AN INITIAL ASSESSMENT OF THE PRODUCTION, CONSUMPTION AND EMISSION OF SILVER IN THE NORDIC COUNTRIES

Arun B. Mukherjee
University of Helsinki
Helsinki, Finland

Abstract

This is the first attempt to provide scenarios for silver in the Nordic countries. In the Nordic countries, silver recovery from non-ferrous metallurgical plants occurs in Sweden and Finland. In Sweden, the average recovery of silver for the last 23 years is about 230 metric tons (7.4 Million Troy Oz) whereas in Finland, it is about 30 metric tons (0.96 Million Troy Oz). In addition, silver is also recovered by the secondary metal industry from photographic materials, electronic and jewelry scrap.

The silver use pattern in the Nordic countries differs somewhat from the global use pattern. The global use pattern of silver for the 1980s was maximum (38%) in the sector of photography whereas in the Nordic countries, maximum use was observed in jewelry/silverware. In Norway, the maximum amount of silver (90 tons i.e. 2.89 Million Troy Oz) was used in jewelry/silverware whereas in Finland, the total consumption of silver was noted to be 66.5 x 10^6 g (2.22 Million Troy Oz) per year.

An attempt has also been made to determine source categories of silver emissions and also to estimate the discharge of silver to the environment of Finland and the other Nordic countries.

Introduction

The last decades have witnessed progressive increase in the influence of industrial activities due to which there is sharp increase of the emission of toxic metals (Nriagu and Pacyna 1988; Nriagu 1990). Emission data for trace elements such as arsenic, cadmium, lead, mercury and many others from low- or high-temperature processes are available. But very limited information exists on the emission, bioaccumulation and toxicity of silver in the ecosystem. It is no doubt that dissolved silver compounds are toxic to the aquatic species.

The purpose of this study is to find out the recovery pattern of silver, its use and industrial discharge to the ecosystem of the Nordic countries. This information will be helpful to the responsible bodies to formulate policies for the prevention of heavy metal emission. In addition, information gaps between governmental authorities, industry and scientists on silver scenarios in the Nordic countries will be reduced to some extent.

Production

The quest for precious metals by primitive man has been mentioned by the early Egyptians and Babylonians and still today the same quest is followed by the modern civilization and hence the Nordic countries are no exception.

In the Nordic countries, there is no primary production of silver but it is recovered from the non-ferrous metallurgical industry in Sweden and Finland. In Sweden, the average recovery of silver for the last 23 years is about 230 metric tons (7.4 Million Troy Oz) whereas in Finland, it is about 30 metric tons (0.96 Million Troy Oz) (Fig. 1).

Silver is also recovered from photographic materials, electronic scrap and jewelry waste. The recovery of silver from photographic processes is based on several processes including electrolysis, ion exchange and oxidation of silver complexes with hydrogen peroxide (Knorre et al. 1988). It is estimated that in Denmark, Finland and Norway about 12 to 13 million m^2 of photographic materials containing 2.5 g Ag m^{-2} (average) were imported and the recovered silver percentage was estimated to be 95%. On the other hand, in Sweden, the import of photographic films and papers varied between 12 to 15 million m^2 in 1993. The total recovery of silver from the photography industry in the Nordic countries (excluding Iceland) was about 57 to 67 tons (1.81 to 2.15 Million Troy Oz) per year.

Silver use in the Nordic countries

The silver use pattern in the Nordic countries differs somewhat from the global use pattern. The global use pattern of silver for the 1980s was maximum (38%) in the sector of photography (Silver Institute 1994) whereas jewelry and silverware use became largest end use market in Norway, followed by Finland, Sweden and Denmark in 1993. It is amazing that about 20 g Ag per capita was used in jewelry and silverware in Norway whereas the minimal use pattern (2 g Ag per capita) was noted in Denmark (Fig. 2). The use pattern of silver in the Nordic countries is cited in Table 1. Though some data are not available for Sweden, Denmark and Norway but still this study indicates that the maximum demand of silver was noted to be 100.54 metric tons (3.23 Million Troy Oz) in Norway where the total population is about 4.2 million. However, the consumption pattern of silver varies in the following order: Norway > Sweden > Finland > Denmark.

Table 1. The Use of Silver in the Nordic Countries (Excluding Iceland), 1993.

Sources	Finland	Sweden	Denmark	Norway
		kg* yr^{-1}		
Jewelry & silverware	42,000	26,000	12,000	90,000
Photography	10,000	37,000	10,500	10,000
Coinage	7,470	1,250	310	20
Electroplating	2,000	400	-	-
Brazing[1]	1,350	2,000	-	-
Mirrors[2]	700	0	0	0
Dental[3]	520	1,720	645	520
Batteries	100	-	-	-
Electronics	2,370	-	-	-
Miscellaneous, (Lab. etc)	-	1,000	-	-
Total	**66,510**	**69,370**	**23,455**	**100,540**

Note: A dash indicates that the quantity used is not available.

Note: 1. 15% Ag is in the material. 2. Calculated as pure Ag. 3. It is assumed that amalgam contains 43% Ag. 4. Scrap contains 500 to 1400 g Ag t^{-1} (average value: 950 g t^{-1}).

*To convert metric ton to Million Troy Oz, divide by 31.1.

Fig. 1.

Silver Recovery
Non-ferrous Metallurgical Plant

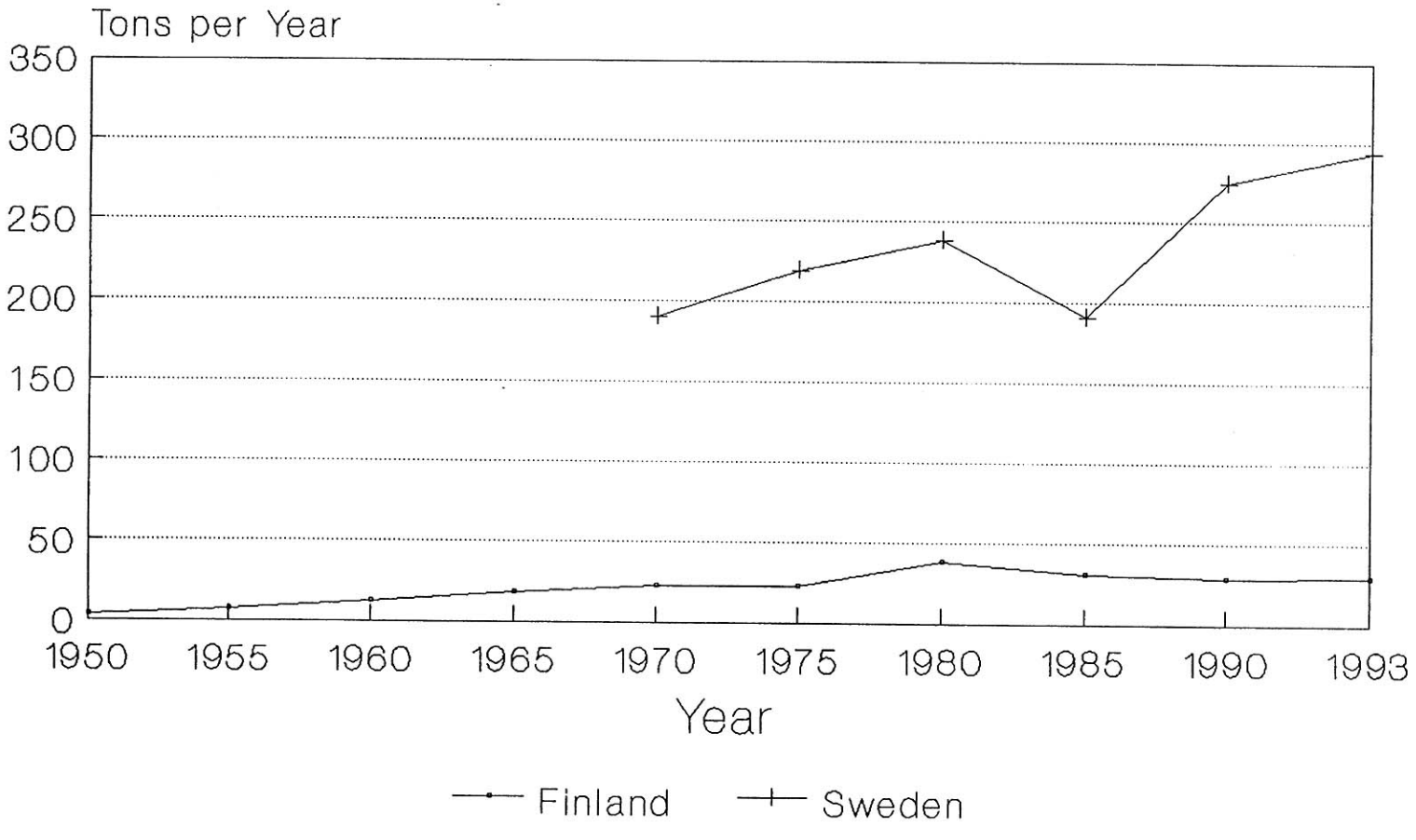
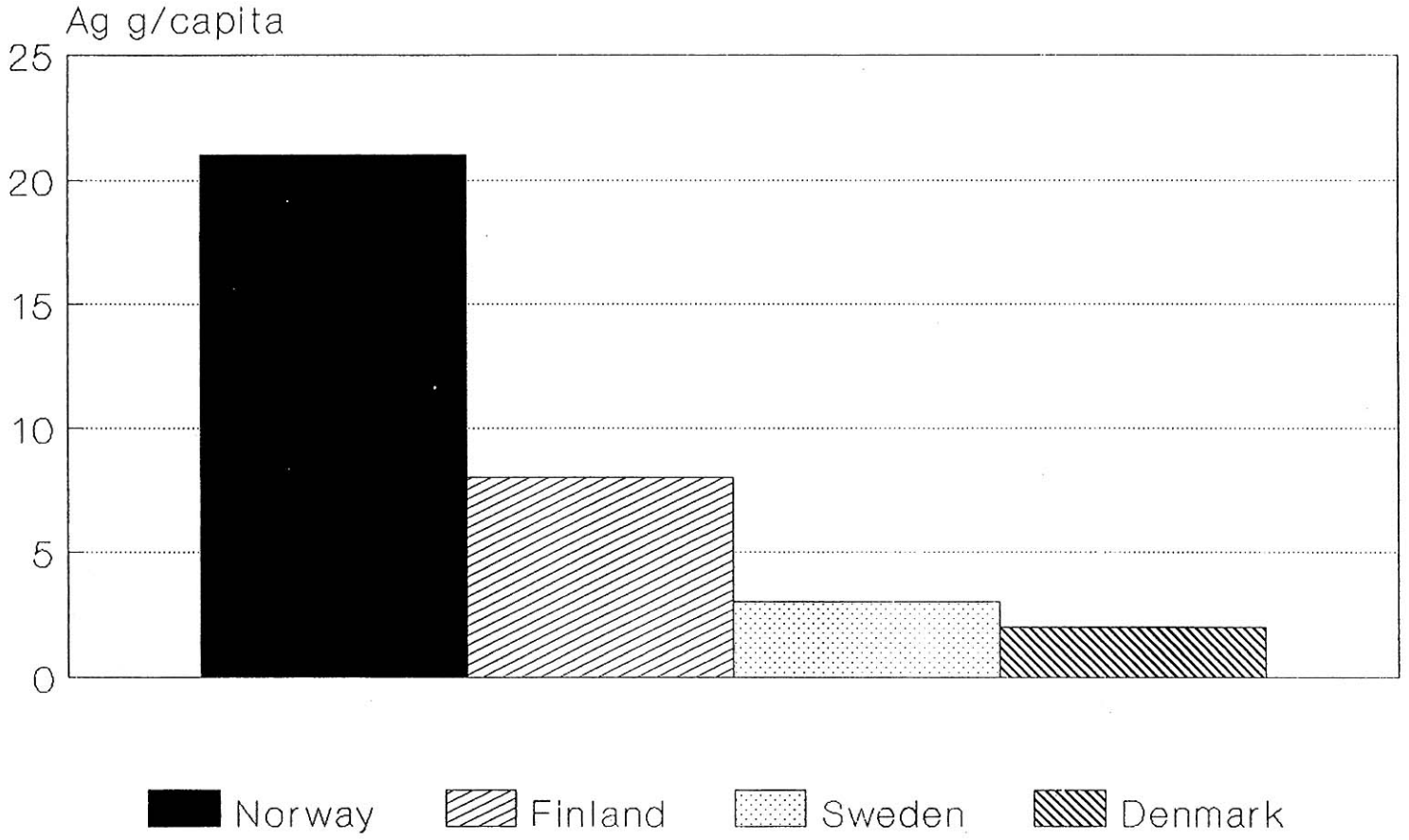


Fig 2.

Silver use in Jewelry / Silverware
Per Capita in Nordic Countries



Silver discharge from anthropogenic sources

The chief sources of silver losses to the environment have been identified and their annual magnitude to the environment of Finland is shown in Table 2. It is believed that due to high boiling point of silver (2163 °C; 3925 °F), its emission to air is in the particulate form. Very little is known about possible vapor concentration of silver to the atmosphere (Bertine and Goldberg 1971). In this study, it is observed that maximum emission of silver occurs from utility boilers and forms of silver in the atmosphere are probably as silver sulphide, silver sulfate, silver carbonate, silver halide and also metallic silver (Smith and Carson 1977). Maximum aquatic discharge of silver occurs from photofinishing and silver recovery plants.

Table 2. The Release of Silver (kg yr^{-1}) into the Finnish Environment, 1993.

Source Category	Air	Water	Land
Mining & milling	0	0	0
Zinc plant	0	0	20,000[1]
Copper plant[2]	50 + ?	-	-
Cement industry	0	0	0
Power plants[3]			
- Coal	460	0	5,600
- Peat	50	0	600
- Crude oil	3,500	0	0
Secondary metal industry	-	-	-
Photo finishing & silver recover plant	10	500	0
Dental	0	0	520
Scrap	0	0	2,300
Waste water treatment plant	0	-	-
Total	**4,070**	**500**	**29,000**

Note: A dash indicates that the quantity discharged is not known

Note: 1. Silver as silver jerosite (Karlman, pers. commun.). 2. (Outokumpu Oy, pers commun.). 3. Air emission calculated on the basis: Ag content mg kg^{-1} (Coal: 1.7; Peat: 0.4 and oil: < 2.2); fuel burned: Coal: 5.39 x 10^6 t; Oil: 1.64 x 10^6 t; Peat: 5.2 x 10^6 t (containing 50% water).

The Finnish emission inventories and the best estimates have been applied to find out the total emission of silver to air and water in the other Nordic countries (Table 3).

Table 3. The Tentative Estimation of Total Discharge of Silver to the Environment of the Other Nordic Countries, 1993 (Unit: kg yr^{-1}).

Country	Air	Water
Sweden	6,100	1,700
Denmark	4,000	500
Norway	4,000	525

Conclusions

The present study indicates that the maximum recovery of silver occurs in Sweden and it was about 320 metric tons (10.28 Million Troy Oz) in 1993. The use pattern of silver varies from country to country and the maximum use (100.54 tons, i.e., 3.23 Million Troy Oz) was noted in Norway though complete information was not available.

This is the first attempt to estimate the emission of silver in the environment of the Nordic countries. Hence, there exists more latitude for future studies. However, it is observed that maximum silver emission to the atmosphere occurs from the energy producing industry whereas estimated maximum aquatic discharge of silver stemmed from photofinishing and silver recovery units.

It is necessary to study further discharge of silver from precious metal plant and photoprocessing industry. In addition, silver in drinking water, sludge, lake sediments should be measured. It is also necessary to find out fate and effects of silver in photoprocessing effluent.

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Questions & Answers: An Initial Assessment of the Production, Consumption and Emission of Silver in the Nordic Countries

No questions.