

GEO-CHEMICAL EVALUATION OF HEAVY METALS IN THE LAKES OF SOUTH CHENNAI, TAMIL NADU, INDIA

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Abstract

The salient geochemical features of heavy metals in the lakewater and the seasonal variations were determined. Forty water samples were collected in the South Chennai lakes of TamilNadu, South India and the concentration of heavy metals were determined to characterize and evaluate the hydrogeochemical nature and water quality. Results of total dissolved solids(TDS)show that all the lake water samples in the study area during both monsoon periods are found to be higher than the desirable limit of 500mg/L. Among the heavy metals, Copper (Cu) concentration in the water reveals that about 60% of the samples exceed the desirable limit of 0.05mg/L but no sample exceeds the maximum permissible limit of 1.5mg/L.The concentration of Iron (Fe) in these water is found to be high which could be attributed to the leaching of waste dumps adjacent to the lakes as well as inside the lakes and further leaching from the soil/rock due to rock-water interaction also increases the iron content in these water. Spatial distribution of Cr illustrates that the eastern and northeastern part of the study area are found to have the highest concentration of chromium. Results of Lead concentration in the lakes of the region illustrates that all the values during both the monsoon periods found to exceed the permissible limit which could be attributed to the higher content of e-waste including Lead (Pb)based batteries in the solid wastes, dumped inside the lake area which has been continuously leached into the lake water by way slow dissolution. Correlation analysis show highly significant correlation between manganese (Mn)and zinc (Zn) and also Mn have good correlation with cobalt (Co) indicating the industrial activity of the region increases the concentration of the metals in this water.

Key words: Lake Water; Hydro geochemistry; Water quality studies; Trace metals

Introduction

In recent years, many parts of the world witnessed rapid pace of development due to the technological innovation and a general rise in the livelihood of man. This development especially in the core industrial and its allied small scale to tiny industries creates new settlements attracting migration from remote areas. As water is a basic requirement, such new settlements concentrate or conglomerate in proximity to the water bodies, creating new urban sprawls with high density of population. This unplanned rapid expansion of urbanization adjacent to a metropolitan or urban area warrants many basic facilities mainly the underground sewage system and municipal domestic waste clearing system. In most of such new developments, especially in developing countries, such basic requirements are not adequate which creates new environmental issues in such regions. One such region is the south Chennai where in the last two decades, tremendous growth of urbanization occurred and the population increases to multi-folds whereas the basic requirements are still not adequate. Many settlements are concentration very near to the lakes in this region and in the catchment area. In some regions, the domestic effluents are directly directed into the lakes. Further the municipal dump yards are located adjacent to the two major lakes in this region, especially the PeriyayEri and Pallikaranailake. The leaching of the wastes directly enters into the water bodies which affects the quality of not only this surface water but also on the groundwater of the region.

In addition to the contamination caused by major ions and nutrients such as nitrates and phosphates; heavy metal contamination poses major threat to human health. Researchers throughout the world have focused their attention on the heavy metal contamination in the surface water and groundwater because of the high significance append with this research area. Usually, contamination caused by major ions or the nutrients could be visually observed or can be inferred from the taste of the water but the contamination raised by heavy metals could not be detected from such observation except by carrying out detailed geochemical investigation. Most of the heavy metals are required for human health but at very low concentrations except zinc. There are certain heavy metals have toxic nature even at very low levels especially, Chromium, Nickel and Lead. Chromium in its hexavalent state is carcinogenic in nature whereas in its lower oxidation state, it is essential for human health but at lower level. Many researchers reported on the origin and source of heavy metals in both surface waters and groundwater and they indicated

that they originate both from the point and non-point sources (Jameel et al, 2012, Kwon et al, 2012, Lonescu et al, 2017)

From the point of view of water quality and the influence of heavy metal contamination, detailed evaluation of the factors effecting the contamination and the level of contamination becomes pertinent for effective water management. Hence in the present study, geochemical scientific applications including various indices have been effectively used to characterize the hydro chemical nature of heavy metals in the water resources of the region.

Study Area

Chennai metropolitan city is located near the shores of Bay of Bengal. It is the capital of the state of Tamil Nadu and also ranks as the 4th largest metropolitan city in India. The metropolis lies on the southern part of the Coramandal coast. The urbanization status of Chennai in the overall context of urban development/growth visualized in the world can be categorized as a vibrant development not limited within the metro region but extended beyond the fringes of the city.

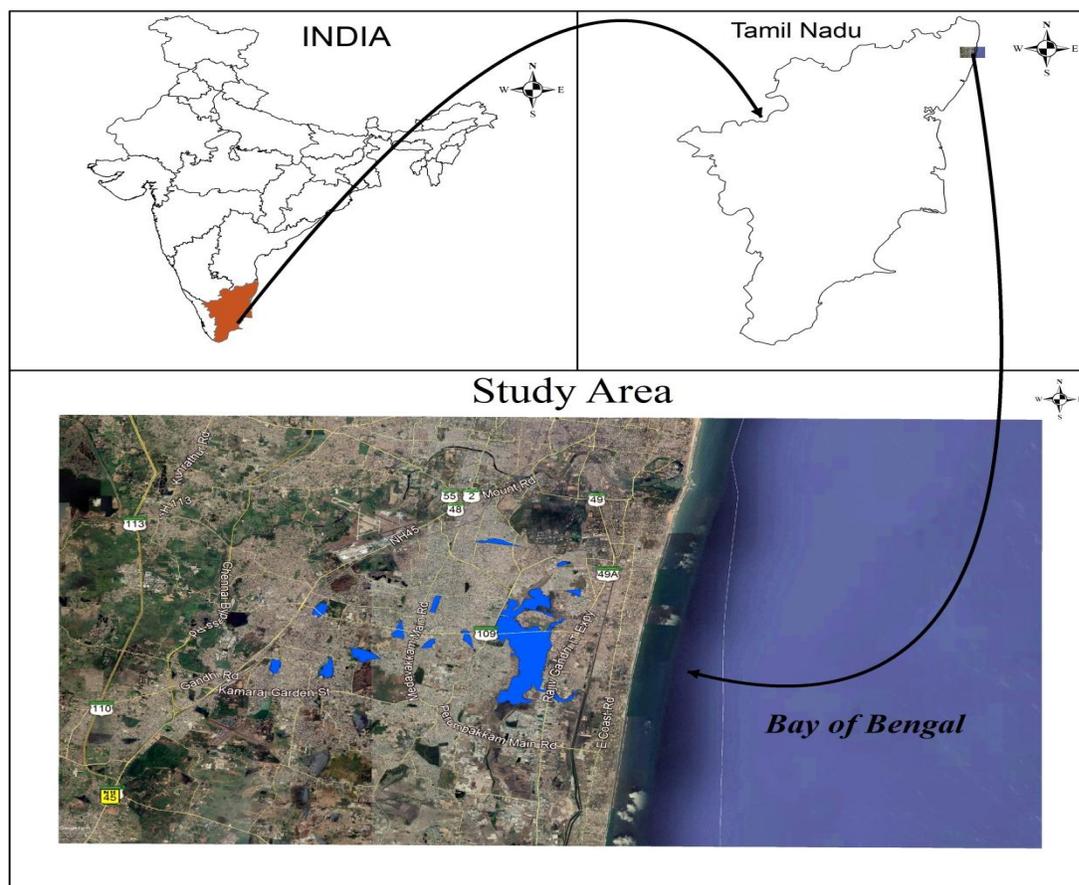


Fig.1. Location map of the Lakes of South Chennai

In the recent decades, South Chennai visualized new type of modern settlements with high rise buildings and many IT corridors are engulfing. The region visualizes new developments including long and broad roads, flyovers, bridges etc but lacks the basic amenity facilities such as proper underground sewage system, solid waste management system etc and much of this region is left with septic tanks which only supports the newly developed dense population in this region. The lack of adequate sewage system and improper planning of settlements creates huge quantum of domestic effluents and solid wastes which was indiscriminately being directed into the surface water bodies leading to the deterioration of lakes in this region.

The region is so chosen as the study area witness's lack of proper urban solid waste management system and the level of contamination of surface water bodies is alarming. Solutions sought for solid waste management are in general, not in line with land use planning. Further, most of the South Chennai areas are still connected only with open drains rather than with underground ones leading to contamination of the ground and surface water. Further, the settlements on the bank of the lakes are often being done without any regard to the hydrology. Developments have taken place without regard to the carrying capacity of the aquifers as well. In this region, number of tiny and small scale industries is agglomerated in the western part of the study area wherein leather tanning works are being carried out in huge volumes. The effluents including chromic acid used for tanning is not properly treated and is directly directed into the canals/surface water bodies. The tanning solid waste and the leather wastes are dumped which creates environmental problem in the region. In the Pallikaranai region, the aesthetic marshy, large Pallikaranilake which houses many birds and other habitats now is used as a garbage waste dump yard which also affects the aquifer system of the region.

Methodology

Lake water samples were collected from 12 representative lakes in the study area during the month of June 2015 and January 2016. Forty water samples from twelve lakes were collected and stored in new polyethylene bottles and preserved at 4°C. The containers were pre-cleaned by soaking them in 2 mol.L⁻¹ HNO₃ for 24 hours and washed 3–4 times with de-ionized water. Before collecting the samples, the containers were rinsed with the samples. About one litre of

water samples were collected for physical and chemical examinations from each location and half litre water samples were collected from the same locations in separate bottles and few drops of HNO₃ were added for the estimation of trace elements. Samples were analyzed within a short period of time so as to get more reliable analytical results. EC and pH of water samples were measured in the field immediately after the collection of samples using pH and electrical conductivity meters. Before each measurement, pH meter was calibrated with reference to buffer solution of pH=4 and 7. Total dissolved solids (TDS) were determined by evaporation method (Hem, 1991). Trace elements were studied using AAS with graphite furnace. A known Standard Reference Material (MESS-1) was run after every tenth sample throughout the analysis to maintain the precision.

The analytical results so obtained were processed using Statistical Package for Social Sciences (SPSS) 20.0 package software for correlation analysis. Spatial distribution of each trace element are expressed using Arc GIS software and the values were compared with the Bureau of Indian Standards (BIS 2012). Bureau of Indian Standards (BIS 2012) for water quality are used to assess the quality of lakewater of the region with respect to the heavy metal concentration.

Results and Discussion

Table.1 Summary statistics of the lake water hydro chemical parameters

Parameters (mg/L)	Pre-monsoon			Post-monsoon			BIS limit 2012	
	Min	Max	Mean		Min	Max	Mean	
pH	7.30	8.10	7.72	7.20	8.10	7.63	65-8.5	No relaxation
TDS	654.0	5480.0	1743.1	548.0	4280.5	1487.4	500.0	2000
Cu	0.01	0.08	0.05	0.01	0.08	0.04	0.05	1.50
Zn	0.01	0.36	0.16	0.02	0.32	0.15	5.00	15
Fe	0.10	0.89	0.53	0.04	0.79	0.44	0.30	No relaxation
Cr	0.003	0.15	0.02	0.001	0.04	0.02	0.05	No relaxation
Mn	0.04	0.77	0.18	0.01	0.58	0.14	0.10	0.30
Pb	0.01	0.27	0.08	0.01	0.25	0.09	0.01	No relaxation
Co	0.03	0.22	0.11	0.03	0.21	0.11	---	---

Table.2a Results of correlation co-efficient matrix during pre-monsoon

Parameters	pH	TDS	Cu	Zn	Fe	Cr	Mn	Pb	Co
pH	1.00								
TDS	0.14	1.00							
Cu	-0.22	-0.28	1.00						
Zn	0.21	0.51	0.00	1.00					
Fe	0.05	-0.07	0.41	0.35	1.00				
Cr	0.13	0.16	-0.32	0.25	-0.11	1.00			
Mn	0.07	0.79	-0.05	0.70	0.19	0.14	1.00		
Pb	-0.34	-0.41	0.26	-0.44	0.11	-0.14	-0.25	1.00	
Co	0.23	0.56	-0.06	0.89	0.40	0.18	0.77	-0.44	1.00

Table.2b Results of correlation co-efficient matrix during post-monsoon

Parameters	pH	TDS	Cu	Zn	Fe	Cr	Mn	Pb	Co
pH	1.00								
TDS	0.17	1.00							
Cu	0.06	-0.01	1.00						
Zn	0.34	0.48	0.17	1.00					
Fe	-0.05	0.00	0.31	0.22	1.00				
Cr	-0.09	-0.17	0.17	-0.24	-0.12	1.00			
Mn	-0.06	0.61	0.10	0.51	0.09	-0.19	1.00		
Pb	-0.19	-0.14	-0.13	-0.59	-0.01	0.21	-0.33	1.00	
Co	0.24	0.65	0.15	0.87	0.30	-0.24	0.71	-0.50	1.00

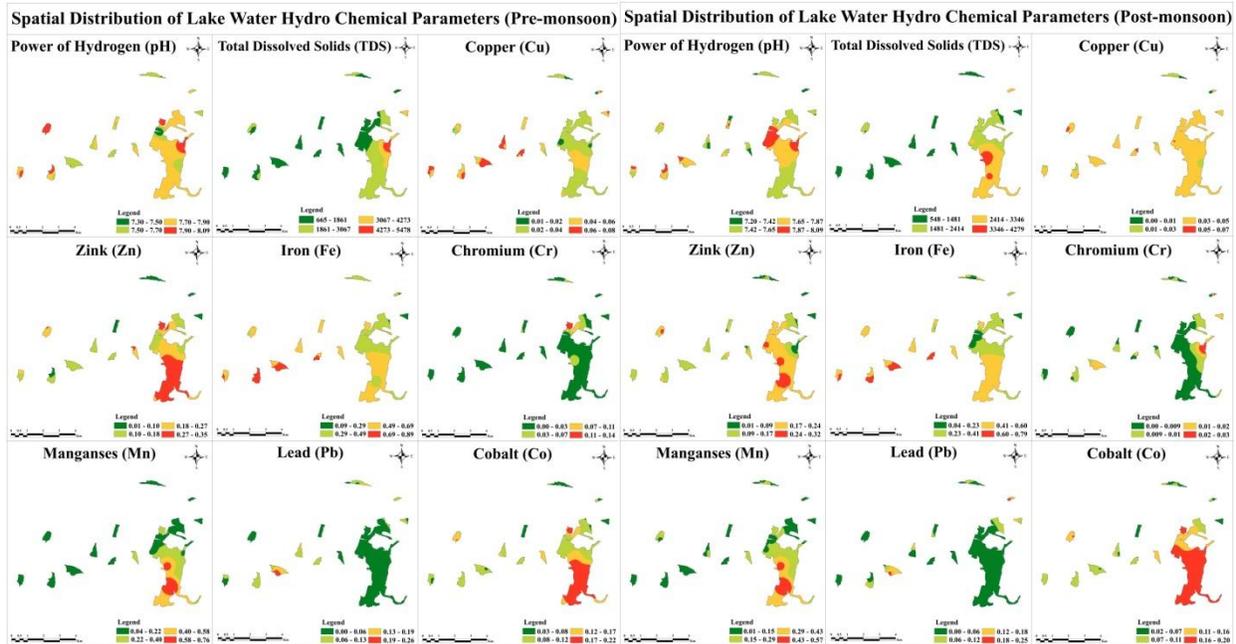


Fig 2a

Fig 2b

The summary statistics of the hydro chemical data of lakes in the study area including minimum, maximum and average values of pre-monsoon and post-monsoon are presented in Table 1. The salient hydro-geochemical characteristics of the trace metals including pH and TDS of the study area are summarized as follows: pH values of the lakewater in the region are found to be alkaline ranging from 7.30 to 8.10 with an average value of 7.72 during pre-monsoon. In the case of post-monsoon, pH values are found to be in the range of 7.20 to 8.10. All the samples are found to be alkaline and all the lakewater samples during both the monsoon periods fall within the permissible limit of BIS (BIS, 2012). Total dissolved solids (TDS) ranges from 654 to 5480mg/L with an average value 1743mg/L during pre-monsoon and in the case of post-monsoon, TDS values varies from 548 to 4280mg/L with a mean value of 1487.5mg/L. Results show that all the values during both monsoon periods are found to be higher than the desirable limit of 500mg/L.

The variation in the concentration of trace metals due to the seasonal impact was evaluated in the lakewater samples of the region. Concentration of copper during pre-monsoon was ranged from 0.01 to 0.08mg L⁻¹ with a mean value of 0.05. Results illustrate that 60% of the sample exceeds the desirable limit of 0.05mg/L but no sample exceeds the maximum permissible limit of

1.5mg/L.Cu values during post-monsoon ranges from 0.01 to 0.08 with an average value of 0.04mg/L. Though none of the values are higher than the permissible limit, relatively higher concentrations of Cu at certain zones in the region could be attributed to the agricultural activity where copper would have leached from the copper based fertilizers/pesticides(Al-Subu et al. 2003; Mirlean et al. 2009).

Spatial distribution map (Fig.2a&2b) of Cu during pre-monsoon illustrates that the southern and south-western and central part of the study area are found to have the highest concentration of copper in the range of 0.054-0.081mg/L indicating that these water are affected with respect to this metal ion as they show values higher than the desirable limit. Most of the lakes in the northern and north-western part of the region have moderate concentration of copper values well within the desirable limit of 0.05mg/L. During post-monsoon, contour map shows that the southern, southwestern and northwestern part of the study area shows higher concentration of Cu in the range of 0.05 to 0.077mg/L.

Concentration of Zn during pre-monsoon varies from 0.01 to 0.36 with a mean value of 0.16mg/L and in post-monsoon, the values of Zn ranges from 0.02 to 0.32mg/L. Results show that none of the sample exceeds the desirable limit of 5.0mg/L during both the monsoon periods (Fig. 2a& 2b). Iron values in pre-monsoon ranges from 0.10 to 0.89 with an average value of 0.53mg/L and during post-monsoon, the values varies from 0.04 to 0.79 with a mean value of 0.44mg/L. Results show that only 4 and 10 samples are found to be below the permissible limit of 0.03mg/L during pre-monsoon and post-monsoon periods respectively. Higher values of iron in the lake water could be attributed to the leaching of waste dumps adjacent to the lakes as well as inside the lakes. The domestic wastes includes many waste corroded iron pipes, fittings and other iron based articles and further leaching from the soil/rock due to rock-water interaction also increases the iron content in aqueous medium (Papachristodoulou et al. 2015, Ngah and Nwankwoala 2013). Spatial distribution map (Fig.2a& 2b) of Fe during pre-monsoon illustrates that the southern and south-western part of the study area are found to have the highest concentration of iron in the range of 0.0575-0.892mg/L indicating that these water are affected with respect to this metal ion as they show values higher than the permissible limit. Most of the lakes in the north-western and eastern part of the region have also show higher concentration of

iron values. During post-monsoon, contour map shows that the southwestern part of the study area shows the highest concentration of Fe as in the case of pre-monsoon.

Concentration of chromium during pre-monsoon ranges from 0.003 to 0.15 with a mean of 0.02mg/L and in post-monsoon, the values varies from 0.001 to 0.04 with an average value of 0.02. Results show that except 4 samples during pre-monsoon, none of the samples exceed the permissible limit of 0.05mg/L. Spatial distribution map (Fig.2a& 2b) of Cr during pre-monsoon illustrates that the eastern and northeastern part of the study area are found to have the highest concentration of chromium in the range of 0.061-0.15mg/L indicating that these lakewater are affected with respect to this metal ion as they show values higher than the permissible limit. Most of the lakes in the north-western and southern part of the region show values well within the permissible limit of chromium values. During post-monsoon, contour map shows relatively higher values in the eastern part of the study area but well within the permissible limit for chromium.

Cobalt values during pre-monsoon ranges from 0.03 to 0.22 with an average value of 0.11mg/L and in post-monsoon period, the value varies from 0.03 to 0.21 with a mean value of 0.11 mg/L (Fig.2a& 2b). Manganese values during pre-monsoon ranges from 0.04 to 0.77 with a mean of 0.18mg/L and in post-monsoon, the values varies from 0.01 to 0.58 with an average value of 0.14mg/L. Results show that 2 and 4 samples exceeds the maximum permissible limit of 0.3mg/L during pre-monsoon and post-monsoon periods respectively but most of the samples in both the monsoon periods exceeds the desirable limit. Leaching of municipal waste dumps and other domestic solid wastes increases the concentration of Mn in these waters. Consumption of water containing higher concentration of Manganese leads to various neurological disorders (WHO 2011a, b; Spangler and Reid 2010).

Spatial distribution map (Fig.2a& 2b) of Mn during pre-monsoon illustrates that the southeastern part of the study area are found to have the highest concentration of Manganese in the range of 0.187-0.768mg/L indicating that these lakes are affected with respect to this metal ion as they show values higher than the permissible limit. Most of the lakes in the northern, southwestern and northeastern part of the region show values well within the permissible limit of 0.3mg/L but

most of these lakes exceed the desirable limit of 0.1mg/L. During post-monsoon, contour map shows relatively higher values in the southeastern part of the study area where the concentration ranges from 0.24 to 0.578mg/L exceeding the permissible limit for Manganese and in all other regions, the values are less than permissible limit but demonstrates higher values than the desirable limit .

Concentration of Lead values during pre-monsoon ranges from 0.01 to 0.27 with a mean of 0.08mg/L and in post-monsoon, the values varies from 0.01 to 0.25 with an average value of 0.09mg/L. Results clearly shows that all the values during both the monsoon periods found to exceed the allowed limit of 0.01mg/L. It is because of the higher content of e-waste including Pb-based batteries in the solid waste dumps which has been continuously leached into the lake water by way slow dissolution. Further, lead containing plumbing waste materials including plasticized polyvinyl chloride (UPVC) used and scrap pipes react with the water especially with alkaline water and get leached into the aqueous medium (Zhang and Lin 2014). Usage of such water containing higher concentration of Lead leads to kidney damage and also creates hypertension to humans (WHO, 2011 a,b). Spatial distribution map (Fig.2a& 2b) of Pb during pre-monsoon illustrates that most of the region shows higher values than the permissible limit; relatively higher values are observed in the southern part of the study area where the concentration lead varies from 0.107-0.265mg/L indicating that these water are affected with respect to this metal ion as they show values higher than the permissible limit. During post-monsoon, contour map shows a relatively higher values in the southern and northeastern part of the study area where the values ranges from 0.101 to 0.251.

Correlation studies

Data obtained from the chemical analysis were used as variable inputs for statistical analysis. The experimental data were analyzed using Statistical Package for Social Sciences (SPSS) version 20.0 for statistical analysis as described by Nie et al (1985). In this study, the principal component analysis (PCA) was based on the Eigen analysis of the correlation matrix. Keen examination of correlation matrix is essential since it can clearly highlight the inter-relationships between variables that can show the overall coherence of the data set and indicate the participation of the individual chemical parameters in several influence factors, a fact which

commonly occurred in hydrochemistry (Helena et al., 2000). The correlation coefficient value exhibiting +1 or -1 between the variables reveals that there exist strong correlation and the value at zero indicates no relationship between them. In general, the geo-chemical parameters showing correlation coefficient > 0.7 are considered to be strongly correlated whereas value between 0.5 and 0.7 shows moderate correlation. The results of correlation analysis are presented in Table.2a&2b.

During pre-monsoon, Results of correlation analysis show highly significant correlation among various metal ions. Mn and Zn are found to have good correlation and also Mn have good correlation with Co indicating the industrial activity of the region increases the concentration of the metals in these water. In the case of post-monsoon, cobalt is found to have good correlation with Zinc and Manganese. During both the monsoon periods, Correlation between Fe and Mn is found to be insignificant which indicates that the co-precipitation and scavenging action of these metals are not that much significant in these lakewaters. Low positive correlation is observed between iron and zinc indicating that they might have been derived from the same source such as corrosive activity of iron-zinc alloy of household material dumps in the solid waste municipal dumps inside the lakes (WHO 2003a, 2003b; Papachristodoulou et al. 2015)

Conclusion

In the present research, geo-chemical assessment of heavy metals with regard to water quality of the study area has revealed that the pH of lakewater samples of the region indicates the values are within the permissible limit and found to be of alkaline in nature. TDS show that all the lake water samples in the study area during both monsoon periods are found to be higher than the desirable limit of 500mg/L. Among the heavy metals, Copper concentration in the water reveals that about 60% of the samples exceed the desirable limit of 0.05mg/L but no sample exceeds the maximum permissible limit of 1.5mg/L. A higher value of iron in the lake water is observed which could be attributed to the leaching of waste dumps adjacent to the lakes as well as inside the lakes. The domestic wastes includes many waste corroded iron pipes, fittings and other iron based articles and further leaching from the soil/rock due to rock-water interaction also increases the iron content in aqueous medium.

Spatial distribution of Cr illustrates that the eastern and northeastern part of the study area are found to have the highest concentration of chromium indicating that these lake water are affected with respect to this metal ion as they show values higher than the permissible limit. Manganese concentration in these waters show that few samples exceeds the maximum permissible limit of 0.3mg/L but most of the samples in both the monsoon periods exceeds the desirable limit. Lead concentration clearly shows that all the values during both the monsoon periods found to exceed the permissible limit which may be attributed to the higher content of e-waste including Pb-based batteries in the solid waste dumps which has been continuously leached into the lake water by way slow dissolution. Correlation analysis show highly significant correlation between Mn and Zn and also Mn have good correlation with Co indicating the industrial activity of the region increases the concentration of the metals in this water. Correlation between Fe and Mn is found to be insignificant which indicates that the co-precipitation and scavenging action of these metals are not that much significant in these lakewaters.

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