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Assessment of heavy metal contamination using pollution load index and geo-accumulation index in sediment of River Ganga at Pratapgarh and Allahabad

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Abstract-

In the present investigation we analyze the geo-accumulation index and pollution load index of heavy metal concentration in river sediment at studying sites viz: Kalakankar, Shringverpur, Phaphamau, Rasoolabad and Sangam. The four heavy metal were taken for analysis viz: Co, Cu, Zn and Ni. The results indicates that the geo-chemical index of sediments at all the sites remain in the unpolluted state for the heavy metals like Co,Cu and Zn whereas only Ni shows slightly polluted condition of sites Phaphamau and Shringverpur during the summer season. And higher pollution load index were observed at the site Phaphamau for winter and summer season whereas for monsoon it was seen at the site shringverpur. And lower pollution load index were observed at the sites Kalakankar for winter and summer season whereas for the monsoon season it was seen at the sites Sangam. The sites Kalakankar were taken from Pratapgarh, whereas the sites Shrigverpur, Phaphamau, Rasoolabad and Sangam were taken from the Allahabad.

Keywords- Ganga, Heavy metal in sediment, Contamination factor, Pollution load index

Introduction

In India most of the industries are situated along the river banks for easy availability of water and also disposal of the wastes. These wastes often contain a wide range of contaminants such as petroleum hydrocarbons, chlorinated hydrocarbons and heavy metals, various acids, alkalis, dyes and other chemicals which greatly change the pH of water. The waste also includes detergents that create a mass of white foam in the river waters. The intensive use of chemical fertilizers, poor waste management by industries and mass bathing activities during festivals etc. have led to environmental stress on water ecosystem [Tripathi, Beenu., et.al (2015)] . . Indian rivers are facing a threat because the discharge of various contaminants through various industries, agricultural runoff, untreated sewage, and improper disposal of solid waste has led to deterioration in the quality of river water (Gupta *et al.* 2020a,2020b; Ali *et al.* 2021). Measuring water quality by quantifying numerous physicochemical parameters is a highly challenging task, which nevertheless only provides a loose approximation of the overall situation. Therefore, an effective evaluation tool is needed that can integrate all the relevant parameters to represent the water quality as a single numerical value (Gupta *et al.* 2019).

All these chemicals are quite harmful or even fatally toxic to fish and other aquatic populations .There are basically three reservoirs of metals in the aquatic environment: water, sediment and biota [S. B. Saha, S.B Abhijit and A. Choudhury,]. The analysis of river sediment is a useful method of studying environmental pollution with heavy metals[G.E. Batley, A. Goorzadi, G. Vahabzadeh and A. R. Carbassi,]. The presence of heavy metals in water ecosystem is a real threat to the river because metals cannot be naturally degraded like organic contaminants. And present in the ecosystem by accumulating in different part of the food chain. Trace amounts of heavy metals also exhibit extreme toxicity. In many fast growing cities the heavy metal contamination in River water is a major problem. The heavy metal contamination in the river water grows every year presenting serious problem for human health & environment. Heavy metal comes in the river ecosystem from different sources such as natural and anthropogenic. In the River ecosystem the sediment acts as both source and sink for heavy metal and also the sources for the assessment of man made contamination in the River water. The biotic component of an aquatic ecosystem constituted by River sediment. Heavy metal toxicity affect the both plant and animals. But the degree of toxicity varies for different organism. The metals selected for the analysis were assumed to be both from point and non point sources has been identified in River Ganga at Allahabad and in its major sampling sites such as Shringverpur, Phaphamau, Rasoolabad and Sangam whereas sampling sites Kalakankar from Pratapgarh. Bioavailability of trace elements or heavy metals in River ecosystem indicate to the availability of trace elements to the biological organisms such as plants, animals and human beings. The plants produce visible symptoms of toxicity and growth retardation due to high accumulation of heavy metals when exposed to undiluted industrial waste water [Naaz, S. and Pandey, S.N. (2010),]. The occurrence of elevated concentrations of trace metals in sediments found at the bottom of the water column can be a good indicator of man induced pollution rather than natural enrichment of the sediment by geological weathering [F. T. D. Wakida, E. J. Lara-Ruiz and P. Temores,].The pollution load index (PLI) represents the number of times by which the heavy metal concentrations in the sediment exceeds the background concentration, and gives a summative indication of the overall level of heavy metal toxicity in a particular sample [C.P. Priju, and A.C. Narayana,]. The identification and quantification of the heavy metal in water and sediments are important environmental issues [Addo, M. A., Okley, G. M., Affum, H. A.,Acquah, S. and Gbadago, J. K. (2011)]. Metals released into aquatic environments become bound to the particulate matters which in due course settle down and become part of the sediments [Suthar, S., Nema, A. K., Chabukdhara, M. and Gupta, S. K. (2009)].Heavy metal pollution of waste water is a significant environmental problem and has a negative impact on human health and agriculture [Michalak, A.(2006)].The presence of heavy metals in indusatrial and urban waste water is one of the main causes of water and soil pollution[Oliveria, S.A.,Ana,B., Tania, M., Beltramini, T., Angela, M., Takayanagui, M. an Domingo, J.L. (2007)]. Heavy metals can pose health hazards if their concentration exceed allowable limits. While when the concentration of metals does not exceed the limits there is still a potential for long-term contamination, and heavy metals are known to accumulate within biological system [M.M., Masood, F. and Malik, A.(2008),]. This study can be considered the first attempt to evaluate the heavy metals pollution in sediments of River Ganga by using geoaccumulation index and pollution load index.

Experimental Methodology

Samples of River sediments were taken from five studying sites viz; Kalakankar(Pratapgarh), Shringverpur, Phaphamau, Rasoolabad and Sangam(Allahabad) in the winter,summer and Monsoon period. The River sediment samples were collected by using clean plastic scoop and stored in polyethylene bags. The concentrations of Co, Cu, Zn and Ni were determined in all samples using Atomic absorption Spectrophotometer (Perkin-Elemer model 5000).

1. Geo-accumulation index (I-geo) Geo-accumulation index was determined by the following equation according to Müller [G. Muller]. which was described by [Boszke *et al*].

I-geo = log 2 (Cn / 1.5 Bn)

where,

Cn = Measured concentration of heavymetal in the studying sites of River Ganga.

Bn = Geochemical background value in

average shale (15) of element n. The factor 1.5 is used for the possible variations of the

background data due to lithological variations.

I-geo was classified into seven grades: I-geo ≤ 0 (grade 0), unpolluted; 0< I-geo ≤1 (grade 1), slightly polluted; 1 < I-geo ≤ 2 (grade 2), moderately polluted; 2< I-geo ≤3

(grade 3), moderately severely polluted; 3< I-geo ≤4 (grade 4), severely polluted; 4< I-geo

≤5 (grade 5), severely extremely polluted;I-geo > 5 (grade 6), extremely polluted (17).

Pollution load index

The pollution Load Index (PLI) evaluate the degree to which the sediment associated chemical status might adversely affect aquatic organisms and are designed to assist sediment assesssors and manager responsible for the interpretation of sediment quality. It is also to rank and prioritize the contaminated areas or the chemicals for the further investigation.

Calculation method of PLI:

CF= C metal /C background value

$CF = n\sqrt{(CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)}$

Where,

CF= contamination factor, n=number of metals

C metal = metal concentration in sediments

C Background value = background value of that metal.

The background value of metal (Co,Cu,Zn and Ni) was taken from the paper of [Turekian KK, Wedepohl KH,]. . The background value of these metals are Co=19,Cu=45,Zn=95 and Ni=68.

Result and Discussion-

Heavy metal in the Sediment

Cobalt (Co)(s)

In the sediment of the River Ganga at the site Kalakankar the average Cobalt were recorded 11.43±5.66 in the all three season, whereas at the site Shringverpur the average Cobalt were recorded 14.88±7.40 in the all three season ,whereas at the site Phaphamau the average Cobalt were recorded 13.24±8.73 in all three season,whereas at the site Rasoolabad the average Cobalt were recorded 12.34±8.19 in all three season,whereas at the site Sangam the average Cobalt were recorded 11.9±7.27 in all three season.

Cupper (Cu))(s)

In the River Ganga at the site Kalakankar the average Cupper were recorded 26.41±16.70 in the season,whereas at the site Shringverpur the average Cupper were recorded 43.17±17.88 in the season, whereas at the site Phaphamau the average Cupper were recorded 42.25±11.63 in the season. At the site Rasoolabad the average Cupper were recorded 35±17.16 in the all season at the site Sangam the average Cupper were recorded 26.56±18.4 in the all three season.

Zinc (Zn) (s)

In the River Ganga at the site Kalakankar the average Zinc were recorded*25.6± 7.44* in the all three season,whereas at the site Shringverpur the average Zinc were recorded 38.99±22.80 in the all three season,whereas at the site Phaphamau the average Zinc were recorded 39.61±19.79 in the all three season, whereas at the site Rasoolabad the average Zinc were recorded 31.03±16.08 in the all three season,whereas at the site Sangam the average Zinc were recorded 27.67±14.01 in the all three season.

Nickel (Ni) (s)

In the River Ganga at the site Kalakankar the average Nickel were recorded 63.26±16.56 in the all three season,whereas at the site Shringverpur the average Nickel were recorded 57.11±25.73 in the all three season, whereas at the site Phaphamau the average Nickel were recorded 79.44±43.71 in the all three season, whereas at the site Rasoolabad the average Nickel were recorded 62.56±43.11 in the all three season, whereas at the site Sangam the average Nickel were recorded 62.12±36.25 in the all three season.

Geo-accumulation Index

The geo-accumulation index is a quantitative measure of the degree of pollution in aquatic sediments (25). Table (3) presents the geo-accumulation index for the quantification of heavy metal accumulation in the studying sites. The I-geo grades for the study area sediments varies from metal to metal and site to site (across metals and sites). Cobalt, Cupper, Zinc and Nickel remain in grade 0 (unpolluted) in the all studying sites except the sites Phaphamau and Shringverpur where I-geo for Nickel attain in grade 1 indicates that sediments of these sites in the summer season were slightly polluted by Nickel. The I-geo showed that all heavy metals are in grade 0 and only Nickel in grade 1 during the summer season at the sites Phaphamau and Rasoolabad (Table (3)). This suggests that the generally the sediments of the all sites having background concentrations for Co, Cu, and Zn , and these elements are practically unchanged by anthropogenic influences, while the concentration of Nickel exceeded the average shale value.

Pollution load index in the sediment

The value of pollution load index determined the pollution severity and its variation along the sites. According to [Mohiuddin et.al]. PLI = 0 indicates perfection; PLI = 1 points to only baseline levels of pollutants present and PLI values > 1 represent progressive deterioration of sites. The concentrations of heavy metals in sediments are varied according to the rate of particle sedimentation, the rate of heavy metals deposition, the particle size and the presence or absence of organic matter in the sediments[W. N. Saloman, H. Rooij, and J. Bril,]. In the winter season contamination factor at Kalakankar site of Co was (0.512),Cu (0.460),Zn(0.204), and Ni(0.890). The Pollution load Index (PL1) for the winter season was 0.452. In the summer season contamination factor of Co was (0.934),Cu(1.005),Zn(0.528) and Ni(1.191). The pollution load index for the summer season was (0.876). In monsoon season contamination factor of Co was (0.358), Cu(0.295),Zn(0.117), and Ni(0.709). The pollution load index for the monsoon season was (0.299).

In the winter season contamination factor at Shringverpur site of Co was (0.811),Cu (1.049),Zn(0.444), and Ni(0.883). The Pollution load Index (PL1) for the season was (0.759). In the summer season contamination factor of Co was (1.158),Cu(1.303),Zn(0.631) and Ni(1.194). The pollution load index for the summer season was (1.032). In monsoon season contamination factor of Co was (0.380), Cu(0.526),Zn(0.155), and Ni(0.441). The pollution load index for the monsoon season was (0.337).

In the winter season contamination factor at the site Phaphamau of Co was (0.713),Cu (0.918),Zn(0.456), and Ni(1.24). The Pollution load Index (PL1) for the season was (0.779). In the summer season contamination factor of Co was (1.138),Cu(1.207),Zn(0.601) and Ni(1.76). The pollution load index for the summer season was (1.097). In monsoon season contamination factor of Co was (0.229), Cu(0.691),Zn(0.190), and Ni(0.490). The pollution load index for the monsoon season was 0.316.

In the winter season contamination factor at Rasoolabad site of Co was (0.751),Cu (0.725),Zn(0.259), and Ni(0.924). The Pollution load Index (PL1) for the season was 0.6004. In the summer season contamination factor of Co was (1.02),Cu(1.182),Zn(0.519) and Ni(1.55). The pollution load index for the summer season was (0.985). In monsoon season contamination factor of Co was (0.176), Cu(0.425),Zn(0.201), and Ni(0.238). The pollution load index for the monsoon season was (0.251).

In the winter season contamination factor at the site Sangam of Co was (0.811),Cu (0.607),Zn(0.225), and Ni(0.966). The Pollution load Index (PL1) for the season was (0.570). In the summer season contamination factor of Co was (1.01),Cu(0.991),Zn(0.460) and Ni(1.41). The pollution load index for the summer season was (0.897). In monsoon season contamination factor of Co was (0.380), Cu(0.171),Zn(0.187), and Ni(0.355). The pollution load index for the monsoon season was (0.251).

Conclusion-

More pollution load index were observed at the site Phaphamau in the winter and summer season but in monsoon season more PLI were observed at the site Shringverpur. Whereas less pollution index among the sites were observed at Kalakankar for winter and summer season whereas for the monsoon season less PLI were observed at the Sangam site

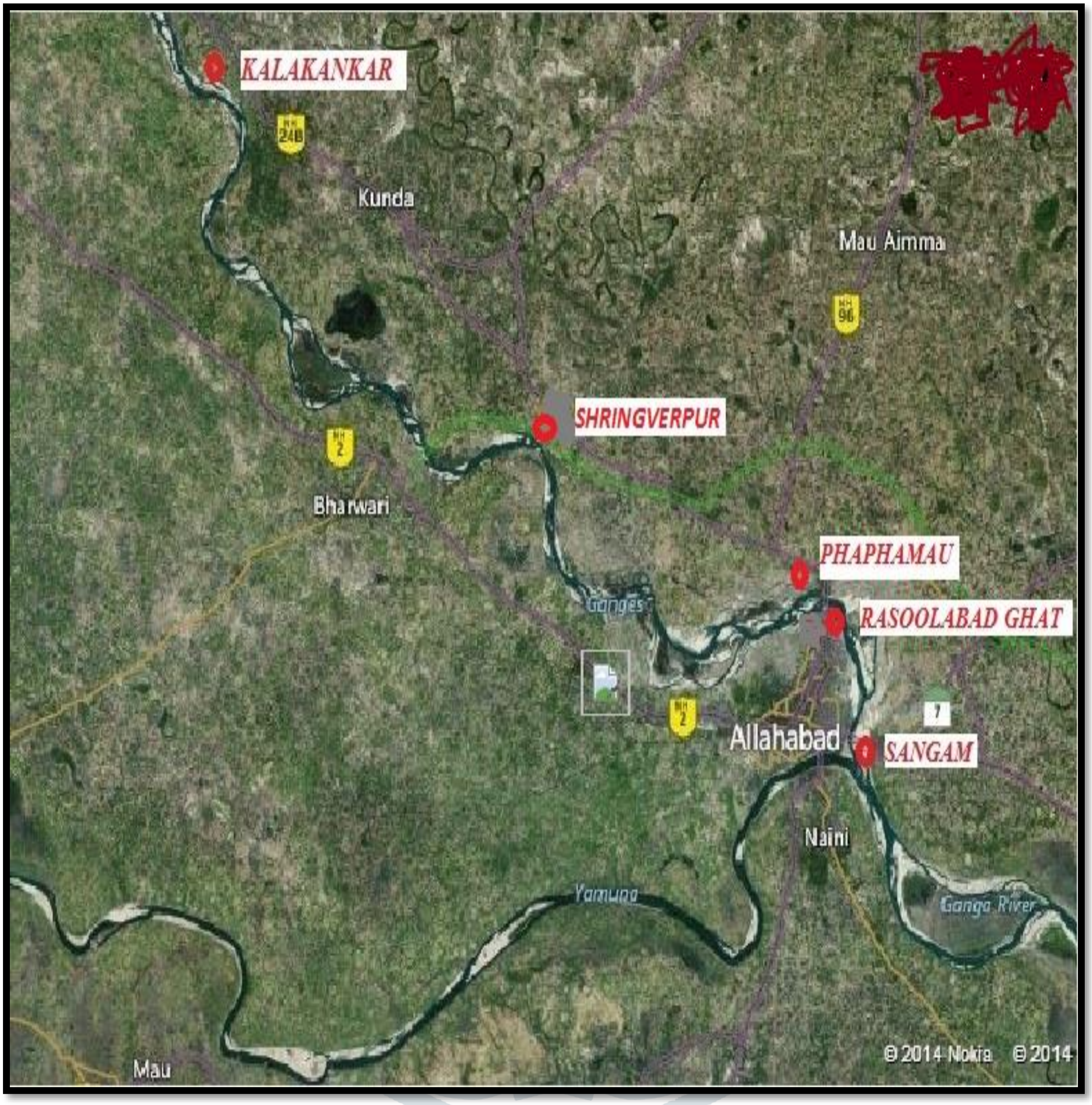
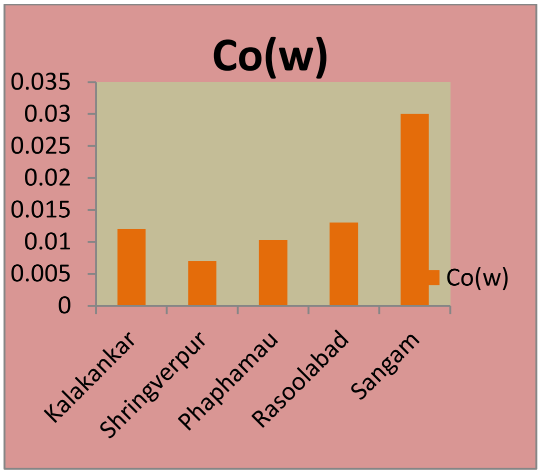
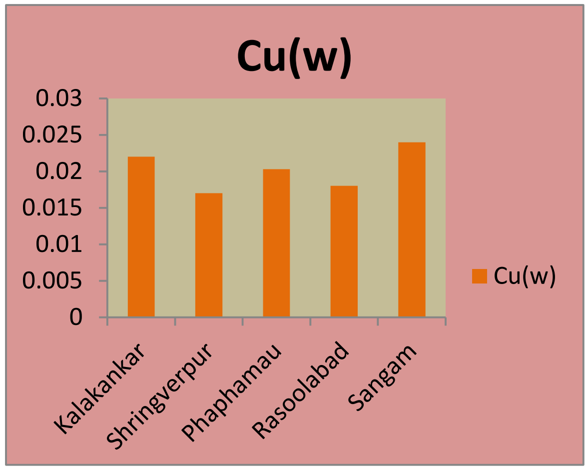


Fig:1 Map showing the studying sites Kalakankar, Shringverpur, Phaphamau, Rasoolabad and Sangam





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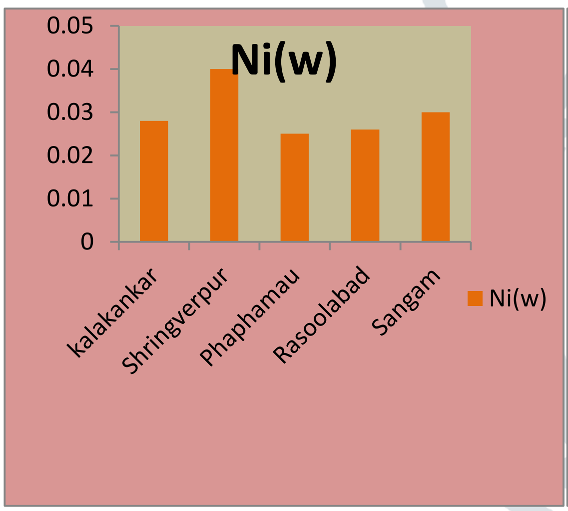
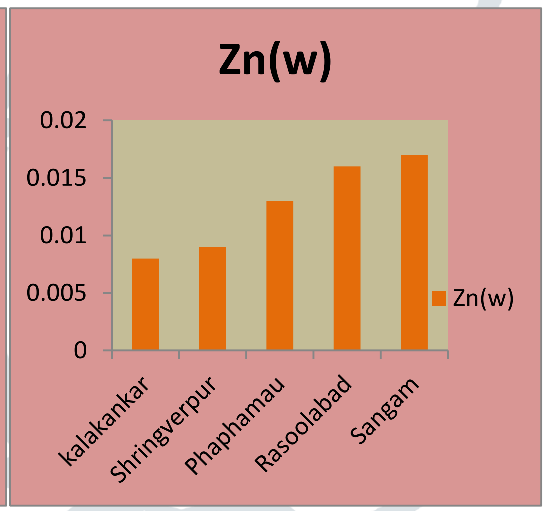
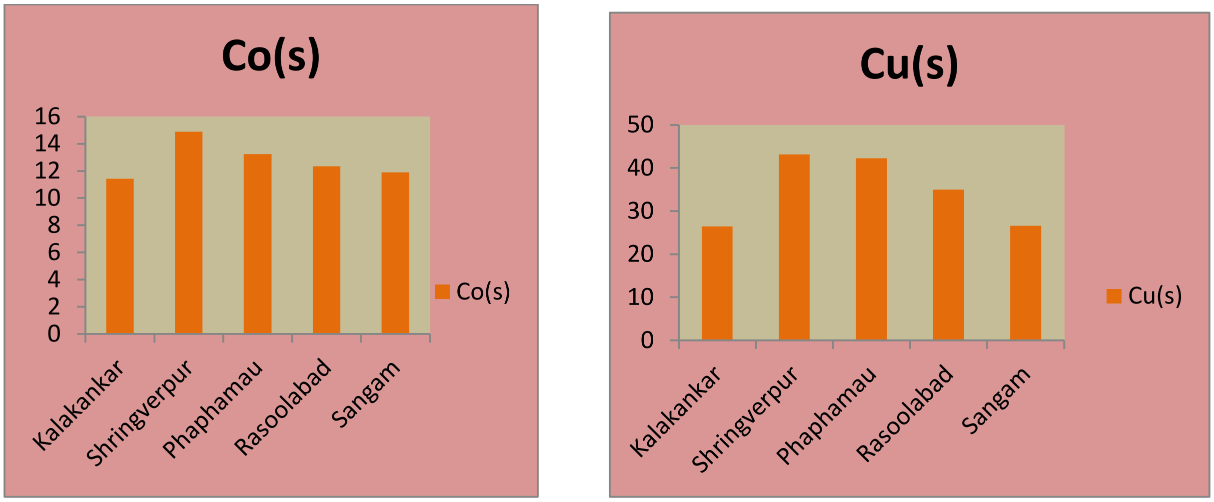
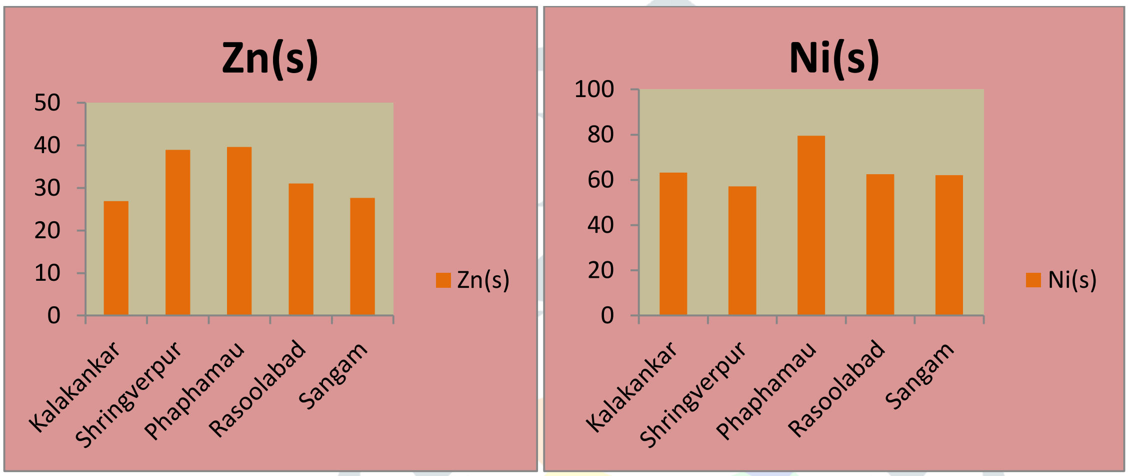




C D

Fig:2 Graph showing heavy metal concentration in water of River Ganga from (A to D) at all its studying sites Kalakankar, Shringverpur,Phaphamau,Rasoolabad and sangam in all three season (W=showing in water)





C D

Fig:3 Graph showing heavy metal concentration in sediments of River Ganga from (A to D) at all its studying sites Kalakankar, Shringverpur,Phaphamau,Rasoolabad and sangam in all three season (S=showing in sediment)

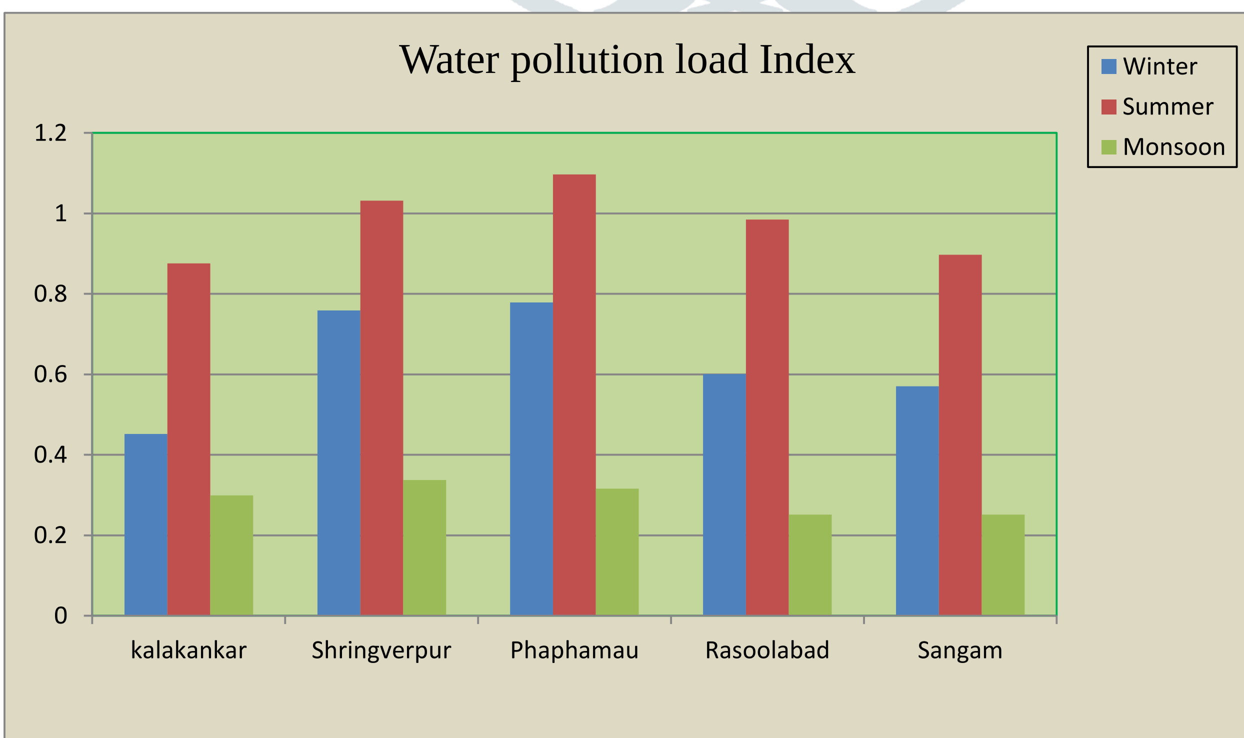


Fig:4 Water pollution load Index at the studying sites Kalakankar, Shringverpur, Phaphamau, Rasoolabad and Sangam

Table 1: Analysis of heavy metals in river water at its studying sites in all three season

2013-14	Kalakankar sites			
	Winter	Summer	Monsoon	Mean± SD
Co(mg/l)	0.014	0.016	0.007	0.012±0.004
Cu(mg/l)	0.024	0.027	0.016	0.022±0.005
Zn(mg/l)	0.007	0.016	0.002	0.008±0.007
Ni(mg/l)	0.028	0.032	0.025	0.028±0.0035
Shringverpur sites				
Co(mg/l)	0.004	0.01	0.008	0.007±0.003
Cu(mg/l)	0.014	0.027	0.011	0.017±0.008
Zn(mg/l)	0.012	0.016	0.001	0.009±0.007
Ni(mg/l)	0.028	0.08	0.022	0.04±0.031
Phaphamau sites				
Co(mg/l)	0.014	0.016	0.001	0.0103±0.008
Cu(mg/l)	0.016	0.033	0.012	0.0203±0.011
Zn(mg/l)	0.014	0.023	0.004	0.013±0.009
Ni(mg/l)	0.023	0.033	0.021	0.025±0.006
Rasoolabad sites				
Co(mg/l)	0.011	0.025	0.004	0.013±0.01
Cu(mg/l)	0.018	0.026	0.012	0.018±0.007
Zn(mg/l)	0.014	0.028	0.007	0.016±0.010
Ni(mg/l)	0.026	0.033	0.019	0.026±0.007
Sangam sites				
Co(mg/l)	0.031	0.039	0.021	0.03±0.009
Cu(mg/l)	0.021	0.046	0.005	0.024±0.02
Zn(mg/l)	0.018	0.024	0.011	0.017±0.006
Ni(mg/l)	0.031	0.035	0.024	0.03±0.005

Table 2: Analysis of heavy metals in river sediment at its studying sites in all three season

2013-14	Kalakankar sites			
	Winter	Summer	Monsoon	Mean± SD
Co(mg/kg)	9.73	17.75	6.81	11.43±5.66
Cu(mg/kg)	20.72	45.23	13.3	26.41±16.70
Zn(mg/kg)	19.47	50.16	11.14	26.92±20.55
Ni(mg/kg)	60.56	81.01	48.22	63.26±16.56
Shringverpur sites				
Co(mg/kg)	15.42	22.01	7.23	14.88±7.40
Cu(mg/kg)	47.24	58.67	23.61	43.17±17.88
Zn(mg/kg)	42.22	60.01	14.75	38.99±22.80
Ni(mg/kg)	60.11	81.22	30.01	57.11±25.73
Phaphamau sites				
Co(mg/kg)	13.56	21.82	4.36	13.24±8.73
Cu(mg/kg)	41.33	54.32	31.1	42.25±11.63
Zn(mg/kg)	43.63	57.1	18.12	39.61±19.79
Ni(mg/kg)	84.65	120.33	33.36	79.44±43.71

Rasoolabad sites				
Co(mg/kg)	14.27	19.41	3.36	12.34±8.19
Cu(mg/kg)	32.64	53.22	19.14	35±17.16
Zn(mg/kg)	24.64	49.33	19.12	31.03±16.08
Ni(mg/kg)	62.86	105.52	19.3	62.56±43.11
Sangam sites				
Co(mg/kg)	12.54	18.84	4.33	11.9±7.27
Cu(mg/kg)	27.32	44.63	7.73	26.56±18.4
Zn(mg/kg)	21.45	43.73	17.85	27.67±14.01
Ni(mg/kg)	65.73	96.45	24.2	62.12±36.25

Table 3: Geochemical index of heavy metals in River sediments at all its studying site in all three season

2013-14	Geochemical Index			
	***I-geo* Co**	***I-geo* Cu**	***I-geo* Zn**	***I-geo* Ni**
	Kalakankar sites			
Winter Season	**-1.07**	**-1.15**	**-1.99**	**-0.522**
Summer Season	**-0.47**	**-0.373**	**-1.044**	**-0.230**
Monsoon Season	**-1.43**	**-1.59**	**-2.55**	**-0.750**
	Shringverpur sites			
Winter Season	**-0.614**	**-0.329**	**-1.21**	**-0.52**
Summer Season	**-0.258**	**-1.093**	**-0.865**	**-0.228**
Monsoon Season	**-1.37**	**-1.02**	**-2.27**	**-1.22**
	Phaphamau sites			
Winter Season	**-0.744**	**-0.463**	**-1.184**	**-0.18**
Summer Season	**-0.267**	**-0.191**	**-0.865**	**0.164**
Monsoon Season	**-1.88**	**-0.748**	**--2.06**	**-1.11**
	Rasoolabad sites			
Winter Season	**-0.693**	**-0.70**	**-1.76**	**-0.484**
Summer Season	**-0.384**	**-0.210**	**-1.06**	**0.033**
Monsoon Season	**-2.14**	**-1.23**	**-2.00**	**-1.666**
	Sangam sites			
Winter Season	**-0.820**	**-0.879**	**-1.897**	**-0.440**
Summer Season	**-0.414**	**-0.387**	**-1.184**	**-0.056**
Monsoon Season	**-1.890**	**-2.14**	**-2.07**	**-1.43**

Table 4: Pollution load index of heavy metals in River sediments at all its studying sites in all three season

2013-14	Contamination Factor(CF)				PLI
	*CF*Co	*CF*Cu	*CF*Zn	*CF*Ni	
	Kalakankar sites				
Winter Season	0.512	0.460	0.204	0.890	0.452
Summer Season	0.934	1.005	0.528	1.191	0.876
Monsoon Season	0.358	0.295	0.117	0.709	0.299
Shringverpur sites					
Winter Season	0.811	1.049	0.444	0.883	0.759
Summer Season	1.158	1.303	0.631	1.194	1.032
Monsoon Season	0.380	0.526	0.155	0.441	0.337
Phaphamau sites					
Winter Season	0.713	0.918	0.456	1.24	0.779
Summer Season	1.138	1.207	0.601	1.76	1.097
Monsoon Season	0.229	0.691	0.190	0.490	0.316
Rasoolabad sites					
Winter Season	0.751	0.725	0.259	0.924	0.6004
Summer Season	1.02	1.182	0.519	1.55	0.985
Monsoon Season	0.176	0.425	0.201	0.283	0.251
Sangam sites					
Winter Season	0.811	0.607	0.225	0.966	0.570
Summer Season	1.01	0.991	0.460	1.41	0.897
Monsoon Season	0.380	0.171	0.187	0.355	0.251

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