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Research article

Biomonitoring and Water Quality Evaluation of River Beas in Mid Himalayan Zone, India

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Abstract

Keywords

Beas;
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turbidity;
hydrobiology;
macroinvertebrate;
PCA;
water quality index

The present investigation was carried out on the Beas River, a major tributary of the Indus riverine system in the Mid Himalayan zone, to evaluate the physico-chemical and microbiological parameters during different seasons. For this, based on altitudinal differences, four observation sites were selected: S_1 - Manali (urban land), S_2 - Takoli (agricultural land), S_3 - Mandi town (urban land) and S_4 - Kunn Ka Tarr (forest land), located in the Kullu and Mandi districts of Himachal Pradesh. Lotic ecosystems can undergo rapid changes in their hydrology. Hence, biomonitoring using EPT index (Ephemeroptera, Plecoptera and Trichoptera) was also carried out at every station. Furthermore, temporal biological components (macroinvertebrates seasonal analysis) were added to the information acquired by traditional physico-chemical analysis. Macroinvertebrates are sensitive organisms and can act as bioindicators of water quality. The physico-chemical parameters analyzed in the study area were water temperature, pH, turbidity, total alkalinity, TDS, total hardness, chloride, dissolved oxygen, biological oxygen demand, chemical oxygen demand, and total coliforms. Species diversity indices such as Simpson, Shannon and Wiener, and Margalef's diversity index of macroinvertebrates were calculated for all the monitoring sites on the river. There was no homogeneity observed among the stations, and it was concluded that every station had different trends due to different geographic location, altitude, land use in catchment, and most importantly nature of anthropogenic interference. The study also revealed that anthropogenic interferences not only changed the physico-chemical parameters of the river but also disturbed the macroinvertebrate fauna. The EPT index was low at stations (S_1 and S_3) where anthropogenic impact was relatively high.

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1. Introduction

The Beas River, one of the most important tributaries of the Indus River system (it is the only tributary confined to India), rises near the Rohtang Pass (3978 m) in Himachal Pradesh. The present investigation was carried out in its upper reaches in the Kullu and Mandi districts, and was done around three major human settlements. The river has a very steep gradient from Rohtang to Larji, but when it emerges out of the Mid Himalayan range, the gradient becomes milder. The Parvati, Sainj, Hurla, Tirthan, Uhl, Suketi and Looni are the major tributaries of the Beas River in this stretch. Rivers in the region serve as the main sources of drinking water, and it is imperative to monitor their water quality. River water quality is closely related to aquatic life, and it is possible to analyze water quality by observing the aquatic biodiversity of the river. Besides being major sources of drinking water, rivers such as the Beas also play important roles economically (hydroelectric power generation, fisheries and tourism) and socially (sacred bodies of water) in the region. In this work, the macroinvertebrate fauna (EPT) of the river was compared with the seasonal physico-chemical parameters and used as monitoring tool to assess the river health [1]. The water quality of the river was analyzed using WQI (water quality index) for different physico-chemical variables, and the results were compared to standards prescribed by various organizations [2-4].

2. Materials and Methods

2.1 Study area

The Beas River comes out from the southern slopes of the Pirpanjal range in the Mid Himalayas and its course spans around 132 km from S_1- Manali to S_4- Kunn Ka Tarr. Observation sites S_1, S_2, S_3 and S_4 (Figure 1) were selected on the basis of altitude and because they were point sources of waste water discharge and had identified pollution problems related to urban, agricultural and forest land, and thus places where human impact could be assessed. The main habitat in the river was one of riffles and runs with few pools and substrates of boulders and cobbles. The areas of interest can be described as follows: S_1- Manali, Kullu district (Urban land, 2050 m above msl, open defecation, garbage dumping and sewage entry point); S_2- Takoli, Mandi district about 55 km downstream from S_1 (post-urban area and near agricultural land, 1100 m above msl, open defecation, mining and domestic waste); S_3- Mandi Town, about 45 km downstream from S_2 (urban land, 760 m above msl, water velocity is low, open defecation, sewage, domestic waste dumping) and S_4- Kunn Ka Tarr in Mandi district about 24 km downstream from S_3 (forest land, 671 m above msl, little human habitation). The drainage patterns in the surveyed regions and all the streams/*nullahs* have been organized in proper order [5].

2.2 Sampling and analysis

Water samples were gathered on a seasonal basis during January to October 2020, i.e. winter (January-February); spring (March-April); summer (May-June); monsoon (July-August) and post-monsoon (September-October) from all observation sites. Physico-chemical parameters of the water were evaluated according to the standard methods, and the water quality index was calculated [6-8].

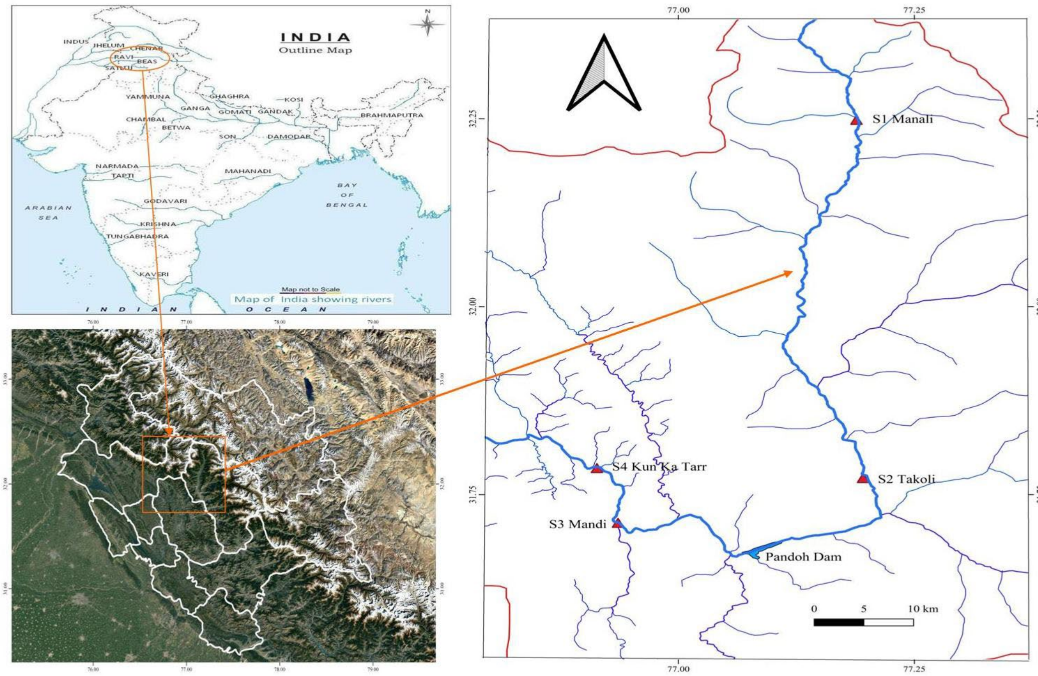

Figure 1. Map showing surveyed region and drainage basin of the Beas River in Kullu and Mandi districts of Himachal Pradesh, India. S_1, S_2, S_3 and S_4 are the observation sites.

Macroinvertebrates were collected using Surber sampler nets by creating disturbances on the bottom of the stream, which unsettled them. They were gathered in bucket, and preserved in 4% formaldehyde solution. Macroinvertebrate quantity was represented as individuals per m^2. The benthos were identified by following appropriate morphological characters [9-11].

Species diversity was calculated using diversity indices [12, 13].

1. EPT Index (Epheameroptera, Plecoptera, Trichoptera) = $\frac{\text{Total EPT Taxa}}{\text{Total Taxa Found}} \text{x} 100$

2. Water quality index (WQI) was calculated for nine physico-chemical parameters of the water samples [14, 1].

Water Quality Index (WQI) = qi.wi

where,

qi (water quality rating) = $\frac{100\text{x}(\text{Va}-\text{Vi})}{\text{Sn}-\text{Vi}}$

Va = recorded value of a parameter in water sample

Vi = ideal value (DO in r/o water temperature, pH-7.0 and 0 for remaining seven parameters)

Sn= standard value (from different standard prescribed)

wi (unit weight) = k/Sn

where,

K (constant) = $\frac{1}{(\sum 1/Sn = 1,2 \ldots n)}$

3. Simpson's index

$$D = \sum n_i (n_i - 1) / N (N-1)$$

D = diversity index, N = total number of individuals of all species, n = number of individuals of a specific species, i = subscript to denote the number of different species.

4. Shannon and Wiener Diversity Index

$$H = -\sum pi \log_e pi$$

where, H = diversity index; pi = ni/N (ni = number of individuals in species i; N = total number of individuals in the sample)

Statistical analysis of the data for ANOVA (one way analysis of variance) and Principal component analysis (PCA) were performed using SPSS.16 software.

3. Results and Discussion

3.1 Physico-chemical analysis

Average ($\overline{X}$), range and permissible limits prescribed by different standards and pollution monitoring agencies for drinking water of different physico-chemical parameters recorded at different research stations on the river are shown in Table 1. Temperature is responsible for regulating many natural processes and affects both chemical and biological characteristics of water bodies. Temperatures at all the observation sites rose from January to May with the lowest temperature (4°C) recorded at S_1 in January (winter and high altitude), whereas the highest value (18°C) was at S_3 in May (urban, no forestation, high turbidity). Temperature showed positive correlation with turbidity [15] and had an inverse relation with pH [1].

The pH was within the tolerable limit of 6.5-8.5 at all observation sites, except S_3 (Mandi) which had a pH below 7 [3]. The low pH of water at S_3, the lowest value, was recorded during summer (6.5) and might have been harmful for the biota as well as for human consumption. Low pH favors solubility of heavy metals. Moreover, after the Pandoh Dam, a low water level in the river flows through Mandi town which has granite bed rock that does not have good buffering capacity. Turbidity was inversely proportional to light penetration, and the highest value was recorded during summer at S_3 (7.4 NTU), and the lowest in winter at S_1 (0.9 NTU). Turbidity demonstrated a rise towards summer. At S_1, S_2 and S_4 turbidity was within the permissible limits [3]. During spring and summer, it was higher than the permissible limit at S_3 due to the addition of suspended particles from four-lane highway construction, mining and accelerating soil erosion. Turbidity at S_1 and S_2 was relatively high due to turbulence caused by the melting of glaciers and by the many riffles and runs at this site that stirred the silt and sand from the bottom of the river [1]. S_4, which is in forest land, has high turbidity as the river basin is rich in siltstone and clay stone, and also because tributaries like Looni, with high silt content, join the river before the last station [16].

Table 1. Average with standard deviation, one way analysis of variance (ANOVA) and range of different physico-chemical water parameters and their comparison with various water quality standards at different observation sites set up on the Beas River (S_1, S_2, S_3 and S_4) (January-October 2020)

Parameters	S_1		S_2		S_3		S_4		BIS Desirable - Permissible Limits	CPCB Values of drinking water#	ICMR (1975)	WHO 2011	
	$\overline{X} \pm SD$	Range	$\overline{X} \pm SD$	Range	$\overline{X} \pm SD$	Range	$\overline{X} \pm SD$	Range				Desirable	Permissible
Water temperature (°C)	9.2 ± 3.35	04-13	10.3 ± 2.6	6.0-13	14.4 ± 3.2	10.0-18	11.9 ± 2.6	8.0-15					
pH	$7.8 \pm 0.12^{c*d*}$	7.7-7.99	$7.6 \pm 0.1^{c*}$	7.52-7.84	$6.68 \pm 0.3^{a*b*d*}$	6.3-7	$7.5 \pm 0.2^{a*c*}$	7.28-7.7	6.5-8.5	6.5 - 8.5	6-8.5	7.0-8.5	6.5-8.5
Turbidity (NTU)	$2.12 \pm 1.42^{c*}$	0.9-4.5	$2.8 \pm 1.5^{c*}$	1.2-5.2	$5.86 \pm 1.8^{a*b*d*}$	4-8.2	$3 \pm 1.1^{c*}$	1.3-4.2	5 to 10		2.5 to 10		
Total alkalinity (mg/l)	$63.8 \pm 25.6^{d*}$	32-96	$77.8 \pm 30.8^{d*}$	45-118	$54 \pm 11.3^{d*}$	43-70	$190.2 \pm 37.2^{a*b*c*}$	150-236	200 - 600			120	200
TDS (mg/l)	$93.4 \pm 16^{c*d*}$	72-112.8	$110.84 \pm 7.1^{c*d*}$	102.5-120.2	$213.5 \pm 13.5^{a*b*d*}$	200.5-235	$274.4 \pm 25^{a*b*c*}$	230-289	500 - 2000	500	500-1500	600	1000
Total hardness (mg/l)	50.4 ± 3.65	46-55	60 ± 14.2	42-80	$40.6 \pm 10.9^{d*}$	28-52	$71.6 \pm 18.6^{c*}$	55-100	300 - 600	200	200-600	100	500
Chloride (mg/l)	$21 \pm 2.24^{c*d*}$	20-25	$17 \pm 2.7^{c*d*}$	15-20	$47 \pm 10.4^{a*b*d*}$	35-60	$35.4 \pm 6.6^{a*b*c*}$	25-42	250 -1000	250	200-1000	200	300
Dissolved oxygen (mg/l)	8.2 ± 0.22	8-8.5	$8.4 \pm 0.1^{c*}$	8.3-8.5	$7.94 \pm 0.1^{b*d*}$	7.8-8.1	$8.5 \pm 0.2^{c*}$	8.1-8.8		>6			
BOD at 27°C for 3 Days (mg/l)	$3.16 \pm 0.67^{b*c*d*}$	2.1-3.9	$1.14 \pm 0.3^{a*c*}$	0.8-1.5	$4.48 \pm 1.2^{a*b*d*}$	3-5.7	$0.6 \pm 0.4^{a*c*}$	0.3-1.2		3		5	
COD (mg/l)	42.8 ± 9.4	30-56	23.4 ± 8.8	12.0-32	60.4 ± 18.7	37-80	10.9 ± 2.6	8.0-15					
Total Coliform (MPN/100 ml	1100	1100	1100	1100	1100	1100	460	460		500		no relaxation	
E. coli	**P**		P		P		P		no relaxation				

Note: # www.cpcb.nic.in [31] *in the table to depict significance of difference **S_1 = a, S_2 = b, S_3 = c, S_3 =d** while the mean difference is significant at $p \leq 0.05$ level

The values of alkalinity were within the tolerable limit of 500 mg/l prescribed by the Bureau of Indian Standards [3]. The maximum value was recorded during winter at S_4 (220 mg/l), whereas the lowest was in summer at S_3 (44 mg/l). There was a drastic decrease in the values of total alkalinity from March to May which could be attributed to the increase in water level due to melting of glaciers and dilution of carbonates and bicarbonates. Moreover, melting of glaciers also lead to acid shock due to the melting of acid snow. Higher values during winter were also reported [17]. TDS, also a measure of turbulence, increased from winter to summer, and during the monsoon [1, 18]. The rise in TDS between S_2 to S_3 can be attributed to the mining, the four-lane construction, and nitrates and phosphates released from treatment plants. S_4 had the highest value of TDS which could be attributed to the high concentration of mineral ions released by the river bed.

Monthly values of total hardness were within the acceptable limit [3]. The maximum value of total hardness (100 mg/l) was recorded at S_4 in winter, and the minimum (28 mg/l) was at S_1 during summer. A decrease in total hardness at each station towards summer was noticed [1]. Lower values of total hardness were observed at S_3. Low hardness was also linked to the absence of limestone and dolomite, minerals which can add huge numbers of hard ions in comparison to granite, which constitutes the river basin at S_3. Chlorides at each site were within the tolerable limit of 250 mg/l [3]. These demonstrated a fall in values at S_2, S_3 and S_4 towards summer, which was because of dilution due to increase in water discharge [19-21]. In general, the chloride concentration in the study area was found to be low. The maximum value was recorded at S_3 which could be linked to human waste discharge and open defecation [22]. At S_4, there was no human impact; however, the values were higher than at S_1 and S_2, which might be because of the type of catchment area, and also because of the confluence with the Looni stream just before S_4. The Looni stream drains the Gumma and Darang areas of Mandi district which have salt deposits [16].

Dissolved oxygen showed inverse correlation with temperature, as shown in Table 2. Higher values were recorded during winter at each station, and the lowest in summer [23]. Furthermore, all sites, except for S_3, had sufficient amount of water, riffles, runs and cascades, all of which enhanced aeration [24]. At S_3, the minimum DO could have been associated with decreased water level due to presence of the Pandoh Dam, the existence of more well-populated pool types and the entry of sewage from the town.

According to CPCB water quality standards, the BOD recorded at S_1 and S_3 exceeded permissible limit of 3 mg/l whereas S_2 and S_4 were within the limit. The maximum BOD recorded (5.7 mg/l) was at S_3 during the monsoon as rain water runoff brought lots of organic matter, and the lowest (0.3 mg/l) at S_4 during winter. As mentioned in Table 2, BOD increased with temperature [25]. At S_1, sewage discharge and open defecation added organic matter; however, due to high aeration with water velocity, the dissolved oxygen was maintained. At S_3, the water level decreased by a half due to the addition of sewage into the river and no self-purification in the vicinity of town [26].

The fluctuation in COD at each sampling site was almost parallel to that of the BOD values. The maximum value was recorded at S_3 (80 mg/l), and the minimum at S_4 (8 mg/l). Furthermore, COD showed positive correlation with temperature, and therefore higher values at each station were seen during summer.

The statistical comparisons were performed by ANOVA (one way analysis of variance) followed by Tukey's honesty significant difference test, and the results are given in Table 1. The results were considered statistically significant if the *p*-values were ≤ 0.05 for different variables. During the present investigation, it was found that environmental variables such as pH, turbidity, TDS, chloride and BOD varied significantly at S_3 (Mandi), while S_3 showed significant differences in total alkalinity and total hardness with S_4, and with DO at S_2 and S_4. These results supplement the findings of water quality by different indices along different stretches of the river.

The values of different physico-chemical variables (turbidity, DO, pH, chloride, alkalinity, total hardness, BOD, TDS and coliforms) during the study period (January-October

2020) were correlated with different standards of drinking water specified by various agencies [2-4] and the Central Pollution Control Board (Table 1). WQI helps in numerically expressing the health of a water body. Analysis of water quality of the Beas River in the study area (Table 3) showed that Kunn Ka Tarr (S_4) has pristine and pure water quality, while at Mandi town (S_3) the water quality had deteriorated due to anthropogenic interferences (entry of sewage, throwing of solid wastes and open defecation at some points) [27]. The order of water quality was S_4 (high) > S_2> S_1> S_3 (low).

Table 2. Correlation coefficient between different environmental variables along the Beas River from January-October 2020

	Water temp.	pH	Turbidity	Total alkalinity	TDS	Total hardness	Chloride	DO	BOD	COD	Coli-form
Water temperature (°C)	1										
pH	-0.77	1									
Turbidity (NTU)	0.81	-0.87	1								
Total alkalinity (mg/l)	-0.15	0.26	-0.36	1							
TDS (mg/l)	0.51	-0.53	0.39	0.62	1						
Total hardness (mg/l)	-0.56	0.56	-0.69	0.78	0.22	1					
Chloride (mg/l)	0.51	-0.77	0.64	0.13	0.70	-0.19	1				
Dissolved oxygen (mg/l)	-0.60	0.67	-0.74	0.66	-0.03	0.83	-0.51	1			
BOD at 27°C for 3 days (mg/l)	0.48	-0.62	0.62	-0.71	-0.11	-0.80	0.41	-0.89	1		
COD (mg/l)	0.46	-0.59	0.62	-0.73	-0.18	-0.82	0.32	-0.82	0.96	1	
Total Coliform (MPN/100 ml)	-0.08	-0.09	0.12	-0.90	-0.77	-0.56	-0.23	-0.45	0.59	0.63	1

Table 3. Water Quality Index (WQI) at different stretches on the Beas River from January-October 2020

Parameter	S_1 (qi)	S_2 (qi)	S_3 (qi)	S_4 (qi)	wi (unit weight	S_1 (qi.wi)	S_2 (qi.wi)	S_3 (qi.wi)	S_4 (qi.wi)
Turbidity	21.20	28.00	59.00	30.00	0.16	3.41	4.51	9.50	4.83
Dissolved oxygen	-27.3	-24.30	-32.63	-22.63	0.27	-7.33	-6.52	-8.76	-6.07
pH	3.00	0.06	-10.53	-1.12	0.19	0.55	0.01	-1.99	-0.21
Chloride	10.50	8.50	23.50	17.70	0.01	0.08	0.07	0.19	0.14
Total alkalinity	53.20	64.83	45.00	158.50	0.01	0.71	0.87	0.60	2.13
BOD	25.20	30.00	20.30	35.80	0.30	0.20	0.24	0.16	0.29
Total hardness	31.10	36.93	71.2	91.467	0.01	0.17	0.20	0.38	0.49
TDS	63.20	22.80	90	12.00	0.01	18.96	6.84	27.00	3.60
WQI						16.76	6.22	27.09	5.19

3.2 Bacteriological study

The presence of coliforms and *Escherichia coli* is very useful to determine water contamination. The total coliform count (MPN) is essential as these microbes do not make humans sick; however, a high total coliform count helps in ascertaining contamination of water due to fecal matter. All the observation sites except for S_4 had total coliforms (MPN) of 1100 per 100 ml during all the seasons, values that exceeded the acceptable limit of 500 per 100 ml whereas presence of *E. coli* at every site also crossed the permissible limit for drinking water [3]. Hence, untreated river water at S_1, S_2 and S_3 was not suitable for drinking (Table 1). The main reason of this was open defecation at S_1, S_2 and S_3, [27].

3.3 Biomonitoring

Biomonitoring of the Beas River was carried out by measuring diversity and EPT indices for macroinvertebrates. Twenty-five species of macroinvertebrates belonging to different orders were collected from S_1, S_2, S_3 and S_4 during the study period. The species recorded during the study (Table 4) were used to compute Ephemeroptera, Plecoptera and Trichoptera (EPT) indices (Table 5) as well as to find species richness and diversity by applying diversity indices [12, 13], which can be used to predict the water quality. The EPT index was excellent at S_4, and good at S_1 and S_2, but at S_3 it was below average value. These insect orders showed direct relationships with dissolved oxygen and pH. S_3 had low DO compared to other stations. S_4 (Kunn Ka Tarr) demonstrated the highest species diversity and richness (20 species belonging to seven orders) which might be due to diversified habitats (run, rifles and pools), moderate water flow, and low level of anthropogenic interference.

The Simpson biodiversity index offers precise observation of species richness and evenness, and it indicated that at S_4, diverse populations were more evenly scattered in the community. Meanwhile, the Shannon and Wiener, and Margalef indices inferred that diversity of macroinvertebrates at different observation sites were in the order of $S_4 > S_2 > S_1 > S_3$ (Table 5).

The investigation revealed that the site with no human impact had good water quality and species richness, while the site where there was anthropogenic interference (S_3) had low EPT index, and more pollution tolerant species such as dipterans (*Polypedilum* sp., *Culex* sp. and *Cricotopus* sp.). The water quality index (WQI) demonstrated a similar pattern and the highest water quality was at S_4 (Table 2). Self- purification of water with different natural agents (dilution, sedimentation, sunlight, biological oxidation, and reduction) was seen on the river after water had travelled about 24 km downstream from S_3 to S_4, as demonstrated by improved water quality. Principal component analysis (PCA) was used to find clustering, principal components and behavior of different factors in lotic water ecology. Analysis showed that with a total of 12 variables analyzed for all observation sites, PC-2 had been extracted using eigen value (>1), and different principal components extracted showed their importance season wise (Figure 2) as well as throughout the stream (Figure 3). From spring to monsoon season the values of COD, BOD, TDS and chloride were high, which meant that during this period water quality was low, while in post monsoon and winter periods, it was good. Coliforms, TDS, BOD, COD were high at S_3 in comparison to other observation sites which meant that there was more pollution in this stretch of river. Meanwhile, different parameters were in good condition at S_2 and S_4. The richness and evenness of EPT taxa at different observation sites were affected positively by DO (dissolved oxygen) and alkalinity, while they were inversely affected by BOD, COD, turbidity and chlorides. Macroinvertebrates belonging to EPT taxa are very sensitive to any depletion in water quality.

Table 4. Macroinvertebrate diversity, frequency of appearance and feeding habits at different observation sites on the Beas River (January-October 2020)

Order of organisms	Name of organism	Appearance frequency				Feeding habit
		S_1	S_2	S_3	S_4	
Plecoptera	*Nemoura* sp.	+	+		+	C+G/ Shr
	Perla sp.	-	-	-	+	Pr/ Scr/ C+F
	Cryptoperla sp.	+	+	-	+	C+G/ Shr
	Isoperla sp.	-	-	-	+	Pr
Ephemeroptera	*Baetis* sp.	+	+++	+	++	C+F
	Isonychia sp.	-	+	-	+	C+F
	Caenis sp.	-	++	+	+	C+F
	Heptagenia sp.	+	+	-	+	Scr
	Ecdyonurus sp.	+	-	-	+	C+F
	Epeorus sp.	+	+++	-	++	C+F
	Ephemera sp.	-	++	+	+	C+F
	Cinygma sp.	-	-	-	+	Scr/ C+G
	Rhithrogena sp.	-	+	-	+	G/C+F
Trichoptera	*Rhyacophila* sp.	+	+	-	++	Pr
	Hydropsyche sp.	-	+	+	+	C+F
	Brachycentrus sp.		+	-	+	C+F
Stylommatophora	*Limax* sp.	-	+	+	+	-
Coleoptera	*Helophorus* sp.	-	+	+	+	Pr
	Hydaticus sp.	-	-	+	-	Pr
	Psephnus sp.	+	+	-	+	Scr
Heteroptera	*Enithares* sp.	+	+	-	-	Pr
Hemiptera	*Micronecta* sp.	+	+	+	+	Scr/Pr
Diptera	*Polypedilum* sp.	-	-	+	-	-
	Culex sp.	-	-	+	-	
	Cricotopus sp.	+	-	+	-	-
	Water mite	+	+	-	+	Pr

Frequency: **+++** Frequent; **++** Moderately present; **+**: Rare; **-** Absence; Feeding habit: Predator = Pr; Collector & Gatherer = C+G; Scrapper = Scr; Collector & Filter feeder = C+F; Shredder = Shr

Table 5. Various biodiversity indices across different stretches of the Beas River (January-October 2020)

Observation site	EPT index*	Simpson index	Shannon index	Burger & Parker index	Margalef richness index
S_1 (Manali)	58%	0.08	3.34	0.15	2.5
S_2 (Takoli)	67%	0.04	4.14	0.07	3.7
S_3 (Mandi)	36%	0.08	3.4	0.14	2.4
S_4 (Kunn Ka Tarr)	76%	0.04	4.25	0.7	4.2

* [28]

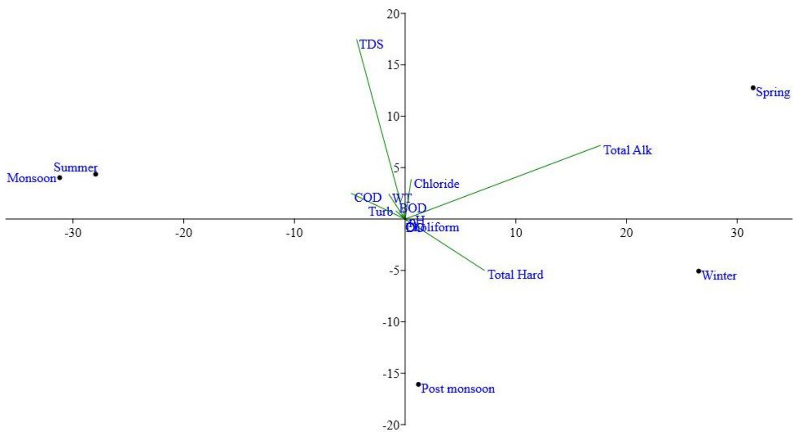

Figure 2. PCA ordination season wise for the Beas River: Abbreviations: PC principal component, DO dissolved oxygen, WT water temperature, BOD biological oxygen demand, COD chemical oxygen demand, TDS total dissolved solids, Cl chlorides, Turb Turbidity

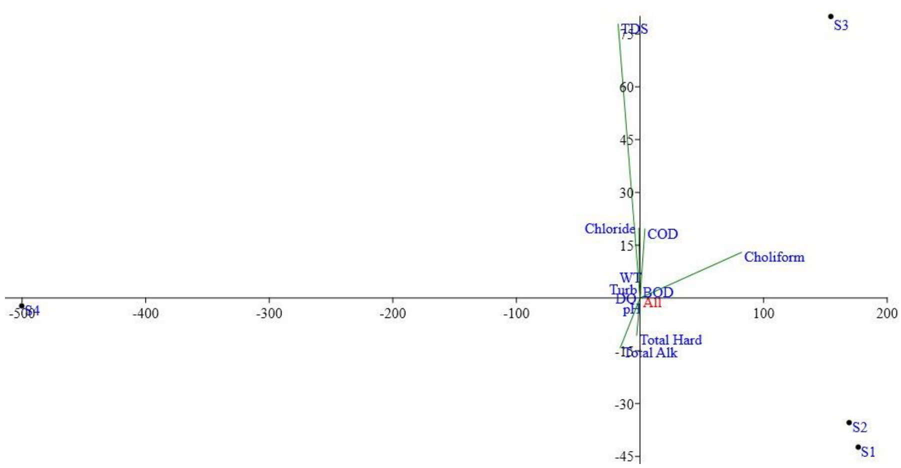

Figure 3. PCA ordination for the Beas River: a) S_1 (Manali), b) S_2 (Takoli), c) S_3 (Mandi), and d) S_4 (Kunn Ka Tarr). Abbreviations: PC principal component, DO dissolved oxygen, WT water temperature, BOD biological oxygen demand, COD chemical oxygen demand, TDS total dissolved solids, Cl chlorides, Turb turbidity

The results from the present observations are not in conformity with the findings for other streams, where water quality deteriorated downstream (hill stream of South Korea [19], Tanzanian river [29], Binwa stream of Western Himalaya [21]). It is opined that catchment areas and urbanization significantly affect the water quality of a water body [30].

As some of the study was carried out during Covid-19 pandemic, no drastic changes or improvements were noticed in water quality in this stretch of the river, and this might be due to the low number of industrial projects being set up on its banks. However, a slight improvement was noticed during the monsoon season, which might be due to the non-functioning of tourism in hill stations such as Manali (S_1), Kullu (between S_1 and S_2) and at Mandi (S_3). Threats to the freshwater aquatic ecosystem occurred due to over exploitation, water pollution, devastation of habitat, and changes in river current.

4. Conclusions

Human impact not only changed the physico-chemical parameters of water in the Beas River but it also disturbed macroinvertebrates. One way analysis (ANOVA) revealed that environmental variables showed significant difference at S_3 (Mandi). Similarly, PCA revealed that BOD, COD, TDS and coliforms were the main parameters affected at the third observation site. Due to disturbances of habitat (because of unscientific and uncontrolled mining), the macroinvertebrates were wiped out by the current due to the absence of suitable hiding places such as cobbles and boulders. Himachal is one of the states that had successfully implemented the Swatch Bharat Mission campaign, but still open defecation was noticed at all of the observation sites, except S_4. This led to the addition of coliforms as well as fecal bacteria to the river, causing the levels of those microorganisms to be above permissible limits. Moreover, dams, four-lane road construction (between S_3 and S_4) and the entry of sewage form major townships (S_1 and S_2) resulted in deteriorating or reduced water quality of the river. Moreover, WQI, after using several variables to give single values to capture the water quality at each station was ranked $S_4 > S_2 > S_1 > S_3$.

The study based on EPT fauna, the order of water quality was as follows: $S_3 < S_1 < S_2 < S_4$, and the diversity order of macroinvertebrates was $S_1 < S_3 < S_2 < S_4$ (lowest diversity at Manali). On the basis of above findings, the use of macroinvertebrates provides an easy and fast mode for monitoring the water quality in lotic as well as lentic waters. Our conclusion can be used to aid the testing of water quality when sewage treatment plants are built and mining activities need regulating.

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