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# Assessment of heavy metal contamination within the sediments in some fresh water lakes of Udaipur

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**Abstract**
Heavy metal concentrations were assessed in sediment samples collected from three lakes of Udaipur, Rajasthan. The aim of the present investigation was to compare the lakes for season wise addition of pollution load. The assessment of heavy metals was done using Contamination factor (CF), Geo accumulation index (Igeo) and Pollution load index (PLI). In summer CF varied from 0.01 to 7.43 i.e low to very high but in winter season all three lakes represented high CF factor. Likewise Igeo index in the sediments for summer ranged between 0.41 to 14.48 mg/kg i.e uncontaminated to moderate to heavy to extreme levels in sediments of lakes and trends were of the order Mn>Zn>Pb>Ni>Cu>Cd. In winter Igeo index ranged between 1.34 to 19.3 mg/kg which is uncontaminated to extreme contamination in bottom sediments and trends were of the order Mn>Zn>Pb>Ni>Cu>Cd. Pollution load index in winter season represented high value i.e more than 1 in both Dudh Talai and Udai Sagar Lake. The proposed study suggested that heavy metal accumulation in sediments during winter was higher than summer season. This has a very significant relevance where the contaminated sediments have one of the most challenging pollution issues ow-ning to the toxicity persistence and bioaccumulation issues of food web.

**Keywords**
*Trace metals, heavy metal load, lake sediments, pollution indices, sediment, water pollution*

## Introduction

In the recent years, there have been an increasing interest for heavy metal contamination in the environment, apparently due to their toxicity and perceived persistency within the aquatic systems (Tijani *et al.,* 2005). There have been basically three reservoirs of metals in the aquatic environment namely water, sediment and biota itself (Saha *et al.,* 2001). The analysis of lake sediment is a useful method for studying environmental pollution related to heavy metals (Batley1988; Goorzadi *et al.,* 2009). Sediment accumulate through complex physical and chemical adsorption mechanisms depending on the nature of the sediment matrix and the properties of the adsorbed compounds (Ankley *et al.,* 1992).

Lake sediments provide a useful storage of

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information on changing lacustrine and watershed ecology (Cohen, 2003). Sediments are sensitive indicators for monitoring contaminants in aquatic environments. Sediments can be polluted with various kinds of hazardous and toxic substances that flush to the nearby low lying areas through catchment run off including heavy metals. They accumulate in sediments via several pathways, including disposition of liquid effluents, terrestrial runoff and leachate carrying chemicals originating from numerous urban, industrial and agricultural activities, as well as atmospheric deposition (Verma and Pandey, 2016).

Heavy metal pollution in aquatic ecosystems is a worldwide emerging environmental problem that has received increasing attention over the last few decades (Jarvie *et al.,* 1998; Liao *et al.,* 2008; Mahvi *et al.,* 2005; Nouri *et al.,* 2008). These metals are identified as a significant indicators for degradation of aquatic environments. The contamination of aquatic systems by heavy metals, especially in sediments, has become one of the most challenging pollution issues owing to the toxicity, abundance, persistence, and subsequent bio-accumulation of these materials (Joarder *et al.,* 2008; Jyothi & Nithya, 2011). When discharged into aquatic ecosystems, heavy metals can be absorbed by suspended solids, get settled as sediments or biomagnified along various aquatic food chains (Gajendran & Thamarai, 2008). Moreover, these sediments also act as sink and later as store house for heavy metals (Dash *et al.,* 2006; Mulla *et al.,* 2007). Thus, heavy metal pollution in the sediments of aquatic ecosystems has recently been extensively investigated for effective management of ecosystems (Joarder *et al.,* 2008; Kumar & Sinha, 2010). Due to various anthropogenic activities for rapid and uncontrolled economic development, especially by industry, it has intensified universally particularly in and around Udaipur (Verma and Karki, 2020).

Udaipur also known as the "City of Lakes" is located in the southernmost part of Rajasthan, surrounded by the Aravali Range. Three major lakes were taken in this study for assessment of pollution load in sediments due to urbanization, rapid industrialization and discharge of waste runoff. Udai Sagar Lake has large catchment area so that all the water coming from Fateh Sagar to Ayad River finally channel itself into Udai Sagar along with the waste coming from pesticides industries, agriculture runoff, anthropogenic activities and mining waste, whose runoff also get deposited as soil sediments. While Badi Lake is taken as Control Lake due to least human activity and DudhTalai is taken as moderately polluted due to mild anthropogenic disturbance. The assessment of pollution load and sediment enrichment with heavy metal can be done by numerous ways. Most common ones are the Index of Geo-accumulation (I-geo), Contamination Factor (CF) and Pollution Load Index (PLI). Igeo has been widely used as a measure of pollution in freshwater sediment(Venkatachalam & Nithya, 2011) while CF represents the number of times by which heavy metal concentrations in the sediment exceeds the background concentration and PLI gives a summative indication of the overall level of heavy metal toxicity in a particular lake.

This study can be considered as the first attempt to evaluate the heavy metal load in sediments of Badi Lake, Dudh Talai and Udai Sagar by using Geo accumulation index, Contamination factor and Pollution load index due to increasing anthropogenic interference and pollution pressure.

## Material and Methods

### Sample collection

Three samples from the periphery of the each of the Lake Badi, Dudh Talai and Udai Sagar Lake were collected. Soil Samples were collected for one whole year (2019) covering summer and winter season. Sediment samples were collected and preserved in air-dried clean zip-lock plastic bags. Each bag was labelled carefully and brought to the laboratory for further analysis. The sediment samples were air-dried and sieved as a part of primary treatment and further analysis was carried out using sediment suspension.

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**For heavy metals detection in soil**

The collected samples were air dried and ground to 100 mesh size. The samples were put into hot air oven at 115°C for 3 hours. 5 gm of each dried samples were taken in 250 ml beaker. The sediment samples were digested with triacid mixture (5 mL Perchloric acid + 20 mL Nitric acid) for three hours. The solutions were filtered through Whatman filter paper no. 42 into 100 mL volumetric flask and rinsed with 1M $HNO_3$ solution. The solution were made up to mark with 1M $HNO_3$. The heavy metal contents were measured by AAS against 1M $HNO_3$ as a blank using specified parameters for each metals by Lindsay & Norvell (1978).

**Sediment quality assessment**

Numerous geochemical assessment techniques, including Geo accumulation index (Igeo) and Contamination Factor have been used in order to determine the levels of metal contamination in the sediments in focus (Turekian and Wedepohl 1961; Hakanson 1980; Muller 1981; Ergin *et al.,*1991). Although each evaluation method has its own weakness, assets and liabilities, the use of these tools can provide valuable information to elucidate different aspect of pollution.

**Contamination factor**

The level of contamination in lake sediment by given toxic substance (metals) is often expressed in terms of a contamination factor and is calculated as follows (Hakanson, 1980)

$$CF = \frac{CMetal}{Cbackground} \quad [1]$$

where, CF is the contamination factor, $C_{metal}$ is the concentration of pollutants in sediment, $C_{background}$ is the background value for the metals. Background concentration standard of Cd, Zn, Cu, Mn, Fe and Pb was 0.30 mg/kg, 95 mg/kg, 45 mg/kg, 850 mg/kg, 47200 mg/kg and 20 mg/kg respectively (Turkerian and Wedepohl, 1961).

**Geo accumulation index (Igeo)**

The degree of contamination from the trace metals can be assessed by determining the geo accumulation index (Igeo) proposed by Muller (1969). The index of geo accumulation (Igeo) has been widely applied to the assessment of soil contamination. In order to characterize the level of pollution in the sediment, geo accumulation index (Igeo) values were calculated using the equation [2]

$$Igeo = \log_2 [Ci / (1.5 * Bn)] \quad [2]$$

where Ci is the measured concentration of the examined metal in the sediment and Bn is the geochemical background concentration or reference value of the metal and the factor 1.5 is used because of possible variations in background values for a given metal in the environment.

The geo-accumulation index (Igeo) was distinguished into seven classes by Muller (1969):

i) Igeo≤0=uncontaminated
ii) 0<Igeo≤1=uncontaminated to moderate contamination
iii) 1<Igeo≤2=moderate contamination
iv) 2<Igeo≤3=moderate to heavy contamination
v) 3<Igeo≤4=heavy contamination
vi) 4<Igeo≤5=heavy to extreme contamination
vii) 5<Igeo≤6=extreme contamination

**Pollution Load Index**

Tomlinson *et al.,*(1980) has developed a simple method to assess the degree of pollution by metals in aquatic sediments. The PLI is defined as the $n^{th}$ root of the multiplication of the contamination factor of metals:

$$PLI = (CF_1 \times CF_2 \times CF_3 \cdots\cdots\cdots CF_n)^{\frac{1}{n}} \quad [3]$$

where $Cf_1$ = Conc. of $1^{st}$ metal, $Cf_2$ = Conc. of $2^{nd}$ metal, Cfn = Conc. of metal n and n = total no. of metals studied.

Therefor PLI value of 0 indicates excellent, a value of 1 indicates the presence of only baseline level pollution and value above 1 indicate progressive deterioration of the site (Tomilson *et al.,* 1980).

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## Results

### Spatial distribution of heavy metals

Table 1 and Figure1 represent the season wise CF of the heavy metals in the lakes under study. Heavy metal contamination in summer was found low with respect to Pb, Zn, Cu, Mn and Ni but highest contamination factor was seen for Cd in all lakes. The trends of heavy metal contamination was of the order Cd>Cu>Pb>Zn>Mn>Ni in summer season.

Table 1. *Season wise variation of CF (Contamination Factor) within lake sediments*

| Heavy Metal | Contamination factor within sediments | | | | | |
|---|---|---|---|---|---|---|
| | Summer | | | Winter | | |
| | Badi Lake | Dudh Talai | Udai Sagar | Badi Lake | Dudh Talai | Udai Sagar |
| Pb | 0.11 | 0.83 | 0.14 | 1.33 | 13.11 | 17.33 |
| Zn | 0.05 | 0.77 | 0.48 | 0.80 | 23.40 | 59.25 |
| Cu | 0.03 | 0.72 | 0.30 | 5.50 | 10.75 | 8.25 |
| Cd | 3.43 | 4.00 | 7.43 | 0.45 | 142.86 | 482.86 |
| Mn | 0.01 | 0.03 | 0.02 | 0.93 | 0.80 | 0.22 |
| Ni | 0.01 | 0.03 | 0.01 | 0.56 | 0.95 | 0.65 |
| Pollution indices (HMPI) | i.) CF<1 = low CF; ii) 1≤CF<3 = moderate CF; iii) 3≤CF<6 = considerable CF; iv) CF≥6 = very high CF | | | | | |

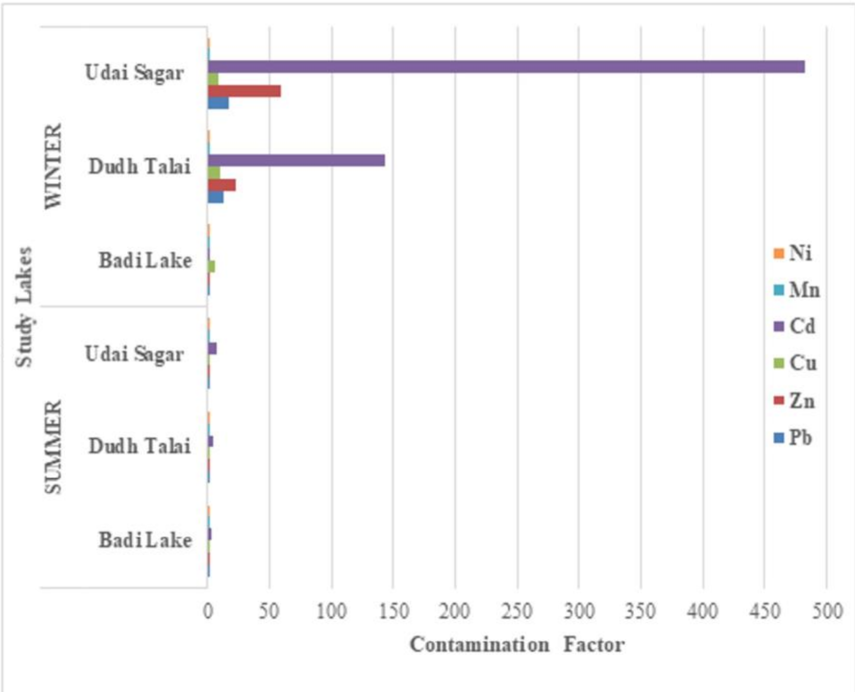


**Figura 1.** *Showing Contamination Factor variation in lake sediments.*

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On the other hand heavy metal absorption in winter season showed that metal contamination varied between 0.45 to 482.86 mg/kg i.e from very low to very high. Pb and Cu were seen having range from moderate CF to considerable CF in Badi Lake while in Dudh Talai and Udai Sagar presence of Pb, Zn, Cu and Cd showed value greater than 6 which is very high for these two lakes. However the trend was of the order Cd>Zn>Pb>Cu>Ni>Mn. The calculated Igeo of the investigated trace heavy metals in the sediments of the Badi, Dudh Talai and Udai Sagar Lake is shown in Table 2 and Figure 2 for summer and winter season.

Table 2. *Index of geo-accumulation representing heavy metal concentration in lake sediments*

| Heavy Metal | Index of geo-accumulation in sediments | | | | | |
|---|---|---|---|---|---|---|
| | Summer | | | Winter | | |
| | Badi Lake | Dudh Talai | Udai Sagar | Badi Lake | Dudh Talai | Udai Sagar |
| Pb | 2.59 | 5.49 | 2.96 | 6.16 | 9.46 | 9.87 |
| Zn | 3.73 | 7.67 | 7 | 7.73 | 12.6 | 13.9 |
| Cu | -1.9 | 2.93 | 1.67 | 5.87 | 6.84 | 6.45 |
| Cd | -8.48 | -8.25 | -7.36 | -5.15 | -3.09 | -1.34 |
| Mn | 12.84 | 14.48 | 14.21 | 18.4 | 19.3 | 17.4 |
| Ni | 0.41 | 2.73 | 1.95 | 7.22 | 7.98 | 7.43 |

Among the six heavy metals analysed, Pb in Badi, Dudh Talai and Udai Sagar fall into class IV (2<Igeo≤3: moderate) to class VII (5<Igeo≤6: extreme contamination) and Cu and Ni in Dudh Talai and Udai Sagar ranged from class III(1<Igeo≤2) to class IV(2<Igeo≤3) i.e. moderate to heavy metal contamination during summer season. Zn concentration was found highest in all three lakes but when compared with Dudh Talai and Udai Sagar, Badi lake fell into class V(3<Igeo≤4) which show heavy contamination. Test metal levels depicted the trend: Mn>Zn>Cu>Pb>Ni>Cd.

Similarly in winter season for three study lakes, the data varies from 1.34 to 18.4 mg/kg i.e uncontaminated to extreme contamination. All three lakes indicated extreme contamination of heavy metals in sediment i.e class VII (5<Igeo≤6: extreme contamination) except for Cd pollution. In both seasons Igeo values for Cd in all lakes indicated that lakes were not polluted with Cd (Table 2). Overall concentration represented Cd levels trend in order Mn>Zn>Pb>Ni>Cu>Cd (Table 2).

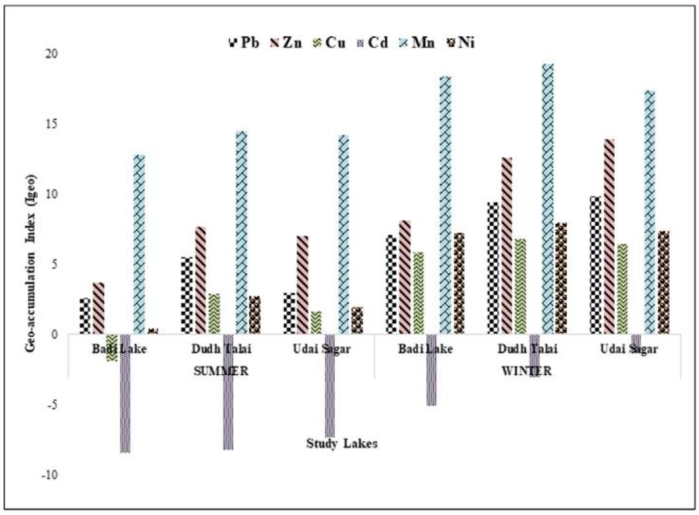


**Figure 2.** *Showing season wise variation in Igeo index within lake sediments.*

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In summer season PLI is less than 1 in all three lake sediments as represented in Table 3. However in Figure 3 in winter season pollution load index for all study lake sediments shows value more than 1 which indicates deterioration of sediments quality. Trend of PLI in lakes is of the order Udai Sagar>Dudh Talai>Badi Lake in winter.

**Table 3.** *Season wise Pollution Load Index (PLI) in lakes.*

| Pollution load index (PLI): Summer | | | Pollution load index (PLI): Winter | | |
|---|---|---|---|---|---|
| Badi Lake | Dudh Talai | Udai Sagar | Badi Lake | Dudh Talai | Udai Sagar |
| 0.053 | 0.330 | 0.194 | 1.053 | 8.43 | 9.12 |

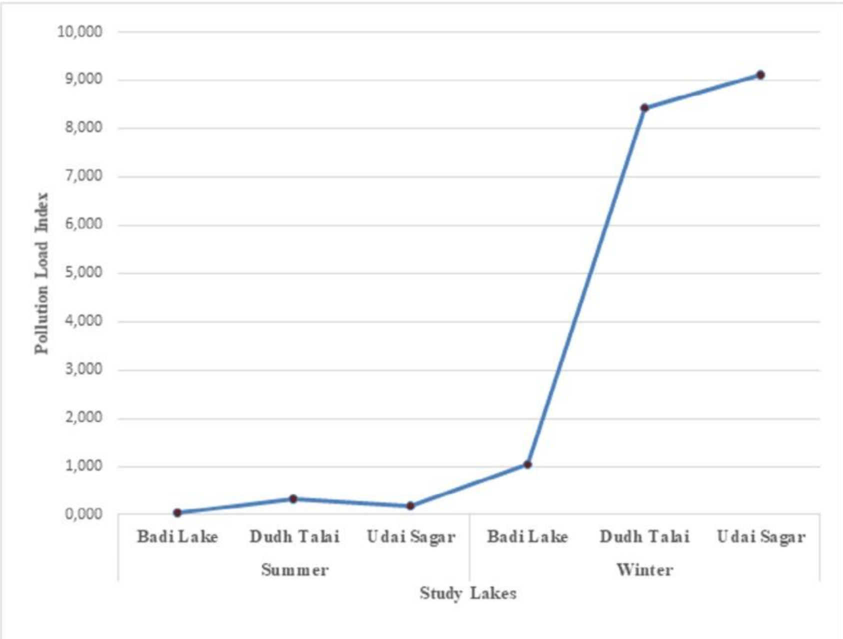


**Figure 3.** *Showing PLI (Pollution Load Index) variations in lakes.*

## Discussion

Rapid increase in human population and unconstrained economic development has significantly contributed to the current pollution problems. The present study has also supported the higher inputs of contaminants through direct and indirect sources.

As seen in Table 1 Contamination factor of Cu in Badi, Dudh Talai and Udai Sagar Lakes indicated a rise from 5.50 to 10.75 i.e considerable CF to very high CF, while Pb, Zn and Cd showed low CF to very high CF in winter season. A study by V. Gopal *et al.,* (2017) showed similar trend with our study in Yercaud Lake where very high CF values were found for Cu, Zn; for Cd it showed low to very high and Pb was found to be between moderate to very high CF range.

The index of geo-accumulation (Igeo) in the sediments of the Badi, Dudh Talai and Udai Sagar

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Lake and its corresponding contamination intensity is illustrated in Table 2. The values ranged from null to extreme contamination for the metals Pb, Zn, Cu, Mn and Ni in summer and winter season due to direct and indirect loading of pollutants through sewage disposal, idol immersion, pesticide and other indirect additions in form of industrial waste runoff and illegal waste disposal of mining. Cu content in these lakes displayed moderate to extreme contamination in sediments similar to the study conducted by V. Gopal *et al.,* (2017) in Yercaud Lake while assessing its sediment quality. Gessey *et al.*, (1984) stated that heavy metals react readily with suspended particulate matter and through sedimentation process, accumulate in bottom deposits. Similarly, the main source of Cu in Udai Sagar Lake is owing to the discharge of industrial and municipal wastewaters, agrochemicals, landfill leachates and geogenic material (DVWK 1998; Wantzen *et al.,* 2008; Iqbal *et al.*, 2016). While in Dudh Talai, it is due to close system and rapid/high evaporation with low water levels.

Ben Bouih *et al.*, (2005) study reveal that the concentrations of Pb and Zn recorded in Fouara Lake (Morocco) were mainly from waste water, domestic garbage, agricultural activities and atmospheric depositions. Present study also states that concentration of Pb and Zn in Badi, Dudh Talai and Udai Sagar lake was observed from moderate to very high during winter and summer season which can be due to the deposition from point and non-point sources such as leaded gasoline, municipal runoffs and atmospheric deposition (Mukai *et al.,* 1994; Mohiuddin *et al.,* 2012; Shikazono *et al.,* 2012).

The study on Yercaud Lake revealed that the PLI value was found higher for all sites of the lake. Metals content in sediment during winter season were higher than summer which was due to the lower flow of water during winter season that facilitated the accumulation of heavy metals in bottom sediments as found through our study also (Table 3 & figure 3). In present study all three lakes were found to be having more than 1 PLI during winter season which is similar to this study (Islam *et al.,* 2014; Mohiuddin *et al.,* 2011).

## Conclusion

This study provides the first comprehensive analysis of heavy metals status in sediments of Udai Sagar, Dudh Talai and Badi Lake through various pollution indexes. From this investigation, it is clear that the heavy metal levels were much higher in winter as compared to summer. Therefore, Udai Sagar and Dudh Talai Lakes were more polluted as compared to Badi Lake due to serious anthropogenic activities and effluents discharge from nearby industries, factories and direct or indirect runoff from peripheral agricultural fields. Hence it is clear that the sediment quality in all the three lakes have been deteriorating and on verge of becoming potentially hazardous to public health. This requires proper vigilance and hard core steps by the authorities for continuous monitoring, diligent restrictions on entry through point and non-point sources of waste and effluents into these lakes.

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