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ASSESSMENT OF RIVER WATER QUALITY USING MACRO-INVERTEBRATES AS INDICATORS: A CASE STUDY OF BHALU KHOLA TRIBUTARY, BUDHIGANDAKI RIVER, GORKHA, NEPAL

Anju Rana*, Jeevan Chhetri
College of Applied Sciences-Nepal
Kathmandu, Nepal
*Corresponding author: anju_rana75@yahoo.com

Abstract

Macroinvertebrates are widely considered as indicators of water quality. The present research work was conducted in Bhalu khola, a tributary of Budhigandaki River, Nepal, to identify water quality using macro invertebrates with Nepalese Biotic Score (NEPBIOS), and examine its applicability by comparing with Water Quality Index (WQI).The diversity of macro invertebrates in the studied river was high as depicted by Shannon Wiener Diversity Index. Altogether, 103 macro invertebrates were identified from 11 families and five orders. There were no dominant species, and most of the species were in clumped distribution. According to NEPBIOS index, river water was found to comply with the characteristics of WQ class I-II that means water quality of the river was good. Other indices such as Hilsenhoff and Lincoln quality index (LQI) index also supported this result. Similarly, water quality index (WQI) also showed similarity with NEPBIOS index, indicating water appropriate for drinking purpose. Thus, it is concluded that the macro invertebrates can be used as economic tools for determining water quality of streams and rivers as efficient water quality indicators.

Key Words: Water quality, Macro invertebrates, NEPBIOS, Bhalu khola

Introduction

Water quality refers to the ability of water resources to support human, animal and plant life. Good water quality is necessary for providing us with drinking water that is safe and clean; for providing habitat for aquatic plants, and animals; for providing recreational opportunities like wading, swimming, and fishing; and for providing a place for people to connect with nature. Thus, quality of water is of vital concern for mankind. There are various methods for determining water quality such as standard lab method using chemicals, analysis of bacteriological parameters (APHA, 2005) and use of biological indicators like macro-invertebrates. Use of chemicals is a traditional water quality assessment approach which is much expensive than the latter one due to the sampling and analysis. Also complete reliance upon chemical-physical and bacteriological water quality criteria for the maintenance of healthy communities of aquatic organisms often are inadequate (Olive, 1973). On the other, biological approach using benthic macro invertebrates to water quality assessing (bio-monitoring) is one of the extensively used approach (Junquiere *et al.*, 2000). The main reasons are the preference due to some characteristics such as sedentary nature, long life cycles and the high sensitivity to different levels of pollution that provides a broad variety of responses to environmental contamination (Hellawell, 1986).

Benthic "macro invertebrates" are bottom-dwelling invertebrates large enough to be seen with the naked eye. They are usually greater than 1 mm or 1/32 inch long. They may be aquatic insects and other aquatic invertebrates associated with the substrates of water bodies. Each organism has unique characteristics. Some are pollution tolerant and some cannot resist the pollution. Those organisms that survive and commonly thrive in water heavily polluted with organic wastes are called pollution tolerant forms. Oligochaetes, certain chironomids, leeches, and pulmonate snails usually are included in this category. Pollution- tolerant organisms have special respiratory, food-gathering, and reproductive adaptations that enable them to live under low-oxygen and/or highly turbid, muddy conditions (Olive, 1973). Also, many organisms are capable of living under a wide variety of conditions and do not exactly fit either of the above classifications. These organisms are intermediate or facultative forms and may be associated with either clean or moderately polluted areas. Thus, numerical characteristics of bio communities have been applied to water quality investigations which may involve number of species (or taxa) present , density of organisms, frequency of occurrence, or a variety of biological diversity indices (Beck *et al.*, 1955). One of the most widely used biological methods for evaluating water quality is to divide the organisms into categories depending upon the tolerance of each species to organic pollution (Gaufin, 1958). The density of organisms also is a useful index of water quality. An optimal density of organisms exists in undisturbed areas of most natural waterways, although the density of some benthic invertebrates fluctuates widely with changes in the seasons (Hynes, 1960).

Based upon those benthic macro-invertebrates, rapid assessment protocols have been developed to reduce time and effort. Additionally qualitative sampling of those organisms is actually a rather easy way if there is a well developed methodology. It often includes large-meshed nets, since those apparently are not a problem (Resh, 1993). These sampling techniques are frequently used in projects searching for priority conservational areas as in bio monitoring protocols (Barbour *et al*., 1999). Also, several stream water quality metrics are currently used, such as: richness measures (e.g., total richness and EPT richness – Ephemeroptera, Plecoptera and Trichoptera), enumerations (e.g., number of specimens of a given Order), diversity measures (e.g., Shannon-Wiener), similarity indices (e.g., Sorensen index), biotic indices (HILSENHOFF, Biological Monitoring Working Party (BMWP), BMWP/ASPT (Average Score per Taxon) and functional measure indices (e.g., proportion between shredders and scrapers-collectors) (Resh, 1993). Among several biotic indices, Nepalese Biotic Score (NEPBIOS) given by Sharma (2011) is considered to be the standard monitoring system for Himalayan streams of Nepal.

In view of the above, the present paper attempts to assess the water quality of Bhalukhola , a tributary of Budhigandaki River and test the applicability of NEPBIOS by calculated value and class of water quality index (WQI) obtained considering six chemical parameters pH, conductivity, turbidity, nitrate, potassium, and phosphate (Gebrehiwot *et al.*, 2011).

Materials and Methods

Sampling Sites

Bhalukhola (Bear River) is a perennial river situated at latitude of 28° 21' 05" and longitude of 84° 53' 45", which ultimately meets Budhigandaki River. It is situated in Jagat, Sirdibas VDC of Gorkha district, central Nepal in Manaslu Conservation Area at an altitude of 1300m. The river is near to the settlement area as well as the trekking route to Manaslu. It is known as Nupri in the local Tibetan dialect. The average maximum temperature of the area is 25^{o}C while the average minimum temperature is 14^{o}C with average annual rainfall of 1492 mm. There are 11 rivers and rivulets in the VDC viz. Budhigandaki, Bhaluwan, Dudhpokhari river, Yawang River, Yayu river, Sano Philim river, Dhungang river, Angjung river, Ghattekhola, Lokpa river and Chirlang river.

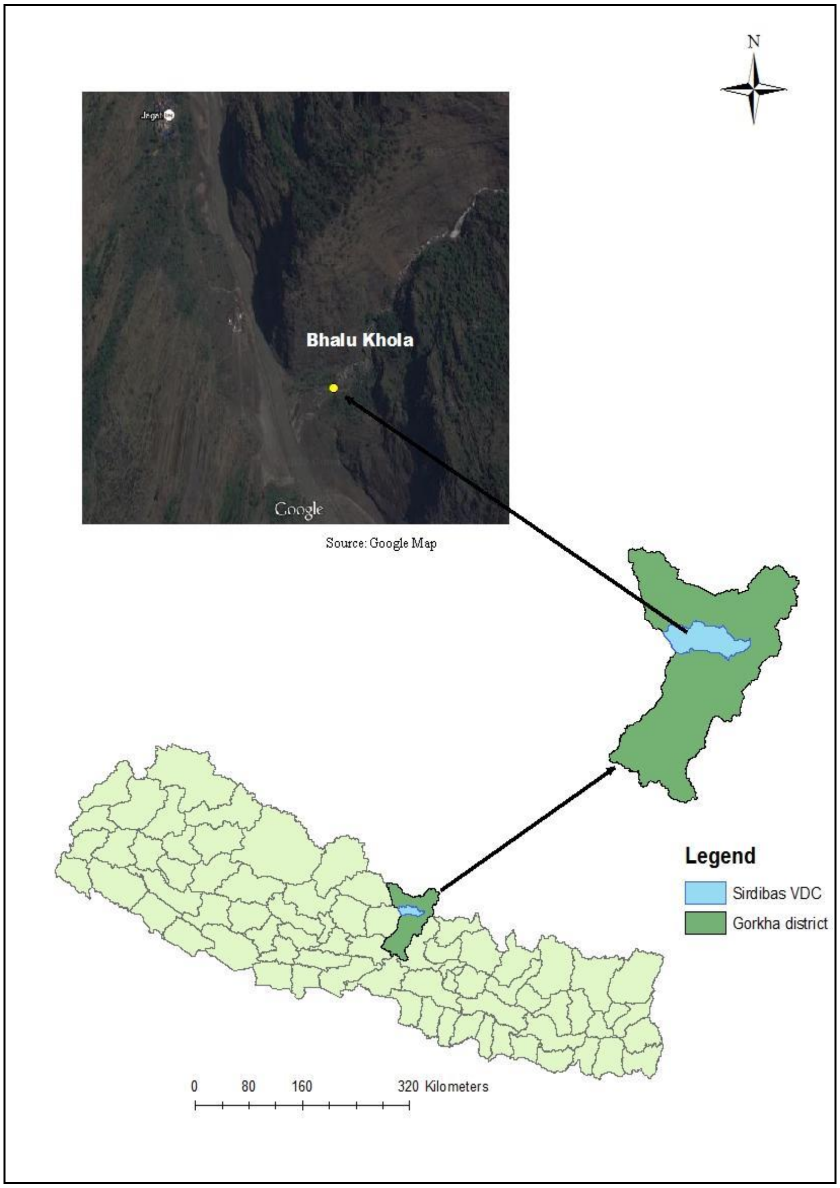

Figure 1: Study Area

Methods

For sampling purpose, a section of the river of about 100 meter length was selected as per the accessibility. Then multi habitat assessment protocol was used to determine the qualitative sampling points. Five different micro habitats megalithal, macrolithal, mesolithal, microlithal and akal were recognized and 10 different sampling points were identified, three from megalithal, three from macrolithal, two from mesolithal and one from microlithal and akal region.

Rapid field assessment (RFA) was used for water quality assessment of streams or river in Nepal that involves screening protocol or Nepalese Biotic Score (NEPBIOS) (Sharma, 2011).

It is also known as manually calculated overview method on the river water quality investigation site.

For the collection of macro invertebrates, the sites from each microhabitat types were disturbed. In addition, kick method (Lenat *et al.*, 1981; Victor and Ogbeibu, 1985) was also applied for creating disturbance and the fauna were collected with the help of a net of mesh size of 200 µm. Each sample was emptied in a white tray before taking the samples from next habitat. The animals found in each site were picked by the forceps and placed in petridish for identification. The unidentified ones were stored in the vials containing 70% alcohol and brought to the laboratory for further identification using the manuals by Pennak (1953), Needham and Needham (1962), Victor and Ogbeibu (1985) and Egborge (1995).

After assessment and identification of macro invertebrates, different ecological parameters such as frequency, relative frequency, abundance, relative abundance, ecological dominance, dispersion, and Shannon wiener diversity index were calculated. Then, the water quality class was identified using index NEPBIOS (Sharma, 2011). Similarly, the water quality parameters such as pH, temperature, turbidity, nitrate, phosphate and potassium were calculated according to APHA (2005) and Trivedi and Goel (1986) and water quality index (WQI) was identified considering these physicochemical parameters (Gebrehiwot *et al.*, 2011). For determining water quality index three major steps were followed. First of all, each parameter was given weight from 1 to 5 according to their relative importance in overall quality for drinking purpose. Maximum weight was given to the most important parameter and minimum to the least important one. Then their relative weight (Wi) was computed. In the next step quality rating for each parameter was assigned by dividing the concentration in each water sample by respective standard according to the guidelines and the result was multiplied by 100.

$q_i = c_t/s_t \times 100$

where,

q_i= is the quality rating

c_t= is the concentration of each chemical parameter in each water sample in milligrams per litre

s_t = is the standard for each chemical parameter in in milligrams per litre

Finally, water quality index was calculated by adding the sub index of i^{th} (SIi) parameter.

Where $SI_i = W_i \times q_i$

Therefore,
Water Quality Index (WQI) = $\sum_{i=1}^{n} SIi$

The water quality of river thus obtained was used to compare applicability of biological index for determining water quality. Classification of water quality index was done as excellent (index range <50), good (index range >50-100), Poor (index range >100-200), Very poor (index range >200-300) and unfit for drinking (index range >300) (Ramakrishnaiah *et al.*, 2009).

Results and Discussion

The species found in the river and their ecological characteristics depicted that the river is in unpolluted condition. Altogether, 103 macroinvertebrates were identified from the studied river, distributed within 11 families viz., Glossomatidae, Baetidae, Elmidae, Gyrinidae, Perlolidae, Chironomidae, Simuliidae, Chloroperlidae, Nemouridae, Epiophlebiidae, and Heptagemidae, with five orders: Trichoptera, Diptera, Plecoptera, Ephemeroptera, and Coleoptera(Table 1). Maximum numbers of individuals found were from Ephemeroptera order which is considered to be one of the sensitive organisms and their presence indicates less environmental stress (EPA, 1996). Similarly, the calculated value of EPT: Chirinomidae also supported the fact that the water is not polluted. When the macro invertebrates found in the stream were compared with that of Balkhu khola in Kathmandu district, distinct diversity of species was found. In Bhalu River, species such as Ephemeropterons, Trichopterons, Plecopterons and Odonates were found in significant numbers which are generally found in pure water while in Balkhu River the pollution tolerant species such as Oligochaetes and Gastropods were abundant that depicted that the river is polluted (Dhakal, 2006). This research further confirmed that Ephemeropterons, Trichopterons, Plecopterons are found in unpolluted water.

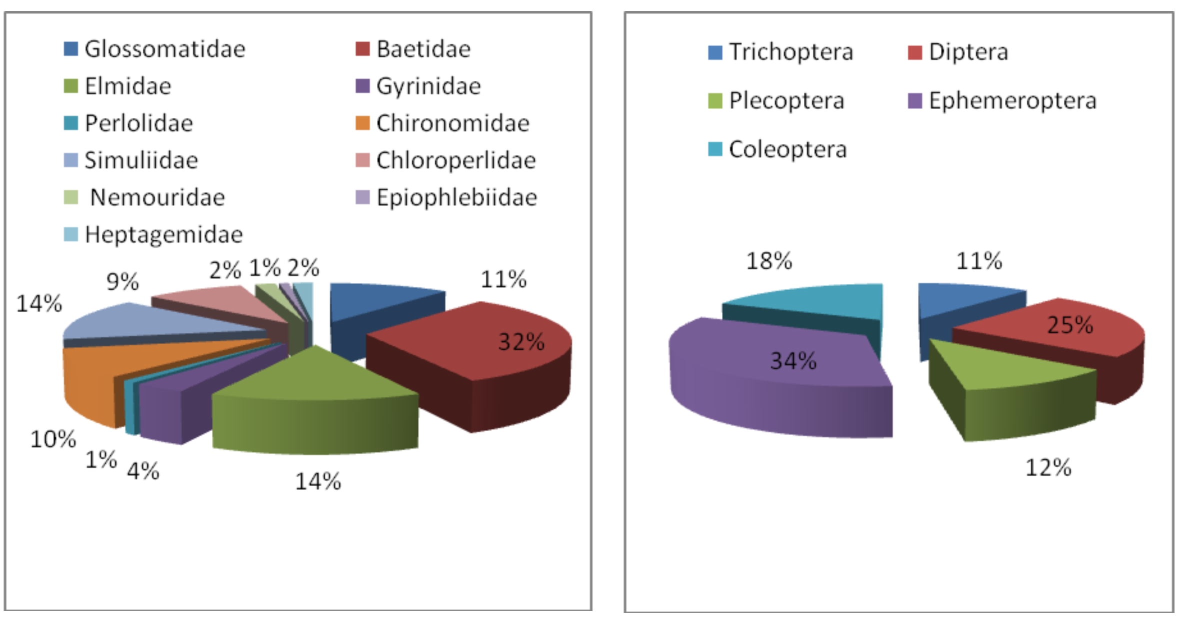

Figure 2: Frequency of species according to family (Lt) and order (Rt)

Similarly, individuals from the families Baetidae, Similiidae and Chloroperlidae was found to be abundant with the value 3.5 whereas that of Perlolodae, Gyrinidae, Nemouridae and Epiophlebiidae was found to be minimum i.e. 1. The abundance and distribution of such species are highly dependent on water chemistry variables or trophic status (Friday, 1987 and Bordersen *et al.*, 1998). Thus these species can sufficiently represent the water quality of a stream or river.

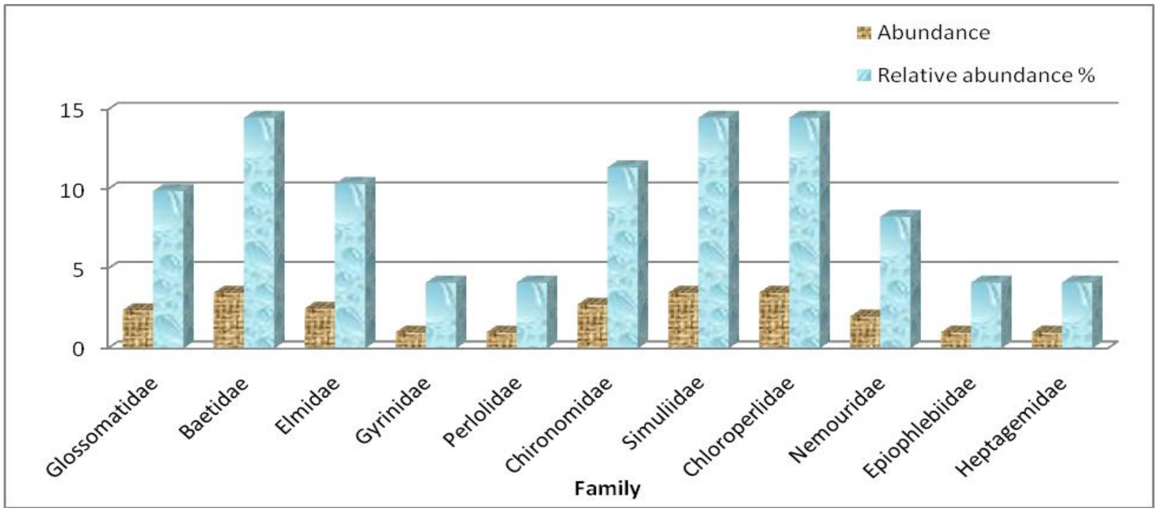

Figure 3: Abundance and relative abundance of different family

Likewise, the Simpsons index of dominance was also calculated which was found out to be low i.e. 0.185. According to EPA (1996), dominant species less than 25% indicates the water to be of good quality. Thus, since its only 18.5%, it confirms the river water to be good.

Furthermore, the calculated value of Shannon wiener diversity index in the river was 1.97 with high equitability index 0.82. This again illustrated that diversity of macro invertebrates in the stream is high and is undisturbed. Similarly, most of the species were in clumped distribution which is commonly found in undisturbed environment (Odum, 1971).

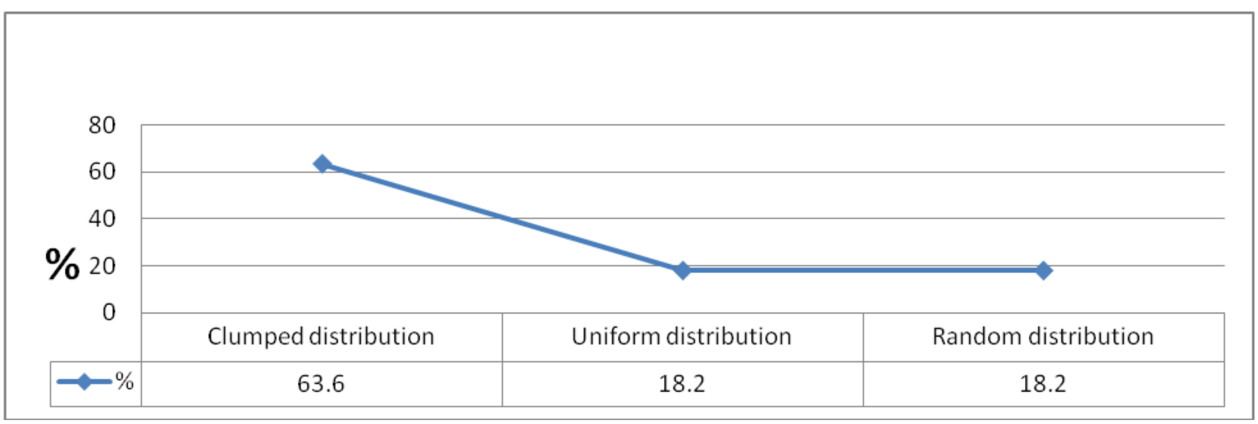

Figure 4: Distribution pattern of species of different family

After determining all the ecological parameters, NEPBIOS water quality index was calculated whose value was 6.64 (Table 1). This value meant that the stream water quality resembled with the water quality class I to II. Thus, while characterizing the water quality according to the class, water in the river is clear with exception of natural turbidity and can be polluted with little or moderate organic matter and very little concentration of nutrients. As explained by the water quality class I- II, the river water is well oxygenated and it may range from 6 to 8 mgl^{-1} while the oxygen saturation can be between 70 to 125 per cent. Similarly, BOD_5 and COD_5 can range below 6 $mgl^{-1}$and 12 mgl^{-1} respectively. The result was also supported by Hilsenhoff family based biotic index (3.125) and Lincoln Quality Index (LQI) (6.8).

Table 1: Frequency, Abundance, Distribution and NEPBIOS scores of benthic macro invertebrates

S.N	Order	Family	Relative frequency (%)	Relative Abundance (%)	Distribution	NEPBIOS
1.	Tricoptera	Glossomatidae	12.5	9.9	Clumped	9
2.	Coleoptera	Elmidae	10	10.35	Clumped	7
		Gyrinidae	10	4.14	Uniform	10
3.	Diptera	Chironomidae	10	11.39	Clumped	1
		Simuliidae	10	14.5	Clumped	7
4.	Plecoptera	Chloroperlidae	10	14.5	Clumped	5
		Nemouridae	2.5	8.28	Clumped	9
		Perlolidae	2.5	4.14	Random	9
5.	Ephemeroptera	Epiophlebiidae	2.5	4.14	Random	8
		Heptagennidae	5	4.14	Clumped	10
		Baetidae	25	14.5	Uniform	7
					Average	6.64

Finally, the applicability of the macro invertebrates based bio monitoring system was tested by determining the water quality index considering six physicochemical parameters pH, conductivity, turbidity, nitrate, phosphate and potassium. All the parameters were within the permissible limit of drinking water quality standard. The measurement of hydrogen ion concentration (pH) in water is the negative alogarithm of the concentration of hydrogen ion and acidic water has pH less than 7 and basic water has pH greater than 7. The mean pH of river was approximately neutral i.e. 6.7 and 100% of the samples were within the permissible limit prescribed by Nepal drinking water quality standard (NDWQS) (2005)and WHO (2011). Similarly, measure of turbidity (7.2 NTU) and conductivity (41.20 μScm^{-1}) were also within the limit. The concentration of nutrients were also very low in the river – nitrate- 0.325 mgl^{-1}, ortho-phosphate- 0.62 mgl^{-1} and potassium- 0.68 mgl^{-1} which were again within the permissible limit of drinking water standards. Major source of nutrients in river water are the biological oxidation of organic nitrogenous materials and are found in less amount in natural water. Thus the river can be said to be in natural condition. The calculated water quality index calculated taking consideration of these parameters was 66.4 which depicted that the water quality is 'good' not reaching the level of very clean water though (Table 3) that resembled with the water quality index obtained from NEPBIOS index.

This concludes that the bio assessment based upon the macro invertebrates can prove to be an efficient tool for evaluating the water quality of the water bodies. Research conducted by Sharma *et al.* (2008) also found similarity between water quality assessed through NEPBIOS index and national sanitation water quality index in Ninglad stream, India.

Table 2: Water quality parameters and WQI

S.N	Parameter	Value	Weight	Relative Weight	Standard (For drinking water)	Qi (Quality Index	WiQi	WQI
1	pH	6.7	5	0.23	6.5-8.5 (NDWQS 2005)	103.07	23.69	Good Water Quality
2	Turbidity	7.2 NTU	5	0.23	5-10 NTU (NDWQS 2005)	144	33.12	
3	Conductivity	41.20 μScm^{-1}	3	0.14	1500 μScm^{-1} (NDWQS 2005)	2.746	0.42	
4	Nitrate	0.325 mgl^{-1}	5	0.23	50 mgl^{-1} (NDWQS)	0.65	0.23	

5	Phosphate	0.62 mgl^{-1}	3	0.14	< 1 mgl^{-1} (Swaziland Water Services Corporation (SWSC))	62	8.68	
6	Potassium	0.68 mgl^{-1}	1	0.05	12 mgl^{-1} (WHO DWQ standards 2011)	6	0.30	
			19			Total	66.44	

Conclusion

Both methods, NEPBIOS and WQI explained that the stream possess good water quality showing compatibility with each other. Hence, the bio monitoring tool using macro invertebrates can be suitably used as quick and economic tool for assessing the ecological status of rivers reducing time, effort and cost of determining water quality by lab method.

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