BIOSCIENCES BIOTECHNOLOGY RESEARCH ASIA, June 2022. Vol. **19**(2), p. 529-541

Water Quality and Heavy Metal Load in Water and Sediments of Behlol Nullah, a Tributary of River Tawi, Jammu (J & K), India

Arti Sharma and Bandhana*

Department of Zoology, University of Jammu, 180006 (J and K), India.

http://dx.doi.org/10.13005/bbra/3007

(Received: 03 February 2022; accepted: 23 March 2022)

Behlol nullah is an important tributary of river Tawi and its water quality is the major cause of concern because it receives untreated sewage as well as industrial waste from Gangyal and Bari Brahamana industrial complexes. A current effort is underway to examine the water quality and heavy metal load in the water and sediments. With various anthropogenic activities in mind, this water body has been divided into three stations namely Station-I, Station II and Station III, where Station I receives industrial effluents directly from Gangyal industrial area through Gadigarh nullah, Station II is situated downstream about 400 metres away from the site where industrial waste is directly drained into the nullah and station III is located at chatha around 6.6 kilometres away from station II and this station is devoid of any anthropogenic impacts. Standard procedures were used to analyse physicochemical parameters such as air temperature, water temperature, pH, DO, FCO2, Carbonates, Bicarbonates, Chlorides, Calcium, Magnesium, BOD, Nitrates, Phosphates and Sulphates in both water and sediments. Based on WQI score, the results of this investigation revealed variances in water quality. AAS was used to assess the level of pollution in the water and sediments of Behlol nullah for the heavy metals Fe, Cu, Zn and Pb. Heavy metal concentrations in sediments were found to be greater than in water, with the sequence of Fe>Zn>Cu>Pb in water and Fe>Cu>Zn>Pb in sediments. However, Fe was found to be highest in both water and sediments at all the study sites, and some heavy metal concentrations was found to be beyond the WHO- recommended tolerable level, indicating that this water body needs immediate attention.

Keywords: Behlol Nullah; AAS; Gadigarh; Heavy Metals; Tawi; WQI.

Water is amongst the five elements described in "Shastra" as life. Earth is referred to as "Blue Planet" because of the presence of abundant water and out of the entire water on earth; fresh water constitutes only 2.5%. Fresh water ecosystems are the most productive ecosystems in the world and a large proportion of the earth's biodiversity inhabits them[1, 2]. There was no pressure on aquatic ecosystems in the past, but in the recent times, the natural condition of these ecosystems has been altered due to increased population, urbanization and industrialization[3] which has affected their water quality and biota. It has been reported that the water quality of about 70% of Indian rivers are degraded due to contaminants which have made them unfit for human utilisation[4].

*Corresponding author E-mail: bandhanasharma17@gmail.com

Domestic effluents, along with industrial waste, eventually find their way into rivers, causing physical and chemical changes to its water quality.

All over the world, fresh water ecosystems act as the receptacle for various contaminants all over the world. Their entry into the water body due to anthropogenic as well as natural activities is one of the most important issues faced by today's communities. These contaminants may be organic, inorganic, degradable, non degradable matter, heavy metals, hydrocarbons etc. Heavy metals are the most hazardous or toxic of all the pollutant, even at low quantities[5]. Every aquatic system contains metals in an appropriate amount that are necessary for the physiological activities of its biota, but when their levels exceed their natural concentration, problems arise. Heavy metal contamination in the aquatic environment has become a worldwide problem in recent years as a result of their high toxicity, long persistence, bioaccumulation and biomagnification in the food chain[6]. Heavy metals deteriorate water quality, accumulate in sediments, and harm both floral and faunal populations, making them sensitive markers for monitoring change in water[7].

Sediments have long been utilized as an indication for assessing heavy metal pollution in the natural waters[8]. The discharge of heavy metals into rivers and their accumulation in water and sediments pose a great threat to the aquatic food chain[9]. Moreover, sediment also serves as a sink for many contaminants, allowing them to be remobilizing in the aquatic system. Heavy metal concentration in water and sediments, thus, depicts the level of pollution in a water body and its increase adversely affects benthic invertebrates, fishes and humans[10, 11, 12, 13]. Heavy metals liberated into water bodies get strongly accumulated and biomagnified along water, sediments and aquatic food chain resulting in severe effects or death of local fish population[9, 14, 15].

Heavy metals analysis in water and sediments could be used to evaluate the human and industrial impacts and risks posed by waste discharge on riverine ecosystem[16, 17]. Therefore, it is essential to measure the heavy metals concentration in water and sediments of any contaminated water body. The quantity of heavy metals in living organisms is the reflection of environmental conditions in which they live and aquatic organisms bioaccumulate them from the water and sediments, causing toxicity across the entire food chain when the contaminated species are consumed by organisms occupying the higher trophic level. Heavy metal polluted water and sediments have an impact not just on aquatic creatures, but also the terrestrial organisms that ingest them. These heavy metals also enters humans through drinking water and eating aquatic organisms, creating a slew of health issues.

As a result, the current study focused on the estimating of physico-chemical parameters of both water and sediments from the Behlol nullah along with the analysis of heavy metal load in order to assess the anthropogenic as well as industrial impacts of waste discharge on riverine ecosystem.

Study Area

Behlol nullah (74 ^{f} 50^{2} E and 32 ^{f}40^{2} N), one of the major tributaries of river Tawi in Jammu (J&K, India), emerges from a natural spring near village Purmandal and flows through Birpur, Kaluchack, Gadigarh, Chatha and Simbal Camp before joining the river Tawi near village Nadwal. Water's ecology has been severely altered as a result of deterioration of its water quality caused by the discharge of industrial and sewage pollutants from the adjoining areas. Three study stations were established along the profile of this nullah based on various anthropogenic loads, namely Station-I, Station II and Station III, where Station I directly receives industrial effluents from Gangyal industrial area (SICOP) through Gadigarh nullah, Station II is situated downstream about 400 m from Station-I, receiving sewage waste from housing the complexes of Gandhinagar, Jiwan nagar and Ranibagh, Station III is located at Chatha about 6.6 km away from Station II which is designated as the zone of revival.

METHODOLOGY

Assessment of physico-chemical parameters of water and sediments

Water analysis

Water samples were collected seasonally from selected stations for a period of one year (2019-2020) and analysed for various physicochemical parameters using an established procedure[18]. The parameters viz. air and water temperature, pH, DO, FCO_2, calcium, magnesium, and chlorides were measured at the sampling site, while for BOD, nitrates, phosphates, and sulphates, water samples were collected in pre-cleaned bottles and transferred to the laboratory for analysis within 6-8 hours of collection .

Sediment analysis

Sediment samples were collected seasonally, just like water samples for the period of one year (2019-2020) using a grab sampler in polythene bags and brought to the laboratory. In the laboratory, the temperature and pH were measured using a mercury bulb thermometer and a digital pH metre, respectively. Also a small quantity of wet samples from each station were weighed separately and then dried in the oven. After drying, the samples were weighed again so as to determine the moisture content of each sample. All the samples were air dried, powder and then sieved using a 2mm sieve. For further analysis of various physicochemical parameters, the sediment samples were kept in sealed plastic bottles and standard methodology was followed[18].

Assessment of heavy metals in water and sediments

Water sample

Water samples were collected in 1L plastic bottles from selected locations and transported to the laboratory for heavy metal testing, including such as Fe, Cu, Zn, and Pb. The pH of water was kept at 2.0 by adding 2-3 ml of concentrated HNO_3 to prevent it from any degradation and to stop microbial growth[19]. All the samples thus collected were kept in the refrigerator (4!) prior to analysis through AAS (Model no. Shimadzu AA 7000). No digestion of the water sample was done.

Sediment samples

Sediment samples from three different stations were collected into polythene bags. The samples were air dried, pulverised using a mortar and pestle, and sieved through a 5 mm mesh. 1gram of the homogenous sediment from each location was weighed and mixed with 8 ml of HNO_3. The mixture was then heated on a hot plate with a magnetic stirrer until a transparent solution was obtained. The digested sample was left to cool, filtered using whatmann filter paper no. 41 into a volumetric flask, and diluted up to 25 ml. The resultant solution was analysed for heavy metals, viz. Fe, Cu, Zn, and Pb, through an Atomic Absorption Spectrophotometer. Digestion and detection were done in triplicate.

Statistical Analysis

Water quality index (WQI)

It is regarded as the most efficient method of measuring water quality. A number of water quality parameters are included in the mathematical equation to rate water quality, thereby determining the appropriateness of water for drinking[20]. The mathematical expression of WQI is given by

$$WQI = \frac{\sum WnQn}{\sum Wn}$$

Where Q_n is the quality rating of nth water quality parameter

W_n is the unit weight of nth water quality parameter[21].

$Q_n = 100\ [(V_n - V_i)/(V_s - V_i)\ ]$

V_n = Assessed value of the nth parameter at a given sampling station

V_s = Standard permissible value of the nth parameter.

V_i = Ideal value of nth parameter in pure water [i.e., 0 for all parameters except for pH (7.0) and dissolved oxygen (14.6 mg/l).

Contamination Factor (CF)

The Contamination Factor (CF) is an important pollution index and is considered as a useful tool in monitoring heavy metal contamination. It is a quantification of the degree of contamination relative to the average crustal composition of a respective metal. It was calculated by comparing the mean of heavy metal concentration with the background value of the metal[22].

$$CF = \frac{\text{Mean metal concentration in sediments}}{\text{Background value of metal}}$$

CF values have been classified into four grades, i.e., CF<1 in class 1 with low pollution, 1 d" CF < 3 in class 2 with moderate pollution, 3 d"CF < 6 in class 3 with considerable pollution, and CF e" 6 in class 4 with very high contamination of sediments[21]. By using this classification, the pollution status of a given water body has been assessed.

RESULTS AND DISCUSSION

Physico-chemical parameters

The physico-chemical parameters of the water and sediments of Behlol nullah revealed both spatial as well as temporal variations.

Water

Air and Water Temperature

During the present study, the temperature of both air as well as water was found to be higher during the summer and lower in winter season, as reflected in Table. 1 and 2. Water temperature followed the same trend as that of air temperature throughout the year. Summer time increase in water temperature (32.83 ±1.041) may be linked to increase in day length[23], high air temperature[24], clear atmosphere and low water level[25]. The water temperature was observed to be maximum at station I (26.87 ᶠC ±8.605) and minimum at S-III (25.75 ±8.798). This may be attributed to the direct discharge of heated industrial effluents at station I.

pH

In the currently studied water body, the pH remained acidic to neutral. Temporal variations reported high pH during winter (7 ± 0.100) and low in summer (6.23 ±0.462) as shown in Table. 1. Along the profile, pH was found to be slightly acidic at station I (6.2) and approaching neutral at stations II (6.8) and III (6.75). This low pH at S-I is due to the addition of acidic waste from the industrial complex (Fig. 1).

DO and FCO_2

The dissolved oxygen content of the water of Behlol nullah recorded a maximum (3.6 mg/l ± 1.058) during winter season and minimum (2.26 mg/l ±1.006) in summer season. This winter maxima may be due to its greater solubility at low water temperatures. The station wise analysis of DO concentration revealed variations that ranged from 1.2- 2.4 mg/l with a mean of 1.9 mg/l ±0.503 at S-I, 2.4- 4 mg/l with a mean of 3.3 mg/l ±0.683 at S-II and 3.2- 4.4 mg/l with a mean of 3.9 mg/l ±0.503 at S-III. A higher value was found at station III and lower at station I (Table. 2).

During the present investigation, FCO_2 showed spatio-temporal variations as inferred by Table. 1 and 2. Seasonal tabulated data revealed higher values of FCO_2 during summer (18.48 mg/l ± 4.032) and lower in winter (11.15 mg/l ±1.016). Perusal of Table 2 further indicated variations in the concentration of FCO_2 at S-I, S-II, and S-III and it varied from 12.32-22 mg/l with an annual average of 17.38 mg/l ±4.024 at S-I, 10.56-19.36 mg/l with an annual average of 14.96 mg/l ±4.189 at S-II and 10.56-15.84 mg/l with an annual average of 12.98 mg/l ±2.423, respectively. A comparative analysis of all the three stations revealed its high level at S-I, followed by S-II and S-III. Low DO and low pH at S-I appear to increase FCO_2 concentration because they are inversely related [26, 27].

Carbonates and Bicarbonates

Throughout the study period, a complete absence of carbonates was observed at all the sites, which may be ascribed to the presence

Fig. 1. Station I

Fig. 2. Station II

Fig. 3. Station III

of FCO_2[28], as both of them exhibit an inverse relationship[29, 30, 31].

During the present study, well marked seasonal variations were observed in bicarbonate levels, with the highest values in winter (750 mg/l 45.692) and the lowest in the monsoon season (540 mg/l 49.305) (Table 1). Less uptake of bicarbonates by plants due to reduced photosynthetic activity

Table 1. Seasonal Variations In Physico-Chemical Parameters Of Water Of Behlol Nullah

Seasons\Parameters	Winter	Spring	Summer	Monsoon
Air temperature (^{f}C)	15.83 ±0.764	30.16 ±1.041	36.33 ±1.258	32.83 ±0.577
Water temperature (^{f}C)	13.66 ±0.763	28 ±0.577	32.83 ±1.041	30.5 ±0.5
pH	7 ± 0.100	6.53 ±0.378	6.23 ±0.462	6.6 ±0.346
Dissolved Oxygen (mg/l)	3.6 ± 1.058	3.07 ±1.006	2.26 ±1.006	3.2 ±1.058
Free Carbon Dioxide (mg/l)	11.15 ±1.016	13.4 ±2.828	18.48 ±4.032	17.31 ±1.344
Carbonates (mg/l)	0	0	0	0
Bicarbonates (mg/l)	750 ±45.692	704 ±46.394	612.03 ±118.96	540.87 ±49.305
Chlorides (mg/l)	44.49 ±2.291	53.656 ±10.016	153.32 ±68.068	90.82 ±30.142
Calcium (mg/l)	110.32 ±6.468	62.24 ±8.208	59.71 ±8.904	50.46 ±16.82
Magnesium (mg/l)	54.027 ±4.885	53.56 ±2.265	51.34 ±0.885	47.68 ±3.494
BOD (mg/l)	1.47 ±0.611	2 ±0.8	3.07 ±1.222	2.4 ±1.058
Nitrates (mg/l)	0.078 ±0.043	0.143 ±0.061	0.618 ±0.344	0.333 ±0.05
Phosphates (mg/l)	0.64 ±0.185	1.27 ±0.762	1.479 ±1.064	0.866 ±0.553
Sulphates (mg/l)	0.0064 ±0.017	0.076 ±0.0101	0.291 ±0.115	0.137 ±0.031

Table 2. Variations In Physico-Chemical Parameters Of Water Of Different Stations Of Behlol Nullah

Stations\Parameters	Station I	Station II	Station III
Air temperature (ffC)	27.88 ±8.929 (15 - 35)	28.75 ±8.938 (16 - 36.5)	29.63 ±9.150 (16.5 - 37.5)
Water temperature (ffC)	26.87 ±8.605 (14.5 - 34)	25.63 ±8.340 (13.5 - 32)	25.75 ±8.798 (13 - 32.5)
pH	6.2 ±0.499 (5.7 - 6.9)	6.8 ±0.245 (6.5 - 7.1)	6.75 ±0.208 (6.5 - 7)
Dissolved Oxygen (mg/l)	1.9 ±0.503 (1.2 - 2.4)	3.3 ±0.683 (2.4 - 4)	3.9 ±0.503 (3.2 - 4.4)
Free Carbon Dioxide (mg/l)	17.38 ±4.024 (12.32 - 22)	14.96 ±4.189 (10.56 - 19.36)	12.98 ±2.423 (10.56 - 15.84)
Carbonates (mg/l)	0	0	0
Bicarbonates (mg/l)	719.2 ±93.782 (585.6 - 802.8)	639.59 ±78.298 (549 - 732)	597.19 ±123.11 (488 - 717.36)
Chlorides (mg/l)	116.74 ±82.536 (46.99 - 299.99)	75.49 ±39.688 (42.49 - 129.99)	64.49 ±26.044 (43.99 - 99.99)
Calcium (mg/l)	81.37 ±24.293 (67.28 - 117.75)	68.97 ±25.928 (50.46 - 107.23)	61.71 ±30.977 (33.64 - 105.97)
Magnesium (mg/l)	54.64 ±3.328 (51.69 - 58.86)	51.28 ±3.718 (46.06 - 54.13)	49.03 ±2.647 (45.29 - 51.21)
BOD (mg/l)	3.2 ±1.033 (2 - 4.4)	2.1 ±0.503 (1.6 - 2.8)	1.4 ±0.516 (0.8 - 2)
Nitrates (mg/l)	0.428 ±0.317 (0.127 - 0.73)	0.21 ±0.263 (0.045 - 0.603)	0.241 ±0.228 (0.063 - 0.577)
Phosphates (mg/l)	1.771 ±0.778 (0.804 - 2.501)	0.808 ±0.148 (0.438 – 1.343)	0.613±0.385 (0.442 - 0.781)
Sulphates (mg/l)	0.19 ±0.159 (0.083 - 0.421)	0.13 ±0.08 (0.062 - 0.249)	0.11 ±0.069 (0.049 - 0.203)

results in an increase in its concentration in water during winter season[32] and monsoon minima owing to dilution effect of rains[29]. While station-wise data revealed its highest concentration at S-I (719.2 mg/l 93.782) and lowest concentration at S-III (597.19 mg/l 123.11), this could be due to the release of untreated industrial effluents at S-I.

Chlorides

From the tabulated data (Table. 1) it is inferred that during the course of investigation,

Table 3. Seasonsal Variations In Physico-Chemical Parameters Of Sediments Of Behlol Nullah

Seasons\Parameters	Winter	Spring	Summer	Monsoon
Temperature (ᶠC)	12.33 ±1.892	25.83 ±1.89	32 ± 2.65	28.83 ±2.362
pH	6.4 ±0.378	6.1 ±0.251	5.6 ±0.404	5.9 ±0.305
Carbonates (mg/g)	0	0	0	0
Bicarbonates (mg/g)	0.22 ±0.038	0.12 ±0.018	0.10 ±0.009	0.09 ±0.024
Chlorides (mg/g)	0.27 ±0.051	0.25 ±0.06	0.56 ±0.085	0.21 ±0.041
Calcium (mg/g)	1.55 ±0.305	1.03 ±0.243	0.81 ±0.137	0.64 ±0.144
Magnesium (mg/g)	2.28 ±0.215	1.315 ±0.255	1.044 ±0.279	0.911 ±0.348
Nitrates (mg/g)	0.022 ±0.021	0.052 ±0.024	0.072 ±0.025	0.015 ±0.006
Phosphates (mg/g)	0.015 ±0.006	0.026 ±0.0125	0.086 ±0.008	0.012 ±0.191

Table 4. Variations In Physico-Chemical Parameters Of Sediments Of Different Stations Of Behlol Nullah

Stations\Parameters	Station I	Station II	Station III
Temperature (ᶠC)	27.2 5±8.968	23.75 ±8.846	23.25 ±8.149
	(14.5 - 35)	(11 – 31)	(11.5 – 30)
Ph	5.65 ±0.341	6.1 ±0.374	6.3 ±0.294
	(5.2 – 6)	(5.7 – 6.6)	(6 - 6.7)
Carbonates (mg/g)	0	0	0
Bicarbonates (mg/g)	0.155 ±0.074	0.131 ±0.050	0.113 ±0.058
	(0.1 – 0.265)	(0.086 – 0.202)	(0.062 – 0.196)
Chlorides (mg/g)	0.38 ±0.163	0.33 ±0.176	0.26 ±0.132
	(0.26 – 0.62)	(0.2 – 0.59)	(0.18 – 0.46)
Calcium (mg/g)	1.2 ±0.443	1.02 ±0.445	0.79 ±0.297
	(0.789 – 1.803)	(0.643 – 1.632)	(0.501 – 1.209)
Magnesium (mg/g)	1.66 ±0.593	1.38 ±0.575	1.12 ±0.689
	(1.213 – 2.513)	(0.993 – 2.23)	(0.529 – 2.09)
Nitrates (mg/g)	0.062 ±0.034	0.035 ±0.027	0.026 ±0.019
	(0.02 - 0.098)	(0.011 – 0.071)	(0.009 – 0.048)
Phosphates (mg/g)	0.051 ±0.031	0.032 ±0.188	0.009 ±0.149
	(0.022 - 0.096)	(0.013 – 0.411)	(0.010-0.328)

Table 5. Water Quality Index (WQI) And Status Of Water Quality (Chatterji And Raziuddin, (2002)

Stations	WQI values	WQI level	Water Quality Status
S-I	108.4	> 100	Not Suitable for Drinking
S-II	73.03	51-75	Poor Water Quality
S-III	65.99	51-75	Poor Water Quality
Mean	82.5	76-100	Very Poor Water Quality

chloride concentration was recorded at its peak in the summer season (153.32 mg/l ±68.068) and dipped to the lowest level in the winter season (44.49 mg/l ±2.291). The chloride concentration was found to oscillate at different stations in the studied water body. At S-I, it fluctuated from 46.99-229.99 mg/l with a mean of 116.74 mg/l ±82.536, 42.49-129.99 mg/l at S-II with a mean of 75.49 mg/l ±39.688 and 43.99- 99.99 mg/l at S-III with a mean of 64.49 mg/l ±26.044. The maximum chloride concentration recorded at S-I is an indicator of pollution caused due to the decomposition of organic and inorganic industrial waste.

Table 6. Variations In Water Quality Index At Different Stations Of Behlol Nullah

Water Quality Index Level	Water Quality status
0-25	Excellent Water Quality
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
>100	Not Suitable for Drinking

Calcium and Magnesium

The content of calcium and magnesium ions generally indicates the hardness of water. Present investigative studies revealed seasonal variations in their concentration with an elevation during winter and a decline in the monsoon season as shown in Table. 1. During the present study period, a comparative analysis among the stations reported the maximum concentration of calcium at S-I (81.37 mg/l ±24.293) and the minimum at S-III (61.71 mg/l ±30.977 as shown in Table 2. A similar

Table 7. Seasonal Variations In Heavy Metal Concentration (mg/l) In Water Of Behlol Nullah

Seasons\ Heavy metals	Winter	Spring	Summer	Monsoon
Iron (mg/l)	0.141 ±0.077	0.240 ±0.151	0.400 ±0.172	0.053 ±0.027
Copper (mg/l)	0.046 ±0.017	0.096 ±0.024	0.275 ±0.215	0.010 ±0.005
Zinc (mg/l)	0.557 ±0.344	0.955 ±0.248	1.873 ±0.995	0.139 ±0.184
Lead (mg/l)	0.0013 ±0.0004	0.0029 ±0.0012	0.037 ±0.018	0

Table 8. Variations In Heavy Metal Concentration (mg/l) In Water Of Different Stations Of Behlol Nullah

Stations\ Heavy metals	Station I	Station II	Station III
Iron (mg/l)	0.328 ±0.223 (0.080 - 0.594)	0.174 ±0.124 (0.053 – 0.343)	0.124 ±0.102 (0.026 -0.264)
Copper (mg/l)	0.178 ±0.231 (0.016 – 0.519)	0.090 ±0.080 (0.010 - 0.195)	0.05 ±0.047 (0.0042-0.112)
Zinc (mg/l)	1.357 ±1.139 (0.348 – 2.982)	0.79 ±0.636 (0.067 – 1.577)	0.494 ±0.480 (0.002 – 1.059)
Lead (mg/l)	0.016 ±0.027 (BDL – 0.056)	0.010 ±0.017 (BDL – 0.035)	0.006 ±0.010 (BDL – 0.021)

Table 9. Seasonal Variations In Heavy Metal Concentration (mg/g) In Sediments Of Behlol Nullah

SeasonsHeavy metals	Winter	Spring	Summer	Monsoon
Iron (mg/g)	12.94 ±2.55	16.85 ±1.09	19.6 ±2.37	11.44 ±1.656
Copper (mg/g)	1.37 ±0.615	1.69 ±0.526	3.55 ±0.723	0.764 ±0.2865
Zinc (mg/g)	1.25 ±0.284	1.79 ±0.552	2.53 ±1.210	0.939 ±0.192
Lead (mg/g)	0.54 ±0.346	1.27 ±0.501	1.95 ±0.837	0

Table 10. Variations In Heavy Metal Concentration (mg/l) In Sediments Of Different Stations Of Behlol Nullah

Stations\Heavy metals	Station I	Station II	Station III
Iron (mg/g)	17.274 ±3.821	14.857 ±3.654	13.499 ±3.789
Copper (mg/g)	2.342 ±1.391	1.899 ±1.142	1.289 ±1.085
Zinc (mg/g)	2.215 ±1.221	1.548 ±0.535	1.117 ±0.345
Lead (mg/g)	1.37 ±1.172	0.898 ±0.899	0.549 ±0.496

Table 11. Contamination Factor (CF) Values Of Heavy Metals In Behlol Nullah

Stations	Fe	Cu	Zn	Pb
S-I	4.812	0.073	0.0172	0.069
S-II	4.138	0.059	0.012	0.045
S-III	3.760	0.040	0.0087	0.027

trend was observed in magnesium ion content, with higher values at S-I (54.64 mg/l ±3.328) and lower at S-III (49.03 mg/l ±2.647).

BOD

A seasonal comparison of BOD revealed a rise in its value during the summer season (3.07 ±1.222) and a fall in winter season (1.47 mg/l ±0.611) as shown in Table. 1. Perusal of Table 2, further revealed that BOD values oscillates from 2 - 4.4 mg/l with an average of 3.2 mg/l ±1.033 at S-I, 1.6 - 2.8 mg/l with an average of 2.1mg/l ±0.503 at S-II and 0.8 - 2.0 mg/l with an average of 1.4 mg/l ±0.516 at S-III. High rate of decomposition of industrial waste, accompanied by higher microbial activity at S-I, seems to be the sole reason for high BOD values at S-I.

Nitrates, Sulphates and Phosphates

The presence of nitrates, sulphates and phosphates in water causes eutrophication[33]. Seasonal variations in nitrates, sulphates, and phosphates have been depicted in Table. 1. All three parameters reflected maximum values during the summer and minimum values in the winter season (Table. 1). Spatial variations in all these three parameters along the different stations of the water body were also reported (Table. 2). S-I had the highest nitrate concentration (0.428 mg/l 0.317), followed by S-II (0.21 mg/l 0.263) and S-III (0.241 mg/l 0.228). Also, the sulphate concentration revealed a peak at S-I (0.19 mg/l 0.159) and the lowest at S-III (0.11 mg/l 0.069). A similar trend was followed by phosphate concenteration with a maximum value of 1.771 mg/l ±0.778 at S-I, followed by S-II (0.808 mg/l ±0.140) and S-III (0.613 mg/l ± 0.385). The direct influx of industrial waste at S-I resulted in the elevation of these three parameters. However, as a consequence of dilution and sedimentation, their level started declining at S-II and reached its lowest value at S-III due to the revival of the water body.

Physicochemical parameters of sediments

Sediment is an important habitat as well as a main source of nutrients for aquatic organisms and forms a natural buffer and filter system in the material cycles of water[34]. The analysis of physico-chemical properties of the sediments from Behlol nullah for a period of one year, viz., 2019- 2020, inferred both temporal and spatial variations.

Sediment Temperature

Seasonal variations in sediment temperature of the studied water body revealed its elevated temperature in the summer (32 ^{f} C ± 2.65) and fall in winter season (12.33 ^{f} C ±1.892) which occurred mainly due to the high temperature of the water overlying it. A strong correlation between water and sediment temperature has already been recorded[35]. Moreover, station wise sediment temperature also revealed variations, and it fluctuated from 14.5 ^{f} C to 35 ^{f} C (27.25 ^{f} C ±8.968) at S-I, 11 ^{f} C to 31 ^{f} C (23.75 ^{f} C ±8.846) at S-II and 11.5 ^{f} C to 30 ^{f} C (23.25 ^{f} C ±8.149) at S-III, thereby depicting maximum temperature at S-I and minimum at S-III.

pH

From Table. 3, it has been concluded that the pH of the sediments of the present water body varied from moderately acidic to slightly acidic. Comparative analysis of seasonal data reported a minimum pH (5.6 ±0.404) during the summer and a maximum in the winter season (6.4 ±0.378). However, moderately acidic conditions with a pH of 5.65 were found at S-I, whereas, at S-II and

S-III, slightly acidic conditions were recorded with a value of 6.1 and 6.3, respectively (Table. 4). This may be attributed to the direct discharge of effluents from the industrial complex at S-I.

Carbonates and Bicarbonates

Similar to the absence of carbonates in surface water, the carbonates were found to be absent in the sediments of Behlol nullah at all the study sites. Well marked spatio-temporal variations were registered in bicarbonates content. Bicarbonate seasonal values ranged from 0.09 0.024 mg/g (minimum) during the monsoon season to 0.22 0.038 mg/g (maximum) during the winter season (Table 3). Minimum content of bicarbonates recorded during monsoon season may be the effect of dilution of deposited ions caused by heavy rain and frequent flooding[36, 37].

However, bicarbonate concentration was found to be high at S-I (0.153 mg/g ± 0.074), followed by S-II (0.131 mg/g ± 0.050) and S-III (0.113 mg/g ± 0.058) as shown in Table. 4.

Chlorides

It is apparent from Table. 3 that chloride content showed a spike in its concentration during the summer season (0.56 mg/g ±0.085) and a decline in the monsoon (0.21 mg/g ±0.051). This could be attributed to the high rate of decomposition during the summer, as well as dilution caused by rains during the monsoon season. Data tabulated in Table. 4 clearly represented that among the three stations, S-I (0.38 mg/g ±0.163) showed a maximum value of chloride, followed by S-II (0.33 mg/g ±0.176) and S-III (0.26 mg/g ±0.123). Due to an increase in the discharge of industrial waste releasing more of its content in water from where it gets accumulated in sediments.

Calcium and magnesium

Well marked seasonal variations in calcium and magnesium content were noticed in the sediments of Behlol nullah (Table. 3). Calcium concentrations were highest during the winter season (1.55 mg/g 0.305) and lowest during the monsoon season (0.64 0.144). This winter maxima may be due to low metabolic activity and a decrease in the uptake of these ions by the biota and their higher residence time. It is apparent from Table 3 that magnesium content recorded at its peak during winter (2.28 mg/g ±0.215) and after acquiring its maximum level during the winter season, the magnesium ions started declining in spring (1.315 mg/g ±0.255) and continued to fall throughout the summer (1.044 mg/g ±0.279) season to attain its lowest value in rainy season (0.911 mg/g ±0.348). Similar observations were reported earlier[36, 37]. However, station wise data (Table. 4) revealed a maximum level of calcium at station I (1.2 mg/g ±0.443) followed by S-II (1.02 mg/g ±0.445) and S-III (0.79 mg/g ±0.297) as S-I is under the direct influence of industries. While, at S-II and S-III, dilution and sedimentation resulted in decrease in calcium content. Magnesium levels also follow the same spatio-temporal trend as that of calcium. Seasonal data analysis revealed that magnesium content increases during the winter (2.28 mg/g 0.215) and decreases during the monsoon season (0.911 mg/g 0.348). Comparative analysis among stations revealed that magnesium ions pursue same trend as calcium ions with the highest level at S-I (1.66 mg/g ±0.593) and the lowest at S-III (1.12 mg/g ±0.689).

Nitrate and Phosphate

During the investigative period of one year (2019-2020), it was observed that the nitrate and phosphate content in sediments closely followed their content in the water column. Seasonal variations in sediment nitrate and phosphate content disclosed that their values oscillate from minimum of 0.015 mg/g ±0.006 and 0.012 mg/g ±0.191 in rainy season to maximum of 0.072 mg/g ±0.025 and 0.086 mg/g ±0.008 in summer season (Table. 3), respectively. However, station wise comparison revealed their high concentration at S-I, followed by a decline at S-II, and low at S-III, as represented by Table 4. At S-I, direct addition of untreated waste led to an elevation of both nitrate and phosphate content, while, at S-II and S-III, dilution resulted in a fall in their concentration.

Water Quality Index (WQI)

The water quality Index is an effective tool for the measurement of water quality and the level of its contamination in order to ascertain its usage for public consumption, recreational, and other purposes. These indices also convert intricate water quality data into an information that is understandable and utilisable by the common public[38].

In the present study, 10 important parameters, viz., DO, pH, bicarbonate, calcium, magnesium, chloride, nitrate, phosphate, sulphate, and BOD, were selected for the calculation of the water quality index by using the standards of drinking water quality. The values calculated were 108.4, 73.03 and 65.99 at stations I, II and III, respectively (Table. 6). Based on WQI and status of water quality[20], the water of Behlol nullah is not suitable for drinking at station I, while it is poor at stations II and III (Table. 5). As shown in the table, the overall water quality index (82.5) was very poor.

Heavy Metals

During the investigation period of one year (2019 to 2020), the level of heavy metals, viz., iron, copper, zinc and lead was determined temporally as well as spatially in both the water and sediments of Behlol nullah (Table. 7, 8, 9 &10) .

Water

Waste discharged into the water body directly influences its quality. Throughout the year, temporal variations in Fe content of this lotic water body showed elevation during summer (0.4 mg/l ±0.124) and fall in monsoon season (0.053 ±0.027). Moreover, the iron concentration in water varied from 0.080 - 0.594 mg/l with a mean of 0.328 mg/l ±0.223 at S-I, 0.053 – 0.343 mg/l with a mean of 0.174 mg/l ±0.124 at S-II and 0.026 - 0.264 mg/l with a mean of 0.124 mg/l ±0.102 at S-III (Table. 8). The level of Fe was recorded to be the highest and above the permissible limit as suggested by WHO and BIS at S-I[39, 40]. This may be ascribed to the direct discharge of industrial effluents at S-I.

During the course of investigation, the seasonal deviations in Cu concentration were reported, with higher and lower values during summer (0.275 ±0.215) and the monsoon season (0.010 ±0.005), respectively. Also, the copper level illustrated wide variations in its content at different study sites (Table. 8). The maximum concentration of Cu was recorded at S-I (0.178 mg/l ±0.231) followed by S-II (0.090 mg/l ±0.080) and S-III (0.050 mg/l ±0.047). At S-I and S-II, the levels were detected to be above the permissible limits.

Temporally, Zn concentration exhibited maxima (1.873 mg/l ±0.995) during summer and minima (0.139 mg/l ±0.184) in monsoon season (Table. 7). While, the station wise assessment of Zinc concentration showed its mean values to fluctuate from a minimum of 0.494 mg/l ±0.048 at station III to a maximum of 1.357 mg/l ±1.139 at station I (Table. 8). During the present investigation period, its level remains within the permissible limit of 3ppm[39].

Perusal of Table. 7 reveals seasonal variations in lead concentration. Its level was recorded to fluctuate from the lowest i.e. below the detection level during the monsoon to the highest level (0.037 mg/l ±0.018) in the summer season. But its spatial distribution in Behlol nullah revealed a minimum concentration at station III (0.006 mg/l ±0.010) and maximum at station I (0.016 mg/l ±0.027). However, its concentration remained above the optimum limits, i.e., 0.01mg/l at S-I[39, 40]. Direct discharge of untreated waste from battery, paint, dye and pipe manufacturing industries of the industrial complex are the causative agent for enhancing the Pb ions in the water. Overall, the heavy metal trend in the water was found to be in the decreasing order of Fe>Zn>Cu>Pb in water of the Behlol nullah.

Sediments

Perusal of Table. 9, the heavy metal level followed the same trend as that in the overlying water. From cumulative results (Table. 9) it could be inferred that analysis of heavy metals viz. Fe, Cu, Zn and Pb present in sediments of Behlol nullah exhibited their maximum concentration during summer and minimum during monsoon season as already reported by researchers[41]. Out of all the three stations, sediment sample of S-I showed highest concentration of Fe, Cu, Zn and Pb with an average of 17.274 mg/g ±3.821, 2.342 mg/g ±1.391 , 2.215 mg/g ±1.221 and 1.37 mg/g ±1.172, respectively followed by S-II i.e. 14.875 mg/g ±3.654 , 1.899 mg/g ±1.142, 1.548 mg/g ±0.535 and 0.898 ±0.899 mg/g and least at S-III with mean of 13.499 mg/g ±3.789 , 1.289 mg/g ±1.085 , 1.117 mg/g ±0.345 and 0.549 mg/g ±0.496, respectively (Table. 10). However, the heavy metal trend in sediment was found to be in the decreasing order of Fe >Cu >Zn >Pb similar to that of water.

Contamination Factor (CF)

In order to assess the extent of heavy metal pollution in sediments, the contamination factor (CF) was also calculated at three different stations for Fe, Cu, Zn and Pb. Contamination factor values of Fe, Cu, Zn and Pb were recorded to be 4.812, 0.073, 0.0172 and 0.069 at S-I, 4.138, 0.059, 0.012 and 0.045 at S-II and 3.760, 0.040, 0.0087 and 0.027 at S-III, respectively.

Table. 11 clearly revealed that the CF value of Fe falls into class 3 (3d" CF< 6) depicting considerable pollution in the sediments of Behlol nullah[22] while, CF values of Cu, Pb and Zn were found to be less than 1, indicating low pollution.

CONCLUSION

The study of physico-chemical parameters of water showed that the water quality index of S-I (108.4) showed that water is inapt for drinking purposes, while at S-II (73.03) and S-III (65.99) it was found to be of poor quality. However, the overall WQI value (82.5) of Behlol nullah described it as being of very poor quality. Therefore, this water body is of basic concern. Heavy metal concentration was found to be higher in sediments than water and reported to be in the order of Fe>Zn>Cu>Pb in water and Fe>Cu>Zn>Pb in sediments. Moreover, the content of some heavy metals was higher than permissible limits, which may cause health hazards to the aquatic biota residing in that water body which directly or indirectly affects human health through consumption of water and fish. Also, the contamination factor values of copper, zinc and lead were found to be less than 1 depicting low pollution of sediments by these heavy metals, while for iron its value falls into class 3, signifying considerable pollution. So, the present study suggests that strict management methods should be adopted in order to regulate the increased industrial effluent rich in heavy metals. Also, proper treatment of waste water should be done before discharging it into the water body. Mass awareness should be done and certain management strategies should be formulated to improve the status of Behlol nullah, which in turn protects the environment as well as public health.

ACKNOWLEDGEMENT

The authors are highly thankful to the Head, Department of Zoology, University of Jammu, for providing necessary facilities and availability of equipments which have been purchased out of RUSA/ PURSE/ FIST grant.

Conflict of interest

The authors declare no conflict of interest.

Funding Source

The authors are highly grateful to DRS, University of Jammu for financial assistance.

REFERENCES

1. Mc Allister DE, Hamilton AL and Harvey BH. Global freshwater biodiversity: Striving for the integrity of freshwater ecosystems. Sea Wind, 1997; 11(3).
2. Groombridge B and Jenkins M. Freshwater biodiversity: A preliminary global assessment. Cambridge, United Nations Environment Programme-World Conservation monitoring centre, World Conservation Press. 1998.
3. Dale VS, Chang M and Ojima D. Ecological impacts and mitigation stratergies for rural land management. Ecological applications, 2005; 15: 1879-1892.
4. Ramakrishnan N. Bio-Monitoring approaches for water quality assessment in two waterbodies at Tiruvannamalai, Tamil Nadu India. In Martin J. Bunch, V. Madha Suresh and T. Vasantha Kumaran, eds., Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December, 2003. Chennai: Department of Geography, University of Madras and Faculty of Environmental Studies, York University, 2003; pp 374 – 385.
5. Lenntech. Heavy metals. www. Lenntech.com/ heavy metals. 2004; pp 34.
6. Rahman MM, Asaduzzaman M and Naidu R. Consumption of arsenic and other elements from vegetables and drinking water from an arsenic contaminated area of Bangladesh. Journal of Hazardous Materials, 2013; 262: 1056-1063**.**
7. Mohiuddin KM, Ogawa Y, Zakir HM, Otomo K and Shikazono N 2011. Heavy metal contamination in water and sediments of an urban river in a developing country. International Journal of Environmental Science and Technology, 2013; 8 (4): 723-736.
8. Islam MS, Ahmed MK, Raknuzzaman M, Mamun M, Islam MK. Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country. Ecological. Indicators, 2015; 48: 282-291.
9. Megeer JC, Szebedinszky C, Mc Donald DG and Wood CM. Effect of chronic sublethal exposure of water borne Cu, Cd, Zn in Rainbow trout1: ion regulatory disturbance and metabolic cost. Aquatic Toxicology, 2000; 50 (3): 231-243.

10. Yi Y, Yang Z, Zhang S. Ecological risk assessment of heavy metal in sediment and human health risk assessment of heavy metals in fishes in the middle and lower reaches of the Yangtze river basin. Environmental Pollution, 2011; 159: 2575-2585.
11. Islam MS, Ahmed MK, Mamun M, Islam KN, Ibrahim M and Masunaga S. Arsenic and lead in foods: a potential threat to human health in Bangladesh. Food Additives and Contaminants: Part A., 2014; 31 (12): 1982-1992.
12. Ahmed MK, Shaheen N, Islam MS, Al-Mamun MH, Islam S, Mohiduzzaman M and Bhattacharjee L. Dietary intake of trace elements from highly consumed cultured fish (*Labeo rohita, Pangasius pangasius and Oreochromis mossambicus*) and human health risk implications in Bangladesh. Chemosphere, 2015; 128: 284-292.
13. Martin JAR, Arana CD, Ramos-Miras JJ, Gill C, Boluda R**.** Impact of 70 years urban growth associated with heavy metal pollution. Environmental Pollution**,** 2015; 196: 156-163.
14. Jones L, Kille P and Sweeney G. Cadmium delays growth hormone expression during rainbow trout development. Journey of Fish Biology, 2001; 59: 1015-1022.
15. Almeida JA, Diniz YS, Marques SFG, Faine IA, Ribas BO, Burneiko RC and Novelli EIB. The use of oxidative stress response as biomarkers in Nile Tilapia (*Oreochromis niloticus*) exposed to in-vivo cadmium contamination. Environment International, 2002; 27: 673-679.
16. Yi YI, Wang ZY, Zhang K, Yu GA**.** Sediment pollution and its effect on fish through food chain in the Yangtze River. International Journal of Sediment Research, 2008; 23: 338-347.
17. Zhang N, Wang QC, Liang ZZ and Zhang DM. Characterization of heavy metal concentrations in the sediments of three freshwater rivers in Huludao City, Northeast China. Environmental Pollution, 2008; 154: 135-142.
18. APHA. Standard Methods of the Examination of Water and Wastewater Investigations. Washington,D.C, 2012.
19. APHA. Standard methods for the examination of water and wastewater. American Public Health Association. Washington D.C, 1985.
20. Chatterji C and Raziuddin M. Determination of water quality index (WQI) of a degraded river in Asanol Industrial area, Raniganj, Burdwan, West Bengal. Nature Environment and Pollution Technology, 2002; 1 (2): 181-189.
21. Brown RM, Mcclellan NI, Deininger RA and Tozer RG. A water quality index- do we dare? Water and sewage Works,1970; 117: 339-343
22. Hakanson L. An ecological risk index for aquatic pollution control, a sedimentological approach. Water Resource, 1980; 14 (8): 975-1001.
23. Saini M. Limnological characterization of Gharana Wetland (Reserve) Jammu. M. Phil. Dissertation, University of Jammu, Jammu, 2009.
24. Manjare SA, Vhanalaker SA and Muley DV. Analysis of water quality using physicochemical parameters Tamdalge tank in Kohlapur district, Maharashtra. International Journal of Advanced Biotechnology and Research, 2010; 1(2): 115-119.
25. Shinde SE, Pathan TS, Raut KS and Sonawane DL. Studies on the physico-chemical properties and correlation coefficient of Harsool- Savangi Dam, Aurangabad, India. Middle- East Journal of Scientific Research, 2011; 8 (3): 544-554.
26. Saini M. Impact assessment of pollution load on abiotic and biotic characteristics of River Basantar (Jammu). Ph.D.Thesis, University of Jammu, Jammu, 2016.
27. Devi A. Impact of anthropogenic influences on the ecology of Ban Ganga stream Katra J and K. Ph.D.Thesis, University of Jammu, Jammu, 2018.
28. Sharma SP. Studies on impact of anthropogenic influences on the ecology of Gharana wetland, Jammu. Ph.D. Thesis, University of Jammu, Jammu, 2002.
29. Sawhney N. Limnology of Ban- Ganga with special reference to some consumers inhabiting the stream. M. Phil. Dissertation, University of Jammu, Jammu, 2004.
30. Kour S. Studies on the impact of tourism on stream Ban Ganga and the dwelling micro and macro organisms. Ph.D. Thesis, University of Jammu, Jammu, 2006.
31. Sharma A, Sharma KK, Sharma N and Jamwal H. Assessment of water quality using physicochemical parameters of a lentic water body of Jammu, J&K. International Journal of Recent Scientific Research, 2014; 5(6): 1138-1140.
32. Sharma A and Singh R. Temporal changes in physico- chemical parameters of water of Gharana Wetland Reserve (J&K) and assessment of its pollution status using Comprehensive Pollution Index. Indian Journal of Ecology, 2021; 48 (0): 1284-1289.
33. Rao AM. Studies on limnology and fisheries in Tilapia dominated perennial tank, Julur, Nalgonda district, Andhra Pradesh. Ph.D. Thesis, Osmania University, Hyderabad, India, 2004.
34. Adeyemo OK, Adedokun OA, Yusuf RK and Adeleye EA. Seasonal changes in physic-

chemical parameters and nutrient load of river sediments in Ibadan City, Nigeria. Global Nest Journal, 2008; 10 (3): 326-336.

35. Sarvankumar A, Rajkumar M, Serebian J and Thirukaran GA. Seasonal variations in physicochemical characteristics of water, sediment and soil texture in arid zone mangroves of Kachh, Gujrat. Journal of Environmental Zoology, 2008; 29(5): 725-732.
36. Sharma V. Sediment characterization of some section of river Tawi and its impact on macro-benthic invertebrate faunal diversity. Ph.D. Thesis, University of Jammu, Jammu, 2015.
37. Sharma N. Studies on the impact of barrage construction on the ecology of river Tawi. Ph.D. Thesis, University of Jammu, Jammu, 2018.
38. Yogendra K and Puttaiah ET. Determination of water quality index and suitability of an Urban water body in Shimoga Town, Karnataka. Proceedings of Taal2007: The 12th World Lake Conference, 2008; 342-346.
39. WHO. Global fresh water quality assessment report, WHO Int. Rept/Pep/88, 1998.
40. BIS. Bureau of Indian standards. Manak Bhavan, 9Bahadur Shah Zafar Marg, New Delhi, 110002, 2012.
41. Singh H, Pandey R, Singh SK and Shukla DN. Assessment of heavy metal contamination in the sediment of the River Ghaghara, a major tributary of the River Ganga in Northern India. Applied Water Science, 2017; 7: 4133-4149.