Assessment of sewage treatment plant effluent and its impact on the surface water and sediment quality of river Ganga at Kanpur

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ABSTRACT

Heavy Metals contamination has expected significant issue because of their lethality and accumulative behavior. The river Ganga is facing serious threat of heavy metal pollution problem especially at Kanpur district of Uttar Pradesh, India. The goal of current research is to determine level of heavy metal contamination in municipal waste water and impact of treated sewage on the surface water and sediment nature of river Ganga at Kanpur. This study deals with the measurement of heavy metals i.e. Cu, Zn, Mn, Pb, Cr, and Cd. The heavy metals found in water samples in the range of Cu (0.006 to 1.103mg/l), Zn (2.25 to14.07mg/l), Mn (0.146 to 4.02mg/l), Pb (0.005 to 3.88mg/l), Cr (0.068 to 10.79mg/l), and Cd (0.073 to 0.447mg/l). The order of occurrence of heavy metals was Zn>Cr>Mn>Pb>Cu>Cd. The trend of heavy metals found in sediments were in the range of Cu (7 to 9.99mg /kg), Zn (28.02 to 30.23mg/kg), Mn (41.65 to 44.65mg/kg), Pb (14.96 to 19.07mg/kg), Cr (48.86 to 441mg/kg), and Cd (0.83 to 1.01mg/kg). The order of occurrence of heavy metals in sediments was Cr>Mn>Zn>Pb>Cu>Cd. The information has been inspected factually to clarify metal-metal affiliation utilizing Pearson relationship coefficient. Various major trace elements i.e. Al, Ca, Fe, K, Na, Rb, Si, Sr, Ti, Zr and Mg also analyzed with the help of WD-XRF in sediments collected from upstream and downstream of river Ganga.

Key words: - Heavy Metals, River Ganga, STP, Upstream, Downstream, Major trace elements.

1 INTRODUCTION

Contamination in the aquatic environment with substantial metals has turned into an overall issue amid late years, since they are non-biodegradable and they have capacity to bioaccumulate in aquatic ecosystem (Censi et al., 2006). Water contamination seriously affects every single living animal, and can contrarily influence the utilization of water for drinking, family unit needs, entertainment, angling, transportation and business. Several studies on substantial metals in waterways, lakes, fish and sediments (Fernandes et al., 2008; Oztürk et al., 2008; Pote et al., 2008 and Praveena et al., 2008) have been a fundamental ecological concentration for the most part amid the most recent decade. Silt are critical sinks for different contaminations like substantial metals and pesticides likewise assume a noteworthy part in the remobilization of poisons in oceanic frameworks under positive conditions and in cooperation amongst water and dregs. Overwhelming metals, for example, copper, iron, chromium and nickel are basic metals since their assume a vital part in organic frameworks, though cadmium and lead are unnecessary metals, as they are lethal, even in follow sums (Fernandes et al., 2008).Sediments close urban zones generally contain large amounts of contaminants (Cook and Wells, 1996; Lamberson et al., 1992) which constitute a noteworthy natural issue confronted by numerous anthropogenically affected sea-going situations (Magalhaes et al., 2007).

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The Ganga River is a standout amongst the most contaminated river on the planet. Expanded urbanization and industrialization in the basin, has brought about dirtying the stream, since the river has been favored waste transfer site for mechanical and local effluents. The Ganga River in Kanpur is in a matter of seconds being dealt with as a characteristic sewer, waste stop and funeral home. The Ganga in Kanpur is dependably strewn with human bodies and creature bodies, waste, for example, non-biodegradable polybags, worship materials e.g., floral offerings, clay idols, account books and so on. It is important to note that Kanpur generates approximately 400 million liters per day (MLD) of sewage that is discharged through dozens of drains either into river Ganga or river Pandu. The aim of this study is to examine the impact of substantial metal contamination in surface water and sediment nature of river Ganga at Kanpur city.

2 MATERIALS & METHODS

2.1 Study area

Kanpur is the industrial capital of Uttar Pradesh located at 26.4583° north and 80.3173° east. Its altitude is 126 meter above sea level. Kanpur also one of the oldest industrial townships of India lies on bank of river Ganga. The Ganga has been one of the most prominent and important river of India.

2.2 STP and Sampling sites:

Sewage treatment plant was being constructed in the year 1999. It is located at 26°24'52"North and 80°25'13"East near Jajmau industrial area at Kanpur. The installed capacity of the STP is 130 MLD. There are three units in that plant inlet, aeration tank, and outlet. The water samples have been collected from three

different points (Inlet, Aeration, & Outlet) of STP and two points (Upstream and Downstream) of river Ganga (*Fig 1*). The upstream of river Ganga near Siddhnath temple is around 500m behind the STP and downstream of river near Shiva temple ghat is around 500m ahead from the discharge point of STP in river Ganga. The water samples were from each sampling site in plastic container adding 1ml HNO_3 as metals preservation and stored in refrigerator at 4°C temperature. The sediments samples were collected from the upstream (unpolluted) and downstream (polluted) of river Ganga in the plastic bags. Both water and sediments samples were collected for the heavy metals analysis.

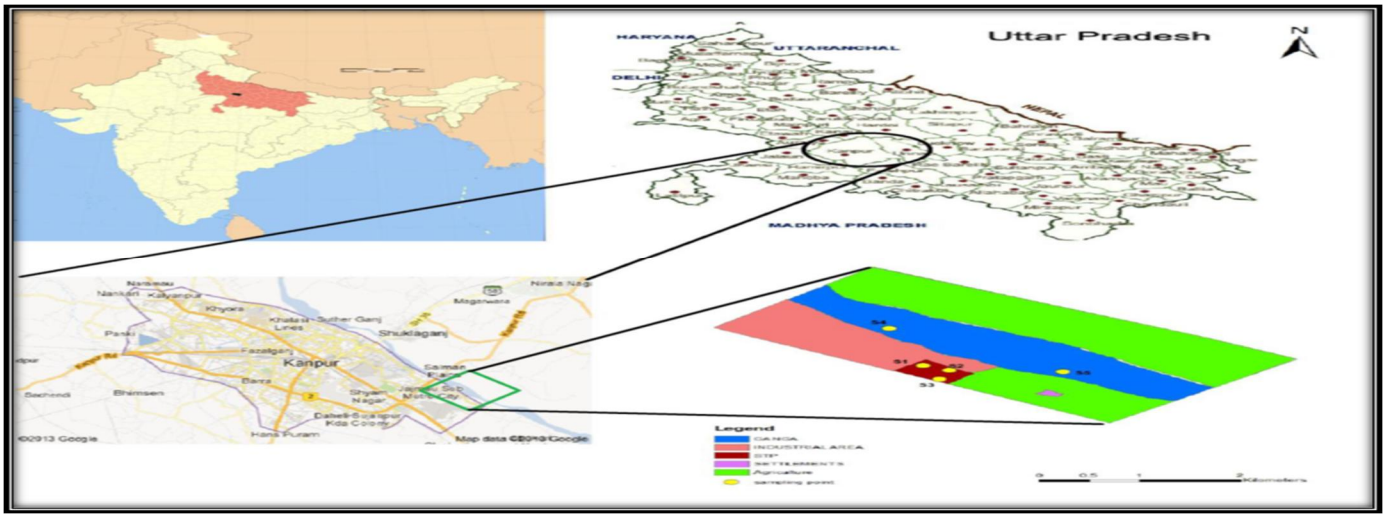

Fig 1: Study area map

2.3 Samples preparation:

After collection the water samples were filtered using Whatman filter paper no 42 and sediments sample were air dried at room temperature for 2 days. Water and sediments samples were prepared for acid digestion method for metals analysis. Determination of major trace elements like Al, Ca, Fe, K, Na, Rb, Si, Sr, Ti, Zr, and Mg in the river sediments has been also done using of WD XRF (Wave length Dispersive X-ray Fluorescence). About 3 grams of sample was taken and crushed properly and passed through the 2mm mesh sieve. About 1 gram of boric acid mixed and taken for the analysis in WD XRF.

2.4 Acid digestion and metal analysis:

The heavy metals concentration in the water and sediments samples were determined by following standard methods that are given by APHA (1998) using Atomic Absorption Spectrometer (AAS). The water (about 50ml) and sediments samples (2 grams) subjected to acid digestion with 20ml of Aqua regia (HCl & HNO_3 in 3:1 ratio). The mixture was then digested on hot plate at 80 to 90°C temperature till the solution became transparent. The resulting solution was filtered and diluted to 30ml using distilled water for the determination of metals concentration using Atomic Absorption Spectrometer (AAS).

2.5 Statistical Analysis

The results were analyzed and represented in the form of charts, tables, and bar-graphs. Two-way analysis of variance was used to analyze the significant difference between heavy metals in five different sampling stations of water and two sampling stations of sediments. Correlation analysis was done to find out the Correlation among the heavy metals in the waste water samples and river surface water. Bray–Curtis cluster analysis (CA) was carried out for water samples of STP and Ganga River to analyze the spatial similarity group of the different sites.

3 RESULTS AND DISCUSSION

3.1 Heavy metals concentration in water samples

The water samples from STP and from the upstream and downstream are collected in the month of January 2013. The concentration of different heavy metals Cu, Cd, Pb, Cr, Zn, Mn in the collected samples that recorded are shown in the (*Fig 2 and Fig 3*)

3.1.1 Copper

The average concentration of copper in the inlet (1.08±0.341 mg/l), aeration tank (0.863±0.318mg/l) and outlet (0.7±0.154mg/l) of STP. The concentration in the upstream (0.006±0.003mg/l) and in the downstream (1.103±0.112mg/l) of river, shown in (*Fig.2*), so the ranking pattern of average concentration of copper was Downstream>inlet>aeration tank>outlet>upstream.

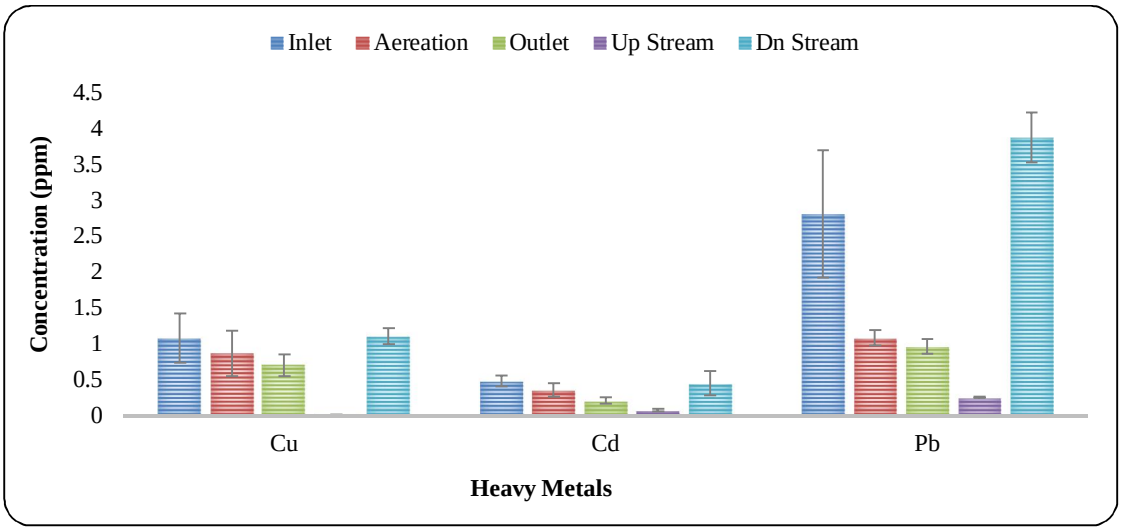

Fig 2: Concentration (Mean±Sd) of Copper, Cadmium & Lead at different sites

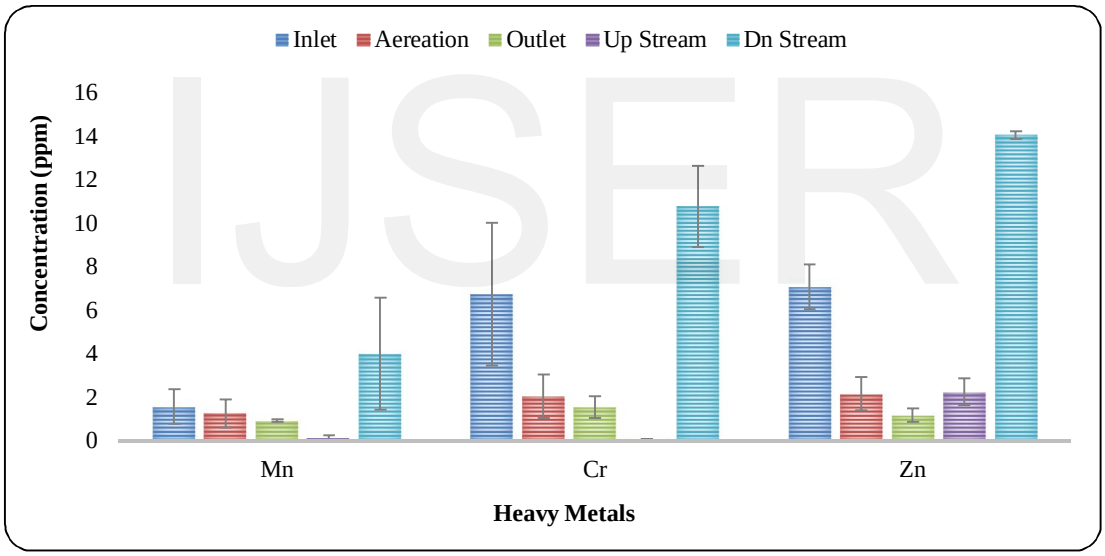

Fig 3: Concentration (Mean±Sd) of Manganese, Chromium & Zinc at different sites

3.1.2 Cadmium

The mean concentration of Cadmium found in the inlet (0.48±0.0790mg/l), aeration tank (0.353±0.093mg/l) and outlet (0.207±0.045mg/l) of STP. The concentration in the upstream (0.073±0.015mg/l) and in the downstream (0.447±0.170mg/l) of river, shown in (*Fig. 2*), so the ranking pattern of average concentration of cadmium was Inlet>downstream>aeration tank>outlet>upstream.

3.1.3 Lead

The mean concentration of lead (Pb) found in the inlet was (2.81±0.890mg/l), aeration tank (1.08±0.108mg/l) and outlet (0.963±0.103mg/l) of STP. In addition the concentration in the upstream was measure to be (0.055±0.010mg/l) and in the downstream (3.88±0.348mg/l) of river, shown in (*Fig.2*), so the ranking pattern of average concentration of the lead was Downstream>inlet>aeration tank>outlet>upstream.

3.1.4 Manganese

The average concentration of Manganese in the inlet (1.58±0.801mg/l), aeration tank (1.267±0.643mg/l) and outlet (0.93±0.070mg/l) of STP. The concentration in the upstream (0.146±0.117mg/l) and in the downstream (4.02±2.572mg/l) of river, shown in (*Fig.3*), so the ranking pattern of average concentration of manganese was Downstream>inlet>aeration tank>outlet>upstream.

3.1.5 Chromium

The average concentration of chromium in the inlet (6.75±3.297 mg/l), aeration tank (2.057±1.0mg/l) and outlet (1.557±0.506mg/l) of STP. The concentration in the upstream (0.068±0.015mg/l) and in the downstream (10.79±1.864mg/l) of river, shown in (*Fig.3*), so the ranking pattern of average concentration of chromium was Downstrea>>inlet>aeration tank>outlet>upstream.

3.1.6 Zinc

The average concentration of zinc in the inlet (7.086±1.036 mg/l), aeration tank (2.170±0.769mg/l) and outlet (1.183±0.318mg/l) of STP. The concentration in the upstream (2.25±0.616mg/l) and in the downstream (14.07±0.176mg/l) of River, shown in (*Fig.3*), so the ranking pattern of average concentration of the zinc was Downstream>inlet>upstream>aeration tank>outlet.

3.1.7 Correlation Matrix

It is inferred from the (*Table 1*) that coefficient of variance found to be highly significant between the heavy metals in the water occurred as follows– Cu with Cd (r =0.95), with Cr (r =0.77), with Pb (r =0.83), with Mn (r =0.73), Cd with Zn (r =0.68), with Cr (r =0.82), with Pb (r =0.87), with Mn (r =0.73), Zn with Cr (r =0.97), with Mn (r =0.93), with Pb (r =0.93), Cr with Pb (r =0.99), with Mn (r =0.99), Pb with Mn (r =0.92) at $p<0.01$. The results clearly indicate that the source of origin of heavy metals occurred due to the industrial effluent and various anthropogenic activities adjacent to the Ganga River.

Table 1: Correlation matrix among the heavy metals at different sampling sites

	Cu	Cd	Zn	Cr	Pb	Mn
Cu	1					
Cd	0.95132	1				
Zn	0.601521	0.683845	1			
Cr	0.772284	0.824456	0.9686262	1		
Pb	0.838202	0.875246	0.9306627	0.992386	1	
Mn	0.735995	0.728949	0.9349074	0.942186	0.922547	1

3.1.8 Bray Cluster Analysis

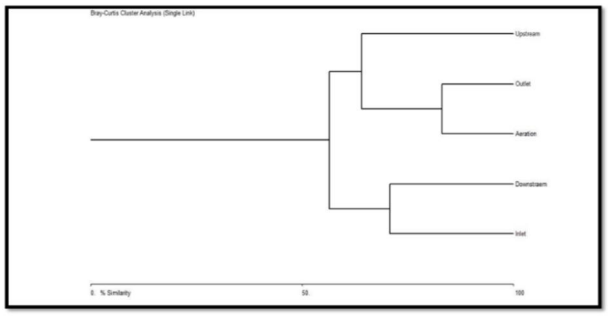

Fig 4: Bray – Cluster diagram based on the Curtis cluster analysis of concentrations heavy metals among different sampling sites of STP and Ganga River in Kanpur

3.1.9 Similarity Matrix

CA was applied to detect spatial similarity of the five sites of the STP and River Ganga based on the elemental concentration characteristics in water (*Table 2*). The Bray-Curtis cluster analysis based on the heavy metal concentrations of the water Collected from STP and at different discharge points into the river from STP resulted in a Dendogram (*Fig 4*). Dendogram described 4 clusters among the sites for the water showed that outlet and aeration tank of STP formed one cluster with 83.12% of similarity, indicating these are moderately contaminated. Inlet of STP and downstream of river formed one cluster with 70.7%. And upstream of river forming one separate cluster showing that it is comparatively less contaminated.

Table 2: Similarity Matrix among the different sampling sites

	INLET	AERATION TANK	OUTLET	UPSTREAM	DOWNSTREAM
INLET	*	56.4984	43.7495	32.1656	70.7247
AERATION TANK	*	*	83.1208	64.0995	34.2092
OUTLET	*	*	*	53.7934	25.4466
UPSTREAM	*	*	*	*	20.4409
DOWNSTREAM	*	*	*	*	*

3.1.10 Anova:

Two-way analysis of variance was used to analyze the significant difference between heavy metals in five different sampling sites of water (*Table 3*). Analysis shows that the result of the study has been acceptable as compared to the other study with the related study.

Table 3: Heavy metals in five different sampling sites of water

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Heavy Metals	303.6068	5	60.72135	68.22248232	1.83357E-23*	2.36827
Sampling Sites	343.0537	4	85.76344	96.35810746	2.05015E-25*	2.525215
Error	53.40294	60	0.890049			
Total	998.2909	89				

***Indicates highly significant**

4.1.1 Cadmium

Cadmium is a highly toxic heavy metal. It is a carcinogenic chemical mostly used in industrial effluents. The mean concentration of Cd in the upstream (0.83±0.125mg/kg) and in the downstream (1.01±0.675 mg/kg), shown in (**Fig 5).**

4.1.2 Copper

Copper (Cu) is extremely toxic and highly bio-accumulative. The mean concentration of Cu in the upstream (7±0.615mg/kg), and in the downstream (9.99±0.81mg/kg), shown in (**Fig 5).** The value obtained in current study of Cu concentration was within the permissible limit as assigned by ISQG (Interim freshwater sediment quality guidelines) that is (35.7mg/kg).

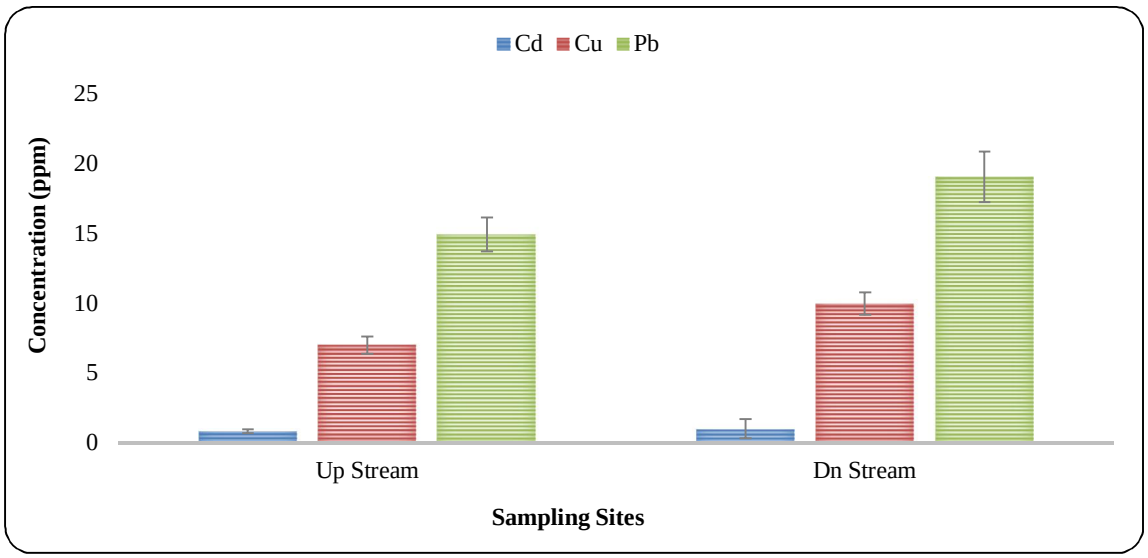

Fig 5: Concentration (Mean±Sd) of Cadmium, Copper & Lead at different sampling sites

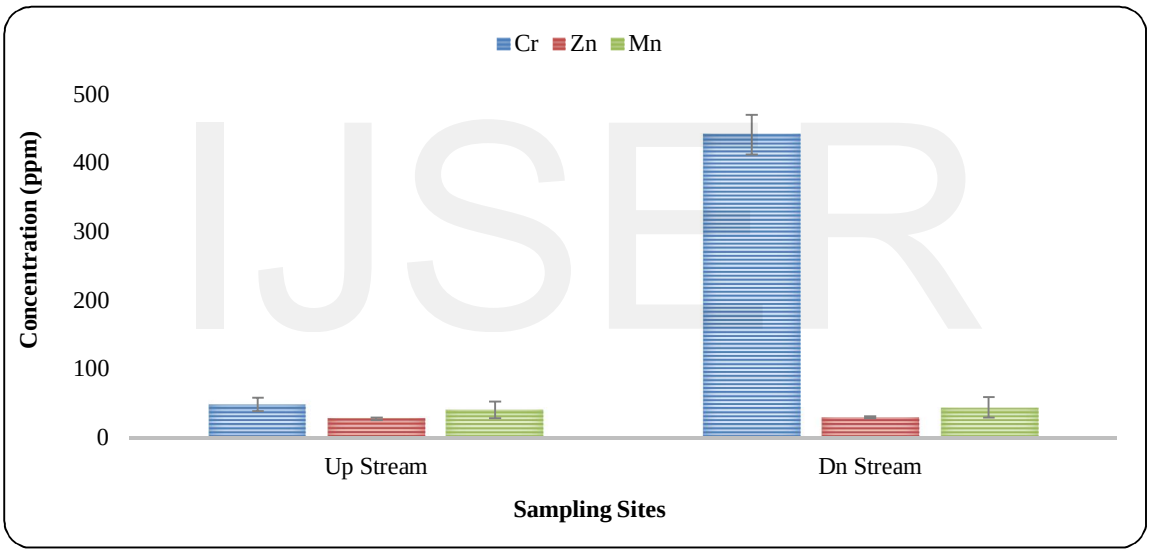

Fig 6: Concentration (Mean±Sd) of Chromium & Zinc, & Manganese different sampling sites

4.1.3 Lead

Lead is a very toxic heavy metal in high concentration. It is a non-essential element. The mean concentration of Lead in present study were found in sediments of upstream (14.96±1.222mg/kg) and in downstream (19.07±1.817mg/kg), shown in (*Fig 5)*.Its permissible limit in sediments assigned by ISQG guideline was (35.0 mg/kg).

4.1.4 Chromium

Environmental concentration of chromium is known to increase due to industrial development. The mean concentration of Cr in the upstream (48.86±9.534mg/kg), and in the downstream (441±29.00mg/kg), shown in (*Fig 6*). The permissible limit of Cr in sediments assigned by ISQG guideline was (37.3mg/kg).

4.1.5 Zinc

Zinc is an essential metal but it is also toxic in high concentration. The mean concentration of Zinc in sediments of Upstream (28.02±1.670mg/kg) and in downstream (30.23±1.502mg/kg), shown in (*Fig 6*.) The result obtained in current study of Zinc concentration in river bed sediment was within the permissible limit according to ISQG guideline that is (123mg/kg).

4.1.6 Manganese

Manganese is an extremely regular compound that can be discovered wherever on earth. Manganese is one out of three harmful fundamental follow components, which implies that it

is essential for people to make due, as well as poisonous when too high focuses are available in a human body. The mean concentration of Manganese in present study were found in sediments of upstream (41.65±12.303mg/kg) and in downstream (44.65±14.775mg/kg), shown in (*Fig 6*).

4.1.7 Anova

Two-way analysis of variance was used to analyze the significant difference between heavy metals in two sampling sites of sediments (Table 4).

Table 4: Heavy metals in two sampling sites of sediments

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Heavy Metals	261075.9	5	52215.18	477.25814	3.4E-23*	2.620654
Sampling Sites	41176.53	1	41176.53	376.36245	3.57E-16*	4.259677
Errors	2625.758	24	109.4066			
Total	495192.8	35				

***Indicates highly significant.**

5 Concentration of major trace elements in sediments of river Ganga

In present study the major trace elements like Al, Ca, Fe, K, Na, Rb, Si, Sr, Ti, Zr and Mg in sediments of river Ganga also analyzed. The mean concentration of major trace elements in the upstream and downstream sediments of Ganga River had shown in *Fig 7 & Fig 8.* The mean concentration of Al in the upstream (4.255±0.009), and in the downstream (4.519±0.340), shown in (*Fig 7*).The mean concentration of Ca in the upstream (2.072±0.008), and in the downstream (3.357±0.063), shown in (*Fig 7*).The mean concentration of Fe in the upstream (2.565±0.023), and in the downstream (3.462±0.080), shown in (*Fig 7*).The mean concentration of K in the upstream (2.219±0.022), and in the downstream (2.193±0.084), shown in (*Fig 7*).The average value of Si concentration was found in our study in the upstream of river (26.51±0.267), and in downstream (26.86±0.998) shown in (*Fig 7*).

The mean concentration of Na in the upstream (0.590±0.016), and in the downstream (0.668±0.050), shown in (Fig 8). The mean concentration of P in the upstream (0.079±0.002), and in the downstream (0.143±0.009), shown in (Fig 8). The mean concentration of Rb in the upstream (0.033±0.0008), and in the downstream (0.025±0.001), shown in (Fig 8).The average value of Sr concentration was found in the upstream of river (0.037±0.0008), and in downstream (0.040±0.0009) shown in (Fig 8).

In current study the mean concentration of Ti in upstream (0.426±0.006) and in downstream (0.760±0.037) shown in (Fig 8).The average concentration of Zr concentration was found in the upstream of river (0.16±0.007), and in downstream (1.075±0.058) shown in (Fig 8).The average value of Mg concentration was found i in the upstream of river (0.646±0.007), and in downstream (0.819±0.069) shown in (Fig 8).

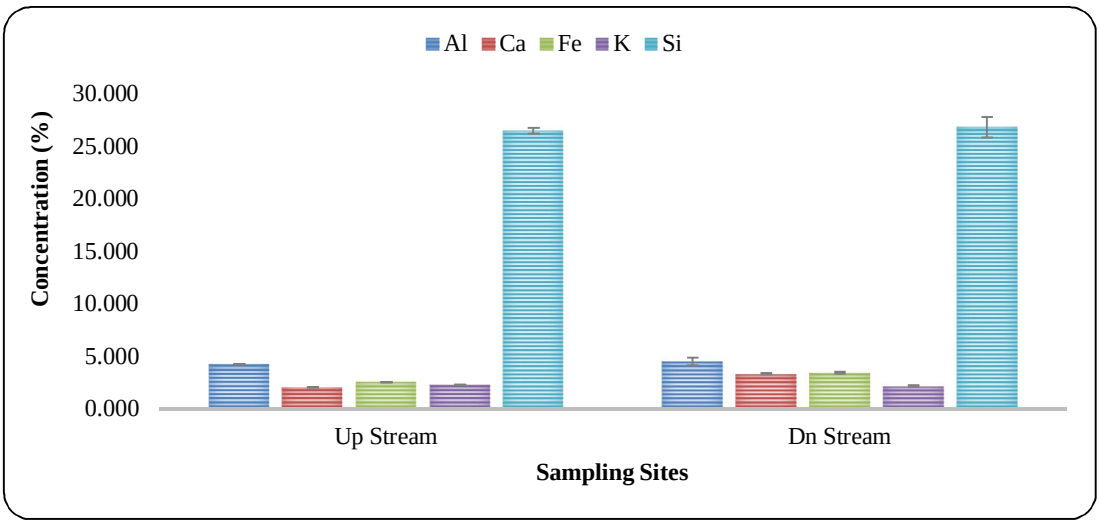

Fig 7: Concentration (Mean±Sd) of Al, Ca, Fe, K, & Si at different sampling sites

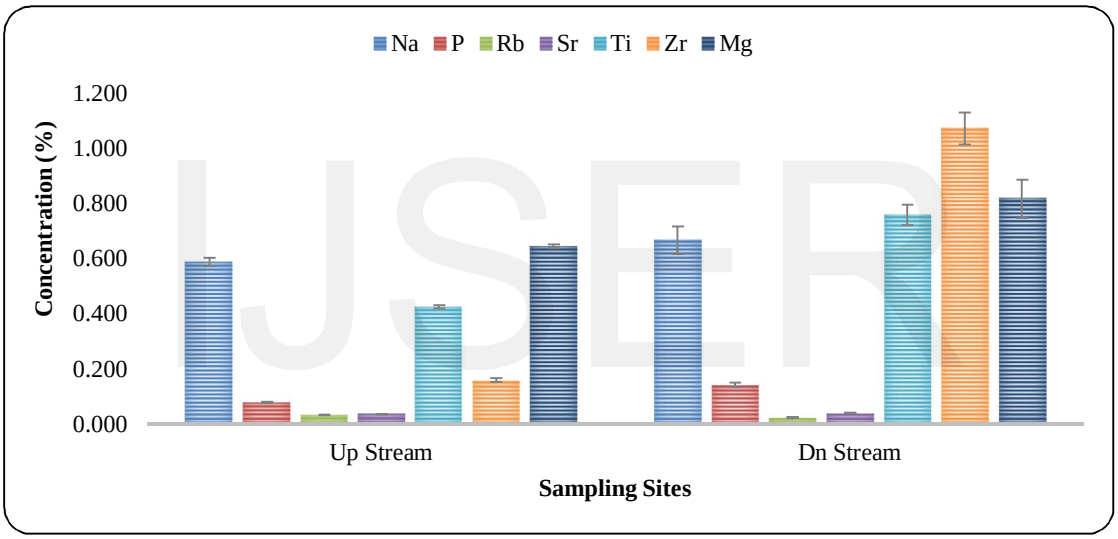

Fig 8: Concentration (Mean±Sd) of Na, P, Rb, Sr, Ti, Zr, & Mg at different sampling sites

5.1 Anova

Two-way analysis of variance was used to analyze the significant difference between trace elements in two sampling sites of sediments (Table 5).

Table 5: Significant difference of trace elements at sampling sites of sediment

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Major Trace Elements	6508.86	11	591.7145	2993.398	4.1E-64*	1.99458
Sampling Sites	2.023401	1	2.023401	10.23609	0.002441*	4.042652
Errors	9.488314	48	0.197673			
Total	6523.763	71				

***Indicates highly significant**

6 CONCLUSIONS

The present study expressed that there is a critical variety in the grouping of substantial metals in water and sediments at different sampling sites. These varieties might be because of the adjustment in the volume of mechanical and sewage being added to waterway at different sampling stations. The diverse sorts of toxins present in the wastewater released from the modern improvement are bringing on genuine medical issues for the occupants in and around Kanpur City because of incapable treatment plants. The water of the River Ganga is turning out to be genuinely polluted by lethal metals. The smaller industries are releasing their wastewater neither into the River Ganga nor into the channels yet into open lakes and this is bringing about difficult issues for nearby occupants. The examination of metal contamination in river water and sediments might be utilized to distinguish significant contamination sources entering into River Ganga. Sewage blended with modern effluents extremely bothers the water quality of River Ganga. Released water from all the treatment plants is likewise being utilized for irrigating the agricultural fields by the neighborhood agriculturists of the area and admission of polluted vegetables may posture genuine health perils. High rate estimations of anthropogenic info and high advancement elements of different metals and in sediments and soils show that the zone is profoundly contaminated by different metals. This study obviously highlights the prerequisite of quick control measures for the outstandingly serious metal contamination in the Kanpur area of the Ganga Plain. These sediments are unfavorably influencing the natural working of stream because of overwhelming metals activation from urban circle into biosphere. For financial development, urban advancement arrangements of the Ganga Plain ought to be provincial, as opposed to confined in nature, to keep its new water streams free from silt contamination for what's to come. In the developing consciousness of connections between human health and geochemistry, assist multidisciplinary thinks about including researcher, organic chemists, geologists and disease transmission specialists are basic to comprehend the biogeochemical cycle of individual metal and to survey urbanization impacts on the Ganga plain rivers. With our propelling learning, we may soon have the capacity to anticipate the toxicological impacts of contaminated sediments on human health. These standard information are essential in outlining the administration and preservation strategies of the River Ganga.

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