

## CHAPTER 3

### *Group Report: Cadmium*

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#### INTRODUCTION

Cadmium is a relatively rare metal which occurs in nature as a minor component of other non-ferrous metal ores. It may be considered as an element of concern peculiar to the twentieth century since commercial extraction began only at the beginning of this century. Over half the cadmium ever produced has been refined in the last 20 years (Nriagu, 1979).

Given the striking increase in cadmium consumption over recent years, it is pertinent to ask whether there has been a corresponding change in the global cycling of the metal. This question can be partially answered by examination of data from studies into the historical trends of metal levels in dated ice cores from remote areas of the world. Such studies reveal that there is no evidence for any increase in the cadmium content of recent ice cores from either Greenland or the Antarctic (Zoller, 1984). Thus, human activities have not, at present, had a measurable impact on the global, or even hemispheric cycling of the metal. This is in marked contrast to lead, where human activities have enhanced lead concentrations in recent ice cores from Greenland and the Antarctic, as well as in surface waters from mid-ocean sampling locations (Zoller, 1984).

The human health significance of cadmium can be placed in perspective by comparison with the situation for lead. In the case of lead, there is now a consensus that children, particularly in urban localities, are at risk from the neurobehavioral effects of the metal. In contrast, reports of health effects of cadmium in environmentally-exposed populations have been restricted to certain communities in Japan and, recently, elderly populations from an industrialized city in Europe (Roels *et al.*, 1981).

## SOURCES OF CADMIUM

### Source Inventories

To understand the biogeochemical cycle of cadmium, it is essential to identify and quantify the sources of the metal in the environment. Many of the major human sources have been known for some time, but only in recent years have efforts been made to quantify these discharges. Such studies have produced source inventories for areas ranging from extensive details of an industrial sector in one country to a much more poorly known full global inventory. Most global inventories have only been concerned with atmospheric emissions of cadmium. Little attention has been paid to discharge to land and water. In only a few instances have natural sources of cadmium release been taken into account. Table 3.1 provides a list of published source

Table 3.1 Published source inventories of cadmium for country, regional and global areas

Study area	Time period	Natural sources	Environmental compartment			Reference
			Atmosphere	Water	Land	
Sweden	1977/78	—	×	×	—	SNV, 1982
USA	—	—	×	—	—	EPA, 1979
USA	10-year period	—	×	×	×	Yost, 1979
Denmark	1977/78	—	×	×	×	Miljøministeriet, 1980
Switzerland	—	—	×	×	×	Brunner and Baccini, 1981
EEC	1979/80	×	×	×	×	Hutton, 1982
Europe	1979	×	×	—	—	Pacyna, Semb and Hanssen, 1984
North Sea	—	×	—	×	—	Norton, 1982
World	1975	×	×	—	—	Nriagu, 1979
World	—	×	×	—	—	Lantzy and Mackenzie, 1979
World	—	×	×	—	—	Jaworowski, Bysiek and Kownacka, 1981

inventories for cadmium which have been prepared for countries, regions or at the global level. This list is not intended to be exhaustive but rather to illustrate the range of inventories which have been carried out in the last five years. Examination of the data in these studies would reveal large disparities in the source strengths and emission factors (gm cadmium emitted/tonne material produced or consumed) assigned to a particular process. It will

therefore be necessary to carry out a 'quality control' study in order to determine the validity of the values employed in these inventories. In addition, it is suggested that special attention should be paid to the construction of accurate inventories for those countries or regions where human activities may be mobilizing large amounts of the metal. Of particular interest will be those countries which are large producers and consumers of cadmium. SCOPE can play a significant role in this, together with such international organizations as UNEP.

### **Natural Sources**

Volcanic action is considered to be a major natural source of atmospheric cadmium. This situation results from the vast amount of matter discharged, together with the enrichment of cadmium in the volcanic aerosol. However, considerable variation exists in the degree of enrichment reported for different volcanoes and this presents problems when attempting to estimate worldwide discharges from this source. The periodicity of volcanic events as well as their often remote and poorly monitored locations also present considerable difficulties.

Other natural sources of atmospheric cadmium include ocean sprays, forest fires and the release of metal-enriched particles from terrestrial vegetation. These sources are difficult to quantify and only in the case of release from vegetation are the quantities likely to be significant on a global scale.

The weathering of crustal materials plays a major role in the natural cycle of cadmium but rarely results in any marked enrichment of the metal in the environment. A notable exception is that of certain carboniferous shales found in various parts of the world which are enriched with cadmium. The soils derived from these deposits and the vegetation growing in the soils also contain elevated cadmium levels.

### **Anthropogenic Sources**

The sources of environmental cadmium associated with human activities can be conveniently divided into two broad categories; (a) those which produce a marked cadmium impact in the vicinity of the discharge source and (b) those which do not. The former category includes non-ferrous metal mines, smelters and refineries together with those industries involved in the manufacture of cadmium-containing articles. The second source category contains many 'inadvertent' sources in which cadmium is a natural constituent of the material being consumed or processed, such as coal combustion, refuse incineration and the iron and steel industries. Studies around the above facilities have, in general, been unable to detect any enhancement of soil or atmospheric cadmium levels. However, the cadmium emissions from such



sources may still make a significant contribution to the overall atmospheric burden of cadmium at the local or regional level. The size of the particles involved in cadmium transport is just one key factor in determining local accumulations.

Non-ferrous metal mines can be a significant source of local cadmium contamination, particularly those mines which exploit zinc and lead ores. Zinc ores invariably contain the most cadmium but the actual content varies widely between different ore bodies. This factor together with mining practices, local topography and drainage all influence the intensity of contamination. Airborne contamination can arise from the wind-blown dispersal of metal-rich spoil heaps, while water-borne transport of cadmium-rich material may result in contamination of agricultural land some distance downstream of the mine. This form of dispersal can be particularly marked during flood and storm conditions. This problem is not confined to active mines and many disused zinc-lead mines act as persistent sources of cadmium. Mine spoil heaps in Wales still discharge into rivers a century after the mines closed.

It is suggested that attention should be drawn to this long-term and persistent source of cadmium contamination in those developing countries with a large or rapidly growing mine production of zinc. Two countries of particular concern are Peru and Mexico which together account for about a quarter of the world's total mine production of zinc (International Lead and Zinc Study Group, 1983).

Cadmium is extracted as a by-product during the refining of zinc ores. The two basic processes of zinc production, thermal smelting and electrolytic refining, produce different kinds of cadmium-rich discharge. Thermal smelters are responsible for much larger atmospheric emissions of cadmium and also produce liquid wastes rich in cadmium which require safe disposal. In contrast, the only major wastes associated with electrolytic plants are solid leach residues.

In the last two decades, electrolytic refining has assumed an increasingly important share of the world's production of zinc and cadmium and at present accounts for over 75% of the market. Over the same period, the Imperial Smelting Furnace process has become the major thermal route of production. The once important vertical and horizontal retort processes, which emit large quantities of cadmium to the atmosphere, have been phased out in many countries. However, smelters of these types are still in operation in Japan, Mexico, China and the USSR (International Lead and Zinc Study Group, 1980).

Several published inventories have assigned extremely large atmospheric emissions of cadmium to zinc production. It is considered that such studies may have erroneously assumed that all zinc production occurred by thermal processes.

The primary production of lead and copper also releases cadmium to

the environment, the amount mobilized being dependent on the cadmium content of the ore concentrate being processed. Generally, copper ores are only modestly enriched with cadmium, while larger discharges of cadmium can be expected from the primary production of lead. This situation may be reversed in the secondary production of the two metals as a large proportion of the feed material for lead refineries is relatively pure scrap lead while copper refineries may handle copper-cadmium alloy scrap.

Cadmium has five principal uses: (1) as a protective plating on steel, (2) in various alloys, (3) in pigments, (4) in stabilizers, and (5) in nickel-cadmium batteries. Cadmium discharges to the environment arise both during the manufacture of cadmium-containing materials and when these products are discarded. Currently, only about 5% of the cadmium consumed is recovered after disposal compared with about 40% recovery for lead. The reason for this poor recovery is that, unlike other metals of commercial importance, most cadmium is consumed in the form of compounds. These are present in materials at relatively low concentration and pose economic and technical problems for recovery.

The liquid and solid cadmium wastes arising from the manufacture of the above items are, in many countries, discharged to the sewage system. Those countries without a sewage network presumably dispose of these wastes to adjacent watercourses or to specific disposal areas. In the case of product disposal, all cadmium-containing articles can enter the municipal waste disposal pathway where their fate is either to be landfilled or incinerated. A considerable proportion of the cadmium-plated products will ultimately be recycled but these will enter the scrap steel cycle and a proportion will ultimately be emitted to the atmosphere.

In terms of identifying those areas of the world where large amounts of cadmium may be mobilized, the situation in the European Community is of particular interest. Currently, more cadmium is produced and consumed in this region than in either the USSR or USA. Several developing countries in south-east Asia exhibit large growth rates in the consumption of cadmium but at present the quantities consumed are relatively small.

### **Pathways for Human Exposure**

Dietary intake represents the largest source of cadmium exposure in the non-smoking general population. Tobacco is an additional source in smokers, and can be as important as cadmium in food to overall body burdens. In general, cadmium levels in drinking water are low and intake from beverages is trivial compared with dietary intake. Plant-based foodstuffs represent the largest source of dietary cadmium in most populations and thus changes in crop **cadmium levels may have a marked impact on cadmium exposure.**

Studies of dietary cadmium exposures from several countries indicate that



average daily intakes in populations from Europe and the USA are about 20–40  $\mu\text{g}$ . These values are lower than the tolerable intake for dietary cadmium of 1  $\mu\text{g}/\text{kg}$  body weight/day, or for Europeans, about 70  $\mu\text{g}/\text{day}$ , proposed by the FAO/WHO. Certain groups are exposed to higher than average quantities of cadmium, either because their food is contaminated or because of unusual dietary habits. Examples include individuals who consume large quantities of shellfish and those who regularly eat food plants grown on contaminated soils. Such soils are those which have received heavy applications of sewage sludge and phosphate fertilizers, those in areas of mineralization and those close to non-ferrous metal smelters and other point sources of airborne cadmium.

Generally, cadmium uptake from air represents only a minor contribution to total intake, despite the relatively high uptake efficiency of the lungs. However, certain populations living close to point sources of airborne cadmium may inhale significant quantities of the metal.

Cadmium is present as a finely dispersed aerosol in cigarette smoke, resulting in an efficient uptake of the metal. It has been calculated that the daily consumption of 20 cigarettes results in the absorption of an amount of cadmium equivalent to an additional dietary intake of 25–30  $\mu\text{g}$  cadmium. Individuals who smoke two or more packets of 20 will, of course, absorb correspondingly more cadmium.

There is no doubt that there has been a marked increase in the consumption and consequent environmental dissipation of cadmium in this century. There is also some evidence that there has been a corresponding increase in the exposure levels of the general population in some regions. The findings of a study of preserved wheat samples from Sweden, collected between 1916 and 1972, are equivocal but there is some indication of an increase in cadmium content of wheat in recent years. More convincing evidence exists for an increase in the body burden of cadmium during this century in populations from Europe and Japan. Comparison of the cadmium content of historic specimens of kidney with present-day values revealed that present values exceeded those found in historic specimens.

### INFORMATION NEEDS

- (1) Improvements are needed in the accuracy of existing source inventories for cadmium, paying attention to regional differences in industrial production technology and efficiency of control devices. Further studies are required into cadmium discharges to aquatic systems, particularly estuaries and coastal waters.
- (2) Studies into the impact of human activities on the biogeochemical cycling of cadmium should pay particular attention to those areas of the

world which are either important mine and smelter producers of non-ferrous metals or are major consumers of cadmium.

- (3) More information is needed on the sources of cadmium in crop plants together with the relative significance of cadmium inputs to agricultural land from phosphate fertilizers, sewage sludge and atmospheric deposition. The long-term behaviour of cadmium in arable soils requires investigation in different regions of the world.
- (4) Further research is required into the significance of crops grown in areas of elevated cadmium for human dietary intake in different parts of the world. Such studies should take into account local marketing and distribution patterns of food crops.

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