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TRANSFER OF HEAVY METALS FROM LAKE WATER TO BIOTA: A POTENTIAL THREAT TO MIGRATORY BIRDS OF *MATHURA* LAKE, WEST BENGAL, INDIA.

Piyal Bhattacharya*
Department of Environmental Science, Kanchrapara College, West Bengal-743 145, India
E-mail: piyal_green@yahoo.co.in

Abstract

The present study was conducted in the *Mathura* oxbow lake, West Bengal, India to assess the severity in transferring harmful heavy metals from lake water to its biota. Plenty of common and seasonal migratory birds are dependent on this lake for their food and nesting. The results of current investigation right away threaten the living and survival of lake biota including the migratory birds. The lake water was found to be highly polluted with cadmium (0.001–0.003 mg/l) and chromium (0.01–0.05 mg/l), and moderately polluted with zinc (0.06–0.08 mg/l) and coliform load (2×10^4 cfu/ml). The studied plant and fish samples of the lake were detected to bioaccumulate heavy metals viz. cadmium and zinc far exceeding the recommended toxicity threshold levels. From contaminated fishes these toxic metals may ultimately transmit and be biomagnified in birds, and thus may endanger the entire migratory bird population.

Key words: Heavy metal; Migratory birds; Lake Pollution*; Mathura* Lake.

Introduction

A lake ecosystem encompasses biotic plants, animals and micro-organisms, as well as numerous abiotic physical and chemical interactions. Due to the different natural and anthropogenic pollutant sources there is a risk of bioaccumulation of various toxicants including heavy metals among aquatic biota. The quality of lake water and sediment as prime sources of heavy metal pollution had been reported by Sreejith et al. (1998). Contamination of heavy metals (Pb, Cd, Zn, Ni, Cu, Cr and Hg) in a lake of Bhopal was evaluated in the samples of water, sediments and different fish tissues (Malik et al., 2010). Heavy metals may get transferred from lake water to planktons, then to fishes, and finally they may get bioaccumulated in bird species.

The *Mathura* oxbow lake is situated at the junction of Kalyani and Kanchrapara cities of West Bengal, India, covering over 0.769 km^2 areas with an average depth of nine feet (Bala and Mukherjee, 2010). The shallow and stagnant water of the lake serves as the source of food to the fish and other fauna, including numerous aquatic birds. Presently, it is one of the preferred spots of thousands of migratory birds from

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late October to middle of March. Eutrophication, discharge of domestic sewage, aquaculture run-off, immersion of idol, bathing are the different sources of pollutant influx in this lake (Bhattacharya, 2014). This study was aimed to investigate the possible flow of heavy metals from the *Mathura* lake water to biota which may ultimately threaten the seasonal migratory birds.

Materials and Methods

Study area

The *Mathura* Lake (Fig. 1) is situated in the lower sub-basin of the river Ganges and the general slope is from north to south and southeast. The entire surrounding area is agriculture-based and characterized by periodic occurrence of hot summers, moderate rains and dry winters. The lake is perennial in nature. It is mostly rain-fed as well fed by the river Ganges. The lake water is mainly utilized for irrigation, pisciculture, domestic and jute retting purposes.

Sample collection

Water, sediment, plant and fish samples from the *Mathura* Lake were collected from four sampling sites: Dhankal Fishery Ghat, Ramkrishna Colony Ghat, Dharampur Hostel Ghat and Saradapalli Ghat (Table 1) for analysis of various physicochemical and biological parameters, including concentrations of different heavy metals. The sampling was done purposefully in March with the premise that it will help to record the highest possible value of heavy metals in lake water over the other months since the heavy rains received during monsoonal months (July–October) would dissolute major amount of present heavy metals in lake water.

Sample treatment

The water samples (~ 50 ml) were filtered through 0.45 µ Millipore filter paper and 50 ml filtered samples were kept in polyethylene bottles at 4^{o}C for analysis. The sediment samples were immediately sun dried after collection and later dried in the Hot Air Oven at 60^{o}C for 72 h. The dried sediment samples were then grinded and passed through sieves of different sizes to get homogenized representative powder sample. Finally the samples were stored in polyethylene bags at room temperature. The plant and fish samples were washed thoroughly with tap water to remove sediment and other contaminants, and finally rinsed with de-ionized water with continuous shaking for several minutes. The samples were then dried in the Hot Air Oven at 60^{o}C for 72 h and were stored in polyethylene bags at room temperature. Proper care was taken at each step to minimize any contamination (Bhattacharya et al., 2013).

Sample digestion

Sediment, plant and fish samples were digested following the heating block digestion procedure (Samal et al., 2013). About 0.5 g of the sample was taken into clean dry digestion tubes and 5 ml of concentrated HNO_3 was added to it. The mixture was allowed to stand overnight

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under fume hood. In the following day, the digestion tubes were placed on a heating block and heated at 60^{o}C for 2 h. The tubes were then allowed to cool at room temperature. About 2 ml of concentrated $HClO_4$ was added to the plant samples. For the sediment samples 3 ml of concentrated H_2SO_4 was added in addition to 2 ml of concentrated $HClO_4$. Then the tubes were heated at 160^{o}C for about 4−5 h. The heating was stopped when the dense white fume of $HClO_4$ emitted. The content was then cooled, diluted to 25 ml with de-ionized water and filtered through Whatman No. 42 filter papers for sediment samples and Whatman No. 41 for plant and fish samples and finally stored in polyethylene bottles. Prior to sample digestion all glass apparatus were acid washed with 2% HNO_3 followed by rinsing with de-ionized water and drying.

Fig. 1. *Mathura* Lake, West Bengal, India

Sample analysis

The different physicochemical parameters of water and sediment samples were analyzed according to the APHA Standard Methods for the Examination of Water and Waste water (APHA, 2012), and the analyzed parameters were pH, conductivity, hardness, alkalinity, chloride, nitrate, phosphate and potassium. Similarly, the different biological parameters of water and sediment samples were analyzed by standard methods, and the analyzed parameters were total coliform count, total viable count and total fungal count. After proper processing concentrations of different heavy metals (Cu, Pb, Cr, Zn, Ni and Cd) in the collected water, sediment, plant and fish samples of the lake were analyzed in Atomic Absorption Spectrophotometer (AAS) by the standard method (Welsch et al., 1990).

Results and discussion

Water quality of the *Mathura* Lake

The importance of research on heavy metal pollution on lakes and possible threats to biota is manifold. Fish population in the *Mathura* Lake is not only an important source of livelihood of the local community; it also provides the necessary food for the migratory birds. Table 2 shows the detailed water quality status of the *Mathura* Lake.

Table 1. Description of the sampling sites on the *Mathura* Lake

Sampling sites	Latitude (N)	Longitude (E)
Dhankal Fishery Ghat	22^o 55.947'	88^o 28.665'
Ramkrishna Colony Ghat	22^o 55.967'	88^o 29.007'
Dharampur Hostel Ghat	22^o 56.074'	88^o 29.448'
Saradapalli Ghat	22^o 55.952'	88^o 28.790'

Comparing with the water quality standards for protection of aquatic life as suggested by Wright and Welbourn (2002) the results show that the lake water is highly polluted with cadmium (0.002 ± 0.001 mg/l) and chromium (0.04 ± 0.01 mg/l), and moderately polluted with zinc

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(0.07 ± 0.02 mg/l) and total coliform load (2 × 10^4 cfu/ml). Moderate concentrations of nitrate and phosphate implied the less possibility of eutrophication in lake water. Cu, Pb and Ni were also detected, but their concentrations were within the recommended toxicity threshold level in fresh water (Wright and Welbourn, 2002).

Sediment quality of the *Mathura* Lake

Sediments play a very important role in physicochemical and ecological dynamics; any change in toxic concentrations of heavy metal residues on the sediments will affect the natural aquatic life support systems. Like soils in the terrestrial system, sediment is the primary sinks for heavy metals in the aquatic environment.

Table 2. Physicochemical and microbial status of the *Mathura* Lake water.

Parameter	Mean	Range
pH	6.7 ± 0.47	6.1 – 6.9
Conductivity (µS/cm)	600 ± 77	541 – 682
Chloride (mg/l)	65 ± 14	59 – 80
Nitrate (mg/l)	0.27 ± 0.09	0.18 – 0.33
Phosphate (mg/l)	0.21 ± 0.10	0.11 – 0.29
Total alkalinity (mg/l of $CaCO_3$)	111 ± 30	95 – 142
Total hardness (mg/l of $CaCO_3$)	118 ± 27	99 – 138
Sodium (mg/l)	48 ± 14	36 – 57
Potassium (mg/l)	13 ± 4	10 – 17
Cadmium (mg/l)	0.002 ± 0.001	0.001 – 0.003
Lead (mg/l)	0.009 ± 0.002	BDL – 0.01
Copper (mg/l)	0.02 ± 0.01	BDL – 0.03
Zinc (mg/l)	0.07 ± 0.02	0.06 – 0.08
Nickel (mg/l)	0.01 ± 0.01	BDL – 0.02
Chromium (mg/l)	0.04 ± 0.01	0.01 – 0.05
Total coliform count (cfu/ml)	2 × 10^4	–
Total viable count (cfu/ml)	4 × 10^4	–
Total fungal count (cfu/ml)	Absent	–

BDL, below the detection limit (<0.0003 mg l^{-1})

Hence, the assessment of sediment is significant to study the risk of aquatic ecosystem. The physicochemical status of the *Mathura* Lake sediment is shown in Table 3. It is clearly visible that the lake sediment is polluted with cadmium (118 ± 22 mg/kg) while other heavy metal (Cu, Pb, Cr, Zn and Ni) concentrations were within their background levels.

Accumulation of heavy metals in aquatic plants and fishes of the *Mathura* Lake

Different aquatic organisms respond to external contamination in different ways. Metals dissolve in water and are easily absorbed by plants and fishes. Fishes assimilate heavy metals through ingestion of water, food and constant ion-exchange process of dissolved metals across lipophilic membranes like gills or adsorption on surface membrane like skin. The accumulation of heavy metals in aquatic plants and fishes of the *Mathura* Lake is presented in the Table 4. The results indicate that the biota of the lake is bioaccumulating heavy metals (mg/kg) viz. cadmium (120 ± 16 in plants and 188 ± 29 in fishes) and zinc (69 ± 11 in plants and 108 ± 30 in fishes) from lake water and sediment. The most bioavailable as well as the most toxic form of cadmium is the divalent ion (Cd^{+2}). Exposure to Cd^{+2} induces the synthesis of metallothionen, a low molecular weight protein. Normally it can bind with Cd^{+2} and decrease its toxicity in the liver of fish and humans. But for higher cadmium concentration, the metallothionen detoxification can become insufficient and the excess cadmium will produce toxic effects (Bradl, 2005; Wright and Welbourn, 2002).

Cadmium affects skeletal deformities and impairs functioning of kidneys in fish. Cadmium hinders aquatic plant growth and thus endangers the food chain in the whole lake ecosystem. On the other hand, excessive presence of zinc causes adverse effects on all living biota. Zinc poisoning occurs in birds when liver or kidney concentrations exceed 2100 mg/kg and in mammals when levels exceed 274 mg/kg in kidney or 465 mg/kg in liver (Eisler, 1993). In the present investigation the mean concentration of zinc in fishes (108 ± 30 mg/kg) was found to be much higher than the recommended toxicity threshold level of 20 mg/kg (Munkittrick et al., 1991).

Table 3. Physicochemical status of the *Mathura* Lake sediment.

Parameter	Mean	Range
pH	8.1 ± 0.29	7.6 – 8.8
Conductivity (µS/cm)	664 ± 76	480 – 787
Chloride (mg/kg)	76 ± 15	57 – 89
Nitrate (mg/kg)	521 ± 61	436 – 609
Phosphate (mg/kg)	1774 ± 109	1626 – 1853
Total alkalinity (mg/kg of $CaCO_3$)	545 ± 123	408 – 634
Total hardness (mg/kg of $CaCO_3$)	1698 ± 327	1490 – 1854
Sodium (mg/kg)	691 ± 107	538 – 780
Potassium (mg/kg)	4806 ± 296	4185 – 5032
Cadmium (mg/kg)	118 ± 22	105 – 149
Lead (mg/kg)	13 ± 4	10 – 21
Copper (mg/kg)	23 ± 10	16 – 36
Zinc (mg/kg)	52 ± 11	40 – 72
Nickel (mg/kg)	26 ± 8	20 – 35
Chromium (mg/kg)	20 ± 9	13 – 28

Impacts of heavy metals on migratory birds of the *Mathura* Lake

Mathura Lake is one of the preferred spots of thousands of migratory birds from late October to middle of March. During this time the lake becomes decorated with multifarious wings of birds like Northern Shoveller, Pintail, Gadwal, Red Crested Poachard, Common Coot and Lesser Whistling Teal. Not only these winter guests, *Mathura* lake is permanent habitat of common birds like Pond Heron, Red Wattled Lapwing, different types of snipes, Sand Pipers, Purple Heron, Gray Heron, Purple Moor Hen, Open Billed Stork, Kingfishers and Cormorants (Bhattacharya, 2014).

Biota	Heavy metals	Mean (mg/kg)	Range (mg/kg)
Plants	Cadmium	120 ± 16	110 – 144
	Lead	7 ± 2	6 – 10
	Copper	15 ± 6	11 – 26
	Zinc	69 ± 11	55 – 74
	Nickel	7 ± 2	5 – 13
	Chromium	8 ± 3	4 – 12
Fishes	Cadmium	188 ± 29	151 – 214
	Lead	15 ± 6	10 – 24
	Copper	6 ± 2	4 – 12
	Zinc	108 ± 30	75 – 147
	Nickel	8 ± 2	5 – 12
	Chromium	5 ± 3	3 – 10

Table 4. Accumulation of heavy metals in aquatic plant and fish samples of the *Mathura* Lake.

Female birds are able to transfer certain contaminants to eggs. Hence bioaccumulation of cadmium and zinc in the analyzed fish samples of the lake water is of particular concern.

These toxic metals may further get transferred from contaminated fishes to the birds. Moreover, if these toxicants get biomagnified in the tissues of migratory

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birds they may cause hazard to the entire present and future population of them. Cadmium tends to increase in concentration with age of the organism and eventually acts as a cumulative poison. White-tailed ptarmigans on exposure of high cadmium diet were reported to experience cadmium-induced nephrosis of kidney tissues and were observed to develop calcium-poor leg bones (Larison, 2001). Zinc poisoning is known to cause reduced appetite, decreased body weight, inability to stand/fly straight, dysfunction of kidney and even death in birds. Hence, the bioaccumulation or future biomagnification of heavy metals in fishes of the *Mathura* Lake may have severe impacts on the migratory birds.

Conclusions

The present investigation has established the transfer of heavy metals from *Mathura* Lake water to its biota. Cadmium and zinc were detected to be bioaccumulated from lake water and sediment to the studied plant and fish samples. This poses a potential threat to the survival of present and future population of the seasonal migratory birds of the *Mathura* Lake, West Bengal, India. Moreover, the fish samples of the lake hit the various markets spread all over the surrounding regions, thus accumulation of cadmium and zinc in the studied fish samples of the lake and their possible effect on human food chain are of other crucial concerns, which need to be analyzed separately in details.

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