Biomonitoring of Health of Chubachu Stream Using Macroinvertebrate Diversity

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Abstract

Biomonitoring, to assess the water quality of the Chubachu stream was conducted using macroinvertebrate diversity as an indicator to determine the level of pollution and the impact of wastewater discharge from settlements along the stream. The study site was divided into two zones based on the density of settlements as dense or sparse, with 3 sampling points in each zone. The assessment was performed using the Biological Monitoring Working Party (BMWP) score system. A total of 693 specimens were collected belonging to 19 families. The study found that the level of water pollution is directly correlated to settlement density. The water flowing through the sparse settlements is substantially lesser polluted compared to a densely populated area. The study found 4.5 – 61500 CFU/100mL of thermotolerant coliform in the area, significantly higher than the permissible limit for drinking water as per Bhutan Drinking Water Quality Standard (BDWQS) & World Health Organization (WHO); which is 0 CFU/100mL. The study also found that the discharge of untreated sewage and dumping waste directly into the stream is the primary source of pollution. Realigning sewage discharge into municipality sewage network, treatment of wastewater, and proper management of waste by residents living along the stream can help reduce pollution and improve the water quality.

Key words: *Chubachu stream, macroinvertebrate, BMWP, biomonitoring, water pollution*

Introduction

Freshwater sustains and supports the diversity of life including aquatic biodiversity. Bhutan has rich freshwater resources in varieties of glaciers, lakes, wetlands, marshes, springs, streams and rivers. Bhutan is known to have abundant freshwater resources with a per capita availability of 94,508 cubic meters per person annually, one of the highest in the world (Wangdi, Yoezer & Wangchuk, 2018). Freshwater is used for domestic purposes, drinking and irrigation besides its essential role in all four of Bhutan's major economic drivers – agriculture, hydropower, tourism and small-scale industry (National Environment Commission [NEC], 2016). It is therefore essential to know and value our freshwater resources and use them sustainably.

The streams are one of the important habitats that host various aquatic species and it is important to monitor and maintain their quality. One of the ways to monitor streams is through the use of macroinvertebrates as an indicator. Chubachu stream is one of the many streams flowing through Thimphu city, home to approximately 114,551 people (National Statistics Bureau of Bhutan, 2018), at an altitude of 2350 meters above sea level. In 2017, the National Environment Commission Secretariat in collaborative partnerships with the Royal Society for Protection of Nature (RSPN), Bhutan Red Cross Society, Clean Bhutan and Thimphu municipality, adopted the Chubachu stream to maintain it clean. The adoption was expected to control stream contamination, manage waste and instil the mindset of proper waste management through education and awareness (RSPN, 2017). The adoption of the Chubachu stream was followed by a mass cleaning campaign resulting in the removal of massive waste. The organizations also agreed to clean the stream every month, however, with the passing days, the participation of partner organizations reduced drastically, and despite occasional cleaning by RSPN, it showed no improvement in the quality of water (RSPN, 2019). The water from the stream is probably used by the residents as there are eight locations were water is being tapped through pipelines. The largest of all the facilities is the tank below the bridge near the Faculty of Traditional Medicine. Despite its regular use and proximity to the settlements, no assessment has been conducted to check the quality and health of the stream. Therefore, in this study, we used macroinvertebrates as a bioindicator to assess the level of pollution and health of the Chubachu stream.

Materials and Method

i. *Study Area*

The Chubachu stream flows through the Thimphu city starting at an altitude of 2800m to 2350m. From the source, the stream flows through Royal Takin Preserve where there is a sparse human settlement and passes via the densely populated areas, namely Motithang, Kawajangsa and joins Wangchhu below Chubachu resident.

In this study, the stream was stratified into two zones based on the density of settlement and six sampling points (Table 1) were selected to collect data, as shown in figure 1. The stream is located at the core of Thimphu municipality, with settlements on either side that warrant impact assessment due to the disposable of garbage, improper discharge of sewage and filthy drain water from the highway.

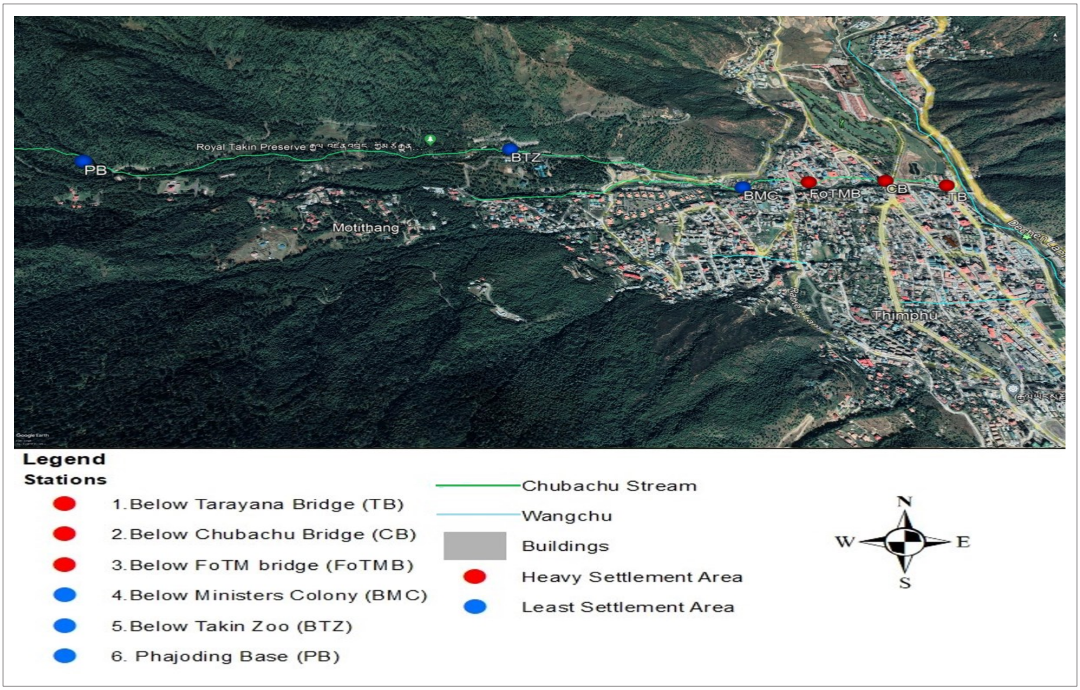

Figure 1: Map Showing the Study Area and Sampling Points

Table 1: GPS Locations Sampling Points and Settlement Density

Stream name	Sampling station	Geographical position	Household	Settlement status
Chubachu	1.Below Tarayana Bridge (**TB**)	27.4800, 89.6385	150-300	Dense settlement
	2.Below Chubachu Bridge (**CB**)	27.4802, 89.6352		Dense settlement
	3.Below Faculty of Traditional Medicine bridge (**FoTMB**)	27.4799, 89.6310		Dense settlement
	4.Below Ministers Colony (**BMC**)	27.4793, 89.6274		Sparse settlement
	5.Below Takin Zoo (**BTZ**)	27.4815, 89.6155	<50 0r 50-100	Sparse settlement
	6. Phajoding Base (**PB**)	27.4789, 89.5956		Sparse settlement

ii. Methodology

Biological Monitoring Working Party - Score System (BMWP) created by Hellawell in 1978 was used to assess the health of the stream using macroinvertebrates as bioindicators. BMWP index is simple and easy to apply, which requires only taxonomic identification of the invertebrates at the family level and even accepts the order or class for some groups. The overall BMWP score evaluated as sum of all scores of each taxon (class, order or family) present in the study site and, the total determines the biological evaluation of the watershed (Table 2) (Uherek & Pinto Gouveia, 2014).

As per Alba-Tercedor (1996), the score obtained indicates water quality as; very good; good; questionable; moderate; poor or very poor categories. The quality of water is interpreted as clean water; clean or not significantly altered; clean but slightly impacted; moderately impacted; polluted or impacted; and heavily polluted.

Each invertebrate taxon gets a score that reflects their susceptibleness to pollution. Pollution-intolerant taxa receive high scores, whereas pollution-tolerant taxa are given low scores (Uherek & Pinto Gouveia, 2014). The BWMP taxa score is based on the study conducted by Uherek & Pinto Gouveia (2014), with the addition of three families Heptageniidae, Limnephilidae and Ephemerellidae (Walley & Hawkes, 1997) (Table 3).

Table 2: BMWP Classes, Scores, Categories, and Results Interpretation

Class	BMWP Score	Category	Interpretation
I	> 150 101-149	Very Good Good	Very Clean Water Clean or not Significantly Altered
II	61-100	Questionable	Clean but Slightly Impacted
III	36-60	Moderate	Moderately Impacted
IV	16-35	Poor	Polluted or Impacted
V	0-15	Very Poor	Heavily Polluted

Table 3: BMWP Taxa Scores (Class, Order, or Family)

Taxa		Score
Class/Order	**Family**	
Ephemeroptera	Leptophlebiidae, Leptohphidae, Heptageniidae, Ephemerellidae	10
Plecoptera	Perlidae	
Trichoptera	Brachycentridae, Leptoceridae, Odontoceridae, Sericostomatidae	
Odonata	Coenagrionidae, Calopterygidae, Cordulegastridae, Gomphidae, Libellulidae	8
Trichoptera	Calamoceratidae, Glossomatidae, Philopotamidae, Psychomyiidae	
Plecoptera	Nemouridae	7
Trichoptera	Polycentropodidae, Limnephilidae	
Trichoptera	Hydrobiosidae, Hydroptilidae	6
Coleoptera	Elmidae, Dryopidae	5
Diptera	Simuliidae, Tipulidae	
Ephemeroptera	Euthyplociidae, Polymitarcidae	
Tricladida	Planariidae	
Trichoptera	Helichopsychidae, Hydropsychidae	
Arachnida	Hidracarina	4
Coleoptera	Chysomelidae, Curculionidae, Haliplidae	
Diptera	Anthomyidae, Ceratopogonidae, Chaoboridae, Dixidae, Dolichopodidae, Empididae, Limoniidae, Psychodidae, Stratiomyidae, Tabanidae	
Ephemeroptera	Baetidae, Caenidae	
Megaloptera	Corydalidae, Sialidae	
Coleoptera	Dytiscidae, Gyrinidae, Helodidae, Hydrophilidae, Notoridae	3
Hemiptera	Belostomatidae, Corixidae, Gerridae, Hydrometridae, Limnocoridae, Mesovellidae, Naucoridae, Nepidae, Notocectidae, Pleidae, Vellidae	
Diptera	Chironomidae, Culicidae, Ephydridae, Muscidae, Thaumaleidae	2
Oligochaeta	Lumbricidae	1
Blattodae	Blattidae	
Diptera	Sciomyzidae, Syrphidae, Thagionidae	

Shannon–Wiener (H) diversity index was also used to determine water quality (Equation 1). World Health Organization (WHO) (2011 & 2017) and Bhutan Drinking Water Quality Standard (BDWQS) (2016) were used to find out the variables responsible for the pollution.

$$H = \sum_{i=1}^{s} -(P_i * \ln P_i) \quad \textbf{Equation 1}$$

Where:
H = the Shannon diversity index
P_i = fraction of the entire population made up of species i
S = numbers of species encountered
∑ = sum from species 1 to species S

iii. Environmental variables

A total of five Physico-chemical parameters and thermotolerant coliform were analyzed (Table 5). The physicochemical parameters include temperature (□C), pH, conductivity (µS/cm), total dissolved solids (TDS) in mg/L and turbidity (NTU). The Royal Centre for Disease Control, Ministry of Health, analyzed the physicochemical parameters and thermotolerant coliform once a month from October to November 2019.

iv. Macroinvertebrate Sampling

Macroinvertebrate sampling was conducted twice from October to November 2019. The insects grow into a bigger size that can be best identified (Hill, Sayer, & Wood, 2016) in this period. Macroinvertebrate were sampled using kick net (30cm X 30cm) in riffle habitats and pools. Six sampling stations were selected considering different aquatic habitats. The kick net was held against the stream current in the riffle habitat, and the stream bed of area 30cm X 30cm in front of the net was disturbed for around two minutes. In pools, the net was jabbed about ten times along an area of 30cm X 30cm (Gurung & Dorji, 2014). In each reach, two riffles and two pools samples were taken. Samples were live picked in the field on a sorting tray using forceps. The sampling always started from the downstream to upstream to avoid the repeated collection of specimens. The specimens were preserved in 70% ethanol in specimen bottles and labelled with location, date, time, GPS coordinates and altitude. The macroinvertebrates were identified through family using Bouchard, Ferrington & Karius (2004), Birmingham *et al.* (2005), Subramanian & Sivaramakrishnian (2007) and Nesemann, Shah & Shah (2011).

Result

A total of 693 specimens belonging to 19 families were collected from 6 sampling points. Baetidae (n = 192) was the most abundant Family followed by Hydropsychidae (n = 108) Lumbricidae (n = 87), Tipulidae (n = 72), Heptageniidae (n = 69), Gomphidae (n = 51), Perlidae (n = 30), Planariidae (n = 18), Psychomyiidae (n = 15) Philopotamidae (n = 15), Hydrophilidae (n = 9), Ephemeridae (n = 6), Polymitarcyidae (n = 3), Caenidae (n = 3), Corydalidae (n = 3), Brachycentridae (n = 3), Limnephilidae (n = 3), Cordulegastridae (n = 3) and Nemouridae (n = 3) (Figure 2). After the identification, qualitative values (BMWP index) were assigned to each taxon as given in Tables 4 & 5 below. The sum resulted in 38 points for station 1 (TB), 31 points for station 2 (CB), 28 points for station 3 (FoTMB), 43 points for station 4 (BMC), 64 points for stations 5 (BTZ) and 87 points for station 6 (PB) (Table 5). Accordingly the water quality at station 1 (TB) was found moderately impacted, station 2 (CB) polluted or impacted, station 3 (FoTMB) polluted or impacted, station 4 (BMC) moderately impacted, stations 5 (BTZ) and station 6 (PB) was clean but slightly impacted.

To study the diversity of the macroinvertebrate families, we calculated Shannon-Wiener diversity index as given in Table 5. We found that sampling point 3 had lowest diversity while point 6 had the highest.

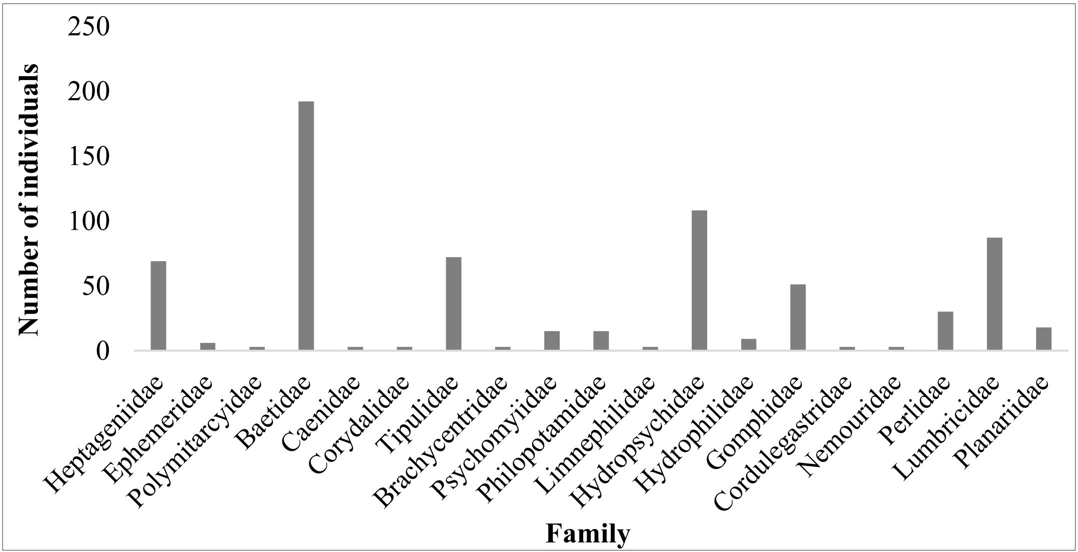

Figure 2*: Number of Individual Insects Sampled In each Family*

Table 4: The Overall Composition and Distribution of Macroinvertebrates in the Chubachu Stream Sampling Points

Macro-invertebrates		Sampling points					
Order	Family	1	2	3	4	5	6
Ephemeroptera	Heptageniidae				+	+	+
	Ephemeridae						+
	Polymitarcyidae						+
	Baetidae	+	+	+	+	+	+
	Caenidae						+
Megaloptera	Corydalidae					+	
Diptera	Tipulidae		+	+	+	+	+
Trichoptera	Brachycentridae					+	
	Psychomyiidae	+					+
	Philopotamidae						+
	Limnephilidae						+
	Hydropsychidae	+	+	+	+	+	+
Coleoptera	Hydrophilidae		+				+
Odonata	Gomphidae	+	+	+	+	+	+
	Cordulegastridae					+	
Plecoptera	Nemouridae	+					
	Perlidae				+	+	+
Tricladida (Platyhelminthes)	Planariidae	+	+	+			
Oligochaeta (Lumbricidae)		+	+	+	+		

Table 5: Mean Values of Obtained Water Quality Parameters, Diversity Index and BMWP Score

Study area		Variables							
Zones	Stations	Thermotolerant coliform (CFU/100mL)	Conductivity (µS/cm)	TDS (mg/L)	pH	Turbidity (NTU)	Temperature (°C)	Diversity index (H)	BMWP score
Heavy settlement	TB	46750*	74.99	37.3	7.13	4.1	11	1.6	38
	CB	52150*	77.06	38.2	7	4.79	10.5	1.8	31
	FoTMB	61500*	69.38	34.5	6.93	3.86	10.3	1.39	28
Least settlement	BMC	22400*	59.11	29.5	6.86	2.13	9.75	1.77	43
	BTZ	126*	25.21	13.2	7.58	1.71	9.25	1.94	64
	PB	4.5*	22.34	11.5	8.4	0.77	8.5	2.13	87
WHO, 2011 & 2017 Standard		0	1000	250	6.5-8.5	5	NGG		

NGG= No guideline given
* = Exceeding permissible limit

Discussion

The research area was divided into two, namely dense settlement and sparse settlement, based on the density of settlements. Under each zone, 3 sampling points were identified from where sampling was done to see the impact of settlements using biomonitoring method. Following BMWP standards, two out of three sampling points located in a densely populated area; Below Chubachu Bridge (CB) and Below Faculty of Traditional Medicine Bridge (FoTMB) were found polluted or impacted whereas point Below Tarayana Bridge (TB) is moderately polluted. Two sampling points; Phajoding Base (PB) and Below Takin Zoo (BTZ) located at the sparsely populated area were clean but slightly affected and the station Below Ministers Colony (BMC) is moderately polluted.

Shannon-Wiener diversity index of macroinvertebrates in the study area ranged from 1.39 to 2.13. Sampling point 3 in the densely populated area had the lowest diversity index while sampling point 6 at sparsely populated area had the highest diversity (Table 5). This study found that macroinvertebrate diversity is inversely correlated to the intensity of pollution while the level of pollution is directly linked to the density of settlement. Therefore, it is pertinent that water pollution caused by sewage discharge and dumping of waste along the stream is severely impacting the macroinvertebrate diversity and health of the stream.

The study also found that the concentration of thermotolerant coliform CFU/100mL is directly correlated to the density of settlement. Research conducted by Jabbar (2013) and Poma, Mamani & Iniguez (2016) displayed similar findings. The primary source of thermotolerant coliform was from direct discharge of sewage and septic waste into the stream from the households' closets to the stream. It also revealed that temporary camps of construction workers have poor hygiene and, waste from their septic tanks are discharged directly into the stream. The stream flowing through sparsely populated areas and further away from settlements, on the other hand, contained minimal thermotolerant coliform contamination. Therefore, the primary source of thermotolerant coliform contamination along the stream is a result of improper management of the sewage by residents and temporary workers in the area.

Table 6: Major Contamination Points and Sources along the Stream

Sl. No.	sampling stations	Coordinates	Sewage
1	Phajoding Base (PB)		
		27.4788, 89.5969	Drainage
		27.4789, 89.5975	Toilet outlet
2	Below Takin Zoo (BTZ)		
		27.4799, 89.6245	Drainage
		27.4798, 89.6247	Drainage
3	Below Ministers Colony (BMC)		
		27.4793, 89.6261	bathroom drainage
		27.4794, 89.6260	drainage
		27.4794, 89.6261	small drainage and dumping area
		27.4794, 89.6266	drainage
		27.4793, 89.6270	toilet
		27.4793, 89.6273	dumping and drainage
		27.4795, 89.6280	drainage
		27.4793, 89.6284	dumping area
		27.4793, 89.6298	toilet sewage
		27.4795, 89.6302	drainage
		27.4795, 89.6305	dumping and filtration
4	Below Faculty of Traditional Medicine Bridge (FoTMB)		
		27.4798, 89.6320	drainage opposite
		27.4799, 89.6319	Dumping
		27.4803, 89.6348	Drainage from Telecom
		27.4801, 89.6353	drainage Chubachu bridge
5	Below Chubachu Bridge (CB)		
6	Below Tarayan Bridge (TB)		

Conclusions

The Chubachu stream is located at the centre of Thimphu city. The stream is used as a source of water by many communities. Biomonitoring using macroinvertebrates showed that the stream's pollution levels are correlated to the settlement density. For instance, the part of the stream flowing through the sparse settlement area had significantly less pollution compared to the part of the stream flowing through the dense settlement area. The study found 4.5 - 61500 CFU/100mL of thermotolerant coliform in the study site, exceeding the permissible limit for drinking water as per Bhutan Drinking Water Quality Standard (BDWQS) & World Health Organization (WHO). Thus, confirming thermotolerant coliform as a variable responsible for the pollution of the stream. The primary source of thermotolerant coliform contamination along the stream is a result of improper management of the sewage by residents and temporary workers in the area.

Sewage and untreated wastewater discharge into the stream should be immediately disconnected and realigned into the proper network. Public education and awareness on the impact of untreated sewage discharge into the stream and environment should be carried out. Besides, residents should be made responsible for managing their waste and sewage. Water from the stream must be treated (boiling, biological, chlorination) before use, to minimize the health risk. Monitoring and strict enforcement of relevant rules, regulations, and policies, on waste and water, can potentially reduce stream pollution. The construction workers living temporarily along the stream should be monitored and enforced to use proper toilets and sanitation. The water from the stream, if maintained clean, can be used to solve water scarcity in the area and, it could be exemplary for other developing cities across Bhutan facing water crises.

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