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BIOLOGICAL HEALTH ASSESSMENT OF RIVER GANGA IN UTTAR PRADESH STRETCH (BIJNORE TO BADAUN): A COMPARATIVE PERSPECTIVE

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Abstract

The present study was carried out on the river Ganga stretch from Bijnore to Badaun (250 km long approximately) from 2017-2020. This stretch is an important habitat for the Gangetic Dolphins (*Platanista gangetica gangetica)* which are among the world's most threatened mammals. Biological water quality was assessed using benthic macro-invertebrates as indicator organisms. Dissolved Oxygen (DO) concentration observed to be in the range of 4.5-10.1 mg L^{-1} in summer and 7.5-13.5 mg L^{-1} in winter season. A total of 3,217 macro-invertebrates were collected from all the four locations during the studied period. These were found to be belonged to 11 taxonomic Orders and 67 Families. Benthic fauna at all the locations in all the seasons were found to be predominantly pollution intermediate families (BMWP Score 3-9). As per Saprobic Score values, biological water quality at all the locations was found to be in the Moderate Class. Pollution Tolerance Index (PTI) at the selected locations ranges from 18.2 to 74.7 in summer and 9.0 to 76.6 in winter season and water quality varies from Good to Poor. Shannon Wiener index values range from 0.66 to 2.52 in summer season and 0.51 to 2.24 in winter season. The study showed the successful evaluation of biological water quality in terms of Saprobic score in correlation with Dissolved Oxygen (Physico-chemical parameters) and Shannon Wiener Diversity index but Pollution Tolerance Index (PTI) showed deviation indicating that PTI alone is not an efficient index for biological water quality study.

Keywords: **Benthic Macro invertebrates, diversity, Ganga River, pollution tolerance index, water quality**

INTRODUCTION

Ganges, the mother of Goddess, a sacred river has divinity in Hindu text, bathing in it cleanses the soul. It is the most sacred and holy river with over 2,525 km long main-stem. It is one of the resource that sustains multiple functions—pertaining to ecological, socio-cultural and livelihoods. Due to unplanned urbanization and rapid industrialization, pollution of river Ganga in India has now reached a point of disaster in restoration for self-purification (Roy et al., 2020). Added to industrial effluents, sewage and religious offerings wrapped non-degradable plastics in the water bodies are prime sources of toxicity, which endangers aquatic biota and deteriorating water quality (Pillai, .2019: Hindustan Times). Water quality assessment based on Physical and Chemical parameters limited to change in their chemical characteristics, while, biological parameter of biotic components helps to determine cumulative impact of pollution to know the "**Health of Water body**".

Bio means living while organisms means an individual animal or plant or single celled life form which basically used to define the characteristics of a biosphere and these organisms are known as Bioindicators or biomonitors (Offem *et al*. 2011). The responses of biological communities, or of the individual organisms, can be monitored in a variety of ways to indicate effects on the ecosystem. The objective of biomonitoring is to observe the temporal and spatial changes in river health status, assessing the impacts of specific environment or anthropogenic stressors and also assessing the viability of anthropogenic measures like reclamation, remediation, and reintroduction (Hosmani, 2013 and 2014). Alterations in benthic community structure are widely used in pollution assessment studies Camur-Elipek *et al.,* 2006). Bio-monitoring is a powerful tool for control of pollution and for improvement of water quality of rivers. Among all the biotic components, Benthic macroinvertebrate communities is the most suitable biological parameter, as they are sensitive to change in water quality showing decline in population resulting habitat degradation. Benthic macro-invertebrates are sedentary and are unable to avoid the effects of pollutants due to limited mobility. They are the good indicators of pollution especially organic pollution (Sewage) that hampers the distribution of benthic macro-invertebrates. They act as natural bio-indicators for surface water bodies quality assessment in forming baseline data on their taxonomical distribution and reappears quickly when conditions become favorable.

One of the most frequently used biotic indices is Biological Monitoring Working Party score (BMWP) requires taxonomical identification of Benthic macro-invertebrates upto family level. This method has been developed by Department of Environment, United Kingdom (Armitage et al., 1983). This BMWP score was standardized by the International Organization for Standardization (ISO) in 1979. All observed families have assigned a specific saprobic individuals and are classified on the scale of 1 to 10 wherein sensitive families to organic pollution are scored 10, tolerant families are scored 1 while intermediate sensitive families are scored between 2 to 9. BMWP score is greatly influenced by the number of individuals collected in the sample, in order to overcome this limitation saprobic score system has been used which is generated by dividing BMWP score with the total number of families observed and the average sensitivity of families of macro-invertebrates is Average Score Per Taxon (ASPT)/Saprobic Score (CPCB, 2021).

Benthic macro-invertebrates are a critical part of the aquatic food web. In streams, they form a vital link in the food chain connecting aquatic plants, algae, and leaf litter to the fish species (Jessup *et al*., 2003). The condition of the benthic macro-invertebrate community reflects the stability and diversity of the larger aquatic food web. To widen the scope of bio-monitoring techniques further in national perspective, Biological Water Quality Criteria (BWQC) based on ASPT, the water quality class has been divided into 5 classes to assign river stretches to develop bio-mapping.

The efficacy of bio-monitoring applications in river management seeks to provide basic information of benthic macro-invertebrates structure in freshwater ecosystems taking into account of the environmental data. Water quality Index (WQI) and Pollution tolerance indexes (PTI) are effective bio-monitoring tools being applied in river management by freshwater ecologists (Odigie, 2019). The present study aimed at the biological health assessment of river Ganga stretch from Bijnore to Badaun which is an important habitat for the Gangetic dolphins, the National Aquatic Animal of India in terms of Biological Water Quality Criteria (BWQC) based on ASPT score and the comparison of index with the Water Quality Score based on Pollution tolerance index (PTI).

MATERIALS AND METHODS

Site Description

The present study was carried out on the river Ganga stretch from Bijnore to Badaun (250 km long approximately), from 29.373889°N and 78.040833°E to 27.930736°N and 78.857806°E,. This stretch is an important habitat for Gangetic Dolphins (*Platanista gangetica gangetica)* which are among the world's most threatened mammals. A total of 04 locations were selected for the purpose (Fig. 1). Bijnore is the location where the river enters the plains and the barrage namely Madhya Ganga Barrage at this location to store the water and channelize it through Madhya Ganga Canal for crop irrigation is considered to have an impact on the river ecology. Haiderpur Wetland in its vicinity has been recognized as the 47th Ramsar site (MoEF&CC, 2020). Bijnore is the location where the river enters the plains and the barrage namely Madhya Ganga Barrage at this location to store the water and channelize it through Madhya Ganga Canal for crop irrigation is considered to have an impact on the river ecology.

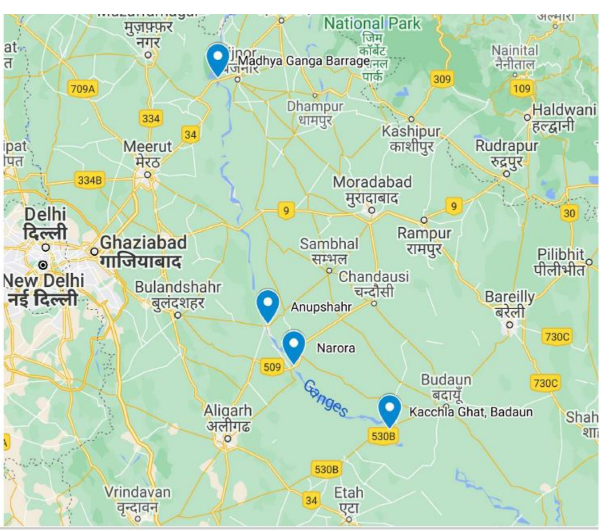

Fig. 1: Map of the selected locations

Haiderpur Wetland in its vicinity has been recognized as the 47th Ramsar site (MoEF&CC, 2020). Anupshar, also known as chhotti Kashi, is significant in terms of religious activities. Barrage at Narora and Lower Ganga canal from Narora may have impact on the river biota at this location. 70 km long stretch from Narora to Kacchla Ghat, Badaun is important due to wide floodplains and agricultural activities in river bed mainly Cucurbetaceous crops and extremely low flow during non-monsoon periods (Report: River Ganga at a glance, 2010)

Benthic macro-invertebrate collection, sorting and preservation

The sampling procedure was equivalently distributed over all the possible aquatic habitats including the bed substrate (stones, sand or mud), macrophytes (floating, submerged, emerged), immersed roots of overhanging trees and all other natural or artificial substrates, floating or submerged in the water. Substratum of river Ganga in the selected stretch was devoid of boulders and cobbles but mainly consists of pebbles, sand, silt, clay, detritus and macrophytes. Therefore, the samples were collected qualitatively from all the habitats using shovel sampler and kick net, and washed using standard sieve (mesh size 0.6 mm). (APHA, 2017a). The organisms were collected in 250 mL reagent grade plastic bottle and preserved in 70% ethanol. Preserved samples were brought to the Bioscience Division, CPCB, Delhi for further identification.

Identification of benthic macro-invertebrates

As broad taxonomic classifications are acceptable when empirical relationships involving benthic macro-invertebrates are to be developed, the fauna was identified up to the family level using stereozoom microscope. The distribution of different families was calculated on percentage basis.

Mollusca, Crustacea and Annelida were identified using the taxonomic key developed by Nessemann *et al.* (2007). Ephemeroptera, Trichoptera, Plecoptera, Hemiptera, Coleoptera, Diptera, Odonata and Planaria taxa were identified using the reference keys of Zwart and Trivedi (1995), Jessup *et al*. (2003), Graf *et al*. (2006) and Akolkar *et al.* (2017).

Physicochemical parameters

Physicochemical parameters *viz*., dissolved oxygen (DO), water temperature and flow were recorded at the time of sample collection. Dissolved oxygen was estimated using the standards methods of water and wastewater analysis (APHA, 2017b). Water temperature was measured using a calibrated thermometer. Water flow (m sec-1) was estimated by measuring the time taken by floating object (plastic ball) over a set distance of 10 m (approx.).

Biological water quality assessment

Biological water quality was assessed by using saprobic score index developed by CPCB, New Delhi (India). Saprobic score is a measure of taxonomic composition whereas diversity score is a measure of taxonomic richness of riverine ecosystem. Each taxonomic family is given a score on the scale of 1 to 10 by BMWP (Biological Monitoring Working Party). The biological water quality was evaluated and classified as 7.0 - 10.0 very good; 5.0 - 6.9 good; 3.0 - 4.9 moderate; 1.1 - 2.9 poor; and < 1.0 severe (CPCB, 2021)

Pollution Tolerance Index (PTI)

It is a Bio survey based on the simple macroinvertebrates sampling approach currently used by the Department of Environmental Protection for streams. It provides rapid means of assessing stream quality degradation i.e. determines health of a stream (Creek Connections Aquatic Macroinvertebrates Module – PTI Bag of Bugs 1996). The collected macro-invertebrate organisms identified up to family level and after recording all organisms in the data sheet, assign each type of organism with an abundance code as given under:

R (Rare) = 1 to 9 organisms found in the sample; C (Common) = 10 to 99 organisms found in the sample; D (Dominant) = 100 or more organisms found in the sample

This index classifies the macro-invertebrates into three groups based on their ability to tolerate pollution as:

Group I – Organisms that are sensitive to pollution and are typically found in Good quality water.

Group II – Organisms that are somewhat sensitive to pollution and are typically found in fair quality water.

Group III – Organisms that are tolerant of pollution and are typically found in Poor quality water.

Each of the three groups is given index value as per weighting factors and the sum of these values the water quality score and ratings is estimated to determine the water quality of stream like Good > 40; Fair 20 – 40 & Poor < 20 i.e. the least tolerant group having the highest value.

RESULTS AND DISCUSSION

The river water temperature was found in the range of 27.0 - 35.3°C in summer season and 14.0 - 23.6°C in winter season (Table 1). High water temperature of the river at all the studied locations may be due to the changes in meteorological conditions. Dissolved Oxygen (DO) concentration observed to be in the range of 4.5-10.1 mg L^{-1} in summer and 7.5-13.5 mg L^{-1} in winter season (Table 1). Higher DO concentration in winter season at almost all the selected locations may be due to reduced water temperature and comparatively more water quantity in the river. The colonization of benthic macro-invertebrates is affected greatly by the water temperature and dissolved oxygen content of the water bodies (Kale, 2016).

Macro-invertebrate community

A total of 3,217 macro-invertebrates were collected from all the four locations during the studied period (Table 2). There were found to be belonged to 11 taxonomic Orders and 67 Families. Though the pollution sensitive families were observed in the selected stretch but in very few number. Families belonging to the Order Ephemeroptera and Trichoptera (BMWP Score 10) were observed in a very few numbers like Family Ameletidae in 06 no. at Madhya Ganga Barrage in summer season and 07 no. at Narora Barrage in winter season of 2018-19 and 02 no at Narora Barrage in summer season of 2019-20. A rare occurrence of families Leptohyphidae (01 no.) and Helicopsychidae (01 no.) was observed at Madhya Ganga Barrage in summer season of 2017-18 and winter season of 2018-19, respectively (Table 2). Benthic fauna at all the locations in all the seasons were found to be predominantly pollution intermediate families (BMWP Score 3-9) except the dominance of Family Chironomidae (BMWP Score 2) 103 no. in summer season of 2018-19 at Anupshahr (Table 2). This is correlated with the low Dissolved Oxygen content (6.1 mg/L) at this location (Table 1). This indicated sudden discharge of municipal sewage at this location in this particular season. Agarwal et al. (2019) studied the taxonomic diversity of benthic macro-invertebrates in Haridwar stretch of river Ganga and correlated the abundance of Chironomidae species with the direct discharge of partially/untreated sewage from Jagjeetpur Sewage Treatment Plant. Dominance of Molluscs belonging to the family Planorbidae (78 no.) and Lymnaeidae (157 no.) (BMWP Score- 3) at Narora barrage during both the seasons of 2019-20 (Table 2). Abundance of Gastropods is indicative of sewage borne organic pollution (Dudhani *et al.*, 1998). Bhadwal *et al*. (2018) assessed the distribution of macro-zoobenthos with respect to phyla Arthropoda, Mollusca, Annelida and Platyhelmintha in Halali river in Madhya Pradesh and reported the dominance of Arthropoda species in the river. De et al., (2021) studied the diversity of three major predatory insect groups – Odonata, Hemiptera and Coleoptera in the upper river Ganga stretch from Brij Ghat to Narora during March, 2019 and reported 03 species of Coleoptera, 04 Hemiptera, 14 Dragonflies and 08 Damselflies.

Saprobic score and PTI values

The Saprobic Score values at all the selected locations were observed in the range of 4.8 to 5.5 in the summer season and in the range of 4.0 to 5.5 in the winter season during the study period. The corresponding biological water quality at all the locations was found to be in the Moderate Class (Table 3).

The summary of the results of Water Quality Index of the river Ganga in the selected locations ranges from 18.2 to 74.7 in summer and 9.0 to 76.6 in winter seasons during the study period. The pollution tolerance index (PTI) accorded with the water quality index (WQI) values found to be Good (WQI score >40) in Madhya Ganga Barrage location in both seasons except in winter season of 2017-18 revealing PTI Poor water quality (WQI score <20) pointed pollution. The PTI value of Anupshahr location rooted Poor (WQI score <20) to Fair (WQI score 20-40) water quality significant pollution throughout year irrespective of seasons excluding summer season of 2017-18 showing Good water quality. In Narrora Barrage, the PTI revealed Good water quality in all the seasons omitting winter season of 2019-20 reflected Fair water quality indicative of mild pollution. The calculated PTI of Kacchala Ghat, Badaun pointed Fair to Poor in almost all the seasons evident of serious pollution due to religious activities ruling out Good water quality of PTI of 2017-18, summer season (Table 3). Ghosh and Biswas (2017) studied efficiency of Pollution Tolerance Index (PTI) established by Olomukoro & Dirisu, 2014 of macro-invertebrates in detecting aquatic pollution in Oxbow lake in India and concluded that macro-invertebrate PTI values alone are not reliable aquatic health diagnostic tools unless they are complemented or contrasted to diversity indexes (e.g. SWI) however provides pivotal baseline data to improve more efficient and sustainable management of oxbow lakes.

Table 1: Physicochemical parameters at studied locations

Parameter	2017-18								2018-19								2019-20							
	Summer				Winter				Summer				Winter				Summer				Winter			
	MGB	AS	NB	KG	MGB	AS	NB	KG	MGB	AS	NB	KG	MGB	AS	NB	KG	MGB	AS	NB	KG	MGB	AS	NB	KG
Temperature, ^{0}C	30.7	27.5	27.0	30.5	16.7	15.5	15.0	15.9	30	30.8	35.3	33.2	19.3	21.3	22.2	23.6	30	34	33	28	21	15	15	14
Flow, m/s	0.66	0.6	0.04	0.3	0.42	0.13	0.2	0.7	0.62	0.6	-	0.66	0.66	1	-	0.45	-	0.68	-	-	-	0.87	0.1	0.7
pH	7.0	7.0	7.0	7.0	7.0	7.5	7.0	6.8				7.5	6	7.2	7.4	8		7	7	7				
Dissolved Oxygen, mg/l	8.45	6.0	6.8	8.5	-	9.5	7.5	8.7	8.2	6.1	8.9	9.32	7.68	8.33	14.2	9.02	4.5	8.1	10.1	7.5	13.5	9.2	10	9.6

Table 2: Macro-invertebrates at the studied locations

Order	Family	Madhya Ganga Barrage						Anupshahr						Narora Barrage						Kacchla Ghat, Badaun					
		2017-18		2018-19		2019-20		2017-18		2018-19		2019-20		2017-18		2018-19		2019-20		2017-18		2018-19		2019-20	
		Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]	Sum[1]	Win[2]
Ephemeroptera	Caenidae	11	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0
	Leptohyphidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Baetidae	61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
	Ameletidae	**0**	0	6	0	0	0	0	0	0	0	0	0	0	0	0	7	2	0	1	0	0	0	0	0
	Neoephmeridae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heptageniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Trichoptera	Brachycentridae	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Helicopschydae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Hydropsychidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0
Mollusca	Planorbidae	1	1	1	13	33	2	10	0	0	6	2	2	8	48	2	1	7	78	3	0	1	0	2	1
	Corbiculidae	**0**	**1**	1	0	5	0	2	0	0	0	1	0	0	2	1	0	0	0	25	0	0	1	0	0
	Lymnaeidae	**0**	**10**	1	6	30	6	2	0	1	0	2	0	4	2	10	5	157	0	4	0	10	0	0	0
	Viviparidae	0	0	0	25	13	0	1	0	0	2	0	0	0	2	14	1	5	0	0	0	0	0	2	0
	Thiaridae	0	0	0	1	1	0	33	0	0	0	0	0	0	2	9	5	6	0	0	0	0	0	39	0
	Stenothyridae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
	Physidae	0	0	0	0	5	0	9	0	0	0	0	0	4	37	5	2	30	20	0	0	0	0	0	0
	Bithynidae	0	0	0	0	0	1	3	0	0	0	0	0	0	8	5	0	0	0	0	0	0	0	2	0
	Unionidae	0	0	0	0	0	0	3	0	0	0	0	0	1	0	1	1	0	0	6	0	0	67	0	0
	Amblemidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	13	0	0
Hemiptera	Ranatranidae	1	0	0	0	1	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Corixidae	49	5	1	11	4	69	2	0	1	0	6	0	10	49	1	44	15	14	11	27	4	0	1	1
	Nepidae	1	0	1	0	1	8	0	0	0	0	1	0	1	0	0	1	3	0	0	2	0	0	0	0
	Notonectidae	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Belastomatidae	0	0	0	2	11	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Pleidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0		0	0	0	0
	Gerridae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Odonata	Protoneuridae	2	0	3	2	0	0	5	0	0	0	0	0	13	1	6	1	3	0	2	0	5	0	3	0
	Calopterygidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Macromidae	**0**	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

	Gomphiade	**0**	0	1	0	0	0	6	22	5	0	1	0	4	2	4	0	0	0	2	0	13	0	0	0
	Libellulidae	0	0	0	4	7	3	6	0	0	0	0	0	0	0	19	1	2	1	1	0	16	0	0	0
	Coenogrinidae	0	0	0	0	22	1	0	0	0	0	0	0	0	7	4	9	3	0	0	0	1	0	0	0
	Calopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Coleoptera	Dytiscidae	2	5	2	34	22	7	1	0	3	0	2	1	13	109	13	7	35	5	6	20	7	0	161	0
	Noteridae	2	0	0	0	4	7	2	0	0	0	0	0	0	1	0	0	0	1	3	5	0	0	0	0
	Hydrophilidae	**0**	1	0	7	2	2	0	0	0	0	5	0	1	0	0	7	0	8	0	13	0	0	0	0
	Histeridae	**0**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Carabidae	**0**	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Haliplidae	**0**	0	1	0	61	34	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Chrysomelidae	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Curculionidae	0	0	0	1	5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
	Staphylinidae	0	0	0	1	17	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0
	Dryopidae	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
	Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Diptera	Chironomidae	1	0	28	15	2	0	0	0	103	0	0	0	1	10	7	36	0	20	13	39	18	0	1	0
	Culicidae	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	1	0	0	0	0
	Ephydridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Tipulidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tabanidae	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0	2	0	0	0	0	0
	Simulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Phoridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Nymphomyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Crustacea	Atyidae	41	0	38	63	1	30	0	1	1	5	0	3	43	0	1	0	0	0	0	0	0	0	4	0
	Varunidae	1	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Palaemonidae	**0**	1	25	3	0	10	0	13	8	60	4	14	0	1	106	2	0	0	2	0	3	8	53	21
	Potamidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Hirudinea	Salifidae	**0**	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Glossiphonidae	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
	Erpobdellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Hirudidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Lepidoptera	Pyrallidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	Lumbricidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Naididae	0	0	0	0	0	0	0	11	0	0	0	0	0	22	2	0	7	0	0	0	0	0	0	0
	Tubificidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
	Microchaetidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	Georysidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aegridae	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1]Sum-summer;[2] win- winter

Table 3: Saprobic Score and Pollution Tolerance Index values at the studied locations

Year	Season	Sampling point	Parameters			
			Saprobic Score, SS	Water Quality	Pollution Tolerance Index, PTI	Water Quality Index Score, WQI
2017-18	Summer	Madhya Ganga Barrage	5.47	Moderate	Good	59.8
		Anupshahr	5.0	Moderate	Good	54.7
		Narrora Barrage	5.25	Moderate	Good	49.5
		Kacchla Ghat, Badaun	5.25	Moderate	Good	58.3
	Winter	Madhya Ganga Barrage	4.3	Moderate	Poor	13.7
		Anupshahr	5.33	Moderate	Poor	16.1
		Narrora Barrage	4.31	Moderate	Good	62.6
		Kacchla Ghat, Badaun	4.71	Moderate	Poor	27.1
2018-19	Summer	Madhya Ganga Barrage	5.11	Moderate	Good	47.1
		Anupshahr	5.0	Moderate	Poor	18.2
		Narrora Barrage	5.08	Moderate	Good	74.7
		Kacchla Ghat, Badaun	5.36	Moderate	Fair	28
	Winter	Madhya Ganga Barrage	5.46	Moderate	Good	76.6
		Anupshahr	5.0	Moderate	Poor	16.0
		Narrora Barrage	5.44	Moderate	Good	59.3
		Kacchla Ghat, Badaun	5.25	Moderate	Poor	13.2
2019-2020	Summer	Madhya Ganga Barrage	4.86	Moderate	Good	70.4
		Anupshahr	4.78	Moderate	Fair	24.8
		Narrora Barrage	5.0	Moderate	Good	45.6
		Kacchla Ghat, Badaun	5.27	Moderate	Fair	39.0
	Winter	Madhya Ganga Barrage	4.9	Moderate	Good	53.8
		Anupshahr	5.0	Moderate	Poor	11.0
		Narrora Barrage	4.4	Moderate	Fair	25.1
		Kacchla Ghat, Badaun	4.0	Moderate	Poor	9.0

Shannon Wiener Index values

The values of Shannon-Wiener diversity index showed a gradual increase from 1.62 to 2.51 and a slight drop to 2.00 in the winter season of 2019-20 at Madhya Ganga Barrage. At Anupshahr, the values fluctuated being lowest 0.66 in the summer season of 2018-19 and the highest 2.32 in summer season of 2017-18 (Fig. 2). The lowest values of Shannon-Wiener Diversity index is correlated with the abundance of family Chironomidae (Table 2) and low Dissolved Oxygen content (Table 1) at this location in this season of the year. At Narora barrage, values were almost stable in the first four seasons and then drop slightly in 2019-20. At Kacchla Ghat, lowest values of 0.51 was observed in the winter season of 2019-20. This indicated some natural/ anthropogenic pressure at this location that affected the colonization of macro-invertebrates without influencing the Dissolved Oxygen content at this location.

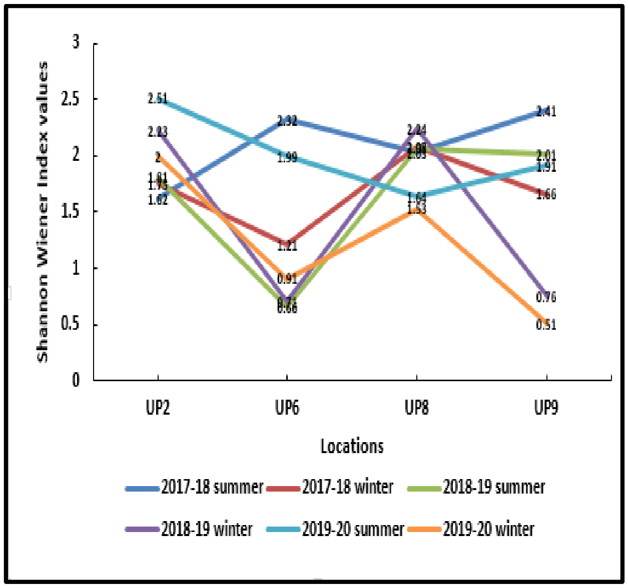

Fig. 2: Shannon-Wiener index values at the studied locations

In a study on the diversity of three major predatory insect groups – Odonata, Hemiptera and Coleoptera by the researchers on the upper river Ganga stretch from Brij Ghat to Narora during March, 2019, reported the Shannon diversity index values ranged from 2.465 to 2.782 (De et al. 2021).Goel et al. (2021) studied the population of benthic macro-invertebrates in the Patna stretch of river Ganga during 2017-18 and reported the Shannon-Wiener index value ranged from 1.788 to 1.943 in summer season and from 1.589 to 2.359 in winter season and concluded the moderate impact of anthropogenic activities on macro-invertebrate community in the studied river stretch.

Conclusion

This paper showed the successful evaluation of biological water quality in the Ganga river stretch from Madhya Ganga Barrage to Kacchla ghat, Badaun in terms of Saprobic score of benthic macro-invertebrates in correlation with Dissolved Oxygen (Physico-chemical parameters) and Shannon Wiener Diversity index but Pollution Tolerance Index (PTI) showed deviation. Hence, it can be concluded that PTI alone is not an efficient index for biological water quality study.

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