Status of Trace and Toxic Metals in Indian Rivers

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ABSTRACT:
To observe the current status of toxic metal content of Indian Rivers, 3113 no. of river water samples from 688 water quality monitoring stations spread over major river basins in India were collected during Aug 2018 to Dec 2020. These samples were analyzed for Arsenic, Cadmium, Chromium, Copper, Nickel, Lead, Iron and Zinc. The samples were collected in polyethylene containers and analysed by atomic absorption spectrophotometer. The study was carried out on Agilent 240FS atomic absorption spectrophotometer by graphite tube analyzer (GTA) using argon gas and Iron analyzed by flame operation using air and acetylene gas. It was found that 180 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. Out of remaining 508 WQ Stations; 187 stations were found beyond the acceptable limits with respect to more than one toxic metal. Further, river water at 240 numbers of stations was found beyond the acceptable limit with respect to only Iron concentration according to the BIS: 10500-2012. Similarly, river water is found beyond the acceptable limit at 2 stations due to presence of only arsenic, 2 stations due to presence of only copper, 1 station due to presence of only cadmium, at 7 stations due to presence of only Chromium, at 61 stations due to presence of only nickel and 8 stations due to presence of only lead contamination.

INTRODUCTION

The environmental pollution is caused by a variety of pollutants in water, air and soil (Briffa et al., 2020 and Masindi et al., 2018). One of the major concerned pollutants of living environment is “Heavy Metals” (metal and metalloid element having density from 3.5 to 7 g/cm^3). Beryllium (Be), Aluminium (Al), Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Selenium (Se), Molybdenum (Mo), Silver (Ag), Cadmium (Ca), Tin (Sn), Antimony (Sb), Barium (Ba), Mercury (Hg), Thallium (Tl) and Lead (Pb) are the common toxic ‘heavy metals’ which are of public health concerns as per World Health Organization (WHO) (Csata et al., 1968). Heavy metals have the property of environmental persistence and bioaccumulation, and can enter the aquatic system through various routes (Jarup, 2003). Heavy metals pollution in river water is mainly due to anthropogenic and natural activities. Over the last few decades, the concentration of these heavy metals in river water and sediments has increased rapidly which may cause distressing effects on the ecological balance of the aquatic environment and eventually affect the grains and vegetables grown with contaminated soil and water (Begum et al., 2009; Kaushik et al., 2009; Khan et al., 2021, Kumar et al., 2022; Paul, 2017, Sharma et al., 2014 and Bhardwaj et al., 2017). This may pose a serious threat to humans (Singh et.al., 2022) and the environment because of heavy metal’s toxicity, non-biodegradability and bioaccumulation (Dutta et al., 2018 and Fergusson et al., 1990).

In view of the direct consumption of water by human beings, the domestic water supply is considered to be most important use of water and drinking use has been given first priority on utilization of water resource in the National Water Policy. Drinking water standards for selected 8 trace and toxic metals according to BIS 10500:2012 are given below in Table 1.

Table 1. Drinking Water Standards for Trace & Toxic metals (BIS-10500:2012)

S.No.	Toxic metal	Requirement (Acceptable Limit)		Permissible Limit in the Absence of Alternative Source	
		(mg/L)	(µg/L)	(mg/L)	(µg/L)
1	Total arsenic as As	0.01	10	0.05	50
2	Cadmium as Cd	0.003	3	No relaxation	
3	Total Chromium as Cr	0.05	50	No relaxation	

4	Copper as Cu	0.05	50	1.5	1500
5	Iron as Fe	0.30	300	No relaxation	
6	Lead as Pb	0.01	10	No relaxation	
7	Nickel as Ni	0.02	20	No relaxation	
8	Zinc as Zn	5	5000	15	15000

Methodology

In the present study, samples were collected in polyethylene containers. These water samples were prepared for the determination of heavy metals, viz., arsenic, cadmium, chromium, copper, iron, lead, nickel and zinc by atomic absorption spectrophotometer. The study was carried out on Agilent 240FS atomic absorption spectrophotometer by graphite tube analyzer (GTA) using argon gas and Iron analyzed by flame operation using air and acetylene gas. The wavelength, current, slit and method employed using atomic absorption spectrophotometer is given in Table 2.

Table 2. The wavelength, current, slit and method used for chemical analysis by AAS

S.No.	Parameter	Wave length (nm)	Current (mA)		Slit (nm)	Method used for analysis
			Recommended	Maximum		
1	Arsenic (As)	193.7	10	12	0.5	By AAS with VGA
2	Cadmium (Cd)	228.8	4	10	0.5	By AAS with Graphite Tube Analyzer (GTA)
3	Chromium (Cr)	357.9	7	15	0.2	
4	Copper (Cu)	324.8	4	10	0.5	
5	Mercury (Hg)	253.7	4	8	0.5	By AAS with VGA
6	Iron (Fe)	248.3	7	10	0.2	By AAS with Flame
7	Lead (Pb)	217	10	12	1.0	By AAS with Graphite Tube Analyzer (GTA)
8	Nickel (Ni)	232	4	10	0.2	
9	Zinc (Zn)	213.9	5	10	1.0	

Study Area

A total number of 688 water quality stations covering all the major river basins in India right from East to West and North to South were studied for trace and toxic metals during Aug 2018 to Dec 2020. The studied 688 monitoring stations on the Indian Rivers is shown in GIS map as Fig 1.

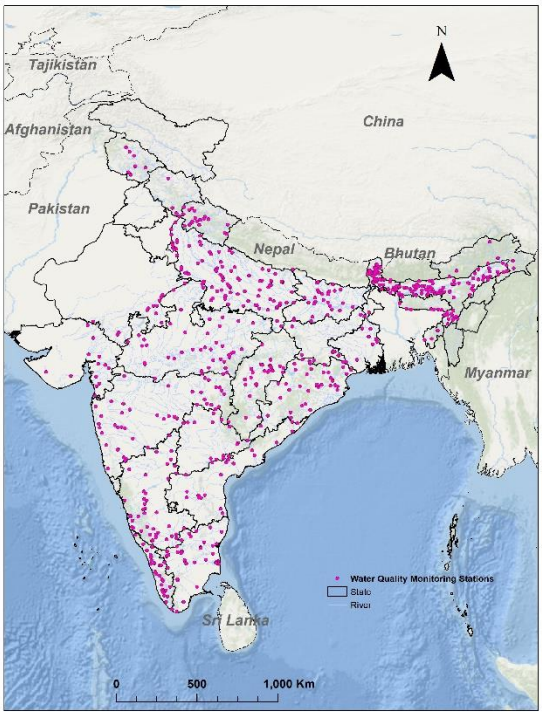


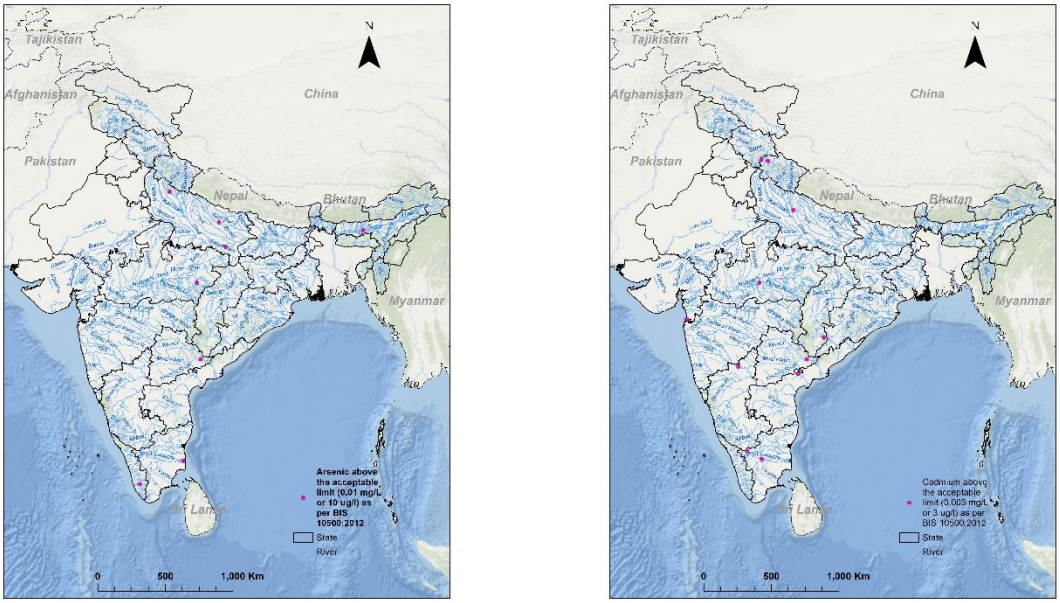
Figure 1. 688 Water quality stations monitored on important rivers covering all the major river basin of India.

RESULTS AND DISCUSSION

ARSENIC (As) in Indian Rivers: BIS has recommended 0.01 mg/L (10 µg/L) as acceptable concentration of arsenic in drinking water. Total 2834 numbers of water samples were analysed and collected from 688 water quality monitoring stations for arsenic content in Indian Rivers during the period Aug, 2018 to Dec, 2020. The arsenic concentration varies from 0.00 to 13.33 µg/L. Maximum arsenic concentration (13.33 µg/L) was observed at Porakudi water quality monitoring station on Arasalar River (a tributary of Cauvery River) during Dec, 2019. From reported data of all River water quality stations, it was found that arsenic concentration was above the acceptable limits at 8 sites.
It is also observed that, the acceptable limit exceeds only during non-monsoon period. The details of stations with respect to their river where Arsenic concentration exceeded the acceptable limits is given in Table 3. WQ monitoring station is also shown in GIS map as Fig 2(i).

Table 3. Rivers and WQ monitoring stations where Arsenic exceeded the acceptable limits

S.No.	Name Of Site	Month/Year	Arsenic (µg/L)	River	State
1	Bhadrachalam	Dec-19	10.17	Godavari	Telangana
2	Changsari	Dec-19	12.60	Brahmaputra	Assam
3	Faizabad U/S	Dec-19	10.11	Ghaghra	Uttar Pradesh
4	Madamon	Dec-19	10.45	Pamba	Kerala
5	Mirzapur	Dec-19	10.36	Ganga	Uttar Pradesh
6	Mohgaoan	Dec-19	10.76	Burhner	Madhya Pradesh
7	Moradabad	Dec-19	10.85	Ramganga	Uttar Pradesh
8	Porakudi	Dec-19	13.33	Arasalar	Tamil Nadu



(i) (ii)

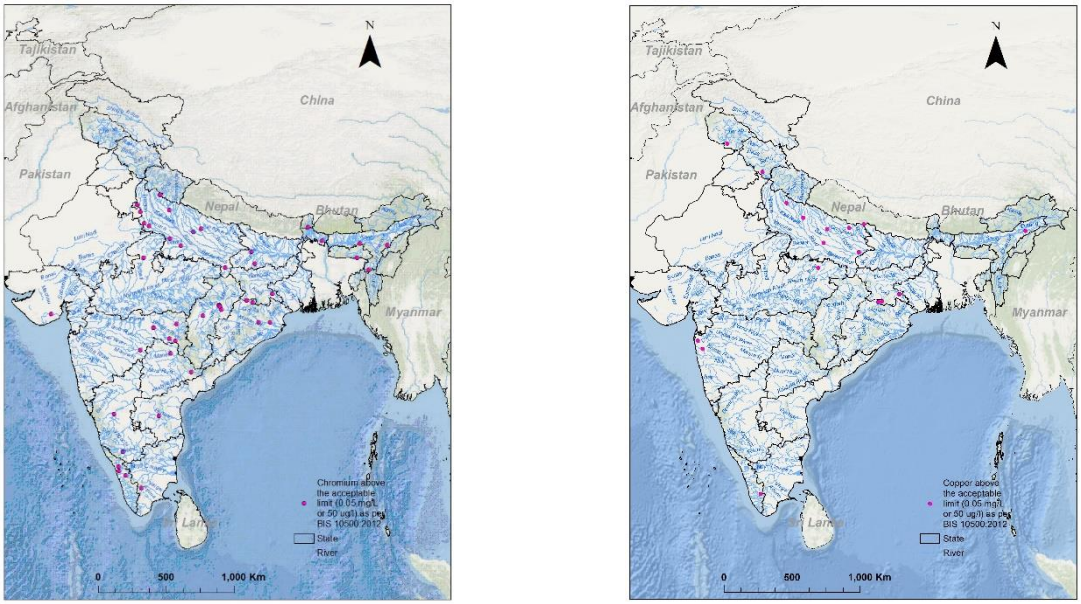
Figure 2. WQ monitoring stations where Arsenic exceeded the acceptable limits. (ii) WQ monitoring stations where Cadmium exceeded the acceptable limits.

CADMIUM (Cd) in Indian Rivers: BIS has recommended 0.003 mg/L (3 µg/L) as acceptable concentration of Cadmium in drinking water. Total 3113 numbers of water samples were analysed and collected from 688 water quality monitoring stations for cadmium content in Indian Rivers during the period Aug, 2018 to Dec, 2020. The cadmium concentration varies from 0.00 to 12.57 µg/L. Maximum cadmium concentration (12.57 µg/L) was observed at Todarpur water quality monitoring station on Sukheta River during Dec, 2020. From reported data of all River water quality stations, it was found that cadmium concentration was above the acceptable limits at 11 sites. Table 4 shows the details of stations with respect to their river where Cadmium concentration exceeded the acceptable limits. WQ monitoring station is also shown in GIS map as Fig 2(ii).

Table 4: Rivers and WQ monitoring stations where Cadmium exceeded the acceptable limits

S.No.	Name Of Site	Month/Year	Cadmium (µg/L)	River	State
1	Bhadrachalam	Aug-19	4.08	Godavari	Telangana
2	Deongaon Bridge	Aug-19	3.25	Bhima	Karnataka
3	Elunuthimangalam	Dec-20	12.29	Noyyal	Tamil Nadu
4	Hoshangabad	Aug-19	3.09	Narmada	Madhya Pradesh
5	Jagdalpur	Aug-19	3.15	Indravati	Chattisgarh
6	Keesara	Aug-19	5.18	Munneru	Andhra Pradesh
7	Kuthnuor	Dec-20	3.21	Yamuna	Uttrakhand
8	Thengumarahada	Dec-20	3.19	Moyar	Tamil Nadu
9	Todarpur	Dec-20	12.57	Sukheta	Uttar Pradesh
10	Tuini/Tons	Dec-20	12.31	Tons	Uttarakhand
11	Vapi	Dec-18	4.22	Damanganga	Gujarat

CHROMIUM (Cr) in Indian rivers: BIS has recommended 0.05 mg/L (50 µg/L) as acceptable concentration of Chromium in drinking water. Total 3106 numbers of water samples were analysed and collected from 688 water quality monitoring stations for Chromium content in Indian Rivers during the period Aug, 2018 to Dec, 2020. The Chromium concentration varies from 0.00 to 180.47 µg/L. Maximum Chromium concentration (180.47 µg/L) was observed at M.B.P.L. water quality monitoring station on Hasdeo River during Dec, 2019. From reported data of all River water quality stations, it was found that Chromium concentration was above the acceptable limits at 46 sites. The stations with respect to their river where Chromium concentration exceeded the acceptable limits is shown in GIS map as Fig 3(i).



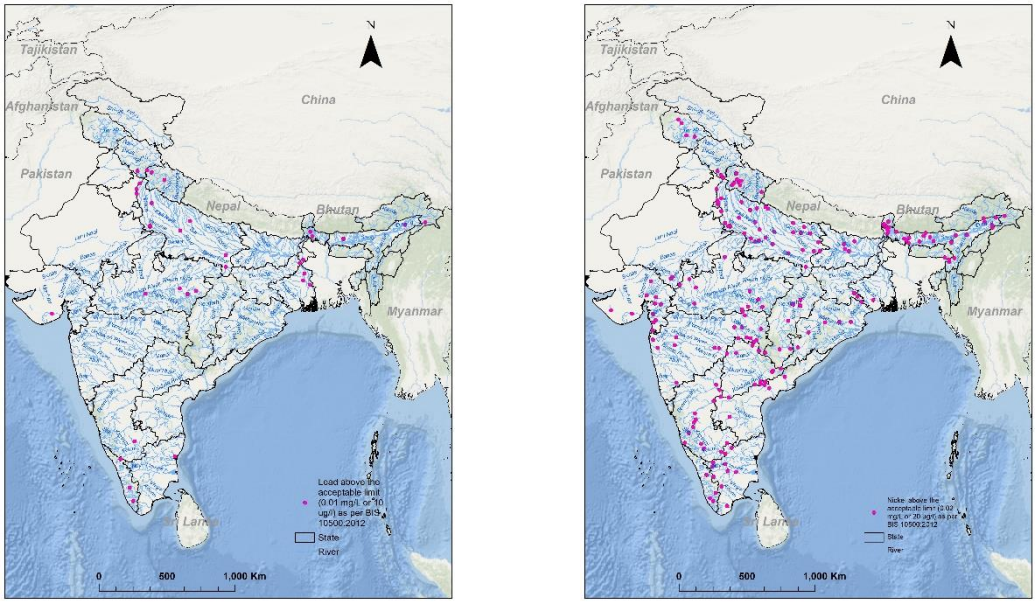
(i) (ii)

Figure 3. WQ monitoring stations where Chromium exceeded the acceptable limits. (ii) WQ monitoring stations where Copper exceeded the acceptable limits.

COPPER (Cu) in Indian rivers: BIS has recommended 0.05 mg/L (50 µg/L) as acceptable concentration of Copper in drinking water. Total 3107 numbers of water samples were analysed and collected from 688 water quality monitoring stations for Copper content in Indian Rivers during the period Aug, 2018 to Dec, 2020. The Copper concentration varies from 0.00 to 132.64 µg/L. Maximum Copper concentration (132.64 µg/L) was observed at Badlapur water quality monitoring station on Ulhas River during Dec, 2019. From reported data of all River water quality stations, it was found that Copper concentration was above the acceptable limits at 17 sites. The stations with respect to their river where Copper concentration exceeded the acceptable limits is shown in GIS map as Fig 3(ii).

Lead (Pb) in Indian Rivers: BIS has recommended 0.01 mg/L (10 µg/L) as acceptable concentration of Lead in drinking water. Total 3111 numbers of water samples were analysed and collected from 688 water quality monitoring stations for Lead content in Indian Rivers during the period Aug, 2018 to Dec, 2020. The Lead concentration varies from 0.00 to 67.55 µg/L. Maximum Lead concentration (67.55 µg/L) was observed at Chopan water quality monitoring station on Sone River during May, 2020. From reported data of all River water quality stations, it was found that Lead concentration was above the acceptable limits at 34 sites. The stations with respect to their river where Lead concentration exceeded the acceptable limits is shown in GIS map as Fig 4(i).

Nickel (Ni) in Indian rivers: BIS has recommended 0.02 mg/L (20 µg/L) as acceptable concentration of Lead in drinking water. Total 3111 numbers of water samples were analysed and collected from 688 water quality monitoring stations for Nickel content in Indian Rivers during the period Aug, 2018 to Dec, 2020. The Nickel concentration varies from 0.00 to 242.90 µg/L. Maximum Nickel concentration (242.90 µg/L) was observed at Elunuthimangalam water quality monitoring station on Noyyal River during Dec, 2020. From reported data of all River water quality stations, it was found that Nickel concentration was above the acceptable limits at 199 sites. The stations with respect to their river where Nickel concentration exceeded the acceptable limits is shown in GIS map as Fig 4(ii).



(i) (ii)

Figure 4. (i) WQ monitoring stations where Lead exceeded the acceptable limits. (ii) WQ monitoring stations where Nickel exceeded the acceptable limits.

Iron (Fe) in Indian Rivers: 3113 water samples from 688 water quality stations were analyzed for Iron content; 756 samples of 414 water quality stations were found to contain Iron concentrations above the acceptable limits. The Iron concentration varies from 0.00 to 11.24 mg/L.
Zinc (Zn) in Indian Rivers: Total 3113 water samples from the 688 water quality monitoring stations were analyzed during the reporting period. Maximum Zinc concentration (1.70 mg/L) was observed at Belkheri water quality monitoring station on Sher River (Tributary of Narmada River) during May, 2020. In the study area, all the river water quality stations are reported to have zinc concentration well within the acceptable and permissible limits of Bureau of Indian Standards (BIS).

KEY FINDINGS

Brahmani-Baitarni Basin: As per the analysis of 8 Trace and Toxic metals data for 27 WQ stations in the Brahmani-Baitarni Basin for the period Aug, 2018 to Dec, 2020; it was found that none of the water quality stations was within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. All 27 stations were obtained beyond the permissible limit due to presence of one or more toxic metals (Cr/Cu/Ni/Fe). Nevertheless, it was found that Arsenic, Cadmium, Lead and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Brahmani-Baitarni Basin.

Brahmaputra Basin: As per the analysis of 8 Trace and Toxic metals data for 52 WQ stations in the Brahmaputra Basin for the period Aug, 2018 to Dec, 2020; it was found that 9 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 25 stations were obtained beyond the permissible limit due to presence of only Iron. However, one or more toxic metals (As/Cr/Ni/Fe/Pb) were obtained beyond the permissible limit at 18 WQ Stations. Further, Copper and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Brahmaputra Basin.

Cauvery Basin: As per the analysis of 8 Trace and Toxic metals data for 37 WQ stations in the Cauvery Basin for the period Aug, 2018 to Dec, 2020; it was found that 21 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 16 stations were obtained beyond the permissible limit due to presence of one or more toxic metals (As/Cd/Cr/Ni/Fe/Pb). However, Copper and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Cauvery Basin.

Ganga Basin: As per the analysis of 8 Trace and Toxic metals data for 202 WQ stations in the Ganga Basin for the period Aug, 2018 to Dec, 2020; it was found that 55 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 67

stations were obtained beyond the permissible limit due to presence of two or more toxic metals (As/Cd/Cr/Cu/Pb/Ni/Fe). Nevertheless, it was observed that Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Ganga Basin.

Godavari Basin: As per the analysis of 8 Trace and Toxic metals data for 50 WQ stations in the Godavari Basin for the period Aug, 2018 to Dec, 2020; it was found that only 2 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 48 stations were obtained beyond the permissible limit due to presence of one or more toxic metals (As/Cd/Cr/Ni/Fe). Nevertheless, Lead, Copper and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Godavari Basin.

Indus Basin: As per the analysis of 8 Trace and Toxic metals data for 8 WQ stations in the Indus Basin for the period Aug, 2018 to Dec, 2020; it was found that 3 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 5 stations were obtained beyond the permissible limit due to presence of Cu or Ni. Nevertheless, Arsenic, Cadmium, Chromium, Iron, Lead and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Indus Basin.

Krishna Basin: As per the analysis of 8 Trace and Toxic metals data for 42 WQ stations in the Krishna Basin for the period Aug, 2018 to Dec, 2020; it was found that 18 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 11 stations were obtained beyond the permissible limit due to presence of two or more toxic metals (Cd/Cr/Ni/Fe). However, it was observed that Arsenic, Lead, Copper and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Krishna Basin.

Mahanadi Basin: As per the analysis of 8 Trace and Toxic metals data for 36 WQ stations in the Mahanadi Basin for the period Aug, 2018 to Dec, 2020; it was found that 18 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 5 stations were obtained beyond the permissible limit due to presence of two or more toxic metals (Cr/Ni/Fe). But Arsenic, Cadmium, Copper, Lead and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Mahanadi Basin.

Mahi Basin: As per the analysis of 8 Trace and Toxic metals data for 5 WQ stations in the Mahi Basin for the period Aug, 2018 to Dec, 2020; it was found that all 5 water quality stations were found beyond the permissible limit due to presence of two or more toxic metals (Fe and Ni). However, it was found that Arsenic, Cadmium, Chromium, Copper, Lead and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Mahi Basin.

Narmada Basin: As per the analysis of 8 Trace and Toxic metals data for 18 WQ stations in the Narmada Basin for the period Aug, 2018 to Dec, 2020; it was found that 2 water quality stations were within the acceptable limit as far as toxic metals are concerned according to the BIS: 10500-2012. While 8 stations were obtained beyond the permissible limit due to presence of two or more toxic metals (As/Cd/Pb/Ni/Fe). However, Chromium, Copper and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Narmada Basin.

Pennar Basin: As per the analysis of 8 Trace and Toxic metals data for 6 WQ stations in the Pennar Basin for the period Aug, 2018 to Dec, 2020; it was found that 1 water quality station was obtained beyond the permissible limit due to presence of only Chromium and 1 station was found Nickel beyond the acceptable limits as per Bureau of Indian Standards (BIS).
Sabarmati Basin: As per the analysis of 8 Trace and Toxic metals data for 15 WQ stations in the Sabarmati Basin for the period Aug, 2018 to Dec, 2020; it was found that all 15 stations were obtained beyond the permissible limit due to presence of one or more toxic metals (Cu/Cr/Ni/Fe). However, Arsenic, Cadmium, Copper, Lead and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) in rivers located in Sabarmati Basin.

Tapi Basin: As per the analysis of 8 Trace and Toxic metals data for 4 WQ stations in the Tapi Basin for the period Aug, 2018 to Dec, 2020; it was found that 3 water quality stations were obtained beyond the permissible limit due to presence of only Iron and 1 station was found Nickel and Iron beyond the acceptable limits as per Bureau of Indian Standards (BIS).

SUMMARY

A comprehensive study of the results reveals that out of 688 River water quality stations monitored, water samples collected at 180 water quality stations are found within the permissible limit for all purposes. While 187 stations were obtained beyond the permissible limit due to presence of two or more toxic metals (As/Cd/Cr/Cu/Pb/Ni/Fe). There are 240 numbers of stations where only Iron concentration beyond permissible limit (0.3 mg/L). Similarly, river water is found beyond the acceptable limit at 2 stations due to presence of only arsenic, 2 stations due to presence of only copper, 1 station due to presence of only cadmium, at 7 stations due to presence of only Chromium, at 61 stations due to presence of only nickel and 8 stations due to presence of only lead contamination. Summary of contamination of different toxic metals are given in Table 5 & 6.

Table 5. Overall analysis statistic

S. No	Metals	Total Samples Analysed	Total Contaminated Samples	Total Contaminated Stations	Total Contaminated Rivers
1	As	2834	8	8	8
2	Cd	3113	11	11	11
3	Cr	3106	50	46	33
4	Cu	3107	17	17	17
5	Pb	3111	36	34	24
6	Ni	3099	265	199	122
7	Fe	3113	756	414	234
8	Zn	3113	0	0	0

Table 6. Summary of Metal Contamination

S. No	Parameters	No. of Sites/Stations
1	Arsenic only	2
2	Cadmium only	1
3	Chromium only	7
4	Copper only	2
5	Lead only	8
6	Nickel only	61
7	Iron only	240
8	Two or More metals	187
Total Contaminated WQ Stations		508
Total WQ Stations where all toxic metals found within acceptable limits		180
Total Stations studied		688

Further State-wise stations were analysed for metal contamination, details of which are given below in Table 7.

Table 7. State-wise statistical data

S.No.	State	Total Sites	WQ Sites where all metals found within the permissible limit	Total Contaminated WQ Stations							
				As	Cd	Cr	Cu	Pb	Ni	Fe	Zn
1	Andhra Pradesh	21	5		1	1			7	14	
2	Arunachal Pradesh	7	1					1	1	6	
3	Assam	89	16	1		3	1	2	18	64	
4	Bihar	30	6			2	1		5	20	
5	Chattisgarh	32	15		1	5			13	7	
6	Delhi	3	1			1			2	1	
7	Gujarat	13			1	1		1	11	13	
8	Haryana	2				1		1	2		
9	Himachal Pradesh	5	2				1	1	3	2	

10	Jammu & Kashmir	7	2				1		4		
11	Jharkhand	12	1			1	1		4	11	
12	Karnataka	40	16		1	2		1	12	13	
13	Kerala	26	1	1		3	1	3	4	25	
14	Madhya Pradesh	42	12	1	1	1	1	4	11	27	
15	Maharashtra	45	17			5	2		17	24	
16	Manipur	1								1	
17	Meghalaya	8	2			1			1	6	
18	Odisha	47	3			5	2		6	43	
19	Pondicherry	3	2					1			
20	Rajasthan	14	10						2	4	
21	Sikkim	26	18			1			6	3	
22	Tamil Nadu	38	17	1	2	1			11	11	
23	Telangana	13	2	1	1	2			8	5	
24	Tripura	3								3	
25	Uttar Pradesh	92	15	3	1	9	6	9	33	71	
26	Uttrakhand	30	12		2			3	11	9	
27	West Bengal	39	4			1		7	7	31	
Total		688	180	8	11	46	17	34	199	414	0

COMPARISON STUDY

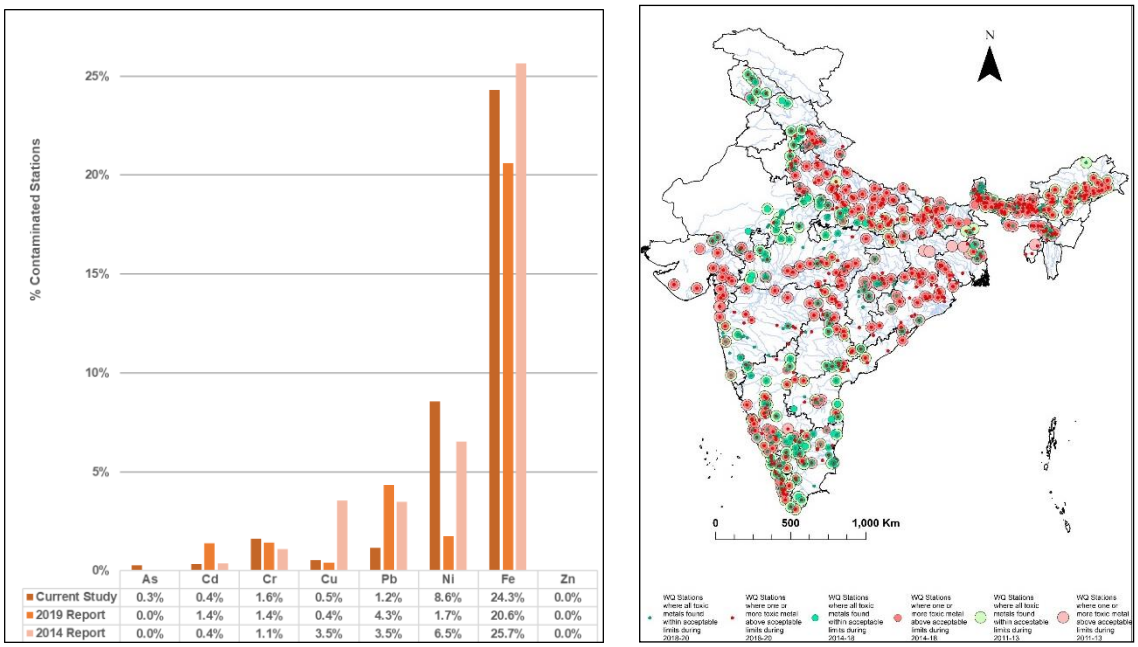
The comparison has been done with water quality data published by CWC in 2014 and 2019. CWC report-2014 has studied the 387 River water quality stations metal data of Sep 2011 to Aug 2013 period. Water samples collected at 171 water quality stations were found to be within the permissible limit for all purposes, while 100 stations were beyond the permissible limit due to presence of two or more toxic metals. CWC report published in 2019 considering the data of May 2014 to Apr 2018 of 424 River water quality stations reveals that 137 water quality stations are found within the acceptable limit as per BIS: 10500-2012. While results of samples from 101 stations were beyond the acceptable limit due to presence of two or more toxic metals.

During study period Sep 2011-Aug 2013; 44% stations were reported metal content within acceptable limit while 32% stations were reported during study period May 2014 to Apr 2018. However, in the current study (data period Aug 2018 to Dec 2020); only 26% stations were found within acceptable limits. Each Metal wise statistic comparison details are given in Table 8 and Fig 5i.

Comparison of current study with 2014 and 2019 reports showed the increasing metal concentration in Indian Rivers. All the stations of three study period have been projected in GIS Map (Fig 5ii) to locate the increase in metal concentration in rivers with respect to time period.

Table 8. Historical data analysis

S. No.	Metals	Study Period: Aug 2018 to Dec 2020		Study Period: May 2014 to Apr 2018		Study Period: Sep 2011 to Aug 2013	
		Total Analysed Samples	Total Contaminated Samples	Total Analysed Samples	Total Contaminated Samples	Total Analysed Samples	Total Contaminated Samples
1	As	2834	8	2293	0	1921	0
2	Cd	3113	11	2908	40	1934	7
3	Cr	3106	50	2959	42	1932	21
4	Cu	3107	17	2959	12	1924	68
5	Pb	3111	36	2959	128	1919	67
6	Ni	3099	265	2582	45	1637	107
7	Fe	3113	756	2959	610	1918	492
8	Zn	3113	0	2959	0	1913	0



(i) (ii)

Figure 5. (i) Metal-wise beyond the acceptable limits stations. (ii) Locations of stations studied is shown in Indian Rivers.

CONCLUSION AND WAY FORWARD

It was concluded that water quality of the Indian rivers particularly at some identified stations may have been affected adversely by presence of high concentration of heavy metals. Over the last decade, the concentration of these heavy metals in river water have been increasing. Consequently, concentrations of toxic metals in grains and vegetables grown with contaminated river water will be increasing. Hence, there is an urgent need for stringent Government policy and monitoring for the following activities to control the metal concentration in river water:

- Ore processing, smelting, and refining operations
- Heavy metals discharge in river system by natural or anthropogenic sources
- The metal containing unregulated enormous discharge of untreated industrial waste waters into riverine system
- Storm water runoff from urbanized areas.

ASSUMPTION

In absence of a standard of water quality for river waters specifically, BIS 10500:2012 has been used as a baseline for comparison of data. This standard for drinking water has specified limits of various Trace & Toxic metals. However, it should be understood that this standard is directly not applicable for river waters.

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