Ecology of Binwa a Western Himalayan Hill Stream in relation to Water Quality

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Abstract
Binwa is a perennial hill stream of the Western Himalayan region of Himachal Pradesh. During the present investigation, four observation sites based on altitudinal differences were selected, i.e., Khari (S₁), Baijnath (S₂), near Chobin (S₃), and Triveni (S₄) and water samples were analyzed for physico-chemical and biological parameters for one year (Mar.2011-Feb.2012). Water temperature, water current, dissolved oxygen, turbidity, T.D.S., electric conductivity, total Hardness, phosphate, and nitrate had played an essential role in determining the variations in planktonic and macroinvertebrate fauna of the stream. Species diversity indices such as Simpson, Shannon and Wiener, and Margalef’s diversity index of macroinvertebrates were worked out for all the observation sites. Based on the comparison of physico-chemical parameters of water samples with different standards prescribed for drinking water, water quality index for four stations calculated. Similarly, EPT taxa (Ephemeroptera, Plecoptera, Trichoptera) measured, and EPT index computed. The water quality of the stream deteriorates downstream from head to mouth due to different types of anthropogenic interferences. The findings revealed that stream has no pollution at S₁, while it is oligotrophic from S₂ to S₃ and meso-oligotrophic at S₄.

Introduction
A stream is a watercourse of all sizes having a specific course, in which minerals and nutrients (inorganic and organic matter) are essential parts, flow along the longitudinal gradient from the head to mouth. Streams located in the Western Himalaya play a significant role ecologically (vast biodiversity), economically (hydroelectric and fishery potential), and socially (sacred religiously to adjoining inhabitants). Hill streams have some unique...
features such as swift water current, heterogeneous substratum, high dissolved oxygen, and low nutrient, and have unique biodiversity, which is intolerant to pollution. Binwa stream which is selected for the study has two religious places on its left bank, visited by thousands of people; stream is sacred to Gaddi people (a tribal community) living in its vicinity and also an important breeding ground of *Tor* sp. (Mahaseer fish) from Beas river (Sharma,1). By determining the water quality of the stream, one can assess the stream’s health as well as its suitability for drinking. This is the reason that during the investigation, water samples were analyzed for hydrobiological (physio-chemical, phytoplankton, zooplankton) and macroinvertebrates of the stream. Water quality is determined by using water quality index (W.Q.I.) on different physico-chemical parameters and their comparison with the standard prescribed by different organizations such as ICMR,2 BIS,3 CPCB, and WHO,4. Macroinvertebrates were used to determine the species diversity at different observation sites, while the taxa belonging to Ephemeroptera, Plecoptera, and Trichoptera were used to determine the EPT index. A checklist of macroinvertebrates has been also given.

**Study Area**

During the present study, four observation sites selected for collection of water samples and macroinvertebrates, i.e., Kharli as S1, (2822 m above msl), Bajinnath as S2, (945 m above msl), near Chobin as S3, (746 m above msl) and Triveni as S4, (572 m above msl) on Binwa, a Western Himalayan perennial hill stream, located in district Kangra, Himachal Pradesh. It originates from the southern slopes of the Dhauladhar range of Mid Himalaya and has confluence with Beas river at Triveni, after covering a distance of 48 Km from head to mouth. Along its course, it supports a vast human population of the Baijnath block of Kangra district for drinking and irrigation facilities. However, in this relatively short distance, it experiences an impressive fall of about 3100 m (3678 m elevation at its head and 539 m at its mouth). The primary habitat is comprised of runs and riffles with some pools and a substrate of boulders and cobbles. Drainage network in the study area, all the streams/Nullah have been ordered as per Strahler,5 and Rosgen,6. A stream is categorized as B3-type.

![Fig. 1: Map showing study area and catchment region of Binwa stream](image-url)
Material and Method

Water samples were collected monthly for a period of one year (March 2011 to February 2012) from all observation sites. Physico-chemical parameters of the water were analyzed according to the standard methods (APHA,7). For the plankton study, 100 liters of water were filtered through the plankton net made up of bolting silk No.25 (0.3 mm mesh) and fitted with a wide-mouthed bottle. Planktons were preserved in 4% formaldehyde solution. Macroinvertebrates were collected in the Surber sampler net by making a disturbance in the substratum of the stream, unsettling them, and then collected in the bucket and at last preservation in 4% formaldehyde solution. The density of these macroinvertebrates mentioned as an individual per square meter. The books consulted for the identification of the plankton and benthos were: (Pennak,8; Merritt & Cummins,9; Thorp and Covich,10 and Subramanian and Sivaramakrishnan,11). Counting of plankton was done with the help of the Sedgwick-Rafter cell counter (Wetzel and Likens,12).

Species diversity was calculated using diversity indices (Shannon and Wiener,13; Simpson.14). Since there is no industrial development occurred around the stream, and also there is not much change in other conditions (anthropogenic disturbances). So the findings will be useful in determining the water quality for various uses and maintaining the biodiversity of the stream.

Simpson's Biodiversity Index

$$D = \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

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

Shannon and Wiener Diversity Index

$$H = -\sum p_i \log p_i$$

Where, $H =$ diversity index; $p_i =$ $n_i/N$ ($n_i =$ number of individuals in species $i$; $N =$ total number of individuals in the sample

EPT Index (Ephemeroptera, Plecoptera, Trichoptera)

$$= \frac{\text{Total EPT Taxa}}{\text{Total Taxa Found}} \times 100$$

Results and Discussion

During the present investigation, 14 physico-chemical parameters have been studied for one year Mar. 2011-Feb.12), while in biotic fauna phytoplanktons 36 species (Bacillariophyceae-14, Chlorophyceae-10, Cynophyceae-7, Chrysophyceae-2, Euglenophyceae-3); zooplanktons 17 species (Protozoa-6, Rotifera-9, Crustacea-2) and macroinvertebrates (27 species) reported from the stream. The monthly average values of studied physico-chemical parameters have been given and compared with different standards prescribed for drinking water (Table-1). Water temperature was maximum during summer (May and June), minimum during winter throughout the stream, and increased water temperature in summer increase the respiratory rate, decrease oxygen holding capacity so as elevate the free CO$_2$ in the system; water velocity observed maximum in monsoon (July and August) due high rate of precipitation throughout the course ($S_4$-$S_1$), at $S_4$ water velocity is high this might be due to great fall in a gradient from $S_1$ to $S_2$, while slightly high water current at $S_1$ during pre-summer (April) and summer (May and June) have been observed, which might be due to melting of a glacier in the catchment area. High water current during monsoon posed a threat of
wash away to planktons and aquatic insect larvae and showed an inverse relation with them. While T.D.S., turbidity, chlorides, and nutrients such as nitrates and phosphates showed their maxima during the monsoon period, and are in direct relation with water current. The rise of these parameters during monsoon might be due to loose and fragile catchment downstream, agricultural runoff from catchment area, sewage at S3 and dumping of solid waste at different places into the stream. Dissolved oxygen was maximum during winter and minimum in summer, as water has high oxygen holding capacity at low temperature (Malik and Bharti,17, Jindal and Singh,18).

Bacillariophyceae, Chrysophyceae and aquatic insects (EPT taxa) showed positive correlation with dissolved oxygen at all the observation sites (Jabeen and Barbhuiya,19). While Chlorophyceae, Cynophyceae, Euglenophyceae, and Protozoa showed an inverse relation with dissolved oxygen, and direct relation with T.D.S., electric conductivity, nitrate, and phosphates. Chrysophyceae showed complete absence from S1 (Triveni), which might be due to low dissolved oxygen and high nutrient load. In contrast, Euglenophyceae reported only from S3 and S4 and utterly absent at S1 and S2, might be due to shallow water temperature.

Macroinvertebrates were dominated by aquatic insects. Aquatic insects belonging to seven orders: Plecoptera (Perla sp., Isoperla sp., Cryptoperla sp.), Coleoptera (Psephenus sp., Helophorus sp., Hydroporus sp., Hydaticus sp.), Hemiptera (Naucorius sp.), Ephemeroptera (Baetis sp., B.bifurcatus, Ecdyonurus sp., Epeorus sp., Ephemerons consors, E. remensa, Heptagenia sp., Iron suspicatus, Cinygma sp.) Trichoptera (Hydropsyche sp., Stenopsyche sp. and Rhyacophila sp.), Odonata (Euphaea sp., Orthetrum sp.), and Diptera (Chironomus sp., Simulium sp., Culex sp.) noticed in the stream (Table-4). Plecopters observed upstream (S1 and S2), whereas dipterans collected downstream (S3 and S4), as stoneflies prefer high oxygen section such as runs, rifles, and cascade, in which mixing of oxygen is comfortable, while dipteran larvae prefer pool sections and with low dissolved oxygen (Jindal and Singh,18).

Values of different physico-chemical parameters (turbidity, D.O., pH, chloride, total alkalinity, nitrate, total Hardness and T.D.S.) for the study period (Mar.2011 to Feb. 2012) were compared with a different standard of drinking water prescribed by BIS (IS 10500-2012), Central Pollution Control Board, ICMR and WHO. Turbidity was observed slightly high according to BIS (IS 10500-2012) at S1, S3 and S4 during monsoon months, this might be attributed to increase surface runoff with suspended particles, so water quality during monsoon months reduced. Water Quality Index (W.Q.I.) reduces the huge information from the analyzed water sample into a single value. The water quality of the stream was observed, excellent from drinking. Irrigation perspective from S1 to S4, water was pristine at S1; in midstream region (S2 and S3), the values of W.Q.I. were almost similar (fixed catchment, thick vegetation cover and self-purification). At the same time, it is slightly reduced at S4, due to high values of above mentioned eight parameters (sewage, mining, agricultural runoff, low ruggedness, and loose catchment). However, water is still potable (Table-2). Similar results of deterioration of water quality downstream reported by Atique and Guk An,21 in a hill stream of South Korea.

Insect larvae belonging to order Ephemeroptera, Plecoptera and Trichoptera are used to monitor the water quality, while different diversity indices used to study the species richness and evenness of species composition in the stream to overall access the health of the stream. Role of Baetidae as bioindicator has been used to monitor the rivers health in western ghats (Kubendran et al.,22).

EPT index values showed that water quality at S1 is of ‘Excellent,’ while on remaining stations, it is reasonably suitable for human consumption (Table-3). More dipterans depicted the more nutrient level in stream added by various anthropogenic interferences (tourist activities at S2 and S4, agricultural runoff from the catchment area, soap & detergent wastes, and addition of sewage) leads to decrease in D.O. level (Patang et al.,23). The observed values for EPT index inferred that more D.O. level needed for EPT taxa than rest of insects of coleopteran and dipteran (Plecoptera > Ephemeroptera > Trichoptera (more D.O.) > Coleoptera > Odonata (relatively less D.O.) > Diptera).
Table 1: Monthly average value and range of various physico-chemical parameters of water and their comparison with different water standards at four stations (S₁, S₂, S₃, and S₄) on the Binwa stream (Mar. 2011 to Feb. 2012)

| Parameter               | Kharli (S₁)* | Baijnath (S₂) | near Chobin (S₃) | Triveni (S₄) | BIS Desirable Limits | CPCB Values of drinking water** | ICMR (1975) | WHO 2011 |
|-------------------------|--------------|---------------|-------------------|--------------|----------------------|----------------------------------|-------------|----------|
|                         | Mean | Range          | Mean | Range         | Mean | Range         | Mean | Range         | Mean | Range         | Desirable Permissible |
| Water temperature (°C)  | 10.23 | 8.3-11.5       | 17.09 | 8.5-23.5      | 18.10 | 9.67-24.5    | 19.01 | 10.5-24.9    |      |                |
| Water current (cm/sec.) | 92.50 | 65-110         | 97.15 | 80-124.8      | 86.15 | 67.3-113     | 75.12 | 60.1-96.4    |      |                |
| Conductivity (µS/cm)    | 103.25 | 90-115         | 206.92 | 150-260       | 213.25 | 158-266     | 221.58 | 165-285      |      |                |
| Turbidity (NTU)         | 3.77  | 0.5-6.5        | 4.68  | 0.4-11.25     | 5.56  | 0.5-13.5     | 5.80  | 1.9-11.7     | 5 to 10 |                |
| Dissolved oxygen (mg/L) | 10.54 | 9.8-11.4       | 10.27 | 8.21-12.7     | 9.51  | 8.1-11.3     | 8.78  | 6.5-10.8     | >6   |                |
| Free CO₂ (mg/L)         | 2.10  | 1.5-2.7        | 7.47  | 3.8-11.25     | 8.70  | 4.5-14.2     | 11.13 | 6.4-17.8     |      |                |
| pH                      | 8.10  | 7.95-8.2       | 7.85  | 7.5-8.1       | 7.88  | 7.5-8.2      | 8.27  | 7.85-8.54    | 6.5 to 8.5 | 6.5 to 8.5 |
| Chloride (mg/L)         | 3.45  | 1.3-4.5        | 13.08 | 8.05-19       | 14.73 | 10.2-20.6    | 16.73 | 10.7-24.3    | 250 to 1000 | 250          |
| Total alkalinity (mg/L) | 48.73 | 24-72.3        | 101.78 | 70.2-120.2    | 104.59 | 73.4-122.5  | 106.25 | 68.2-134.5   | 200 to 600 | 120          |
| Phosphates (mg/L)       | 0.02  | 0.011-0.033    | 0.04  | 0.01-0.068    | 0.05  | 0.02-0.078   | 0.11  | 0.037-0.22   | Upto 5     |              |
| Nitrates (mg/L)         | 0.01  | 0.003-0.02     | 0.03  | 0.015-0.05    | 0.04  | 0.025-0.06   | 0.07  | 0.032-0.11   | 45 to 100  | 20           |
| Total hardness (mg/L)   | 76.34 | 45.2-122.1     | 102.98 | 62.1-137.2    | 116.31 | 70.1-160.5  | 109.82 | 65.35-145.63 | 300 to 600 | 200          |
| TDS (mg/L)              | 75.26 | 62.5-95.5      | 114.96 | 94.4-140.5    | 117.09 | 95.4-142.3  | 134.77 | 109.3-162.3  | 500 to 2000 | 500          |

*Water samples were collected only for eight months (April-November 2011), ** www.cpcb.nic.in
Simpson's biodiversity index is more sensitive for species richness and evenness, and it showed that at S1, diverse populations are more evenly distributed in the community. Shannon and Wiener index values from the middle region of the stream indicated moderate to high diversity at S2, S3, and S4. Simpson, Shannon, and Wiener, and Margalef indices inferred that diversity of macroinvertebrates at different observation sites were in order S2 > S4 > S3 > S1 (2011-12).

Table 2: Showing water quality index on four observation sites for study period Mar.2011-Feb.2012

| Parameter               | S1 (qi) | S2 (qi) | S3 (qi) | S4 (qi) | wi (unit weight) |
|-------------------------|---------|---------|---------|---------|-----------------|
| Turbidity               | 37.7    | 46.8    | 55.6    | 58      | 0.16            |
| Dissolved oxygen        | -22.2   | 1.57    | -7.57   | -17.97  | 0.27            |
| pH                      | 6       | 3       | 3.35    | 7.94    | 0.19            |
| Chloride                | 1.7     | 6.54    | 7.37    | 8.37    | 0.01            |
| Total Alkalinity        | 40.6    | 84.82   | 87.16   | 88.54   | 0.01            |
| Phosphate               | 2.0     | 4       | 5       | 11      | 1.61            |
| Nitrate                 | 0.1     | 0.15    | 0.2     | 0.35    | 0.08            |
| Total Hardness          | 38.2    | 51.49   | 58.2    | 54.91   | 0.01            |
| TDS                     | 25.1    | 38.32   | 39.03   | 44.92   | 0.01            |
| W.Q.I.*                 | 5.46    | 16.79   | 17.53   | 25.70   |                 |

W.Q.I.* 0-24 (Excellent), 25-49 (Good), 50-74 (Poor) and more than 100 unfit for drinking

Table 3: Showing different Biodiversity Indexes on all the observation sites on Binwa stream (2011-12)

| Stations | EPT index | Simpson's Biodiversity index (D) | Shannon and Wiener’s index | Margalef Richness index | Water quality* values |
|----------|-----------|---------------------------------|---------------------------|-------------------------|-----------------------|
| S1       | 87.5%     | 0.19                            | 2.05                      | 1.93                    | Excellent             |
| S2       | 64.28%    | 0.06                            | 2.59                      | 3.10                    | Good                  |
| S3       | 50%       | 0.04                            | 2.94                      | 4.24                    | Good                  |
| S4       | 33.33%    | 0.06                            | 2.6                       | 3.27                    | Good-fair             |

*Values are in comparison to values provided by (NCDEHNR,24) for EPT Index

Table 4: Station wise distribution of organism recorded from Binwa stream showing their diets and feeding habits as observed during the study period (Mar. 2011 to Feb. 2012)

| Organism recorded | S1 * (2822 msl) | S2 (945 msl) | S3 (746msl) | S4 (572msl) |
|-------------------|-----------------|--------------|--------------|-------------|
| Perla sp.         | +               | -            | -            | -           |
| Cryptoperla sp.   | +               | -            | -            | -           |
| Euphaea sp.       | -               | +            | -            | -           |
Orthetrum sp.     -     -     +     +
Isoperla sp.      -     +     -     -
Culex larvae      -     +     +     +
Hydropsyche sp.   +     +     -     -
Stenopsyche sp.   +     +     +     -
Rhyacophilia sp.  -     -     +     +
Psephalus sp.     +     +     -     -
Hydaticus sp.     -     -     +     +
Naucoris sp.      -     +     +     +
Baetis sp.        -     +     +     -
Baetisbifurcatus  +     +     +     -
Ecdyonurus sp.    +     +     +     +
Epeorus sp.       -     +     +     -
Ephemera consors  -     -     +     +
E. remensa       -     +     +     +
Heptagenia sp.    -     -     +     -
Cinygma sp.       -     -     +     +
Iron suspicatus   +     +     -     -
Glossiphonia sp.  -     -     +     +
Limex sp.         -     -     +     -
Hydroporus sp.    -     -     +     +
Helophorus sp.    -     -     +     +
Chironomus sp.    -     +     +     +
Simulium sp.      -     -     -     +

* Observations made only April to November 2011-12.

**Conclusion**
Chrysophyceae and plecopteran naiads are predominantly the pollution intolerant (observed upstream) and perished in polluted waters, while euglenoids, blue-green algae, and dipterans observed in polluted waters. The results of the water quality index and EPT index revealed that water quality deteriorates down the stream due to anthropogenic interferences such as entry of domestic sewage, agricultural runoff, mining, dumping of solid waste, and tourist activities in the stream habitat. While species diversity indices of macroinvertebrates showed that in the middle section (S2 and S3) of stream moderate water current, high dissolved oxygen, nutrients, allochthonous addition, and, more importantly, the heterogeneity in habitat and substratum contribute to high biodiversity. Since there is no industrial establishments happened in and around the vicinity and no study are conducted on hydrobiology of the stream, so the findings will be of immense use for biodiversity conservation, maintaining fish breeding grounds and monitoring the water quality of Binwa.

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**Conflict of Interest**
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