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Anthropogenic impact on heavy metal accumulation in the urban wetland: Oussudu Lake

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ABSTRACT

Oussudu Lake is an important freshwater body of Puducherry and one of the primary sources of drinking water supply to Puducherry city. This study aims to assess the accumulation of heavy metals as a result of anthropogenic intervention. Heavy metals such as Cu, Zn, Mn, Cd and Pb in the surface water and sediments are determined using Atomic Absorption Spectrophotometer. The mean concentration of Pb was found to be 0.15±0.07mg/l, whereas Cu was found to be within the safe limits for surface water (Central Pollution Control Board). The concentrations of heavy metals in the sediments were: Cd (0.25±0.31µg/g); Pb (1.1±2.32µg/g); Cu (6.6±4.63µg/g); Zn (10.16±8.79 µg/g) and Mn (44.56±21.28 µg/g). The Principal Component Analysis (PCA) resulted in two principal components accounting for a cumulative variance of 94.438%. This study reveals that the water of Oussudu Lake stands exposed to contamination with lead and constant monitoring is essential to maintain water quality.

Introduction

Oussudu Lake is a shallow wetland of Puducherry region, India is a prominent wintering ground for many migratory birds. Considering the ecological, faunal, floral, geomorphological and zoological significance of the lake, it was declared as a sanctuary to protect, propagate and develop wildlife and its environment. It has also been identified as one of the heritage sites by IUCN and also ranked among the most important wetlands of Asia [1]. Recently the lake and its surroundings are facing threats and pressures from several anthropogenic activities like encroachment, poaching and pollution on account of rapid urbanization and industrialization in the vicinity of the lake. Industries surrounding Oussudu Lake namely glass industry, rubber industry, coir industry, cosmetic industry, brewery, dairy and plastic moulding factory release runoff waters into the lake periodically. Oussudu lake has become an informal recreational spot with the efforts of the Federal Government of Puducherry in developing a restaurant, boat house and trekking facilities. Determined efforts are to be made to prevent recreational activities from becoming a source of pollution to the lake and disturbance to the wildlife. The Puducherry administration has been planning to augment drinking water supply to residents of the town from the Oussudu lake. They are planning to construct a conventional water treatment plant of capacity 20 million litres per day by utilizing surface water from the lake during 2012-2013 [2].

Metals that gradually become concentrated in water bodies, are proven toxins for marine biota and humans at higher concentrations [3]. Sediments serve as sensitive indicators for monitoring contaminants in aquatic environments. The process of accumulation of contaminants in sediments occurs through: disposal of liquid effluents, terrestrial runoff and leachate carrying chemicals. These chemicals originate from urban, industrial and agricultural activities and atmospheric deposition [4]. Heavy metals are one of the important contaminants of water bodies and are responsible for causing serious health effects to human beings and animals [5]. Metal content in sediments indicate the degree of pollution and serves as a source of solubilization into water depending on the physico-chemical conditions and the uptake by benthic organisms [6]. The results of multivariate statistical analyses such as correlation analysis and principal component analysis enables to deduce the sources of origin of metal contaminants in the water bodies [7].

The present study aims for assessing the variations in heavy metal concentrations, besides their accumulation in both surface water and sediments of Oussudu lake.

Materials and Methods

Description of the study area

Oussudu lake is geographically located around 11°56´ - 11°58´ N and 79°44´- 79°45´ E (Fig.1).

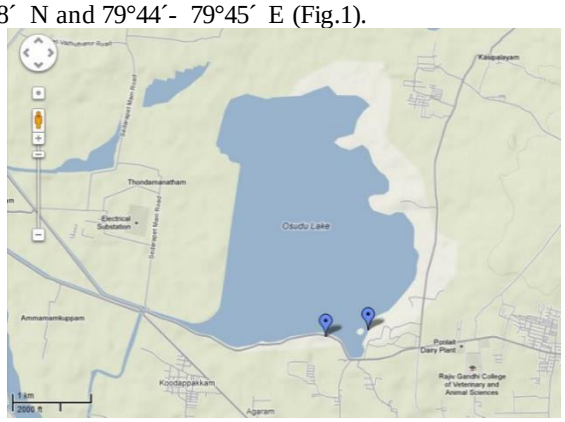

Figure1. Map of the study area showing sampling locations

The study area has a tropical sub humid type of climate with an annual mean temperature of 25 ºC and average annual precipitation of 1200 mm [8]. Surface water and sediment

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samples were collected monthly from the lake during the period April 2010 to March 2011.

Collection of water samples

Water samples were collected using l liter glass bottles that had been cleaned by soaking in 10% nitric acid and rinsed with distilled water. At the sampling site the bottles were rinsed twice with the water to be sampled prior to sampling.

Water Samples

Water samples were thoroughly mixed and Aliquots of 50 ml from the thoroughly mixed water samples were taken in triplicates. These were acid digested with nitric acid and perchloric acid (l:3) until clear solutions were obtained, digests were filtered and stored in a refrigerator.

Soil and Surface Sediments

Soil samples collected from two different depths of 0-5cm were pooled to obtain a composite sample and the samples were dried overnight at 105 °C, crushed in a mortar and pestle and sieved to remove plant parts and debris. One gram(<2mm) of sample portions weighed using digital analytical balance with an accuracy of 0.001 grams and were digested using aqua regia in a microwave assisted digestor (Anton Paar, GMBH, Austria -Multiwave 3000 Model) in accordance with USEPA (1997) method SW 3051 [9]. The resulting solutions were filtered through 0.45µm filter paper and topped to 100 ml with distilled water.

AAS Analysis

Flame atomic absorption spectrophotometer (GBC Scientific Equipment Pvt. Ltd., Australia -Avanta PM Model) is used for the analysis. Triplicates of samples were used for analysing metal concentrations are determined in triplicates. The accuracy of the analytical procedures was determined initially. A series of standards were prepared for calibration of the instrument by serial dilution of working solutions (100ppm) prepared from analytical grade stock solutions (1000ppm) from Merck. A standard and blank sample was run after every seven samples to check for instrumental drift. Solutions were aspirated into the air-acetylene flame. For the determination of metals, background correction and the D2 method (Deuterium lamp method) were used.

Statistical Analysis

Statistical approaches such as ANOVA, Principal Component Analysis (PCA) were applied using SPSS 7.5 for Windows for elucidating the interrelationship among the analysed metals in the sediments [10].

Results and Discussion

Accumulation of lead in surface water

Hydrogen ion concentration (pH) of water varied from 6.5 to 7.2; mean concentrations of COD (mg/l) estimated was 75.58±35.53 (CPCB limit 30mg/l). Higher COD reflects organic compounds and the nutrient level of lake contributed by urban and industrial wastewater drainage thus demonstrating higher COD as an indication of anthropogenic intervention in Oussudu Lake.

Pb concentration ranged from 0.098±0.01µg/l to 0.15±0.01µg/l and Cu ranged from BDL to 0.003±0µg/l (Fig 2) in surface waters though Cd, Mn and Zn were Below Detectable Levels (BDL). Lead, the predominant metal found in the water samples had a mean concentration of 0.145± 0.007µg/l, above the CPCB permissible limit of 0.1µg/l (Table.1).

Table 1. Mean concentration of heavy metals of sediments collected from the study area.

S. No.	Heavy Metals	Mean (µg/g)	STDEV	USEPA (2002)(µg/g)
1.	Pb	1.1	2.3200	31 -250
2.	Cu	6.06	4.6311	49.98
3.	Zn	10.16	8.7938	140.48
4.	Mn	44.46	21.2844	460 -1110
5.	Cd	0.25	0.3077	0.6 -10.0

High concentration of Pb in the surface water of the lake could be attributed to the industrial and agricultural discharge [1], as well as from spillage of leaded petrol from fishing boats and traffic dust. Pb content above CPCB permissible limits in water of the Oussudu Lake could be attributed to the release of industrial effluents and the rapid use of motor boats that carry tourists in the entire wetland besides heavy vehicular traffic as witnessed during our study.

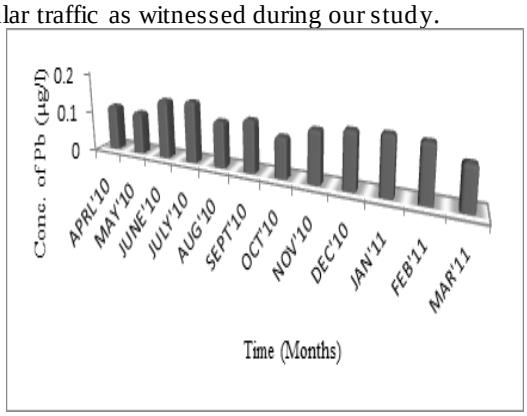

Figure 2. Monthly variations in the concentration of Lead in surface water of Oussudu lake.

Lead and lead compounds generally toxic pollutants and Lead (II) salts and organic lead compounds eco-toxicologically detrimental. Lead salts attributed to water hazard class 2, are consequently harmful [8]. Pb present in wine bottle closures, batteries and tires. The lake is found to be infested with weeds and shrinking due to siltation (Fig.3).

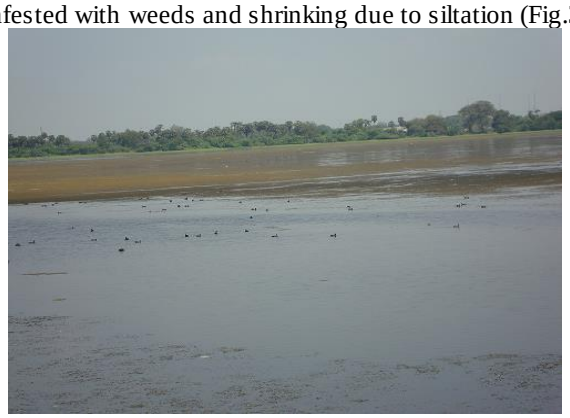

Figure 3. A view of Oussudu lake infested with weeds.

Solai, *et al*. (2010) reported metal enrichments close to the major urban areas in the Pondicherry coast. Metal enrichments known to be associated with the industrial activities contribute to Zn and Pb in the coastal sediments. Heavy metal toxicity and bioaccumulation in rivers and lakes should be a matter of great concern in any ecosystem. Hence, continuous monitoring of pollution levels in the lakes [6] should be mandated.

Heavy metals in soil sediments

The mean annual concentration of Pb found was 1.1±2.32µg/g; Cu (6.6±4.63µg/g); Zn (10.16±8.79 µg/g); Mn (44.56±21.28 µg/g); and Cd (0.25±0.31µg/g) in sediment samples indicating that (Table 1) these heavy metal

concentrations within the threshold limits for contaminated soils [11].

Principal Component Analysis (PCA)

PCA, an efficient tool [12] is utilized to identify the relationship among the experimental variables in heavy metals in soils. Principal Component Analysis (PCA) extracts eigen values and related loadings from the covariance matrix of original variables to produce new orthogonal variables, through Varimax rotation, which are linear combinations of the original variables. In this study, PCA is used to extract significant principal components and further to reduce the contribution of variables with minor significance; these PCs are also subjected to Varimax rotation generating original variables to assess the relationships of sediment properties and heavy metal contents in surface sediments [13].

Table 2. The total variance explained by principal component analysis.

	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.709	74.181	74.181	3.709	74.181	74.181	3.690	73.791	73.791
2	1.013	20.257	94.438	1.013	20.257	94.438	1.032	20.647	94.438
3	0.133	2.659	97.097						
4	0.109	2.173	99.269						
5	.0036	0.731	100.00						

The initial eigen values, variance explained and cumulative variance explained for the extracted components are shown in Table 2. The 'Total' column in initial eigen values category gives the amount of variance in the observed variables accounted by each component. The ratio of eigen values is the ratio of explanatory importance of the components with respect to the variables. Generally, in a good PC analysis, there are a few components that explain a majority of the variance and the rest of the components explain relatively small amounts of variance [14]. Accordingly in our study among the five components only first two components have shown significant loadings. The first two principal components of the 5 heavy metals accounted for 94.438% of the overall variability in the data (Component 1–73.791%; Component 2–20.647%). Pb, Zn, Cu and Mn had higher positive loadings on Component 1. Cd had higher loadings on Component 2 (Table 3).

Table 3. Principal component loadings of the heavy metals for soil samples of Oussudu Lake (Varimax-normilzed).

Metal	PC1	PC2
Pb	0.951	-4.900E-02
Zn	0.966	7.220E-02
Cu	0.945	0.171
Mn	0.979	-3.963E-04
Cd	0.045	0.998

The highest positive loading corresponds to toxicity of a particular contaminant [15]. Weak correlations displayed for the elements between the two groups suggest that the elements of the two groups had different origins [10] in sediments of the northern delta lakes compared to other areas of the world. In Lake Balaton higher levels of Zn, Cu, Mn, Cd and Pb (13–150, 0.7–36, 160–760, 0.1–0.7 and 2.4–160 μg/g dry wt., respectively) were documented [16].

Conclusion

The concentration of trace metals (Pb, Cu, Zn, Mn, Cd, and Cr) from two different samples i.e. water and sediments from Oussudu Lake were monitored over a period of twelve months. Between Pb-Zn, Cu–Pb, Cu–Zn, Mn- Pb and Pb–Zn a significant correlation at level 0.01 was observed. PCA and correlation between heavy metals indicated that heavy metal pollution in Oussudu Lake originates from a single source (Pb, Zn, Cu and Mn) and is assumed to be due to anthropogenic activities related to rapid urbanization like tourism activities involving usage of motor boats and increased vehicular traffic. If this trend is allowed to continue unabated, it is most likely that the food web in Oussudu ecosystem might be at risk of induced heavy metal contamination.

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