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Biological Assessment of Major Water Bodies of Metropolitan Region Kolkata

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Abstract

Benthic macroinvertebrate monitoring or biological monitoring is use of biological responses for populations and communities of certain indicator organisms to evaluate anthropogenic environmental changes. Biomonitoring is a special way of assessing water quality using macroinvertebrates to find the Saprobic score and Diversity score to indicate the level of pollution as well as to assess the biological quality of water. It entails the use of indicator species, generally, benthic macroinvertebrates/ fish and algae communities as well as certain aquatic plant species are also used. From several studies, benthic macro-invertebrate populations have been regarded as the most acceptable biological parameter to assess the quality of water out of all the biotic components. The mapping based on bio-monitoring has been proven as a powerful tool for the preparation of future action plans to control water pollution and improve the water quality of water bodies. The present study has been conducted in four major water bodies of city, Kolkata (West Bengal) using benthos monitoring to understand the prevailing scenarios.

The benthos samples were collected from all the four water bodies selected for study, sieved, washed, and transferred into a large tray for identification purposes and classified according to their taxa. As per the score obtained, most of the sampling sites were found to be moderately polluted. Gastropods, annelids, crustacea, and insects made up the majority of the benthic macro-invertebrate species that were collected. The various opportunities and lessons learned from past experiences of monitoring of different water bodies have also been included in this study. The details and significance of the work have been discussed in the full paper.

Keywords: Biomonitoring, Benthos, Water Quality, Pollution, Diversity

Introduction

The basic concept of using benthic macroinvertebrates in biological water quality monitoring as indicator species is of central importance nowadays (Rout, 2010). Various procedures are available to assess the quality of water of both lotic (flowing waters such as streams) and lentic (still waters such as lakes) waterbodies; among which physicochemical parameters such as temperature, Dissolved oxygen (DO), Chemical oxygen demand (COD), Biochemical oxygen demand (BOD), pH, chlorides, alkalinity of waterbodies are mostly prioritized. The physicochemical parameters routinely practiced, however only provide a quick snap-shot of the condition of a waterbody. These cannot detect the impacts of toxicants that are dynamic in nature, failing to give a comprehensive assessment of the state of waterbodies at times, and thus inappropriately identifying contaminated waters (United States Environmental Protection Agency, USEPA, 2005). Biomonitoring using benthic macroinvertebrates provides a detailed, comprehensive assessment of the health of a waterbody over a long period of time (Karr,1999). Therefore, biological objectives can be added to supplement the physicochemical parameters while assessing the quality of a waterbody (Yoder and

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Rankin, 1998; Karr, 1995; Yoder, 1995). As 98% of animal species are invertebrates in the animal kingdom, benthic macroinvertebrates, which are small aquatic invertebrate animals and the aquatic larval stages of insects (including dragonfly and stonefly larvae, snails, worms, beetles, etc.), are majorly used in biomonitoring to determine the biological water quality in terms of the Saprobic and Diversity score. From several studies, benthic macro-invertebrate populations have been regarded as the most acceptable biological parameter to assess the quality of water. The ubiquitous and sedentary nature of benthic macroinvertebrates (Rosenberg and Resh, 1993), their cumulative response to stress, the length of their life cycles, and their long-term exposure to toxic substances (Rossaro *et al.*, 2011; Szivák, and Csabai, 2012) collectively favors their utilization as an important bio-indicator within the environmental policies (Yoder and Rankin, 1998). Moreover, adapting biological monitoring using benthic invertebrates can be efficient, simple to grasp, and cost-effective. The benthic macroinvertebrates usually live in inmate contact with the sediments, which enhances their interaction with various pollutants, and thus their community structures are influenced by the level of exposure to pollutants (Bhadrecha *et al.* 2016; Khatri *et al.* 2020). In India, various studies have been conducted on river using benthic macroinvertebrates (Singh *et al.*, 2019), Recently, CPCB has conducted a study on River Ganga using benthic macroinvertebrates (CPCB, 2017). Changes in distribution patterns of macroinvertebrates due to anthropogenic activities are recorded in rivers Teesta and Ganga (Bhatt & Pandit 2010; Nautiyal, 2010). In 2015, a study was conducted on benthic macroinvertebrates in river Mahi and it was reported that the water was polluted (Khatri *et al.*, 2021). For stream benthic macroinvertebrate monitoring, a survey was conducted by USA state agencies (Carter & Resh, 2001). Different types of biomarkers based on their effectiveness, suitability, specificity to certain pollutants, their ability to detect different chemicals, ecological relevance have also been used according to their suitability while lot many more biomarkers are still under trial to be included in the water monitoring programme (Kumari and Khare, 2018). Indices based biomonitoring approach has been exploited internationally to assess the status of water bodies, for example in ETHbios is such biomonitoring tool developed for assessing streams and rivers in Ethiopia (Mezgebu, A., 2022). The use of benthic macroinvertebrates increased dramatically in the past few decades in both North America and Europe in the biological assessment of water quality in lakes and streams (Rosenberg, and Resh, 1993; Tampo et al, 2021). However, such monitoring reports are scarcely available for the major water bodies of Kolkata and therefore the present study was undertaken to comprehend the present scenario of the biological water quality status.

Materials and Methods

Sampling Sites: Four sampling sites were selected in and around Kolkata, West Bengal (**Figure 1**) based on reconnaissance survey conducted in January, 2023 followed by detailed study in the month of February and March, 2023. These water bodies were Rabindra Sarovar (S-1), Subhash Sarovar (S-2), Santragachi Jheel (S-3), and East Kolkata Wetlands (S-4).

Rabindra Sarovar Lake (S- 1) (Coordinates- 22.5121°N, 88.3637°E) is a 72-acre artificial lake located near Dhakuria with a length of 1770 m and a width of 206 m. It is a rain-fed water body (Khan & Sinha, 2002) and is majorly used for recreational activities. Subhas Sarovar Lake (S-2) (Coordinates- 22.5684°N, 88.4007°E) is also a manmade artificial lake located at Beleghata covering an area of approximately 39 acres. It is 366 m in width at its broadest point and 533.3 m in length where moderate human intervention such as bathing, washing clothes, dumping food leftovers, etc. takes place. Santragachi Jheel (S- 3) (Coordinates- 22.5813°N, 88.2841°E), locally known as 'Makal Jheel' is an important urban wetland of Howrah, West Bengal, India. It is spread over an area of almost 31.57 acres with a length and width of 915 m and 305 m respectively. It is locally regarded as a bird sanctuary as it draws prominent migratory birds in the winter season. East Kolkata Wetland (S- 4) (Coordinates- 22.5528°N, 88.4501°E), is one of the largest assemblages of sewage-fed fish ponds located in the Eastern region of Kolkata. It covers an area of nearly 30888.173 acres and consists of 37 mouzas of South and North 24 Parganas district and Kolkata district (Ghosh and Das, 2020). It is an important Ramsar site and is known to be one of the largest waste waters fed aquaculture systems in the world. This wetland is also called the "Kidney of East Kolkata" as it has a crucial role in purifying sewage water (Ghosh *et al.*, 2018).

Collection, Identification, and Preservation of Benthic macroinvertebrates: Benthic samples were primarily collected from three separate points of each sampling site, and the invertebrates were sampled both qualitatively and quantitively for the saprobic and diversity scoring. Standard protocol for benthic invertebrates sampling techniques was followed (CPCB, 2017) where hand nets were used to collect the samples from the substratum, a 0.6 mm pore-sized sieve was used to collect the benthic invertebrates directly from the roots of aquatic plants and a shovel to collect the benthic samples from mud, clay, and sandy substratum. After collection, the organisms were washed and transferred into collection bottles for further identification (taxonomical groups) and scoring purposes.

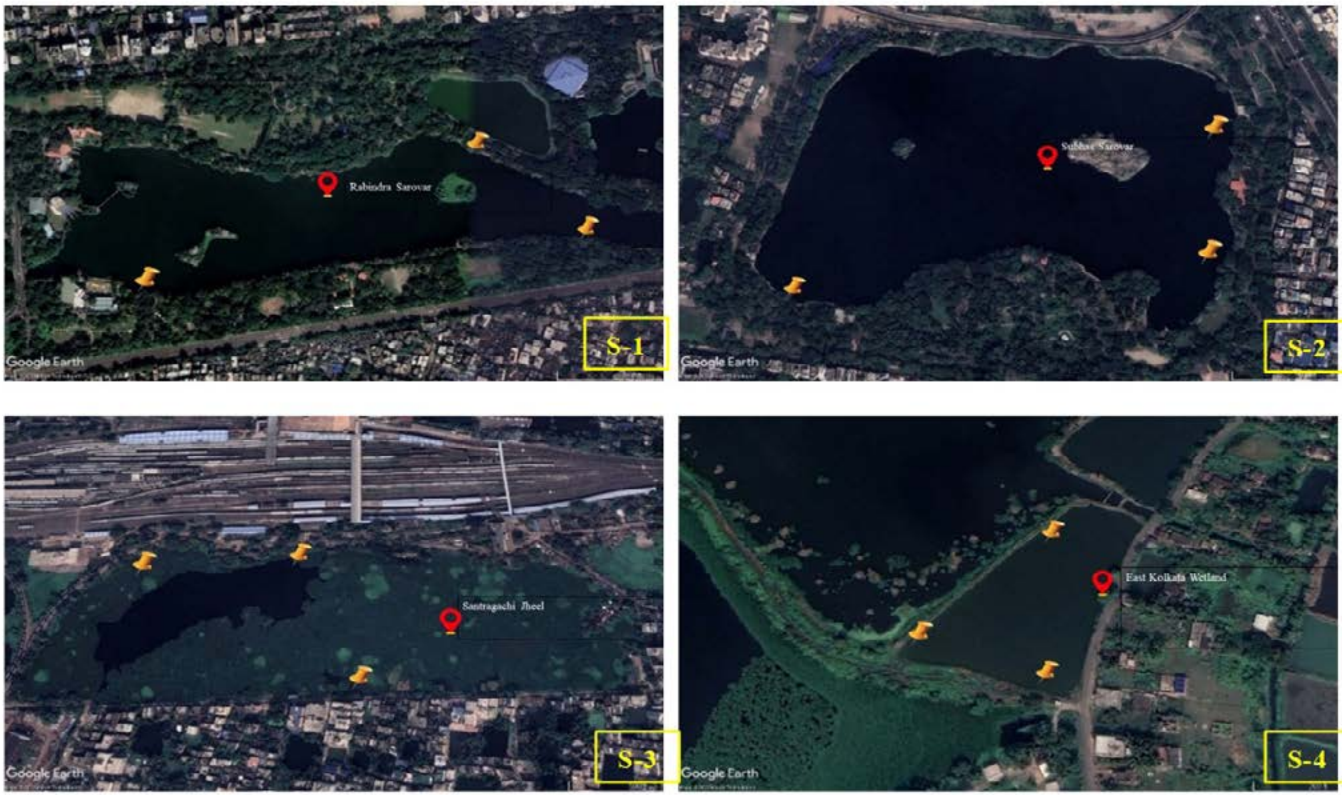

Figure 1: Satellite image of all the four sampling locations i.e. S-1: Rabindra Sarovar, S-2: Subhash Sarovar, S-3: Santragachi Jheel and S-4: East Kolkata Wetlands. [Legends: - Sampling site, - Sampling point.]

Calculation of Saprobic and Diversity Score

The saprobic score and the diversity score of each sampling site (Khatri *et al.*, 2021; Varnosfaderany *et al.*, 2010; Armitage *et al.*,1983) were determined using the following formulas given in standard operating procedures (SOPs) of CPCB:

$$\text{Saprobic Score} = \frac{\text{Grand total of multiplied score}}{\text{Grand total of number of families encountered}}$$

$$\text{Diversity Score} = \frac{\text{Total number of runs}}{\text{Total number of organisms}}$$

The saprobic score [Biological Monitoring Working Party (BMWP] shows the presence of benthic macro invertebrate's up to the family level with relation and accuracy up to genus level of taxonomic precision. All the families are classified here with scale between 0-10 according to their preference for saprobic water quality. The families that are most sensitive to pollution are placed at the top of the table and get the highest score of 10 while the species that are tolerant to pollution gets score of 1 and 2. The other species that are intermediate gets score between 10-1.

The diversity Score is the ratio of the total of different animals found (runs) with the total number of organisms encountered. The ratio of diversity score has a value between 0 and 1.

On the basis of the range of saprobic score and diversity score the biological water quality criteria (BWQC) has been derived by CPCB for evaluating the water quality (Table-4).

Water samples were also collected from each site and physical parameters such as water depth, temperature, pH, dissolved oxygen (DO), and flow rate were measured (Table 1) following the Standard Methods (APHA,1989).

Results and Discussion

The benthic macroinvertebrate samples, collected from 4 sites were identified according to their taxonomical groups, classes, families, and order with the help of identification keys. The identified species mostly consisted of Gastropods, Annelids and Crustacea (Table 2). Furthermore, the presence or absence of anthropogenic intervention at each site influenced the thriving of the benthic species and thus were also simultaneously correlated with the reported invertebrates. At S-1, there were no sewage discharges found; the main source of water was runoff water which was mostly used for recreational purposes. Moderate macrophyte growth was found in the littoral area of the lake at the time of sampling. Notable invertebrates that were recorded from S-1 included Gastropoda, family Viviparidae, Thiaridae, and Lymneidae; Annelida, family Salifidae (*Barbronia weberi*) and Crustacea, family Atyidae and Palaemonidae. Also, species belonging to the order Odonata consisting of family Libellulidae, and Coenagrionidae, the order Coleoptera consisting of the family Hydrophilidae, the order Hemiptera consisting of the family Belostomatidae, and the order Lepidoptera consisting of the family Pyralidae were found (Plate 1). Fishes like *Glossogobius giuris* and *Tilapia sparrmanii* were also present in the samples collected. S-2, also a rainwater-fed ecosystem where moderate human activities like bathing, washing clothes and utensils, dumping food leftovers, fishing, etc. were noted having moderate macrophytes growth in its vicinity. Samples collected from S-2 included Gastropods of the family Viviparidae, Thiaridae, Lymneidae, and Planorbidae, two families of Crustacea (Atyidae and Palaemonidae), two families of Hemiptera (Nepidae and Belostomatidae), three families of Odonata (Libellulidae, Coenagrionidae, and Aeshnidae), and one family of Coleoptera (Hydrophilidae) (Plate 2). S-3 was surrounded on almost all sides by human settlements, shops, railway quarters, etc. The jheel received sewage wastes from cattle sheds, domestic waste materials, and sewage from roadside shops (Patra *et al.*, 2011) and so a dense growth of macrophytes (mainly water hyacinth) covering the jheel was noted. Gastropods of the family Viviparidae, Thiaridae, Lymneidae, and Planorbidae, and Annelids of the family Nereididae Namalycastis sp were recorded in S-3 samples. The order Odonata, represented by the family Libellulidae and Coenagrionidae, two families of Hemiptera (Nepidae and Belostomatidae), one family of Coleoptera (Curculionidae), and the family Chironomidae (*Chironomus sp.*) of the taxonomical group Diptera were also identified (Plate 3). S-4 is a wetland and an assemblage of sewage-fed shallow ponds, mostly used for pisciculture and thus a little growth of macrophyte vegetation was noted. Human interference like bathing and washing clothes was also noticed during sampling. Species identified from the S-4 samples included the family Viviparidae, Thiaridae, Lymneidae, and Planorbidae of Mollusca. Among them, Lymneidae was abundant in number. Three families of Hemiptera (Nepidae, Belostomatidae, and Notonectidae), and one family of Oligochaeta (Lumbricidae) were also detected (Plate 4).

Following the identification an evaluation of the biological water quality was done where the BMWP, the saprobic and the diversity scores were calculated (CPCB, 2017; Khatri *et al.*, 2021; Varnosfaderany *et al.*, 2010; Armitage *et al.*,1983). Table 3 presents that, with the decrease in BMWP score, the pollution tolerance of species is increasing (CPCB 2017) i.e. more BMWP-scored species are less pollution tolerant. The presence of Viviparidae excessively in every site is a direct indication of the mesotrophic condition of water bodies (Rout,2011; Kumar and Bohra, 1999). The presence of Lumbricidae (*Lumbricus terrestris*) in S-4 indicates sewage discharge from surrounding polluted areas. Also, the detection of the family Chironomidae (*Chironomus* *sp.)* and Nereididae (*Namalycastis sp.)* in S-3 samples, strongly indicated the eutrophic condition of the water body. Combining the Saprobic score (1 – 10) and Diversity score (0 - 1), prescribed in Biological Water Quality Criteria (BWQC) (Table 4), the biological water quality class was also determined (Table 5).

Table 1 – Results of Field measurements performed at the four sampling sites

Location	Code	General Water Quality Parameters					Human Activity
		Temperature (°C)	**pH**	**DO (mg/l)**	**Flow rate (m/sec)**	**Depth (meter)**	
Rabindra Sarovar	S-1	25	8.46	10.54	0.01	7.5	Recreational activities, Morning walk
Subhas Sarovar	S-2	27	8.66	6.6	0.030	12	Fishing, Bathing
Santragachi Jheel	S-3	26	8.43	2.8	0.81	2	Waste dumping, cloth washing, cattle washing
East Kolkata Wetlands	S-4	30	8.89	11.94	0.030	1	Pisciculture, bathing

Plate 1 – Representative species collected from all four sites.

Family: Libellulidae
Pantala flavescens

Family:Palaemonidae
Macrobrachium equidens

Family: Thiaridae
Melanoides tuberculata

Family:Chironomidae
Chironomus sp.

Family:Lumbricidae
Lumbricus terrestris

Family:Belostomatidae
Diplonychus rusticus

Family: Viviparidae
Filopaludina bengalensis

Family: Coenagrionidae
Agrocnemis sp.

Family: Nepidae
Ranatra sp.

Family: Aeshnidae
Aeshna sp.

Table 2- Identified families and genera of Benthic macro- invertebrates of Rabindra Sarovar, Subhas Sarovar, Santragachi Jheel and East Kolkata Wetlands

Sl No.	Taxonomical group	Family	Genus/Subfamily	Rabindra Sarovar (S-1)	Subhas Sarovar (S-2)	Santragachi Jheel (S-3)	East Kolkata Wetlands (S-4)
1.	Mollusca	Viviparidae	*Filopaludina bengalensis*[a]	+	+	+	+
2.	Mollusca	Thiaridae	*Melanoides tuberculata*[a]	+	+	+	+
3.	Mollusca	Lymnaeidae	*Lymnaea accuminata*[a]	+		+	+
4.	Mollusca	Planorbidae	*Indoplanorbis exustus*[a]		+	+	+
5.	Odonata	Aeshnidae	*Aeshna sp*[a]		+		
6.	Odonata	Libellulidae	*Orthetrum albistylum*[a]	+	+	+	
7.	Odonata	Coenagrionidae	*Agriocnemis sp.*[a]	+	+		
8.	Odonata	Libellulidae	*Pantala flavescens*[b]		+		
9.	Coleoptera	Hydrophilidae	*Hydrophilus sp.*[b]	+	+		
10.	Coleoptera	Dytiscidae	*Dytiscus sp.*[a]	+			
11.	Hirudinea	Salifidae	*Barbronia weberi* [a]	+			
12.	Crustacea	Palaemonidae	*Macrobrachium equidens*[a]	+	+		
13.	Crustacea	Atyidae	*Caridina peninsularis*[a]	+	+		
14.	Hemiptera	Nepidae	*Ranatra sp.*[a]		+	+	+
15.	Hemiptera	Belostomatidae	*Diplonychus rusticus*[a]	+	+		
16.	Hemiptera	Notonectidae	*Anisops sp.*[a]				+
17.	Hemiptera	Nepidae	*Laccotrephes sp*[a]				+
18.	Odonatan	Coenagrionidae	*Enallagma sp.*[b]		+	+	
19.	Lepidoptera	Pyralidae	*Pyralis sp.*[a]	+			
20.	Oligochaeta	Lumbricidae	*Lumbricus terrestris*[a]				+
21.	Polychaeta	Nereididae	*Namalycastis sp.*[a]			+	
22.	Diptera	Chironomidae	*Chironomus sp.*[a]			+	

Sources: [a]Akolkar, P. (2017). Benthic Macro-Invertebrates of River Ganga. CPCB, [b]Srivastava & Sinha, 1993, Ghosh and Nilsson, 2012

Table 3 : Site-wise availability of Taxonomical families.

BMWP Score	Taxonomical Families	Site-1	Site-2	Site-3	Site-4	Pollution tolerance
8	Libellulidae	+	+	+		Increasing Pollution Tolerance ↓
	Aeschnidae		+			
6	Viviparidae	+	+	+	+	
	Thiaridae	+	+	+	+	
	Atyidae	+	+			
	Palaemonidae	+	+			
	Coenagrionidae	|	|	|		
	Nereididae			+		
5	Balostomatidae	+	+	+	+	
	Hydrophilidae	+	+			
	Dytiscidae	+				
	Pyralidae	+				
	Notonectidae				+	
	Nepidae		+	+	+	
3	Salfidae	+				
	Lymnaeidae	+		+	+	
	Planorbidae		+	+	+	
2	Chironomidae			+		
1	Lumbricidae				+	

Table 4: Biological Water Quality Criteria (BWQC) developed by Central Pollution Control Board.

Range of Saprobic Score	Range of Diversity Score	Water quality Class	Water Quality	Indicating Colour
7 and more	0.2 – 1	A	Clean	Blue
6 – 7	0.5 – 1	B	Sight Pollution	Light Blue
3 – 6	0.3 – 0.9	C	Moderate Pollution	Green
2 – 5	0.4 - less	D	Heavy Pollution	Orange
0 – 2	0 – 0.2	E	Severe Pollution	Red

Table 5: Results of Biological Water Quality Class of four sampling sites as per CPCB criteria

Name of the sites	Station Code	Range of Saprobic Score (0-10)	Range of Diversity Score (0-1)	Biological Water Quality	Biological Water Quality Class	Indicator Colour
Rabindra Sarovar	S-1	5.33	0.440	Moderate Pollution	C	Green
Subhas Sarovar	S-2	5.82	0.620	Moderate Pollution	C	Green
Santragachi Jheel	S-3	5.40	0.643	Moderate Pollution	C	Green
East Kolkata Wetlands	S-4	4.25	0.571	Moderate Pollution	C	Green

Conclusion

Biomonitoring of water bodies based on the saprobic and diversity index can be a useful tool to assess the water quality status of different aquatic ecosystems of the country The results of present study based on saprobic and diversity score indicates that all four sites selected for the study namely Ravinder Sarovar, Subhash Sarovar, Santragachi Jheel and East Kolkata Wetlands were moderately polluted during the sampling period due to many anthropogenic activities and non-point sources of pollution. A total of 11 taxonomical groups comprising of 19 different families with total of 609 individual organisms were accounted during the study. Among all the groups, members of group odonata, hemiptera and molluscs were found in abundance. Species like *Chironomus sp.* and *Lumbricus terrestris* reveal the organic pollution in Santragachi Jheel and East Kolkata Wetland respectively. Assessment of biological water quality from all the sampling stations revealed that the water is unfit for potable use and requires proper conventional treatments. All four sites therefore need proper maintenance along with environmentally sound management of sewage effluents presently mixing with the water of aquatic ecosystem selected for study in order to make the water ecologically appropriate. If proper management practices are not adopted in near future, it can be detrimental to the aquatic life of all four water bodies.

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