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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., Kharli(S_1), Baijnath (S_2), near Chobin (S_3), and Triveni (S_4) 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 S_1, while it is oligotrophic from S_2 to S_3 and meso-oligotrophic at S_4.

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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

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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 S_1, (2822 m above msl), Baijnath as S_2, (945 m above msl), near Chobin as S_3, (746 m above msl) and Triveni as S_4, (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 ofKangra 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.

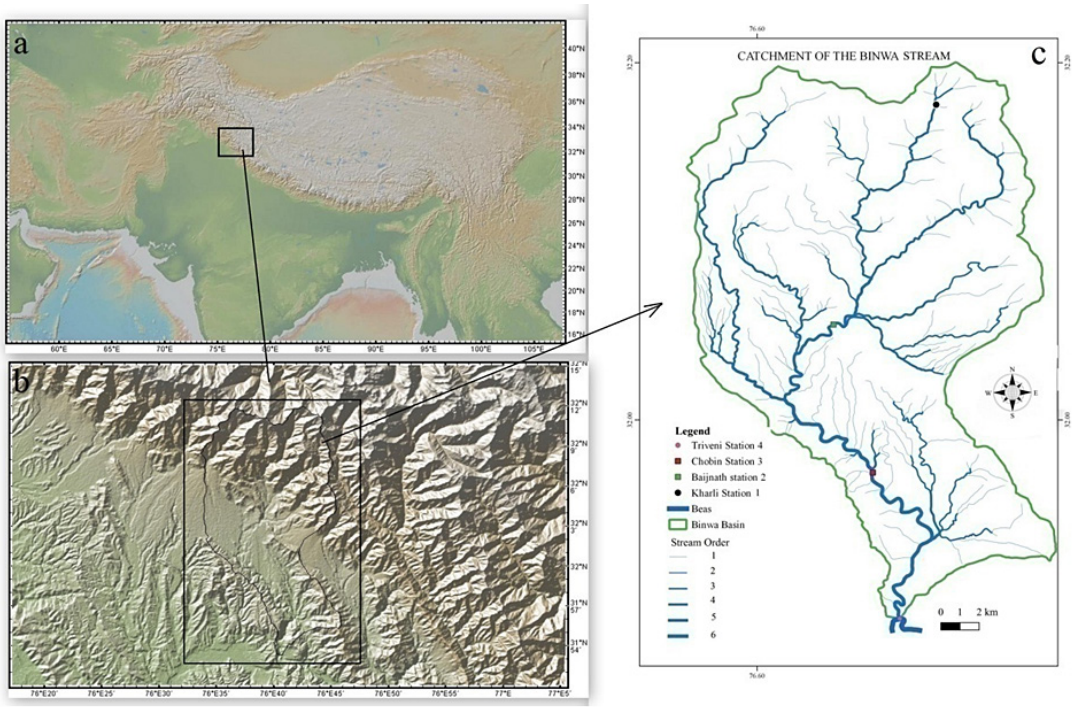

Fig. 1: Map showing study area and catchment region of Binwa stream

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 litters 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

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

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.

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

EPT Index (Epheameroptera, Plecoptera, Trichoptera) =(Total EPT Taxa) /(Total Taxa Found)×100

Water quality index has been calculated for nine physico-chemical parameters of a water sample by consulting the Jindal and Sharma,[15] and Batabyal& Chakraborty,[16]

Water Quality Index (WQI) = qi.wi

Where,

qi (water quality rating) = (100×(Va-Vi))/(Sn-Vi)

Va = recorded value of a parameter in water sample

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

Sn= standard value (from different standard prescribed)

wi (unit weight) = k/Sn

Where,

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

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_1-S_4), at S_2 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 S_2 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 S_4 (Triveni), which might be due to low dissolved oxygen and high nutrient load. In contrast, Euglenophyceae reported only from S_3 and S_4 and utterly absent at S_1 and S_2, 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 *(Psephnus* sp., *Helophorus* sp., *Hydroporus* sp., *Hydaticus* sp.), Hemiptera (*Naucoris* sp.), Ephemeroptera(*Baetis* sp., *B.bifurcatus, Ecdyonurus* sp., Epeorus sp., *Ephemera 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). Plecopterans observed upstream ($S_1$and S_2), whereas dipterans collected downstream (S_3 and S_4), as stoneflies prefer high oxygen section such as runs, rifles, and cascade, in which mixing of oxygen is comfortable, while dipterans larvae prefer pool sections and with low dissolved oxygen (Jindal and Singh,[20]).

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 S_2, S_3 and S4during 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 S_1 to S_3, water was pristine at S_1; in midstream region (S_2 and S_3), 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 S_4, due to high values of above mentioned eight parameters (sewage, mining, agricultural runoff, low ruggedness, andloose 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 S_1 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 S_2 and S_4, 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 (S_1, S_2, S_3, and S_4) on the Binwa stream (Mar.2011 to Feb. 2012)

Parameter	Kharli (S_1)*		Baijnath (S_2)		near Chobin (S_3)		Triveni (S_4)		BIS Desirable - Permissible Limits	CPCB Values of drinking water**	ICMR (1975)	WHOin 2011	
	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		2.5 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 CO_2 (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	6-8.5	7.0-8.5	6.5-8.5
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	200-1000	200	300
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	200
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	45		
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	200-600	100	500
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	500-1500	600	1000

*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 S_3, 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 S_2, S_3, and S_4. Simpson, Shannon, and Wiener, and Margalef indices inferred that diversity of macroinvertebrates at different observation sites were in order $S_3 > S_4 > S_2 > S_1$ (2011-12).

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

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	37.7	46.8	55.6	58	0.16	6.07	7.53	8.95	9.34
Dissolved oxygen	-22.2	1.57	-7.57	-17.97	0.27	-5.96	0.42	-2.03	-4.82
pH	6	3	3.35	7.94	0.19	1.13	0.57	0.64	1.50
Chloride	1.7	6.54	7.37	8.37	0.01	0.01	0.05	0.06	0.07
Total Alkalinity	40.6	84.82	87.16	88.54	0.01	0.54	1.14	1.17	1.19
Phosphate	2.0	4	5	11	1.61	3.22	6.44	8.05	17.71
Nitrate	0.1	0.15	0.2	0.35	0.08	0.00	0.01	0.02	0.03
Toatal Hardness	38.2	51.49	58.2	54.91	0.01	0.31	0.41	0.47	0.44
TDS	25.1	38.32	39.03	44.92	0.01	0.13	0.21	0.21	0.24
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 Biodiver -sity index (D)	Shannon and Wiener's index	Margalef Richness index	Water quality* values
S_1	87.5%	0.19	2.05	1.93	Excellent
S_2	64.28%	0.06	2.59	3.10	Good
S_3	50%	0.04	2.94	4.24	Good
S_4	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	S_1* (2822 msl)	S_2 (945 msl)	S_3 (746msl)	S_4 (572msl)
Perla sp.	+	-	-	-
Cryptoperla sp.	+	-	-	-
Euphaea sp.	-	+	+	-

Orthetrum sp.	-	-	+	+
Isoperla sp.	-	+	-	-
Culex larvae	-	+	+	+
Hydropsyche sp.	+	+	-	-
Stenopsyche sp.	+	+	+	-
Rhyacophila sp.	-	-	+	+
Psephnus sp.	+	+	-	-
Hydaticus sp.	-	-	+	+
Naucoris sp.	-	+	+	+
Baetis sp.	-	+	+	-
Baetisbifurcatus	+	+	+	-
Ecdyonurus sp.	+	+	+	+
Epeorus sp.	-	+	+	-
Ephemera consors	-	-	+	+
E. remensa	-	+	+	+
Heptagenia sp.	-	-	+	-
Cinygma sp.	-	-	+	+
Iron suspicatus	+	+	-	-
*Glossiphoni*a 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 idex 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 (S_2 and S_3) 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

Authors did not have any conflict of interest.

References

1. Sharma I. Ichthyo diversity of Beas river system north western Himalaya (H.P.), India. *J. Env. Bio. Sci*. 2019. 33(1):11-17.
2. ICMR. Manual of standards of quality for drinking water supplies. Special report series no. 44. New Delhi: Indian Council for Medical Research; 1975.
3. BIS (Bureau of Indian Standrads). Drinking water – specification I.S.10500:2012. ManakBhawan, 9 Bahadur Shah Zafar Marg, New Delhi. 2012.
4. W.H.O. Guidelines for drinking water quality. Geneva, World Health Organisation; 2011.
5. Strahler A.N. Quantitative analysis of watershed geomorphology. Transactions of *American Geophysical Union*. 1957: 38913-920.
6. Rosgen D.L. Applied River Morphology. Pagosa Springs, Colorado. 1996.
7. APHA. Standard Methods for the Examination of Water and Waste Water, 25 ed., Washington, DC: American Public Health Association; 1998.
8. Pennak R.W. Freshwater Invertebrates of United States. Protozoa to Mollusca. 3rd ed. John Wiley and Sons, New York. 1989.
9. Merritt R.W, Cummins K.W. An Introduction to the Aquatic Insects of northAmerica. 3rd ed. Kendal / Hunt, Duduque, IA. 1996.
10. Thorp J.H, Covich A.P. Ecology and Classification of North American Freshwater Invertebrates, 2nd ed. San Diego, CA: Acadmic Press; 2001.
11. Subramanian K.A, Sivaramakrishnan K.G. Aquatic insects of India-A fieldguide. Bangalore, India, Ashoka Trust for Ecology and Environment (ATREE); 2007.
12. Wetzel R.G, Likens G.E. Limnological Analysis. 2nd ed., New York, Springer-Verlag; 1991.
13. Shannon C.E, Wiener W. The Mathematical Theory of Communication, University of Illinois Press, Urbana.1949.
14. Simpson G.H. Measurement of diversity. *Nature.* 1949. 163: 688.
15. Jindal R, Sharma C. Studies on water quality of Sutlej river around Ludhiana with reference to Physicochemical parameters. *Environ. Moni Assess.* 2011 a.; 174: 417425.
16. Batabyal A.K, Chakraborty S. Hydrogeochemistry and water quality index in assessment of groundwater quality for drinking uses. *Water Enviroment Research*. 2015; 87 (7):607-617
17. Malik D.S, Bharti U. Status of plankton diversity and biological productivity of Sahastradhara stream at Uttarakhand, India. *J. Appl. & Nat. Sci.* 2012; 4(1): 96-103.
18. Jindal R, Singh D. Biodiversity of Seer stream (District Bilaspur, H.P.) in relation to hydrobiological factors. *Eco. Env. & Cons.* 2013; 19(2):245-249.
19. Jabeen F, Barbhuiya A.H. Diversity of Plankton of Manas river, Assam, India. *International Journal of Applied Biology and Pharmaceutical Technology*. 2018; 9(1):1-11.
20. Jindal R, Singh D. Checklist of macroinvertebrates of Binwa a Westren Himalayan hill stream and their role as bioindicator. *Plant Archives* 2020; 20(1) 2674-2677.
21. Atique U, Guk An K. Stream health evaluation using a combined approach of multi-metric chemical pollution and biological integrity models. *Water.* 2018; 10:2-26.
22. Kubendran, T., Selvakumar, C., Sidhu, A.K., Nair, A. and Krishnan, S.M. Baetidae (Ephemeroptera: Insecta) as biological indicators of environmental degradation in Tamiraparani and Vaigai river basins of southern western Ghats, India. *International Journal of Current Microbiology and Applied Sciences.* 2017; 6(6): 558-572.
23. Patang F, Soegianto A, Hariyanto S. Benthic macroinvertebrates diversity as bioindicator of water quality of some rivers in east Kalimantan, Indonasia. *International Journal of Ecology*. 2018; 2018: 1-11.
24. NCDEHNR. Standrad operating procedures for biological monitoring. Enviromental Sciences Branch Biological Assessment Group. Division of water. Water Quality Section, North Carolina Department of Enviroment, *Health and Natural Resources.* 1997.