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Characterization of heavy metals in water and sediment of river Ganga through index analysis approach

Ruby Pandey[1], Divya Raghuvanshi[2], Anupam Dixhit[3]

1.Botany Department, University of Allahabad, India; Email id:rubypandeybotanyau@gmail.com
2.Botany Department, University of Allahabad, India; Email id: divyaraghuvanshi11@gmail.com
3.Botany Department, University of Allahabad, India; Email id: anupambplau@rediffmail.com

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ABSTRACT

The Ganga, is one of the most sacred and worshipped river of India, is regarded as the cradle of Indian civilization. The major objectives of the present study were to investigate heavy metal's concentration in water and sediments of the River Ganga along the different locations of Allahabad city *viz:* Chatnaag, Sangam, Phaphamau and Shringverpur. Water and sediments collected from four locations were analysed for Iron (Fe), Chromium (Cr), Cadmium (Cd), Lead (Pb) and Manganese (Mn) with Atomic Absorption Spectrophotometer. Contamination Factor (CF), Contamination Degree (CD), Pollution Load Index (PLI) were used to assess the degree of accumulation of heavy metals in sediments. The results showed that the contamination degree (CD) of heavy metals at Chatnaag site is maximum (6.772) and minimum at Sangam ghatt (2.796) whereas maximum Pollution load index (PLI) of heavy metals found at Phaphamau site (0.272) in compare to Sangam ghatt (0.093). A correlation matrix test was carried out to check the

significant relationship between heavy metals in water & sediment ($p< 0.01$ & $p<0.05$). Correlation coefficient showed highly significant positive relationship between heavy metals. The study revealed that the order of heavy metals contamination at the study sites was: Phaphamau >Chatnaag Ghat > Shringverpur> Sangam

Keywords: River Ganga, Heavy metals, Contamination Factor (CF), Contamination degree (CD), Pollution load index (PLI), Correlation

1. INTRODUCTION

Water is one of the weirdest compounds and known for the elixir of life. In India, the water of many rivers has a unique place in all the religious activities. A large numbers of rivers & ponds have great religious significance. The religious sentiments of many pilgrims are so strong that they still regard these waters as pure and holy and drink it. Ganga River is one of them, most holiest river of India and has served as cradle for Indian civilization. Due to increase of population, urbanization and industrialization, the water quality of River Ganga has been damaged from domestic sewage and industrial effluents that contain large number of chemicals and heavy metals. Today, over 29 cities, 70 towns, and thousands of villages extends along the Ganga banks. Nearly all of their sewage - over 1.3 billion liters per day goes directly into the river, along with thousands of animal carcasses, mainly cattle [Bharadwaj et al., 2011]. Waste materials react with each other as a result the water is polluted and may become toxic which ultimately makes the water unpotable and also severely affect the bio-productivity of the aquatic system.Heavy metals are regarded as serious pollutants of aquatic ecosystems because of their environmental persistence, toxicity and ability to be incorporated into food chains (Forstner and wittman, 1983. Dmirbas *et al.,* 2005). Sediments are preferable monitoring tools since contaminant concentrations are orders of magnitude higher and they show less variation in time and space, allowing more consistent assessment of spatial and temporal contamination (Beiras *et al.,* 2003; Caccia *et al.,* 2003). The major activities responsible for river pollution in Allahabad are due to sewage discharge, agriculture and industrial effluents mainly from Naini industrial area, Phaphamau area and Phulpur fertilizers factory which directly discharge into the river. The existing Sewage Treatment plants (STP) at Gaughat and Rajapur are not able to cope with the situation.

The aim of this study is to assess the level of selected metal concentration in water and sediment in Ganga river at Allahabad examining the occurrence and distribution of metals and explore the natural and anthropogenic input of heavy metals and to assess the pollution status on the area and to highlight relationship among metals.

2. MATERIAL & METHODS

2.1. Study area

Allahabad is located in the southern part of the state of Uttar Pradesh, It spread across an area of 3,424 km^2 and lies between North latitudes 24°47′ and 25°47′ and East longitudes 81°09′ and 82°21′ with total population of 62,36,447 as per 2001 census (density: 85 persons/ km2*)*. It is considered a very sacred place as it is located where rivers Ganges, Saraswati and Yamuna unite. Being the oldest Indian city, it has many temples and also plays an important role in Hindu scriptures.

2.2. Sampling procedures and preservation

Water and sediment samples were collected from four sites at Allahabad viz: Shringverpur, Phaphamau, Sangam and Chatnaag, during January, 2015 period. Water samples were collected at 10-15 cm depth in pre-conditioned and acid rinsed clean polypropylene bottles (Ahdy and Khaled, 2009). The samples were immediately acidified with concentrated nitric acid to a pH below 2.0 to minimise precipitation and adsorption onto container walls (APHA, 2005). Surface sediment samples were taken at a depth of about 5 cm and immediately transferred into pre-cleaned polythene bags. The collected samples were oven dried at 40°C for 48 hours, homogenised, sealed in clean polythene bags and then stored at 4°C for further processing (Yongming *et al.,* 2006; Suthar *et al.,* 2009).

2.3. Sample analyses

For the determination of heavy metals in the samples, extraction procedures as described in APHA (2005) were followed. Hot plate digestion of water and sediment samples was carried out with tri-acid Nitric acid-Sulphuric acid-Perchloric acid (10 part HNO3 + 1 part H2SO4 + 4 part HClO4) mixture. The digested samples were filtered through Whatman No. 42 filters and made up to 25 ml by

adding double-distilled water in a volumetric flask. Heavy metal concentrations (Fe, Cr, Pb, Cd, and Mn) were determined using Atomic Absorption Spectrophotometer.

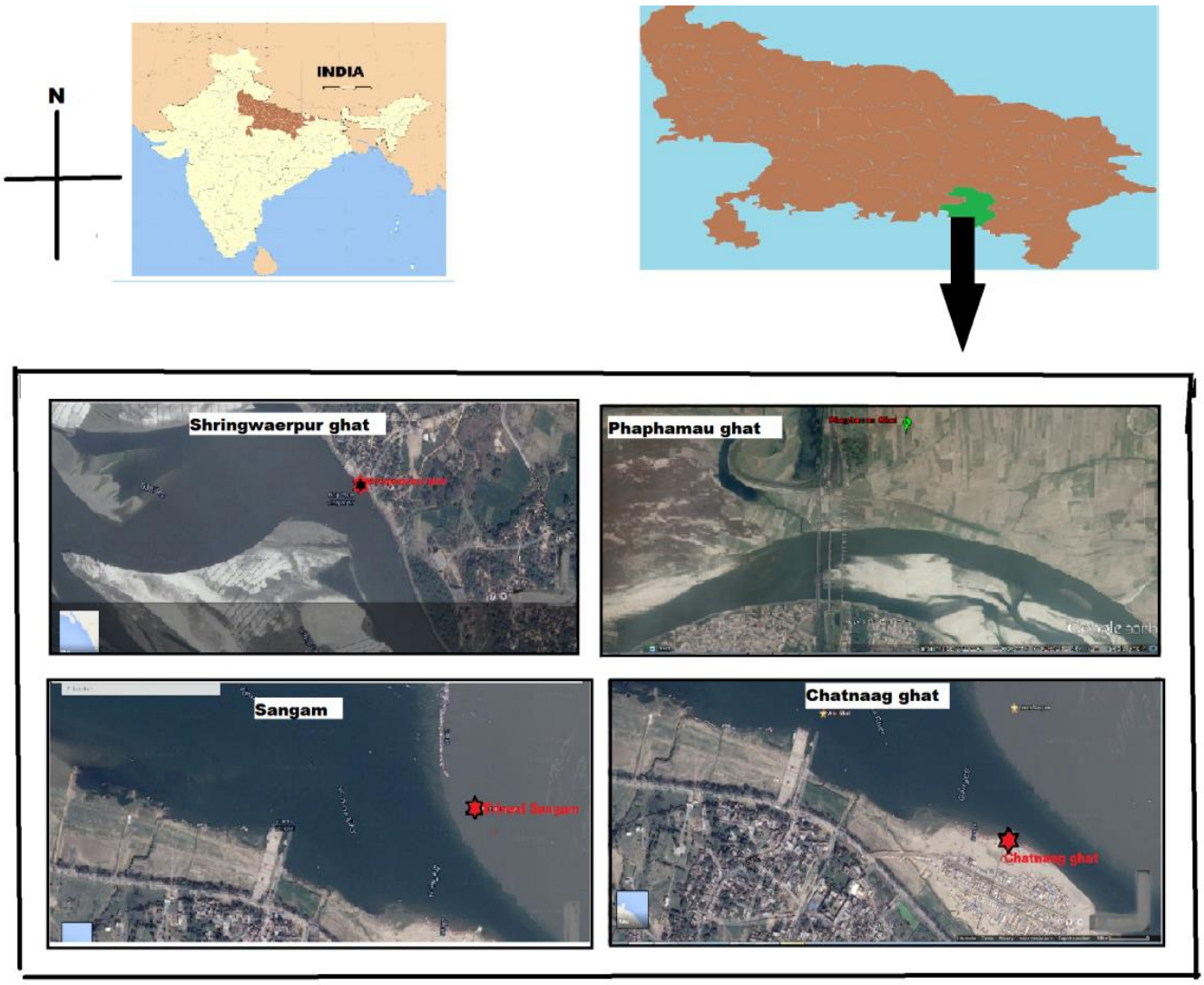

Figure 1 Study area showing four sites along the River Ganga at Allahabad *(Source: www.mapsofindia.com and www.googleearth.com. Map not to scale)*

2.4. Statistical Analysis & Determination of Contamination Factor (C.F) & Contamination Degree (CD)

Contamination factor (Cf) is an arithmetically calculated index, depending on a linear proportion between the concentrations of the metal in the sample taken from study area and earth crust (Hakanson, 1980; Pekey et al., 2004). Concentration values of each surface sample were compared to the background values of average rocks of earth crust (Turekian and Wedepohl, 1961) and according to following formula (Hakanson, 1980; Pekey et al., 2004).

CF for each metal was determined by

$$CF = \frac{\text{Observed metal Concentration}}{\text{Background concentration of the same metal}}$$

CD for each site was calculated as sum of all contamination factors (Ahdy and khaled, 2009).

2.5. Determination of Pollution Load Index (PLI)

Pollution load index for each site was determined following the method proposed by Tomlinson et al., (1980). The PLI for a single site is the *n*th root of *n* number multiplying the factors (CF values) together. PLI for each site was determined by

$$PLI = \sqrt[n]{(CF_1 * CF_2 * CF_3 * \ldots\ldots\ldots\ldots\ldots * CF_n)}$$

Where, CF is the contamination factor and n is the number of parameters.

3. RESULT AND DISCUSSION

3.1. Heavy metals

Concentrations of five heavy metals in water and sediments recorded at different sites of Allahabad *viz:* Chatnaag, Sangam, Phaphamau and Shringverpur showed in table 1. The concentration of Fe is much higher at most of the sites as compared to other metals in both water and sediments. Based on the concentration range and abundance of heavy metals in water and sediments are ranked as Fe > Cr > Pb > Mn > Cd and Fe > Mn > Pb > Cr > Cd respectively. Due to assessment and occurrence of maximum concentration of heavy metals in both water and sediment, Chatnaag site is most one polluted place in Allahabad.

Table 1 Concentration of heavy metals in water and sediment

Concentration of Heavy Metals in Water

S.n	Sites	Heavy Metals				
		Fe	Cr	Cd	Pb	Mn
1.	Chatnaag	1.94	0.30	0.029	0.284	0.055
2.	Sangam	0.054	0.13	0.027	0.248	0.036
3.	Phaphamau	1.523	0.28	0.025	0.254	0.048
4.	Shringverpur	1.109	0.22	0.019	0.247	0.032

Concentration of Heavy Metals in Sediments

S.n	Sites	Heavy Metals				
		Fe	Cr	Cd	Pb	Mn
1.	Chatnaag	687.41	6.40	1.85	8.49	85.96
2.	Sangam	516.48	2.41	0.74	5.02	28.68
3.	Phaphamau	643.94	5.92	1.08	6.35	71.38
4.	Shringverpur	617.03	4.86	0.97	5.98	67.84

3.2. Statistical Analyses

Pearson's correlation coefficient matrix among the selected heavy metals in both water and sediments is showed in Table 2 and Table 3 respectively. Significant correlation in water between the contaminants of Fe and Cr (r = 0.992), Pb and Mn (r = 0.989), Fe and Pb (r= 0.719) could indicate the same or similar source input. Heavy metals showing very high correlation may indicate same origin and controlling factors (Rafiei et al., 2010). Strong association was also noted between Fe-Mn and Cr-Pb. In most cases, however there are no significant correlations among most of these heavy metals, suggesting that these metals aren't associated with each other. Correlation analysis between heavy metals in sediments also showed that almost heavy metals were significantly

positive correlated with each other except Cd & Mn (r = - .075). Heavy metals in environment usually have complicated relationship among them (Li et al., 2012).

Table 2 Correlation Coefficient between metals in River water

		Fe	Cr	Cd	Pb	Mn
Fe	Correlation	1	.992**	.115	.719	.657
	Significance		.008	.885	.281	.343
Cr	Correlation		1	.142	.683	.603
	Significance			.858	.317	.397
Cd	Correlation			1	.663	.627
	Significance				.337	.373
Pb	Correlation				1	.989*
	Significance					.011
Mn	Correlation					1
	Significance					

Table 3 Correlation Coefficient between metals in River Sediments

		Fe	Cr	Cd	Pb	Mn
Fe	Correlation	1	.970*	.907	.943	.252
	Significance		.30	.093	.057	.748
Cr	Correlation		1	.778	.830	.427
	Significance			.222	.166	.573
Cd	Correlation			1	.995**	-.075
	Significance				.005	.925
Pb	Correlation				1	-.015
	Significance					.985
Mn	Correlation					1
	Significance					
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

3.3. Contamination factor (CF)

CF and CD terms are used to gauging the pollution load of the sediments with concerning heavy metals. CF values for heavy metals recorded at five different sampling sites are depicted in Table 4. Hakanson (1980) has provided four grade ratings of sediments based on CF values depicted in Table 5. Maximum values of CF for Cd were noticed for sediment of at Chatnaag site while the minimum CF was recorded at Sangam site, which showed by figure 2. Chatnaag site had high CF value for Cd according to the

Hakanson's classification, while the rest of investigated sites recorded a moderate & considerable contamination for this metal. All sites in the present study recorded low contamination factor for Fe, Cr, Pb and Mn except Phaphamau site, which exhibited moderate contamination for Mn only.

CD is the simply sum of all CF values of a particular sampling site. Ahdy and Khaled (2009) classified CD in terms of four grade ratings of sediments depicted in Table 5. Chatnaag site recorded the maximum value of degree of contamination while at Sangam site recorded the lowest degree of contamination depicted in Table 4. Chatnaag site recorded moderate degree of contamination while rest of sites revealed low degree of contamination.

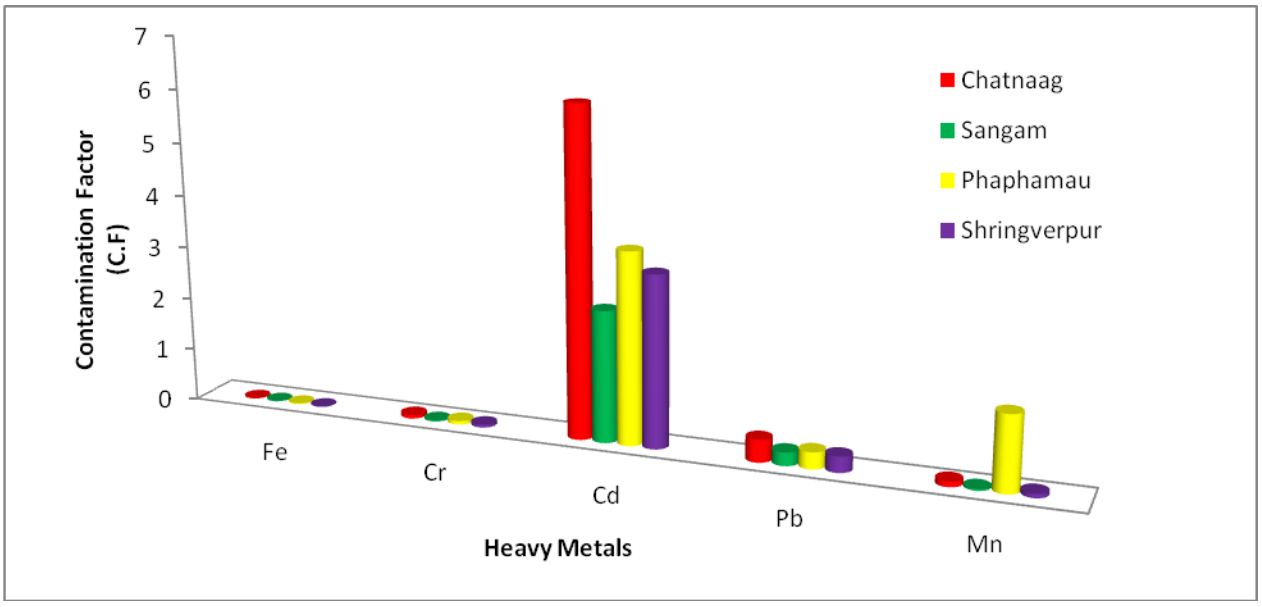

Figure 2 Contamination levels of heavy metals in sediments at four sampling sites in Allahabad

Table 4 Contamination factor, contamination degree and PLI values

	Contamination Factor				
S.N	Parameters	Chatnaag	Sangam	Phaphamau	Shringverpur
1.	Fe	0.015	0.012	0.014	0.0134
2.	Cr	0.071	0.027	0.066	0.054
3.	Cd	6.16	2.472	3.604	3.231
4.	Pb	0.425	0.251	0.317	0.299
5.	Mn	0.101	0.034	1.423	0.079
Contamination Degree (CD)		6.772	2.796	5.423	3.671
PLI		0.195	0.093	0.272	0.141

Table 5 Index classifications of sediment quality

CF values Hakanson (1980)	Class	Sediment quality
CF < 1	1	Low CF
1 ≤ CF <3	2	Moderate CF
3 ≤ CF < 6	3	Considerable CF
CF ≥ 6	4	High CF

CD values Ahdy & Khaled (2009)	Class	Sediment quality
CD < 6	1	Low CD
6 ≤ CD < 12	2	Moderate CD
12 ≤ CD < 24	3	Considerable CD
CD ≥ 24	4	High CD

3.4. Pollution Load Index

The Pollution Load Index (PLI) is depicted in Table 4. According to Mohiuddin et al., (2010), PLI = 0 indicates perfection; PLI = 1 points indicate only baseline levels of pollutants present and PLI > 1 would indicate progressive deterioration of sites. PLI values of sediments of all the studied sites exhibited close to zero in Table 4, reflecting unpolluted nature of sediments. PLI can provide some understanding to the public of the area about the quality of a component of their environment and indicates the trend over time and area. CD and PLI both are used in combination to observe the sediments quality at selected sites showed in Figure 3.

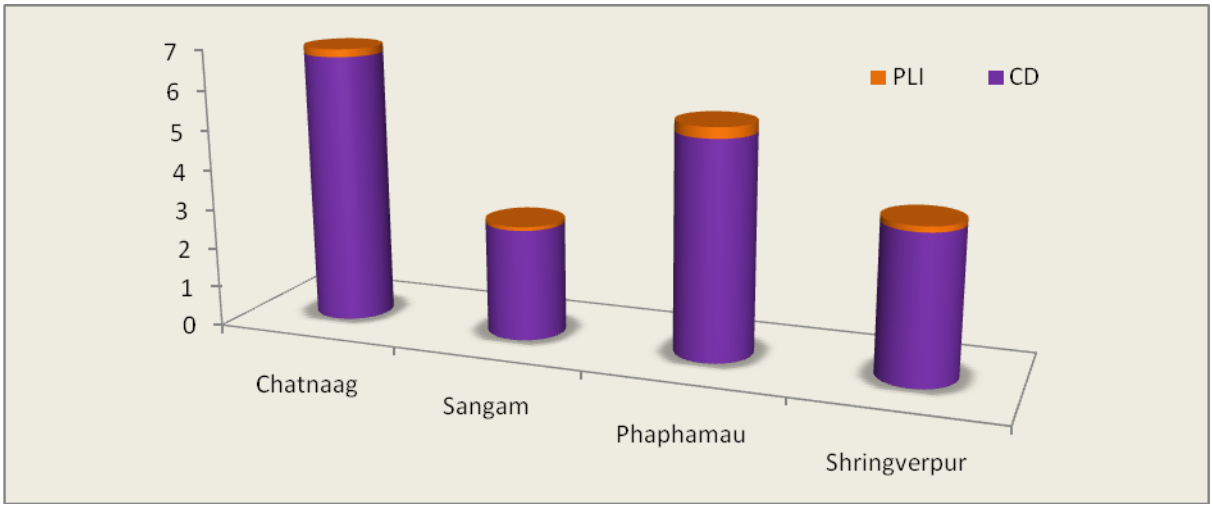

Figure 3 CD and PLI of heavy metals in sediments at four sampling sites in Allahabad

4. CONCLUSION

The results of this study supply valuable information about metal contents in sediment from different sampling sites along the River Ganga at Allahabad. Moreover it concluded that CF and PLI are powerful tools for assessment of contamination of heavy metals in sediment. According to CF classification, all sites under investigation are unpolluted by Fe, Cr, Pb except Phaphamau sites, are moderately polluted by Mn. On the other hand sediment samples were classified unpolluted according to the PLI calculation. For the overall assessment of heavy metals by means of CF and PLI tools, Phaphamau and Chatnaag sites along the river Ganga at Allahabad are more polluted in compare to other sites.

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