International Journal of Ecology and Environmental Sciences 48: 485-494, 2022
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2022.0485

Distribution of Heavy Metals from Upstream to Downstream in the River Ramganga, Uttar Pradesh, India

JUGAL KISHOR PATHAK[1]* AND MOHAMMAD ALAM[2]
[1]*Department of Zoology, Hindu College, MJP Rohilkhand University, Moradabad, India.*
[2]*WWF-India, Ashiyana Phase I, Moradabad, India*
E-mail: jkpathak@hotmail.com, drmhdalam@gmail.com
***Corresponding author**
ORCID ID: 0000-0003-1311-2151 (JKP) and 0000-0001-5102-1933 (MA)

ABSTRACT

Distribution of heavy metals in river Ramganga was studied from Kalagarh (upstream) to Moradabad city (downstream) covering about 100 km stretch during 2018-19, water samples were collected from six sampling stations. The present study aimed to determine heavy metal pollution in the river Ramganga. Eight heavy metals i.e. As, Mo, Mn, Cr, Ni, Pb, Cu, and Cd were analyzed using plasma induction atomic absorption spectrophotometer. Among the heavy metals, Mn and Cu were found dominated in all the six sampling stations, except Kalagarh upstream. It was noticed that values of As, Cr, Mn and Ni crosses the permissible limit as described by WHO in both winter and summer seasons. It was observed that the concentration of As, Cr, Cu, Mn and Ni were found to increase during the summer season which was attributed to low water discharge present in the river. It was noticed that source of heavy metal pollution was different across the six sampling stations. Higher values of arsenic and manganese in the upper reaches of the river was associated with the natural weathering process of rocks while downstream copper, nickel and chromium were dominant because the river water is getting polluted through effluent discharged by the electroplating units of brass industries. Palaze farming is found all along the river downstream and agricultural runoff contributes to the significant pollution in the river. The highest concentration of copper was recorded at Lalbagh which may be due to the metal ash washing activities which are common at this site. The present study indicates that the seasonal mean value of the heavy metal downstream was more than that of upstream.

Key words: Water and Sediment Discharge, Brass city, Electroplating units, Industrial effluent, Pollution

INTRODUCTION

Heavy metals like chromium, lead, cadmium, arsenic, etc. exhibit extreme toxicity even at trace levels. Metals are dominantly transported by rivers (Miller et al. 2003, Harikumar et al. 2009). Pollutions due to heavy metals in the riverine system are very significant (Dassenakis et al. 1998, Akcay et al. 2003). The behavior of metals is a function of sediment composition and water chemistry. During their transport, the heavy metal undergoes numerous changes in their chemical structure, mainly because they get dissolved in water, get precipitated and are absorbed by various ingredients is a complex process (Dassenakis et al.1998, Akcay et al. 2003, Abdel and Elchaghaby 2007) which affect their behaviour and bioavailability (Nicolau et al. 2006, Nauri et al. 2011). Metal is a sensitive index to measure changes in the aquatic environment. Hence, heavy metals are sensitive indicators for monitoring changes in the aquatic environment (Nicolau et al. 2006). According to Morillo et al. (2004) and Mohiuddin et al. (2011), the overall behaviour of heavy metals in an aquatic environment is strongly influenced by the associations of metals with various geochemical phases in sediments. The distribution of geo-chemicals has been used to predict potential contaminants in the aquatic system (Kabala and Singh 2001, Pueyo et al. 2003).

The toxic substances in the form of heavy metals, pesticides, halogens, detergents, oil etc. is accumulating especially in the aquatic environment due to industrial activities. A number of studies on heavy metal pollution in rivers have been carried out by several researchers in India. When the river enters in the urban area of Moradabad city, it started receiving pollution from municipal waste, sewage, industrial effluent released from electroplating units and paper mills. There are 23 drains in urban areas which generally water to the river. Heavy metals contamination in the surface water and sediments is one of the major concerns to the aquatic environment. It has been realized that the heavy metal ions may percolate to the groundwater through the soil strata and contaminate it while they can enter into the food chain from the environment and reaches up to the higher trophic levels through biomagnification. Recently, pollution of the aquatic environment caused by heavy metals has become a very serious concern among the environmentalist (Khan et al. 2019, Devi and Yadav 2018, Sarah et al. 2017, Mavizhi and Devi 2020, Boral et al. 2020, Ali Khan et al. 2020). Most of the rivers and streams, in India, are being used as repositories for the disposal of industrial effluents, domestic sewage and agriculture runoff containing high amounts of pesticides, insecticides, harmful substances and heavy metals. The toxicity produced by any metals depends on the route of administration and the substance with which it binds. When metal binds with an organic compound it may increase or decrease its toxicity. Various geochemical processes such as solubility, mobility, concentration and accumulation of metals are due to organic compounds (Mavizhi and Devi 2020). In the presence of a humic acid high concentrations of metals such as Ni, Cu, Zn, As, Cd, and Hg are known to be the more toxic to phytoplankton, invertebrates and fishes in an aquatic environment.

The unpleasant odour of the black water of Ramganga can be sensed even from more than half a kilometre distance right from Lalbagh Temple. Intensive human intervention, unplanned urbanization, population pressure and various unwanted and unlawful human activities along the river have created a devastating situation. Lack of interest of the local authorities in enforcing the rules and regulations to save the river causes degradation of the river. Nowadays, no fish and other aquatic organisms can be found in the river during the lean period near Katghar, this is because of the regulation of release water by the Hydroelectric Dam authority. Rain plays a vital role to rejuvenate the river, especially in urban areas, all the garbage, excreta, etc. was washed away during the rainy season. A number of studies have been conducted for determining the heavy metal in river water and sediments (Singh et al. 2005, Kaushik et al. 2003, Ayas et al. 2007, Yalcin et al. 2008).

MATERIALS AND METHODS

Study area

River Ramganga, a tributary of the holy river Ganga, is spring-fed originated from the southern slopes of Dudhatoli hills (3,110 m amsl) of the middle Himalaya of Uttarakhand state. The river enters the plains at Kalagarh where a famous hydroelectric dam has been constructed in 1975. The river traverses about 158 km before it meets the reservoir and continues downstream for about 370 km before joining river Ganga. Ramganga meets the river Ganga at Kusumkhora village of Kannaoj district, Uttar Pradesh. The study area lies between 29°29’42" and 28°49’32" N and 78°45’37" and 78°47’53" E. The River was thoroughly surveyed physically as well as with the help of topographic maps keeping in view the objectives of the present study. A detailed survey of the physiography of the catchments area of the river along the stretch of about 100 km from Kalagarh, to Moradabad, was conducted.

In order to carry out an in-depth study, six sampling stations different of river Ramganga were selected on the basis of varied topographical conditions, agricultural, social patterns, and on the location of various large and small-scale industries and also on the basis of human settlement. Moradabad city is well known as “Brass City” which is the first major city in the way of Ramganga where brass, iron, steel, sugar, and paper and pulp industries are situated. More than 500 electroplating units are there in Moradabad city as household units, where toxic chemical compounds are used in plating work on the brass articles. The effluent released from these electroplating units contain various toxic and harmful metals such as ammonium sulphate, copper sulphate and nickel sulphate, etc. that ultimately reaches the river Ramganga through various drains.

The impact of industries with reference to heavy metal on the river water is the aspect of prime importance. It is important to develop a suitable policy and management plan to control such toxic pollution in the river, present study was designed to evaluate heavy metals in the various stretches of the Ramganga River. The samples were collected during the rainy, winter and summer seasons in 2018-19 from six sampling stations viz. Kalagarh (29°29’42" N-78°45’37" E), Seohara (29°14’38" N-78°392 133

E), Mishripur (29°04’06’ N-78°41’49" E), Agwanpur (28°56’58" N-78°43’27" E), Lalbagh (28°50’29" N-78°47’24" E), and Katghar (28°492 323 N 78°47’53" E) and analyzed for the determination of heavy metals (Fig. 1 and Table 1).

METHODOLOGY

Transparency is the depth up to which the light can penetrate in the water body. Light is one of the most important environmental factors, which affects the growth rate of autotrophs in the aquatic system. It is a characteristic of water that varies with the combined effect of colour and turbidity. It was determined by using a standard Sacchi disc having a diameter of 30 cm. The upper surface of the disc was painted black and white partitions. It was lowered directly into the river water and the average value of the two readings at which Sacchi disc disappeared and reappeared was noted as transparency.

Water Discharge at a particular point of the river cross-section was calculated by Q= W x Dm x Vm, where W is average width, Dm is average depth in meter and Vm is average water velocity in m/sec.

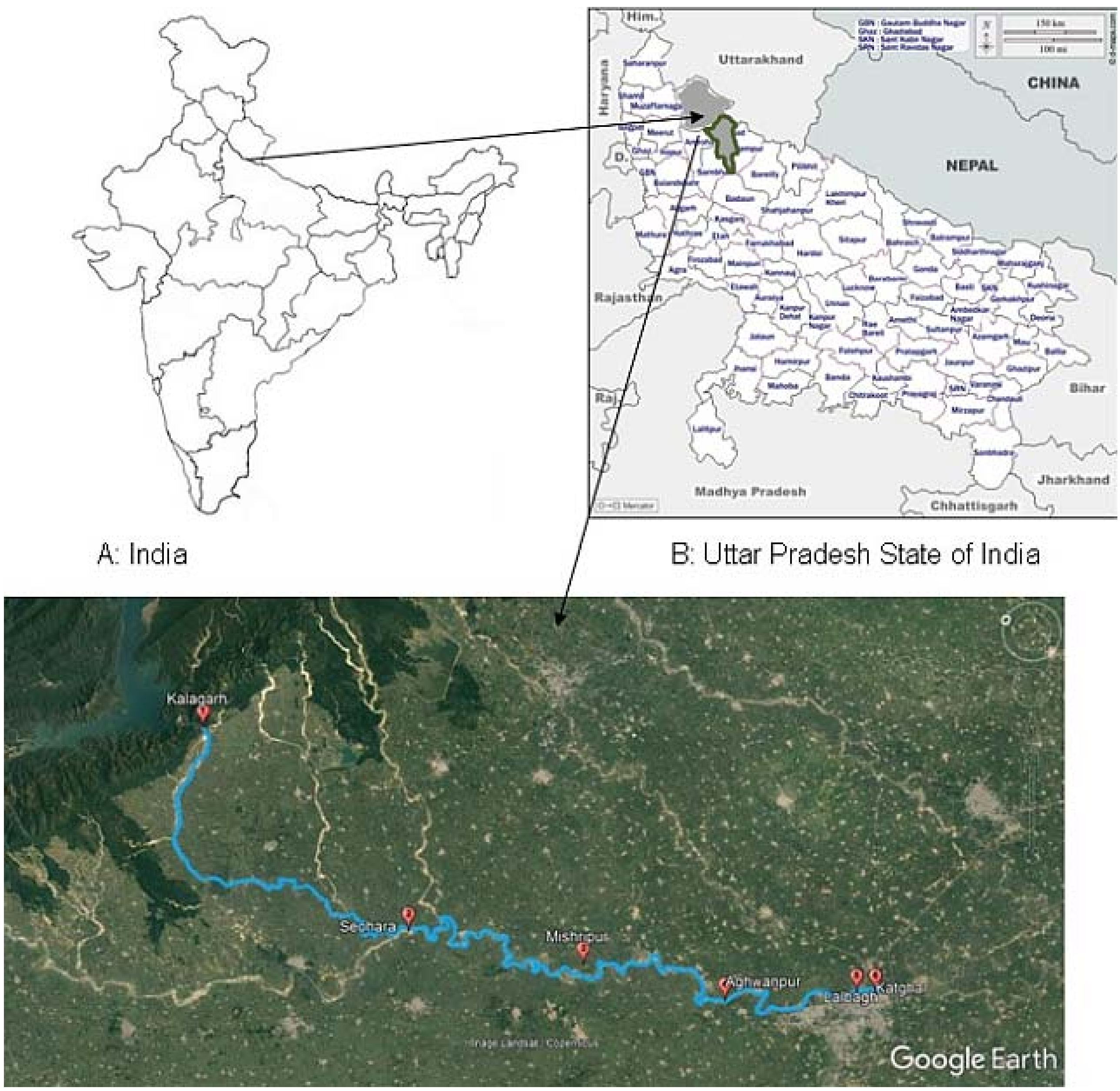

Figure1. Location of sampling sites from upstream to downstream in River Ramganga

Table 1. Geographical location of sampling stations.

Sampling Stations	Latitude	Longitude	Altitude (masl)
SS 1- Afzalgarh Barrage, Kalagarh	29°292 423 N	78°452 373 E	226.40
SS 2- Tanda, Seohara	29°142 383 N	78°392 133 E	216.10
SS 3- Mishripur, Kanth	29°042 063 N	78°412 493 E	206.04
SS 4- Agwanpur, Moradabad	28°562 583 N	78°432 273 E	196.60
SS 5- Lalbagh, Moradabad	28°502 293 N	78°472 243 E	191.72
SS 6- Katghar, Moradabad	28°492 323 N	78°472 533 E	190.77

The formula was further refined taking into account other factors of the river. As river bottom being rough at sampling station 1, i.e. at Kalagarh, Q was multiplied by 0.8, while comparatively smooth for other sampling stations Q was multiplied by 0.9. Sediment Discharge was calculated by multiplying the value of the velocity of the river with total solids carried by the water at the particular point.

For heavy metal analysis, samples are thoroughly mixed by shaking, and 100 ml of it transferred into a glass beaker of 250 ml volume, to which 5 ml conc. HNO_3 is added and heated till the volume is reduced to about 15-20 ml. The mixture is cooled, transferred and made up to 100 ml using metal-free distilled water. Heavy metals were analyzed in research testing and calibration laboratory, Moradabad under the control of the ministry of textiles, the government of India. Arsenic, cadmium, chromium, copper, manganese, nickel, molybdenum and lead were analyzed in a plasma induction atomic absorption spectrophotometer. The data obtained from six sampling stations were prepared and processed for statistical and graphical presentation in SPSS and Statistica software.

RESULTS AND DISCUSSION

Among physical properties like water transparency, water discharge and sediment discharge plays a very significant role in determining the impact of chemical properties including heavy metals and biotic components. In the upstream sampling stations, river water was transparent as depicted in Figure 2. The transparency of any water body is inversely proportional to the turbidity which is caused by dissolved and suspended matter, both living and non-

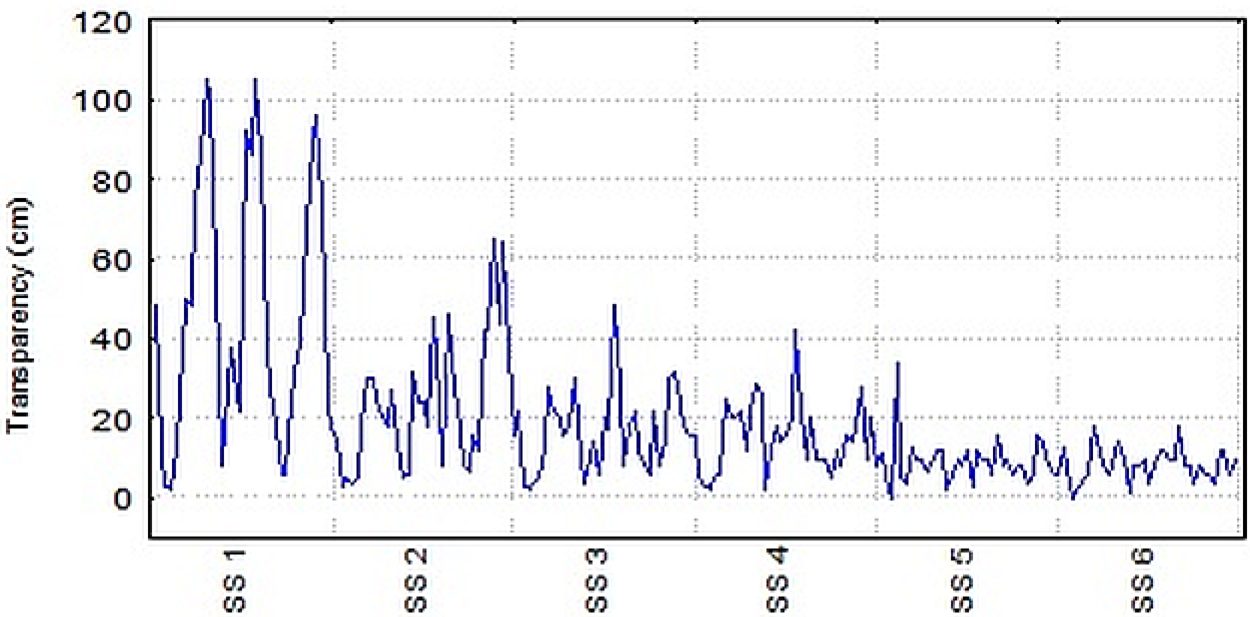

Figure 2. Spatial and temporal variation in transparency

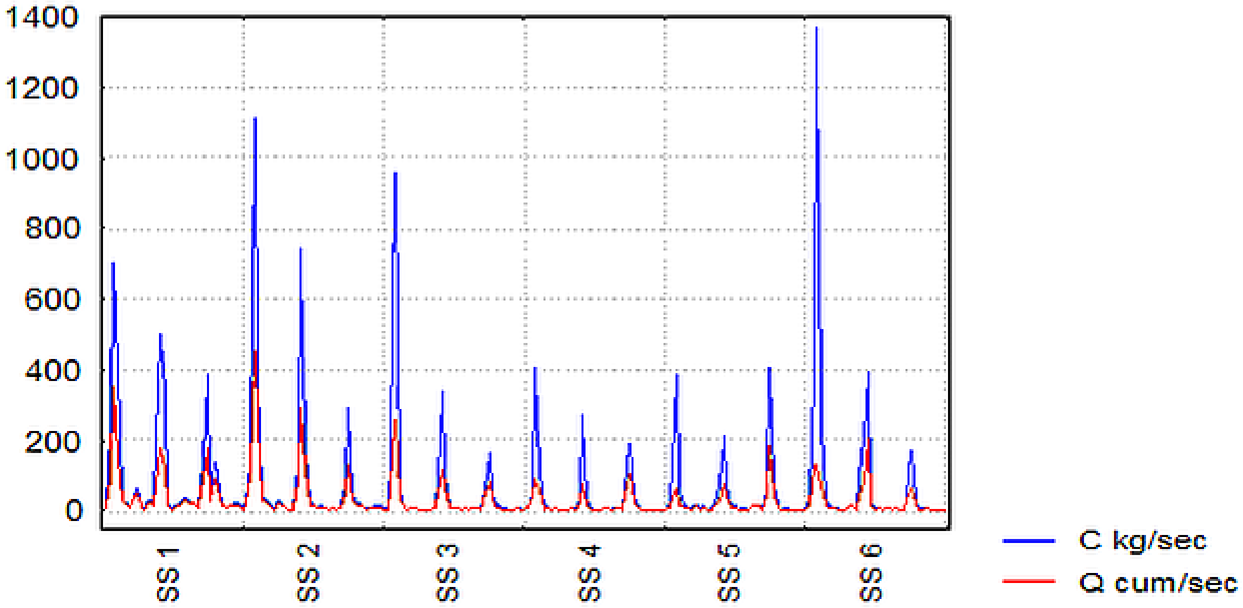

Figure 3. Variation in water discharge and Sediment discharge

living. In the present study, the value of correlation coefficient (r = -0.45) for transparency and turbidity showed a negative correlation between these two variables. The regression line also proved this correlation.

In the present study, the major factor which regulates the water discharge was the release of water from the Kalagarh hydroelectric dam as well as canalization of water for various purposes and precipitation. The maximum average discharge of water was recorded at Seohara because Kho river join before the sampling station. Kho is one of the key tributaries of the Ramganga river which comes through Kotdwar of Pauri District, Uttarakhand. The regime hydrograph of river Ramganga exhibits extreme variations between maximum and minimum discharge. The discharge value registered a rise in July and reached the peak in August during each year of the study period (Fig.3). An abrupt decline in the regime hydrograph during the month of October each year at all the sampling stations may be associated with the precipitation falling in the catchment areas. There is a positive relationship between sediment discharge and water discharge. (Figure 4). Sediment load has been closely related to the water discharge, similar observation has been made by other workers (Bhatt and Pathak 1992). A sudden rise in sediment discharge attributable to rain splash erosion, while the low sediment content and discharge corresponding to the depositional activities, this condition has prevailed at various sampling stations throughout the study period. The sediment concentration recorded at sampling station 1 and 3 may be related to rain splash erosion whereas, sampling stations 2 and 4 were associated with slope channel erosion and sampling station 5 and 6 attributed to depositional activities. Downstream the water discharge and sediment, discharge play important role in determining the concentration of heavy metals, reduced water discharge helps heavy metals to settle down in the riverbed sediments. The

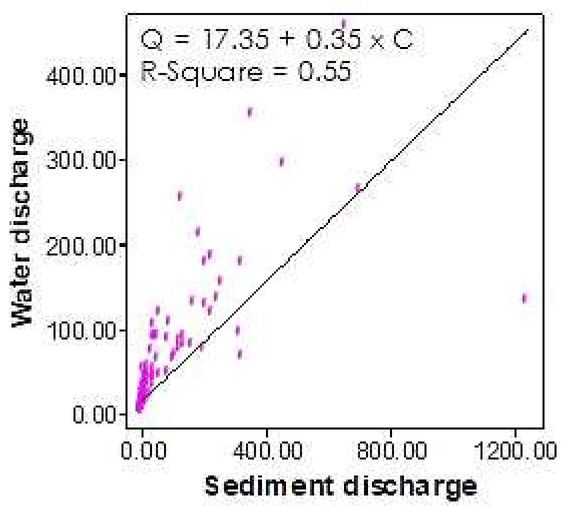

Figure 4. Correlation between Water Discharge and Sediment Discharge

mobility of heavy metals is also affected by water discharge and sediment discharge. In order of dominance, heavy metals at different sampling stations are presented in Table 2 and Figure 5. Descriptive statistics with seasonal mean concentration are depicted in Tables 3 and 4.

Table 2. Sequential trend of heavy metal at different sampling stations

Sampling stations	Metal in order of dominance
Kalagarh	As>Mo>Mn>Cr>Ni>Pb>Cu>Cd
Seohara	Mn>Cr>As>Pb>Ni>Cu>Mo>Cd
Mishripur	Mn>Ni>Cr>Pb>Cu>Mo>Cd>As
Agwanpur	Cu>Ni>Cr>Pb>Mn>As>Mo>Cd
Lalbagh	Cu>Ni>Cr>Mn>As>Pb>Mo>Cd
Katghar	Cu>Ni>Mn>As>Cr>Mo>Pb>Cd

Arsenic (As)

Arsenic is commonly found in natural waters and its concentration depends on the type of geological environment and degree of pollution in the area (Chung et al. 2014). Arsenic contamination in water has caused severe health problems around the world. The highest value of arsenic in the river Ramganga was found (0.3250 mg/l) at Lalbagh during summer. It was below detection (BDL) at Mishripur during

Table 3. Descriptive statistics of heavy metals distributed in Ramganga river (All the values are in mg/l).Abbreviations: R= Rainy, W= Winter, S= Summer, BDL= below detection limit, Min = Minimum, Max = Maximum, Var = Variance

Metal (season)	Mean	Min	Max	Var	SD	± SE
As (R)	.0253	BDL	.0640	.0008	.0285	.0116
As (W)	.0518	BDL	.3100	.0160	.1265	.0516
As (S)	.1237	BDL	.3250	.0232	.1522	.0621
Cd (R)	.0002	BDL	.0004	.0000	.0002	.0001
Cd (W)	.0014	BDL	.0046	.0000	.0018	.0008
Cd (S)	.0121	.0025	.0190	.0000	.0069	.0028
Cr (R)	.0398	.0135	.0650	.0004	.0205	.0084
Cr (W)	.0638	.0250	.1340	.0014	.0369	.0151
Cr (S)	.1653	.0146	.6800	.0691	.2629	.1073
Cu (R)	.1541	.0010	.5640	.0520	.2280	.0931
Cu (W)	.0633	BDL	.2460	.0090	.0948	.0387
Cu (S)	.3575	.0160	1.2300	.2484	.4984	.2035
Mn (R)	.1330	BDL	.6480	.0640	.2530	.1033
Mn (W)	.0340	BDL	.0670	.0006	.0252	.0103
Mn (S)	.2355	.0150	.6480	.0658	.2565	.1047
Mo (R)	.0313	.0003	.0922	.0020	.0446	.0182
Mo (W)	.0306	.0003	.0922	.0020	.0452	.0184
Mo (S)	.0372	.0120	.0820	.0006	.0246	.0101
Ni (R)	.1759	.0012	.6200	.0551	.2347	.0958
Ni (W)	.0360	.0012	.1082	.0016	.0403	.0164
Ni (S)	.2162	.0340	.7000	.0689	.2625	.1072
Pb (R)	.0312	BDL	.0520	.0004	.0205	.0084
Pb (W)	.0545	BDL	.2210	.0070	.0834	.0341
Pb (S)	.0148	.0040	.0210	.0000	.0068	.0028

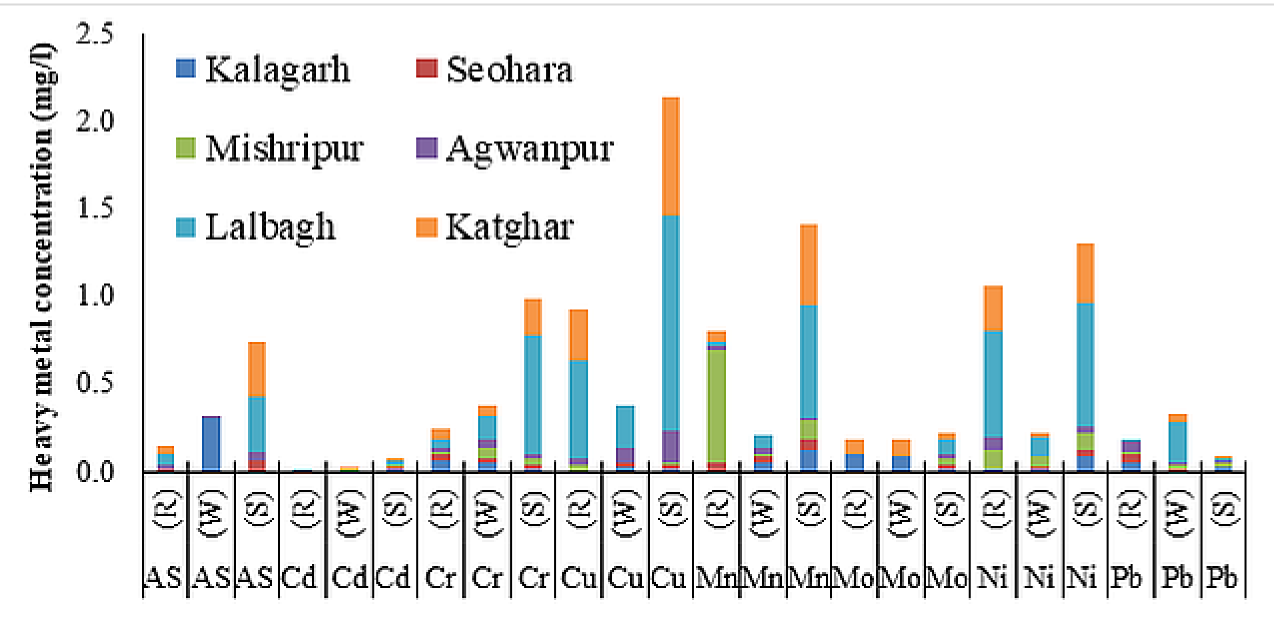

Figure 5. Heavy metal distribution in River Ramganga at six sampling station in different seasons

Table 4. Spatial and seasonal distribution of heavy metals in river Ramganga. R= Rainy, W= Winter, S= Summer, BDL= Below detection limit.

	AS			Cd			Cr			Cu			Mn			Mo			Ni			Pb		
	(R)	(W)	(S)	(R)	(W)	(S)	(R)	(W)	(S)	(R)	(W)	(S)	(R)	(W)	(S)	(R)	(W)	(S)	(R)	(W)	(S)	(R)	(W)	(S)
Kalagarh	0.0001	0.31	BDL	0.0001	BDL	0.016	0.065	0.052	0.017	0.001	0.0276	0.016	BDL	0.054	0.12	0.0922	0.0854	0.012	0.0157	0.017	0.09	0.052	BDL	0.02
Seohara	0.0065	0.0005	0.062	0.0004	0.0025	0.0042	0.028	0.025	0.0146	0.0045	0.0176	0.023	0.048	0.026	0.06	0.006	0.0035	0.025	0.0012	0.012	0.034	0.04	0.01	0.01
Mishripur	BDL	BDL	BDL	BDL	0.0046	0.016	0.0135	0.056	0.042	0.027	0.0025	0.016	0.648	0.0142	0.11	0.0003	0.0015	0.033	0.1082	0.058	0.092	0.022	0.0211	0.014
Agwanpur	0.025	0.0002	0.045	0.0002	0.0012	0.0025	0.0245	0.051	0.028	0.042	0.086	0.18	0.026	0.043	0.015	0.0004	0.0006	0.025	0.064	0.0012	0.041	0.052	0.023	0.021
Lalbagh	0.064	BDL	0.325	0.0004	BDL	0.019	0.056	0.134	0.68	0.564	0.246	1.23	0.022	0.067	0.648	0.0036	0.0003	0.082	0.62	0.1082	0.7	0.0211	0.221	0.004
Katghar	0.056	BDL	0.31	BDL	0.0001	0.015	0.052	0.065	0.21	0.286	BDL	0.68	0.054	BDL	0.46	0.0854	0.0922	0.046	0.246	0.0197	0.34	BDL	0.052	0.02
WHO	0.05	0.05	0.05	0.01	0.01	0.01	0.01	0.01	0.01	1	1	1	0.05	0.05	0.05	-	-	-	0.1	0.1	0.1	0.1	0.1	0.1

the rainy, winter and summer seasons. Arsenic was also absent at Lalbagh and Katghar during winters and at Kalagarh during summer (Table 4). Its concentration was in the range of BDL to 0.0640 mg/l, BDL to 0.3100 mg/l and BDL to 0.3250 mg/l during rainy, winter and summer respectively (Table 3). Arsenic concentration ranging from 3.0 to 50.0 µg/l has been reported in the surface water of Jamsharoo, Sindh Pakistan (Baig et al. 2009). In winters, the concentration of arsenic was always within the permissible limit at all sampling stations except at Kalagarh where an elevated levels of As may be due to the natural weathering and dissolution of rocks (Nimik 1998). The highest concentration of arsenic in the rivers of central Finland was reported in the areas with green stone and arsenic-rich black schist is predominant (Niemi and Raateland 2007). Weathering is the principal pathways in the absence of human activities that arsenic follows from the continent to the oceans (Subramanium et al. 2002). The highest fluctuation of arsenic concentration was seen during summer, especially at the last two sampling stations (Lalbagh and Katghar) which may be due to the large quantity of effluent from industries drained into the river at both the stations. Similar results have been put on the record (Cukrov et al. 2008).

Cadmium (Cd)

Cadmium concentration in the river Ramganga was observed in traces at all the sampling stations. The recorded value was in the range from BDL to 0.0004 mg/l, BDL to 0.0046, and 0.0025 mg/l to 0.0190 mg/l in rainy, winters and summer, respectively. Its highest concentration (.0190 mg/l) was recorded at Lalbagh during summer while it was BDL at Kalagarh and Lalbagh during winter and at Mishripur and Katghar during rain. In the present study, cadmium was found within the permissible standard limits (0.0100 mg/l) of drinking water at all the sampling stations during the rainy and winter seasons and any marked variation was not noted. In summer, it was higher at Kalagarh (0.0160 mg/l), Mishripur (.0160 mg/l), Lalbagh (0.0190 mg/l) and Katghar (0.0150) mg/l). A higher concentration of cadmium at Mishripur may be due to the mixing of effluent released from the paper industry and sugar mill while at the last two stations its higher values are attributed to the low content of water in the river during summer and high discharge of industrial effluent containing cadmium (Rauf at el. 2009).

Chromium (Cr)

Chromium occurs in the effluents discharged from the electroplating units in the form of chromium trioxide and chromium sulphate, paints, dyes and paper industries etc. The study revealed a higher concentration of chromium than the maximum permissible limit (0.0100 mg/l) in drinking water (W.H.O) at all the stations during three seasons. The highest value of chromium (0.6800 mg/l) was noted at Lalbagh in summer attributed to the effluent released from electroplating units and brass industries without any treatment (Pandey at el. 2004). It was minimum (0.0135 mg/l) during the rainy season at Mishripur. Sabbir et al. (2018) has studied heavy metal concentration in the Rupsha river from six locations. Among the six stations, the highest concentration of Cr was observed near Khulna Ship Yard which was attributed to the large amounts of raw sewage, ship breaking activities, agricultural and industrial wastewater discharged into the river.

The salts of chromium are extensively used in industries for various purposes and may enter the water supply through the discharge of wastes into the river. It was reported that the hexavalent form of chromium is more toxic and carcinogenic when inhaled in vapour form in large quantities and cause cancer in the respiratory tract.

Copper (Cu)

The concentration of copper recorded in Ramganga was in the range of 0.0010 to 0.5640 mg/l during rain, BDL to 0.2460 mg/l in winters and 0.0160 to 1.2300 mg/l in summer. The highest value (1.2300 mg/l) of copper was found at Lalbagh during summer that was mainly related to the effluent discharged from the brassware industries and the ash (containing high amount of brass) washing activities at this station. Copper ranged from 0.0200 - 1.80 mg/l has been reported in river Warri, Nigeria (Ayenimo at el. 2005). Elevated level of copper at Agwanpur was observed during winter and summer months may be due to the runoff from agricultural fields containing pesticides containing copper sulphat. It was observed that the downstream of the river was more affected with the copper contamination due to copper containing effluent released from electroplating units of brass industries, metal ash washing activity at Lalbagh and agricultural runoff. Its concentration in summer season in downstream at Lalbagh Sampling site was above the permissible limit of 1.0mg/l as prescribed by WHO.

Manganese (Mn)

The maximum observed value of manganese was 0.6480 mg/l at Mishripur and Lalbagh during rainy and summer respectively. The range of manganese in the river was noted as BDL to 0.6480 mg/l in the rainy season, BDL to 0.0760 mg/l in the winter season and 0.0150 to 0.6480 mg/l in the summer season. The results revealed that the river at Lalbagh is highly polluted with reference to manganese pollution during the summer and winter seasons which is due to the mixing of effluent released by brass industries. Its higher concentration at Mishripur may be attributed to the effluent released from a paper mills that flushed to the river with rainwater. A higher concentration of manganese in river Sai at Raibareilly was reported (Sinha 2004). Similar results has been observed by Yawar et al. (2020); reported Fe and Mn concentrations in tributaries of river Ramganga downstream were exceeded the limit set by WHO.

Molybdenum (Mo)

The maximum molybdenum was found 0.0922 mg/l at Kalagarh and Katghar during rainy and winter respectively. The minimum value (0.0003 mg/l) was recorded at Mishripur and Lalbagh during rainy and winter. It was found in the range from 0.0003 to 0.0922 mg/l in the rainy and winter seasons while 0.0120 to 0.0820 mg/l in the summer season. River water at all the stations except Kalagarh, during rainy and Katghar, during winter, was found to be deficient in molybdenum concentration. More fluctuation was seen during summer where the concentration reached up to the highest level at Lalbagh but not exceed to a standard level.

Nickel (Ni)

The Electroplating waste when discharged into the river without any treatment contributes nickel to it. Nickel is one of the elements, which are used in electroplating works at a very large scale since before coating the silver on the brass utensils a thin layer of nickel is coated on it. In the present study, the highest value of nickel was found (0.7000 mg/l) at Lalbagh during summer and minimum (0.0012 mg/l) at Seohara and Agwanpur during rainy and winter respectively. The concentration of nickel in the river was ranged from 0.0012 to 0.6200 mg/l, 0.0012 to 0.1082 mg/l and 0.0340 to 0.7000 mg/l during rainy, winter and summer, respectively. The value of Nickel higher than the prescribed limit of drinking water was reported from the river Yamuna (Kaushik, at el. 2001).

Lead (Pb)

Lead is a highly toxic element and reached the river with the effluent discharged by the brass industries, battery repair works, electronic wastes, printing and dying works. The electroplating wastes coming to the river contribute to the high concentration of lead in the river. The maximum value of lead (0.2210 mg/l) was observed at Lalbagh during winter and was found BDL at Katghar during rain and at Kalagarh during winters. The concentration of lead was recorded in the range between BDL to 0.0521 mg/l, BDL to 0.2210 and 0.0040 mg/l to 0.0210 mg/l during rainy, winter and summer seasons. None of the stations had a higher concentration of lead the permissible limit (0.1000 mg/l) except Lalbagh. Wastes containing lead from the battery repairing works may contribute to the elevated level in the river (Joseph at el. 2006).

CONCLUSIONS

The analysis of data clearly indicates that the heavy metal distribution in the river Ramganga is increased upstream to downstream, especially at the last two sampling stations. It is concluded that the concentration of most heavy metals reached beyond the permissible limit during the summer season. The quality of water shows slightly improves after the onset of monsoon, which diluted the concentration of metals. The main reason for the high concentration of these metals downstream are the effluent discharged from the electroplating units, brass industries, paper industry, sugar industry and urban discharge. Water quality deterioration due to industrial effluent and municipal sewage discharge has been documented in literature. The higher concentration of heavy metals at Lalbagh was due to metal ash washing activities at the river bank, which contributed higher value of metals, that exposing to domestic animal and human beings directly. Therefore, it is concluded that the water of these stations is unfit for human consumption as well as for domestic animals.

Authors' contributions: Both the authors contributed equally.

Conflict of interest: The authors declare that they have no conflict of interest that could have influenced the work reported in this manuscript.

REFERENCES

Abdel-Ghani, N.T. and Elchaghaby, G.A. 2007. Influence of operating conditions on the removal of Cu, Zn, Cd and Pb ions from wastewater by adsorption. International Journal of Environmental Science and Technology, c4(4), 451-456.

Akcay, H., Oguz, A. and Karapire, C. 2003. Study of heavy metal pollution and speciation in Buyak Menderes and Gediz river sediments. Water Research, 37(4), 813-822.

Ayas, Z., Ekmekci, G., Yerli, S.V. and Ozmen, M. 2007. Heavy metal accumulation in water, sediments and fishes of Nalihan bird paradise, Turkey. Journal of Environmental Biology, 28(3), 545-549.

Ayenimo, J.G, Adeeyinwo, C.E. and Amoo, I.A. 2005. Heavy metal pollutants in Warri river, Nigeria. Kragujevac Journal of Science, 27, 43-50.

Baig, J.A., Kazi, T.G., Arain, M.B., Afridi, H.I., Kandhro, G.A., Sarfraz, R.A., Jamal, M.K., and Shah, A.Q. 2009. Evaluation of arsenic and other Physico-chemical parameters of surface and groundwater of Jamshoro, Pakistan. Journal of Hazardous Mater, 166 (2-3), 662-669.

Bhatt, S.D. and Pathak, J.K. 1992. Himalayan Environment: Water Quality of the Drainage Basins. Shri Almora Book Depot, Almora, 485pp.

Boral, S., Sen, I.S., Tripathi, A., Sharma, B. and Dhar, S. 2020. Tracking dissolved trace and heavy metals in the Ganga River from source to sink: A baseline to judge future changes. Geochemistry, Geophysics, Geosystems, http//doi.org/10.1029/2020GC009203, 1-22.

Chung, J-Y., Yu, S-D. and Hong, Y-S. 2014. Environmental Source of Arsenic Exposure. Journal of Preventive Medicine Public Health, 47(5), 253-257.

Cukrov, N., Cmuk, P. Mlakar, M. and Omanovic, D. 2008. Spatial distribution of trace metal in the Krka river, Croatia: an example of self-purification. Chemosphere, 72(10), 1559-1566.

Daityari, S. and Khan, M.Y.A. 2017. Temporal and spatial variations in the engineering properties of the sediments in Ramganga River, Ganga Basin, India. Arabian Journal of Geosciences, 10(6), 134.

Dassenakis, M., Scoullos, M., Foufa, E., Krasakopoulou, E., Pavlidou, A. and Kloukiniotou, M. 1998. Effects of multiple source pollution on a small Mediterranean river. Applied Geochemistry, 13(2), 197-211.

Devi, N.L. and Yadav, I.C. 2018. Chemometric evaluation of heavy metal pollutions in Patna region of the Ganges alluvial plain, India: implication for source apportionment and health risk assessment. Environmental Geochemistry and Health, 40(6), 2343–2358.

Harikumar, P.S., Nasir, U.P. and Mujeebur Rahman, M.P. 2009. Distribution of heavy metals in the core sediments of a tropical wetland system. International Journal of Environmental Science and Technology, 6(2), 225-232.

Joseph, P.V. and Chacko, J. 2006.Distribution of trace metals in the surface sediments of Chitrapuzha, tropical tidal river on the southwest coast of India and implications to industrial pollution. Indian Journal of Environmental Protection, 26(10), 892-904.

Kabala, C. and Singh, B.R. 2001. Fractionation and mobility of copper lead and zinc in soil profiles in the vicinity of a copper smelter. Journal of Environmental Quality, 30(2), 485-492.

Kaushik, A., Jain, S., Dawra, J. and Sharma, P. 2003. Heavy metal pollution n various canals origination from river Yamuna in Hariyana. Journal of Environmental Biology, 24(3), 331- 337.

Kaushik, A., Jain, S., Dawra, J., Sharma, P. and Kaushik, C.P. 2001. Heavy metal pollution of river Yamuna in the industrially developing state of Haryana. Indian Journal of Environmental Health, 43(4), 164-168.

Khan, M.Y.A., Tian, F., Hasan, F. and Chakrapani, G.J. 2019. Artificial neural network simulation for prediction of suspended sediment concentration in the River Ramganga, Ganges Basin, India. International Journal of Sediment Research, 34(2), 95–107.

Mavizhi, P. and Aruna Devi, P.S. 2020. Heavy Metal Concentration in water of the river Cauvery-A case study of Erode Salem and Namakkal District, Tamil Nadu. Journal of Himalayan Ecology and Sustainable Development, 15, 190-201.

Miller, C.V., Foster, G.D. and Majedi, B.F. 2003. Base flow and storm flow metal fluxes from two small agricultural catchments in the coastal plain of Chesapeake Bay Basin, United States. Applied Geochemistry, 18(4), 483-501.

Khan, M.Y.A., Hu, H., Tian, F. and Wen, J. 2020. Monitoring the Spatio-temporal impact of small tributaries on the hydrochemical characteristics of Ramganga River, Ganges Basin, India. International Journal of River Basin Management, 18(2), 231–241.

Mohiuddin, K.M., Ogawa, Y., Zakir, H.M., Otomo, K., Shikazono, N. 2011. Heavy metals contamination in the water and sediments of an urban river in a developing country. International Journal of Environmental Science and Technology, 8(4), 723-736.

Morillo, J., Usero, J. and Gracia, I. 2004. Heavy metal distribution in marine sediments from the southwest coast of Spain. Chemosphere, 55(3), 431-442.

Nicolau, R., Galera, C.A. and Lucas, Y. 2006. Transfer of nutrients and labile metals from the continent to the sea by a small Mediterranean river. Chemosphere, 63(3), 469-476.

Niemi, J. and Raateland, A. 2007. River water quality in the Finnish environment. Boreal Environmental Research, 12, 571-584

Nimik, D.A. 1998. Arsenic hydrochemistry in an integral river valley - A re-evaluation. Groundwater. ??????, 36(5), 743-753.

Nouri, J., Lorestani, B., Yousefi, N., Khorasani, N., Hasani, A.H., Seif, S., Cheraghi, M. 2011. Phytoremediation potential of native plants grown in the vicinity of Ahangaran lead–zinc mine (Hamedan, Iran). Environment and Earth Sciences, 62(3), 639-644.

Pandey, R.K., Arya, R.K., Verma, A and Mishra, S.K. 2004. Distribution of heavy metals in the wastewater of river Pandu at Kanpur. Pollution Research, 23(2), 335-342.

Pueyo, M., Sastre, J., Hernandez, E., Vidal, M., Lopez-Sanchez, J.F. and Rauret, G. 2003. Prediction of trace element mobility in contaminated soils by sequential extraction. Journal of Environmental Quality, 32(6), 2054-2066.

Rauf, A., Javed, M., Ubaidullah, M. and Abdullah, S. 2009. Assessment of heavy metals in sediments of the river Ravi, Pakistan. International Journal of Agricultural Biology, 11, 197–200.

Sarah, R., Tabassum, B., Idrees, N., Hashem, A. and Abd_Allah, E.F. 2017. Bioaccumulation of heavy metals in *Channa punctatus* (Bloch) in river Ramganga (U.P.). India. International Research Journal of Environment Sciences, 26(2), 62-71.

Sabbir, W., Rahman, M.Z., Hasan, M.M., Khan, M.N. and Ray, S. 2018. Assessment of Heavy Metals in River water, Sediment and Fish Mussel in Rupsha river under Khulna district, Bangladesh. International Journal of Experimental Agriculture, 8(1),1-5.

Singh, V.K., Singh, K.P. and Mohan, D. 2005. Study of heavy metals in water and bed sediments of river Gomti- a tributary of the Ganga river. India. Environmental Monitoring and Assessment, 105(1-3), 43-67.

Sinha, D.K. 2004. Level of some heavy metals in waters from Sai river at Rai Bareli India for the pre-monsoon period and after onset of monsoon. Pollution Research, 23(1), 113-116.

Subramanian. V., Madhavan, N. and Naqvi, S.A.S. 2002. Arsenic in Our Environment: A Critical Review. Pp. 189-214In: Subramaiain, V. (Ed.). Environmental Hazards in South Asia, Capital Publishing Company, New Delhi.

Yalcin, M.G., Aydin, O. and Elphatip, H. 2008.Heavy metal content and the water quality of Karasu creek in Nigce, Turkey. Environmentl Monitoring and Assessment, 137 (1-3), 169- 178.

Received:25th March 2022
Accepted:21st May 2022