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An Investigation of the Presence of Heavy Metals in the Water and Sediment of the Kharun River Stretch Near Raipur, Chhattisgarh

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Keywords

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Abstract

My present study focused on the systematic analysis of Kharun river water and sediment. Samples were collected from the Kharun River in the monsoon, winter, and summer seasons for the duration of one hydrological year (2018–2019). This study deals with the assessment of the physicochemical properties of water and the concentration of heavy metals along with a sediment sample from the Kharun River. The average result of physicochemical analysis in the monsoon, winter, and summer seasons showed that pH (7.91, 7.73, and 7.61), conductivity (435.43, 690, 921.77), total dissolved solids (286.36, 451.75, and 599.15), turbidity (1.17, 3.38, and 4.93), DO (7.85, 8.49, and 6.80), BOD (29.20, 22.55, and 36.83), and COD (53.67, 40.17, and Heavy metal concentration analysis showed that in river water samples were Cu (0.2335, 0.2208, 0.2608 mg/L), Cr (0.7520,0.7989, 0.8108 mg/L), Zn (1.2366, 1.0384, 1.3028 mg/L), Pb (0.1715, 0.1925, 0.1914mg/L), Mn (0.0746, 0.0760, 0.0719 mg/l), As (0.3908, 0.4067, 0.3429 mg/L), Cd (0.2251, 0.2254, 0.2286 mg/L), Co (0.1744, 0.1755, 0.1781 mg/L), Ni (0.1658, 0.1642, 0.1719 mg/L), Sn (0.5894, 0.3472, 0.5943 mg/L) and Fe (0.0736, 0.0654, 0.0981 mg/L).Cu (38.75, 57.57, 66.91 mg/kg), Cr (97.86, 102.71, 140.02 mg/kg), Zn (170.04, 133.71, 177.02 mg/kg), Pb (31.51, 31.91, 38.7 mg/kg), Mn (268.19, 281.80, 52.56 mg/kg), As (17.74, 16.75, 21.73 mg/kg), Cd (0.66, 0. Heavy metals' presence in river water and sediment may exist due to the identical or comparable human and natural source input, which is impacted by the geochemical characteristics. This is shown by a positive Pearson's correlation coefficient. Using pollution indicators such as the contamination factor (CF), contamination degree (CD), pollution load index (PLI), enrichment factor (EF), and geo-accumulation index, researchers will examine the seasonal fluctuation and degree of contamination and pollution (I-geo). The study has indicated that almost all the parameters are at higher levels than the prescribed limit, like WHO, USEPA, and BIS. The water eminence of the Kharun River is reduced due to anthropogenic activity like domestic, agricultural, and industrial discharge and is unsuitable for domestic uses without treatment of this river.

1. Introduction

The most vital and significant natural resource intended for the survival of existence on earth is water. 70.90% of the earth is enclosed in water, with oceans holding 96.5 percent of the globe. The ice caps of Antarctica and Greenland, as well as groundwater, both contain an equal amount of water (1.7% of the total amount), and 0.001% of the atmosphere is made up of vapors, vapor, and precipitation. According to Upadhyay Manish et al. (2014), just 2.5% of the water on earth is available as fresh water, and the remaining 98.8% is found in groundwater. Rivers have a key role in maintaining life on this planet, as they not only create life but also sustain it.

Sewage water and industrial wastewater disposal are currently a big problem, producing pollution of various surface water sources due to the rise in the amount of water utilized and wastewater produced by various towns and industries throughout the world. Industrial, municipal, and pesticides, insecticides, and fertilizers containing agricultural water pollutants have all had severe effects on water resources throughout the past three decades as a consequence of the rapid rise of industrialization and urbanization.

The majority of water resources have been severely impacted by seepage, leaching, and mixing of industrial effluents in most municipal cities and industrial townships during the modern industrialization period [Ramesh R et al., 1990]. Our rivers are rapidly becoming significantly contaminated with dangerous chemicals, heavy metals, and poisonous substances owing to industrialization and rapid urbanization, and the quality of the river water is declining daily.

nonstop release of harmful toxic metals, wastewater, and oxygen demanding substances are introduced to river water, it affects the physicochemical parameters of the water, including pH, temperature, conductivity, turbidity, TDS, BOD, COD, and metal concentration. This waste may contain dangerous chemicals, metals, pesticides, and fertilizers that, upon discharge, combine with the sediments of rivers.

Waste from neighboring rivers is immediately discharged by industrial, mining, and building activities [Wang Y et al. (2011)]. Although heavy metals exist naturally in the earth's crust and can contaminate water through weathering, this natural heavy metal pollution is quite minimal. As sediments have a longer residence time in rivers, they are collected from heavily metal-polluted rivers and examined [Sarkar U.K. et al. (2012)].

Assessment of toxic metals in river water is crucial since they are not biodegradable, accumulate in living things through the food chain, and have negative impacts on the biological system. Problems with water quality have an impact on both human and environmental health; therefore, the more we monitor our water, the better we'll be able to spot and stop contamination problems. According to the World Commission on Water [Garg S. K. et al. (2010)], more than half of the significant rivers in the world are contaminated, which has an impact on both surrounding ecosystems and human health [WHO 2004].

The Kharun River is a perennial river that rises in the Balod Tehsil in the southeast of the Durg district. It joins the Shivnath river near Somnath in the north after running for about 164 kilometers. Its catchment area is 4191 km2 and extends upstream to the point where it combines with the Shivnath River.

SITE DESCRIPTION AND SAMPLE COLLECTION

Geotechnically, the Raipur district's Kharun River is situated between 21° 33' 38" N latitude and 81° 55' 25" E longitude. The location of the Kharun River is located in an industrial and urban region, which includes two major cities: Raipur and Durg.

Figure 1: The sample site is depicted on a map.

COLLECTION OF WATER SAMPLE

A water sample of the Kharun river stretch in Raipur, India, is taken from various locations along the stretch, which falls under the industrial and urban areas. Samples are collected and assessed for physicochemical variables such as pH, EC, TDS, turbidity, OD, chemical oxygen demand, and heavy metal content.

COLLECTION OF SEDIMENT SAMPLE

In the years 2018–2019, samples were taken during the monsoon, winter, and summer seasons. Before each weighing, each sample that was taken was brought to the lab, homogenized, pulverized in a complete mortar, filtered to a 63-ml sediment fraction, and allowed to air dry for 72 hours. Before usage, testing equipment was dried and rinsed in double-distilled water.

2. Materials and Methods

(A) Study of River Water Sample's Physicochemical Parameters

The collected water was examined for the following seven indicators of water quality: DO, COD, TDS, turbidity, EC, and BOD.

Table 1: Physicochemical parameter with used method**.**

S. No.	Parameters	Method used
1.	pH	pH Meter
2.	Conductivity	Conductivity Meter
3.	TDS	TDS Meter
4.	Turbidity	Turbidity meter
5.	DO	Titrimetric
6.	BOD	Dilution
7.	COD	Titrimetric

(B) Analysis of Heavy Metals Using Atomic Absorption Spectroscopy in River Water and Sediment

Using a spectrophotometer, the concentration of metals, including Cu, Cr, Zn, Pb, Mn, As, Cd, Co, Ni, Sn, and Fe, has been determined (Thermo Scientific ICE 3000 series AAS Spectrophotometer). On a hot plate, samples of water and sediment were digested with an acid solution (10 ml HNO_3 + 5 ml HCl_4). The following method of acid digestion of river water and silt was used:

The samples were prepared in 25 ml of deionized water and maintained at 40°C. Metal standard solution calibration curves were used for metal quantification. Surindra Suthar and others (2010) On Whatman paper No. 42 filters were used to filter the digested samples after that.

3. Results and Discussion

(A) Physico-chemical Parameters of the Kharun River Water

Average assessment of the physicochemical parameters varies significantly from one river to another in the Kharun River basin and from year to year, depending on where samples are taken. My research's findings on seasonal variability in river physicochemical parameters in water samples are more readily comparable to WHO-permitted limits in the Kharuna River. (Table no. 2)

Table 2. Physical and chemical parameter average in the water of the Kharun River.

S. No.	Physicochemical parameters	Kharun river			WHO Permissible limits
		Monsoon	Winter	Summer	
1.	**pH**	7.9±0.08	7.73±0.17	7.61±0.15	6.5-8.5
2.	**Conductivity(µS/cm)**	552.10±19.34	690±22.86	993.43±19.73	750 (µS/cm)
3.	**TDS (mg/L)**	353.03±21.23	351.75±10.20	603.15±18.36	500 (mg/L)
4.	**Turbidity (N.T.U.)**	1.16±0.27	3.38±0.88	4.93±0.70	5 (N.T.U.)
5.	**DO (mg/L)**	7.85±0.79	8.49±0.21	6.8±0.72	4-6 (mg/L)
6.	**BOD (mg/L)**	29.2±3.45	22.55±1.31	36.83±1.21	2 (mg/L)
7.	**COD (mg/L)**	53.7±4.32	40.17±10.94	53±5.93	-

According to Table No.2, the water from the Kharun River had an average pH value between 7.61 and 7.9. However, when the pH levels of the three seasons were taken into account, it was discovered that the water of the Kharun River was somewhat alkaline, with the monsoon season having the highest pH level of 7.9 and the summer season having the lowest pH level (Fig. 2). Because carbonates and bicarbonates are present in adequate amounts, river waters are often alkaline. According to Table No. 2, the average electric conductivity of the water in the Kharun River ranged from 552.10 S/cm to 993.43 S/cm during the investigation. The summer saw the highest EC value of river water, which was higher than the permitted maximum value of 993.43 S/cm. The monsoon season saw the lowest EC value (Fig. 2). Lower values were reported during the monsoon season apparently owing to dilution of river water, and greater values of EC in the summer season region are plainly impacted by the industrial municipal effluents released, which may contain various ions like OH, $CO_3^{2-,}$ Cl^-, $Ca^{2+,}$ K^+, Na^+, SO_4^{2+}, etc. According to Table No. 2, the average TDS levels for water from the Kharun River ranged from 351.75 mg/L to 603.15 mg/L. The Kharun River's water had a maximum TDS value during the summer that was greater than the allowable limit of 603.15 mg/L and a minimum TDS value during the winter (Fig. 2). The fact that there are more chemicals, minerals, and wastewater released from industries during the summer is clearly the cause of the higher TDS readings in that area. According to data from the Kharun River, the average turbidity ranged from 1.16 NTU to 4.93 NTU (Table No.2). The turbidity of the water in the Kharun River was found to be at its highest through the summer and at its lowest through the monsoon season (Fig. 2), yet it was always within the allowable limit. One of the most crucial aspects of water quality is dissolved oxygen (DO). The biological aerobic breakdown of huge amounts of organic material causes a significant amount of dissolved oxygen to be rapidly consumed, affecting the water quality and aquatic life. Dissolved oxygen (DO) is the dissolved gaseous form of oxygen. Due to the coldest temperatures in the winter, the greatest values of 8.49 mg/L as well as the lowest value of 6.8 mg/L are discovered (Table No. 2 and Fig. 2). Every season, it is discovered that the BOD and COD values are significantly higher than the thresholds. The summer season has the greatest BOD value (36.83 mg/L), while the winter season has the lowest value (22.55 mg/L). The value of COD was greatest in the monsoon season at 53.7 mg/l and lowest in the winter season at 40.17 mg/l; table 2 shows their change, accordingly. The reason for the elevated BOD and COD readings is undoubtedly improperly treated household and industrial wastewater (Table 2 and Fig. 2).

(B) Heavy metal concentration in the Kharun River Water

In the Kharun River water sample, the seasonal standard concentration of heavy metals dropped in the following order: Zn > Cr > Sn > As > Cu > Cd > Pb > Co > Ni > Fe > Mn. In the river water sample, Zn concentration was higher than that of the other heavy metal in all three seasons, but it was still below the permissible limit (5 mg/l), and Mn concentration was lower than that of the other heavy metal in all three seasons, but it was still below the permissible limit (0.1 mg/l). In all three seasons, Cu and Fe concentrations are below the permitted limits. However, all three seasons had Cr, Pb, As, Cd, Co, Ni, and Sn concentrations that were greater than the permitted limits (0.1 mg/l, 0.05 mg/l, 0.005 mg/l, 0.04 mg/l, 0.02 mg/l, and 0.1 mg/l, respectively) (Table no. 3). the Kharun River's water's seasonal change in heavy metal concentration. Cu, Cr, Zn, Pb, Mn, As, Cd, Co, Ni, Sn, and Fe concentrations during the monsoon, winter, and summer seasons The summer and monsoon seasons have higher concentrations of Cu, Zn, Ni, Sn, and Fe, whereas the winter has lower concentrations. The concentration of Mn and As is highest in the winter during the monsoon season, and the lowest concentration is in the summer. The concentration of Cr, Cd, and Co is highest in the summer compared to the winter season, and the monsoon season has the lowest concentration. Pb concentration is highest in the winter, lowest in the summer, and highest during the monsoon season (Fig. 3). This metal mostly enters the environment through anthropogenic activities including mining, industrial wastewater runoff from agriculture, and urban wastewater, as well as usual activities such as soil corrosion.

Table 3. Average Concentration (mg/L) of Heavy Metal in the Kharun River Water

Heavy Metal Parameters (mg/L)	Kharun river			WHO Permissible limits (mg/L)
	Monsoon	Winter	Summer	
Cu	0.2335±0.0455	0.2208±0.0272	0.2608±0.0974	1.0
Cr	0.7520±0.0373	0.7989±0.0322	0.8108±0.0669	0.1
Zn	1.2361±0.0145	1.0384±0.2671	1.3028±0.0809	5.0
Pb	0.1715±0.0113	0.1925±0.0115	0.1914±0.0187	0.05
Mn	0.0746±0.0049	0.0760±0.0047	0.0719±0.0167	0.1
As	0.3908±0.0669	0.4067±0.0664	0.3429±0.1351	0.05
Cd	0.2251±0.0017	0.2254±0.0020	0.2286±0.0051	0.005
Co	0.1744±0.0017	0.1755±0.0021	0.1781±0.0010	0.04
Ni	0.1658±0.0031	0.1642±0.0033	0.1719±0.0019	0.02
Sn	0.5894±0.1142	0.3472±0.1452	0.5943±0.1992	0.1
Fe	0.0736±0.0074	0.0654±0.0073	0.0981±0.0262	0.3

(C) Correlation study of heavy metals in the Kharun River water

The table below lists the correlation coefficients for the heavy metals present in the water of the Kharun River in the Raipur region. According to Table 3.1's findings, Cr-Cu, Ni-Cu, Ni-Cr, and Ni-Mn all showed substantial positive associations (>0.5) during the monsoon season. Fe-Cu, Fe-Pb, Fe-Mn, Ni-As, Fe-Ni, Zn-Cr, Fe-Cr, and Ni-Cd were discovered to have a strong inverse connection [> (-0.7)]. The Pb-Cu, Mn-Cu, Pb-Cr, Mn-Pb, Ni-Pb, Cd-As, Fe-As, and Fe-Cd corrosion had the strongest association or significance correlation (>0.8). The remaining components have less correlation in each case. (Table 3.2) shows that during the winter season, As-Cu, Cd-Cu, Fe-Cu, Zn-Cr, Pb-Cr, Mn-Cr, Co-Cr, Sn-Cr, Co-Zn, and Fe-Ni were all shown to have substantial positive associations (>0.5). There was a significant inverse correlation [> (-0.7)] between Cd-Zn, Fe-Zn, Cd-Mn, Ni-Mn, Fe-Mn, Sn-As, Sn-Cd, and Fe-Sn. The elements with the strongest positive correlations (>0.8) were Mn-Zn, Sn-Zn, Co-Mn, Sn-Mn, Cd-As, Fe-As, and Fe-Cd, respectively. The other elements have weaker correlations. Table 3.3 shows that throughout the summer, Cd-Cr, Co-Cr, Sn-Cr, Co-As, and Sn-Co were all shown to have substantial positive associations (>0.5). Between Ni-Zn, Co-Mn, Sn-Pb, and Ni-As, respectively, there was a significant negative correlation [> (-0.7)]; the remaining components have a weaker correlation. Heavy metal contamination from industrial wastewater, urban wastewater, and agricultural wastewater dumped into rivers led to a wide range of compound pollutants.

Table 3.1. Heavy metal pair correlations in samples of Kharun River water taken during the monsoon.

	Cu	Cr	Zn	Pb	Mn	As	Cd	Co	Ni	Sn	Fe
Cu	1										
Cr	**0.707**	1									
Zn	-0.368	-0.791	1								
Pb	**0.835**	**0.839**	-0.349	1							
Mn	**0.857**	**0.955**	-0.661	**0.891**	1						
As	-0.817	-0.630	0.413	-0.688	-0.688	1					
Cd	-0.660	-0.291	0.113	-0.479	-0.359	**0.901**	1				
Co	0.098	-0.562	**0.823**	-0.123	-0.315	-0.009	-0.220	1			
Ni	**0.756**	**0.765**	-0.522	**0.816**	**0.730**	-0.822	-0.744	-0.325	1		
Sn	-0.460	0.027	-0.080	-0.119	-0.162	-0.010	0.073	-0.313	-0.082	1	
Fe	-0.894	-0.734	0.350	-0.890	-0.802	**0.936**	**0.814**	-0.002	-0.899	0.083	1

Table 3.2. Heavy metal pair correlations in samples of Kharun River water taken during the **winter**

	Cu	Cr	Zn	Pb	Mn	As	Cd	Co	Ni	Sn	Fe
Cu	**1**										
Cr	-0.085	1									
Zn	-0.318	**0.705**	1								
Pb	-0.300	0.687	0.285	1							
Mn	-0.360	0.631	**0.908**	0.480	1						
As	0.594	-0.427	-0.814	0.038	-0.605	1					
Cd	0.517	-0.670	-0.939	-0.263	-0.837	**0.917**	1				
Co	-0.059	0.622	0.709	0.379	0.828	-0.406	-0.706	1			
Ni	0.318	-0.434	-0.628	-0.643	-0.845	0.218	0.470	-0.537	1		
Sn	-0.270	0.626	**0.949**	0.108	**0.839**	-0.851	-0.954	**0.788**	-0.434	1	
Fe	0.528	-0.478	-0.942	-0.115	-0.851	**0.917**	**0.948**	-0.605	0.556	-0.925	1

Table 3.3. Heavy metal pair correlations in samples of Kharun River water taken during

	Cu	Cr	Zn	Pb	Mn	As	Cd	Co	Ni	Sn	Fe
Cu	1										
Cr	-0.213	1									
Zn	-0.313	-0.390	1								
Pb	-0.427	-0.255	0.135	1							
Mn	-0.527	-0.467	-0.049	0.482	1						
As	0.351	0.031	0.383	-0.619	-0.659	1					
Cd	-0.143	**0.725**	-0.458	0.010	-0.300	0.158	1				
Co	0.155	**0.757**	0.024	-0.565	-0.883	0.598	0.471	1			
Ni	0.260	0.129	-0.802	0.146	0.236	-0.751	-0.026	-0.299	1		
Sn	-0.144	**0.731**	-0.370	-0.714	-0.241	0.258	0.471	0.599	-0.015	1	
Fe	0.295	-0.053	0.413	0.256	-0.548	0.074	-0.271	0.275	-0.067	-0.547	1

(D) Heavy Metal Concentration in Kharun River Sediment

In the sequence Fe>Mn>Zn >Cr >Ni>Cu >Pb >Co>As>Sn>Cd, the seasonal average concentration of heavy metals in the sediment sample from the Kharun River dropped. In all three seasons, the average seasonal variation of Cu, Cr, Cd, Ni, and Fe is higher than the permitted limit. The seasonal order of concentration in these metals shows that Pb concentration is over the allowed limit in the summer season and Co concentration is below the permissible level in all three. Zn, Mn, As, and Sn concentrations are higher than the permitted limits in all three seasons, while Zn and As concentrations vary periodically from summer to winter to monsoon season. The seasonal order of Mn concentration is summer, monsoon, and winter. The seasonal order of Sn concentration is summer > winter > monsoon. In the sediment of the Kharun River, winter came before summer and then the monsoon. In addition to weathering, which raises the concentration of heavy metals in Kharun River sediments, anthropogenic activities like mining, metallurgical, industrial, and agricultural operations, fuel emissions, domestic sewage disposal, and solid waste disposal also contribute to elevated levels of heavy metals. (Fig. 4 and Table No. 4)

Table 4. Average Concentration (mg/kg) of Heavy Metals in Kharun River Sediment

Heavy Metal Parameters (mg/kg)	Kharun river			WHO	USEPA	ASV
	Monsoon	Winter	Summer			
Cu	38.75±5.97	57.57±4.12	66.91±16.49	25	31.6	45
Cr	97.86±5.61	102.71±4.37	140.02±3.65	25	43.4	90
Zn	170.04±10.69	133.71±4.67	177.02±8.00	123	121	95
Pb	31.51±2.78	31.92±4.20	38.70±2.65	-	35.8	20
Mn	268.19±18.36	281.80±17.34	252.56±26.11	-	30	850
As	17.74±2.70	16.75±3.26	21.73±2.34	-	-	13
Cd	0.66±0.02	0.68±0.06	0.70±0.05	0.6	0.99	0.30
Co	26.00±2.40	28.73±5.11	33.04±5.53	-	50	19
Ni	62.76±3.26	100.84±5.27	102.09±5.07	20	22.7	68
Sn	10.69±1.77	13.05±2.73	11.20±2.91	-	-	6
Fe	1576.96±5.31	1836.15±4.93	3075.60±3.70	-	30	46000

(F) Correlation study of heavy metals in Kharun river sediment

Seasonal heavy metal availability in river Kharun sediment indicates considerable levels of correlation between various levels of correlation. Co-Cr exhibits a strong positive association (>0.5); the closest or most significant correlation was (>0.8) between Mn-Cr, As-Pb, and Fe-Co; and during the monsoon season, a strong negative relationship (> -0.7) was discovered between Cr-Cu, Mn-Cu, Cd-Zn, Cd-Pb, Sn-Mn, Ni-Co, and Fe-Ni (Table No. 4.1). Strong positive relationships (> 0.5) were found between Zn-Cu, As-Cu, Co-Cu, Zn-Cr, As-Cr, Ni-As, Sn-As, Fe-As, and Sn-Co during the winter season. The closest or most significant relationship (>0.8) was found between Cr-Cu, Co-Cr, Co-As, and Fe-Ni. Strong negative relationships (> (-0.7)) between Cd-Cu and Cd-Cr During the summer, a strong negative association [> -0.7] was discovered between As-Cu, Co-Zn, Fe-Pb, and Sn-Co, and a high level (>0.5) of positive relationship was seen between Fe-Cu, Ni-Zn, Sn-Zn, Fe-Zn, Mn-Pb, Co-Mn, Ni-As, Sn-As, and Sn-Ni (Table No. 4.3). The remaining components in each of the three seasons are minimally correlated. The positive association may be pointing to shared anthropogenic and natural sources, as well as the possibility that additions may have an impact.

Table 4.1. Correlation between heavy metals analyzed in the sediment of the Kharun River for the monsoon

	Cu	**Cr**	**Zn**	**Pb**	**Mn**	**As**	**Cd**	**Co**	**Ni**	**Sn**	**Fe**
Cu	1										
Cr	-0.872	1									
Zn	-0.034	0.168	1								
Pb	-0.493	0.230	0.367	1							
Mn	-0.706	**0.906**	-0.137	-0.025	1						
As	-0.523	0.351	0.315	**0.831**	0.234	1					
Cd	0.370	-0.311	-0.798	-0.809	0.052	-0.575	1				
Co	-0.532	0.500	-0.084	0.136	0.317	-0.255	-0.253	1			
Ni	0.135	-0.241	-0.458	0.092	0.046	0.453	0.391	-0.700	1		
Sn	0.186	-0.616	-0.074	0.314	-0.796	-0.002	-0.126	0.002	-0.042	1	
Fe	-0.222	0.286	0.267	0.146	0.036	-0.330	-0.468	**0.879**	-0.871	0.036	1

Table 4.2. Correlation between heavy metals analyzed in the sediment of the Kharun River for the winter

	Cu	**Cr**	**Zn**	**Pb**	**Mn**	**As**	**Cd**	**Co**	**Ni**	**Sn**	**Fe**
Cu	1										
Cr	**0.934**	1									
Zn	0.658	0.669	1								
Pb	0.135	0.130	0.259	1							
Mn	0.443	0.215	0.190	-0.120	1						
As	0.667	0.781	0.067	-0.114	0.083	1					
Cd	-0.888	-0.718	-0.773	-0.166	-0.639	-0.268	1				
Co	0.774	**0.895**	0.494	-0.180	-0.067	**0.819**	-0.474	1			
Ni	0.108	0.399	0.079	0.225	-0.149	0.522	0.170	0.313	1		
Sn	0.030	0.248	-0.175	-0.726	-0.294	0.573	0.287	0.588	0.351	1	
Fe	0.092	0.307	-0.298	0.317	-0.254	0.667	0.297	0.273	**0.812**	0.293	1

Table 4.3. Correlation between heavy metals analyzed in the sediment of the Kharun River for the summer

	Cu	**Cr**	**Zn**	**Pb**	**Mn**	**As**	**Cd**	**Co**	**Ni**	**Sn**	**Fe**
Cu	1										
Cr	0.404	1									
Zn	0.341	0.372	1								
Pb	-0.186	-0.207	-0.414	1							
Mn	0.270	0.315	-0.435	**0.755**	1						
As	-0.781	-0.252	0.245	0.185	-0.365	1					
Cd	-0.276	-0.440	-0.217	-0.094	-0.317	-0.005	1				
Co	0.050	0.064	-0.823	0.419	0.724	-0.477	-0.290	1			
Ni	-0.337	0.187	0.514	-0.164	-0.354	**0.708**	-0.610	-0.362	1		
Sn	-0.245	-0.471	0.592	-0.149	-0.675	0.670	0.024	-0.784	0.564	1	
Fe	0.564	0.333	0.594	-0.824	-0.494	-0.323	-0.366	-0.322	0.295	0.198	1

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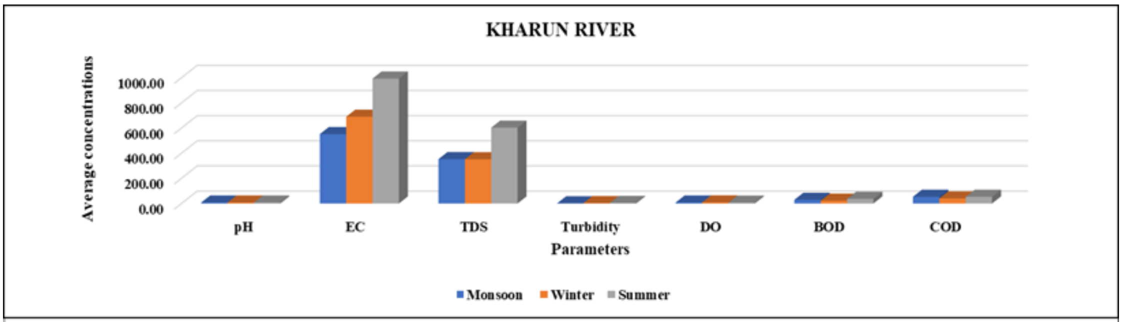
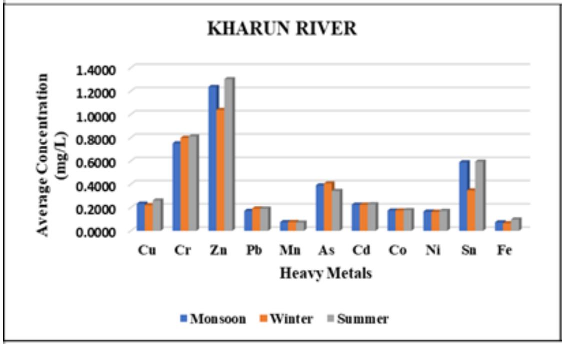


Fig.2: Average Concentration of Physicochemical parameters in Kharun River water pH; EC (µS/cm); TDS (mg/L); Turbidity (N.T.U.); DO; BOD; COD (mg/L).



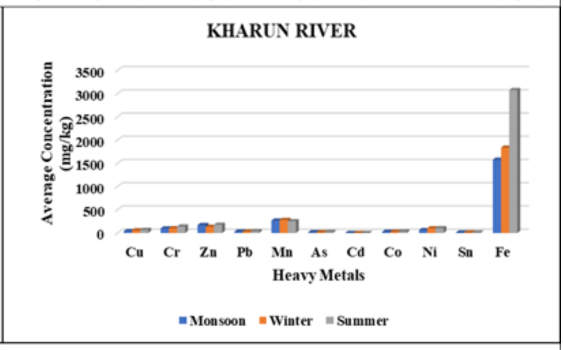


Fig.3: Average Concentration of Heavy Metals (mg/L) in Water Samples.

Fig.4: Average Concentration of Heavy Metals (mg/kg) in Sediment Samples.

Metal contamination factor (CF), contamination degree (CD), pollution load index (PLI), enrichment factor, and geo-accumulation index (Igeo)

Contamination factor (CF)

Heavy metal content was compared with background values of typical rocks found in the earth's shell or to middling shale concentrations [Turekian and Wedepohl 1961], which serve as the recognized global benchmark for unpolluted silt, to establish the CF. The CF for each element is determined through the equation shown below:

$$\textbf{Contamination factor (CF)}=\frac{\text{Mean metals concentration at contamination type}}{\text{Matal avarege shale concentration}}$$

Contamination degree (CD): The sum of each pollutant's individual contamination factors is known as the CD [Hakanson, 1980].

Pollution load index (PLI)

The approach suggested by Tomlinson et al. to calculate the PLI for each site (1980). The pollutant load index for a single spot is calculated by multiplying the factors (CF values) collectively to obtain the nth root of n. The subsequent equation was used to calculate the PLI for each site: -

$$\textbf{Pollution load index (PLI)} = n\sqrt{CF1 \times CF2 \times CF3 \times \ldots CFn}$$

Enrichment factor

To determine the stage of contamination as well as comprehend the allocation of anthropogenic-derived components in sediments by individual elements, enrichment factorial (EF) techniques were used. Since Fe is one of the most often used reference elements and is mostly supplied by sediments in wetlands, it was considered the normalization factor when evaluating EF values. 2015 [Jun Ren et al.]. Here is how the EF is defined: -

$$\textbf{Enrichment factor (EF)} = \frac{(\text{M}\backslash\text{Fe})\text{sampie}}{(\text{M}\backslash\text{Fe})\text{background}}$$

Geo-accumulation Index (I-$_{geo}$)

The I-geo was used for evaluating the level of metal pollution in aquatic sediment investigations by assessing the extent of heavy metal uptake in sediment [Muller, 1969].

$$\text{I-geo} = \log_2[C_n/(1.5B_n)]$$

Where factor 1.5 be used to account for potential fluctuations in conditions values for a precise metal in the environment as well as very modest anthropogenic influences. Cn was the measured concentration of heavy metal in river sediments; BN was the geochemical background value of element n within typical shale.

The silt of the Kharun River is contaminated with heavy metals. As indicated in Table No. 5, Cu, Cr, Zn, Pb, As, Cd, Co, Ni, and Sn exhibit an intermediate level CF value (1 to CF 3), whereas Mn and Fe exhibit a low CF value (CF 1). According to the mean value CF, the order of metals in the sediment from the Kharun River was Cd>Sn>Pb>Zn>Co>As>Ni>Cr>Cu>Mn>Fe. The level of heavy metal contamination in Kharun River silt was measured at 14.71, indicating a high-level CD value (12 CD-24), as indicated in Table No. 5. The Kharun River sediment's 0.99 PLI intended for heavy metals shows the extent of the problem. According to Table No. 5's analysis of the enrichment factor of heavy metals in Kharun River sediment, Mn is showing a considerable enrichment value (5 EF 20), very high enrichment values (20 EF 40), and extremely high enrichment (EF>40) for Cu, Cr, Zn, Pb, As, and Ni. According to the average value, the heavy metal enrichment value of the sediment from the Kharun River is in the following order:

Cd>Co>Sn>Pb>Zn>Co>As>Ni>Cr>Cu>Mn., the heavy metal accumulation index in the silt of the Kharun river. Cu, Cr, Mn, As, Ni, and Fe exhibited an unpolluted (I-geo) result, while the computed values of Zn, Cd, Co, Sn, and Pb may be regarded as unpolluted to highly polluted (Table No. 6). According to average values, the heavy metals I-geo value of the sediment from the Kharun River is in the following order: Cd>Co>Sn>Pb>Zn>As>Ni>Cr>Cu>Mn>Fe.

Table 5: Contamination Factor, Contamination Degree, Pollution Load Index, and Enrichment Factor Values

S. No.	**Heavy Metals**	**Kharun River sediment**	
		Contamination Factor	**Enrichment Factor**
1.	**Cu**	1.21	25.71
2.	**Cr**	1.26	26.83
3.	**Zn**	1.69	35.88
4.	**Pb**	1.70	36.20
5.	**Mn**	0.31	6.69
6.	**As**	1.44	30.66
7.	**Cd**	2.27	48.21
8.	**Co**	1.54	47.17
9.	**Ni**	1.30	27.70
10.	**Sn**	1.94	41.28

11.	**Fe**	0.05	1.00
CD		14.71	
PLI		0.99	

Table 6: Geo-accumulation Index (Igeo) Values

I-geo of Kharun river sediment				
S.No.	**Heavy metals**	**Monsoon**	**Winter**	**Summer**
1.	Cu	-0.80	-0.23	-0.01
2.	Cr	-0.46	-0.39	0.05
3.	Zn	0.25	-0.92	0.31
4.	Pb	0.07	0.09	0.37
5.	Mn	-2.25	-2.18	-2.34
6.	As	-0.14	-0.22	0.99
7.	Cd	0.55	0.60	0.64
8.	Co	-0.13	0.01	0.21
9.	Ni	-0.70	-0.02	0.00
10.	Sn	0.25	0.54	0.32
11.	Fe	-5.45	-5.23	-4.49

4. Conclusion

Observing the seasonal variations, it is concluded that water from the Kharun River cannot be used for drinking purposes as most of the parameters were confirmed to be at a high concentration. The high-level pollution from industrial effluents and municipal waste that causes environmental issues will have both direct and indirect impacts on plants and animals, as well as on human existence. It is recommended that the proper treatment of municipal and industrial effluent is essential in the study area before discharging.

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