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Emissions of Arsenic in Sweden and Their Reduction

by Lars Lindau*

The role of arsenic in Sweden is generally described, including raw materials, exports/imports, products, consumption, etc. An attempt was also made to es"'nate the transport of arsenic in Sweden. The quantities of arsenic in raw materials, the emissions of arsenic from such processes as copper smelters and chemical industries, and the amounts of products containing arsenic were calculated. The studies show that a copper smelter is the main user of arsenical materials, the very largest emitting source and also the plant which manufactures most arsenic products.

A summary of measurements of arsenic in air, water and soil in Sweden has also been made. The concentrations near a smelter, in the Baltic, in cities and in "clean-air areas" are given.

The efforts made to date to reduce the emissions of arsenic and the measures planned for the next few years are described. A reduction has already been achieved and a further rather large decrease will come, especially in arsenic levels in water. The possibilities of minimizing the use of materials and products *containing arsenic is also discussed.*

Introduction

Recent findings indicate that lung cancer mortality might be increased in communities surrounding industrial sources of arsenic. Arsenic can be methylized and it aan also be enriched in certain plants. In the brackish water of the Baltic, a metal like arsenic, with cumulative poison characteristics and biological availability, is of special interest. These findings have resulted in further research projects on effects of arsenic and also in studies of sources and measures to minimize the quantities of arsenic emissions, and products. This report summarizes the data currently available in Sweden of the occurrence of arsenic and the emissions to air, water, soil. Measures for reducing the quantities of arsenic are also considered.

Occurrence of Arsenic

Arsenic and its various compounds occur in nature primarily in inorganic forms and are mainly found in Sweden in ores of copper but also in such other minerals as pyrite. They are, however, widely distributed in small amounts in soil, sea water, and ambient air. They are also found in different types of products used by man, e.g., food, metal alloys, glass, wood preservatives, fertilizers, and chemicals. The amount of a metal in waste often gives an indication of the flow in society. However, the levels in dust from waste incinerators and in sludge from sewage treatment plants are low, 0.03 g/kg and 7 μg/g, respectively.

The background concentrations are found to be 0.5 μg/g in moss and 5–15 mg/kg in soil. In the Baltic (a brackish water) the concentration is 0–2 μg/l. In sea water along the west coast of the country the levels are 1–3 μg/l. The figures are low, in food also; in drinking water, 0.08–3 μg/l, in vegetables and grain, 0.1 μg/g, and in cod 0.5–3.4 μg/g. Only in crustaceans are there high levels (40–174 μg/g).

The investigations in Sweden of arsenic in the environment have been focused on the surroundings of a copper smelter using concentrates containing arsenic. The measurements around the smelter show much higher figures. Of importance is also that the plant includes a unit for production of arsenic products. In fact, the emissions to the Baltic show an influence over very long distances. On the terrestrial side the concentration in moss is 40–60 μg/g at a distance of 2–3 km from the plant, sus-

*National Swedish Environment Protection Board, Technical Department, Industry Division 2, Fack, S-171 20 Solna, Sweden.

pended dust shows < 1 $\mu g/m^3$ at a distance of 1–2 km. Falling dust shows a maximum of 25 g and an average of about 3 g per 100 m^2 in 30 days; the maximum levels in soil are 30 mg/kg, in barley, 0.06 $\mu g/g$ near the plant and 0.01 $\mu g/g$ at a distance of 40 km; and in field mice and foxes caught near the plant 20–200 $\mu g/g$. If we study the aquatic neighborhood we also find high levels. The maximum concentration is 500 $\mu g/l$, but at a distance of 30 km it is down to 5 $\mu g/l$. In water organisms levels are calculated to be increased at a distance of 400 km and in sediments at a distance of 1000 km.

Flow of Arsenic in the Society

An attempt has been made to calculate the flow of arsenic in Sweden; results are shown in Figure 1. Unfortunately, all values are not known, and many cannot be published due to industrial security. This is especially true for supply. The main sources are copper and lead ores and pyrites, other sources being small by comparison. On the outlet and deposit side the export of products containing arsenic are most important, but the emission to water and later on to sediments is also large. The arsenic content in food is low, and that flow is very small compared with most others. More details, especially about emissions from industrial sources are given in the following.

Sources of Arsenic and Control Technology

The most important source of arsenic appearing in the environment is a copper smelter with an arsenic production plant. It is the largest emission source to air, soil, and water and it also covers almost all of the production of arsenic products. Tables 1 and 2 give information about the quantities of different products and solid wastes containing arsenic and also the emissions to air and water of arsenic from different sources.

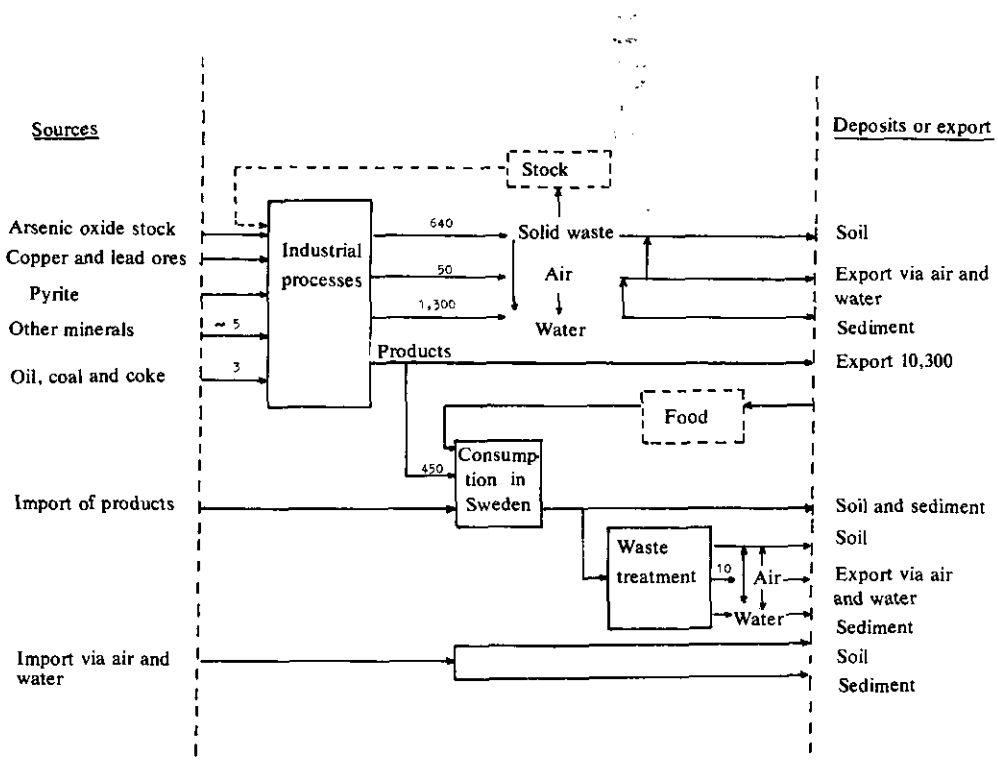

FIGURE 1. Flow of arsenic in Sweden (in tons/yr).

Table 1. Products and waste containing arsenic used or deposited in Sweden.

	As, tons/yr
Products	
Wood preservatives	300
Arsenic metal	100[a]
Arsenic oxide	25[a]
Steel	20[a]
Fertilizers	5
Chemicals	1
Wastes	
From arsenic work	480
From copper and lead smelter	90
From sulfuric acid production	50
From sulfite cellulose plant with pyrite as a sulfur raw material	10[a]
From glass manufacture	10[a]
From waste incineration	2
From burning of coal	1
From used wood containing arsenic	100[a]
From other wastes	?

[a]Estimate.

Table 2. Emissions of arsenic in Sweden.

	As, tons/yr
To water	
Arsenic work	1100[a]
Copper and lead smelter	150[b]
Sulfuric acid plants	4
Sulfite cellulose plants with pyrite as a sulfur raw material	<1
Fertilizer plant	<1
To air	
Copper- and lead smelter	25
Arsenic work	15
Sintering plants with roasted pyrites as raw materials	<1
Sulfite cellulose plants with pyrites as sulfur raw materials	<1
Burning of coal	1
Burning of fuel oil	<1
Mines	<1
Glass manufacture	0.1

[a]In 1977 70 tons/yr.
[b]In 1978 35 tons/yr.

Products

Arsenic products manufactured in Sweden come from arsenic trioxide, which is obtained as a by-product of the smelting of sulfide ores. The main products are metallic arsenic, arsenic trioxide, arsenic acid, and arsenic wood preservatives. Products with smaller amounts of arsenic are fertilizers, aluminum sulfate, and calcium phosphates. The total amount of arsenic in products produced in Sweden is about 11,000 tons/yr, and 95% of this is exported. The figures can be compared with the U.S. consumption of arsenic trioxide which was 32,000 tons in 1974 (*1*) and the world production which is about 50,000 tons/yr (*2*).

The effect on the environment of the use of arsenic products in Sweden is very difficult to evaluate. As stated above, the main use is in wood preservatives. In a new suburb of Stockholm the houses contain a large amount of wood with an arsenic wood preservative. What will happen to this wood when the houses are pulled down in about 50 or 100 years? Most likely, some part of it will be reused (which is the best way from an environmental point of view), another part will be put in a landfill and the rest will be incinerated. From the landfill the arsenic can get out in the water and from the incinerator some of it will get out in the air and then it will be deposited over a large area. The views of the authorities in Sweden are that in the long run the content of arsenic in products should be decreased as far as possible, that products like arsenic wood preservatives should be replaced with substances free from arsenic and without other serious effects to the environment, and that materials containing arsenic should be reused as far as possible. The reason for this attitude lies in the effects of arsenic on man and nature.

Copper and Lead Production

Swedish cooper ores are complex and contain various metals, mainly copper, lead, zinc, and arsenic. There is one smelter which treats these ores, at a capacity of 60,000 tons copper and 50,000 tons lead per year. The most important parts of the smelter are multihearth roasters, an electric smelting oven, converters, lead ovens, a fuming furnace, a copper refining plant, sulfuric acid and sulfur dioxide plants. The emissions, deposits, and amounts of products of arsenic are shown in Figure 2; as can be seen, the emission to water is high. The levels have been reduced in recent years; the annual emissions to air were 300–1000 tons 25 years ago and to water 2400 tons 10 years ago. Compared with the emission levels in the U.S. (*1*), the actual figures (25 tons to air and 150 tons to water per year) are a bit lower on the air side but higher on the water side.

An important measure taken in recent years is the installation on the multihearth roasters of new electrostatic precipitators with a cooling tower between. In the first step, metals are precipitated and in the second step arsenic is condensed and collected. These installations did reduce the arsenic emission to 25 tons/yr to the water. The investment was profitable in that the result was cleaner copper dust, and increased sulfur dioxide concentration in the gas, and a larger amount of arsenic retained.

In the next two years an entirely new system is planned for taking care of gases from the metal producing ovens, namely, a central gas scrubber

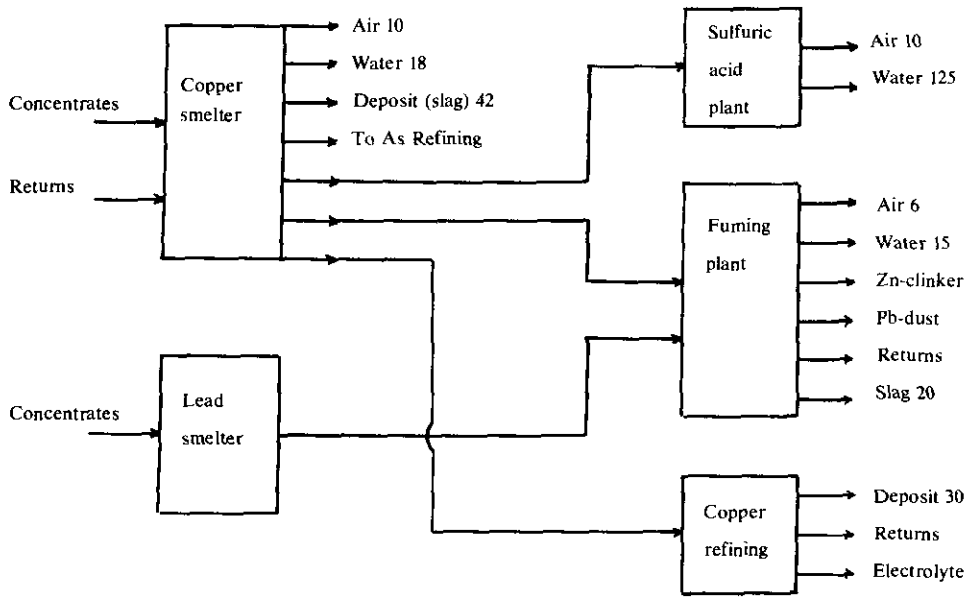

FIGURE 2. Emissions of arsenic from a copper smelter (in tons/yr).

equipped with a wastewater cleaning unit. The latter includes floculation, precipitation (with caustic and sodium sulfide) and filtration. Wastewaters from the sulfuric acid plant, various wet electrostatic precipitators, wet scrubbers, rinse water, and storm water will also be connected. The reason for the investment (20 million dollars) is recovery of not only arsenic but perhaps more important also other metals and increased recovery of sulfur. The content of arsenic in the effluent will be 10–20 mg arsenic/l., and emissions will be reduced from 10 to 5 tons/yr to the air and from 125 to 10 tons/yr to the water.

Some other measures are also planned for reducing emissions of arsenic and other metals, e.g., a ventilation system with bag-house for the fugitive dust escaping from the copper converters. Other fugitive emissions will also be or are taken care of by measures like closed transport systems and indoor storage. In the future it may be possible to reduce the emissions to both water and air to very low levels.

Manufacture of Arsenic Products

The arsenic trioxide from the smelter is processed to arsenic chemicals at a plant nearby. Figure 3 gives the emission and some production data. Refining of arsenic oxide involves its dissolution and crystallization at different temperatures, that of arsenic metal, reduction; and that of the wood preservatives, oxidizing and transformation to a copper salt. Emissions from the arsenic refining plant to the water have been reduced from 960 to about 70 tons/yr, with a precipitation plant with lime added for the washing water and excess of lye. The investment was 0.9 million dollars. The emissions from the arsenic metal production will be reduced to almost zero by building an entirely new plant in which the possibilities to reduce emissions are much better.

Use of Pyrite

There is arsenic in Swedish pyrite, which is used as a raw material for sulfur in production of sulfuric acid and in sulfite cellulose plants. However, the emissions to air and water are small, less than 1 ton/yr to air and about 5 tons/yr to water. The main part of the arsenic in pyrite goes to the sulfuric acid production, where most of it is processed to a product which is reused for manufacturing arsenic chemicals. What is needed is to roast the pyrite to an iron oxide, which does not bind the arsenic and to have gas cleaning equipment to prevent the arsenic from reaching the sulfuric acid. However, in one plant the roasting is done in such a way that the arsenic remains in the roasted pyrite. What happens then to the arsenic in further sintering and steel plants we do not know, but most of it will probably be found in the steel.

Other Sources

From Tables 1 and 2 it is seen that there are some other sources of arsenic emissions, but they are very small. If coal, in the future, is used in Sweden for power production in a larger scale than at pres-

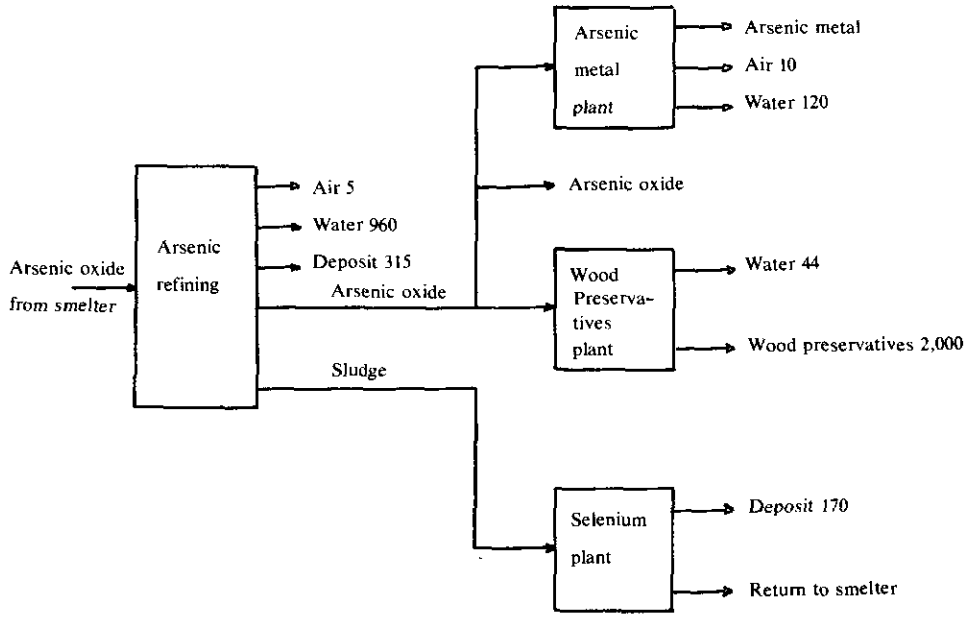

FIGURE 3. Emissions of arsenic from an arsenic chemical plant (in tons/yr).

ent, it might be another source of interest. We think, however, that precipitators for dust and scrubbers for sulfur dioxide will minimize the emissions.

Implication and Current Activities

Although arsenic is not a widespread pollution problem in Sweden, there are certain areas of concern, especially just around a smelter and in the Baltic, which is very sensitive to changes of environmental factors. An interesting project in preparation is the measurement and calculation of the transport of different metals, e.g., arsenic around the smelter. Transport from chimneys, wastewater pipes, and other sources to air and water and further transport to soil and sediments will be investigated. The results will be used to estimate the effects on the environment and where further research and investigation activities are needed.

The present activities and some further possibilities to reduce the release of arsenic to the environment have been presented. In the long run it will be possible to reduce the quantities to almost zero. Future research on the effects on the environment will show us whether this will be necessary.

REFERENCES

1. Air pollutant assessment report on arsenic, U. S. Environmental Protection Agency, July 1976.
2. Minerals Yearbook, Vol. 1 1970, U. S. Bureau of Mines, Washington, 1972.