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Chemicals Branch, DTIE

Final review of scientific information on cadmium

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Key scientific findings for cadmium

I. Hazardous properties, exposures and effects

1. Cadmium is a non-essential and toxic element for humans mainly affecting kidneys and the skeleton. It is also a carcinogen by inhalation. Cadmium is accumulated in bone and may serve as a source of exposure later in life.

2. In the environment, cadmium is toxic to plants, animals and micro-organisms. Being an element, cadmium is persistent – it cannot be broken down into less toxic substances in the environment. The degree of bioavailability and potential for effects varies depending on the form of cadmium. Cadmium bioaccumulates mainly in the kidneys and liver of vertebrates and in aquatic invertebrates and algae.

II. Environmental transport: extent to which cadmium is transported on intercontinental, regional, national and local scales

3. Cadmium is released by various natural and anthropogenic sources to the atmosphere, aquatic environments (fresh and salt water environments) and terrestrial environments. There are fluxes between these compartments. Cadmium released to the atmosphere can deposit to land and aquatic environments, and some cadmium released to soil over time will be washed out to the aquatic environments. The long-term sinks are deep-sea sediments and, to a certain extent, controlled landfills, in cases where, owing to its physico-chemical properties, cadmium is immobilized and remains undisturbed by anthropogenic or natural activity (climatic and geological).

4. Cadmium, once emitted to air, is subject to atmospheric transport. It is mainly emitted to the atmosphere in particle form. The atmospheric transport of cadmium is governed by aerosol (particle) transport mechanisms: in the atmosphere, cadmium may be transported on local, national, regional or intercontinental scales, depending on various factors, including, for both natural and anthropogenic sources, particle size, the height of emission outlets and meteorology. Because it has a relatively short residence time in the atmosphere (days or weeks), however, this metal is mainly transported over local, national or regional distances.

5. Based on the relatively scarce specific evidence available, cadmium is considered to be subject to a certain degree of long-range air transport on an intercontinental scale. Intercontinental transport is, however, expected to make only a minor contribution to cadmium levels in regions affected by other, local emitting sources. The regional and intercontinental atmospheric transport of cadmium contributes to deposition in remote regions, such as the Arctic, where there are few local sources for cadmium releases.

6. There is no hemispheric transport modelling for cadmium. As cadmium transport is governed by aerosol transport mechanisms similar to those governing the transport of lead (both are transported on aerosol particles with similar properties), the transport of lead might be used as a rough surrogate of the potential intercontinental transport of cadmium. Lead modelling is described in the UNEP review of scientific information on lead. Taking into account the general similarities between the long-range atmospheric transport of cadmium and lead and building on observations for lead, major contributions to Arctic cadmium pollution can be expected, as is the case with lead pollution, to come from sources located in Europe and in Siberia.

7. With regard to aquatic systems, rivers transport cadmium and other heavy metals on a national and regional scale. Ocean transport also occurs. The oceanic residence time of cadmium has been estimated at about 15,000 years. This indicates that cadmium may be accumulated and transported in sig-

nificant amounts over long distances in the ocean. It should be noted, however, that oceans have large natural reservoirs of cadmium. The contribution of cadmium via rivers into the marine environment of the North Sea is in the same order of magnitude as the atmospheric deposition, which is the other main pathway of cadmium inputs in the region.

III. Sources of releases

8. Important releases of cadmium may be grouped in the following categories: releases from natural sources, in other words, releases resulting from natural mobilization of naturally occurring cadmium from the Earth's crust and mantle, such as volcanic activity and weathering of rocks; current anthropogenic releases from the mobilization of cadmium impurities in raw materials such as phosphate minerals, fossil fuels and other extracted, treated and recycled metals - particularly zinc and copper; current anthropogenic releases of cadmium used in products and processes, as a result of use, disposal, recycling, reclamation, open burning or incineration; releases from municipal installations; and the mobilization of historical anthropogenic and natural cadmium releases previously deposited in soils, sediments, landfills and waste or tailings piles.

A. Atmospheric releases (emissions)

9. The most recent study of global anthropogenic emissions estimated the total in the mid-1990's at 2,983 tonnes. Newer estimates are not available. Available data indicate, however, that anthropogenic emissions of cadmium have decreased by an average of about 50 per cent from 1990 to 2003 in developed countries. Adequate data are not available to evaluate trends in developing countries. The main sources of emissions are non-ferrous metal production and fossil fuel combustion. Other sources include iron and steel production, waste incineration and cement production. In some developing countries, open burning of cadmium-containing products and indiscriminate dumping contribute to local and regional exposure.

10. The major natural sources for emission to air are volcanoes, airborne soil particles, sea spray, biogenic material and forest fires. Very different estimates of total releases of cadmium to the atmosphere by natural processes have been reported. A study from 1989 estimates the total emissions in 1983 at between 150 and 2,600 tonnes per year, whereas a new study estimates the total emissions from natural sources at between 15,000 and 88,000 tonnes per year. The large discrepancy is mainly due to different estimates of the amount of cadmium released to air with soil particles. Because of the limited data and huge differences between the findings of these two studies, there is uncertainty about the relative magnitude of natural emissions as compared to anthropogenic emissions. The more recent study suggests that natural emissions might be between 5 and 30 times higher than anthropogenic emissions.

11. Various human activities (such as mining, metal production, combustion of fossil fuels and other industrial processes) have resulted, however, in elevated cadmium concentrations in the environment. For example, cadmium deposition in the 1960's and 1970's in the Greenland ice core was eight times higher than in pre-industrial times. These data suggest that industrial emissions have been more important as a source of deposition in Greenland – and perhaps other Arctic areas – than natural emissions. Recent data indicate that cadmium deposition levels have steady declined since the 1970's.

12. The open burning in some developing countries of waste products containing cadmium could be an important source of local and regional cadmium emissions to the atmosphere.

B. Releases to land and aquatic systems

13. Some cadmium-containing products are disposed of in various waste deposits, released to soil or the aquatic environment. Major categories of these releases include residues from coal combustion, mine tailings, and smelter slag and waste. In recent years, nickel-cadmium (NiCd) batteries and primary batteries with cadmium content have constituted a major source of cadmium disposed of in landfills with municipal waste. The long-term fate of the cadmium accumulating in the landfills is uncertain and

may represent a future source of releases. The handling of wastes may lead to elevated local and regional release levels for developing countries.

14. Atmospheric deposition, phosphate fertilizers and sewage sludge appear to be the major contributors to cadmium levels in agricultural soils. In a number of European countries, atmospheric deposition, animal manures, sewage sludge and the presence of cadmium in fertilizers are causing the content of cadmium in topsoil to increase. Atmospheric deposition has been decreasing, but in the late 1990's it was still a major source of cadmium input to agricultural soils. As cadmium is taken up by plants, increased soil concentrations can result in increased concentrations in food products.

15. The weathering of rocks releases cadmium to soils and aquatic systems and plays a significant role in the global cadmium cycle. This release is enhanced by acidic emissions. Weathering and erosion result in the transport by rivers of large quantities of cadmium to the world's oceans. An annual gross input of 15,000 tonnes of cadmium has been estimated. Moreover, between about 900 and 3,600 tonnes of cadmium are estimated to be deposited to aquatic environments throughout the world through atmospheric deposition of emissions originating from anthropogenic and natural sources.

16. The open burning in some developing countries of waste products containing cadmium could be an important source of local and regional cadmium releases to land and aquatic systems.

IV. Production and uses of cadmium

17. Cadmium is produced mainly as a by-product of mining, smelting and refining of zinc and, to a lesser degree, as a by-product of lead and copper production. It is therefore primarily a function of zinc production rather than cadmium demand. Global cadmium production almost doubled between 1950 and 1990. Since 1990, global consumption has remained constant, at about 20,000 tonnes per year, although major changes have occurred with the geographical distribution of this production. Until 1997, production in Europe, the Americas and Asia remained constant. Since 1997, however, production in Asia has increased sharply, whereas the production in Europe has decreased. Major shifts in smelting and refining technology by many of the world's zinc refiners from pyrometallurgical to hydrometallurgical processes (50 per cent in 1958 to 81 per cent of capacity in 2003) have led to significant decreases in releases of cadmium to the environment.

18. Recycled cadmium accounts for about 18 per cent of total global supply. Countries with significant collection and recycling activities include France, Germany, Japan, the Republic of Korea, Sweden and the United States of America.

19. Cadmium is used and traded globally as a metal and as a component in various products. A growing proportion of refined cadmium consumption is accounted for by NiCd batteries, which in 2004 represented 81 per cent of the total. Other major uses of refined cadmium are: pigments for plastics, ceramics and enamels; stabilizers for plastics; plating on iron and steel; and as an alloying element of some lead, copper and tin alloys. Since 1990, consumption for pigments, stabilizers, alloys and other uses has decreased significantly.

20. Products containing cadmium are not typically collected separately from the general waste stream in developing countries. Therefore cadmium discards will end up in municipal waste and disposed of in landfills, incineration, open burning or indiscriminate dumping. Some of the cadmium in these products will be released to the environment, the extent of which depends on disposal method, control technologies applied and other factors.

V. Cadmium issues in developing countries

21. As awareness of the adverse impacts of cadmium has increased, many uses have been reduced significantly in industrialized countries. In addition, as public awareness has grown, waste management systems have increasingly been put in place in industrialized countries to reduce releases of cadmium into the environment. That said, however, some of the uses of cadmium which have been phased out in

industrialized countries have continued in developing countries. In addition, use of cadmium has continued or increased in some less developed regions or countries, e.g., in plastics or in paints. Regulations and restrictions are less comprehensive or less well enforced in some developing regions. This has resulted in some of the health and environmental risks, local and regional, that accompany the use, management (including collection, storage, recycling and treatment) and disposal of products containing cadmium. These hazardous disposal practices include open burning and indiscriminate dumping in sensitive ecosystems such as rivers and wetlands.

22. Another issue faced by developing countries is the export of new and used products containing cadmium, including electronic equipment and batteries, to those countries which lack the capacity to manage and dispose of the cadmium in these products in an environmentally sound manner at the end of their life. Another problem is posed by products containing cadmium that may cause exposure through normal use, such as certain toys.

VI. Levels and time trends in air and deposition

23. Most of the identified monitoring measurements for atmospheric cadmium concentrations and deposition come from Europe and the United States of America; data from Japan, China, Canada, Antarctica and New Zealand are, however, also available. Data are very limited to assess trends. In Europe, however, between the early 1990's and 2003, average concentrations of cadmium in air decreased by about 50 per cent in central and north-western Europe. Measured concentrations in precipitation decreased by about 65–75 per cent in central and north-western Europe. From 1990 to 2003 in the northern part of Europe and from 1990 to 1996 in a few North American locations, there were no observable trends in concentrations of precipitation.

24. Some modelling has been performed, mostly in Europe, to estimate deposition rates. When reported emissions are used in the models, they generally underestimate deposition (compared to measured data). The underestimation is believed to be due to the failure to include natural emissions and re-emissions of historical releases in the models and to uncertainties in reported emissions.

25. Measured air levels tend to be much higher near sources and in urban areas compared to remote locations. For example, in remote areas of the United States of America, atmospheric cadmium concentrations are generally below 1 ng/m^3. Levels in urban air are significantly higher (3–40 ng/m^3). Over the Great Lakes, atmospheric cadmium concentrations ranged from 0.2 to 0.6 ng/m^3. These data indicate that atmospheric cadmium concentrations are much higher close to sources of emissions and that long-range transport results in much lower levels in the atmosphere.

26. Cadmium concentrations in Spitsbergen, Norway, did not exhibit any noticeable trend over the period 1994–2003. Cadmium appears to deposit more readily in the Arctic than other particulate elements. In these areas, however, the total cadmium deposition and atmospheric depositions is much