



INTERNATIONAL JOURNAL OF ENVIRONMENT

Volume-6, Issue-3, Jun-Aug 2017

ISSN 2091-2854

Received:19 June

Revised:21 July

Accepted:10 August

MACROINVERTEBRATE ASSEMBLAGES AS INDICATORS OF WATER QUALITY OF THE WEST SETI RIVER, BAJHANG, NEPAL

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Abstract

Water quality of the West Seti River, a tributary of the Karnali in West Nepal was assessed using macroinvertebrates as bioindicators. The main objective of the study was to assess the ecological water quality of the West Seti River and to generate a baseline data on macroinvertebrate assemblages. The sampling was conducted during December 2015 and a total of 11 sampling sites were selected from the West Seti River and its tributaries. Qualitative samples of macroinvertebrates were collected from different habitats. Selected physico-chemical parameters such as pH and temperature were estimated on-site. Dissolved oxygen (DO) was estimated by Winkler's method. The macroinvertebrate samples were enumerated and identified up to Family level following standard literature. Chi-square test was performed to see whether macroinvertebrate taxa varied significantly along the altitudinal gradient and between the West Seti River and its tributaries. An ecological assessment tool Nepalese Biotic Score/ Average Score Per Taxon (NEPBIOS/ASPT) was applied to assess the water quality of the sampling sites. The pH value ranged from 7.9 to 8.7 indicating the alkaline nature of the river. A total of 1666 individuals belonging to 34 Families and 7 Orders of macro-invertebrates were observed. The highest diversity of the macroinvertebrate taxa was observed at site T5 with nineteen Families whereas the lowest taxa diversity was observed at R3 with only five Families. The variation in macroinvertebrate assemblages between the sub-tropical and temperate zones; and the West Seti River and its tributaries were not significant. NEPBIOS/ASPT revealed a score of Water Quality Class of III-IV at Site R3 indicating that the site was polluted. This site was characterized by the abundance of red Chironomids which are considered as the indicators of organic pollution.

Keywords: *Water Quality, macroinvertebrates, pollution, bioindicators, West Seti River, Nepal*

Introduction

The origin and development of human civilization are often closely related to rivers (Mihov and Hristov, 2011). The distribution and movement of river water can influence the state and dynamics of terrestrial, aquatic and riparian ecosystem species (Padmalal and Maya, 2014) by forming habitats as well as passages for connectivity and exchange of materials (Sponseller et al., 2013). Accordingly, river ecosystems are considered as critical resources, necessary to support a number of biological processes (McCluney and Sabo, 2012; Sponseller et al., 2013). However, being so close to human activities, rivers are also often subject to various stressors and negative impacts (Mihov and Hristov, 2011). A variety of stressors associated with anthropogenic activities such as eutrophication (Dodds, 2006); agricultural intensification (Dahal et al., 2007); organic pollution (Dahal et al., 2012); dams and sand gravel extraction (Boudaghpour et al., 2008; McCabe, 2010) are known to have profound impacts on river morphology and biota resulting in river deterioration (Dahal et al., 2012; Gurung et al., 2013). For instance, construction of dams results into the isolation of river systems (McCabe, 2011) which in turn can hinder fish migration (Postel and Richter, 2003). Similarly, sand and gravel extraction can destroy spawning and breeding habitats of fishes (Boudaghpour et al., 2008).

In Hindu Kush Himalayan countries like Bangladesh, Bhutan, Pakistan, India and Nepal also; waste disposal, water resource development, urbanization, land use and climate change have been identified as the major stressors of river degradation (Moog et al., 2008; Edwards et al., 2010). Such impacts result into failure of rivers in providing ecosystem services like recreation, biodiversity, scenic beauty, fisheries, irrigation (Moog et al., 2008). Therefore, monitoring and assessment of impacts of stressors is necessary (Li et al., 2010) for proper management of these water bodies. In routine monitoring practices, a range of physical, chemical and biological components are assessed and monitored (Meybeck et al., 1996) as these components are known to provide comprehensive information on the impacts of stressors on water quality making such assessments as holistic approaches (Balian et al., 2008). Monitoring and assessment methods using biological indicators are often considered advantageous over chemical-based approaches

since the latter provides only the “snapshots” whereas the biota provides more information on the ecological status of the ecosystems (Li et al., 2010).

A number of studies related to water quality using physico-chemical parameters and biological indicators particularly macro-invertebrates, have been carried out in Western (Suren, 1994; Sharma et al., 2005; Gurung et al., 2013), Central (Shrestha et al., 2008; Rana and Chhetri, 2015) and Eastern (Jha et al., 2015; Gurung et al. 2016) parts of Nepal. However, such studies in the far western part of Nepal are scarce. Few studies have focused on geo-chemical characterization (English et al., 2000); diatom assemblages (Cantonati et al., 2001); ground water quality assessment (Gurung et al., 2015). Therefore, it is important to study the water quality of the rivers in the far western region of Nepal using holistic approaches. Since macro-invertebrates are considered as useful indicators of water, this study attempts to assess the water quality of West Seti River using these bioindicators.

The main objective of the research is to assess the water quality of West Seti River of Bajhang by using biological indicators. The specific objectives are:

- i. To assess the selected physico-chemical parameters of the river.
- ii. To assess the macroinvertebrate diversity along the altitudinal gradient.
- iii. To estimate the Water Quality Class (WQC) by using NEPBIOS/ASPT.

Methods

Study area

The study was conducted in the West Seti- one of the major tributaries of the Karnali River (the longest river of Nepal) (Figure 1). The headwaters of the West Seti and its basin are primarily on the southern slopes of the Great Himalayas (Alford, 1992). The average elevation of basin is 2505m but it varies from 315 masl at basin outlet to 7045 masl of Api and Nampa high mountain ranges.

The study area has two types of vegetation classification (Hagen, 1980). The area with altitude ranging from 1000-2000 masl has sub-Tropical evergreen mountain forests (having pine or fir, chestnut, walnut, oak, peepal etc.); whereas the sites with altitude ranging from 2000-3000 masl is characterized by temperate moist forest of oaks and conifers (with bamboo and ferns) (Alford, 1992). A total of 11

sampling sites were considered; among which 4 were from the main river and 7 from its tributaries (Table 1, Figure 2). The selection of the sampling sites was based on the accessibility of the West Seti River and its tributaries.

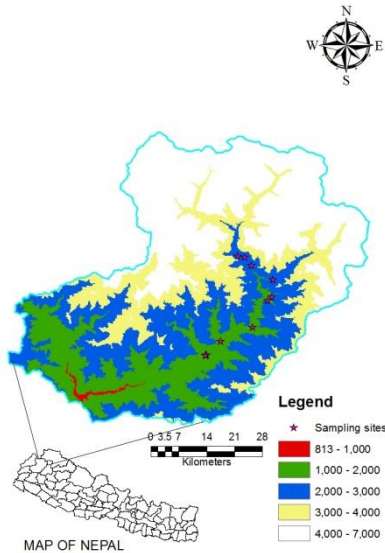


Figure 1: West Seti River

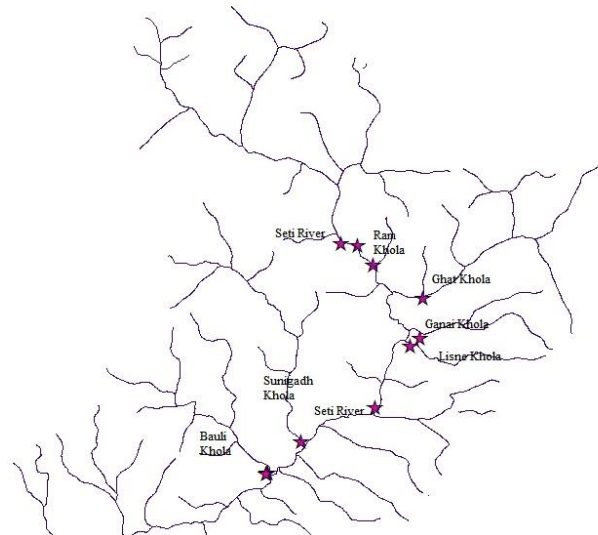


Figure 2: Map showing the sampling sites in the West Seti River

Table 1: Description of the sampling sites of the study area

S.N.	River	Location	Site Code	GPS Co-ordinates	Altitude (m)
1	Seti River	Dhuli	R1	29.77356°N/81.26819°E	2214
2	Lokante Khola	Lokante	T1*	29.77153°N/81.28373°E	2340
3	Ram Khola	Kaya	T2*	29.752°N/81.29922°E	2021
4	Ghat Khola	Karankot	T3*	29.72047°N/81.34782°E	2029
5	Ganai Khola	Between Jailekh and Dhalaun	T4*	29.68122°N/81.34492°E	1826
6	Lisne Khola	Between Panalt and Jailekh	T5*	29.67316°N/81.33592°E	1735
7	Seti River	Between Talkot and Rupalola	R2	29.61317°N/81.30152°E	1372
8	Sunigadh River	Sunigadh	T6*	29.58019°N/81.22916°E	1324
9	Seti River	Chainpur before confluence	R3	29.54947°N/81.19646°E	1234
10	Bauli Khola	Chainpur	T7*	29.54986°N/81.19528°E	1243
11	Seti River	Chainpur below confluence	R4	29.54878°N/81.19485°E	1251

*Tributary

Field Methods

Physico-chemical parameters:

Selected physico-chemical parameters such as pH and temperature of the water were estimated in the field using a portable pH meter and thermometer respectively. For dissolved oxygen (DO), 300 ml of water samples were collected in BOD bottles. The samples were fixed with 2 ml of Manganous Sulphate and 2 ml of Potassium Iodide and were transported to the laboratory for further analysis. Similarly, 300 ml of the samples were taken for Nitrate, Ammonia and Total Phosphate estimation in plastic bottles. All the water samples were first filtered by using Whatmann filter paper.

Macro-invertebrates:

The qualitative sampling method was adopted in the field for the collection of macro-invertebrates following [Barbour et al., \(1999\)](#). A net with a mesh size of 250µm was used in the field to collect the macroinvertebrates. The samples were collected by kicking off and disturbing the substrates in the site. 20 samples were collected following a multi-habitat approach along a 100 m stretch of the river and a composite sample was made. The samples were transferred to vials and preserved in 70% ethanol and brought to the laboratory for identification.

Laboratory Analysis

Physico-chemical parameters:

DO was estimated by Winkler's method with azide modification; Nitrate, Total Phosphate and Ammoniacal-N were estimated by standard procedures ([APHA, 2012](#)).

Benthic Macro-invertebrates

The organisms were sorted, identified and enumerated with the help of available keys ([Merrit and Cummins, 1996](#); [Dudgeon, 1999](#)). Most of the organisms were identified only up to the Family level. Water Quality Class (WQC) was estimated using a macroinvertebrate-based ecological assessment tool- Nepalese Biotic Score/ Average Score Per Taxon (NEPBIOS/ASPT) - a water assessment tool developed by [Sharma \(1996\)](#) which can be applied to estimate water quality class. In this method, around 82 macro-invertebrate Families (mostly insects) are assigned a numeric value ranging from 1 to 10 based

on their pollution tolerance. The pollution sensitive taxa are given higher scores while the pollution tolerant taxa are given lower scores. The water quality class is determined by adding the total score of the taxa divided by the total numbers of the groups of the taxa present in each site. Water quality class was determined with the reference to the transformation table (Table 2) for the NEPBIOS/ASPT values obtained.

Table 2: Transformation table showing Water Quality Class and Mapping Colour

Water Quality Class	NEPBIOS/ASPT midland	Description	Mapping Color
I	7.50-10.00	Not Polluted	Blue
I-II	6.51-7.49	Slightly Polluted	Blue/ Green
II	5.51-6.50	Moderately Polluted	Green
II-III	4.51-5.50	Critically Polluted	Green/ Yellow
III	3.51-4.50	Heavily Polluted	Yellow
III-IV	2.01-3.50	Very Heavily Polluted	Yellow/ Red
IV	1.00-2.00	Extremely Polluted	Red

Source: Sharma, 1996

The species diversity of macro-invertebrates was calculated through the use of Shannon's Diversity Index formula.

$$\text{Shannon's Diversity Index } (H') = \sum p_i \ln p_i$$

Where, p_i = proportion of individual in the site; $\ln p_i$ = natural log of p_i

The evenness of the macro-invertebrates was calculated by using the formula:

$$\text{Evenness} = H' / \ln S$$

Where, H' = Shannon's Diversity Index; $\ln S$ = natural log of number of species that occurred in the site

Sorensen's Similarity Index:

Sorensen's Similarity Index between two communities of Temperate and Sub-Tropical Ecological Zones; and between those of the West Seti River and its tributaries was calculated by using the given formula:

$$\text{Sorensen's Similarity Index} = 2C / (A+B) \dots \dots \dots (1)$$

Where, C=Number of common species to both the communities; A= Number of species in one community; B= Number of species in another community.

Results

Physico-chemical Parameters:

The results of the estimated physico-chemical parameters are given in Table 3. The highest pH value was 8.7 (R1) and the lowest was 7.8 (T1) in the sampling sites (Table 3) with a mean of 8.16 indicating the alkaline nature of the river water. The mean temperature of the study area was 3.18°C; where the highest temperature was 8.5°C (T7) and the lowest was -1°C (T1); and the Dissolved Oxygen (DO) ranged from 7 mgL⁻¹ (R3) to 13.3 mgL⁻¹ (R2) with a mean of 10.57 mgL⁻¹. Nitrate concentration ranged from 0.18 mgL⁻¹(T7) to 0.27 mgL⁻¹ (T1) with a mean concentration of 0.2 mgL⁻¹; Total Phosphorus concentration ranged from 0.01mgL⁻¹ to 0.03mgL⁻¹ (T5, T6 and T7) with a mean concentration of 0.02 mgL⁻¹(Site T4 and Site R4).

Table 3: Physico-chemical parameters of the sampling sites

Site Code	Temp. (°C)	pH	Nitrate-N (mgL)	Total Phosphorus (PO ₄ -P)(mgL ⁻¹)	Ammoniacal-N (mgL)	DO (mgL ⁻¹)
R1	0.5	8.7	0.23	0.01	N.D.	9.73
T1	-1	7.8	0.27	0.01	N.D.	10.13
T2	1	8.2	0.18	0.01	0.07	13
T3	2	8.1	0.2	0.01	0.06	9.73
T4	3	8.1	0.2	0.02	N.D.	11.75
T5	2.5	7.9	0.2	0.03	0.11	12.97
R2	2.5	8.3	0.2	0.01	N.D.	13.3
T6	5.5	8.2	0.08	0.03	0.27	8.9
R3	4.5	8	0.23	0.01	0.17	7
T7	8.5	8.3	0.18	0.03	N.D.	8.5
R4	6	8.3	0.22	0.02	N.D.	11.3

Macroinvertebrates Assemblages:

A total of 1666 individuals of macroinvertebrates were enumerated from the sampled sites. The highest number of individuals of macroinvertebrates were found at site R4 (443 individuals) whereas the lowest number of the individuals were found at site T1 (17 individuals). These individuals represented a total of 34 Families of the macroinvertebrates belonging to 7 Orders. With the exception of water mite, all macroinvertebrates represented the insect fauna. Dipterans were found to be the most dominant taxon in the study area representing 66.36% (1106 individuals), followed by Ephemeropterans with 23.71% (395 individuals); Trichopterans with 6.84% (114 individuals); Plecopterans with 1.86% (31 individuals); Coleopterans with 0.96% (16 individuals); Odonates with 0.18% (only 3 individuals) and water mite with 0.06% (only 1 individual). Chironomidae and Baetidae were found to occur in 10 sampling sites out of total 11 sampling sites (Table 4).

Site T6 and T2 were shown to have maximum numbers of Orders i.e. six Orders (16 Families and 14 Families respectively) followed by Sites T4 and T5 with five Orders (16 and 19 Families respectively); T3 with 5 Orders (13 Families); R4 with 4 Orders (11 Families); R2 with 5 Orders (10 Families); T7 with 3 Orders (8 Families); T1 with 4 Orders (6 Families); R3 with 2 Orders (5 Families); whereas, the least number of Families were found at R1 with two Orders (3 Families) (Table 4, Figure 3).

Table 4: Macroinvertebrate taxa at the sampling sites of the study area

Taxa	R1	T1	T2	T3	T4	T5	R2	T6	R3	T7	R4
Baetidae	7	10	59	12	6	28	16	51	-	51	80
Caenidae	-	-	-	12	1	3	-	-	-	-	-
Ephemerellidae	-	-	1	-	2	-	-	2	-	2	-
Ephemerellidae (<i>Drunella</i>)	-	-	-	-	-	-	-	1	-	-	-
Heptageniidae	1	2	-	7	9	2	27	3	-	-	-
Capniidae	-	1	2	8	-	1	-	-	-	-	-
Perlidae	-	-	-	1	1	2	-	-	-	-	-
Plecoptera indet. (a)	-	-	-	-	-	-	-	1	-	-	-
Plecoptera indet. (b)	-	-	-	-	-	-	13	-	-	-	-
Plecoptera indet. (c)	-	-	-	-	-	-	1	-	-	-	-
Hydropsychidae	-	-	9	1	1	1	-	3	-	-	-
Philopotamidae	-	-	4	1	6	6	-	-	-	-	3
Rhyacophilidae	-	-	-	-	3	1	-	7	-	-	-
Stenopsychidae	-	-	-	-	5	3	-	-	-	-	-
Trichoptera indet. (a)	-	2	5	2	3	2	2	1	1	5	2
Trichoptera Indet. (b)	-	-	-	-	-	-	-	35	-	-	-
Athericidae	-	1	2	-	-	-	-	-	-	-	-
Blephariceridae	-	-	-	-	1	-	-	-	-	-	-
Ceratopogonidae	-	-	-	-	-	-	1	-	-	1	3
Chironomidae	34	-	186	112	19	57	40	39	71	82	335
Limoniidae(<i>Antocha</i>)	-	-	12	12	26	3	1	10	6	3	6
Limoniidae	-	-	-	1	1	1	-	-	-	-	3
Simuliidae	-	-	5	-	-	1	-	3	-	1	3
Tabanidae	-	-	-	-	-	1	-	2	1	-	1
Tipuliidae	-	1	-	-	-	-	-	-	-	-	-
Diptera indet. (a)	-	-	-	-	-	1	2	4	1	1	5
Diptera indet. (b)	-	-	1	3	-	-	-	-	-	-	-
Elmidae	-	-	-	-	2	1	-	-	-	-	-
Gyrinidae	-	-	-	-	-	-	1	-	-	-	-
Coleoptera indet. (a)	-	-	1	1	4	2	-	-	-	-	-
Coleoptera indet. (b)	-	-	2	-	-	-	-	-	-	-	-
Coleoptera indet. (c)	-	-	-	-	-	1	-	1	-	-	-
Gomphidae	-	-	-	-	-	-	-	1	-	-	2
Water mite	-	-	1	-	-	-	-	-	-	-	-
Total by site	42	17	290	173	90	117	104	164	80	146	443
Grand total	1666										

Indet: Indeterminate

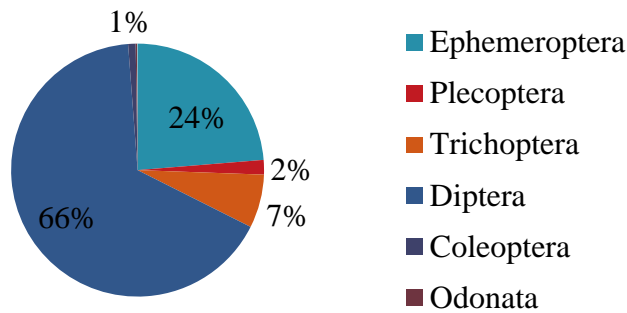


Figure 3: Percentage contribution of different Orders in the study area

Shannon's Diversity Index and Evenness:

The ShannonWeiner Diversity Index ranged from highest 2.2 (T4) to lowest 0.47 (R3); with a mean of 1.29. The highest value of evenness was 0.79 (T4) and lowest was 0.19 (R1); whereas, the mean evenness was 0.4 for the study area (Table 5). The range of Shannon's Diversity Index is 0.4 to 4.6 where 0.4 depicts very less diversity and 4.6 depicts the highest diversity. The value of evenness ranges from 0 to 1 where 0 refers to very less evenness and 1 refers to highest evenness. In the study area, site T4 (Ganai Khola) had moderate diversity (2.2) of the Families of macroinvertebrates along with the slightly more even distribution of the macroinvertebrates. The value of evenness at this site was 0.793.

Table 5: Shannon Weiner Diversity Index and Evenness of macroinvertebrates in sampling sites

Site Code	Shannon Diversity Index	Weiner Evenness
R1	0.56	0.187
T1	1.321	0.74
T2	1.183	0.45
T3	1.347	0.53
T4	2.2	0.793
T5	1.7705	0.6
R2	1.596	0.693
T6	1.911	0.6
R3	0.465	0.2809
T7	1.047	0.5
R4	0.83	0.345

Macroinvertebrate assemblages along the altitudinal gradient

21 Families of macroinvertebrates were observed in the Sub-tropical Ecological Zone (1000-2000 masl) and 19 Families were observed in Temperate Ecological Zone (2000-3000masl). The Chi-square test revealed that there was no significant variation between the macro-invertebrate assemblages with the altitudinal gradient for the studied area ($p > 0.05$) (Table 6). The communities of two altitudinal zones were moderately similar in their composition and the Sorensen's Similarity Index was observed to be 0.583. The families like Baetidae, Caenidae, Ephemerillidae, Capniidae, Hydropsychidae, Philapotamidae, Chironomidae, Limoniidae, Simuliidae were common to these two areas.

Table 6: Result of the Chi-square test showing difference in macroinvertebrate assemblages between the different ecological zones

Ecological zones	Observed	Estimated	(O-E) ²	(O-E) ² /E	$\chi^2(\text{tab})^*$	$\chi^2(\text{cal})^{**}$
Sub-Tropical Zone	29	28	1	0.0357	3.841	0.0357
Tropical Zone	19	19	0	0		

*Chi-square tabulated value; **Chi-square calculated value

Macro-invertebrate assemblages in the main river and its tributaries

A total of 31 Families of macroinvertebrates were found in the tributaries of the Seti whereas, only 14 Families were observed in the main river of the study area. There was no significant variation between the macro-invertebrate communities and the main river and its tributaries ($p > 0.05$) (Table 7). The Sorensen's Similarity Index (Table 8) was observed to be 0.49 indicating moderate similarity in macroinvertebrate composition between the main river and its tributaries. Baetidae, Heptageniidae, Philopotamidae, Chironomidae, Limoniidae (*Antocha*), Tabanidae, Ceratopogonidae, Gomphidae, Trichoptera¹ and Diptera¹ were observed in the both river and its tributaries of the study area.

Table7: Result of the Chi-square test showing difference in macroinvertebrate assemblages between the West Seti River and its tributaries

Rivers	Observed	Estimated	(O-E) ²	(O-E) ² /E	$\chi^2(\text{tab})^*$	$\chi^2(\text{cal})^{**}$
West Seti River	14	15	1	0.06	3.841	0.1979
Tributaries	31	29	4	00.1379		

*Chi-square tabulated value; **Chi-square calculated value

Table 8: Sorenson's Similarity Index between different ecological zones and between the West Seti River and its tributaries

Sites	Between ecological zones			Between the Main river and tributaries		
	Sub-tropical (A)	Tropical (B)	Common Families (C)	West Seti River(A)	West Seti River tributaries (B)	Common Families(C)
Families	29	19	14	14	31	11
Sorenson's Similarity Index	2C/ (A+B) 2*14/ (29+19) 28/48 0.58			2C/ (A+B) 2*11/ (14+31) 22/45 0.49		

Water Quality Class and Water Quality Map

On the basis of the NEPBIOS/ASPT (Sharma, 1996), T1 had WQC of I which indicates that the site was not polluted. The sites T4 and R2 had WQC of I-II (Slightly Polluted); sites R1, T2, T3 and T5 had WQC of II (Moderately Polluted); the sites T7 and R4 had WQC of II-III (Critically Polluted) Whereas, R3 had WQC of III-IV indicating very heavily polluted site (Table 9).

Table 9: NEPBIOS/ASPT based WQC

Sites	NEPBIOS/ASPT	Water Quality Class	Description	Color code
R1	6	II	Moderately Polluted	Dark Green
T1	8.75	I	Not Polluted	Dark Blue
T2	6.25	II	Moderately Polluted	Dark Green
T3	6.33	II	Moderately Polluted	Dark Green
T4	6.71	I-II	Slightly Polluted	Light Blue
T5	6.21	II	Moderately Polluted	Dark Green
R2	6.8	I-II	Slightly Polluted	Light Blue
T6	6	II	Moderately Polluted	Dark Green
R3	3	III-IV	Very Heavily Polluted	Red
T7	5.4	II-III	Critically Polluted	Light Green
R4	5.25	II-III	Critically Polluted	Light Green



Figure 4: Water Quality Colour Map of the Sampling sites

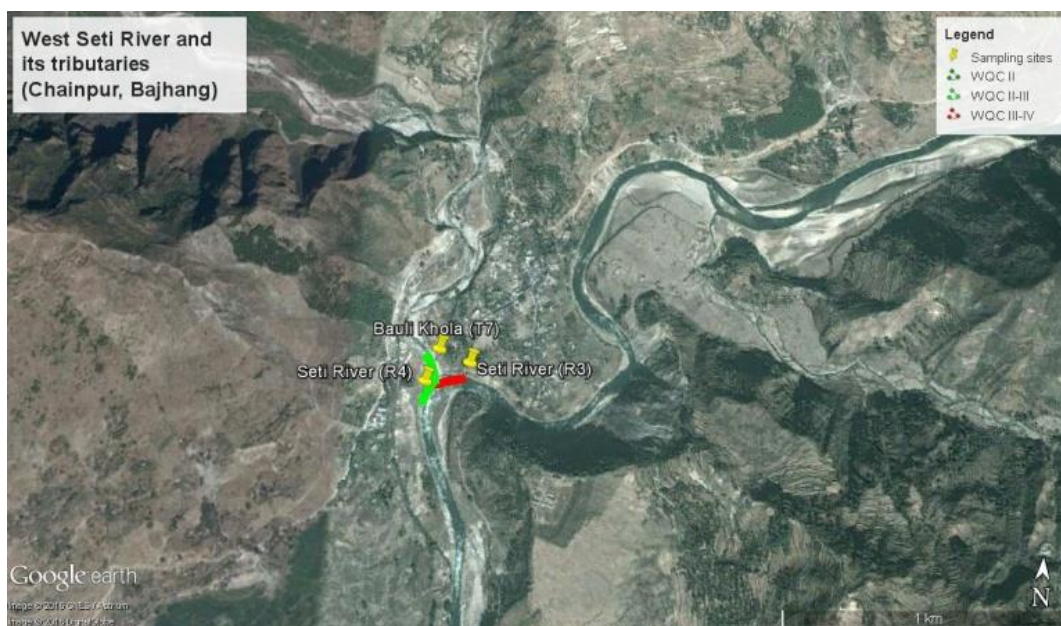


Figure 5: Water Quality Colour map of sites R3 (Red); T7 & T4 (Light Green)

Discussion

The mean pH of 8.16 at the sampled sites indicates the alkaline nature of the water in the West Seti River. The alkaline pH could be contributed by the presence of limestone and carbonates which has been reported in the West Seti (English et al., 2000). The DO concentration was higher particularly in R2. Running waters are known to contain higher DO values than stagnant water bodies. Apart from this, DO is also affected by temperature and there exists a reciprocal relationship between DO and temperature (Wetzel, 2001). In the sampling sites, the surface water temperature was low (Table 3) and this could be the reason for higher DO values.

Insects are often the most dominant macroinvertebrate assemblages in streams and rivers (Merrit and Cummins, 1986). Among the different freshwater macroinvertebrate taxa, Ephemeropterans, Plecopterans, Trichopterans and Diptera were found to be the common taxa and these taxa are considered as the major components of the benthic community (Nautiyal et al., 2004). A number of physico-chemical parameters such as substrates, water temperature are known to affect the macroinvertebrate assemblages in streams and rivers (Mishra and Nautiyal, 2013). Ephemeroptera and Plecoptera are considered as pollution sensitive taxa and are indicators of clean water (Alam et al., 2008). Dipteran and Oligochaetes are considered as pollution tolerant groups (Dhakal, 2006). Similarly, Baetidae are known to be tolerant to sedimentation and nutrient enrichment (Harrington and Born, 2000). Apart from this, Baetidae, Simuliidae and Chironomidae are known to be persistent in high altitudes and high latitudes (Ormerod et al., 1994; Lencioni et al., 2012) along with Heptageniidae. Similar assemblages of macroinvertebrates have also been reported from elevation of 2000- 3000 masl in Nepal (Suren, 1994) as well as India (Mishra and Nautiyal, 2013).

Family Chironomidae belonging to Diptera was the most dominant taxa and this finding is in accordance with previous findings elsewhere (Oliveira, 2010; Scheibler, 2014). This taxon can be found in a range of physico-chemical conditions and have been reported to be one of the most dominant taxa in cold temperatures (Lencioni et al., 2012). Apart from this, the red Chironomids are also good indicators of

organic pollution (Machado et al., 2015). The dominance of Chironomids in the sampled sites explains the dominance of Dipterans in this study.

Site R3 (Seti River at Chainpur before confluence) had the dominance of Chironomids. Chironomidae is commonly known as indicators of multiple stressors (Machado et al., 2015) and the dominance of red Chironomids at this site suggests that it is polluted. There was direct discharge from the hotels and the household effluents of Chainpur Municipality were also discharged directly to the river without any treatment. High human activities around the river releasing waste into the river are accounted for the poor species richness (Okorafor et al., 2012). Accordingly, Site R3 showed only five benthic invertebrate Families. Hydropsychidae was found at only 5 sites of the study area. Although, Hydropsychidae is believed to be in mid-range for tolerances of environmental stressors; they are one of the more tolerant species in caddis flies group (Harrington and Born, 2000).

Water Quality Class (WQC) and Water Quality Map

The WQC values of I (T1), I-II (T4 and R2) , II (R1, T2, T3, T5 and T6) , II-III (T7 and R4) and III-IV (R3) shows site T1 not polluted, T4 and R2 slightly polluted, R1, T2, T3, T5 and T6 moderately polluted, T7 and R4 critically polluted and site R3 was very heavily polluted. Macroinvertebrate assemblage also reflected that site R3 was the most polluted with red Chironomids as the most dominant taxon. Macroinvertebrate assemblages are considered appropriate bioindicators of stream and river water ecological conditions are frequently used to assess these ecosystems (Harrison et al., 2007). A number of macroinvertebrate-based score systems have been developed in Nepal also (Sharma, 1996; Neseemann, 2009; Ofenböck et al., 2010) and have been used in a number of bioassessment studies of streams (Sharma et al., 2005; Gurung et al., 2016). These organisms have provided consistent results with corresponding stressors present in the water bodies proving these organisms as effective bioindicators of aquatic health.

Conclusion

The study dealt with water quality status of the West Seti River using macroinvertebrates as biological indicators. The macroinvertebrate assemblages did not show significant variation between the eco-regions

as well as the river and its tributaries. Site R3 was very heavily polluted due to direct discharge of effluents from Chainpur Municipality. The site was also shown to have the lowest Shannon Diversity Index (0.46) with the dominance of red Chironomids. NEPBIOS/ASPT also showed WQC III-IV at this site indicating that aquatic macroinvertebrates are appropriate indicators of water quality status. The study could not encompass the impacts of season on the macroinvertebrate communities. Nevertheless, this study has generated baseline macroinvertebrate assemblages of the West Seti River. A more comprehensive study encompassing different seasons combined with other physico-chemical parameters could generate more information about the overall ecological status of the West Seti River.

Acknowledgements

This research work was funded by Department of Environment, Kuponhole and CREEW (Centre of Research for Environment, Energy and Water), Baluwatar, Kathmandu.

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