Water Quality Assessment of Behta River Using Benthic Macroinvertebrates

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Abstract: Aquatic macroinvertebrates play significant role in responding to a variety of environmental conditions of rivers and streams and therefore may be used as bio-indicators for water quality assessment. In the past, biological communities like plankton, periphyton, microphytobenthos, macrozoobenthos, aquatic macrophytes, fishes etc. have been used for the assessment of water quality of rivers and streams, but now the use of benthic macroinvertebrates as bio-indicators is gaining importance as these can be easily caught and seen with naked eyes and the method is less costlier and less time consuming compared to other methods given above. Behta River of Paonta Sahib in Himachal Pradesh was chosen to assess the suitability of river water for drinking purposes. The present study involved sampling, pre-identification and identification of macroinvertebrates and computing the percent of occurrence of families of various taxonomic groups and conducting physico-chemical analysis of samples from selected location. Macroinvertebrates chosen were identified up to family level, and bio-assessment at various locations has been done using NEPBIOS score system. It was found that out of total 30 genus belonging to 10 families of taxonomical group like *Ephemeroptera*, *Trichoptera*, *Plecoptera*, *Coleoptera*, *Heteroptera*, *Odonata*, *Diptera Mollusca*, *Oligochaetes* etc. have been found in different composition inhabiting the river. The results further show that all the locations assessed for quality using macroinvertebrates and physico-chemical analysis are in the range of water quality class Ⅲ (Moderately Polluted) and the water can not be used for drinking purposes. The measures to reduce point and non-point sources of pollution have been suggested to get the quality suitable for drinking purposes. [Life Science Journal. 2006;3(4):68–74] (ISSN: 1097–8135).

Keywords: benthic macroinvertebrates; indicators; NEPBIOS; NSF water quality index

Abbreviations: NSF: National Sanitation Foundation; NEPBIOS: Nepalese Biotic Score; WQI: water quality index; APHA: American Public Health Association; ASPT: average score per taxon; BOD: biochemical oxygen demand; DO: dissolved oxygen; NTU: nephelometric turbidity unit; U/S: upstream; D/S: downstream

1 Introduction

Aquatic macroinvertebrates play significant role in responding to a variety of environmental conditions of rivers and streams and therefore may be used as bio-indicators for water quality assessment. Benthic macroinvertebrates are the animals that lack a back-bone and generally are visible with the naked eyes. They live in the lower areas of the streams under rocks. They include larval forms of many common insects such as Dragon flies, Damsel flies and Crane flies. Common features of these are as follows:

* Live in water for all or most of their life. Often live for more than one year.
* Stay in the area suitable for their survival.
* Differ in their tolerance to amount and types of pollution.
* Are easy to identify in the laboratory.
* Have limited mobility.

Macro-invertebrate community responses to environmental changes are useful in assessing the impact of municipal, industrial and agricultural waste and impacts from other land uses on surface water. The macroinvertebrates are highly popular as pollution indicators[1].

Benthic organisms are of great significance because they form the food of fishes and their productivity play an important link in the food chain. Benthic organisms are distrivores and form an important link in the food chain, an account of their ability to convert low quality and low energy detritus into better quality food for higher organisms in the food web with the unfolding of the importance of benthos in food chain, benthic productivity has been correlated with fish resources. The qualitative and quantitative changes in the benthic population have also been used as pollution indices[2–4].

Benthic macroinvertebrates are aquatic macrofauna inhibiting the bottom substrate for at least a part of their life cycle. The reason of selecting macroinvertebrates as bio-indicators is that they are visible to unaided eyes and retained on the sieve with a mesh sized of 0.6 mm diameter. They have sedentary and long life span and sensitive community response to organic loading, thermal impacts, substrate alteration and toxic pollution. Inhabiting the different substratum of river, stream, lake and other water bodies, developed taxonomy and integrated of pollution etc. justifies the reason of selecting them as bio-indicators.

The primary objective of this study was to evaluate the water quality of river Behta for drinking purposes using macroinvertebrates. The other objectives were to describe the importance of using macroinvertebrates as pollution indicator and the bioassessment result validation by physico-chemical analysis using National Sanitation Foundation (NSF) water quality index(WQI). The occurrence of benthic macroinvertebrates community along with the distribution of taxa-group of the river has also been discussed.

2 Materials and Methods

2.1 About Behta River

The Behta River is an important tributary of river Yammuna. It originates in the boulders below the Nahan ridge in the South-Western corner of Himachal Pradesh as the Jalmusa-Ka-Khala (Figure 1). Behta River of Paonta Sahib in Himachal Pradesh was chosen to assess the suitability of river water for drinking purposes.

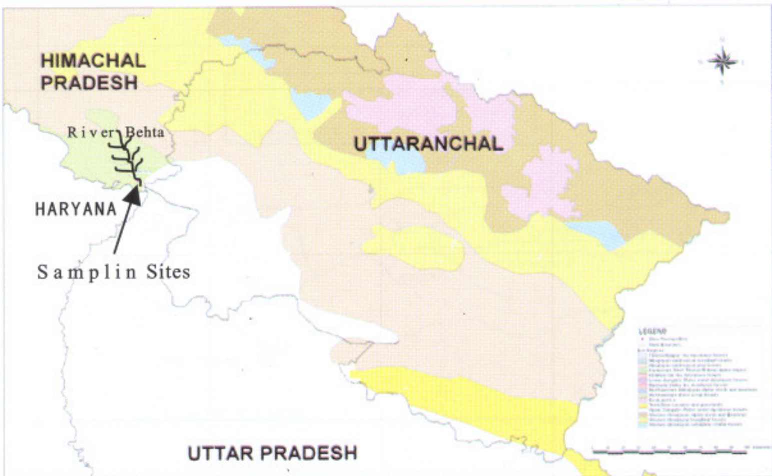

Figure 1. Location map of Himachal Pradesh showing the Behta River

Physico-chemical and biological parameters for two sites on the river Behta at Paonta Sahib were analyzed, and the results revealed that the water quality at the site upstream (U/S) to slaughter house was good which belongs to water quality class Ⅱ, and the water quality at the site downstream (D/S) to slaughter house was moderate which belongs to water quality class Ⅲ. The conclusion of the results is that the water at the D/S to the slaughter house can not be used for the drinking purposes.

This river is mainly fed by the rain water that is cycled as underground water before finally coming up on the surface as a spring. The river flows below the surface for a part of its length in its upper reaches, thereafter the water flows on the surface.

There were two sampling sites selected by us in Paonta Sahib:

i) River Behta at Pownta Sahib U/S to slaughter house (Station-01) at longitude 77.55, lattitude 30.47 and altitude (m) 380.0 (Figure 2).

ii) River Behta at Pownta Sahib 500 m D/S to slaughter house (Station-02) at longitude 77.57, lattitude 30.44 and altitude (m) 369.0 (Figure 2).

The sampling sites are situated within a landscape characterized by cropland, clear cutting, urban sites and industrial activities. 500 m above the sampling site there is a chicken farm. The riverbed is built by meso- and microlithal 60% and 40%, respectively. Filamentous algae and algae tufts are occurring frequently. The average stream width is up to 35 m, mean depth is 40 cm and mean current velocity is 25 cm/s. The water carries foam and is turbid. Mud and stones show reduction phenomena both in lentic and lotic areas.

2.2 Methods

A sample consists of collection of 20 sub-samples each of 0.25×0.25 m^2 taken from all micro-habitat types. This procedure (Figure 3) results in sampling of approximately 1.25 m^2 stream bottom area. Net of mesh size 500 μm is used for collecting the macroinvertebrates. Every large boulder or cobble in the area is picked up if it could be lifted and organisms vigorously washed by hand into the net. Finally, the substrate with smaller boulders should be disturbed by kicking systematically across the area 3 – 4 times such that the invertebrates wash D/S into the net. The organisms are then carefully picked from the net surface and preserved immediately in 80% ethanol or 4% formaldehyde. These samples are returned to the laboratory for processing. Specimen collected are sorted and identified to operational taxonomic unit (at least to family level with the help of regional keys) in the laboratory under a dissecting microscope for identifying the fauna, standard literature was consulted[5–8].

Samples for microbiological examination were collected in non-reactive borosilicate glass bottles that have been cleansed and rinsed carefully, given a final rinse with the distilled water and sterilized in autoclave.

Water samples were collected in plastic container for different physical-chemical parameters. The chemical characteristics were determined by the standard methods suggested of American Public Health Association (APHA)[9] (The results of the analysis are reported in Table 1).

The schematic flow chart of the steps involved in the methodology is given as below (Figure 3).

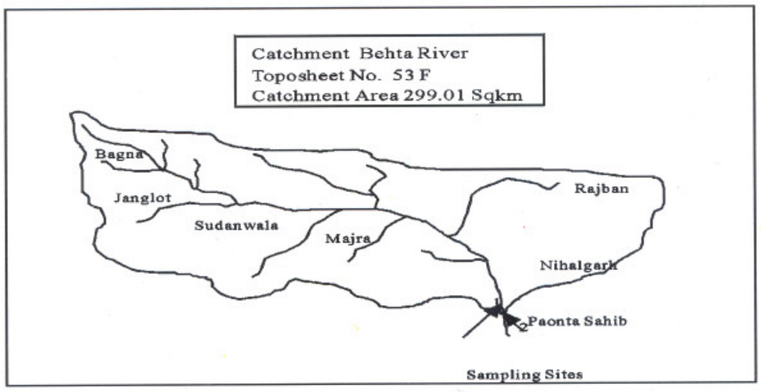

Figure 2. Catchment area of river Behta at Paonta Sahib

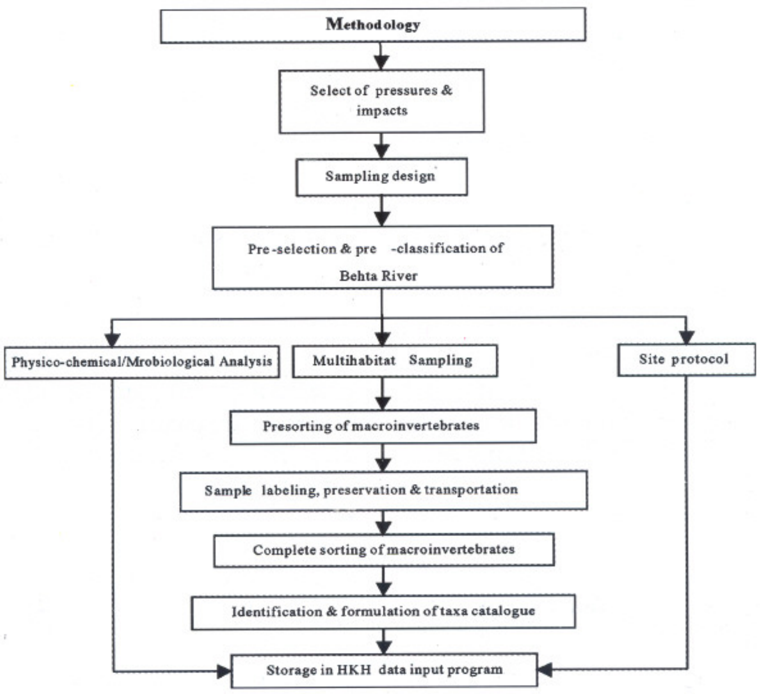

Figure 3. Flow chart of methodology

3 Results and Discussion

3.1 Physical-chemical parameters

Following parameters were analyzed (Table 1).

Table 1. Physicochemical and biological analysis of water samples

Site name	Station-01	Station-02
Pre-classification class	2	3
Estimated discharge [l/s]	510.6	511
Temperature (water) °C	26.5	26.5
Temperature (air) °C	37.0	37
pH	7.84	8.2
Conductivity [μS/cm]	280.0	366
Turbidity NTU	0.84	1.42
Oxygen content [mg/l]	9.54	9.09
% saturation of oxygen	109.4	108.3
Alkalinity [CO_3^{2-}] [mmol/l]	126.0	141
Total hardness [mmol/l]	197.0	201
Chloride [mg/l]	12.2	13.4
Ammonium [mg/l]	0	0
Nitrite [mg/l]	0.001	0.004
Nitrate [mg/l]	0.28	0.3
Ortho-phosphate [μg/l]	98.0	110
Total phosphate [μg/l]	701.0	940
BOD [mg/l]	2.1	3
E. coli [n/100 ml]	500	1600
TDS [ppt]	0.16	0.22
Estimated class using NSF WQI	II	III
NSF index value	75	69
Water quality index legend	71 – 90	50 – 70

On the basis of these chemical parameters the water quality can be determined using NSF WQI.

NSF WQI: NSF International, founded in 1944 as the NSF, is known for the development of standards, product testing and certification services in the areas of public health, safety and protection of the environment. The index is basically a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in a given water basin, such as a lake, river, or stream.

The WQI uses a scale of score from 0 – 100 to rate the quality of the water, with 100 being the highest possible score (Table 2). Once the overall WQI score is known, it can be compared against the following scale to determine how healthy the water is on a given day.

Table 2. WQI quality scale

91 – 100	Excellent water quality
71 – 90	Good water quality
51 – 70	Medium or average water quality
26 – 50	Fair water quality
0 – 25	Poor water quality

Water supplies with ratings falling in the good or excellent range would able to support a high diversity of aquatic life. In addition, the water would also be suitable for all forms of recreation, including those involving direct contact with the water. Water supplies achieving only an average rating generally have less diversity of aquatic organisms and frequently have increased algae growth.

Water supplies falling into the fair range are only able to support a low diversity of aquatic life and are probably experiencing problems with pollution. Water supplies that fall into the poor category may only be able to support a limited number of aquatic life forms, and it is expected that these waters have abundant quality problems. A water supply with a poor quality rating would not normally be considered acceptable for activities involving direct contact with the water, such as swimming.

The range using NSF WQI for the site is 75, which is indicative of good water quality (class II).

The range using NSF WQI for the site is 69, which is indicative of moderate water quality (class III).

3.2 Biological parameters

The common and dominant families of macroinvertebrates of each group encountered are as follows (Table 3).

The calculation of water quality on the basis of macroinvertebrates families was done on the basis of Nepalese Biotic Score (NEPBIOS) using pre-classification sheet.

NEPBIOS biotic index: A suitable biological method based on indices or score system is possible only when local reference communities are properly scored. Taking this fact into consideration the Nepalese taxa were scored, the average score per taxon (ASPT) calculated and a different biotic score method for Nepal developed with the NEPBIOS (Table 4). The calculation of the water quality on the basis of the presence of the macroinvertebrates families is done on the basis of NEPBIOS using the pre-classification sheet.

Table 3. Occurrence of benthic macroinvertebrates community

Taxonomic group		Family	Behta at Paonta Sahib 10 m U/S to slaughter house(Station-01)		Behta at Paonta Sahib 500 m D/S to slaughter house(Station-02)	
			No. of individual	% of abundance	No. of individual.	% of abundance
Mollusca	1	*Thiaridae*	431	25.11	1951	67.67
	2	*Planorbidae*	–	–	4	0.13
	3	*Lymnaeidae*	2	0.11	4	0.13
	4	*Pisidium*	–	–	1	0.03
	5	*Viviparidae*	4	0.23	–	–
Epheneroptera	1	*Neoephemeridae*	13	0.75	1	0.03
	2	*Baetidae*	617	35.95	324	11.23
	3	*Ephemerilidae*	31	1.80	2	0.06
	4	*Heptageniidae*	52	3.03	10	0.34
	5	*Ephemeridae*	23	1.34	–	–
	6	*Leptophlebiidae*	12	0.69	3	0.10
	7	*Caenidae*	17	0.91	1	0.03
Odaonata	1	*Gomphidae*	11	0.64	76	2.63
	2	*Libellutidae*	3	0.17	1	2.67
Colleptera	1	*Elmidae*	21	1.22	1	0.03
	2	*Hydroptillidae*	8	0.46	3	0.10
	3	*Dryopidae*	29	1.68	–	–
	4	*Psepheniidae*	59	3.43	7	0.24
Trichoptera	1	*Hydropsychidae*	53	3.08	110	3.81
	2	*Glossosomatidae*	63	3.6	6	0.20
	3	*Lepidostomatiodae*	12	0.69	–	–
	4	*Polycentropodiae*	19	1.10	9	0.31
	5	*Hydroptillidae*	32	1.86	4	0.13
	6	*Wenoidae*	17	0.99	–	–
	7	*Leptoceredae*	3	0.17	1	0.03
	8	*Rhyacophillidae*	13	0.75	–	–
	9	*Philopotamidae*	17	0.99	2	0.06
	10	*Goeridae*	34	1.98	–	–
Diptera	1	*Tabanidae*	3	0.17	13	0.45
	2	*Chironomidae*	11	0.64	55	1.90
	3	*Tipulidae*	–	–	9	0.31
	4	*Ephydridae*	3	0.17	13	0.45
	5	*Simulidae*	19	1.10	2	0.06
	6	*Ceratopogonidae*	–	–	1	0.03
Hemiptera	1	*orixidae*	22	1.28	3	0.10
Placoptera	1	*Perlidae*	36	2.01	–	–
Crustacea	1	*Palaemonidae*	23	1.24	176	6.10
Annelida	1	*Oligochaetes*	3	0.17	89	3.08

Three procedures were followed in scoring the taxa.

(1) Numerical procedure: This procedure follows the following formula. Guide Score = SⅠ/STot × 10 + SⅠ－Ⅱ/STot × 8.57 + SⅡ/STot × 7.14 + SⅡ－Ⅲ/STot × 5.71 + SⅢ/STot × 4.28 + SⅢ－Ⅳ/STot × 2.85 + SⅣ/STot × 1.43

Where,

SⅠ, SⅠ－Ⅱ, SⅡ, SⅡ－Ⅲ, SⅢ, SⅢ－Ⅳ, SⅣ are the total number of sites representing the pollutional classes Ⅰ, Ⅰ－Ⅱ, Ⅱ, Ⅱ－Ⅲ, Ⅲ, Ⅲ－Ⅳ, Ⅳ.

STot = SⅠ + SⅠ－Ⅱ + SⅡ + SⅡ－Ⅲ + SⅢ

+SⅢ − Ⅳ + SⅣ

1.43 is the score interval with 10 as maximum.

(2) Professional judgments:

Step-Ⅰ: Based on the reference made to the scores that has previously been assigned by different authors in their respective country of origin, and the range of pollution class represented by each taxon in the rivers of Nepal.

Step-Ⅱ: Based on the distribution pattern of each taxon (family level) in response to pollution level, the comparison of family (taxon) distribution with the observed water quality classes was carried out to find out if any families with the same ecological distribution were differently scored. If so, whether or not the reasons are matching.

Once NEPBIOS/ASPT is calculated, reference should be made to the below Table 5 for interpretation of the water quality of the particular investigated site.

Table 4. NEPBIOS assigned to the macroinvertebrates

S. No.	Macroinvertebrates	Score
1.	Capniidae, Ephemerellidae (*Drunella* sp.), Epiophlebiidae, Helicopsychidae, Helodidae (Scirtidae), Heptageniidae (*Epeorus rhithralis*), Heptageniidae (*Rhithrogena nepalensis*), Leuctridae, Peltoperlidae, Perlidae (*Acroneuria* spp.), Perlidae (*Calicneuria* spp.), Siphlonuridae, Taeniopterygidae, Uenoidae.	10
2.	Athericidae, Chloroperlidae, Goeridae, Leptophlebiidae (*Habrophlebiodes* sp.), Limnocentropodidae, Neoephemeridae, Perlodidae, Polycentropodidae.	9
3.	Baetidae (*Centroptilumsp.*), Brachycentridae, Chironomidae (Diamesinae), Elmidae, Euphaeidae, Glossosomatidae, Heptageniidae (*Epeorus bispinosus*), Heptageniidae (*Iron psi*), Heptageniidae (*Rhithrogena* spp.), Hydrobiosidae, Lepidostomatidae, Limnephilidae, Nemouridae, Perlidae, Philopotamidae, Psephenidae, Rhyacophilidae, Stenopsychidae.	8
4.	Aphelocheiridae, Baetidae (*Cloedodes* sp.), Baetidae (*Baetiella* spp.), Baetidae (*Baetis* spp.), Baetidae (*Baetiella ausobskyi*), Baetidae (*Baetis* sp. 1), Corydalidae, Ephemerellidae, Ephemerellidae (*Cincticostella* sp.), Ephemeridae, Gammaridae, Gyrinidae, Heptageniidae, Heptageniidae (*Cinygmina* sp.), Heptageniidae (*Notacanthurus cristatus*), Hydraenidae, Leptophlebiidae, Limoniidae, Pleuroceridae, Psychomyiidae, Salifidae (*Barbronia* sp.), Simuliidae, Tipulidae.	7
5.	Aeshnidae, Baetidae (*Baetis* sp.5), Baetidae (*Baetis* sp.4), Caenidae, Ceratopogonidae, Ecnomidae, Ephemerellidae (Torleya nepalica), Heptageniidae (*Electrogena* sp.), Hydrometridae, Hydropsychidae, Hydroptilidae, Potamidae, Scirtidae, Viviparidae.	6
6.	Baetidae (*Baetis* sp.2), Baetidae (*Baetis* sp.3), Bithyniidae, Chlorocyphidae, Coenagrionidae, Corduliidae, Dryopidae, Hydrophilidae, Leptophlebiidae (*Euthraulus* spp.), Lymnaeidae, Odontoceridae, Protoneuridae, Sphaeriidae, Unionidae.	5
7.	Calopterygidae, Chironomidae (*Microtendipes* sp.), Chironomidae (*Polypedilum* sp.), Corbiculidae, Dytiscidae, Gerridae, Glossiphoniidae, Micronectidae, Naucoridae, Nepidae, Palaemonidae, Planorbidae, Ranatridae, Salifidae (*Barbronia weberi*), Thiaridae.	4
8.	Corixidae, Libellulidae, Lumbricidae, Noteridae, Notonectidae, Salifidae	3
9.	Culicidae, Physidae, Tubificidae	2
10.	Chironomidae [Chironomus group riparius (= *thummi*) and group plumosus]	1

On the basis of the NEPBIOS score system, the species present in the samples of the site at Behta River 10 m U/S to the slaughter house shows that water quality of the river belongs to class-Ⅱ.

On the basis of the NEPBIOS score system, the species present in the samples of the site at Behta River 500 m D/S to the slaughter house shows that water quality of the river belongs to class-Ⅲ.

During the investigation at Station-01, it was found that water quality was good with the pH of 7.84 and turbidity of 0.84 Nephelometric Turbidity Unit (NTU). The Biological Oxygen Demand (BOD) is 2.1. Total 34 families of macroinvertebrates belonging to groups *Ephemeroptera*, *Coleoptera*, *Trichoptera*, *Diptera*, *Plecoptera*, *Hemiptera*, *Crustacea*, *Annelida*, *Mollusca*, *Odonata* were encountered. The insect population represented 72.98% of total fauna and belonging to orders *Trichoptera*, *Ephemeroptera*, *Coleoptera*, *Diptera*, *Odonata* and *Hemiptera*. The order *Ephemeroptera*, *Trichoptera*, *Coleoptera* and *Placoptera* are dominating in numbers. The results further show that all the locations assessed for quality using macroinvertebrates and physico-chemical analysis are in the range of water quality class Ⅱ (Good) and the water can be used for drinking purposes.

Table 5. Water quality scores based on NEPBIOS

NEPBIOS/ASPT	Water quality
8.00 – 10.00	Ⅰ
7.00 – 7.99	Ⅰ – Ⅱ
5.50 – 6.99	Ⅱ
4.00 – 5.49	Ⅱ – Ⅲ
2.50 – 3.99	Ⅲ
1.01 – 2.49	Ⅲ – Ⅳ
1	Ⅳ

During the investigation at Station-02, it was found that river water was a little alkaline with pH of 8.2 and moderately polluted with turbidity. The study of fresh water macroinvertebrates shows that 30 families belonging to groups *Mollusca*, *Odonata*, *Ephemeroptera*, *Coleoptera*, *Trichoptera*, *Diptera*, *Plecoptera*, *Hemiptera*, *Crustacea* and *Annelida* occurred in the river.

The insect population represented 22.53% of total fauna of Behta River and was belonging to the order *Odonata*, *Ephemeroptera*, *Coeloptera*, *Trichoptera*, *Diptera*, *Placoptera*, *Hemiptera*. Insect have the capability to adapt to varied aquatic habitats due to their extra ordinary structural organization[4,5,7]. The benthic population of aquatic insects was dominated by *Trichoptera* comprising 8 families and diptera comprising 6 families. Most of these families to be tolerant to varied aquatic environment[8,10].

The *Mollusca* fauna of Behta River was represented by 4 families out of which *Thiaridae* family dominated the population. Covers 67.82% of the total population of aquatic fauna. This group has significant positive correlation with the total hardness (201.0 mmol/L), alkalinity (141.0 mmol/L), phosphate (0.94 mg/L) and chloride (13.4 mg/L). The rest of the aquatic invertebrate fauna of Behta River of one family of Crustacea, and a Annilida.

4 Conclusion

Benthic macroinvertebrates community as a whole in the river has been found to have significant positive correlation with the total hardness, total alkalinity, chloride, phosphate and transparency.

The results show that all the locations assessed for quality using macroinvertebrates and physico-chemical analysis are in the range of water quality class Ⅲ (Moderately Polluted) at the Station 02 and the water can not be used for drinking purposes. The measures to reduce point and non-point sources of pollution have been suggested to get the quality suitable for drinking purposes.

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