

Heavy metals in sediment ecosystem of Bhavan's College Lake of Andheri, Mumbai

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ABSTRACT

The present study was initiated to understand the accumulation of toxic heavy metals in sediments of Bhavan's College Lake of Andheri, Mumbai. The study was performed for a period of one year starting from June 2011 to May 2012 to quantify the toxic heavy metals like *Cu*, *Pb*, *Cr*, *Ni*, *Fe*, *Hg*, *As* and *Cd* by atomic absorption spectroscopy technique coupled with cold vapour technique (for *Hg* analysis) and hydride generation technique (for *As* analysis). It was observed that the yearly average concentrations of these heavy metals in lake sediments were 0.53, 0.25, 0.42, 0.43, 4.6, 0.14, 0.12 and 0.11 ppm respectively which were above the *WHO* limits for aquatic life and *CPCB* limits for inland surface water. These heavy metals accumulated in lake sediments may enter the water thereby creating threat to aquatic life. They may enter the food chain through biomagnifications and may create adverse effect on human health. It is expected that in addition to the water analysis which is practiced for years, sediment analysis performed in the present investigation will help in evaluating quality of the total ecosystem of the lake. It will also provide environmentally significant information about natural and anthropogenic influence on the water body.

Keywords: lake sediments; heavy metal toxicity; Central Pollution Control Board (CPCB); World Health Organisation (WHO); AAS technique.

1. INTRODUCTION

The problem of aquatic pollution due to toxic heavy metals has begun to cause concern now in most of the major metropolitan cities of India. Although some of the heavy metals in traces are important for proper functioning of biological systems [1-5], but their excess could lead to severe environmental pollution impact on the aquatic ecosystem.

The toxic heavy metals entering the aquatic ecosystem may lead to geoaccumulation, bioaccumulation and biomagnifications; further they may also enter the food chain. Food chain contamination by heavy metals has become a burning issue in recent years because of their potential accumulation in bio-systems through contaminated water and sediments. In

hydrosphere, concentrations of toxic metal are typically orders of magnitude greater in the sediments as compared to those in overlying waters. The capacity of sediments to accumulate most of these heavy metals make them useful and sensitive indicators for monitoring changes in the aquatic environment. Therefore for better understanding of heavy metal sources, their accumulation in the aquatic sediments seem to be particularly important issues of present day research on risk assessments.

The environmental pollution due to accumulation of toxic heavy metals in sediments is an ever increasing problem of our aquatic ecosystem [6-9]. Incidence of heavy metal accumulation in fish, oysters, sediments and other components of aquatic ecosystems have been reported globally [6- 13]. Among the different water bodies, lakes have a complex and fragile ecosystem, as they do not have self-cleaning ability and therefore readily accumulate pollutants.

The increasing trend in concentration of heavy metals in the lake ecosystem has created considerable attention amongst ecologists globally during the last decades. Measurements have been made of atmospheric metallic precipitation in Europe and USA. However no such studies have been carried out in India and there are no past metal load data available. Therefore there is need for extensive monitoring efforts over long periods of time in order to describe average metal precipitation [14] and its trend, which is an essential component of any pollution control management. Several factors like discharge of agricultural, domestic and industrial wastes, land use practices, geological formation, rainfall patterns and infiltration rate are reported to affect the ecosystem of the lake. As the quality of sediment greatly affect the lake vegetation, it is necessary to study the heavy metal content in the sediments.

Therefore we initiated a study to understand the heavy metal content in sediment samples collected from different locations along Bhavan's College Lake of Andheri, Mumbai. It is expected that the present experimental data obtained based on analysis of lake sediments will help to provide a historical record of heavy metal burdens in the lake ecosystem.

2. MATERIALS AND METHODS

2. 1. Study area

The study was carried out for the period of twelve months from June, 2011 to May, 2012 at Bhavan's College Lake of Andheri, Mumbai. The city is one of the most heavily populated city of Mumbai, and is situated between 18° 96' north latitude and 72° 81' east longitude. Climate is subtropical with mild winters and warm summers.

The weather is typical coastal sultry and humid. The average rainfall records from 1500 mm to 2000 mm. The place experiences the onset of the monsoon in the month of June and experiences monsoon till the end of September. The average temperature recorded in varies from 25 °C to 40 °C.

2. 2. Requirements

The chemicals and reagent used for analysis were of analytical reagent grade. The procedure for calculating the different parameters were conducted in the laboratory. The laboratory apparatus were soaked in nitric acid before analysis and then rinsed thoroughly with tap water and de-ionised distilled water to ensure any traces of cleaning reagents were removed.

2. 3. Sediment sampling and sample preparation

The sediment samples from the top layer (0-15 cm) and sub layer (15-30 cm) were sampled separately. The samples were collected by hand-pushing plastic core tubes (7 cm diameter) as far as possible into the sediment. The sediment cores retrieved in the field were sliced on arrival at the lab at 1 cm depth intervals for the first 15 cm, 2 cm depth intervals from 15-25 cm, and then every 5 cm for the deeper sections of the cores. Sediment samples from two different layers were mixed thoroughly, packed in polythene bags and kept in a dry place until analyses. Such sampling was done in morning and evening sessions along different locations of the lake.

The grab samples collected in two sessions for a month were mixed to give gross sample. Such gross samples drawn for a month were air dried, grounded using agate mortar and sieved with a 0.5 mm mesh size sieve to remove stones, plant roots and have sediment sample of uniform particle size. Well-mixed samples of 2 g each were taken in 250 mL glass beakers and digested with 8 mL of aqua regia on a sand bath for 2 h. After evaporation to near dryness, the samples were dissolved with 10 mL of 2 % nitric acid, filtered through Whatman's No. 1 filter paper and then diluted with deionised water to give final volumes depending on the suspected level of the metals [15]. The samples were subjected to nitric acid digestion using the microwave-assisted technique, setting pressure at 30 bar and power at 700 watts [16, 17].

2. 4. Heavy Metal Analysis by AAS Technique

The analysis for the majority of the trace metals like Copper (*Cu*), Lead (*Pb*), Zinc (*Zn*), Chromium (*Cr*), Cadmium (*Cd*), Nickel (*Ni*), Iron (*Fe*), Mercury (*Hg*) and Arsenic (*As*) was done by Perkin- Elmer ASS-280 Flame Atomic Absorption Spectrophotometer. *As* was determined by hydride generation coupled with an atomic fluorescence detector, while *Hg* was analyzed with a cold-vapour atomic adsorption spectrophotometer. The calibration curves were prepared separately for all the metals by running different concentrations of standard solutions. A reagent blank sample was analyzed and subtracted from the samples to correct for reagent impurities and other sources of errors from the environment. Average values of three replicates were taken for each determination.

3. RESULTS AND DISCUSSION

A number of elements are normally present in relatively low concentrations, usually less than a few parts per million (*ppm*), in conventional irrigation waters and are called trace elements. Heavy metals are a special group of trace elements which have been shown to create definite health hazards when taken up by plants. Under this group are included *Cu*, *Pb*, *Zn*, *Cr*, *Cd*, *Ni*, *Fe*, *Hg* and *As*. These are called heavy metals because in their metallic form, their densities are greater than 4 g/cc. From the results it appears that the minimum monthly *Cu* content in sediments was 0.02 *ppm* while maximum *Cu* content was 1.70 *ppm*.

The average annual concentration of *Cu* in the sediments was found to be 0.53 *ppm* (Table.1). It is expected that the accumulated *Cu* in the sediment may get released in the lake water, as a result of which their concentration in water may exceed the permissible limit of 3.0 *ppm* set by *CPCB* for inland surface water [18], and 5.0 *ppb* limit set for aquatic life by *WHO* [19] (Table 2). It is important here to note that *Cu* is highly toxic to most fishes, invertebrates and aquatic plants than any other heavy metal except mercury. It reduces growth

and rate of reproduction in plants and animals. The chronic level of *Cu* is 0.02-0.2 ppm [20]. Aquatic plants absorb three times more *Cu* than plants on dry lands [21]. Excessive *Cu* content can cause damage to roots, by attacking the cell membrane and destroying the normal membrane structure; inhibited root growth and formation of numerous short, brownish secondary roots. *Cu* becomes toxic for organisms when the rate of absorption is greater than the rate of excretion, and as *Cu* is readily accumulated by plants and animals, it is very important to minimize its level in the waterway.

Pb is discharged in the surface water through paints, solders, pipes, building material, gasoline etc. *Pb* is a well-known metal toxicant and it is gradually being phased out of the materials that human beings regularly use. Atmospheric fallout is usually the most important source of lead in the freshwaters [20]. In the present investigation, it was observed that the yearly concentration of *Pb* was in the range of 0.02 ppm to 0.61 ppm, while the average annual concentration of *Pb* was found to be 0.25 ppm (Table 1). It is expected that the accumulated *Pb* in the sediment may get released in the lake water as a result of which their concentration in water may exceed above the permissible limit of 0.1 ppm set by *CPCB* for inland surface water [18], and 25.0 ppb limit set for aquatic life by *WHO* [19] (Table 2). Acute toxicity generally appears in aquatic plants at concentration of 0.1-5.0 ppm. In plants, it initially results in enhanced growth, but from a concentration of 5 ppm onwards, this is counteracted by severe growth retardation, discoloration and morphological abnormalities. There is an adverse influence on photosynthesis, respiration and other metabolic processes. Acute toxicity of *Pb* in invertebrates is reported at concentration of 0.1-10 ppm [20]. Higher levels pose eventual threat to fisheries resources.

In the present study, the yearly concentration of *Zn* in sediment samples was in the range of 4.03 to 5.98 ppm. The annual average concentration of *Zn* was 4.95 ppm (Table 1), this *Zn* which is accumulated in the lake sediments may enter the water resulting in the increase in concentration of *Zn* in the lake water above its permissible limit of 5.0 ppm set by *CPCB* for inland surface water [18], and 30.0 ppb limit set for aquatic life by *WHO* [19] (Table 2). Excessive concentration of *Zn* may result in necrosis, chlorosis and inhibited growth of plants.

The yearly *Cr* content in the lake sediments was found to be minimum of 0.06 ppm and maximum of 1.20 ppm, while the annual average concentration was found to be 0.42 ppm (Table 1). The *Cr* pollutants which are accumulated in sediment may get released back in to the lake water as a result of which their concentration in water may exceed the permissible limit of 2.0 ppm set by *CPCB* for inland surface water [18], and 100.0 ppb limit set for aquatic life by *WHO* [19] (Table 2). *Cr* compounds are used as pigments, mordants and dyes in the textiles and as a tanning agent. Acute toxicity of *Cr* to invertebrates is highly variable, depending upon species [20]. For invertebrates and fishes, its toxicity is not much acute. *Cr* is generally more toxic at higher temperatures and its compounds are known to cause cancer in humans [22]. The toxic effect of *Cr* on plants indicate that the roots remain small and the leaves narrow, exhibit reddish brown discoloration with small necrotic blotches [21].

Cd is contributed to the surface waters through paints, pigments, glass enamel, deterioration of the galvanized pipes etc. The yearly concentration of *Cd* in the sediment samples was found to be minimum of 0.01 ppm and maximum of 0.77 ppm, while the annual average value of *Cd* in the lake sediment was found to be 0.11 ppm (Table 1). The *Cd* which is accumulated in the sediments may get released back into the lake water, as a result of which the *Cd* content in water may exceeds permissible limit of 2.0 ppm set by *CPCB* for inland surface water [18], and 0.20 ppb limit set for aquatic life by *WHO* [19] (Table 2). There are a few recorded instances of *Cd* poisoning in human beings following consumption of

contaminated fishes. It is less toxic to plants than *Cu*, similar in toxicity to *Pb* and *Cr*. It is equally toxic to invertebrates and fishes [20].

The yearly *Ni* content in the sediment samples was found to be in the range of 0.03-1.10 *ppm*, while the annual average concentration of *Ni* was 0.43 *ppm* (Table 1). It is expected that the accumulated *Ni* in the sediments may get released back into the lake water as a result of which its concentration in lake water may exceed the permissible limit of 3.0 *ppm* set by *CPCB* for inland surface water [18], and 25.0 *ppb* limit set for aquatic life by *WHO* [19] (Table 2). Short term exposure to *Ni* on human being is not known to cause any health problems, but long-term exposure can cause decreased body weight, heart, liver damage and skin irritation [23]. The carcinogenic action of nickel carbonyl on rat was reported earlier by Sunderman in 1959 [24]. *Ni* can accumulate in aquatic life, but its magnification along in food chain is not confirmed.

In the present study, the minimum and maximum yearly concentrations of *Fe* was found to be 1.3 *ppm* and 8.9 *ppm* respectively, while the average concentration was obtained as 4.6 *ppm* (Table 2). The accumulated *Fe* in the sediment when released back in to the lake water may increase the concentration of *Fe* above the permissible limit of 3.0 *ppm* set by *CPCB* for inland surface water [18], and 200.0 *ppb* limit set for aquatic life by *WHO* [19] (Table 2). The presence of high concentration of *Fe* may increase the hazard of pathogenic organisms; since most of these organisms need *Fe* for their growth [23].

The yearly *Hg* level in the lake sediment was found to be in the range 0.03-0.64 *ppm* and the average concentration of toxic *Hg* in the sediments was recorded as 0.14 *ppm* (Table 1). This accumulated *Hg* in the lake sediments when released back into the water may result in increase in its concentration above the maximum permissible limit of 0.01 *ppm* set by *CPCB* for inland surface water [18], and 0.20 *ppb* limit set for aquatic life by *WHO* [19] (Table 2). Atmospheric mercury is dispersed across the globe by winds and returns to the earth in rainfall, accumulating in aquatic food chains and fish in lakes [25]. *Hg* compounds were added to paint as a fungicide until 1990. These compounds are now banned; however, old paint supplies and surfaces painted with these old supplies still exist. The use of *Hg* in thermometers, thermostats, and dental amalgam is still continued.

Arsenic is the most common cause of acute heavy metal poisoning in adults, and it is released into the environment by the smelting process of copper, zinc, and lead, as well as by the manufacturing of chemicals and glasses. Arsine gas is a common by-product produced by the manufacturing of pesticides that contain arsenic. Other sources are paints, rat poisoning, fungicides, and wood preservatives. The yearly minimum and maximum *As* level in lake sediment was found to be 0.02 *ppm* and 0.34 *ppm* respectively, while the annual average concentration of *As* was found to be 0.12 *ppm* (Table 1). The *As* pollutants which are accumulated in sediment may get released in the lake water as a result of which their concentration in water may exceed the maximum permissible limit of 0.2 *ppm* set by *CPCB* for inland surface water [18], and 100.0 *ppb* limit set for aquatic life by *WHO* [19] (Table 2).

Table 1. Heavy metals content in Sediments Collected from the Lake of Bhavan's College campus, Andheri, Mumbai.

Toxic metals (ppm)	June 2011	July 2011	Aug 2011	Sept 2011	Oct 2011	Nov 2011	Dec 2011	Jan 2012	Feb 2012	Mar 2012	Apr 2012	May 2012	Average
Cu	1.07	1.2	1.7	0.07	0.02	0.05	0.07	0.06	0.15	0.28	0.56	1.09	0.53
Pb	0.36	0.36	0.23	0.11	0.36	0.02	0.16	0.08	0.54	0.61	0.07	0.04	0.25
Zn	5.11	5.98	5.40	4.82	4.14	4.03	4.08	4.23	5.71	5.63	5.10	5.19	4.95
Cr	0.53	0.06	1.20	0.09	0.23	0.08	0.98	0.08	0.58	0.21	0.43	0.52	0.42
Cd	0.04	0.02	0.01	0.05	0.03	0.09	0.15	0.09	0.01	0.03	0.05	0.77	0.11
Ni	0.99	0.87	1.10	0.08	0.22	0.03	0.05	0.07	0.71	0.20	0.75	0.06	0.43
Fe	8.9	7.7	6.4	5.0	6.2	1.9	2.6	5.0	3.0	4.5	1.3	2.5	4.6
Hg	0.04	0.09	0.04	0.03	0.06	0.07	0.10	0.15	0.14	0.14	0.64	0.21	0.14
As	0.04	0.11	0.02	0.07	0.09	0.03	0.10	0.12	0.30	0.34	0.11	0.10	0.12

Table 2. Maximum Permissible Limit for Some Heavy Metals.

Toxic metals (ppm)	CPCB Standards for inland surface water <i>The Environment (Protection) Rules, 1986</i> (values in ppm)	WHO Standards for aquatic life (values in ppb) (Sudhira <i>et al.</i> ,2000)
Cu	3.0	5.0
Pb	0.1	25.0
Zn	5.0	30.0
Cr	2.0	100.0
Cd	2.0	0.20
Ni	3.0	25.0
Fe	3.0	200.0
Hg	0.01	0.20
As	0.2	100.0

4. CONCLUSION

The raw sewage as well as waste water effluent from the laboratories of nearby Chemistry Department of Bhavan's college finds their way in the lake water due to seepage. The laboratory and sewage waste water contributes the largest source of heavy metal concentration in the lake, so it is expected that this reservoir can serve as a model for studying heavy metal concentration. In the present study, we find that heavy metals content in the lake sediments are in relatively higher concentrations as compared to their permissible limits making the lake water toxic to human beings, aquatic flora and fauna. As this lake is also used for fishing purposes, it is quite possible that these heavy metals may enter the food chain, and thus through biomagnifications enter the human body.

Periodical monitoring of the water quality is thus required to assess the condition of surface water of the water body and immediate steps should be taken to check the release of toxic metals in the lake. This will be helpful in saving the lake ecosystem from further heavy metal pollution. The existing situation if neglected will be a cause of great concern can cause irreparable ecological damage in the long-term well masked by short term economic prosperity.

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