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Heavy Metals Content in Water, Water Hyacinth and Sediments of Lalbagh Tank, Bangalore (India)

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The present study was undertaken for assessing the level of heavy metals such as iron, zinc, copper, nickel, chromium, lead and cadmium in water, water hyacinth and sediment samples of Lalbagh tank, Bangalore. Metals were detected using flame atomic absorption spectrophotometry. The results revealed that by and large all metals are present in all the samples, except cadmium in the sediment samples. The average concentrations of iron in water and sediment samples, and lead in water hyacinth were found exceeding the limits of Indian Standards. In general, the concentrations of iron and zinc were found more, followed by lead, chromium, copper, nickel and cadmium cancentration was low. Bioaccumulation factor for water hyacinth was found maximum for chromium. Geoaccumulation index results revealed that there is moderate input of copper and lead from anthropogenic sources to the tank basin.

Key words: *Anthropogenic sources, bioavailability, bioaccumulation, geoaccumulation index, heavy metals content, Lalbagh tank*

Introduction

Tanks around Bangalore and elsewhere in the state of Karnataka originally were constructed mainly for harvesting rainwater for irrigation and drinking water supply by impounding the monsoon run-off in the valleys. Rapid industrialization and urbanization in recent years have undoubtedly affected lakes and tanks in the cities. Wetlands are increasingly drained and converted into housing sites, stadium and commercial complexes. Satellite images and information available with Survey of India indicate that nearly 2789 lakes have dried up and there are only 330 live lakes in the medium to large range in Bangalore metropolitan region[1].

Urban lakes and tanks all over the country as well as in the state of Karnataka are in varying degrees of environmental degradation. The degradation is due to encroachments, eutrophication loads (from domestic and industrial effluents) and silt. The main causes for the deterioration of water quality in tanks are entering of pollutants due to discharge of untreated or partially treated wastewater from municipal sewage and domestic effluents and discharge of organic, inorganic and toxic pollutants of industrial effluents. These anthropogenic activities are the main sources for the heavy metals contamination. Presence of heavy metals in environment is causing chain effects within the ecosystem and moreover the end of the pipeline is human being. Also low concentration of essential metals (iron, zinc, copper, etc.) in living organisms causes deficiency disorders and their excess concentrations cause toxicity[2].

Studies related to the effects of wastewater irrigation on heavy metal accumulation in soil and plants around Varanasi[3] were carried out. A study on mass balances of total arsenic and copper for a suburban lake in densely populated northern Virginia was undertaken[4]. The inputs and outputs of Hg and Pb, and their distribution in Lochnagar Lake were reported[5]. In the present study, the assessment of distribution of heavy metals in tank system is carried out. Their bioaccumulation factor from water to water hyacinth *(Eichhornia crassipes)* is calculated and degree of metals contamination in sediments with respect to anthropogenic sources is correlated with local control.

Study area

Bangalore city is densely populated and industrialized due to heavy influx of people from north and south India. Besides, Bangalore district alone accounts for 26.2% of total urban migration in the state[1]. Bangalore is located at latitude of $12^0 58'$ N and longitude of $77^0 35'$ E and at an altitude of 921 m above the mean sea level[6]. Lalbagh tank is situated in the south of Bangalore **(Fig. 1)** and it is maintained by the Department of Horticulture, Government of Karnataka. The tank covers an area of 32 acres inside the famous Lalbagh botanical garden, which was laid out over 200 years ago by King Haider Ali and enriched by his son Tipu Sultan[7]. Covering an area of about 240 acres, the garden contains over 1000 varieties of trees and plants, including those of the exotic type, such as Cypress, Thuja, Raspberries, Strawberries and so on. The island in the Lalbagh tank provides resting and breeding

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places for birds. The Lalbagh tank though scenic, has been spoilt due to the flow of untreated sewage water from the surrounding areas. Measures are initiated to divert sewage water flowing into the tank under lake restoration project and it is under progress. However, it is necessary to assess the extent of heavy metals, which have been introduced prior to restoration.

Fig. 1 : A map indicating the location of Lalbagh tank

Methodology

Sampling strategy

Sampling work had been carried out for two years since March 2003 to February 2005. Grab samples of tank water were collected (n=22) in two litre capacity polyethylene cans at monthly intervals. Sediment (n=8) and water hyacinth (n=10) samples were taken in separate polyethylene bags on quarterly basis. All the samples were transported to laboratory and stored at 4° C for a day.

Samples preparation

Water samples (500 mL) were filtered with Whatman No.41 (0.45 µm pore size) filter paper for the estimation of dissolved metals content. Filtrate and the collected water samples (500 mL each) were preserved with 2 mL concentrated nitric acid to prevent precipitation of metals. Both the samples were concentrated to ten folds on water bath and subjected to nitric acid digestion using microwave-assisted technique, setting pressure at 30 bar and power 700 watts, as per the methods for the examination of water and wastewater[8,9].

Sediment samples were air dried and ground into fine powder using pestle and mortar, and passed through 1 mm sieve. Further 2 g of fine powder sediment sample was taken in a conical flask to which 8 mL of aquaregia and 50 mL of distilled water were added. Then the sample was evaporated near to dryness on hot plate using sand bath. Residue was dissolved by adding 5-10 mL of dilute nitric acid to the conical flask. After cooling to room temperature, sample was filtered through Whatman No. 41 filter paper and filtrate was made up to 50 mL with distilled water[10,11].

Water hyacinth 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° C ± 1° C in hot air oven for two hours. In warm condition, the samples were ground and passed through 1 mm sieve. Water hyacinth fine powder samples (2 g/50 mL distilled water) were subjected to acid digestion by adding 10 mL concentrated nitric acid on hot plate and filtrate was diluted up to 50 mL with distilled water[12].

Analysis

Heavy metals analyses were performed on an Atomic Absorption Spectrophotometer (GBC Avanta version 1.31) 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. Suitable blanks were also prepared and analysed in the same manner. The detection limits for iron (Fe), zinc (Zn), copper (Cu), nickel (Ni), chromium (Cr), lead (Pb) and cadmium (Cd) were 0.05, 0.008, 0.025, 0.04, 0.05, 0.06 and 0.009 ppm respectively[13]. The precision of the analytical procedures expressed as the relative standard deviation (rsd) ranged from 5 to 10 %. The X-ray powder diffraction pattern of the Lalbagh tank sediment was obtained on a Phillips X-pert PRO diffractometer, using Ni-filtered, Cu-K_α radiation source (λ = 1.541 Å).

Correlation analyses were performed by Pearson's product moment correlation[14]. For samples with values below the detection limit, half of the respective limit of quantification was substituted to perform statistical analysis[15]. The value of $P < 0.05$ was regarded as statistically significant.

Bioaccumulation factor

Bioaccumulation of metals in different samples of the same tank has been quantified by a bio-accumulation factor (BAF), which is the ratio of particular metal concentration in the plant/organism to the concentration of that metal in tank water[16]. The values of bioaccumulation factor were calculated as follows:

BAF= µg per kg in dry plant / µg per kg in water[17] ……. (1)

Geoaccumulation index (I_{geo})

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[18,19]. A quantitative check of metal pollution in aquatic sediments was proposed by Müller and Suess as equation and is called the Index of Geoaccumulation, that is, the enrichment on geological substrate:

$$I_{geo} = \ln (C_n/1.5\times B_n) \qquad \ldots\ldots\ldots\ldots\ldots(2)$$

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 C_n 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[20], which is shown in **Table 1**.

Table 1 : Geoaccumulation index classification (Förstner *et al*., 1993)[19].

Sediment geoaccumulation index, Igeo	Igeo class	Contamination intensity
>5	6	Very strong
>4-5	5	Strong to very strong
>3-4	4	Strong
>2-3	3	Moderate to strong
>1-2	2	Moderate
>0-1	1	Uncontaminated to moderate
<0	0	Practically uncontaminated

Results and discussion

The maximum, minimum and average values of heavy metals present in water, sediment and water hyacinth samples for the period March 2003 to February 2005 are given in **Tables 2 and 3** and discussed metalwise.

Iron

The desirable concentration of dissolved Fe for Class SW-III waters (surface waters) is 500 µg/L or less according to primary water quality criteria[21]. The permissible concentration of iron in drinking water is 300 µg/L as per the Indian Standards (IS)[22]. The limits of Fe content for soil and food are not fixed. Average value of Fe (total concentration) in water samples is exceeding both the standards. The minimum value of Fe content observed in water hyacinth samples was 44 µg/g. The maximum value 2170 µg/L of Fe was found in water samples during the month of September 2004, because of mixing of bund side mud due to the rain fall. The concentration of bioavailable (water soluble) Fe with respect to total content was found an average of 18 % in water samples.

Table 2: Concentrations of heavy metals in tank water

	Total metal content (µg/L)			Dissolved metal content (µg/L)		
Metal	**Max.**	**Min.**	**Aver -age**	**Max.**	**Min.**	**Aver -age**
Fe	2170	226	924	689	30	166
Zn	278	6	81	192	4	43
Cu	39	BDL	6	7	BDL	1
Ni	8	BDL	2	4	BDL	1
Cr	41	BDL	2	1	BDL	0.1
Pb	30	BDL	3	8	BDL	0.4
Cd	2	BDL	0.1	-	-	-

BDL = Below Detection Limit

Table 3: Concentrations of heavy metals (total) in sediment and water hyacinth.

	Sediment (µg/g dry mass)			Water hyacinth (µg/g dry mass)		
Metal	**Max.**	**Min.**	**Aver -age**	**Max.**	**Min.**	**Aver -age**
Fe	16375	513	4230	495	44	204
Zn	68	30	49	69	13	33
Cu	145	10	45	12	2	4
Ni	45	6	17	8	BDL	1
Cr	32	1	17	15	BDL	2
Pb	66	9	29	33	BDL	5
Cd	-	-	-	0.25	BDL	0.05

BDL = Below Detection Limit

Zinc

The permissible concentrations of Zn in drinking water, soil and food according to IS are 5.0 mg/L, 300-600 mg/kg and 50 mg/kg respectively[22]. The average values of Zn in all three categories of samples (water, sediment and water hyacinth) are below the permissible limits. The concentration of bioavailable Zn with respect to total content is found an average of 53 % in water samples.

Copper

The permissible concentrations of Cu in drinking water, soil and food according to IS are 0.05 mg/L, 135-270 mg/

kg and 30 mg/kg respectively[22]. It was found that all the samples collected from three sources were free from Cu contamination. The average values of Cu are much below the permissible levels. The bioavailable Cu content with respect to total content is found an average of 17 % in water samples.

Nickel

The allowable concentrations of Ni in drinking water, soil and food are - (value is not fixed for water), 75-150 mg/kg and 1-5 mg/kg respectively[22] as per IS. It was found that all the samples from various sources contain Ni much below the limits prescribed. But in water hyacinth sample (root part), the maximum value 8 µg/g was found to exceed the limit during the month of March 2003, which might be due to the concentration effect in water during summer. The concentration of bioavailable Ni with respect to total content in water samples is found an average of 50 %.

Chromium

The maximum permissible levels of Cr in drinking water, soil and food according to IS are 0.05 mg/L, not fixed for soil and 20 mg/kg respectively[22]. From average values, it was found that all the samples collected from three sources contain Cr below the permissible levels. But the maximum values were found nearer to the limits. The concentration of bioavailable Cr with respect to total content in water samples is found an average of 5 %.

Lead

The maximum permissible concentrations of Pb in drinking water, soil and food as per IS are 0.1 mg/L, 250-500 mg/kg and 2.5 mg/kg respectively[22]. The average values of Pb concentration in all the samples were found below the limits. But in water hyacinth samples, the mean value (5 µg/g) was found two times higher than the permissible level, and in water hyacinths root sample, the maximum value of Pb was found 33 µg/g. The concentration of bioavailable Pb with respect to total content in water samples is found an average of 13 %.

Cadmium

The maximum permissible levels of Cd in drinking water, soil and food as per IS are 0.01 mg/L, 3-6 mg/kg and 1.5 mg/kg respectively[22]. It was found that average values of Cd in the samples of water (total) and water hyacinth are much below the permissible levels. Water soluble Cd is not available to plants and animals.

Bioaccumulation factor (BAF)

BAFs are obtained by substituting average concentrations of each metal in water (in dissolved form) to that in water hyacinth samples as per equation 1. It is found that maximum metal accumulation appears for Cr (20000) and minimum accumulation for Zn (767) in water hyacinth samples. The second highest BAF value (12500) was recorded for Pb metal. BAF values for Cu, Ni and Fe were found as 4000, 1000 and 1229 respectively. Accumulation of a particular metal is adjudged by comparison with the presence of that metal in the tank water. It is interesting to find that though Cr is least bioavailable in water but its BAF value is highest. It is further interesting to note that, Zn metal accumulates less in water hyacinth even though its bioavailability is more. It reveals that BAF values are independent of bioavailability values and are mainly depend on metals specificity, environmental influences, exposure route and species-specific characteristics[23].

Characterization of minerals in sediment

The powder XRD analysis of sediment sample showed the dominance of mineral quartz (SiO_2) followed by feldspar ($NaAlSi_3O_8$) **(Fig. 2),** which are in good agreement with the literature data -JCPDS No. 33-1161 and 9-466 respectively.

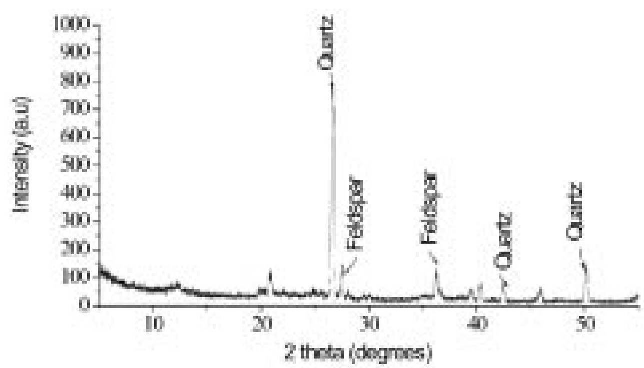

Fig. 2 : XRD pattern of sediment sample of Lalbagh tank

Geoaccumulation index (Igeo)

Geoaccumulation indices of metals in Lalbagh tank are calculated using equation 2 by considering the average values of Lalbagh tank sediment samples (mentioned in **Table 3** and Vasanthapura tank (as local control) sediments as geochemical background values (Fe-6571, Zn-51, Cu-27, Ni-23, Cr-32 and Pb-10 µg/g) and their corresponding contamination intensities are given in **Table 4**. Results of the geoaccumulation index calculated for the sediment metal analysis of Lalbagh tank are compared with the values of geoaccumulation index classification **(Table 1)**. Fe, Zn, Ni and Cr remain in class 0, and Cu and Pb are in class 1. Based on the geoaccumulation indices, the Lalbagh tank sediments are considered unpolluted with respect to Fe, Zn, Ni and Cr and moderately polluted with Cu and Pb.

Table 4 : Geoaccumulation indices of metals in Lalbagh tank sediments

Metal	Index of geoaccumulation Igeo	Sediment quality
Fe	<0	Practically uncontaminated
Zn	<0	Practically uncontaminated
Cu	0.11	Uncontaminated to moderate
Ni	<0	Practically uncontaminated
Cr	<0	Practically uncontaminated
Pb	0.66	Uncontaminated to moderate

Conclusions

The metals average concentrations in water and water hyacinth samples are found varying greatly. However, in sediment samples except Fe, other metals concentrations did not vary much. The bioavailability of heavy metals (water soluble) to plants and animals is in the following order: Zn > Ni > Fe > Cu > Pb > Cd > Cr. Lalbagh garden is one of the country's famous tourist spots and the tank inside the garden is a glory for it. Hence, it becomes necessary that the tank should be properly maintained for the future generation. Besides, diversion of sewage lines and stopping of idols immersion would help to reduce deterioration of water quality and for the survival of rare varieties of plants.

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