Water quality assessment using macroinvertebrates as bio-indicator (A case of Sundarijal)

Kusum Gurung[1*], Sanju Banjara[2]
, Xavier International College, Bouddha, Kathmandu
*Correspondence: kusum.gurung@xavier.edu.np

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Abstract
Macroinvertebrates and selected physio-chemical parameters were considered as the primary indicators in this study for assessing the river quality of Sundarijal, Bagmati river. 3 sites were selected for water quality assessment during May 2018. Physico-chemical parameters such as temperature, dissolved oxygen, pH and conductivity were measured. Macroinvertebrates were sampled in the field and processed in laboratory. RFB and NEPBIOS protocols were useful to identify the water quality classes. 25 families of macroinvertebrates were recorded. Relatively sensitive taxa Ephemeroptera and Trichoptera were found to be higher followed by pollution tolerant taxa Diptera in all sites, indicating a very slight pollution level. Application of RFB showed the river water quality was non-polluted to slightly polluted level on moving to the downstream. NEPBIOS indicated good ecological status in the upstream section which decreased gradually on moving to the downstream.
Keywords: *Macroinvertebrates, RFB, NEPBIOS, Ecological status*

Introduction

Nepal is enriched with freshwater resources with around 6,000 rivers and rivulets with a total drainage area of about 191,000 km^2(WECS 2004, 2011). Freshwater biodiversity provides a broad variety of valuable goods and services for human societies, some of them irreplaceable (Dudgeon et al., 2006), but activities have always affected aquatic system. The deliberate modification of rivers, streams by building dams and reservoirs alter the ecological basin creating impact on running water (Richter et al., 1997).

The removal or diversion of water permanently or temporarily from water bodies such as rivers, lakes, canals, streams, oceans and indirectly from ground water is water abstraction (Castella et al., 1994). For the purpose of water supply to human settlements, irrigation, hydropower generation, flood control, aquaculture, waste disposal, livestock, navigation water abstraction is done (Malmqvist et al., 2002; Sharma, 2004; Goodwin et al., 2006; Brooks et al., 2010). However, there are some environmental impacts along with these benefits. Therefore, water abstraction is considered as one of the major stressors of aquatic ecosystems (Matthaei et al., 2010).

To assess the impacts of stressors, monitoring of physico-chemical and biological parameters is considered the best (Metcalfe, 1989) as such practices provide a comprehensive and overall information on the water quality status of the aquatic ecosystems. Monitoring of physico-chemical parameters provide only a snapshot and fails to give consistent information about the water quality status (Schofield and Davies, 1996). Therefore, bioassessment of water bodies using organisms are considered advantageous over chemical- based approaches (Karl, 1991).

Macroinvertebrates are frequently used bioindicators and are very useful in determing the characteristics of aquatic environment (Sharma, 1996; Dahal et al., 2007; Rana and Chettri, 2015; Benetti and Garrido, 2010; Fernandez-Diaz et al., 2008). For Nepalese rivers, first region-specific score based method (NEPBIOS) was developed in 1990s which represents as adaptation of the BMWP/ASPT system (Sharma, 1996; Sharma and Moog, 1996). Application of macro invertebrate as biological indicators for assessing the impact on rivers due to hydropower projects in Nepal has also been studied in Tinau River (Sharma et al., 2005).

Macroinvertebrates are found in the bottom substrates of freshwater streams and rivers and are large enough to be seen with naked eyes. Nearly all streams are colonized by a community of benthic macroinvertebrates. The species comprising the community occupy a distinct niche defined and limited by a set of environmental requirements (Bode et al., 2004). Generally, due to their large number of species and their wide range of systematic origin (e.g. worms, molluscs, crayfish and insects) benthic macroinvertebrates are capable of reflecting different human-induced deteriorations: organic pollution, acidification, habitat modification and overall stream degradation and disturbances (Moog et al., 2008). Depending on the cleanliness of the river and the type of the habitat available, different types of macroinvertebrates are found. Mayflies and caddisflies are generally intolerant of pollution (Aslam et al., 2008). Large numbers of these insects reveal good water quality. (Aslam et al.,2008) also revealed that pollution tolerant organisms such as non-biting midges, worms and some mollusks present in a sample signify bad water quality. Other macroinvertebrates such as stoneflies, alderflies and dobsonflies are pollution intolerant and are only found in very clean rivers. Dams are a principal threat to freshwater diversity and that threat is largely mediated through loss of habitat frequently involving modifications to the natural flow regime and to blockage of migrations (McAllister et al., 2001). As mentioned in (Lessard and Hayes, 2003), aquatic macroinvertebrates are also affected by habitat changes caused by dams. Such variations can be measured by physical, chemical and biological methods.

(Sharma,1996) mentioned that the water quality of running water must be assessed by biological means, followed by physical and chemical characteristics of water, which provides a complete spectrum of information. Macroinvertebrates give continuous monitoring of river water quality unlike physico-chemical studies which show occasional but significant changes. This research is an attempt to show such alteration in water quality using physico-chemical method as well as bio-indicator i.e. macroinvertebrates.

1.1 Objectives

The main objective of this study is to understand the impact of Sundarijal dam (water abstraction for drinking purpose) on river water quality on pre-monsoon season through response of macroinvertebrates.

Methodology

This study was carried out in Shivapuri Nagarjun National Park at Sundarijal Dam site to the north of Kathmandu Valle. It was constructed in 1934 for the hydroelectricity purpose by damming the river Bagmati and now the water is supplied for drinking purposes. The Bagmati River originates at an elevation of 2732m in Shivapuri Nagarjun National Park and then flows along Sundarijal Sub-catchment before entering into the plain valley area of the city (WEPA Nepal, 2010). The study area falls within Shivapuri Nagarjun National Park; the area of which is 144 km^2 approximately. It is located 15 kilometers from the main city and is surrounded by three districts, Kathmandu, Nuwakot and Sindhupalchowk. It lies between 27°47′42″N and 85°23′24″E.

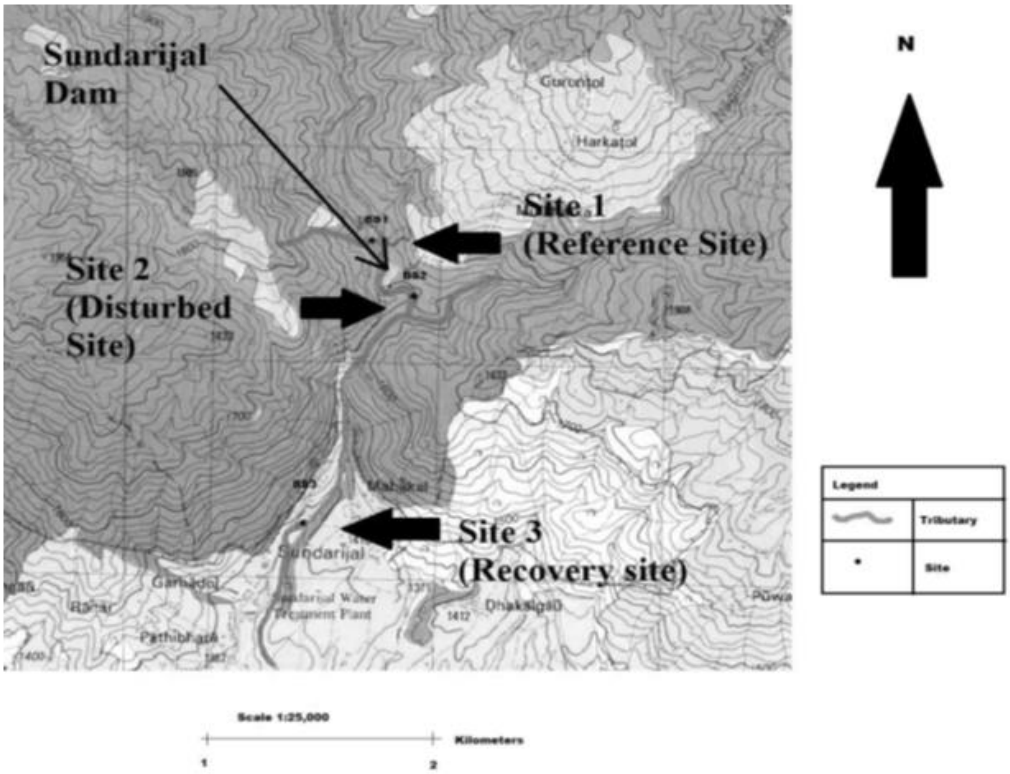

Figure 1: Location of sampling sites

Sampling was conducted in May 2018, three sampling sites were selected, In total: One sites (S1) were selected upstream of water abstraction as reference sites 500m before the dam. The impacted site (S2) was located about 250m downstream of water abstraction (Dam) and a recovery site (S3) was located below the bridge close to Sundarijal settlement (Table 1)

Rapid field bio-assessment pre-classifies the sampling sites into five category classes based on visual observation and relative abundance of the macroinvertebrate fauna. Visual observation on sites include the estimation of some sensorial features such as turbidity, stones with algal vegetation, filamentous green algae presence of suspended solids, non-natural turbidity, foam, odour and waste dumping and ferro- sulphide reduction

Qualitative samples of macroinvertebrates were taken following Barbour et al. (1999). Samples were collected from different micro habitats and substrate types such as riffles, backwater and pools covering a 100 m stream section and moving in an upstream direction.

The substrate was disturbed by kicking action in front of the net with a mesh size of 250µm to collect the organisms Macroinvertebrates were allowed to drift towards the net. Stones were also turned over and observed. Macroinvertebrates were handpicked as well. The organisms were preserved in 70% ethanol and brought to the Aquatic Ecology Centre, Kathmandu University further study and identification. On site physico-chemical variables such as dissolved oxygen (DO), conductivity, pH and temperature were measured using multi-meter probe (Orion series).

Nepalese Biotic Score /Average Score per Taxon (NEPBIOS/ASPT) (Sharma 1996) were applied to estimate the Water Quality Class (WQC) of each site. NEPBIOS is macroinvertebrate-based ecological assessment tool where scores ranging from 1-10 is assigned to around 82 macroinvertebrate families based on their organic pollution tolerance. Higher scores are given to pollution sensitive taxa and lower scores are given to pollution tolerant taxa. Water Quality Class is determined by adding the total scores assigned to the macroinvertebrate families divided by the total numbers of the transformation table to obtain the WQC.

Table 1: Co- ordinates and elevation of sampling sites

Sites	Co-ordinates	Elevation
Site 1	27°46.415′N	1604m
	85°25.559′E	
Site 2	27°46.306′N	1582m
	85°25.581′E	
Site 3	27°44.212′N	1327m
	85°23.172′E	

Results

The value of physico-chemical parameters are shown in table:

Figure 2: physico-chemical parameters of sampled sites of Sundarijal

Sites	pH	DO(mgL^{-1})	Conductivity(µS/cm)	Temperature (°C)
Site 1	6.92	6.52	28.31	14.59
Site 2	6.72	4.39	31.07	14.02
Site 3	6.48	6.2	30.39	16.35

Macroinvertebrate's assemblages

A total of 25 families of macroinvertebrates belonging to nine different orders and one phylum were observed in the sampling sites (Fig. 4.0). Highest diversity was observed with 16 families at Site 1 followed by 14 families at Site 2 and the least number of families were observed at Site 3 with presence of 8 families.

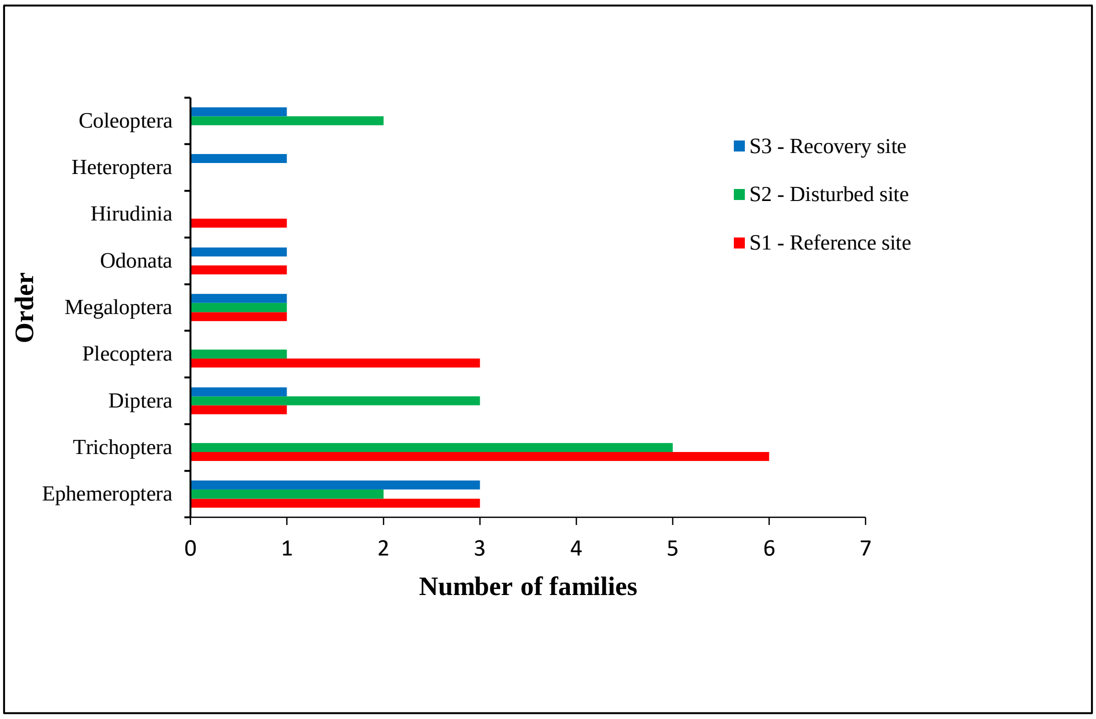

Figure 3: Macroinvertebrates orders with respective families on sampling sites

Water Quality

On the basis of RFB, Site 1 before the dam has high River Quality Class (RQC) of I which means that the water is non-polluted to very slightly polluted. The water of Site 2 and Site 3 with RQC has changed from class I to II which means water is moderately polluted. Site 3 (6 families) distinctly lacked the rich diversity of macroinvertebrates which were observed in the reference sites. This clearly shows that RFB overestimates disturbed site. The result of the Rapid Field Bio assessment (RFB) revealed that the reference sites S1 had high River Quality Class (RQC) of I which means that the water is non-polluted to very slightly polluted. The water of Site 2 and Site 3 with RQC has changed from class I to II which means water is moderately polluted. Site 3 (6 families) distinctly lacked the rich diversity of macroinvertebrates which were observed in the reference sites. This clearly shows that RFB overestimates disturbed site. Similarly, the NEPBIOS/ASPT scores were the water quality class was found to be I-II in Site 1 and Site 2 indicating the water was slightly polluted. However, the water quality class was found to be II in Site 3 which indicated that the water was moderately polluted.

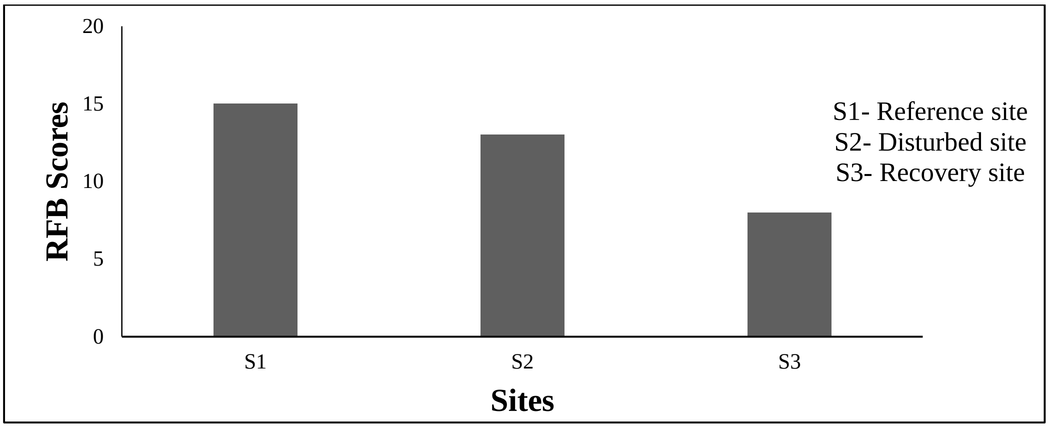

Figure 4: RFB scores of sampling sites

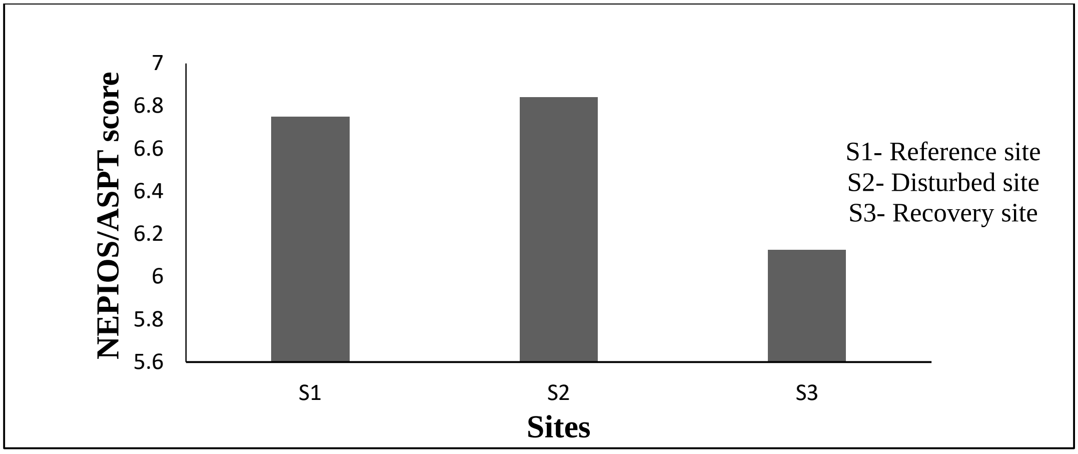

Figure 5: NEPBIOS scores of sampling sites

Discussion

Physico-chemical characteristics

Water temperatures in the streams may vary as a result of incoming solar radiation, air temperature, shading effect which is thought to lower the water temperature (Khan et al., 2012). Water temperature controls the rate of all chemical reactions, and affects fish growth and other insect communities, reproduction (Gibbons 1976; Wotton 1994). 1˚C increase in water temperature could decrease the macroinvertebrates abundance and richness by 11.1% and 6.0% respectively (Li et al., 2012).

The pH of river water varied between 6.92 to 6.48. Natural pH levels typically fall between 6.5 and 9.0 depending on the surrounding soil and vegetation (Mesner & Geiger, 2010). The highest pH level was found at the Site 1. According to Friends of Five Creeks (2012), rapidly growing algae removes carbon dioxide from the water during photosynthesis and this can result in a significance increase in pH levels. The highest micro-algae cover of 50% accounts for maximum pH value (Gurung, 2012) so this might be the reason that Site 1 have the high pH value. Clenaghan et al. (1998) found that high diversity of macroinvertebrates existed in those places which had high pH value which supported the study and Site 1 had high species richness along with high pH value.

There was a heavy rainfall during the study period and the DO in the sampling sites were found to be 6.52 mg/L, 4.39mg/L and 6.2mg/L in all the three sites Site1, Site2 and Site 3 respectively. In the previous studies, in Bagmati river system by ENPHO (1997) and Shrestha (2007) DO value was found to increase from dry season to rainy season. The study exposed that DO at all sampling sites were above 4 mg/L and hence the water is suitable for drinking, bathing, aquaculture and irrigation (Radhika et al., 2004). Higher DO supports the pollution tolerant species to inhabitat the river water (Badruzzaman et al., 2007) while lesser DO enables the biological residues to increase and increase pollution resistant species (Trivedi & Goel, 1986). This supported the study that as all the sites has scored DO value above 4 mg/L and DO was high at Site 1 and supported for pollution tolerant species to be in highest number(i.e. EPT taxa). At the Site 2 and Site 3, DO value decreased with the decrement in the pollution tolerant species and increment of pollution resistant species resulting the pollution of water.

The value of EC varied at different sites with highest value at the Site 2 i.e. 30.39 and lowest at Site 1 i.e. 28.31 while the values of EC was comparatively low during sampling due to rainfall in the catchment area and the successive dilution of water. Electrical conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends upon the presence of ions; on their total concentration, mobility and valence; and on the temperature of measurement (APHA, 1995). Runoff and precipitation determine the conductivity. Higher the discharge lowers the conductivity and vice versa.

The temperature is basically important for its effect on the chemistry and biological reactions in the organisms in waters. The temperature at three sites (Site1, Site 2 and Site 3) were found to be 14.59°C, 14.02°C, 16.35°C respectively. A rise in temperature of the water leads to the speeding up of the chemical reactions in water, reduces the solubility of gases and amplifies the odors (Trivedi & Goel, 1986).

As cited in Bhattarai et al. (2008), water temperature was highest during mid monsoon and lowest during winter similar to the previous report for the same water body (Paudyal, 2001; ENPHO, 1997). Bhattarai et al. (2008) also mentioned that such change in water temperature was found to be related with corresponding changes in atmospheric temperature. Aquatic organism has both an upper and lower temperature limit for optimal growth. This growth varies from species to species.

Macroinvertebrates

Aquatic macro-invertebrates indicate biological response to increasing levels of stressors throughout their stages. Some of these stages are more sensitive than others to particular stressors responding quickly to stress during a sensitive stage of life (Badruzzaman et al., 2007). Aquatic macro-invertebrates as bio-indicators have a wide range of pollutant tolerances among the various species therefore are well suited for the assessment of site specific pollution impacts and to determine the water quality. During study period altogether 92 individuals of 25 taxa (family) belonging to 9 orders were found whereas in the study done by Gurung (2012) in Sundarijal, 116 individuals of 25 taxon belonging to 9 orders were found during the wet season and 139 individuals of 22 taxon belonging to 8 orders were found in dry season.

The benthic population of aquatic taxa was dominated by order Trichoptera comprising 6 families with the highest number of species from the family Hydospsychidae i.e. 15 species. The Hydropsychidae family is sensitive to pollution so it was abundant at site. The family Baetidae was abundantly found in all sites and it may be because Baetidae is intolerant species to organic pollution (Gaufin, 1958; Shrestha, 2007).

Odonata found in a number of samples exhibits a range of sensitivity to pollution. The larvae of Gomphidae have been found outside the thermal plume, are intolerant of pollution and indicate moderate water quality (Badruzzaman et al., 2007; Alam et al., 2008). Chironomidae family under the order Diptera are poor tolerant of organic and inorganic pollution (Sharma et al., 2009). Chironomidae was found in the Site 1 and Chironomidae is commonly known as midges, are the most common of aquatic invertebrates of aquatic environment and indicate multiple stressors (Gaufin, 1958; Shrestha, 2007).

Higher number of EPT taxa (Ephemeroptera, Plecoptera and Trichoptera) indicates the good ecological status of the river and EPT taxa were found to be higher in the Site 1. This indicates that the river water of Sundarijal is healthy and has good ecological status and functioning. While at the Site 2, the EPT taxa is decreased giving an increment to pollution tolerant species of macroinvertebrates. And at the Site 3, no species were found from the families of Plecoptera and Trichoptera resulting in a low ecological status of the water.

5.3 Water quality

On the basis of RFB protocols the water quality class was determined at different altitudes with RQC's I at Site 1 and RQC's II at Site 2 and Site 3, which indicated that the water was none to very slightly polluted at Site 1 and moderately polluted at Site 2 and Site 3. This was supported by Gurung (2012) which confirmed the applicability of RFB protocols and scoring systems for assessing the impacts of damming in a river stretch.

According to NEPBIOS, the water quality ranged between class I-II at Site 1 and Site 2 which indicates a very slight pollution and class II at Site 3 indicating that the water is moderately polluted and the result was backed by Gurung (2012) which mentioned NEPBIOS as a standard method for assessing the river water quality of Nepalese rivers. Altogether 82 benthic macroinvertebrates taxa are listed in the original NEPBIOS table and are scored a discrete value ranging from 1 (tolerant) to 10 (sensitive) (Feld et al. 2010). The effectiveness of the different indices and scores in water quality assessment is based primarily on the macrozoobenthic structure, which varies according to the nature of each substratum and the current type (Sharma, 1999).

The results obtained from the two different protocols show a slight difference in the RQC's at Site 1 and Site 2 while at Site 3 both protocols scored RQC's II with almost the same level of pollution.

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