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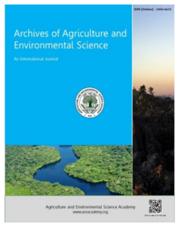

CASE STUDY

Occurrence of heavy metals in Ganga canal water at Haridwar (Uttarakhand), India: A case study

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ABSTRACT

The present investigation was framed to assess the contamination of heavy metals in Ganga canal water at Haridwar (Uttarakhand). The samples of Ganga canal water were collected from five sampling sites namely Bhimgoda Barrage, Haridwar (origin point); Premnagar Ashram Ghat, Haridwar; Pathari Power Plant, Bahadrabad; Rail Bridge, Roorkee and Uttam Sugar Mills Limited, Narsan (exit point). The samples were analyzed for seven metals *viz.,* copper, manganese, cadmium, lead, zinc, chromium and iron in Ganga canal water monthly during March, 2014 to August, 2014. The concentration of manganese was found greater than its desirable limit (0.1 mg/L), while iron was observed more than its permissible limit (0.3 mg/L) according to Bureau of Indian Standards (BIS) specifications. The water quality data was further analyzed using analysis of variance (ANOVA) for monthly and spatial variations. The ANOVA analysis revealed that the contents of different metals such as copper, manganese, lead, zinc, chromium and iron were found statistically significant ($P \leq 0.05$) as per temporal study. These monthly variations in Ganga Canal water quality parameters might be ascribed due to the anthropogenic and hydro-geological activities. However, none of the metals showed significant site variation at any of the sampling site of Ganga Canal. Therefore, the present study emphasized the need of regular monitoring of Ganga canal water to avoid the contamination of heavy metals in the water.

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INTRODUCTION

Haridwar has plenty of water resources in the form of Ganga River and Ganga canal and their water is being used for domestic and drinking purposes. Ganga canal originates from Ganga River after diversion at Bhimgoda Barrage near Har ki Pauri at Haridwar, which is a famous place for the mass bathing of pilgrims. The sacredness of Ganga canal water has attracted millions of tourists, pilgrims and also local peoples of Haridwar. The Ganga canal is the important source of drinking and irrigation water located at the bank and in the vicinity of the canal (Kamboj *et al.*, 2013).

The Ganga canal moves from Haridwar and passes through vicinity of Bharat Heavy Electricals Limited (BHEL), Ranipur, Bahadrabad, Piran Kaliyar, Roorkee, Uttam Sugar Mill Ltd. and Gurukul Narsan, which are densely populated areas of Haridwar district and also face pressure from tourists and pilgrims entering into Uttarakhand. The water quality of Ganga canal is being degraded increasingly from year to year due to increase in pollutant loads particularly from commercial and domestic sources, sewage discharge and industrial effluents. The effluents may be inorganic and/ or organic, which may be toxic in nature depends on their source (Kamboj *et al.*, 2013). Owing to spirituality, lots of pilgrims pertaining activities have led to the problem of water pollution in Ganga canal. Among anthropogenic sources of pollution, domestic and municipal sewages are also contributing to polluting the water quality of Ganga canal. Heavy influx of floating tourists, pilgrims and local peoples of Haridwar exert stress through organic as well as inorganic wastes (Kamboj, 2012). Markandya and Murty (2004) have also reported that most of the untreated or partially/ treated sewage about 1.3 billion liters/ day of human waste and 260 million liters of industrial waste primarily from agricultural fertilizers and pesticides from surrounding cities enter into the Ganga basin waterways. Due to easy channel of transportation, solid and liquid wastes are easily dumped into river water and therefore, in Ganga canal water directly or through ground channels. Change in pH of stream water may affect aquatic life indirectly through affecting other aspects of water chemistry e.g. water with low pH can increase the solubility of certain heavy metals, which allows the metals to be more easily absorbed by aquatic organisms (Simeonov *et al.,* 2003). Apart from domestic and industrial pollutants, hundreds of human corpses and thousands of animal carcasses are also released into the Ganga water every day due to spiritual rebirth (Haritash *et al.*, 2016). It has become major challenge and thus, posed threat up to large extent to the human beings of local population of Haridwar district as well as millions of tourists and pilgrims of country and abroad. Heavy metals are usually present in wastewater and when, it gets mixed with adjacent water body contaminates the aquatic environment. Due to drainage of sewage effluent into adjacent water bodies, there might be significant increase in total dissolved solids (TDS), turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), chlorides, sulphates, and nitrate nitrogen, total phosphorus including heavy metals like iron, zinc, cadmium, chromium, copper, nickel, manganese and lead (Egborge, 1991; Simeonov *et al.,* 2003; Jaji *et al.*, 2007).

Besides, pace of modernization and increasing industrialization, urbanization, agriculture and other human activities are among serious aspects for causing Ganga canal water pollution and resulted deterioration in its water quality. Rapid industrial growth and urban development have resulted into inclusion of variety of pollutants into Ganga canal. Haridwar district has also grown up as industrial hub of the Uttarakhand state, therefore assessment and monitoring of metals in Ganga canal has become necessary for assessing metals pollution of various metals namely calcium, copper, magnesium, manganese, cadmium, lead, zinc, chromium and iron in its water. Presence of metals in water leads metal contamination, when found in excess than desirable or permissible limits and thus, it has become an issue of concern (Kansal *et al.,* 2013). These metals are entered into rivers naturally through rocks weathering as well as variety of human accelerated activities such as mining, smelting, electroplating and other industrial process. In addition, rapid growth of industrialization and urbanization are also adding metals into the river water system (Simeonov *et al.*, 2003; Seth *et al.,* 2006; Kansal *et al.,* 2013). Therefore, major objective of present study was to assess the monthly and spatial variations in the concentration of heavy metals in Ganga canal water at district Haridwar, (Uttarakhand), India.

MATERIALS AND METHODS

Study area: Ganga canal was selected for the present study to determine the contamination of heavy metals in the water. The samples of Ganga canal water were collected on monthly basis from during March, 2014 to August, 2014 selecting five sampling sites *viz.,* Bhimgoda Barrage, Haridwar (origin point) (S_1); Premnagar Ashram Ghat, Haridwar (S_2); Pathari Power Plant, Bahadrabad (S_3); Rail Bridge, Roorkee(S_4) and Uttam Sugar Mill Ltd., Narsan (exit point) (S_5) of Ganga Canal in Uttarakhand, India. The details of all the five sampling sites (S_1) along with their co -ordinates and elevation above mean sea level (MSL) are given in Table 1.

Collection, preservation and analysis of samples: The samples of Ganga canal water from all the five sampling sites were collected through grab sampling. The samples of Ganga canal water were preserved and analyzed for different heavy metals *i.e.* copper, manganese, cadmium, lead, zinc, chromium and iron in water samples were performed by adopting standard protocols and methods cited in APHA (2012) and BIS (2012).

Statistical analysis: Data was statistically analyzed using analysis of variance (ANOVA) to determine the monthly and spatial variations of mean concentrations of different heavy metals in the Ganga canal water (Elbag, 2006).

RESULTS AND DISCUSSION

The values of seven heavy metals in Ganga canal water at all the five sampling sites namely Bhimgoda Barrage, Haridwar (origin point) (S_1); Premnagar Ashram Ghat, Haridwar (S_2); Pathari Power Plant, Bahadrabad (S_3); Rail Bridge, Roorkee (S_4) and Uttam Sugar Mill Ltd., Narsan (exit point) (S_5) are presented in Table 2.

Copper: The maximum concentration of copper (0.043 mg/L) was recorded at the Uttam Sugar Mill Ltd., Narsan (exit point) (S_5), which was observed below the desirable limit (0.05 mg/L) of BIS, 2012. However, the content of copper was detected minimum (0.001 mg/L) at three study sites *viz.,* Bhimgoda Barrage, Haridwar (origin point) (S_1), Pathari Power Plant, Bahadrabad (S_3) and Rail Bridge, Roorkee (S_4). The results are in line with Kumar and Chopra (2012) who reported the higher contents of copper in abandoned old Ganga canal at Haridwar (Uttarakhand), India. Kumar *et al.* (2012) also reported higher concentration of copper in the water of sub canal of upper Ganga canal at Haridwar (Uttarakhand), India due to the discharge of untreated textile effluent.

Manganese: Manganese is usually occurred with iron and is observed as an essential element for various living organisms. It is naturally found in surface water, sub-surface water and ground water as well as in the soil. The manganese concentration was found to be varied from 0.015 mg/L at three study sites *viz.,* Bhimgoda Barrage, Haridwar (origin point) (S_1); Premnagar Ashram Ghat, Haridwar (S_2); Pathari Power Plant, Bahadrabad (S_3) to 0.293 mg/L at Pathari Power Plant, Bahadrabad (S_3). All the sampling sites have been found to have higher values of manganese, which was greater than its desirable limit as per BIS, 2012 specifications. The concentration of manganese in water is mainly increased by various anthropogenic activities. The compounds of manganese might be present in atmosphere as suspended particulates resulting from industrial emissions, soil erosion, and volcanic emission and burning of Methylcyclopentadienyl Manganese Tricarbonyl (MMT) containing petrol (IPCS, 1999). Manganese is an essential element for all living organisms and the lack of manganese might exhibit impaired growth, skeletal abnormalities, reproductive effects, etc. Whereas, its overexposure might cause manganism, which causes weakness, muscle pain, apathy, slow speech and slow clumsy movement of limbs in the human beings (Bowman *et al.*, 2011).

Cadmium: The minimum content of cadmium (0.001 mg/L) was traced at all the studied sites. However, it was detected highest (0.003 mg/L) at three sites *viz.,* Bhimgoda Barrage, Haridwar (origin point) (S_1); Premnagar Ashram Ghat, Haridwar (S_2); and Rail Bridge, Roorkee (S_4) and it might be due to the anthropogenic or geogenic processes. The BIS (2012) has determined desirable and permissible limits as 0.003 mg/L for cadmium in drinking water. Cadmium causes both acute and chronic toxicity in the human beings. Cadmium intake might cause acute gastrointestinal problems *i.e.* vomiting and diarrhea (Nordberg, 2009). Its chronic exposure may cause kidney damage, reproductive problems, bone damage and cancer (Frery *et al.*, 1993).

Lead: Minimum concentration (0.003 mg/L) of lead was recorded at four study sites out of five namely Premnagar Ashram Ghat, Haridwar (S_2); Pathari Power Plant, Bahadrabad (S_3); Rail Bridge, Roorkee (S_4) and Uttam Sugar Mill Ltd., Narsan (exit point) (S_5). While, maximum concentration (0.007 mg/L) of lead was detected at two Bhimgoda Barrage, Haridwar (origin point) (S_1) and Rail Bridge, Roorkee (S_4) sampling sites. Further, lead concentration did not exceed the desirable limit (0.01 mg/L) of BIS in analyzed water samples of Ganga Canal. Kumar *et al.* (2012) also reported the contamination of lead in the water of sub canal of upper Ganga canal in Haridwar due to the drainage of textile effluent.

Zinc: Minimum zinc concentration was recorded as 0.008 mg/L at two monitored sites Premnagar Ashram Ghat, Haridwar (S_2) and Pathari Power Plant, Bahadrabad (S_3) during the study period. Whereas, maximum zinc value was detected as 0.127 mg/L at Rail Bridge, Roorkee (S_4) sampling site during the study period, which was observed well below than its desirable limit (5 mg/L) of BIS, 2012 and it might also be due to the a number of anthropogenic activities like mass bathing, discharge of urban waste and runoff etc. as also reported earlier by Kumar and Chopra (2012).

Chromium: It is considered as one of the essential nutrients for several living organisms only in trace amount (Okendro *et al.*, 2007 and Sati and Paliwal, 2008). The concentration of chromium in drinking water is usually found only at trace level, but chromium (VI) in exceeded concentration is extremely toxic to the consumers from health point of view (Seth *et al.*, 2014). Chromium was detected 0.001 mg/L as minimum concentration at all the study sites, whereas its maximum value was found as 0.007 mg/L at Uttam Sugar Mill Ltd., Narsan (exit point) (S_5) sampling site. The BIS (2012) has prescribed its desirable limit up to 0.05 mg/L, but there is no relaxation beyond this range.

Iron: The iron contamination during water supply may arise from materials such as iron, which can corrode to release iron oxides or from ingress of pollutants into the distribution system (Fawell and Nieuwenhuijsen, 2003). Iron is a necessary element for various physiological activities of all living organisms. The minimum concentration of iron was found as 0.284 mg/L at site Bhimgoda Barrage, Haridwar (S_1), while maximum was recorded as 1.087 mg/L (more than permissible limit of BIS) at S-5 site. Its maximum concentration at all sites exceeded permissible limit (0.3 mg/L) as per BIS (2012). Iron pollution in water is mainly attributed due to weathering of rocks, industrial waste, etc. (Seth *et al.*, 2016). However, its deficiency and overload both can pose harmful threats to animals as well as plants (Anonymous, 2008). These exceeded concentrations in the Ganga canal water may pose possible negative consequences on the health of local peoples, pilgrims, tourists along with its surrounding environment. Moreover, the overload of iron is less common than its deficiency. Its overexposure can even lead to several serious health's related problems *viz.,* cancer, diabetes, liver and heart diseases as well as neurodegenerative disorders in the human beings (Sayre *et al.,* 2000). Simeonov *et al.* (2003) also reported that the nutrients (micro and macro) in the surface water in northern Greece are likely due to the anthropogenic activities.

Monthly variation in the content of heavy metals: Monthly variation was determined by analyzing seven metals. There were total six data points namely March, April, May, June, July and August months for each water quality parameter at each sampling site. According to monthly variation, computed P-values for each water quality parameter by ANOVA are depicted in Table 3. There were total nine metals such as calcium, copper, magnesium, manganese, lead, zinc, chromium and iron, which were found statistically significant because of P-value ($P \leq 0.05$) during the study. Seth *et al.* (2016) reported that the pollution of Gola, Kosi, Ramganga, Saryu and Lohawati rivers in the Kumaun Region, Uttarakhand, India are due to the excess tourism, anthropogenic, geogenic processes and eutrophication.

Table 1. Description of different sampling sites at Ganga canal in Haridwar.

Name of sampling sites	Sampling sites code	Latitude/ Longitude	Elevation above MSL (m)
Bhimgoda Barrage, Haridwar	S_1	N 29º 60’ 25.9”/ E 078º 14’ 28.1”	275
Premnagar Ashram Ghat, Haridwar	S_2	N 29º 55’ 48.8”/ E 078º 08’ 10.3”	266
Pathari Power Plant, Bahadrabad	S_3	N 29º 55’ 41.5”/ E 078º 02’ 24.7”	240
Rail Bridge, Roorkee	S_4	N 29º 50’ 59.4”/ E 077º 52’ 49.0”	244
Uttam Sugar Mill Ltd., Narsan	S_5	N 29º 44’ 00.7”/ E 077º 51’ 30.9”	242

Table 2. Contents of different heavy metals in Ganga Canal water at different sampling sites.

Parameter	BIS: 10500 (2012)		S_1				S_2				S_3				S_4				S_5			
	DL	PL	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Copper (mg/L)	0.05	1.50	0.001	0.034	0.014	0.014	0.002	0.041	0.015	0.016	0.001	0.028	0.011	0.011	0.001	0.040	0.018	0.017	0.003	0.043	0.015	0.016
Manganese (mg/L)	0.1	0.3	0.015	0.255	0.073	0.092	0.015	0.270	0.081	0.098	0.015	0.293	0.097	0.113	0.028	0.287	0.116	0.120	0.033	0.280	0.105	0.095
Cadmium (mg/L)	0.003	No Relax	0.001	0.003	0.002	0.001	0.001	0.003	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.003	0.002	0.001	0.001	0.002	0.001	0.000
Lead (mg/L)	0.01	No Relax	0.004	0.007	0.005	0.001	0.003	0.005	0.004	0.001	0.003	0.006	0.004	0.001	0.003	0.007	0.004	0.001	0.003	0.006	0.005	0.001
Zinc (mg/L)	5	15	0.009	0.093	0.031	0.032	0.008	0.110	0.039	0.038	0.008	0.079	0.030	0.027	0.009	0.127	0.038	0.047	0.017	0.111	0.045	0.036
Chromium (mg/L)	0.05	No Relax	0.001	0.004	0.003	0.002	0.001	0.005	0.002	0.002	0.001	0.002	0..001	0.001	0.001	0.002	0.001	0.001	0.001	0.007	0.002	0.003
Iron (mg/L)	0.3	No Relax	0.284	0.921	0.627	0.277	0.288	0.949	0.653	0.286	0.291	0.962	0.707	0.269	0.295	0.998	0.744	0.298	0.444	1.087	0.923	0.250

S_1-Bhimgoda Barrage, Haridwar; S_2- Premnagar Ashram Ghat, Haridwar; S_3- Pathari Power Plant, Bahadrabad; S_4- Rail Bridge, Roorkee; S_5- Uttam Sugar Mill Ltd., Narsan; DL- Desirable limit; PL- Permissible limit.

Table 3. Showing analysis of variance (ANOVA) for monthly and spatial variations in different heavy metals in Ganga Canal at

Parameter	ANOVA Monthly Variation P-value	ANOVA Spatial Variation P-value
Copper	$1.529^* \times 10^{-11}$	0.997
Manganese	$5.217^* \times 10^{-10}$	0.956
Cadmium	0.824	0.861
Lead	0.031*	0.922
Zinc	$2.030^* \times 10^{-6}$	0.935
Chromium	0.046*	0.420
Iron	$3.726^* \times 10^{-6}$	0.653

*- Values are statistically significant at $P \leq 0.05$ for monthly and spatial variations.

Spatial variation in the content of heavy metals: Total seven metals were analyzed to find out spatial variation among five sampling sites of Ganga Canal at Haridwar district. There were five data points as Bhimgoda Barrage, Haridwar (origin point) (S_1); Premnagar Ashram Ghat, Haridwar (S_2); Pathari Power Plant, Bahadrabad (S_3); Rail Bridge, Roorkee (S_4) and Uttam Sugar Mill Ltd., Narsan (S_5) sites for each water quality parameter during each monitoring month. According to the spatial variation, the calculated data of ANOVA analyses are also presented in Table 3, which showed P-value of each metal as per site variation. Further, none of the water quality characteristic was found statistically significantly ($P \geq 0.05$) different at different sampling sites of Ganga canal. Kansal *et al.* (2013) reported the higher content of Fe, Zn, Cu and Pb in Himalayan Rivers like Ganga, Yamuna and their tributaries is from Uttarakhand state of India.

Conclusions

This investigation concluded that the water quality assessment and regular monitoring of Ganga canal water between origin and exit points at Uttarakhand is essential in order to determine level of metals in its water and subsequently, to adopt corrective and preventive actions to avoid from further deterioration of its quality. Out of seven metals, only one metal i.e. manganese exceeded its desirable limit (0.1 mg/L), whereas iron was found more than its respective permissible limit (0.3 mg/L) as per BIS standards. This might be ascribed due to geo-genic activities and discharge of untreated/ partially treated consumer waste into Ganga canal water. ANOVA showed that any of the analyzed water quality parameter does not show significant site variation at any site of Ganga Canal. Contrary to this, a total of eight metals such as calcium, copper, magnesium, manganese, lead, zinc, chromium and iron were found statistically significantly ($P \leq 0.05$) different as per monthly investigation. These variations in water quality parameters of Ganga canal might be attributed mainly due to the anthropogenic and hydro-geological activities. Therefore, anthropogenic and hydro-geological activities should be prevented to avert the contamination of heavy metals in the water of Ganga canal at Haridwar (Uttarakhand), India.

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