	0.4	Poland	0.9	Yugoslavia	0.3
German Fed.Rep.	0.7				

*1 Belgium and Luxembrug are regarded together.

10. CEMENT PRODUCTION

Table B-11: Cement production in Europe in 1978 (in 10^6 tonnes/year) (8).

Country	Production	Country	Production	Country	Production
Albania	0.8	Greece	11.4	Portugal	4.7
Austria	5.7	Hungary	4.8	Romania	13.9
Belgium	7.6	Iceland	0.1	Spain	29.3
Bulgaria	5.1	Ireland	1.8	Sweden	2.4
Czechoslovakia	10.2	Italy	38.2	Switzerland	3.7
Denmark	2.6	Luxembrug	0.3	Turkey	15.6
Finland	1.8	Netherlands	3.9	USSR	127.0
France	28.2	Norway	2.3	United Kingdom	15.9
German Dem.Rep.	12.5	Poland	21.6	Yugoslavia	8.7
German Fed.Rep.	34.0				

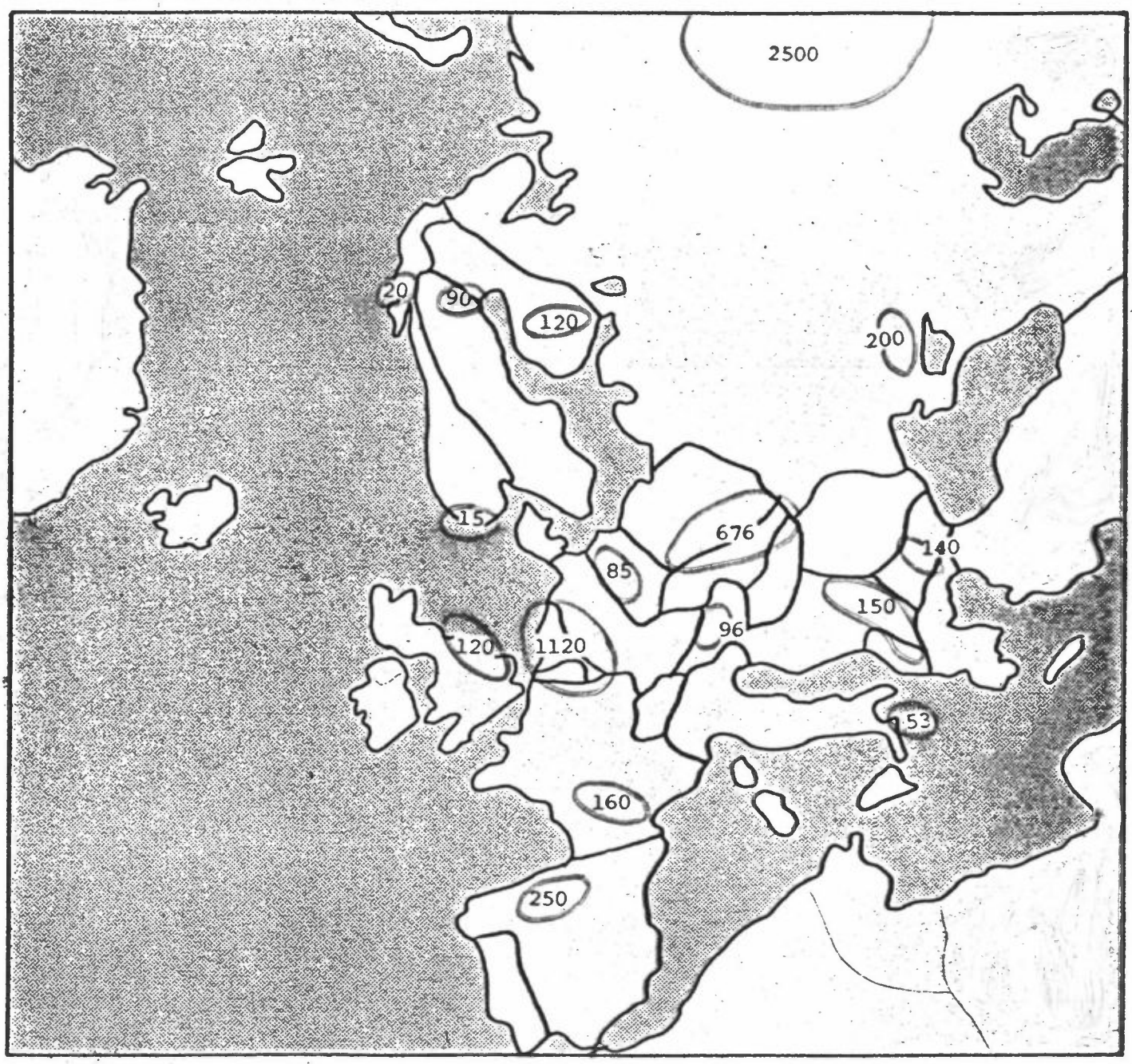

Figure 1: Estimated annual emission of arsenic in Europe (t/year).

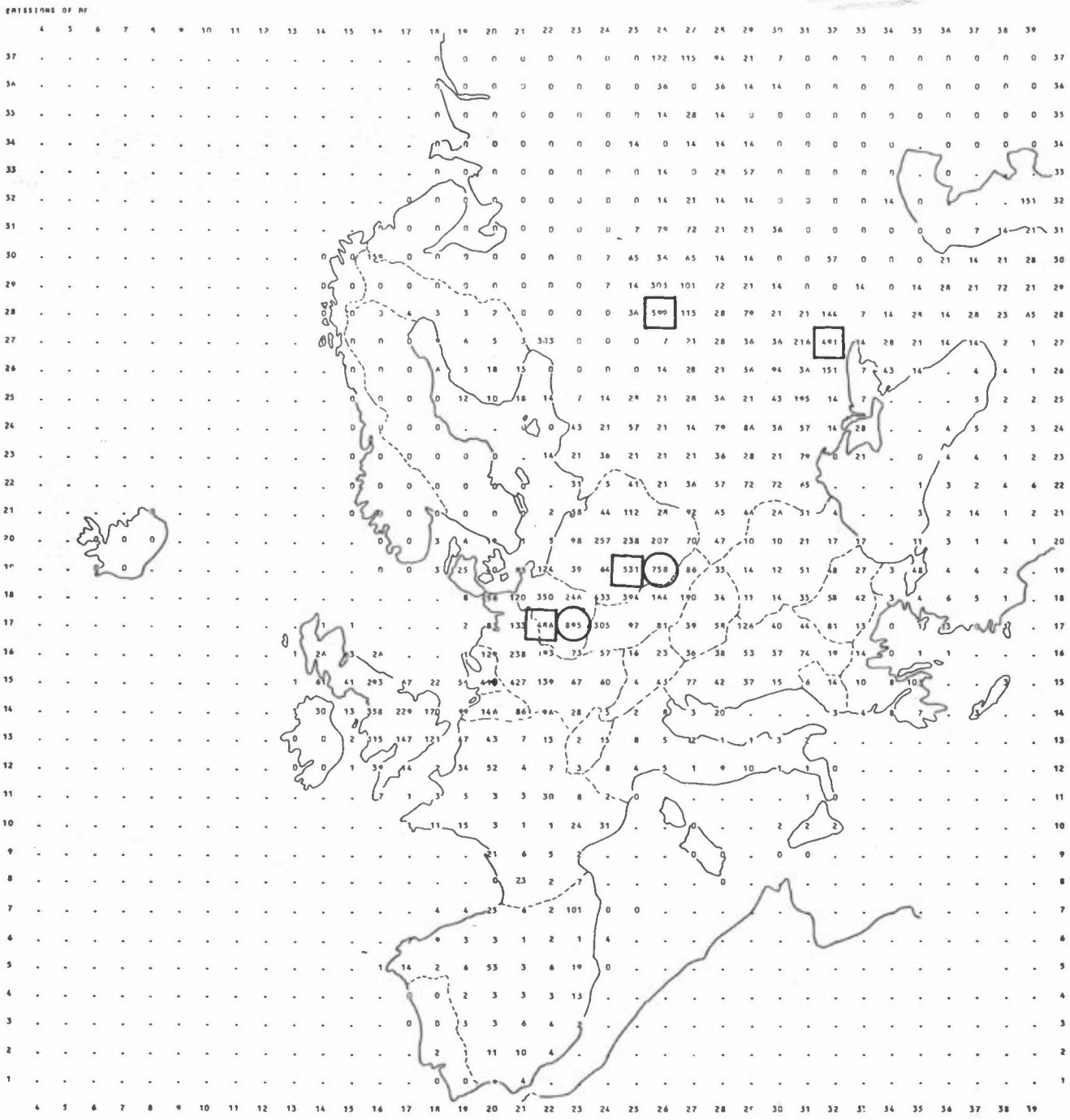

Fig. 2: Estimated annual emission of beryllium (kg Be) from conventional thermal power plants in grid elements with side length 150 km.

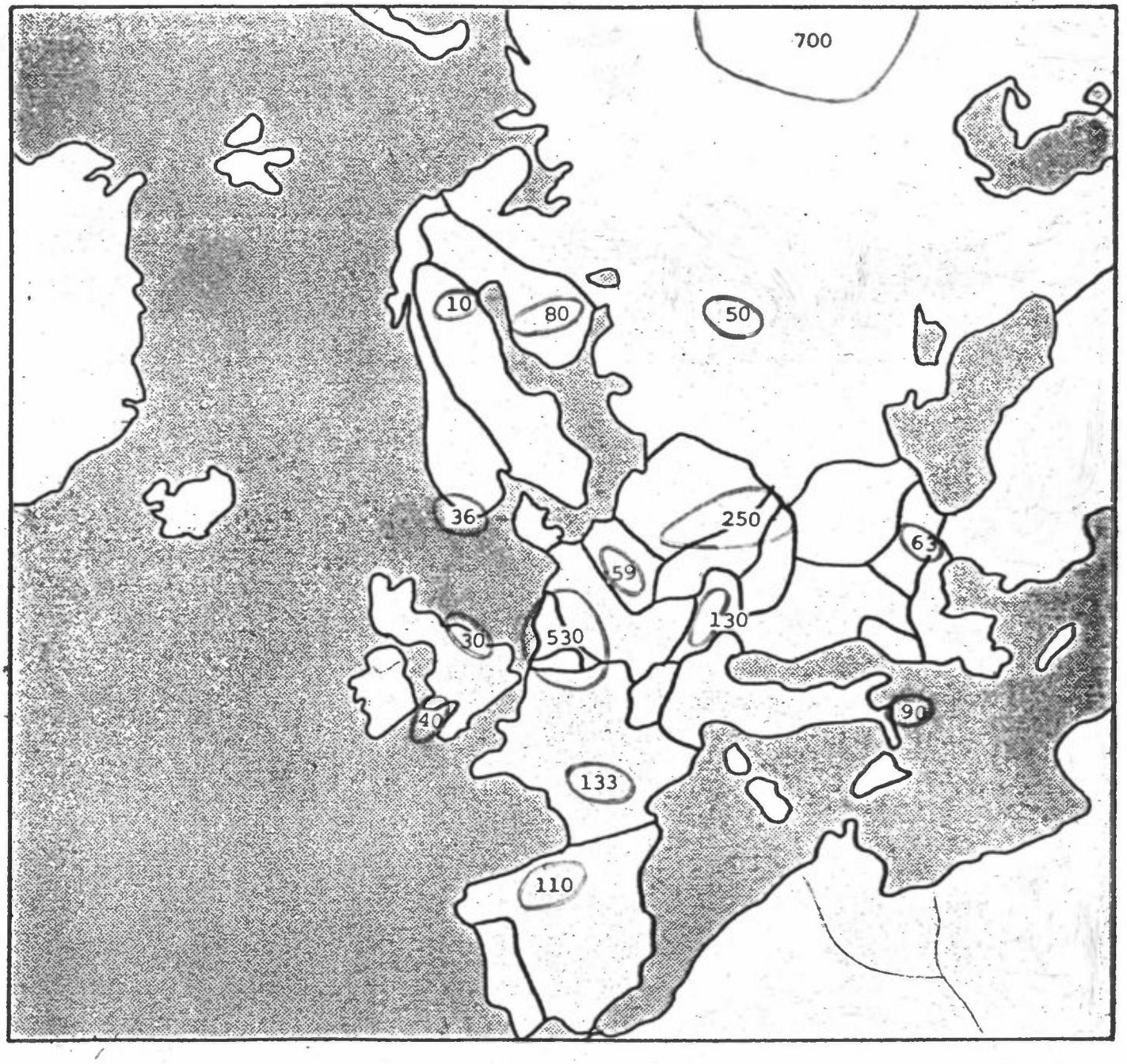

Figure 3: Estimated annual emission of cadmium in Europe (t/year).

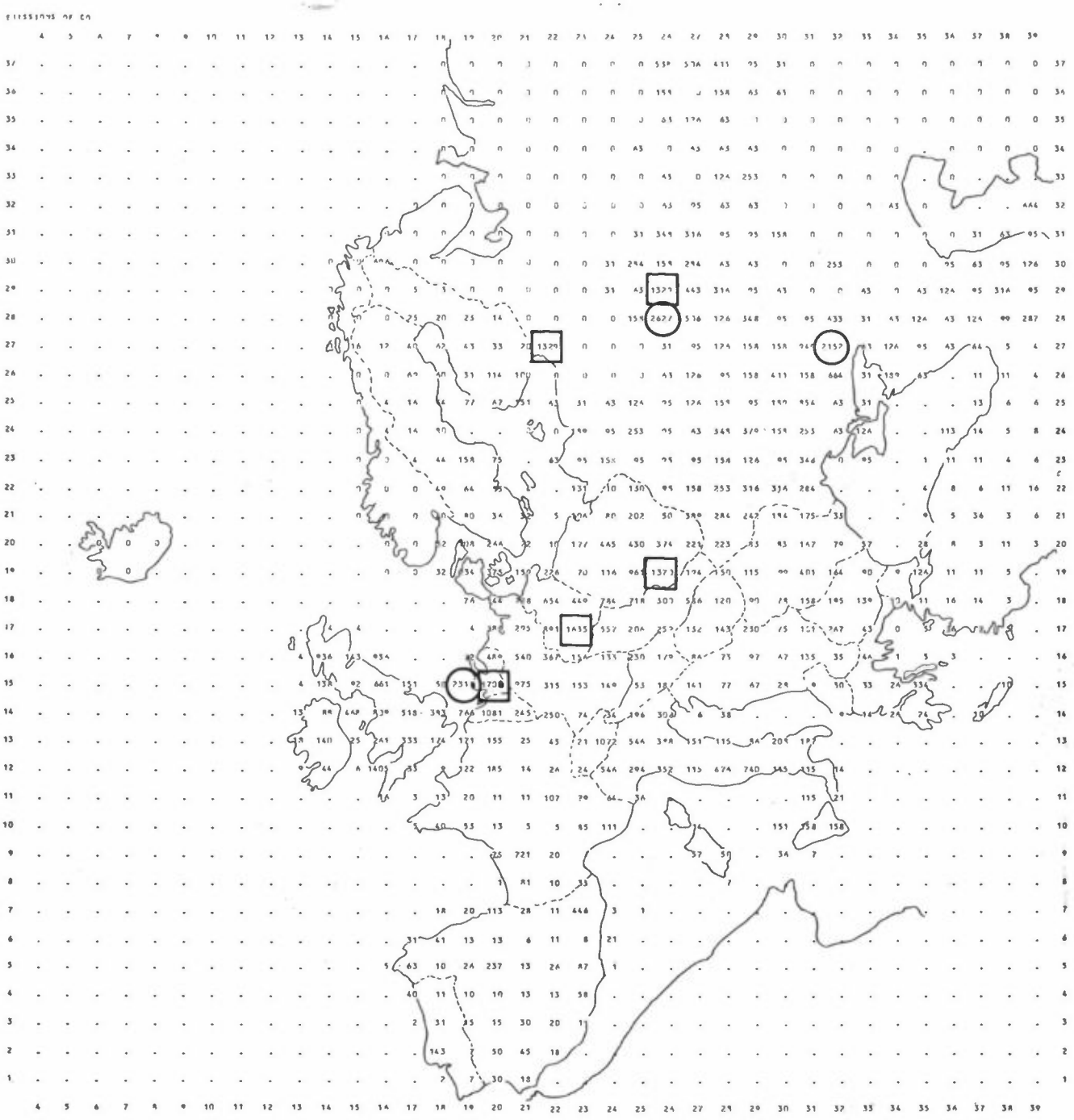

Fig. 4: Estimated annual emission of cobalt (x10 kg Co) from conventional thermal power plants in grid elements with side length 150 km.

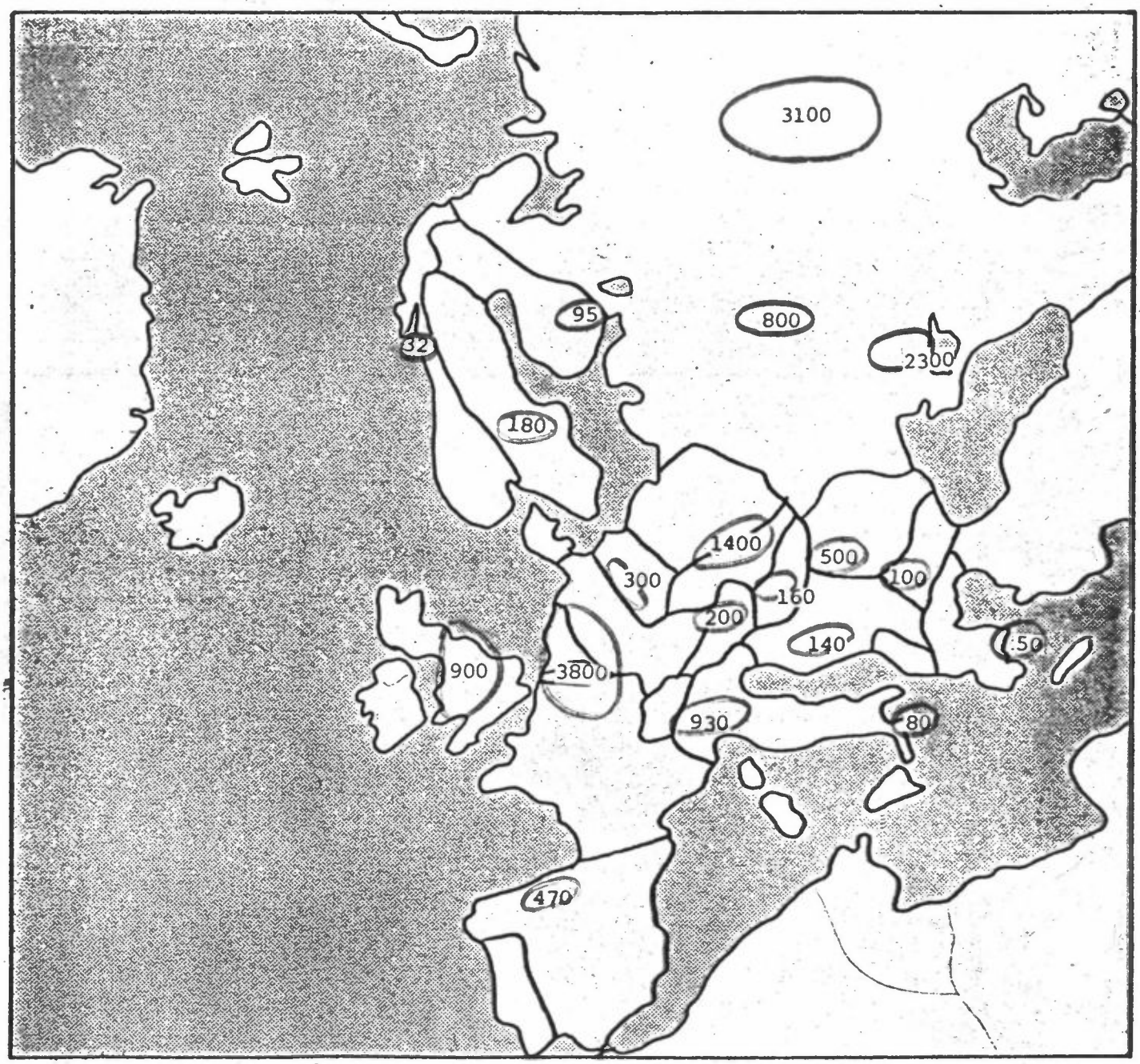

Figure 5: Estimated annual emission of chromium in Europe (t/year).

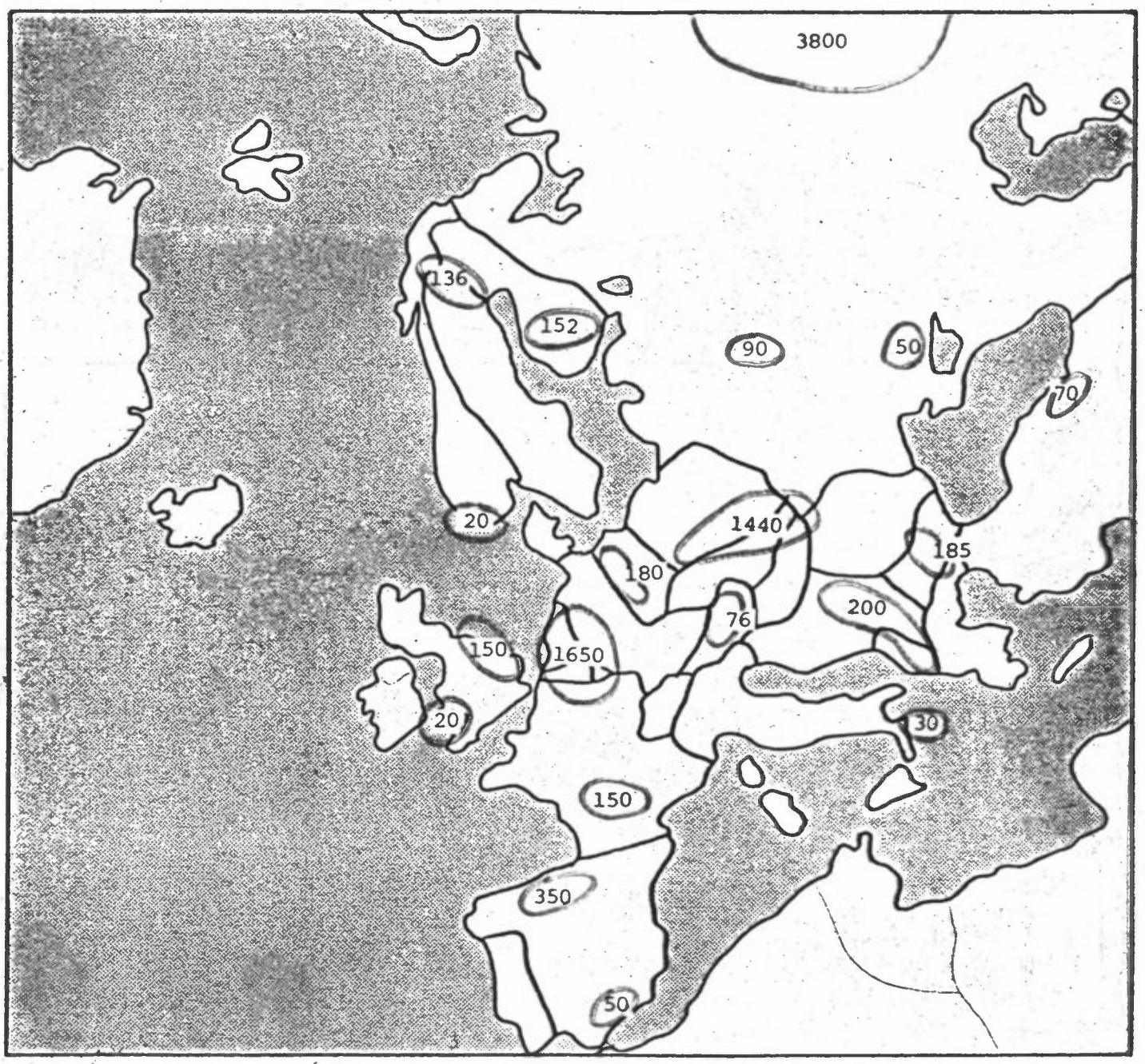

Figure 6: Estimated annual emission of copper in Europe (t/year).

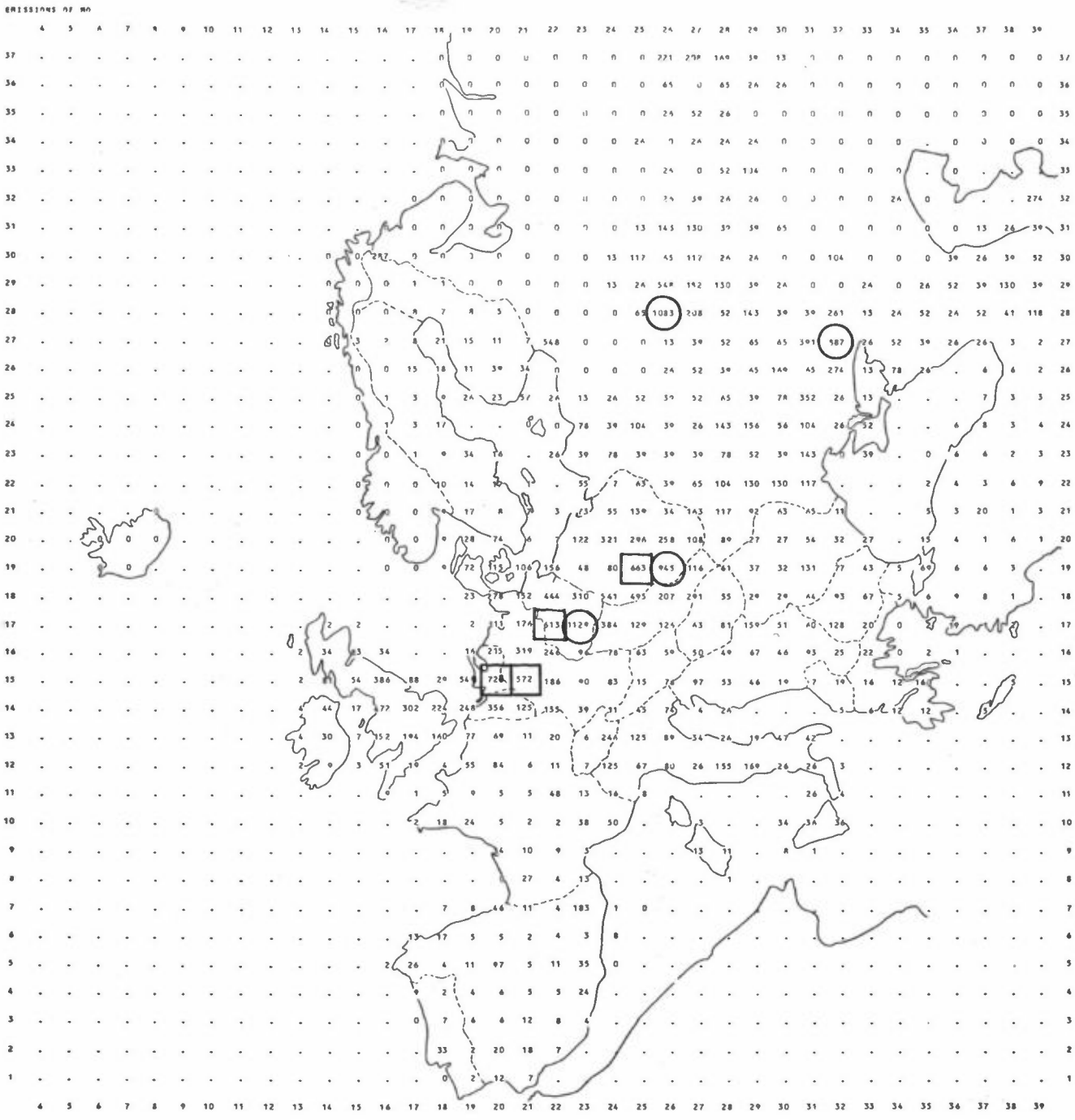

Fig. 7 : Estimated annual emission of molybdenum (x10 kg Mo) from conventional thermal power plants in grid elements with side length 150 km.

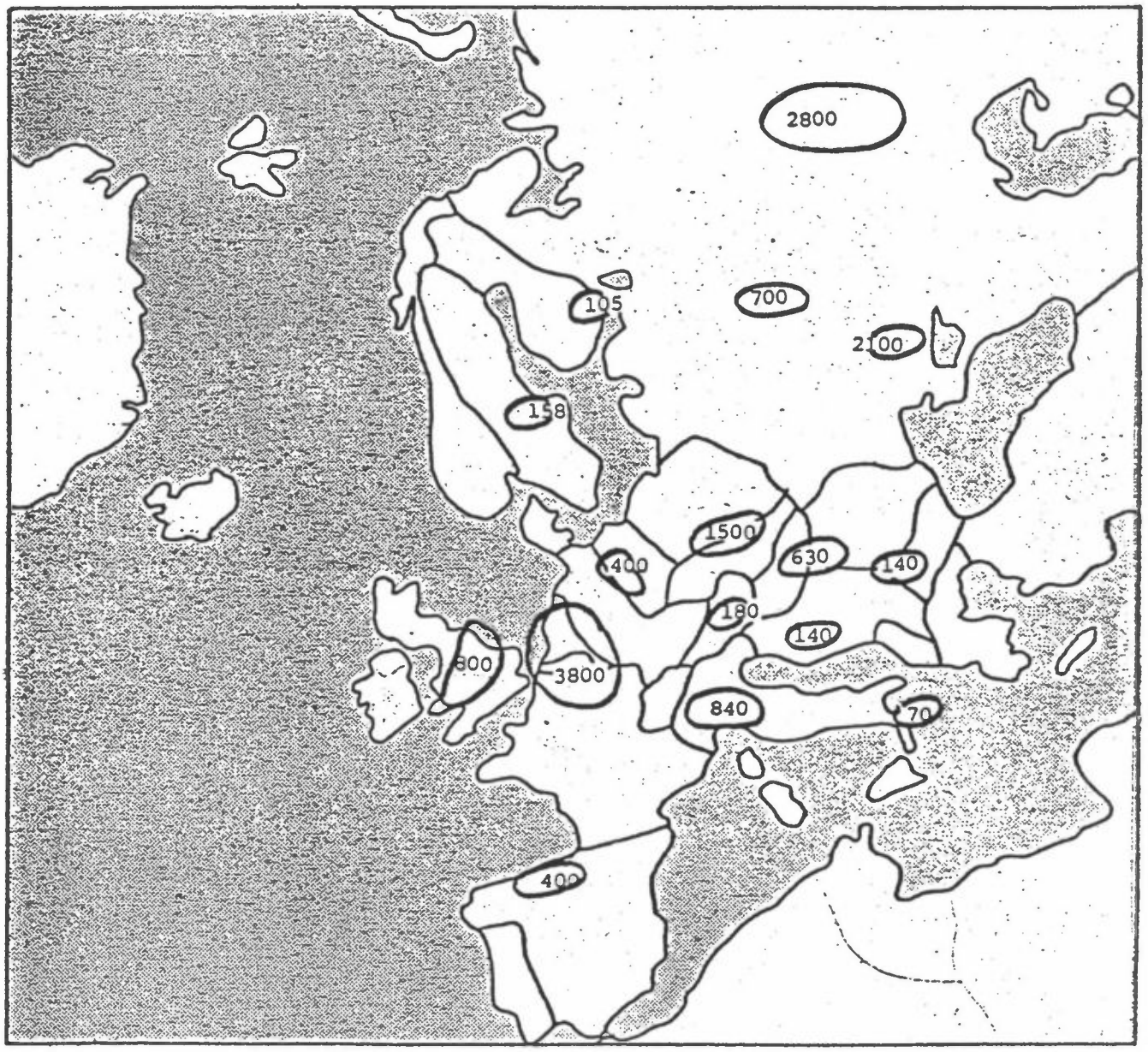

Figure 8: Estimated annual emission of manganese in Europe (t/year).

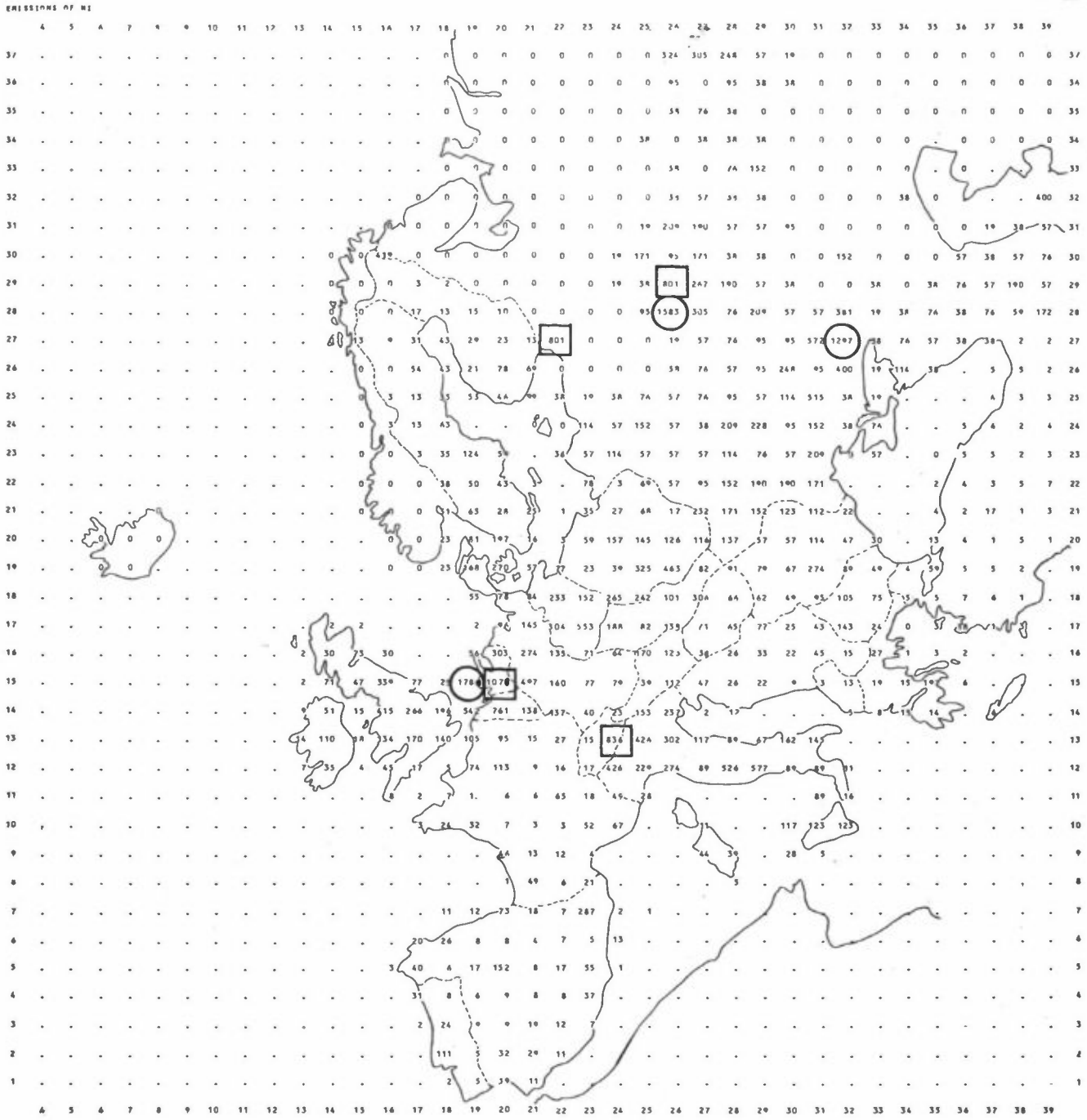

Fig. 9 : Estimated annual emission of nickel (x100 kg Ni) from conventional thermal power plants in grid elements with side length 150 km.

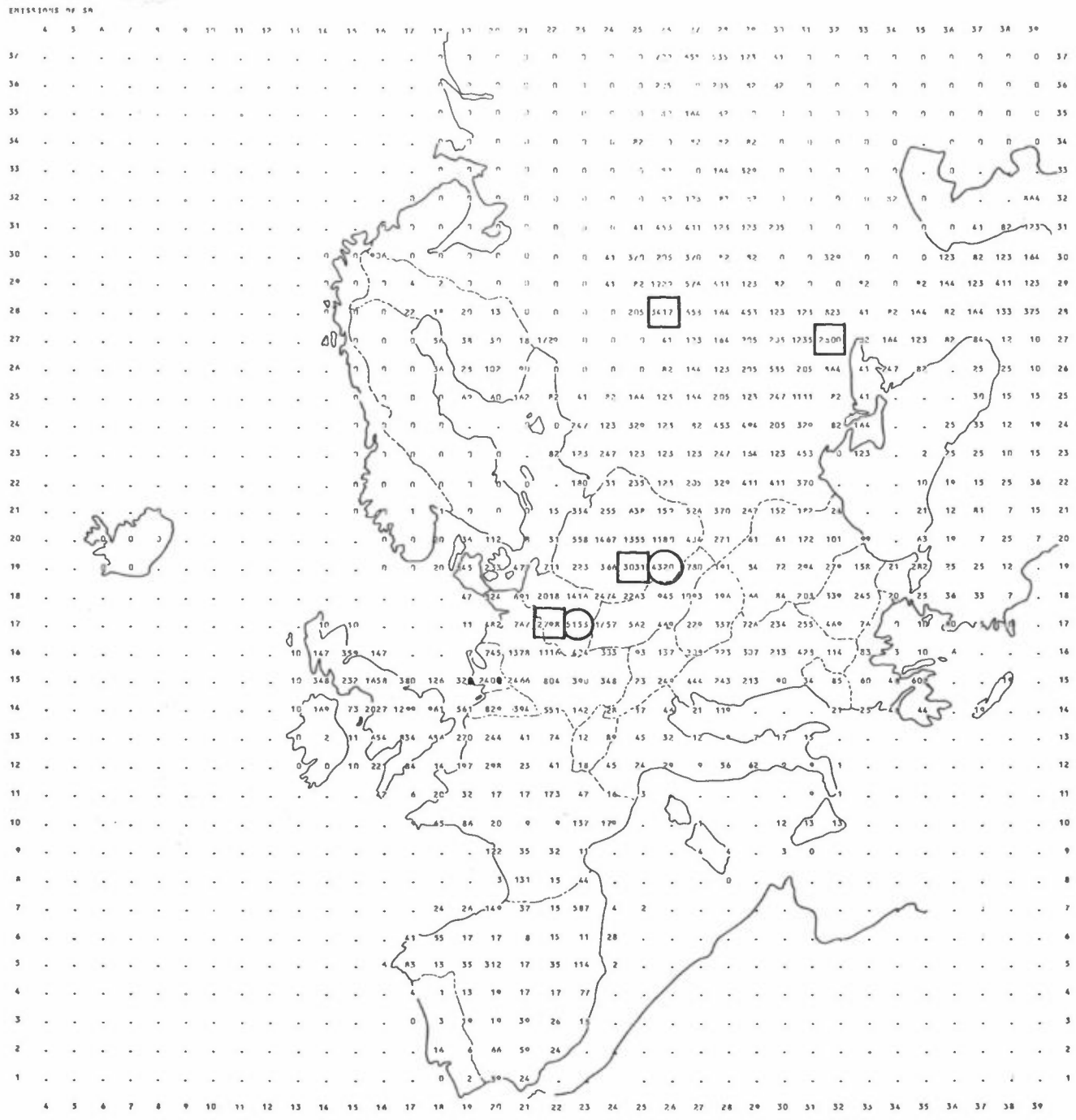

Fig. 10: Estimated annual emission of antimony (kg Sb) from conventional thermal power plants in grid elements with side length 150 km.

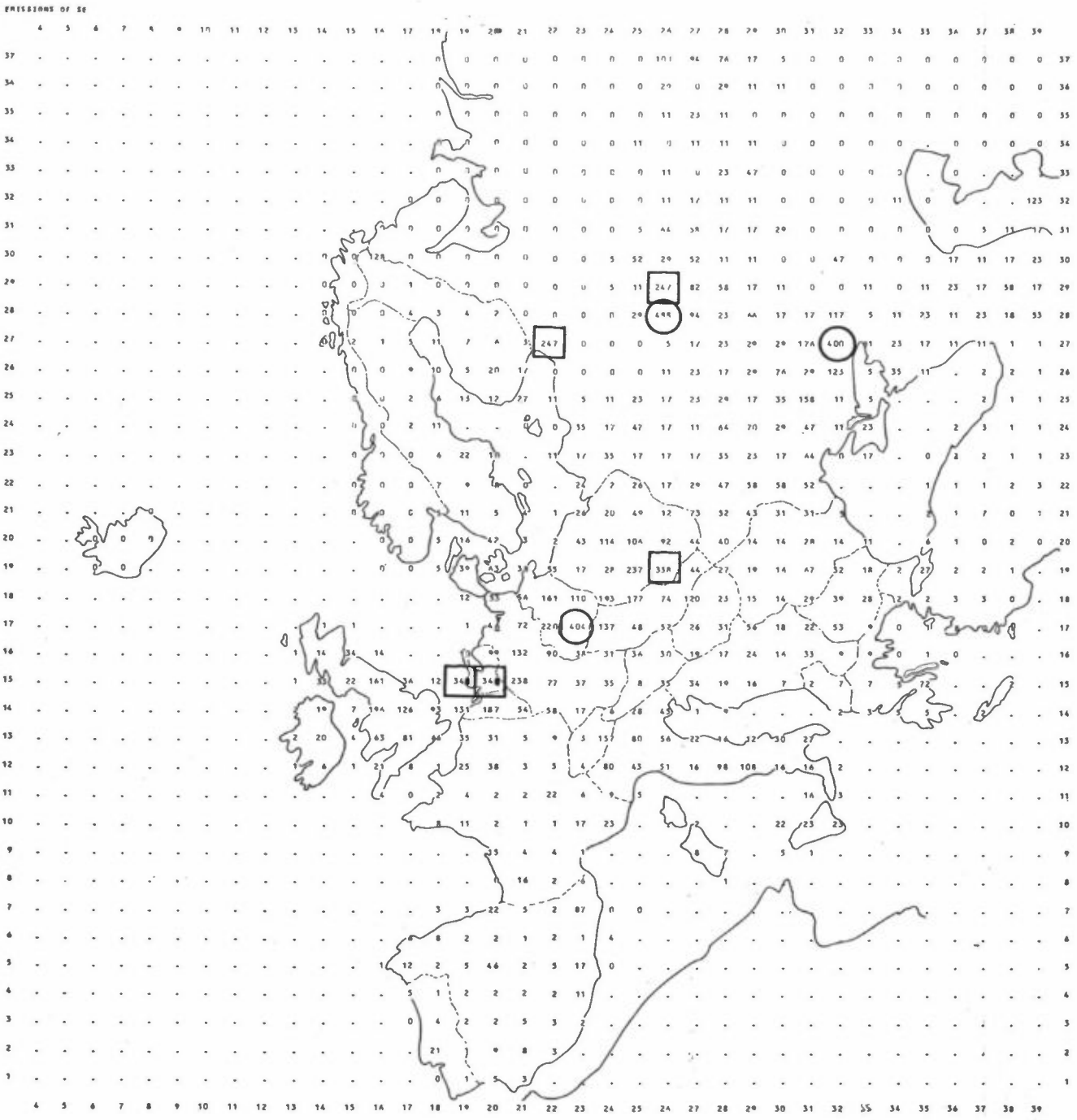

Fig. 11: Estimated annual emission of selenium (x10 kg Se) from conventional thermal power plants in grid elements with side length 150 km.

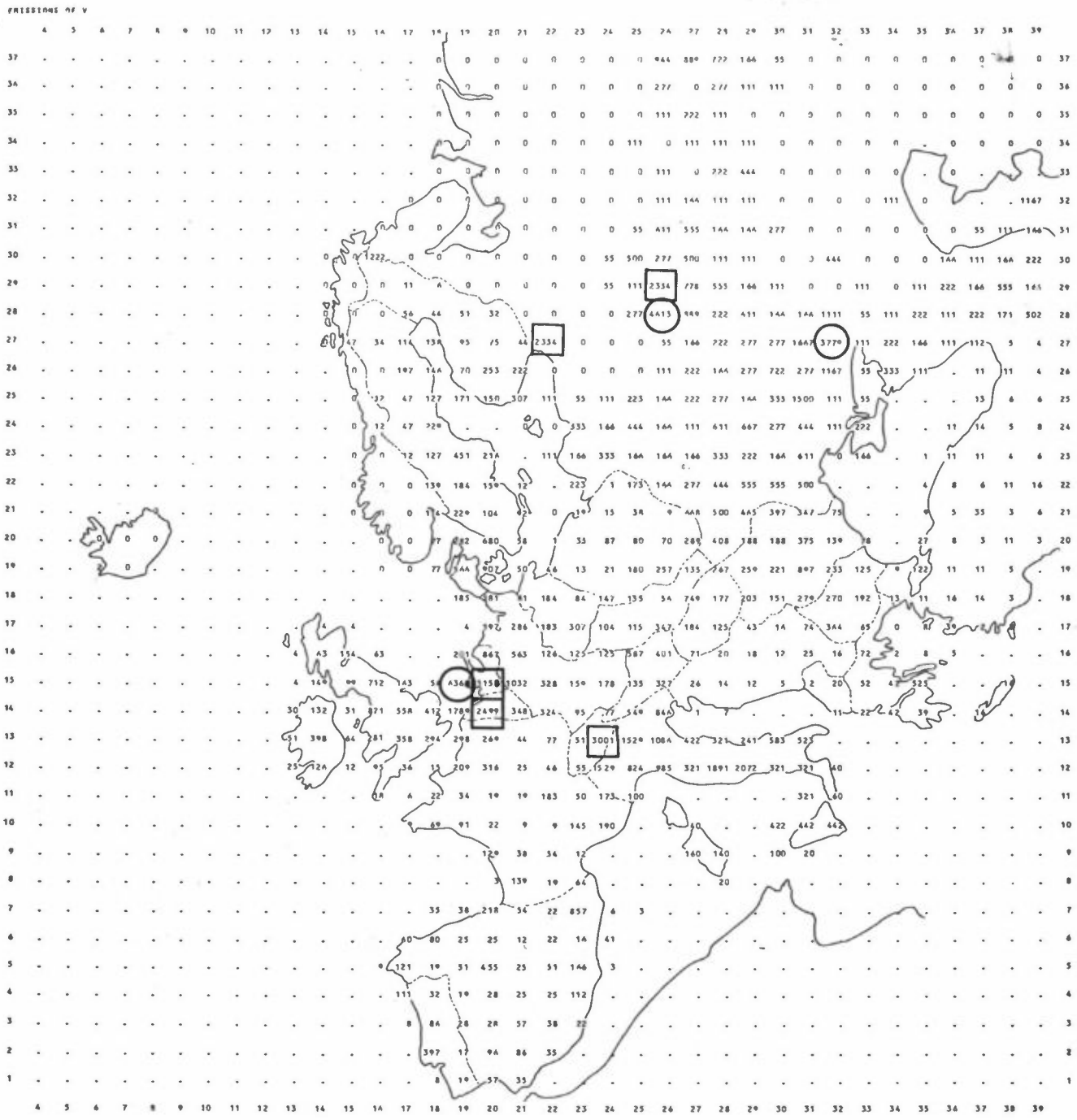

Fig. 12: Estimated annual emission of vanadium (x100 kg V) from conventional thermal power plants in grid elements with side length 150 km.

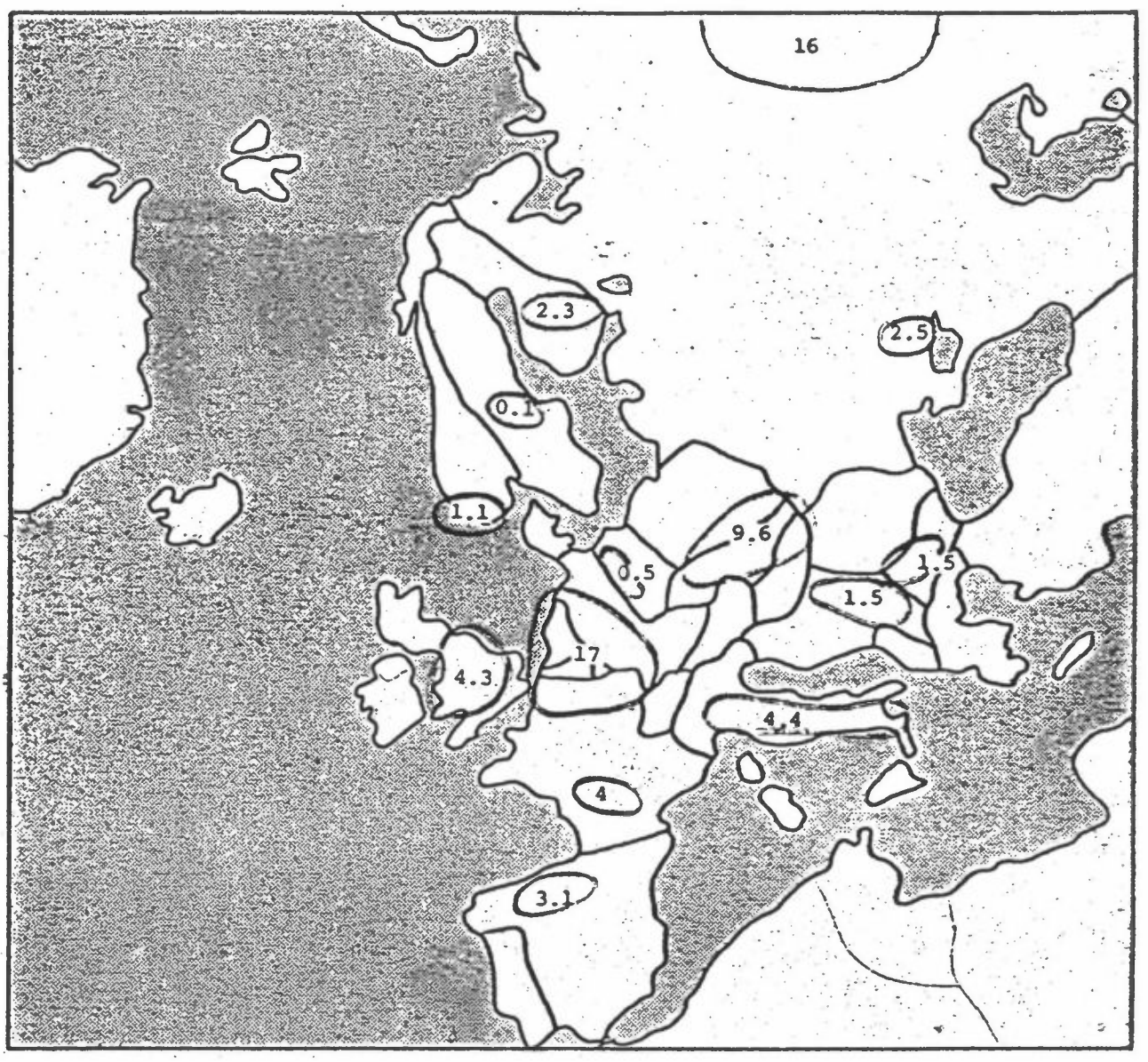

Figure 13: Estimated annual emission of zinc in Europe (1000 t/year).

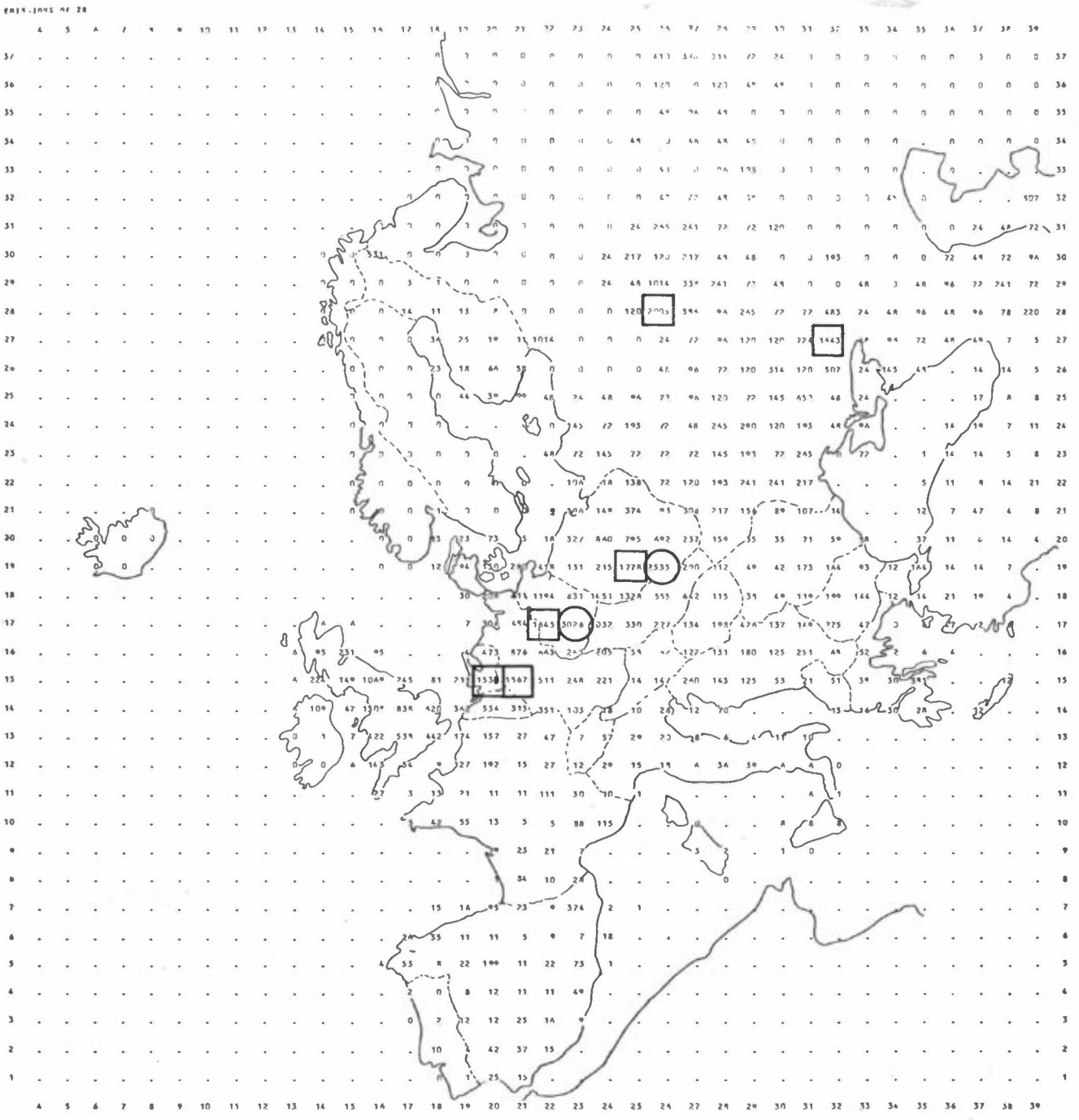

Fig. 14: Estimated annual emission of zirconium (x10 kg Zr) from conventional thermal power plants in grid elements with side length 150 km.

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In the report an attempt is made to estimate the emission of trace elements to the atmosphere from various sources in the European countries. The data have been obtained on the basis of trace emission factors, and statistical information on the consumption of ores, rocks, and fuel and the production of various types of industrial goods. Available information on differences in manufacturing techniques, import-export relations of fuels and ores, different dust removal installations and their effectiveness have been taken into account.

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