# DISTRIBUTION OF HEAVY METALS IN PLANTS AND FISH OF THE YAMUNA RIVER (INDIA)

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**Abstract.** The distribution of cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) in the plants and fish of Yamuna river from Delhi to Allahabad, a distance of about 840 km, at five sampling stations was determined in the year 1981. The results have shown wide variations in the heavy metal levels from one sampling station to the other. The concentrations of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in the plants (*Eicchornia crassipes*) were found to be 0.02–0.12, 2.7–21.3, 4.6–64.8, 9.8–114.0, 193.0–1835.0, 380.0–1443.0, 4.4–83.0, 4.8–30.2, and 22.1–356.5 $\mu g\ g^{-1}$ respectively whereas in the fish (*Heteropnuestes fossilis*) were found to be ND–0.40, 2.3–13.7, 3.7–26.9, 8.33–58.1, 278.3–1108.0, 81.3–213.8, 2.8–32.7, 1.4–12.8 and 101.8–364.8 $\mu g\ g^{-1}$ respectively on dry weight basis.

## 1. Introduction

Biological indicator organisms have been used by many authors to monitor the time-averaged abundance of trace metals and other pollutants in the aquatic environment.

Fresh water flora ranging from algae to mosses and higher water plants have proven to be good indicators of heavy metals in the fresh water environment. Keeney *et al.*, (1976) established that the metal contamination in *Cladophora glomerata* algae was dependent on the heavy metal concentrations in their environment. The Cladophora populations extracted from the heavily polluted Deadman's Bay on lake Ontario had much higher Zn and Cd concentrations than those on a remote island of the lake. Abo-Rady (1977) studied the same algae in the upper Leine river downstream from Göttingen where he found a significantly higher contamination due to Cd, Cu, Hg, Ni, Pb, and Zn than further upstream. Leland and McNurney (1974) found high lead concentrations in the periphyton of the Vermillion river, a water body heavily polluted by urban waste water. Bibo (1977) conducted a study of the amounts of zinc and copper enriched in *Cladophora rivularis* and found that the heavy metal contamination in two separate sections of the Elsenz river differed significantly. Reay (1972) found that algae (*Nitella hookeri*) from geothermically heated areas of New Zealand contained ten times more arsenic than the algae from non-heated areas.

The heavy metal content of aquatic animals originates from two routes of intake, free ions and simple compounds dissolved in the water are taken up directly through the epithelium of the skin, gills and alimentary canal, while others, having being accumulated in food organisms, are incorporated by nutrition (Salanki *et al.*, 1982). Several workers have agreed that the uptake of metals from food is the most important route in the environment (Preston, 1971; Pentreath, 1973; Schulz-Baldes, 1974; Cunningham and Tripp, 1975, Phillips, 1976). Apparently the so-called Minamata (Fujiki, 1972; Kutsuna,

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1968; Tsubaki, 1971) and Itai-itai (Murata *et al.*, 1970) diseases were caused by mercury and cadmium contamination in the aquatic environment. Phillips (1977, 1978) reported higher levels of Zn, Cd, Pb, and Fe in common mussles, *Mutilus edulis* from the Baltic Sea than in those from Kattegat or Skagerrak. Suckcharoen *et al.* (1978) noted the anomalously high concentrations (0.32–3.6 ppm) in fish (*ophiocephalus striatus*) collected from the Chao Phraya river. Recently Ajmal *et al.* (1983) have reported elevated levels of Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb, and Zn in the fish and submerged plants from the Ganges river.

It appears from the literature that no systematic study has yet been carried out regarding the heavy metal content of aquatic species in the Yamuna river. The present paper therefore deals with our findings on the distribution of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in the submerged plants and fish from the Yamuna river in India.

## 2. Study Area

The Yamuna river flows through a distance of 1376 Km and then merges with the Ganges river at Allahabad. The present study covers a distance of about 840 km and five big cities namely Delhi, Mathura, Agra, Etawah and Allahabad. Several samples of submerged plants and fish were collected at each of the sampling stations.

## 3. Materials and Methods

### 3.1. Plants

The plants (*Eicchornia crassipes*) of about 25 cm length were collected and washed several times with the river water in order to remove the adhered invertebrates and large particles of mud. These were brought to the laboratory in the polyethylene bags where each sample was rinsed thoroughly with distilled water. The plants were then dried at 105° C for 24 hr. The dried plant material was ground in an agate mortar and pestle. 5 g of the powdered material was weighed and digested with 20 ml boiling $HNO_3$ (A.R. Grade) in a 50 ml kjeldahl flask. Digestion was complete within half an hour. Digests were made up to 25 ml volume. These solutions were then analysed for heavy metals using Perkin Elmer model 372 atomic absorption spectrophotometer (Harding and Whitton, 1981).

### 3.2. Fish

The fish were captured from the river by net and a common variety identified as (*Heteropnuestes fossilis*). These were measured and weighed and the fish of about 15 cm length and about 175 g weight were chosen. The fish samples were dried at 105 °C for 24 hr in a silica basin. The dried fish were ground in an agate pestle and mortar. 5 g of the dried and powdered fish material was further heated at 450 °C for 2 hr. The residue was dissolved in 20 ml boiling $HNO_3$ (A.R. grade) brought to a 25 ml volume with deionized distilled water and the filtered solution analyzed for heavy metals by Perkin Elmer model 372 atomic absorption spectrophotometer (Parker, 1972).

### 3.3 Quality assurance experiments

In order to assess the precision and accuracy of results, replicate analysis of blank, standard and the sample was done. The relative standard deviations were determined in order to find the precision of the analysis. Recovery results were calculated for the determination of accuracy. Experiments were repeated till an accuracy of 95 to 105% and precision of ± 5% were achieved. Control charts were plotted from these results. One standard one sample was repeatedly analysed routinely. In case the values were found to go out of mean ± 2 S.D. limit, the quality assurance results were repeated again. Values of blank replicates were used for the determination of detection limits.

## 4. Results and Discussion

The sampling stations along the banks of Yamuna river are illustrated in Figure 1. The concentrations of the heavy metals in the submerged plants have been presented in Table I.

Cd, Cr, Fe, Mn, Ni, Pb, and Zn metal concentrations were found highest in the plants collected from Delhi, the capital of India, which houses a large number of factories and

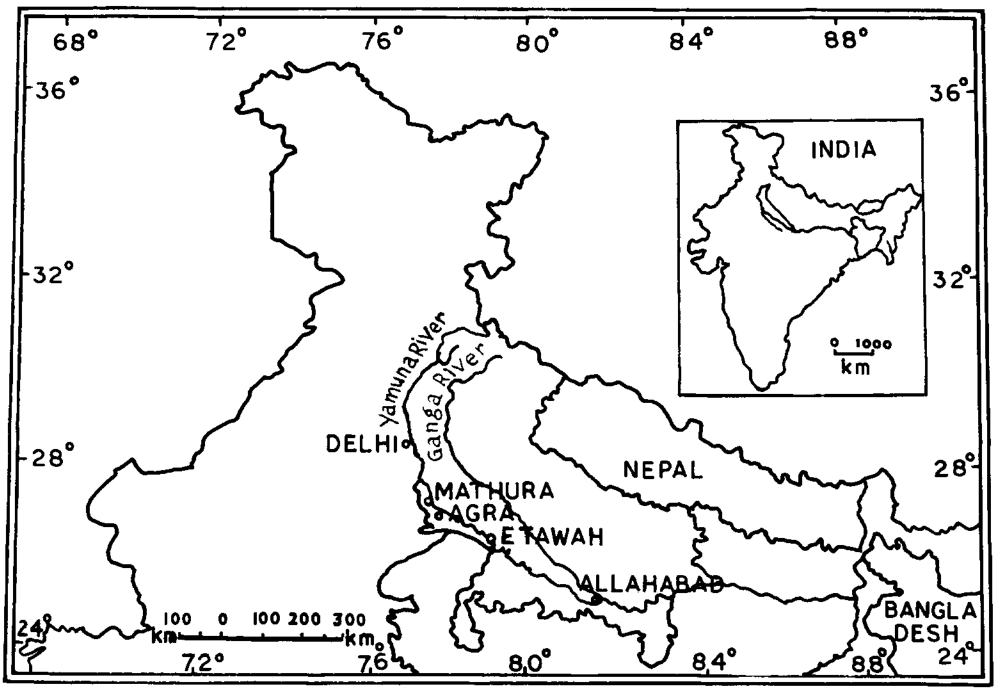


Fig. 1. River Yamuna showing different sampling station.

TABLE I
Concentration of Heavy Metals in Submerged plants (*Eicchornea crassipes*) of River Yamuna ($\mu g\ g^{-1}$)

| Sampling Stations | Cd | Co | Cr | Cu |
|---|---|---|---|---|
| Delhi Rajghat | 0.07–0.08 | 11.9–16.1 | 56.6–64.8 | 92.0–114.0 |
| Delhi Okhla Head | 0.10–0.12 | 10.3–15.0 | 55.1–62.1 | 79.8–100.8 |
| Mathura Upstream | 0.04–0.05 | 3.7– 5.9 | 8.3–11.5 | 22.9– 31.0 |
| Mathura Downstream | 0.03–0.04 | 12.0–21.3 | 21.3–34.4 | 25.8– 37.7 |
| Agra Upstream | 0.06–0.07 | 3.7– 6.6 | 10.6–14.9 | 20.2– 28.0 |
| Agra Downstream | 0.07–0.08 | 3.1– 8.2 | 9.4–13.2 | 28.0– 41.4 |
| Etawah | 0.03–0.04 | 3.0– 6.6 | 5.5– 7.1 | 12.8– 18.3 |
| Allahabad | 0.02–0.03 | 2.7– 4.4 | 4.6– 6.6 | 9.8– 13.3 |

industrial establishments including those manufacturing fertilizers, paper and chemicals. It is known (Khan *et al.*, 1981; Lee and Keeney, 1975) that commercial fertilizers are also responsible for the elevation of cadmium and zinc in water and sediments of rivers. The uptake of cadmium and zinc from sediments and water by the plants is obvious. Sparks (1978) studied the effects of cadmium chloride on the green algae *Oedogonium cardiacum*. It was observed by him that $CdCl_2$ at 1, 10, and 25 ppm concentrations caused distortion of the phycoplast of some young germlings and also caused the distortion in shape and size of the nucleus of young filaments. Prevot and Soxer (1978) reported that $Cd^{2+}$ at $\geqslant 5\ \mu g\ l^{-1}$ decreased the growth of *P. micans* cultures. $Cd^{2+}$ appeared to accumulate in or on the surface of cells, causing rupture of the ascus with the release of cellular material.

Nickel was found to be in the range of 4.4–83.0 $\mu g\ g^{-1}$ at various sampling stations. Accumulation of nickel in the fresh water algae has been found to act as a growth inhibitor even at low concentrations (Spancer and Greene, 1981).

Copper was found in the highest concentrations (92.0–114.0 $\mu g\ g^{-1}$) at Delhi (Rajghat). Copper in the lower concentrations has been used for control of noxious growths of algae in the aqueous system (Sutton *et al.*, 1972).

Chromium levels in the submerged plants were found highest at Delhi (Rajghat) (56.6–64.8 $\mu g\ g^{-1}$). This high concentration of chromium may be due to the effluents of many electroplating industries being poured into the river. Iron was found to be in high concentration at Delhi (Okhla Head) (1813.0–1853.0 $\mu g\ g^{-1}$) and Agra

TABLE II
Concentration of Heavy Metals in fish (*Heteropnuestes fossilis*) of Yamuna River ($\mu g\ g^{-1}$)

| Sampling Stations | Cd | Co | Cr | Cu |
|---|---|---|---|---|
| Delhi | 0.02–0.03 | 8.2–13.7 | 19.1–26.9 | 45.0–58.1 |
| Mathura | 0.10–0.27 | 1.8– 2.3 | 20.0–22.5 | 8.8–10.3 |
| Agra | 0.20–0.40 | 2.7– 3.1 | 14.3–18.6 | 27.2–38.8 |
| Etawah | ND | 2.7– 3.0 | 2.9– 3.7 | 8.7– 8.3 |
| Allahabad | ND | 3.0– 4.3 | 4.7– 6.8 | 6.6– 8.3 |

*Table I* (*continued*)

| Fe | Mn | Ni | Pb | Zn |
|---|---|---|---|---|
| 1593.0–1633.0 | 1200.0–1443.0 | 71.0–83.0 | 24.7–30.2 | 340.2–365.5 |
| 1813.0–1853.0 | 1090.0–1290 | 56.0–68.0 | 21.3–26.0 | 307.5–329.8 |
| 673.0– 694.0 | 390.0– 440.0 | 7.0– 9.8 | 6.0–11.3 | 31.7– 54.7 |
| 623.0– 649.0 | 910.0–1008.0 | 21.2–29.4 | 11.4–15.0 | 118.5–140.3 |
| 723.0– 754.0 | 670.0– 720.0 | 6.1– 9.0 | 6.5– 9.1 | 120.5–144.5 |
| 981.0–1118.0 | 728.0– 794.3 | 8.9–11.1 | 8.8–28.2 | 138.5–171.0 |
| 321.0– 380.0 | 418.0– 436.0 | 6.8– 9.0 | 5.5– 7.1 | 68.3– 76.6 |
| 193.0– 211.0 | 380.0– 428.0 | 4.4– 6.8 | 4.8– 6.3 | 22.1– 31.4 |

(981.0–1118.0 $\mu g\ g^{-1}$). The high iron concentration at Agra may be attributed to the presence of large number of iron foundaries in operations there. There seems a correlation between availability of iron and manganese. At most of the sampling stations where iron was in abundance, manganese was also detected in large quantities. Lead and cobalt were also detected in appreciable quantities at all the Sampling stations.

The levels of metals in the fish are given in Table II. The impact of heavy metals on man has been of great concern for more than three decades. Perhaps, the most striking incident was 'Minamata Disease' in which hundreds of Japanese were seriously affected and many died through consuming mercury contaminated fish. The effects of lead poisoning on man have been described by Snyder *et al.* (1971) while those of cadmium poisoning which caused the Itai-itai disease were reported by Shimizu (1972). Other heavy metals such as Cr, Cu, and Zn when discharged into the water can enter the food chain, be bio-accumulated by fish and hence become a threat to man.

Cadmium which is considered to be one of the most toxic metal was detected in the range ND–0.40 $\mu g\ g^{-1}$. It has been estimated that long term exposure with a daily intake of even small quantities of this metal may produce renal dysfunction (Hagino and Yoshiyoka, 1961). The range of cadmium concentrations in food that may cause vomiting has been reported to be 3–15 ppm (Oak Ridge National Laboratory, 1973). Several deaths following cadmium ingestion have been reported by many workers (Gleason *et al.*, 1969; U.S. Public Health Service, 1962; Browing, 1961). There appears to be no well accepted standards for various heavy metals in the foodstuffs that are safe for human consumption. The Tasmanian Public Health has set the acceptable limit of

*Table II* (*continued*)

| Fe | Mn | Ni | Pb | Zn |
|---|---|---|---|---|
| 740.0– 771.0 | 112.2–121.5 | 27.5–32.7 | 9.6–11.3 | 352.0–364.8 |
| 594.0– 618.8 | 205.6–213.8 | 20.0–24.1 | 5.0– 5.9 | 276.5–286.6 |
| 1050.0–1108.0 | 203.0–208.3 | 10.2–13.0 | 9.3–12.8 | 227.3–233.7 |
| 252.0– 278.3 | 70.5– 81.3 | 1.9– 2.8 | 0.9– 1.4 | 94.9–101.8 |
| 984.0–1014.0 | 164.3–174.6 | 6.1– 8.7 | 7.7– 8.7 | 239.1–254.2 |

cadmium in food as 5.5 $\mu g\ g^{-1}$ wet wt. (Eustance, 1974). All of the fish samples in this study had cadmium contents (dry weight) far below than this limit.

The highest chromium concentrations in the fish were determined in Delhi samples (20.0–22.5 $\mu g\ g^{-1}$). At most of the sampling stations substantial amounts of the metal were found. High concentrations of chromium are carcinogenic (Sawyer and McCarty, 1978). Chromium is also associated with nausea and ulcers after long term exposures (McKee and Wolf, 1963; Camp, 1963).

The highest copper concentrations in fish were detected at Delhi (45.0–58.1 $\mu g\ g^{-1}$). The available values in our study were below the toxic limits. The concentrations of iron and manganese ranged from 252.0 to 1108.0 $\mu g\ g^{-1}$ and 70.5 to 213.8 $\mu g\ g^{-1}$ respectively at different sampling stations.

The maximum lead levels in the fish were detected at Agra (9.3–12.8 $\mu g\ g^{-1}$). It was found from experiments that rats and mice fed with 25 $\mu g\ g^{-1}$ Pb as soluble lead salt in the diet had decreased longevity and impaired reproduction capacity (Luckey *et al.*, 1975). Zinc was found to be in the range of 94.9–364.8 $\mu g\ g^{-1}$ at different sampling stations.

Although man has the ability to reject most of the ingested heavy metals, part of them can be retained and accumulated with age in various organs of the body which with the passage of time may become a health hazard.

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