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HEAVY METAL CONTAMINATION IN BOTTOM SEDIMENTS OF FIVE LARGE LAKES OF RAIPUR, CHHATTISGARH, INDIA

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ABSTRACT

Entry of heavy metals into aquatic environments generally takes place due to human activities like agriculture, combustion, industrial plants, sewage and settlements. Once entered into the aquatic system the heavy metals from different sources pose risk to the aquatic ecosystem. Therefore, a detailed investigation of heavy metals (Mn, Fe, Zn, Cr, Ni, Cu, Pb, V, Co, As, Mo and Cd) concentration in the bottom sediments of five large Lakes of Raipur was carried out. The data were interpreted in terms of Geoaccumulation Index (Igeo), Enrichment factor (EF), Contamination Factor (CF), Pollution Load Index (PLI) and Modified Degree of Contamination (mCd). The study indicates that the degree of heavy metal contamination in the bottom sediments of the five large lakes of Raipur follow the order Maharaja Bandh Talab> Budha Talab > Sarju Bandh Talab > Bhaiya Taraiya Talab > Khokho Talab. Fe, Zn, Cr, Cu, Pb and Mn pose problems to the ecosystem of the Lakes. The contamination level of elements follow the order Zn>Fe>Cr>Mn>Pb. The high Fe, Cr, Cu, Zn, Pb concentrations in the sediments of Lakes are mainly caused by the use of pesticide and fertilizer in agricultural areas and runoff from settlements without sewage systems. The highly toxic heavy metals can have adverse impact on the aquatic organisms including fishes. This study warrants a detailed ecotoxicological investigation in the lakes followed by execution of Lake rejuvenation programme.

KEY WORDS : Heavy Metals, Bottom sediments, Contamination indices

INTRODUCTION

Pollution in terrestrial lakes has been a concern in the recent years. The surface runoff enters into the lakes and transport the pollutants into these depressions from agricultural fields, townships and industrial sectors. The result is eutrophication and toxicity to the organisms in lakes. Once carried out into the lakes the toxic elements because of their high specific gravity (>5) gets deposited into the bottom sediments. It is therefore imperative to investigate the bottom sediments of lakes and ponds because these water bodies in many parts of the world supplies water to the households, industrial and agricultural and fishery sectors.

Lake sediments mostly act as a sink for heavy metals and therefore lake bottom sediments can also act as source of heavy metals to the overlying water and affect the aquatic ecology (Tevenon *et al.,* 2011; Varol and Sen, 2012). The degree of heavy metal pollution of lake bottom sediment and the probable risks due to these metals is assessed using geoaccumulation indices (Igeos), enrichment factors (EFs), contamination factors (CFs), pollution load indices (PLIs) and modified degree of contamination (mCd) (Abrahim and Parker, 2008; Ali *et al.,* 2015; Xu *et al.,* 2017; Salem *et al.*, 2019; Algul and Beyhan, 2020).

Surrounding Raipur city there are several lakes which have unique ecological qualities, though in recent decade pollution has deteriorated the water quality and bottom sediments are likely to have higher concentration of heavy metals. The main sources of pollutants are runoff from agriculture, settlements and development areas. Jena *et al.* (2019) analysed 10 samples from different lakes of Raipur and found that based on Igeo and EF two locations are extremely enriched with all heavy metals. However, this study does not provide the sampling locations. Therefore, the present investigation is aimed at the examination of heavy metal (V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Mo, Cd, Pb) contamination level in the bottom sediments in five selected large lakes in the southern part of Raipur viz. Budha Talab, Maharaja Bandh Talab, Bhaiya Taraiya Talab, Khokho Talab and Sarju Bandh Talab (Fig.1).

MATERIALS AND METHODS

Samples were collected from three locations of each lake using hand driven push-tubes. The collected samples were kept in polythene bag and brought to the laboratory. The samples were dried, powdered with a mortar and pestle and passed through ASTM sieve. The first sample was discarded to prevent contamination from the mortar or sieve. All containers, pipettes, pipette tips were soaked in 2% HNO_3. The acid digestion requires a mixture of strong acids due to the presence of low soluble constituents, common in rock samples, such as silicates or clays. Powdered samples were digested with 2 ml ultrapure concentrated per chloric acid ($HClO_4$), and 1ml 1% trace metal grade nitric acid

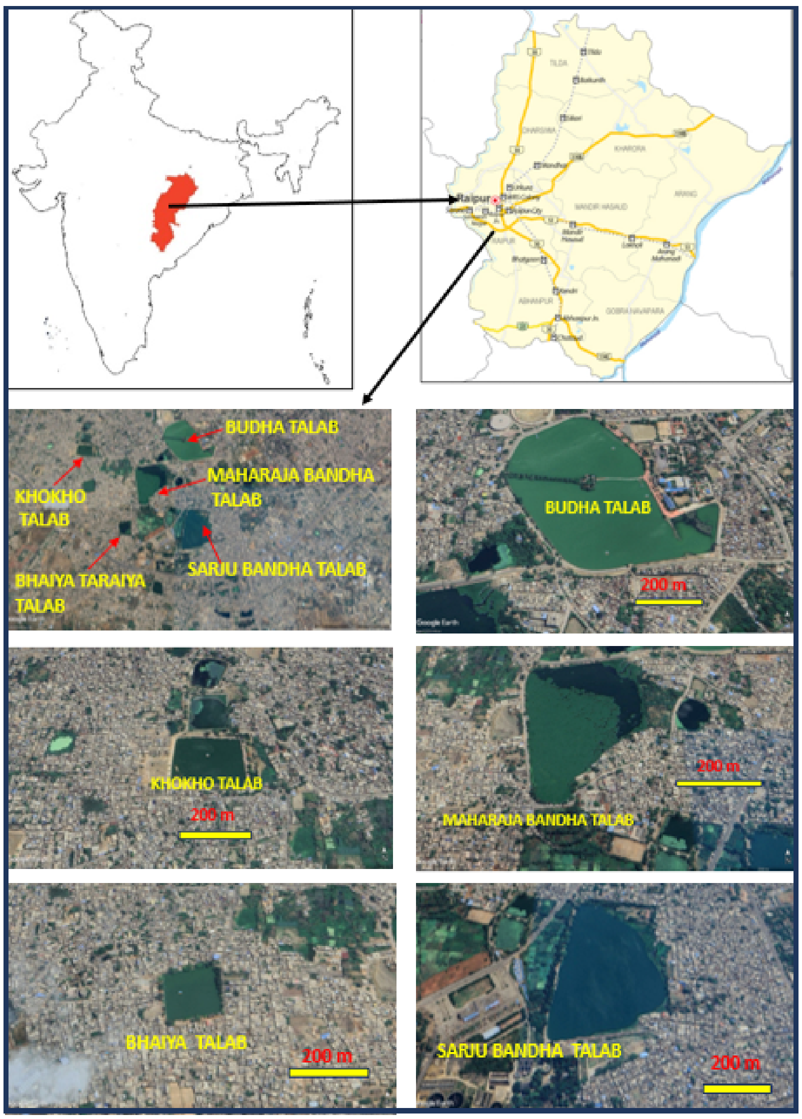


Fig. 1. Map showing the location and surrounding Land use/ Land cover of the ponds (Budha Talab, Maharaja Bandh Talab, Bhaiya Taraiya Talab, Khokho Talab and Sarju Bandh Talab)

(HNO_3) and 1ml HF. After dilution, the samples were filtered through a 0.25 µm membrane to remove particulates. The liquid samples were analysed under ICP-MS to determine the heavy metal concentration in samples.

To examine the pollution level of bottom sediments of the lakes Geoaccumulation Index (Igeo), Enrichment factor (EF), Contamination Factor (CF), Pollution Load Index (PLI) and Modified Degree of Contamination (mCd) proposed by different workers were calculated using the formulae and referred to the Criteria levels (Table 1). The Background concentrations considered in the calculation are those given in Rudnic and Gao, (2003).

RESULTS AND DISCUSSION

In the five lake bottom sediment samples higher concentration are observed in case of Mn, Fe and Zn. The Mn concentration (Wt%) ranges from 0.38 to 1.76 mg/Kg with highest concentration reported

Table 1. Different indices values to estimate the contamination level

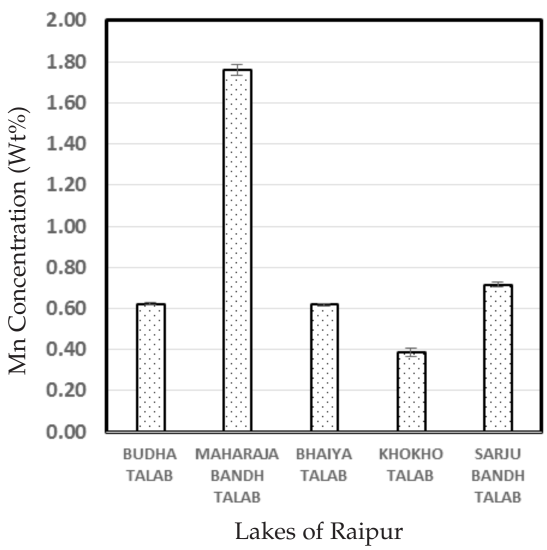
Index	Formula	Criteria	
		Values	Label
Geoaccumulation Index	$I_{geo} = \log_2(C_n/1.5 \times B_n)$	$I_{geo} \leq 0$	Uncontaminated
	References: Abata *et al.* (2016);	$0<I_{geo}\leq 1$	Uncontaminated to Moderately Contaminated
	Ho *et al.*, 2010;		
		$1\leq I_{geo}\leq 2$	Moderately Contaminated
		$2\leq I_{geo}\leq 3$	Moderately to heavily Contaminated
		$3\leq I_{geo}\leq 4$	Heavily Contaminated
		$4\leq I_{geo}\leq 5$	Heavily to extremely Contaminated
		$I_{geo}>5$	Extremely Contaminated
Enrichment factor	$EF=(M/Fe)_{sample}/(M/Fe)_{background}$	EF>1.5	Human Influence
	References:Abata *et al.* (2016);	1.5<EF<3	Minor Modification
	Sinex and Helz (1981)	3<EF<5	Moderate Modification
		5<EF<10	Severe Modification
		EF>10	Very Severe Modification
Contamination Factor	$CF=C_{metal}/C_{background}$		
	References: Harikrishnan *et al.* (2017);	CF<1	Low Contamination
	Hakanson (1980)	1<CF<3	Moderate Contamination
		3<CF<6	Considerable Contamination
		CF>6	High Contamination
Pollution Load Index	$PLI=(CF_1 \times CF_2 \times \ldots \times CF_n)^{1/n}$	PLI<1	Uncontaminated
	*References:*Tomlison *et al.* (1980)	PLI>1	Contaminated
Modified Degree of Contamination	$mCd=(CF_1+CF_2+\ldots+CF_n)/n$	mCd<1.5	Nil to very Low degree of Contamination
	References: Abrahim and Parker (2008)		
		1.5≤mCd<2	Low Degree of Contamination
		2≤mCd<4	Moderate degree of Contamination
		4≤mCd<8	High Degree of Contamination
		8≤mCd<16	Very High Degree of Contamination
		16≤mCd<32	Extremely High Degree of Contamination
		mCd≥32	Ultra High Degree of Contamination

Background value refers to metal concentration in upper crust given in Rudnic and Gao (2003)
M- Metal Concentration, Cn-Sample Concentration, Bn-Background Concentration

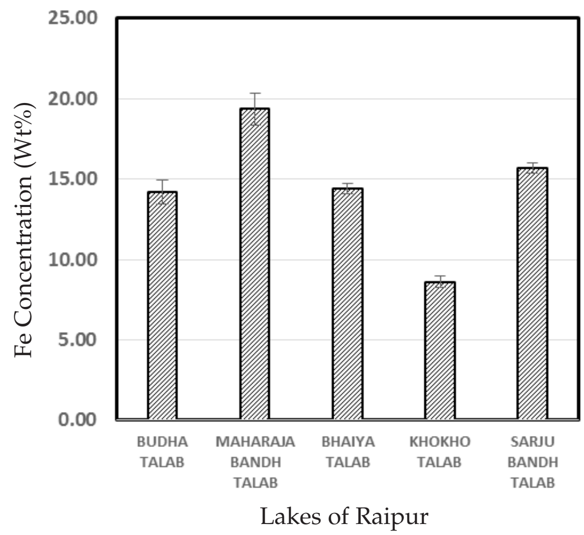
from Maharajah Bandh Talab (Table 2, Fig.2a). The Fe concentration (wt%) ranges from 8.61 to 9.36 mg/Kg with highest concentration reported from Maharaja Bandh Talab and lowest value from Khokho Talab (Table 2, Fig. 2b). The Zn concentration (mg/Kg) ranges from 107 to 410 mg/Kg with highest concentration reported from Maharaja Bandh Talab and lowest value from KhokhoTalab (Table 2, Fig. 2c).

The Cr concentration ranges from 0.79 to 3.04 mg/Kg with highest concentration reported from Maharajah Bandh Talab and lowest value from Khokho Talab (Table 2, Fig. 3). The Ni concentration ranges from 0.74 to 1.96 mg/Kg with highest concentration reported from Maharaja Bandh Talab and lowest value from Khokho Talab (Table 2, Fig.3). The Cu concentration ranges from 0.09 to 0.82 mg/Kg with highest concentration reported from Maharaja Bandh Talab and lowest value from Sarju Bandh Talab (Table 2, Fig. 3). The Pb concentration ranges from 0.003 to 0.49 mg/Kg with highest concentration reported from Budha Talab and lowest value from Sarju Bandh Talab (Table 2, Fig.3).

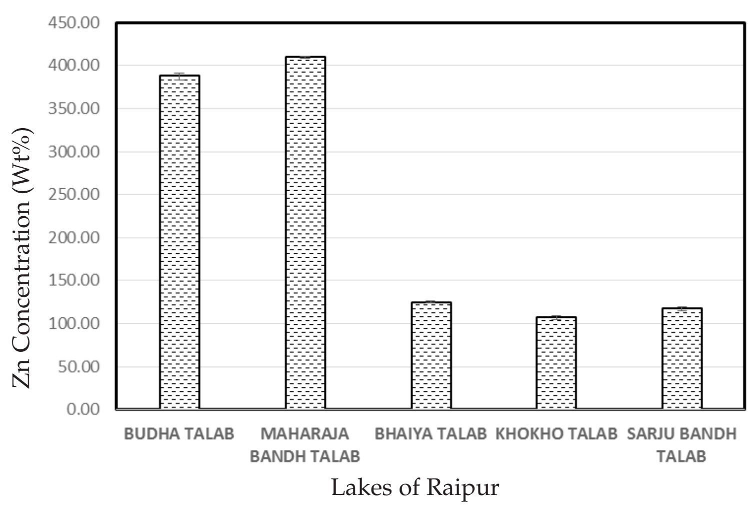
The V concentration ranges from 0.01 to 0.04 mg/Kg with highest value reported from Maharaja bandh Talab (Table 2, Fig.4). The Co concentration ranges from 0.01 to 0.04 mg/Kg with highest value reported from Maharaja Budha Talab (Table 2, Fig.4). The As concentration ranges from 0.04 to 0.16 mg/Kg with highest concentration reported from



(a)



(b)



(c)

Fig. 2. Manganese (a), Iron (b) and Zinc (c) Concentration in the bottom sediments of the Raipur lakes

Maharaja Bandh Talab and lowest value from Sarju Bandh Talab (Table 2, Fig.4). The Mo concentration ranges from 0.003 to 0.028 mg/Kg with highest concentration reported from Maharaja Bandh Talab and lowest value from Khokho Talab (Table 2, Fig.4). The Cd concentration ranges from 0.001 to 0.054 mg/Kg with highest concentration reported from Budha Talab and lowest value from Bhaiya Taraiya Talab (Table 2, Fig.4).

The heavy metal concentration ranges indicate that The Maharaja Bandh talab and Budha Talab bottom sediments have higher heavy metal concentration compared to other three lakes viz. Bhaiya Taraiya Talab, Khokho Talab and Sarju Bandh Talab.

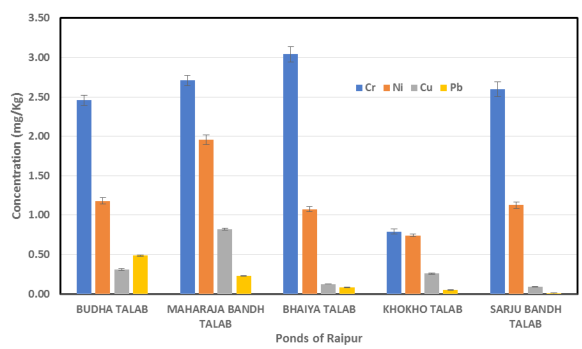


Fig. 3. Chromium, Nickel, Copper and Lead concentration in the bottom sediments of the Raipur lakes

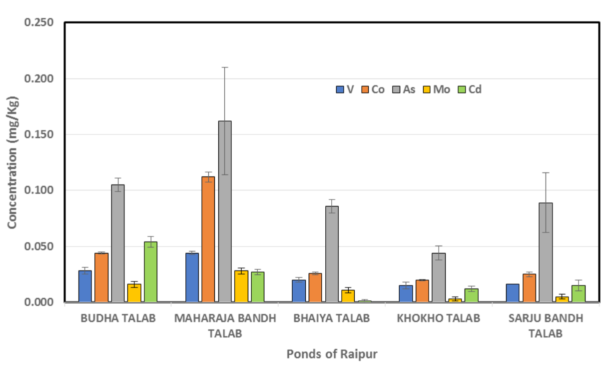


Fig. 4. Vanadium, Cobalt, Arsenic, Molybdenum and Cadmium concentration in the bottom sediments of the Raipur lakes

The Igeo is an important method to interpret the quality of sediment for each sampling station (Nilin *et al.* 2013). The Igeo values for Mn is <1 for bottom sediments of all the lakes and therefore there is no Mn contamination in the Lakes of Raipur (Table 2). In terms of Fe, all the lakes except Khokho Talab are extremely contaminated. In terms of Zn and Cr the bottom sediments of all the lakes are extremely contaminated with ranges of Igeo values 12.22-14.88 and 5.59 to 7.54, respectively. In terms of Ni, the bottom sediments of all the lakes except Khokho Talab are extremely contaminated. In terms of Cu the bottom sediments of the Maharaja Bandh Talab is Heavily contaminated (Igeo=3.94), Budha Talab and Khokho Talab are Moderately to Heavily contaminated (Igeo=2.27-2.52), Bhaya Taraiya Talab is Uncontaminated to Moderately Contaminated (1.22), Sarju Bandh Talab is Uncontaminated. In terms of Pb, the bottom sediments of Budha Talab is Moderately to Heavily contaminated (Igeo=2.46), Maharaja Bandh Talab is Moderately Contaminated (Igeo=1.39) and other three lakes are uncontaminated. In terms of V, the bottom sediments of Maharaja Bandh Talab is Moderately contaminated (Igeo=1.51), and Budha talab and Bhaiya Talab are Uncontaminated to Moderately Contaminated (Igeo= 0.37, 0.86), other lakes are uncontaminated. In terms of Co, As, Mo and Cd all the bottom sediments of all the lakes are uncontaminated.

The Enrichment Factor (EF) was also used to assess the possibility of anthropogenic impact on elemental concentrations in the sediments (Kowalska *et al.*, 2016). The choice of background value for the calculation of the EF played an important role in providing equitable interpretation of elemental pollution in the sediments. In this study Fe was used as the reference element. The Enrichment Factor values indicate that there is indication of human influence in bottom sediments of all the lakes in terms of Mn (EF=2.17 to 4.60) with Moderate modifications in Maharaja Bandh Talab.

The contamination factor (CF) was used to determine the contamination status of the sediment in the present study. In terms of Mn, the bottom sediments of all the lakes except Khokho Talab are showing high contamination (CF>6), with highest contamination in Maharaja Bandh Talab (CF=22.72); the Khokho Talab shows considerable contamination (Table 2). In terms of Fe, the bottom sediments of all the lakes except Khokho Talab are showing considerable contamination; the Khokho Talab is showing Moderate contamination (CF=2.19). In terms of Zn, the bottom sediments of Maharajah Bandh Talab shows high contamination (CF=6.11), Budha Talab is showing Considerable Contamination (CF=5.78) and other three lakes showing Moderate Contamination (CF=1.5-1.8).

When we consider all the elements the Pollution Load Index (PLI) value becomes very low (PLI=0.03

Table 2. Concentration of different Heavy metals in the lake bottom sediments of Raipur (Mn and Fe are in wt% and other elemental concentrations are in mg/Kg)

Elements	Budha Talab	Maharaja Bandh Talab	Bhaiya Taraiya Talab	Khokho Talab	Sarju Bandh Talab
Mn	0.623 ± 0.005	1.76 ± 0.027	0.619 ± 0.006	0.387 ± 0.018	0.715 ± 0.013
Fe	14.203 ± 0.739	19.357 ± 0.982	14.422 ± 0.320	8.61 ± 0.335	15.674 ± 0.330
Zn	388 ± 4.171	410 ± 1.230	125 ± 1.066	107 ± 2.013	117 ± 2.271
Cr	2.457 ± 0.062	2.709 ± 0.068	3.043 ± 0.098	0.79 ± 0.01	2.596 ± 0.094
Ni	1.18 ± 0.040	1.956 ± 0.061	1.076 ± 0.034	0.742 ± 0.016	1.127 ± 0.042
Cu	0.309 ± 0.015	0.823 ± 0.012	0.125 ± 0.002	0.259 ± 0.008	0.091 ± 0.003
Pb	0.486 ± 0.007	0.231 ± 0.004	0.081 ± 0.006	0.049 ± 0.008	0.003 ± 0.006
V	0.028 ± 0.003	0.044 ± 0.002	0.02 ± 0.002	0.015 ± 0.003	0.016 ± 0.001
Co	0.044 ± 0.001	0.112 ± 0.005	0.026 ± 0.001	0.02 ± 0.001	0.025 ± 0.002
As	0.105 ± 0.006	0.162 ± 0.048	0.086 ± 0.006	0.044 ± 0.006	0.089 ± 0.027
Mo	0.016 ± 0.003	0.028 ± 0.003	0.011 ± 0.002	0.003 ± 0.002	0.005 ± 0.002
Cd	0.054 ± 0.005	0.027 ± 0.003	0.001 ± 0.001	0.012 ± 0.003	0.015 ± 0.005
Geoaccumulation Factor (Igeo)					
Mn	-4.96	-3.46	-4.97	-5.65	-4.76
Fe	5.21	5.66	5.24	4.49	5.36
Zn	14.08	14.16	12.44	12.22	12.35
Cr	7.24	7.38	7.54	5.59	7.31
Ni	5.21	5.94	5.08	4.54	5.14
Cu	2.52	3.94	1.22	2.27	0.76
Pb	2.46	1.39	-0.12	-0.85	-4.88
V	0.86	1.51	0.37	-0.04	0.05
Co	-0.98	0.37	-1.74	-2.12	-1.79
As	-1.57	-0.95	-1.86	-2.83	-1.81
Mo	-6.41	-5.61	-6.95	-8.83	-8.09
Cd	-8.27	-9.27	-14.02	-10.44	-10.12
Enrichment factor (EF)					
Mn	2.22057	4.60121	2.17265	2.27495	2.30941
Fe	1.00083	1.00046	1.00075	1.00061	1.00087
Zn	1.59685	1.23805	0.50643	0.72694	0.43732
Cr	0.00737	0.00596	0.00899	0.00391	0.00706
Ni	0.00693	0.00843	0.00622	0.00719	0.00600
Cu	0.00305	0.00595	0.00121	0.00421	0.00081
Pb	0.00789	0.00275	0.00130	0.00131	0.00004
V	0.00008	0.00009	0.00006	0.00007	0.00004
Co	0.00070	0.00131	0.00041	0.00053	0.00036
As	0.00604	0.00683	0.00487	0.00417	0.00464
Mo	0.00402	0.00515	0.00272	0.00124	0.00114
Cd	0.16563	0.06074	0.00302	0.06070	0.04169
Contamination factor (CF)					
Mn	8.0439	22.7243	7.9923	4.9968	9.2318
Fe	3.6254	4.9410	3.6813	2.1978	4.0009
Zn	5.7845	6.1145	1.8629	1.5967	1.7481
Cr	0.0267	0.0294	0.0331	0.0086	0.0282
Ni	0.0251	0.0416	0.0229	0.0158	0.0240
Cu	0.0110	0.0294	0.0045	0.0093	0.0033
Pb	0.0286	0.0136	0.0048	0.0029	0.0002
V	0.0003	0.0005	0.0002	0.0002	0.0002
Co	0.0025	0.0065	0.0015	0.0012	0.0014
As	0.0219	0.0338	0.0179	0.0092	0.0185
Mo	0.0145	0.0255	0.0100	0.0027	0.0045
PLI	0.06	0.09	0.03	0.02	0.03
PLI (3)	2.60	3.23	0.69	1.14	1.83
PLI(4)	0.94	1.00	0.69	0.69	0.86
mCd	1.52	2.86	1.14	0.75	1.27

to 0.09) indicating that the Lake bottom sediments are uncontaminated. When we consider four elements viz. Mn, Fe, Zn and Cr the PLI varies from 0.69 to 1 with highest calculated value from Maharaja Bandh Talab. On the other hand, considering Mn, Fe and Zn the PLI values for lake bottom sediments ranging from 0.69 to 3.23 suggests that the Bhaiya Taraiya Talab is uncontaminated while the other four lakes are contaminated (PLI=1.14-3.23). The Maharajah Bandha talab is highly contaminated (PLI=3.23).

An intrinsic feature of the Modified Degree of Contamination (mCd) index is that it produces an overall average value for a range of pollutants (Abrahim and Parker, 2008). This index value indicates that the bottom sediments of Maharaja Bandh Talab shows moderate degree of Contamination (mCd=2.86) and the Khokho Talab shows Nil to very low degree of contamination (mCd=0.75) while the other four lakes show Low Degree of Contamination (1.14-1.52).

CONCLUSION

Taking all the results into consideration, we conclude that the degree of heavy metal contamination in the bottom sediments of the five large lakes of Raipur follow the order Maharaja Bandh Talab> Budha Talab > Sarju Bandh Talab > Bhaiya Taraiya Talab > Khokho Talab. Fe, Zn, Cr, Cu,, Pb and Mn pose problems to the ecosystem of the Lakes. The contamination level of elements follow the order Zn>Fe>Cr>Mn>Pb. The high Fe, Cr, Cu, Zn, Pb concentrations in the sediments of Lakes are mainly caused by the use of pesticide and fertilizer in agricultural areas, runoff from settlements without sewage systems. These Lakes are potential pisciculture areas. The highly toxic heavy metals can have adverse impact on the aquatic organisms and particularly the fishes harvested in these lakes. The results from this investigation advocate restoration of Lakes of Raipur which requires the local government to implement measures to prevent heavy metal pollution in these lakes, particularly in relation to Fe, Zn, Cr and Pb. The restoration activities require to begin with aware the fishermen of the harms of toxic chemicals to the fish and ecosystem. For clear understanding of the ecological risk caused by the heavy metals in these lakes, ecotoxicological studies on the responses of the biota to these toxic metals are to be conducted.

Conflict of Interest - None

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