Comparative Assessment of Surface Soil Contamination Around Bellandur and Kengeri Lakes

M. T. Prathap Kumar, D. Jeevan Kumar, Ashutosh Kumar, Nikhil Jayaramulu Siregere, and T. V. Venu

Abstract The type and quantity of effluents and wastewater disposed of into highly polluted *Bellandur* and *Kengeri lakes* are different because of the nature and type of zone under the purview of two lakes. Study on the concentration of heavy metals in the lakebed sediments around both the lakes helps to identify the source of contamination and such a comparative study is almost non-existent. The present study comparatively assesses heavy metal contamination of surface soil around these lakes through grab sampling along with physical properties of soil to identify the presence of organic contents. Three locations of Kengeri Lake and four locations of Bellandur Lake were selected depending on the waste discharge locations. Samples of both the lakebed sediments indicate the presence of organic content. Both the lake sediments indicated heavy dosage of iron and chromium, in addition to nickel and zinc beyond the prescribed limits of FAO and WHO standards. The presence of mercury is also confirmed in both the contaminated lakebed sediments of both the lakes. However, the concentration of Fe is more compared to all heavy metals and the concentration of other heavy metals was found to be lower than permissible limits set by FAO as there was no defined source of heavy metal origin.

Keywords Heavy metals · Lakebed · Heavy metals

1 Introduction

Due to rapid urbanization and migration of people to cities, many lake bodies in and around these cities are being encroached upon, thereby subjected to contamination of these water bodies and lakebed sediments. Industrial wastes, atmospheric fall-outs and domestic wastes are among the major sources of heavy metals in urban sewage. Due to increased industrialization and urbanization, soils around these lakes trap

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heavy metals to a varying degree depending on heavy metal concentration in water and frequency of irrigation (Lokeshwari and Chandrappa 2006). It is a fact that heavy concentration of heavy metals in soil, water and air may pose health risk to humans endangering eco-system.

Bellandur and Kengeri lakes are some of the water bodies of Bengaluru City connected to the city's drainage system. Untreated and partially treated domestic sewerage and industrial wastewater from the catchment area of these lakes are let into these water bodies. Surrounding the catchment area of these lakes presents some of the important industries that include tech companies, public sector units, small-scale units (like plating and smelting industries), garment factories, distilleries, etc. These industries are found to release wastewater into storm water and sewerage drains that find their way into these lakes. Varalakshmi and Ganeshmurthy (2012) conducted a study in peri-urban Bengaluru to assess heavy metal contamination in water, soil and vegetable samples. Analyses revealed that concentration of cadmium (Cd) and chromium (Cr) in waters from all the tanks exceeded recommended levels of 0.01 and 0.1 mg/l, respectively, while content of lead (Pb) and nickel (Ni) is found to be in safe limits. It was found that the concentration of Cd was highest in the water of Bellandur tank (0.039 mg/l) and of Cr was highest in the water of Byramangala tank (0.311 mg/l). However, review of these studies indicates that samples used are concentrated away from source water bodies and samples sourced in these studies are from water samples that are being used for irrigation. One of the important aspects revealed in these studies is that the Cd concentration in all the vegetables grown around Varthur and Bellandur tanks exceeded the safe limit prescribed under the Prevention of Food Adulteration Act (PFA 1954). An assessment of water samples along with soil and crop plants using atomic absorption spectrophotometry by Lokeshwari and Chandrappa (2006) for seven heavy metals, viz. Fe, Zn, Cu, Ni, Cr, Pb and Cd. Revealed the fact that some of the heavy metals were present in rice and vegetables, beyond the limits of Indian standards. Evaluation of the degree of heavy metal contamination in lakes of Bangalore City and the extent of sediment concentration were conducted by Jumbe and Nandini (2009). The study indicated a more pronounced presence of Cu followed by Pb and Cd. Comparative assessment of Cd, Cu, Zn, Fe, Pb, Mn, Ni, and Co content in water and sediment from two stations along Red Sea coast by Al-Wesabi et al. (2015) concluded that untreated sewage shall not be let into the water that has significant impact on marine animals such as fisheries. Studies by Chiroma et al. (2014) on the accumulation of heavy metals in soil, water and plants revealed that soil samples have recorded heavy metal in excess of the permissible levels that ranged from severe pollution to slight contamination. Most of the heavy metals in the soil seem to originate sources that included atmospheric deposition, sewage irrigation, improper stacking of the industrial solid waste, mining activities. American Public health association published methods (2005) were referenced to examine waste water contamination. Investigations by Aslan et al. (2004) have indicated antropogenic impact factor that shall be considered prior to and during the recovery of water quality. Bagde et al. (1982) indicated the influence of coliform bacteria in a closed lake. Helen (2008), Huang et al. (2007) and Martin (2004) studied on the influence of heavy metals and their impact on the quality of lake waters. Further, Prajapati and Meravi (2014), Raju et al. (2013), Rao and Rao (1994) and Sulekh et al. (2012) investigated by assessing water quality of different lakes especially with regard to heavy metal concentration. Further the use of pesticides and fertilizers in soils around heavily contaminated lakes also posed significant effect on soil retention of heavy metals. Most of these studies are thus concentrated away from actual lakes around which the contaminated water is drained into the lake bodies. Very few studies thus have assessed the contamination of lakebed soils.

The objective of the present study is to assess levels of contamination of lakebed soils along with lake water contamination due to major toxic heavy metals, viz. Fe, As, Zn, Hg, Cd, Pb, Cr and Ni in both soil and water in both Bellandur and Kengeri lakes. The geotechnical properties of surface soils of both lakes were determined in order to identify the source responsible for such contamination since the type of effluents that is being discharged into both the lakes are different as they are strategically situated in different parts of Bengaluru. Further, the size of both the lakes is significantly different—Bellandur being the largest water body located in Bengaluru urban.

2 Sampling of Sediments

Grab samples were taken from along the banks of the lakebed. All samples were taken from the top 5 and 10 cm layer to a depth of over 30 cm. The results presented are mean of such samples tested in the laboratory. Further, the coordinates of these sampling points are mapped using GPS. Sampling tools were washed and dried with water before the next samples were collected. The collected samples were stored in polythene plastic containers. Samples were air-dried in the laboratory at room temperature, before being sieved under BIS:425-micron mesh. The samples were then stored in a polythene container. Figures 1 and 2 show sampling points located strategically around Bellandur Lake and Kengeri Lake, respectively.

The maximum allowable limits of heavy metals in soil, water and irrigation water have been established by standard regulatory bodies such as WHO guidelines. The heavy metals obtained in lake sediments of Kengeri Lake and Bellandur Lake are thus comparatively assessed using these permissible limits. The geotechnical properties of all the soil samples were evaluated in the laboratory using both air-dried and oven-dried samples. Table 1 shows sample number along with GPS coordinates and description of locations of soil sampling points.

Fig. 1 Sampling points around Bellandur Lakebed

Fig. 2 Sampling points around Kengeri Lakebed

3 Results and Discussions

Both undisturbed and disturbed samples were collected in polyethylene covers and were brought to the laboratory and are air- and oven-dried for further testing, and the properties such as specific gravity, field density, dry density, natural water content were determined as per relevant IS standards. In both the lakes, the field density of all the samples was in the range of 12.4–16.4kN/m^3 with Kengeri like sediments recording higher range of field density. The in-situ water content was in the range of 22–80% for both the lake sediments. All the samples indicated loose to medium dense soils and soft in consistency.

Table 1 Sample locations and coordinates

Sample No.	Description	Coordinates
Bellandur Lake Sample Locations		
Sample-1(**SB1**)	Industrial and domestic discharge point	12° 56′ 18″ N, 77° 40′ 1″ E
Sample-2(**SB2**)	Intermediate point	12° 56′ 19″ N, 77° 40′ 1.2″ E
Sample-3(**SB3**)	Near road side	12° 56′ 22″ N, 77° 40′ 2″ E
Sample-4(**SB4**)	Outlet (waste weir)	12° 56′ 22″ N, 77° 40′ 3″ E
Kengeri Lake Sample Locations		
Sample-1(**SK1**)	Domestic waste discharge point	12° 54′ 56.4″ N, 77° 29′ 10.5″ E
Sample-2(**SK2**)	Intermediate point	12° 55′ 02.8″ N, 77° 29′ 15.8″ E
Sample-3(**SK3**)	Outlet (waste weir)	12° 54′ 04.3″ N, 77° 29′ 20.4″ E

3.1 Plasticity Characteristics of Lake Sediments

The plasticity properties were evaluated for both the lake sediments in terms of liquid limit and plastic limit for both the air-dried and oven-dried samples. Table 2 shows variations in plasticity for both the lake sediments along with liquid limit ratio. Liquid limit ratio (LLR) was determined as the ratio of liquid limit of oven-dried sample to the liquid limit of air-dried sample. Sample exhibiting LLR <0.75 indicates the presence of organic content. All the samples from Bellandur Lake sediment indicated the presence of organic content except sample SB4, which was collected

Table 2 LLR of Kengeri and Bellandur samples

LLR of Kengeri Lake Sediment				
Sample No.	Liquid limit (%)		LLR	Remarks
	Air-dried	Oven-dried		
SK1	43.15	31.93	0.74	Organic soil
SK2	40.05	36.25	0.91	Inorganic soil
SK3	35.32	33.20	0.94	Inorganic soil
LLR of Bellandur Lake Sediment				
SB1	48.8	32.20	0.66	Organic soil
SB2	33.01	23.10	0.70	Organic soil
SB3	27.5	19.80	0.72	Organic soil
SB4	24.05	22.126	0.92	Inorganic soil

near wastewater weir/outlet at Bellandur Lake. High velocity of water at the lake outlet discharging excess water seems to have washed and removed organic matters present in the sample SB4. For the case of Kengeri Lake sample SK1, which was taken at the domestic discharge point, indicated the presence of organic matter and as per its location, and the major effluent being discharged was domestic sewage which has contributed to the soil contamination. For samples SK2 and SK3 of Kengeri Lake, no such waste effluent discharge was noticed, and soil colour was reddish-brown indicating no contamination of lake sediments at these locations.

The presence of organic matter was assessed by conducting "*loss on ignition test (LOI)*" for all the lakebed sediments. The samples SK1 showed percentage of organic matter on LOI at around 12.8%, and both the other samples (SK2 and SK3) showed the percentage of organic matter on LOI less than 7.3. Similarly, all the samples (SB1, SB2 and SB3) showed the percentage of organic matter in excess of 15–16%, except that for sample SB4 that recorded at around 5.8%. Grain size distribution of all the samples of both the lakes indicated the samples are silty-clay, which had the potential to trap the organic matter, if effluents containing organic content are being discharged into the lake water. The trend thus confirms the presence of organic content only in one sample of Kengeri Lake and three samples of Bellandur Lake, indicating higher level of pollution of Bellandur Lakebed sediment. All the samples that indicated organic content in Bellandur Lake and their locations also confirmed that a large quantity of domestic and industrial wastes are being discharged at these locations.

3.2 Heavy Metal Concentration of Lakebed Sediments

Figures 3 and 4 show heavy metal concentration in lakebed sediments of Kengeri and Bellandur lakes. It can be clearly seen that the heavy metal concentration of lakebed sediment obtained from Kengeri Lake is smaller than those obtained for the samples of Bellandur Lake, indicating maximum pollution of Bellandur Lake.

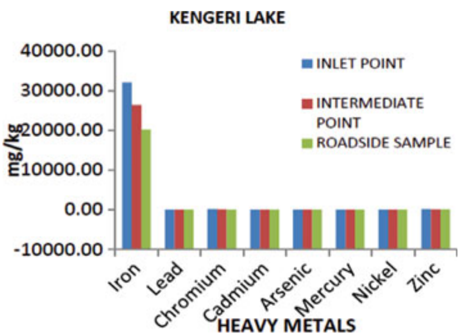

Fig. 3 Heavy metal concentration of Kengeri Lake sediment

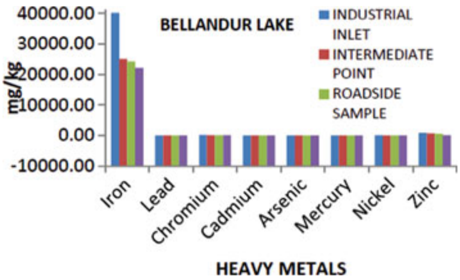

Fig. 4 Heavy metal concentration of Bellandur Lake sediment

Iron concentration of samples obtained from Kengeri Lake is found to be maximum though within permissible limit, for the samples where domestic sewage is being discharged. Similarly, in the case of samples of Bellandur Lake maximum iron concentrations occur where domestic/industrial effluent is being discharged. A minimum concentration is found near the outlet where water washes the lakebed sediments due to the high velocity of excess flowing water being discharged from the outlet. As far as lead content is concerned, both the lakebed sediments indicated concentration within permissible limits of 100 mg/kg. Regarding chromium concentration, samples of Kengeri Lake where domestic waste is being discharged indicated above permissible limit of 100 mg/l and almost all the samples of Bellandur Lake indicated higher concentrations than permissible limit (except near the outlet or waste weir) which is a cause of concern. Similarly, the cadmium and arsenic concentrations in both the lakebed sediments have shown less than permissible limits for all the samples obtained from different locations. However, the concentration of mercury obtained from the lake sediment extracted near domestic/industrial effluent discharged showed slightly higher concentrations though less than the permissible limit but greater than that prescribed for drinking water. The presence of mercury is a major cause for concern about the pollution of groundwater around both the lakes. The nickel concentration of lake sediments obtained around Kengeri Lake is within permissible limits, whereas that obtained for sample located near domestic/industrial effluent discharge point of Bellandur Lake indicated higher concentration than permissible limit. Similarly, it is the case for zinc concentration wherein samples around Kengeri Lake showed within permissible limits and samples obtained around Bellandur Lake showed greater than the permissible limits (except the sample near outlet).

Thus, the comparative assessment of heavy metal contamination of both the lake sediments conclusively proves that Bellandur Lake is polluted to greater extent. Being the largest lake body in Bangalore urban, it seems uncontrolled and untreated disposal of domestic as well as industrial waste has made this water body almost to be brought to the brink of dead lake unless, and until the discharge of sewage water is completely prevented. The water from the Bellandur Lake is being pre-treated and let into the lake at the location represented by SB2 which also indicating the presence of heavy metals beyond permissible limits.

The study thus proves that lake sediments trap the heavy metals present in water and hence is a cause for concern with regard to groundwater pollution. Since the wastewater discharged into the lake is not pre-treated, flows unhindered and is a major source of contamination of both the lakes. Hence, it is a prerequisite to pre-treat the waste effluent before it is being let into the lake water, or else, it is going to lead to "water disaster" (both surface and groundwater) in the surrounding areas.

4 Conclusions

The studies on the magnitude and extent of the heavy metals' deposition in the lakebed sediments along with the presence of organic matters suggest that the lakebed sediments in Bellandur Lake are trapped with large quantity of heavy metals than those in the Kengeri Lakebed sediments. This study therefore indicates the increasing levels of various heavy metals deposited in the sediment deposits of the lakebeds of the urban wetlands. If this trend is allowed to continue unabated, it is mostly likely that the local food web complexes in these fragile wetlands might be at the highest risk of induced heavy metals contamination. Based on the present study, the following major conclusions have been drawn.

i. Samples of both the lakebed sediments indicate the presence of organic content. Samples obtained from locations where sewage/waste domestic water being discharged indicated organic contamination of lakebed sediments.
ii. The samples were analysed for seven heavy metals (Zn, Fe, Cr, Cd, Pb, Hg and Ni) using standard procedures. Both the lake sediments indicated heavy dosage of iron and chromium, in addition to nickel and zinc beyond the prescribed limits of FAO and WHO standards.
iii. Contaminated samples of Kengeri Lake sediments showed iron content at around 32,100 mg/kg and that for Bellandur Lake contaminated sediment indicated at around 40,200 mg/kg. Chromium contamination was at around 150 mg/kg for Kengeri Lake sediment and that for Bellandur sediment it ranged up to 180 mg/kg. The presence of mercury is also confirmed in both the contaminated lakebed sediments of both the lakes.
iv. However, the concentration of Fe is more compared to all heavy metals that the values of other heavy metals concentration were found to be lower than permissible limits set by FAO as there was no defined source of heavy metal origin.

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