Lead, Mercury, Cadmium and Arsenic in the Environment
Edited by T. C. Hutchinson and K. M. Meema


# CHAPTER 19

# *The Cycling of Arsenic, Cadmium, Lead and Mercury in India*

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## ABSTRACT

In this chapter the sources and levels of arsenic, lead, cadmium and mercury in India are examined, as well as the implications to human health and perspectives for research in the future.

Arsenic is found in vegetables at 2–30 μg/100 gm, in the soil at 118–212 μg/100 gm, and in drinking water at 3–15 μg/100 ml. The major sources of As pollution are from coal and from superphosphate.

The major contributing factor to high levels of cadmium in crops is sewage irrigation. The levels of both Cd and Pb in crops on soils irrigated by sewage were 2-3 times those on tubewell-irrigated soils. The high pH, organic carbon and cation exchange capacity appear to be factors in the retention of Cd in the sewage-irrigated soils. Soils of low CEC allowed crop accumulation of Cd more readily.

Lead intake via food is the major source of Pb to humans in India and can account for about 0.4 mg of daily intake. Other important sources are water heated in glazed pottery, tea, paints, pigments, pencil colours and auto-exhaust.

Mercury is not produced in India and the entire requirements of this metal are imported. Nevertheless, the industrial activity of Chembur is responsible for high concentrations of Hg in the air (up to 41.5 ng/m$^3$). Consumption of wheat and rice stored with mercury tablets, used as a preservative, can increase Hg intake to 0.1–0.4 mg Hg/day. In waters on the East Coast of India, the concentration of Hg in estuarine water is 5–15 times that of the backwater, 5–8 times that of mangroves, and 10–12 times that of normal sea water.

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## INTRODUCTION

This chapter addresses some of the problems related to the cycling of arsenic, cadmium, lead and mercury in India. Major developments in agriculture and industry have resulted in these elements showing substantial increases over their pristine levels in the environment. For want of reliable data, the task of making realistic estimates of the fluxes of these elements and consequently the degree of human exposure to them is beset with many difficulties. Much of the information that is likely to be useful in this context is locked up in reports prepared by government agencies for internal use and hence not easily accessible. Published information available to this author was confined to Indian sources. This overview is, therefore, restricted in its scope and indicates trends rather than absolute realities.

## MINERAL PROCESSING AND COAL AND CHEMICAL INDUSTRIES IN THE INDIAN SUB-CONTINENT

India is known to have rich deposits of many ores and minerals, most of which are yet to be tapped for industrial use. Offshore prospecting has revealed commercially exploitable oil and gas wells in the Cambay basin, offshore Bombay, and in offshore basins of the Godavari, Krishna and Kaveri. The coal belt of Jharia and Raniganj in the Ganga basin has been mined for more than 150 years for power production and locomotion. The lignite deposits of Neyveli in Peninsular South India are currently being mined for power generation, cycling huge volumes of sub-soil water. In the absence of other viable options, India has decided to develop major super-thermal stations preferably after processing the locally available high ash coal.

As part of the constraints imposed by a developing economy in search of hard currency, considerable quantities of iron, manganese and other ores are exported, while at the same time large amounts are being used within the country. Statistics given in Tables 19.1–19.3 (Statistical Outline of India, 1982) illustrate the range of activities and products being produced in the country relevant to the cycling of metals and metalloids in general. Budgets need to be developed for their environmental impacts. The country does not produce mercury and consequently the entire requirements of this metal are imported. Substantial quantities of metallic cadmium and lead and arsenic salts are also imported. Total demand for zinc is between 1.2 and $1.3 \times 10^5$ tonnes. Indigenous production varies from 50 000 to 60 000 tonnes and the balance is made up by imports. For lead, the consumption of about 70 000 tonnes is met by indigenous production to the extent of 25 000 tonnes and an import of 45 000 tonnes. The requirement of copper is 90 000 to 100 000 tonnes, 60 000–70 000 being imported and 25 000–35 000 tonnes coming from local production. The annual consumption of $2.5 \times 10^5$ tonnes

aluminum is substantially met by indigenous production. The estimated gap for zinc by the end of 1990 is 80 000–90 000 tonnes and for lead 50 000–60 000 tonnes (Raghavan, 1983). Data on rates of use are given in Table 19.3, and changes in production over the past 20 years in Table 19.4. From such information, inventories can eventually be constructed for the four elements under discussion, and these projected to scenarios of their cycling in air, water and soil and to interactions with biotic and abiotic pathways. What is of particular significance is the almost doubling, within a period of 20 years, of the rate of production of most of the materials of commerce and industry with a potential to diffuse lead, cadmium, mercury and arsenic in the main environmental compartments of the sub-continent.

Table 19.1 Industrial production of items with pollution potential. (Data from Statistical Outline of India, 1982)

| | | 1980–81 | 1960–61 |
|---|---|---|---|
| Pig iron | ($\times 10^6$tonnes) | 8.6 | 4.3 |
| Saleable steel | ($\times 10^6$ tonnes) | 6.3 | 2.5 |
| Nitrogenous fertilizers | ($\times 10^3$ tonnes) | 2164 | 98 |
| Phosphatic fertilizers | ($\times 10^3$ tonnes) | 840 | 52 |
| Sulphuric acid | ($\times 10^6$ tonnes) | 2.1 | 0.4 |
| Caustic soda | ($\times 10^3$ tonnes) | 568.0 | 101.0 |
| Soda ash | ($\times 10^3$ tonnes) | 540.0 | 152.0 |
| Paper and board | ($\times 10^3$ tonnes) | 1145.0 | 350.0 |
| Dry battery | (Million) | 1291 | — |
| Storage battery | (Million) | 25 | — |
| Hydrogenated oils | ($\times 10^6$ tonnes) | 748 | 340.0 |
| Man-made fibre | ($\times 10^6$ metres) | 1328 | 550.0 |

## ARSENIC LEVELS IN THE ENVIRONMENT

A survey was undertaken in Chandigarh, India to measure the arsenic content of the crops cabbage, pea, onion, radish, spinach and cooking banana, and of soil samples collected from the States of Panjab, Haryana, Himachal Pradesh and Uttar Pradesh (UP). The content of arsenic in these vegetables varied from 2–30 $\mu$g/100 gm. The mean value of arsenic in the soil in the study area varied from 118.0 to 212.7 $\mu$g/100 gm, although in some samples collected from the Meerut District of Uttar Pradesh values were found to be as high as 566 $\mu$g/100 gm. High arsenic in vegetables could mostly be related to the high arsenic content of soils. However, the correlation was not statistically significant (Datta and Kaul, 1978). Sample analyses of manure/fertilizers are given in Table 19.4, showing these fertilizers as

Table 19.2 Reserves of minerals and perspectives. (Data from Statistical Outline of India, 1982)

| | Recoverable reserves 1979 ($10^6$ tonnes) | Likely depletion 1979–95 ($10^6$ tonnes) | Balance life after 1994–95 (years) |
|---|---|---|---|
| Non-coking coal | 37 000 | 2 640 | 126 |
| Prime coking coal | 2 700 | 2 370 | 74 |
| Iron ore (Haematite) | 9 300 | 8 364 | 111 |
| Bauxite | 1 900 | 1 838 | 245 |
| Limestone | 53 000 | 51 980 | 519 |
| Zinc | 6.0 | 4.8 | 38 |
| Lead | 2.3 | 1.8 | 37 |
| Manganese ore | 75 | 41 | 14 |
| Chromite | 24 | 17.5 | 29 |
| Copper | 3.2 | 2.4 | 32 |

Depletion by 1994–95 has been officially estimated at 'contemplated rates of exploitation' and the balance life of the reserves, assuming 1994–95 consumption levels.

Table 19.3 Production of some important minerals. (Data from Statistical Outline of India, 1982)

| | | 1980 | 1960 |
|---|---|---|---|
| Coal | ($\times 10^6$ tonnes) | 107.0 | 52.6 |
| Iron ore | ($\times 10^6$ tonnes) | 39.0 | 16.6 |
| Limestone | ($\times 10^6$ tonnes) | 28.2 | 12.9 |
| Bauxite | ($\times 10^3$ tonnes) | 1532 | 387 |
| Copper ore | ($\times 10^3$ tonnes) | 1997 | 448 |
| Manganese | ($\times 10^3$ tonnes) | 1740 | 1452 |
| Gypsum | ($\times 10^3$ tonnes) | 817 | 997 |
| Chromite | ($\times 10^3$ tonnes) | 305 | 107 |
| Zinc concentrate | ($\times 10^3$ tonnes) | 60.3 | 9.6 |
| Lead concentrate | ($\times 10^3$ tonnes) | 16.3 | 6.2 |
| Gold | (kg) | 2341 | 4995 |

Table 19.4 Arsenic content of manures/fertilizers used in India. (Data from Datta, 1976)

| | mg/100 gm |
|---|---|
| Poultry manure I | 13.3 |
| Poultry manure II | 23.7 |
| Cow-dung | 11.2 |
| Superphosphate | 187.8 |

potential factors for soil contamination by As and for subsequent plant uptake. The mean arsenic content of water collected from taps, wells, handpumps, irrigation pumps, ponds, canals, etc. in and around Chandigarh varied from 3–15 μg/100 ml. A value as high as 54.5 μg/100 ml was registered in one sample of water from a hand pump in an area where non-cirrhotic portal fibrosis was endemic (Datta, 1976, 1978a, 1978b; Datta and Kaul, 1976, 1978).

Range and mean concentration of As in samples of food, water and air collected from an independent study in metropolitan Bombay are shown in Table 19.5. Arsenic-containing coal is known to produce arsenious oxide, $As_2O_3$, on combustion. Coal mined in USA and Czechoslovakia has been reported to contain 1–10 and 1500 mg/kg, respectively, of arsenic. In a study of the captive fly ash collected from the Indra Prastha power station in New Delhi, the average arsenic content by EDXA was found to vary from 0.091 to 1.328% as elemental arsenic. The data for five samples of fly ash are summarized in Table 19.6. Since India uses annually 140 million tonnes of its coal reserves, one of the likely sources of arsenic pollution of water is coal. At the rate of about 1 mg/kg, the other important source of arsenic in the soil appears to be superphosphate. Other sources are limestone (0.1–20 mg/kg), smelting of copper and lead ores and the ceramic industries. A traditional use of arsenic as a mixture of arsenic oxide and copper sulphate in the seasoning of timber and as a fungicide, could also contribute to environmental contamination. No reliable data on these sources are available.

Table 19.5 Range and mean concentration of Hg, Cd and As in foods, drinking water and air at Bombay. (Data from Mishra and Sadasivan (1980) based on Anand, 1976a, 1978a)

| | Mean concentration (range) (in ng/gm) | | |
|---|---|---|---|
| Sample | Hg | Cd | As |
| Cereals | 7.0 (0.75–31.1) | 37.9 (15.2–79.8) | 25.7 (1–88.2) |
| Vegetables | 6.5 (0.75–30.3) | 43.8 (16.5–98.1) | 3.1 (1–8.2) |
| Fish | 40.1 (4.6–282.6) | 46.5 (15.9–175.6) | 500 (20.5–1415) |
| Fruits | 1.9 (1–2.8) | BDL* | BDL |
| Milk | (1.2–27.1) (no mean provided) | BDL | BDL |
| Drinking water (ng/ml) | 1.9 (0.72–8.6) | BDL | BDL |
| Air | 0.59 (0.19–0.91) | 2.93 (0.97–6.0) | 1.01 (0.59–1.42) |
| Calculated daily intake in μg | 11.7 | 23.0 | 12.1 |

* BDL – below detection limit.

Table 19.6 Arsenic content of fly ash of the coal-fired Indra Prastha power station, New Delhi. (Data from VP Chest Institute, 1983)

| | Arsenic as % of ash | Arsenic content in coal (ppm) | |
|---|---|---|---|
| | | 10% ash | 20% ash |
| 1 | 0.962 | 962 | 1924 |
| 2 | 1.328 | 1328 | 2656 |
| 3 | 0.539 | 1078 | 2156 |
| 4 | 0.851 | 851 | 1702 |
| 5 | 0.091 | 91 | 182 |

Arsenic content of the coastal waters and estuarine waters around Goa has been reported by Fondekar and Reddy (1979), as part of a general pollution study of the impact of fertilizer plants and other industrial activity on the coast of Goa on the West Coast of India. The values of the inshore waters were higher than those reported for sea water.

## CADMIUM LEVELS IN THE ENVIRONMENT

Preliminary data summarized in Tables 19.7 and 19.8 on environmental pollution by cadmium were collected by a survey in Panjab using samples of fertilizers, water samples and common foodstuffs (Nath *et al.*, 1982). Wheat flour had the highest cadmium content. Water samples tested from various wells in Chandigarh had no detectable cadmium. The concentration of cadmium in crops grown with untreated municipal waste water around the cities of Panjab are given in Table 19.9. Levels in crops grown on land treated with municipal sewage wastes were two to three times higher than in those irrigated with well waters. The accumulation of DTPA-extractable Pb and Cd in soils receiving waste water from different sources is illustrated in Table 19.10. The increase was found to be substantially more in the industrial towns of Jullundur and Amritsar. The amount of Pb and Cd in

Table 19.7 Content of cadmium in some common foodstuffs in Panjab. (Data from Nath *et al.*, 1982)

| | Cadmium (ppm) |
|---|---|
| Whole rice | 0.079 ± 0.001 |
| Whole maize | 0.061 ± 0.001 |
| Whole wheat | 0.089 ± 0.004 |
| Gram | 0.074 ± 0.010 |
| Gramdal | 0.033 ± 0.025 |
| Wheat flour | 0.200 ± 0.040 |

Table 19.8 Content of cadmium (ppm) in fertilizers. (Data from Nath *et al.*, 1982)

| | |
|---|---|
| Calcium nitrate | 0.010–0.016 |
| Superphosphate | 1.190–1.350 |
| Potash | 0.030–0.060 |
| Urea | 0–0.020 |
| Zinc sulphate | 630–400 |

Table 19.9 Cadmium and lead content of crops grown in soils irrigated by tubewell and sewage water. (Data from Kansal and Singh, 1983)

| | Cadmium | Lead |
|---|---|---|
| | (ppm dry weight) | |
| *Tubewell-irrigated* | | |
| Maize | 0.85 ± 0.10 | 1.98 ± 0.20 |
| Berseem | 0.69 ± 0.19 | 1.93 ± 0.43 |
| Cauliflower heads | 0.48 ± 0.14 | 1.27 ± 0.17 |
| Cauliflower leaves | 0.80 ± 0.11 | 2.69 ± 0.11 |
| Spinach | 0.50 ± 0.10 | 3.29 ± 0.20 |
| *Sewage-irrigated* | | |
| Maize | 1.74 ± 0.24 | 3.82 ± 0.66 |
| Berseem | 1.67 ± 0.47 | 4.48 ± 1.00 |
| Cauliflower heads | 1.60 ± 0.53 | 1.80 ± 0.20 |
| Cauliflower leaves | 2.24 ± 0.74 | 5.23 ± 0.25 |
| Spinach | 2.59 ± 0.20 | 6.08 ± 0.35 |

Table 19.10 Average content of DTPA-extractable cadmium and lead in soils receiving tubewell and sewage irrigation. (Data from Kansal and Singh, 1983)

| | Tubewell irrigation | | Sewage irrigation | |
|---|---|---|---|---|
| | Cadmium | Lead | Cadmium | Lead |
| | (ppm in soils) | | | |
| Abohar | 0.05 | 0.35 | 0.06 | 0.76 |
| Bhatinda | 0.02 | 0.20 | 0.04 | 0.69 |
| Jalandhar I | 0.05 | 0.85 | 0.17 | 0.89 |
| Jalandhar II | 0.05 | 0.822 | 0.17 | 1.09 |
| Amritsar I | 0.06 | 0.50 | 0.09 | 1.65 |
| Amritsar II | 0.06 | 0.50 | 0.14 | 1.58 |
| Average | 0.05 | 0.54 | 0.10 | 1.28 |

sewage-irrigated soils was twice as much as in tubewell-irrigated soils. The soils presumably pick up the elements from their direct discharge in soluble and suspended form or as part of organic matter. Path analysis revealed that pH, soil conductivity, organic carbon content and calcium carbonate content all exerted a direct influence on the availability of cadmium. The high value of the indirect effect of soil pH and extractable carbon indicated that interaction between these two factors alone was important in determining the cadmium content of the soils. Chelates of cadmium appeared to be more soluble than those of other metals. Due to the dissolution of the precipitates of cadmium carbonate, hydroxide and phosphate, the salts of cadmium could also contribute significant amounts to their available status. The relative influence of various soil properties on the content of heavy metals in plants grown on sewage-irrigated soils ($n = 24$) is given in Table 19.11.

Table 19.11 Relative influence of various soil properties on the content of lead and cadmium in plants on sewage-irrigated soils ($n = 24$)

| Element | Multiple regression coefficient $R^2$ | Simple correlation coefficient ($r$) | | | | |
|---|---|---|---|---|---|---|
| | | pH | EC | OC | $CaCO_3$ | DTPA-extractable |
| Lead | 0.45* | −0.17 | −0.05 | −0.06 | 0.39 | −0.20 |
| Cadmium | 0.49* | −0.35 | −0.30 | −0.14 | −0.03 | 0.32 |

* Significant at 0.01.

Studies on sorption of cadmium were carried out in some sewage-irrigated soils. The data was found to follow both Langmuir and Freundlich adsorption isotherms. Release of Cd by I.N. neutral ammonium acetate decreased with increases in pH, organic matter, $CaCO_3$, cation exchange capacity and clay content. Soils with high bonding energy constants and adsorption maxima released lesser amounts of Cd (Rana and Kansal, 1983). Total Fe, Cu, Zn and Mn and their DTPA-extractable functions also had a significant and positive correlation with Cd adsorption. The content of Cd in the surface layer (0–15 cm) of the soils analysed are given in Table 19.12. The sewage-irrigated soils with high pH, organic carbon and cation exchange capacity could retain higher amounts of Cd and retain it more tightly than 'normal' ones. These soils thus can act as a sink for the disposal of Cd. However, it may be that after a long disposal these soils become saturated with Cd and consequently its availability in soils will increase to an extent where plant growth would be adversely affected. This may also become hazardous to animals and human beings. Such reports have been made in Europe where

sewage sludge amended soils have built up cadmium to the point of releasing some into milk of cows grazed on such pastures.

Table 19.12 Content of lead and cadmium in the surface (0–15 cm) layer of tubewell- and sewage-irrigated soils. (Data from Singh and Kansal, 1983)

| | Tubewell-irrigated | | Sewage-irrigated | |
|---|---|---|---|---|
| | Cadmium | Lead | Cadmium | Lead |
| | (ppm) | | | |
| Abohar | 3.9 | 14.0 | 9.3 | 20.0 |
| Bhatinda | 6.3 | 16.0 | 13.4 | 22.0 |
| Jalandhar I | 5.3 | 14.0 | 14.1 | 22.0 |
| Jalandhar II | 6.3 | 16.4 | 12.0 | 29.0 |
| Amritsar I | 5.3 | 13.0 | 11.0 | 25.0 |
| Amritsar II | 5.3 | 13.0 | 12.3 | 26.0 |

In alkaline soils of the Punjab, cadmium was retained by adsorption on the mineral interface and by interaction with organic matter and calcium carbonate. At high concentrations Cd precipitates as hydroxides. Sequential desorption with 1 M KCl and 0.05 M $Cu(CH_3COO)_2$ provided a measure of their exchangeable and chelated forms (Singh and Sekhon, 1977).

Limited data on the ambient levels of cadmium and lead in air, water, foodgrains, cooked food, vegetables, cigarettes and beedies (indigenous cigarettes) (Pandya, 1978; Pandya *et al.*, 1983) are summarized in Table 19.13. The content of cadmium in the fly ash collected from the coal-fired Indra Prastha thermal power station was fairly constant in samples collected

Table 19.13 Ambient levels of cadmium and lead in air, water and food samples collected in Ahmedabad. (Data from Pandya, 1978; Pandya *et al.*, 1983)

| | Mean concentration (range) (ppm) | |
|---|---|---|
| | Cadmium | Lead |
| Air ($\mu g/m^3$) ($n=19$) | 0.013 (0.006–0.037) | 0.513 (0.091–1.99) |
| Food grain ($n=9$) | 0.291 (0.074–0.34) | 0.69 (0.55–1.05) |
| Vegetables ($n=13$) | 0.32 (0.0–0.49) | 0.74 (0.20–1.05) |
| Fruits ($n=3$) | 0.38–0.88 | 1.8–2.5 |
| Eggs, fish, meat ($n=5$) | — | — |
| Cooked food ($n=7$) | 0.22 (0.12–0.30) | 0.84 (0.40–1.25) |
| Cigarettes and beedies ($n=16$) | 0.171 (0.077–0.48) | 12.43 (7.37–20.41) |
| Water ($n=7$) | 0.002 (0.001–0.004) | 0.013 (0.008–0.23) |

throughout 1983 (VP Chest Institute, 1983). The cadmium content of sea water estimated at ten monitoring stations located along 15 km of the Madras Coast over a period of one year showed a range of 0.001–0.047 mg/kg. The content of Cd in sediments collected from seven stations over this stretch showed levels ranging from 0.026–0.57 μg/gm dry matter. The content of the metal in samples of biota including 200 plankton, algae, molluscs, crabs and fish, showed Cd content of 0.02 to 7.39 μg/gm dry matter (ZSI, 1984). Seasonal fluctuations of cadmium in the Pichavaram mangrove forest of the East Coast of India have been reported to be 8.2–52.2 μg/gm as monitored at two stations (Subramanian, 1981). Animal feeds marketed commercially were found to contain 0.9–1.8 ppm Cd (ITRC, 1984).

## LEAD LEVELS IN THE ENVIRONMENT

A study conducted in Ahmedabad with limited samples of air, food and water indicated that the ambient air lead concentration varied from 0.35 to 1.77 $\mu g/m^3$. Food grains contained 0.7 μg/gm whereas cooked food showed a mean of 0.8 μg/gm (Jathar *et al.*, 1981). Drinking water samples registered a level around 0.013 μg/gm. Food seemed to be a major source and can account for about 0.4 mg of daily intake. Intake of lead from air is only about 7.2% of the total daily intake. A selected bibliography compiled by Rawal *et al.*, (1982) on environmental exposure to lead and cadmium lists 122 publications from 1921–1982, covering not only ambient levels in air and water and the work-place of industries with a potential exposure to lead, but also some biological effects of lead in aquatic animals. The National Institute of Occupational Health, Ahmedabad, has reported the load of lead in ambient air due to emission of auto-exhaust in traffic-dense areas on Ahmedabad (Lahori *et al.*, 1972; Agarwal *et al.*, 1978, 1980).

Increased accumulation of Pb in soils receiving waste water from the industrial towns of Panjab has been reported (Rana and Kansal, 1983). The amount of Pb in sewage-irrigated soils was twice as much as in tubewell-irrigated soils. Data on DTPA extractable Pb as a function of various soil parameters did not show pH to have any direct effect but its indirect effect through organic carbon depressed the availability of Pb. Organic carbon exerted the maximum influence on the availability of Pb. Plants collected from waste water-irrigated soil had considerably higher concentrations of Pb than those from tubewell-irrigated soils. The increase occurring in the top soil was from 14.0 to 24.0 μg/gm.

Acidic media and higher temperatures facilitated leaching of Pb from glazed pottery sold in North India and 1–1.65 mg/litre could be recovered in tea and cooking waters (ITRC, 1984). One percent of hot decoctions of ten popular brands of tea sold in the North India market were found to contain 0.002–0.012 ppm Pb (ITRC, 1984). Other potent sources of lead identified

by this study were paints, pigments and pencil colours. Commercial animal feed contained 9.66–5.94 ppm whereas over 8% of 650 samples of tap-water collected from Lucknow and Kanpur in Uttar Pradesh were found to contain 0.004–0.008 ppm Pb (ITRC, 1984). Content of Pb in samples of air, food grains, vegetables, fruits, cooked food, water, cigarettes and beedies have been reported by Pandya (1978). The content of Pb in fly ash collected in the Indra Prastha power station ranged from 110–260 g/gm in a twelve-month survey in 1983 (VP Chest Institute, 1983).

In a study of coastal water pollution of a 15 km stretch of the Coromandel coast in Madras, India, lead content of sea water was found to vary from traces to 0.4 mg/litre. The sediments examined registered a mean content of 15.0 $\mu$g/gm although the highest value noted was 41 $\mu$g/gm. The tissue content of Pb in samples of marine organisms collected over the region varied from traces to 25 $\mu$g/gm dry weight of samples (ZSI, 1984).

An important source of lead in the environment is auto-exhaust. The rapid expansion of road transport services in India is evident from data given in Table 19.14. According to a study done by the Environment Cell of the Bombay Municipal Corporation more than 60% of the 1730 tonnes of air pollutants in Bombay can be accounted for by automobiles alone (Despande *et al.*, 1972; Khandekar *et al.*, 1980).

Table 19.14 Number of vehicles (excluding rail track) using petroleum products. (Data from Statistical Outline of India, 1982)

| | 1978–79 | 1960–61 |
|---|---|---|
| | ($\times 10^3$) | |
| Buses | 127 | 57 |
| Trucks | 412 | 160 |
| Jeeps | 119 | 32 |
| Cars | 723 | 256 |
| Taxis | 83 | 22 |
| Two-wheelers | 1678 | 88 |
| Three-wheelers | 139 | 6 |
| Miscellaneous* | 416 | 36 |

* Includes tractors, trailers, three-wheelers, tempos and pick-up vans.

## MERCURY LEVELS IN THE ENVIRONMENT

The occurrence and distribution of mercury in water, particulate matter and sediment samples from three different biotopes, namely estuary, backwater and mangrove, have been studied on the East Coast of India (Kumaraguru *et al.*, 1979). The estuarine water contained 0.0015–0.0045 ppm mercury

while the backwater had 0.002–0.0025 ppm and the mangrove water 0.003–0.0035 ppm. The mercury content of the particulate matter was 0.15–0.4 ppm, 0.28 ppm in the estuarine water, 0.13–0.30 ppm in the backwater and 0.18–0.35 ppm in the mangrove water. The range of concentrations of mercury in sediments was from 0.1–0.33 in the estuary, from 0.13–0.28 in the backwater and from 0.13–0.25 in the mangrove. Oysters of average wet body-weight had mercury contents ranging from 0.32 to 0.72 ppm. The levels of mercury in natural sea-water is reported to be 0.0003 ppm but in polluted waters the concentration can go as high as 0.03 ppm. On this basis, the concentration of mercury in the estuarine region was 5–15 times of the backwater, 5–8 times of the mangrove, and 10–12 times that of normal sea-water. The mercury content of the sediments in the biotopes was comparable with values reported for Lake Erie sediments (Annet *et al.*, 1972) and in the Calshot surface mud of Southampton (Raymont, 1972). The mercury content of the sediment, though less than that of particulate fraction, was 72–100, 50–100 and 33–75 times greater than that of the water of the three biotopes.

The total suspended particulate matter in the Bombay city air and the resulting dust vary over a wide range from 100 $\mu g/m^3$ to 900 $\mu g/m^3$ (the annual average US federal standard = 75 $\mu g/m^3$). The range and mean concentration of Hg in air ($ng/m^3$) over selected stations in the country are Ooty (Hill Station) BDL, Bangalore 0.02–1.70 (0.94), Calcutta BDL, Trombay 0.16–1.29 (0.52), and Chembur 6.92–41.1 (21.5). The industrial activity of Chembur is responsible for the high concentration of Hg observed. The measurement of elemental composition in size-separated aerosols helps in assessing contributions from different sources. Analysis of aerosols collected in the Trombay belt of Bombay showed that the highest concentration of Hg was in the small particulate range of $<0.55$ $\mu m$, deposited in the alveolar region (Mishra and Sadasivan, 1980).

Mercury content of stored grain using mercury tablets as a preservative increases with storage time and even a conservative estimate gives an average intake of Hg of 0.1–0.4 mg/day for those who consume wheat and rice stored with these tablets (Lalit and Ramachandran, 1977). The mercury content of foodstuffs, water and air at Bombay is given in Table 19.5. The calculated daily intake by the Bombay population of toxic elements is 11.7 $\mu g$ Hg, 23.0 $\mu g$ Cd and 12.1 $\mu g$ As (for Hg and Cd the WHO fixed daily intake are 43 $\mu g$ and 64 $\mu g$, respectively). On frying, the mercury burden of fish is reduced by 11–44% due to its volatility, while no change is observed for As and Cd (Anand, 1976a,b 1978a,b).

The bones and muscles of *Tilapia mozambique*, *Mugil dues umierie* and other varieties of fish from Thana and Mumbra creeks revealed concentrations greater than 0.5 ppm wet weight. In the Arabian sea, surface waters showed a range of 26–130 with an average of 78 ng/litre and at 10–100 metre

depth the range was 0–204 with an average of 102 ng/litre. In the Bay of Bengal the surface showed 0–91 (average = 45) and at a depth of 10–100 m the range was 0–222 ng/litre. Hammer-headed shark and the white spot shark showed the highest concentrations of mercury (Qasim and Sen Gupta, 1980).

Analyses of samples of dust extracted from the lungs and lymph nodes of certain domestic animals from West Bengal, Orissa and Bihar provinces of India showed the presence of Hg and Pb in appreciable amounts. It was noted that the samples originating from West Bengal were generally richer in mercury and lead although the two elements were found in almost all samples derived from the coal belt and coal burning region of India (Dwivedi *et al.*, 1980; Krishna Murti, 1981). The Hg content of coal samples analysed in the USA ranged from 0.07 to 33 ppm (Bertine and Goldberg, 1971). The significance of mercury accumulating in the environment and entering the food chain of a variety of animals through burning of coal has been stressed (Falchuk *et al.*, 1977). Studies conducted with the fly ash captively collected from the Indra Prastha Estate in New Delhi have indicated 4–14 $\mu$g/gm of Hg in samples analysed over a year (VP Chest Institute, 1983).

There is no indigenous production of mercury in India and the annual requirement of 170–190 tonnes is entirely imported. There are no reliable data on the content of mercury in the ambient work environment associated with the use of mercury in the chloralkali industry and other heavy chemical and organic industries. The annual capacity for organomercurials permitted as fungicides is 91 tonnes but production in 1982–83 is reported to be 147 tonnes (Sarma, 1983). The caustic alkali industry, the main user of mercury in the electrolytic process, is well dispersed in India and big units are located on the banks of some major water bodies and the port towns of Dwaraka, Trombay, Greater Cochin, Madras and Tuticorinon. The difficulties of estimating the environmental diffusion into the major compartments are obvious. Coastal monitoring programmes have collected some useful information but much more remains to be done.

## HUMAN EXPOSURE TO ARSENIC, CADMIUM, LEAD AND MERCURY IN INDIA

The available data on arsenic levels in water, food and air does not permit even tentative estimates to be made of the potential for human exposure. The figures suggested by the exploratory studies conducted in Bombay or Chandigarh on the daily intake of arsenic must be considered as tentative until more reliable data at a national level on the environmental levels of arsenic are generated. The use of arsenicals as therapeutic agents adds another degree of complexity to the problem. In the Chandigarh region, 29% of well-water samples, 50% of samples from handpumps and 37% of those from springs were found to be contaminated with arsenic (Datta and Kaul,

1976). There are reports of occurrence of non-cirrhotic portal hypertension in subjects consuming arsenic-containing medicine for several years (Datta, 1976). A number of clinical cases of idiopathic neuropathy reported by Chuttani *et al.* (1967) in Panjab have also been traced to the consumption of arsenic-contaminated opium (Datta, 1978a,b).

We can speculate on the outcome to human health of prolonged ingestion of arsenic through drinking water. Assuming 250 μg/litre as the mean content of water, a person who consumes 1500 ml of this water each day for 20 years will consume about 3 gm of arsenic only from water. It is reported in the literature that 3 to 25 grams of arsenic, when consumed over 1 to 22 years produces hepatic damage in the form of cirrhosis (Franklin *et al.*, 1956) and non-cirrhotic portal hypertension (Morris *et al.*, 1974). Arsenic ingestion is associated with cirrhosis in infants (Rosenberg, 1974) and adults (Luchtrath, 1972). From the data on the arsenic content of vegetables it is likely that the daily intake through this item of the diet may be about 70–100 μg. Most of the vegetables grown in Uttar Pradesh and Panjab were found to contain high amounts of arsenic, presumably derived from soil, water and manure (Datta and Kaul, 1978). One has to bear in mind the ability of humus to retain arsenic. Schroeder and Bolassa (1966) have reported that ash obtained on calcination of soil humus contains around 32 mg/100 gm of arsenic. Based on the data collected from Bombay on food, water and air, the daily intake of As in that city has been computed to be 12 μg (Anand, 1981).

Estimates of the daily intake of cadmium through food are given in Table 19.15 and the possible intake of cadmium through air at minimum and maximum ambient air pollution levels are given in Table 19.16. The intake through smoking cigarettes or beedies under Indian conditions has not been accounted for in exposure levels (Patel, 1980). From limited analytical data generated in Bombay the daily intake of cadmium from all sources works out to be 23 μg (Anand, 1981) as compared with the actual figure of 96 μg and calculated figure of 130 μg reported by Pandya (1978) from Ahmedabad.

Table 19.15 Daily intake (mg) of cadmium and lead through food. (Data from Pandya, 1978)

| | India | | USA |
|---|---|---|---|
| | Observed (based on cooked food) | Computed (based on calculation from content of raw food component) | |
| Cadmium | 0.096 | 0.13 | 0.16 |
| Lead | 0.39 | 0.46 | 0.30 |

Table 19.16 Intake of cadmium and lead by man from air at minimum and maximum pollution levels. (Data from Pandya, 1978)

| | Minimum pollution | | Maximum pollution | |
|---|---|---|---|---|
| | Daily intake from air | % | Daily intake from air | % |
| Cadmium | 0.10 | 0.10 | 0.6 | 0.62 |
| Lead | 1.40 | 0.36 | 29.9 | 7.15 |

Daily intakes of lead have been estimated by Pandya (1978) based on the lead levels in food, water and air. The daily intake is around 400 $\mu$g mostly through food and water, with only about 7.0% coming from air (Tables 19.15 and 19.16).

## PERSPECTIVES

Increasing industrial development in India could lead to a significant increase in environmental arsenic, cadmium, lead and mercury. In order to assess the existing levels of ten metallic elements of environmental significance an Integrated Environmental Programme on Heavy Metals (IEPHM, 1980) has been initiated by the Department of Environment (Government of India). In Phase 1 of this programme six regional centres located at Chandigarh, Lucknow, Calcutta, Ahmedabad, Hyderabad and Madras have been identified to conduct a sample survey of Pb, Hg, Cd, Zn, Cu, Mn, Cr, Ni, As and Se in ambient air, water and food. The programme has been designed with due considerations for statistical variation and has an independent unit to monitor the quality of the analytical data generated at the six centres. The results of this first national coordinated study are to be available by early 1986.

As part of the Global Environmental Monitoring Services (GEMS) programme some limited experience has been gained to conduct biological monitoring of lead and cadmium in human blood and kidney cortex. Encouraged by this, a coordinated programme is currently being planned to conduct nationwide monitoring of lead and cadmium in the same six regional centres as indicated above. The per capita intake is very low compared with Japan, and, as such, this item is not likely to play a significant role in contributing to human exposure to toxic metals. However, with greater emphasis on the exploitation of the marine food resources with algae being considered as a human food source, there is need for greater vigilance in monitoring the quality of coastal waters and biota. The National Institute of Oceanography, Goa, and the newly created Department of Ocean Development (Government

of India) have drawn up major plans for studies in this direction.Coastal pollution work which is being done with grants from the Department of Environment (Government of India) is expected to receive subtantial support to build up institutional infrastructure and expertise to keep a vigil on the 5000+ km coastline of India and the ecosystems associated with it.

Problems of bioaccumulation and biomagnification in the food webs have to be identified and investigated. It is proposed that an integrated programme on these aspects should be initiated as part of Phase II of the IEPHM funded by the Department of Environment likely to be commissioned during 1985–90.

India's contribution and participation in the biogeochemical cycles programmes sponsored by international agencies and scientific unions have been hitherto marginal. The national committee of SCOPE is currently addressing itself to the task of stimulating research activities in the major biogeochemical cycles including metals. Besides research, these envisage construction of inventories of toxic metals on a 'cradle to grave' basis, from their extraction and processing to diffusion in the environmental compartments and their impact on human health under the national Hazardous Wastes Control Programme. The Environmental Health Criteria documents on arsenic, lead, mercury and cadmium produced by international cooperation and released by WHO (WHO, 1976; 1977; 1981) do not reflect present situations appropriate to India and other countries with a high population density. Large numbers of people are likely to be exposed to toxic metals under situations totally different from those about which evidence has so far been used as the basis for the WHO documents. Hence, there is a need for more concerted studies on human exposure in the developing countries.

## ACKNOWLEDGEMENTS

The author is grateful to the Department of Environment, Government of India, for financial support in coordinating the Integrated Environmental Programme on Heavy Metals, to all the principal investigators particularly Dr B.B. Chatterjee NOIH, Ahmedabad, Professor R. Nath, PGI, Chandigarh, Dr S.V. Chandra, ITRC, Lucknow, Dr J.C. Katyal, PAU Ludhiana, Dr U.C. Misra, V.P. Institute, Delhi, Dr A. Daniel, Joint Director, ZSI, Madras, for valuable information, reports and reprints. His thanks are due to the Indian National Science Academy, New Delhi for sponsoring his visit to Toronto, Canada to present this paper.

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