Evaluation of heavy metals concentration in Sankey tank system During and after restoration

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ABSTRACT

Present study is aimed to know the concentrations of seven heavy metals namely iron (Fe), zinc (Zn), copper (Cu), nickel (Ni), chromium (Cr), lead (Pb) and cadmium (Cd) in water, grass and surface sediment samples of restored Sankey tank. Measurements were done using Atomic Absorption Spectrophotometer after pretreatment of samples. Average value of Fe in water sample is exceeding the limit of the Indian Standards (IS) prescribed for the drinking water. Naturally, it is observed that, in sediment samples concentration of metals are high compared to the water and grass samples. But Zn and Cd mean values are found maximum in water samples. Data reveals that only four metals (Fe, Zn, Cu and Ni) are available in dissolved form (water soluble) to aquatic plants and bioaccumulation factor of grass samples is found highest for cu. Calculated geoaccumulation index values compare with local standards indicates that sediments are free from metals contamination.

INTRODUCTION

Rivers, lakes, tanks and wells are important sources of water in a region. A community depends on water for its domestic, agriculture and industrial needs. Tanks and wells are introduced to harvest rain and groundwater and are known to be the ecological barometers of the health of a city. They regulate the micro climate of any urban centre. Rapid urbanization has lead to the loss of wetland habitat through encroachment, bad management, pollution from sewage and waste and litter disposal activities. These factors have seriously affected the survival of tanks and lakes and have posed serious threat to the flora and fauna supported by them. Bangalore district has about 141 lakes and tanks and government is spending millions for the development of these lakes and tanks. [1]. One such tank namely, Sankey tank, the main source of ground water to this part of Bangalore considered for the present study has offered a classic example to evaluate heavy metals content during and after restoration.

Contaminants, including heavy metals and toxins, in water and sediments constantly impose threat to aquatic species as well as humans. Use of a water body as an urban disposal site could cause unnaturally high concentrations of pollutants in water column as well as in sediment. Heavy metals possess a potential health hazard by mere presence in the drinking water as well as through accumulation in the food chain [2].

A comparative study of Cu contamination in the sediment column of the Dhaumondi and Ramna lakes, situated at the heart of Dhaka city, have been receiving industrial as well as domestic sewage for a long period of time showed considerable amount of Cu [2]. A study on fish mortality in Bangalore lakes, India in particular Sankey tank revealed a low quantity of Pb and Cd in both water and soil. In water Pb quantity is 0.47 ppm and Cd 0.04 ppm and in soil Pb content 0.55 ppm and Cd 0.05 ppm during the period 1996 [1].

The objective of the present study is to analyze Fe, Zn, Cu, Ni, Cr, Pb and Cd metals distribution in water, grass and sediment samples of this tank. During sampling period (2003) restoration work was started and completed during 2004. Hence, status of heavy metals concentration after restoration of the tank may through light on condition of the tank system in the form of bio-accumulation factor and geoaccumulation index. Increase in metals concentration during Gowri-Ganesha festival due to immersion of idols in a pond attached to it is also studied.

STUDY AREA

Sankey tank is a small, urban, mesotrophic restored tank and situated in the heart of Bangalore city as shown in Figure 1(maximum water spread area 30 acres, maximum depth 23 ft, average depth 9 ft). Tank is a 500 year old, perennial water body and supports a significant biotic community. Since the beginning of 1982, drainage of industrial effluent and other domestic sewage into the tank has been stopped and the tank is expected to be free from noticeable pollution. Long-term studies on hydrology and microbial ecology, conducted during the last decade, have indicated that Sankey tank has high potentiality for development of inland fisheries practices [1].

SAMPLING

Sampling was carried out for two years from March 2003 to February 2005. Samples of water, sediment and grass were colleted from study site. Grab water samples (number of samples, n=21) were collected in a cleaned 2 L polythene cans at monthly intervals. Grass (n=10) and sediment samples (n=8) were collected once in three months in separate plastic bags. All the samples were brought back to the laboratory and stored at 4 °C for 1 day.

Sample preparation

Water samples (500 mL) were filtered using Whatman no.41 (0.45 µm pore size) filter paper for the estimation of dissolved metals content. This filtrate (500 mL) and remained (»1.5 L) as collected water sample both were preserved with 2 mL concentrated nitric acid (HNO_3) to prevent any precipitation of metals and growth of algae. Both the

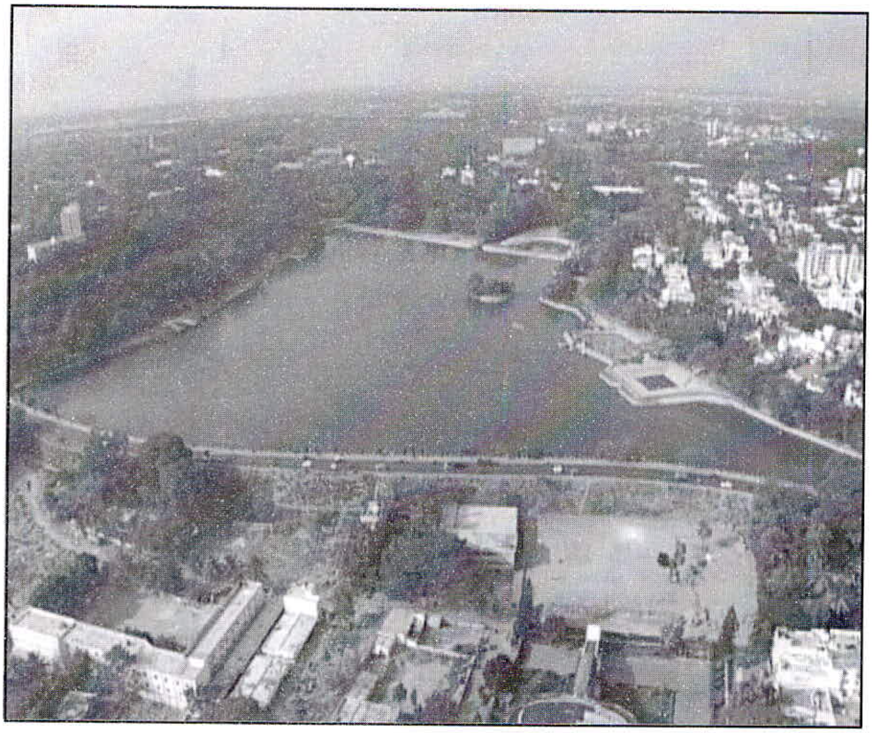

Figure 1 : Aerial view of Sankey tank

samples were ten times concentrated (from 500 mL to 50 mL) on a water bath and subjected to nitric acid digestion using hot plate as per the standard methods for the examination of water and wastewater [3].

Sediment samples were air-dried and ground to fine powder using pestle and mortar and passed through 1 mm sieve. The fine powder samples (2 g in 50 mL distilled water) were taken in 250 mL conical flasks and then subjected for acid digestion with 8 mL aqua regia for 2 hours on hot plate using sand bath. Samples were evaporated to near dryness. The flasks were cooled and the residues were redissolved in 10 mL of dilute nitric acid and filtered. The volume of the filtrate was made up to 50 mL with distilled water [4, 5].

Grass samples were thoroughly washed to remove all adhered soil particles. Samples were cut into small pieces, air dried for 2 days and finally dried at 100 ± 1°C in a hot air oven for 3 hours. The samples were ground to powder as soon as removed from the oven and passed through 1 mm sieve. Fine powder samples (2 g in 50 mL distilled water) were taken in 250 mL conical flasks and subjected to acid digestion using 10 mL concentrated nitric acid on a hot plate and evaporated to near dryness. The flasks were cooled to room temperature and the residues were redissolved in 10 mL of dilute nitric acid and then filtered. The filtrate was diluted to 50 mL using distilled water [6].

Sample analyses

Heavy metals analyses were performed on Atomic Absorption Spectrophotometer (GBC Avanta version 1.31, GBC Scientific Equipment Pty. Ltd., Victoria 3175, Australia) using acetylene gas as fuel (at 8 psi) and air as an oxidizer. Operational conditions were adjusted to yield optimal determination. The calibration curves were prepared separately for all the metals by running suitable concentrations of the standard solutions. Digested samples were aspirated into the fuel rich air-acetylene flame and the concentrations of the metals were determined from the calibration curves. Average values of three replicates were taken for each determination. The detection limits for Fe, Zn, Cu, Ni, Cr, Pb and Cd were 0.05, 0.008, 0.025, 0.04, 0.05, 0.06 and 0.009 respectively [7]. The precision of the analytical procedures expressed as the relative standard deviation (rsd) ranged from 5 to 10 %.

BIOACCUMULATION FACTOR

Bio-accumulation of metals in different samples of the same tank has been quantified by a Bio-Accumulation Factor (BAF), which is defined as the ratio of particular metal concentration in the plant/organism to the concentration of that metal in tank water [8]. The values of bioaccumulation factor are calculated as follows:

BAF= µg per Kg in dry plant / µg per L in water [9] (1)

GEOACCUMULATION INDEX

To be able to quantify the degree of anthropogenic contamination and compare different metals that appear in different ranges of concentration in lake sediments, an approach to indexing geoaccumulation, I_{geo}, was used [10,11]. A quantitative check of metal pollution in aquatic sediments was proposed by Müller and Suess as equation 2 and is called the Index of Geoaccumulation, that is, the enrichment on geological substrate:

$$I_{geo} = \ln (C_n/1.5xB_n) \quad (2)$$

Where

C_n = measured concentration, µg/g and

B_n = geochemical background value, µg/g

In equation 2, average values were used and 1.5 is the factor used for lithologic variations of trace metals. The geoaccumulation index compares the measured concentration of the element in the fine-grained sediment fraction Cn with the geochemical background value $B_{n.}$ Average values of sediment samples of Vasanthapura tank which is taken as reference point are considered as B_n values. The index of geoaccumulation consists of seven grades, whereby the highest grade (6) reflects 100-fold enrichment above background values. Förstner et al. listed geoaccumulation classes and the corresponding contamination intensity for different indices which is shown in Table 1 [12]

Table 1 : Geoaccumulation index classification

Sediment geoaccumulation index, I_{geo}	I_{geo} class	Contamination intensity
<0	0	Uncontaminated
>0–1	1	Uncontaminated to moderate
>1–2	2	Moderately contaminated
>2–3	3	Moderately to strongly
>3–4	4	Strongly contaminated
>4–5	5	Strong to very strong
>5	6	Very strong contamination

RESULTS AND DISCUSSION

Heavy metal concentrations in water, sediment and grass *(Dactylis glomerata)* samples

The results of heavy metals content in water samples is presented in Table 2. Average concentration of Fe is exceeding the limit of Indian Standards (IS) prescribed for drinking water (Table 3) [13]. Percentage bioavailability of metals is calculated from the average values of total content and dissolved content and is found to be in the order Cu (56) > Ni (47) > Zn (44) > Fe (34). The average percentage bioavailability of these metals is 45 %.

The average concentration of Pb in grass samples is found to be slightly exceeding the limit of Indian Standards prescribed for food (Table 4). In the case of sediment samples average values of all metals are within the limits of Indian Standards prescribed for soil (Table 4).

Comparison of metal concentrations in pond water (pond is specially built for the immersion of idols during festivals) with tank water showed considerable increase in total and dissolved content for the metals Fe, Zn, Cu and Ni and marginal increase for Cr and Cd (Table 5). It proves that construction of this type of pond (kalyyani) will save the whole tank from the contamination.

Table 2 : Concentrations of heavy metals in tank water

Metal	Total metal content µg L^{-1}			Dissolved metal content µg L^{-1}		
	Min.	Max.	Mean	Min.	Max.	Mean
Fe	20	1068	440	1	459	151
Zn	3	352	101	1	126	44
Cu	2	16	7.2	1	7.2	4
Ni	1	7.3	3.2	1	2	1.5
Cr	1	48	24.5	-	-	-
Pb	BDL	7	3	-	-	-
Cd	1	2	1.5	-	-	-

BDL- Below Detection Limit

Table 3 : Indian Standards for heavy metals in soil, food and drinking water [13]

Metal	Soil mg Kg^{-1}	Food mg Kg^{-1}	Water mg L^{-1}
Fe	-	-	0.3
Zn	300-600	50	5.0
Cu	135-270	30	0.05
Ni	75-150	1-5	-
Cr	-	20	0.05
Pb	250-500	2.5	0.1
Cd	3-6	1.5	0.01

Table 4 : Concentrations (total) of heavy metals in sediment and grass

Metal	Sediment samples µg g^{-1} dry mass			Grass samples µg g^{-1} dry mass		
	Min.	Max.	Mean	Min.	Max.	Mean
Fe	490	14175	2289	38	410	161
Zn	23	78	48	5.5	58	24
Cu	8	98	34	1	17	5
Ni	3	58	24	0.5	1	0.8
Cr	18	50	31	-	-	1.25*
Pb	4	42	20	0.25	5	2.6
Cd	-	-	0.33*	-	-	0.25*

** only one value during the month of March 2003.*

Table 5 : Comparison of metals concentrations in tank and Kalyani pond water

Metal	Tank water $\mu g\ L^{-1}$		Kalyani Pond water $\mu g\ L^{-1}$	
	Total	Dissolved	Total	Dissolved
Fe	448	37	2160	200
Zn	24	1	145	13
Cu	1	BDL	18	3
Ni	4	1	14	6
Cr	BDL	BDL	1	BDL
Pb	BDL	BDL	BDL	BDL
Cd	1	BDL	2	BDL

BDL- Below Detection Limit

BIOACCUMULATION FACTOR (BAF)

Bioaccumulation of metals in grass samples from water is highest for Cu (1250) and lowest for Ni (533). Metals bioaccumulation is in the sequence: Cu > Fe > Zn > Ni. It is interesting to note that Cr, Pb and Cd did not show their presence in dissolved form in water samples. But they are seldom present in grass samples. This may be due to adsorption mechanism of plant metal uptake [14].

GEOACCUMULATION INDEX (I_{GEO})

Geoaccumulation indices of metals are calculated by considering the average values of sediment samples of Sankey tank and local control tank (Fe-6571, Zn-51, Cu-27, Ni-23, Cr-32 and Pb-10 $\mu g\ g^{-1}$) and their corresponding contamination intensities are given in table 6. Results of the geoaccumulation index calculated for the sediments of Sankey tank are compared with the values of geoaccumulation index classification [10, 11]. Metal such as Fe, Zn, Cu, Ni and Cr remain in class 0 and Pb is in class 1. This indicates that Sankey tank sediment is unpolluted with respect to Fe, Zn, Cu, Ni and Cr and moderately polluted with Pb.

CONCLUSIONS

Thorough investigation into the quality of Sankey tank revealed that only four metals (Fe, Zn, Cu and Ni) are found available to (water soluble) aquatic plants and the bioaccumulation factor in grass (*Dactylis glomerata*) samples were found to be highest for copper. The geoaccumulation indices when compared with local standards indicated that sediments are free from metal contamination. But presence of lead in grass and sediment samples suggested that the tank needs desilting. Examination of water quality of Kalyani pond revealed that it receives pollutants from immersion of idols and construction of a separate pond for this purpose will protect the tank from pollution. This type of data could be used in characterizing sites as minimal,

Table 6 : Geoaccumulation indices of metals in Sankey tank sediments

Metal	Index of geoaccumulation I_{geo}	Contamination intensity
Fe	0	Practically uncontaminated
Zn	0	Practically uncontaminated
Cu	0	Practically uncontaminated
Ni	0	Practically uncontaminated
Cr	0	Practically uncontaminated
Pb	0.28	Uncontaminated to moderate

potential and significant toxicological concern to focus appropriate management strategies.

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