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TRACE METAL ACCUMULATION, BEHAVIOUR AND POTENTIAL TOXICITY IN CENTRAL GANGETIC BASIN

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ABSTRACT

The River Ganga referred to as the Ganges has been one of the major receivers of sewage and industrial effluents in India. The present work collects data from the present published literature on surface water and surface sediment chemistry data across Central Gangetic basin from the published literature. And, the published surface water and surface sediment chemistry data have been used to compute different pollution indices i.e. Contamination Factor (CF); Pollution load index (PLI); Enrichment Factor (EF); Geo-accumulation index (I-geo); Potential ecological risk index (E_{if}); and Potential toxicity response index (RI), for better appraisement of the status of pollution in the Ganga River Basin. Trace metals like Al, As, Cd, Co, Cr, Cu, Fe, Mn, Pb and Zn; contamination in water as well as soil contamination was evaluated on the basis of the geoaccumulation index, enrichment factor (EF), contamination factor and toxicity index.Data collected from the published literature reveals high concentration of trace metal like Cd, Cr, Fe, Ni, Pb and Zn found in several studies at Mirzapur, Varanasi, Narora, Kanpur and Allahabad. High contamination and enrichment of Cd also became evident on the basis of observations made at Kanpur and Allahabad whereas Fe, Mn and Zn were found heavily accumulated at most of sites. Indiscriminate disposal of domestic and hazardous industrial waste in the study area could be the main cause of soil contamination, spreading by rainwater and wind.

KEY WORDS: River Basin, Enrichment, Contamination, Geoaccumulation

INTRODUCTION

In recent decades of industrialization, urbanization and globalization, with the rapid development of industry, agriculture, traffic, transportation and mining industries; trace metal contamination is becoming a serious problem, especially in developing countries (Jung and Thornton, 1997; Ranjan, Ramanathan, *et al.*, 2018; Ranjan, Rao, *et al.*, 2018). Trace metals is one of the most severe pollutants of ecosystem due to their toxicity, non-biodegradable nature, bio-accumulation and bio-magnification(Macfarlane and Burchett, 2001; Ranjan *et al.*, 2017). Sediment is both a sink as well as source (non-point) for trace metals depending on hydrodynamics, pH, redox changes, salinity, temperature and biogeochemical processes (Dickinson *et al.*, 1996).

The present article attempts to analyse the status of trace metal pollution in water and sediment in the Ganga River basin through the analysis of geochemical data compiled from the published literature, briefs about the analytical methodology, and evaluates its pollution status and examined potential risk zone of central Gangetic basin for better appraisement of the status of pollution in the Ganga River Basin.

STUDY AREA

The Ganga River being largest river of India, flows through a distance of 2525 km covering an area of 1.08×10^6 km^2 as Ganga river basin. Ganga River water has 2% water of world's existing river system and it transports 7449×10^6 ton/yr of sediment. Its catchment area constitutes 26% of Indian landmass which supports 43% of Indian population (Ministry of home affairs, 2011).

Ganga alluvial plain is formed by sediment brought from the Himalayan belt and north Indian region. The drainage network of River Ganga consists many tributaries like, Yamuna, Gomti, Son, Ghagharaetc. Many important cities have been settled around its bank like Haridwar, Garhmuktesar, Kanpur, Allahabad, Mirzapur, Varanasi, Buxar, Patna etc. These cities, urban centres, large population residing therein and growth of numerous industrial clusters and belts along both banks of the Ganga increased huge pressure on water and ecological characteristics of Ganga. The domestic sewage, partial or untreated industrial waste, pyre burning, waste disposal has increased concentration of different pollutants in the Ganga river including trace metals.

ANALYTICAL METHODOLOGY

Contamination Factor (CF) - Contamination factor is a geochemical tool developed by Hakanson, to calculate contamination of certain element in respect to its background value (i.e., average shale value). CF refers to the ratio of mean concentration of trace metal to its average background (average shale value). Background concentration of metal is usually refers to world's average shale value (Turekian and Wedepohl, 1961).

Potential ecological risk index (E_{if})

A potential ecological risk factor (E_{if}) is a geochemical tool to quantitatively analyse ecological risk of certain trace metals, it is suggested by Hakanson (1980). Where T_{if} stands for the toxic response factor for a given substance (Toxic response index for different metals are Hg=40, Cd=30, As=10, Cu=Pb=Ni=5, Cr=2 and Zn=1 given by Hakanson, (1980) and CF is the contamination Factor. Index of CF - Eif<40 - Low risk; 40-80 - Moderate risk; 80-160 - Considerable risk, 160-320 - High risk Eif and >320 - Very high risk.

RESULTS AND DISCUSSION

Scenario of trace metal pollution in central Gangetic basin

Mean value of trace metals in River water and sediment of central Gangetic basin is presented in Table – 1 and 2, for water and sediment samples respectively. In all the studies done so far trace metal distribution for cadmium (Cd), shows higher than acceptable and permissible limit except at Mirzapur (Sharma, Prasad and Rupainwar, 1992) and Varanasi (Pandey *et al.*, 2015); highest value were found at Kanpur (Goswami and SS Sanjay, 2014) with 5.8ppm. Chromium (Cr), were below permissible limit in all studies; whereas it crosses acceptable limit at Varanasi (Vaseem and Banerjee, 2013) and Haridwar. Copper (Cu), shows higher than acceptable limit at Haridwar; Varanasi (Vaseem and Banerjee, 2013); Narora and Kanpur (Goswami and SS Sanjay, 2014), Cobalt (Co), were under below detectable limit in almost all studies done so far. Iron (Fe), were found higher than acceptable and permissible limit at Kanpur and Varanasi. Manganese (Mn), were found lower than BIS limit in all the studies done so far whereas, nickel (Ni) and lead (Pb) shows higher than the acceptable and permissible limit in most of the studies done so far.

Trace metal pollution in sediment of central Gangetic Basin were presented in Table 2. Trace metal distribution in river sediment of central Gangetic basin, were below average shale value in the study done by Subramanian *et al.,* (1987) and Gupta *et al.,* (2009); and higher than average shale value for Cd, Ni and Zn in the study done by Pandey *et al.,* (2016); at Allahabad. Higher than average shale value for trace metals were found for Fe and As, Cr, Pb, Zn at Kanpur in the study done by Beg Ali, (2008) and Goswami and Sanjay, (2014). Varanasi shows high trace metals value, higher than average shale value in almost all studies done so far, whereas, Ghazipur, Buxar and Ballia shows higher value of Cd, Cr, Cu and Zn.

Contamination factor (CF)

Contamination factor is shown in Table 3. It shows that Cd were in high contamination at Kanpur (Beg and Ali, 2008) and Allahabad (Pandey *et al.*, 2016). Pb, Zn and Zn, Cr were in considerate contamination at Narora and Kanpur (Goswami, 2014); whereas Cd, Cr, Cu and Zn at Buxar, Ballia

Table 1. Trace metal distribution in Ganga river water of Central Gangetic Basin

Location	Al	As	Cd	Cr	Cu	Co	Fe	Mn	Ni	Pb	Zn	References
Acceptable Limit	0.03	0.01	0.003	0.05	0.05		0.3	30	0.02	0.01	5	(Bis, 2012)
Permissible limit	0.2	0.05	0.003	1.5	1.5		0.3	100	0.02	0.01	15	(Bis, 2012)
Kanpur			0.072	0.0176			4.722	0.0984	0.0146	0.0215	0.0989	(Garg *et al.*, 1992)
Mirzapur			0.00012		0.000816	0.00019	0.004754	0.000139	0.0000481	0.000054	0.000375	(Sharma *et al.*, 1992)
Allahabad		0.008	0.011	0.017						0.043	0.072	(Gupta *et al.*, 2009)
Kanpur		0.075	0.02	0.02					0.7	0.01	0.15	(Singh *et al.*, 2012)
Varanasi			0.043	0.02	0.02				0.55	0.01	0.2	(Singh *et al.*, 2012)
Haridwar				0.1397	0.1449	0	0	0.05919		0.2819	0.1679	(Rai *et al.*, 2012)
Varanasi				0.278	0.29		4.36	1.98	0.918	0.149	12.55	(Vaseem and Banerjee, 2013)
Narora			5.03		36					10.96	26.16	(Goswami and SS Sanjay, 2014)
Kanpur			5.8		10					14.3	57.55	(Goswami and SS Sanjay, 2014)
Allahabad			1.2							5	23.5	(Goswami and SS Sanjay, 2014)
Varanasi			0.02163	0.0502	0.03128		0.0942	0.04978	0.04052	0.0957	0.05041	(Pandey et al., 2015)
Varanasi			0.064	0.062	0.042		0.622		0.292	0.12	0.236	(Naveshika et al., 2016)

Note : All values are in ppm.

Table 2. Trace metal distribution in Ganga river sediment of central Gangetic basin

Location	Al	As	Cd	Cr	Cu	Co	Fe	Mn	Ni	Pb	Zn	References
Shale Value	80000	13	0.3	90	45	19	47200	850	68	20	95	(Turekian, K; Wedepohi, 1961)
Allahabad				43	44	18	22600	414	24		55	(Subramanian *et al.*, 1987)
Kanpur		0.25	3.08	76	12.815		5816.5	148.5	8.402	2.5	49.015	(Beg and Ali, 2008)
Allahabad	`		0.86	3.837	2.483					6.616	14.62	(Gupta *et al.*, 2009)
Ghazipur			0.73	148	51	17			42	19	97	(Singh *et al.*, 2013)
Buxar			0.59	163	60	22			59	19	109	(Singh *et al.*, 2013)
Ballia			0.61	161	57	21			52	21	104	(Singh *et al.*, 2013)
Narora		22.285		60.75						67.295	407.92	(Goswami and SS Sanjay, 2014)
Kanpur		17.465		345.9						51.545	371.99	(Goswami and SS Sanjay, 2014)
Varanasi			9.52-79	126.84-196.11	12.67-84	29.98-102.24	7175.5-9385	350.87 409.44	14.63-82.5	148.83-211.36	137.25 201.2	(Pandey *et al.*, 2014)
Allahabad		0.644	131.8	55.4						23.8	100.6	(Pandey et al., 2016)
Varanasi			1.72	76.27	29.753		31988.6	372.04	26.698	26.67	67.76	(Pandey and Singh, 2017)

Note : All values are in ppm.

Table 3. Contamination factor (CF) and Potential ecological Risk Index (Eif) of river sediment in central Gangetic basin

	Contamination Factor (CF)				Potential ecological Risk Index (Eif)					
Site	Low	Moderate	Considerate	High	Low	Moderate	Considerate	High	Very high	References
Allahabad	Cr, Cu, Co, Fe, Mn, Ni and Zn				Cr, Cu, Ni, Pb and Zn					(Subramanian et al., 1987)
Kanpur	As, Cr, Cu, Fe, Mn, Ni, Pb and Zn			Cd	As, Cd, Cr, Cu, Ni, Pb and Zn					(Beg and Ali, 2008)
Allahabad	Cr, Cu, Pb and Zn	Cd			Cr, Cu, Pb and Zn		Cd			(Gupta et al., 2009)
Ghazipur	Ni and Pb	Cd, Cr, Cu and Zn			Cr, Cu, Ni, Pb and Zn	Cd				(Singh et al., 2013)
Buxar	Ni and Pb	Cd, Cr, Cu and Zn			Cr, Cu, Ni, Pb and Zn	Cd				(Singh et al., 2013)
Ballia	Ni	Cd, Cr, Cu, Pb and Zn			Cr, Cu, Ni, Pb and Zn	Cd				(Singh et al., 2013)
Narora	Cr		Pb and Zn		Cr, Pb and Zn					(Goswami and SS Sanjay, 2014)
Kanpur		Pb	Cr and Zn		Cr, Pb and Zn					(Goswami and SS Sanjay, 2014)
Allahabad	Cr	Pb and Zn		Cd	Cr, Pb and Zn				Cd	(Pandey et al., 2016)
Varanasi	Cr, Cu, Fe, Mn, Ni and Zn				Cr, Cu, Ni and Zn					(Pandey and Singh, 2017)

and Ghazipur were in moderate contamination (Singh *et al.*, 2013). Pb and Zn at Allahabad (Pandey *et al.*, 2016) were also in moderate contamination other than all trace metals from all site were in low contamination.

Potential ecological risk index (E_{if})

Potential ecological risk index of trace metals is shown in Table 3. It was found that, except Cd which is considerate (Gupta *et al.*, 2009); very high (Pandey *et al.*, 2016), in Allahabad and moderate in Ghazipur, Buxar and Ballia (Singh *et al.*, 2013); other than that all trace metals shows low potential ecological risk index.

SUMMARY

Increasing trace metal pollution towards downstream of Ganga river depicts the role of anthropogenic action in deterioration of water quality of The River Ganga. High trace metals concentration near Kanpur, Varanasi, Narora, Ghazipur, Buxar, Ballia and Allahabad suggest impact of industrial cluster in contribution of worsening water quality health. Seasonal variation in trace metals shows higher values in summer and winter but, in the rainy season, it is recorded as comparatively lower which may be due to dilution effect. Trace metal accumulation and retention in aquatic system and sediment is judged by different physio-chemical changes as pH, redox potential, DO, organic carbon, particle size, etc. as well as different environmental and anthropogenic setup.

Sediment at Varanasi and Kanpur shows high trace metals concentration, higher than average shale value. Cd shows highest contamination factor throughout all study site and highly enriched in river sediment at Kanpur. Cd was found most potent ecological risk for Ganga river basin especially near Allahabad, Ghazipur, Buxar and Ballia and from all studied sites of central Gangetic basin Kanpur and Allahabad was found at high potential risk of trace metal pollution. There have been some studies published in 2019 and the first quarter of the but they have been conducted in either upper catchments or lower catchments of the GRB but they all report the grim condition of water and sediment pollution in different sections of the basin. The present study suggests that there is a dire need of water resource management involving stakeholders, research institution, business sector, NGO and local people through water quality monitoring, pollution source identification and pollution control, abatement and rehabilitation projects.

Statement of declaration

No conflict of interest among authors of this manuscript are declared

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