

# Water quality status of River Betwa using Benthic macro-invertebrates

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## ABSTRACT

Water quality of River Betwa has been assessed by identify micro-invertebrates. About 45 families of macro zoobenthos of 10 groups (Ephemeroptera, Plecoptera, Odonata, Mollusca, Crustacea, Hemiptera, Diptera, Coleoptera, Tricoptera,) were identified during study from the period of April 2017 to March 2019 at 12 sampling sites selected across the river stretch. During the entire Bio- monitoring of river Betwa, in all the three zones namely Bhopal Region, Vidisha Region and Bina/Orchha Region at 12 monitoring sites the quality of water classified at most of the sampling locations are from Class B to C as per BWQC score indicate water quality slight pollution to moderate pollution.

**Key words :** Benthic micro-invertebrates

## Introduction

Water is a natural renewable resource, which is universal solvent and one of the most precious substance required for the survival of life. It is used for various purposes like agriculture, forestry, urbanization and several other activities which satisfy human requirement. The water quality of a system depends on the catchment which it flows and its quality affected by physical, chemical and biological constituents (Honda, 1986). Today the freshwater bodies like rivers, lakes, and ponds have become polluted by anthropogenic activities in its catchment. Rivers are the most important water resource in the worlds, it plays an important role on integrating and organizing the landscape and molding the ecological setting of a basin. Monitoring the surface runoff on river in a standard basis provides valuable information on the eco-hydrological conditions. Such

data helps to measure the health of a river.

Bio monitoring has ample scope in ecology where biologists can play a meaningful role in environmental management.. It has been emphasized that nature and degree of pollution of any water body may be judged from the occurrence, abundance and composition of the inhabiting organisms. It is quite possible to arrange the plants and animals of a stream in order of their preference for or tolerance of organic impurities in such a way that their graded list may serve as an index to the level of contamination". Wilhm (1975) reported that environmental stresses eg. Pollution induces changes in the structure and function of biological systems.

Such changes may occur from the molecular to community level. In recent years biochemical, cytological and histological analysis is conducted with sophisticated instruments to assess the extent of pollution with much accuracy. Biological communities

may respond to new or unsuspected pollutants in the environment, which are difficult to analyse chemically. It would be uneconomic and impracticable to regularly determine concentration of number of known pollutants.

Many countries have a long history of using macro invertebrates to monitor the ecological status of river ecosystems (Hellowell, 1986). Among the various biological indicators (such as algae, periphyton, macrophytes, benthic invertebrates and fish), benthic macro invertebrates are the most commonly used biotic assemblage across the world (Rosenberg and Resh, 1993; Resh, 2008).

Benthic macroinvertebrates are the organisms living among the sediments, stones, logs and aquatic plants at the bottom of lakes, ponds, streams and rivers. Relatively larger in size (usually above 6mm) and visible to the naked eye, they comprise wide diversity of organisms viz. sponges, mayflies, stoneflies, worms, molluscs, insects, etc. Mostly they are bottom dwellers but occasionally they may travel upwards (Sampath *et al.*, 1981). Changes in the environment such as pollution, habitat fragmentation and other stresses that degrade biodiversity have a direct effect on these organisms (Gooderham and Tyrslin, 2002)

Macro invertebrate organisms form an integral

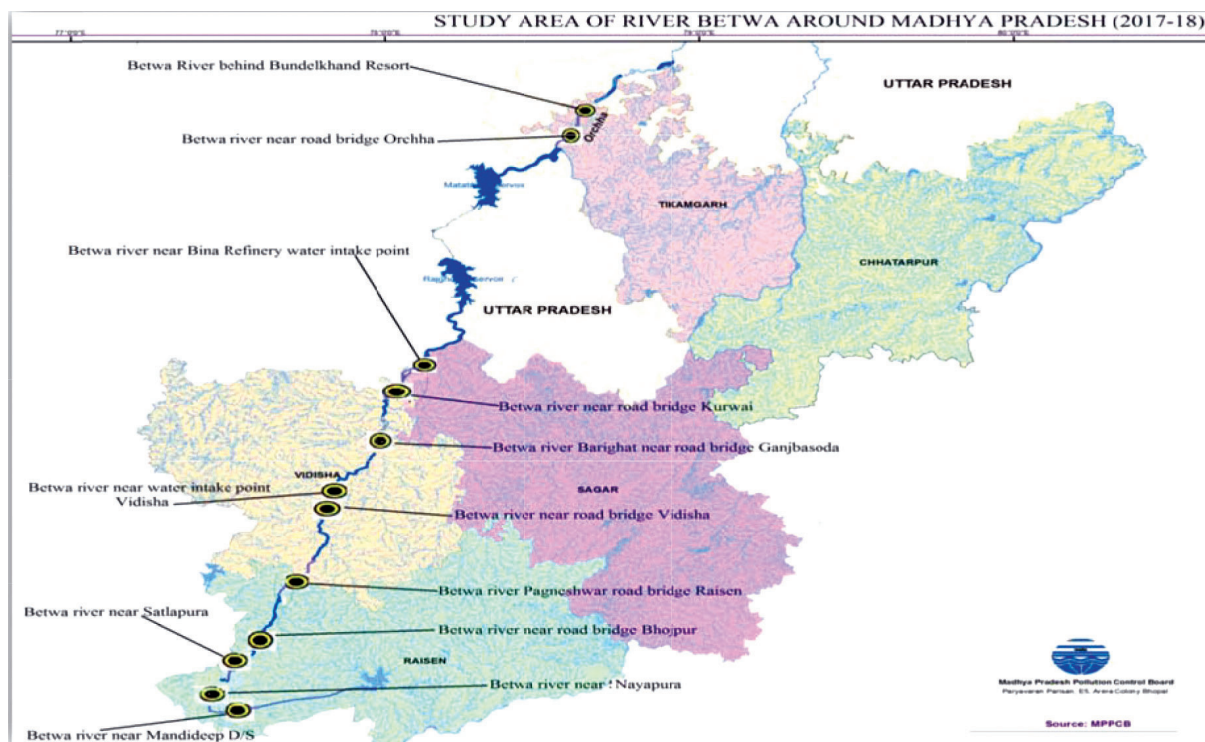
part of an aquatic environment and are of ecological and economic importance as they maintain various levels of interactions between the community and the environment (Anderson and Sedel, 1979).

## Methodology

### Study Area

The Betwa or Betravati is a river in Northern India, and a tributary of the Yamuna. It rises in the Vindhya Range just north of Hoshangabad in Madhya Pradesh and flows north-east through Madhya Pradesh and Orchha to Uttar Pradesh. Nearly half of its course, which is not navigable, runs over the Malwa Plateau. The confluence of the Betwa and the Yamuna rivers is Hamirpur town in Uttar Pradesh, in the vicinity of Orchha. The total length of the river from its origin to its confluence with Yamuna is 590 kilometres (370 mi), out of which 232 kilometres (144 mi) lies in Madhya Pradesh and the balance of 358 kilometres (222 mi) in Uttar Pradesh.

The present study deals with the bio-monitoring of twelve sampling sites of river Betwa from Mandideep region of Bhopal to Orchha region of M.P. using bio-indicator for case study of the entire. The entire river stretch was divided into three zones



viz. Bhopal Region, Vidisha Region and Orchha Region.

### Micro-invertebrate Collection, Preservation and Identification

Micro-invertebrates collected from Betwa River for biological and component at identified selected sampling locations quarterly in the year as per the target. The sampling time for bio monitoring is preferably selected either in the morning or before the sunset because some of the benefit animals avoid extreme solar intensity and temperature, and seek refuge under the rocks in the interstitial sediments.

To obtain the qualitative information of fresh water body (river Betwa), sampling and analysis of benthic macro-invertebrates (biological parameter) was collected at twelve different sampling locations of complete river stretch as per the CPCB biomonitoring protocol. Sufficient numbers of macro-invertebrate were sampled with the help of brush, hand net and shovel samplers. The macro-invertebrate collected with help of sieved & washed with river water for separating the animals. Organisms were picked up from the sieve with forceps and then placed and preserved with 4% formalin in wide mouth polyethylene bottle of 500ml. The saprobity scoring system is used to have the qualitative inventory of the macro-invertebrates

benthic fauna upto family level of taxonomic precision.

The macro benthic invertebrates were identified using many manuals (Pennak, 1953; Needham and Needham 1962; Victor and Ogbeibu 1985).

To access the biological consequences of pollution or diversity score, a rapid numerical method (sequential comparison) was applied on the sample species.

### Results and Discussion

In River Betwa, about 45 families of macro zoobenthos of 10 groups (Ephemeroptera, Plecoptera, Odonata, Mollusca, Crustacea, Hemiptera, Diptera, Coleoptera, Tricoptera,) were identified from the period of April 2017 to March 2019 at 12 sampling sites selected across the river stretch.

In Zone-I Bhopal Region, 21 families of macro zoobenthos were identified. In Zone-II Vidisha Region, about 23 families were identified and in Zone-III Bina/ Orcha Region, about 25 families of macro zoobenthos families were identified. The dominating group as per the identified families appears Mollusca in all the three study zones with families Viviparidae, Neritidae, Thiaridae, planorbidae, Lymnaeidae and Corbiculidae. Saprobic and diversity scores were calculated based on the identified

#### GPS Location of selected Sampling Sites of Betwa river Bhopal Region

S.No.	Sites Name	Latitude	Longitude
1.	Betwa river near Mandideep D/S	23.1108° N	77.5084° E
2.	Betwa river near Nayapura	23.0987° N	77.5050° E
3.	Betwa river near Satlapura	23.1136° N	77.5304° E
4.	Betwa river near road bridge Bhojpur	23.0991° N	77.5781° E

#### Vidisha Region

S.No.	Sites Name	Latitude	Longitude
1.	Betwa river near road bridge Pagneshwar, Raisen	23.4350° N	77.7423° E
2.	Betwa river near road bridge Vidisha	23.5223° N	77.8034° E
3.	Betwa river near water intake point Vidisha	23.5268° N	77.8110° E
4.	Betwa river near Barighat road bridge, Ganjbasoda	23.8501° N	77.9299° E

#### Bina/Orchha Region

S.No.	Sites Name	Latitude	Longitude
1.	Betwa river near road bridge, Kurwai	24.1172° N	78.0383° E
2.	Betwa river near Bina Refinery water intake point	24.1718° N	78.1852° E
3.	Betwa river near road bridge, Orchha	25.3682° N	78.6285° E
4.	Betwa river behind Bundelkhand Resort	25.3544° N	78.6392° E

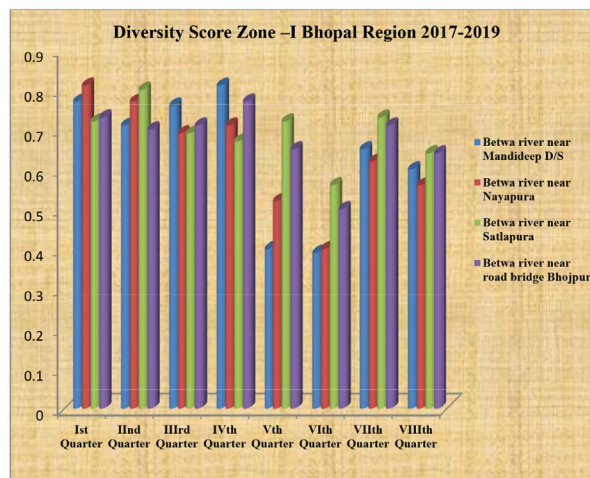
families. In Zone-I only two families of Ephemeroptera (Heptageniidae, Ephemerellidae) were present whereas in Zone-II and Zone-III five families of Ephemeroptera (Ephemeridae, Caenidae, Heptageniidae, Ephemerellidae, Siphonuridae) were found, in addition to these Baetidae was also detected in Zone-III. Plecoptera group with family Perlidae was found in Zone-III whereas it was not detected in other two zones. Two families from the group Crustacea was detected in all three zones. Similarly, two families from group Odonata (Gomphidae, Euphaeidae) was found in all three zones. However Zone-III contained one more family of Odonata group i.e. Libellulidae. One family from each group Diptera, Coleoptera, Hirudinea and Tricoptera were found in Zone-III during the study. Among Diptera, Chironomidae were the only representative in Zone-I and Zone-II, whereas in Zone-III Ephydriidae were present.

In Zone-I Bhopal Region, Betwa River near Madideep D/S location water quality was of Class C i.e. moderately polluted. Here, Saprobic score and diversity score was found between 4.2-7.0 and 0.71-0.81 respectively. Degradation of water quality class "C" is mainly due to mixing of sewage nalla and merging of domestic and industrial effluent within and around the river bed of Mandideep region.

In Betwa River near Nayapura water quality was again moderately polluted due to Idol immersion in this area. Saprobic score and diversity score was found between 5.0-5.3 and 0.69-0.81 respectively. Similarly, water quality of Betwa River near Satlapura degrades due to Human influences (Religious activities) and Due to Anthropogenic activities (cattle wadding). At Betwa River near road bridge Bhojpur water quality improved from 2<sup>nd</sup> cycle to 3<sup>rd</sup> and 6<sup>th</sup> cycle. Lower saprobic value was observed during 1<sup>st</sup> and 2<sup>nd</sup> and 5<sup>th</sup> cycle, when compared to the value obtained during 3<sup>rd</sup> and 4<sup>th</sup> cycle. Diversity score was also higher during 3<sup>rd</sup> and 4<sup>th</sup> cycle (0.71, 0.77), with respect to 1<sup>st</sup> and 2<sup>nd</sup> cycle (0.73, 0.70). Thus, during the study period 2017-2019, the water quality of river Betwa in Zone-I Bhopal Region, based on BWQC classified as class B to C.

At Betwa river near road bridge Pagneshwar, Raisen river quality improved from 2<sup>nd</sup> cycle to 3<sup>rd</sup> cycle (C to B). Saprobic score and diversity score were present in the range of 5.1-6.6 and 0.57-0.78 respectively. Due to Idol immersion in this area water quality was degraded as seen from the results. Water quality of Class C was detected at Betwa river

near road bridge Vidisha. Saprobic score and diversity score were found least (5.2 and 0.56 respectively) during 4<sup>th</sup> cycle. Moderately polluted water was found during 1<sup>st</sup> quarter in Betwa river near water intake point Vidisha which improved (slightly polluted) during 2<sup>nd</sup> and 3<sup>rd</sup> cycle study period. However, in 4<sup>th</sup> cycle again the water quality of class C was found. The degradation in water quality may be due to Anthropogenic activities like religious activities, cremation and influence of industrial effluent within the river etc. At Betwa river near Barighat road bridge, Ganjbasoda water quality class "B" was observed, i.e. slightly polluted. Here, the saprobic score and diversity score were present in the range of 5.5-7.5 and 0.59-0.83 respectively. Thus, in Zone-II Vidisha Region, water quality of river Betwa was observed B to C based on BWQC. In Zone-III Bina/Orcha region water quality class "B" was observed at sampling site near Bina Refinery water intake point and Betwa river behind Bundelkhand Resort whereas water quality class "C" was observed mainly at site near road bridge, Kurwai and near road bridge, Orchha anthropogenic activities was observed during sampling at particular time within and around the river bank. Water quality, class "C" was mainly observed due to anthropogenic activities like bathing, washing, cremation and influence of domestic effluent within the river. Water quality was moderately polluted during 3<sup>rd</sup> and 4<sup>th</sup> cycle of study at Betwa river near road bridge, Orchha, it was due to idol immersion in these areas. At Betwa river behind Bundelkhand Resort saprobic and diversity was found in the range of 6.3-6.8 and 0.67-0.74 respectively. Thus, in



Graph. 1. Diversity Score Zone – I Bhopal Region



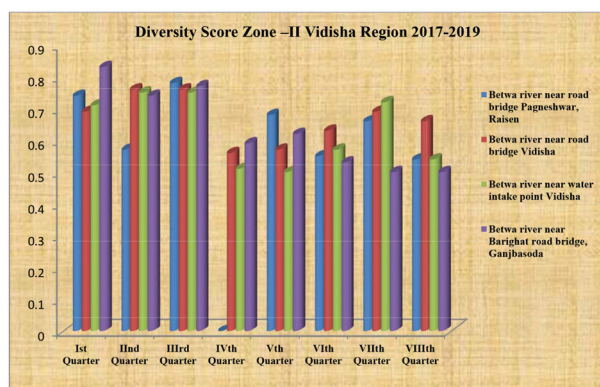
**Table 5.** Water Quality on the Basis of BWQC Score  
**Water Quality on the Basis of BWQC Score 2017-19**

Sampling Location	Quarter	Saprobic score	Diversity score	Water Quality	Water Quality Class
<b>Zone-I Bhopal Region</b>					
Betwa River near Mandideep D/S	1 <sup>st</sup> Quarter	7.0	0.7	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	5.0	0.7	Slight Pollution	B
	3 <sup>rd</sup> Quarter	5.8	0.7	Moderate Pollution	C
	4 <sup>th</sup> Quarter	4.2	0.8	Moderate Pollution	C
	5 <sup>th</sup> Quarter	5.5	0.4	Moderate Pollution	C
	6 <sup>th</sup> Quarter	3.9	0.3	Moderate Pollution	C
	7 <sup>th</sup> Quarter	5.5	0.6	Moderate Pollution	C
	8 <sup>th</sup> Quarter	6.0	0.6	Moderate Pollution	C
Betwa River near Nayapura	1 <sup>st</sup> Quarter	5.1	0.8	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	5.2	0.7	Moderate Pollution	C
	3 <sup>rd</sup> Quarter	5.3	0.6	Moderate Pollution	C
	4 <sup>th</sup> Quarter	5.0	0.7	Moderate Pollution	C
	5 <sup>th</sup> Quarter	5.2	0.5	Moderate Pollution	C
	6 <sup>th</sup> Quarter	4.0	0.4	Moderate Pollution	C
	7 <sup>th</sup> Quarter	5.6	0.6	Moderate Pollution	C
	8 <sup>th</sup> Quarter	6.1	0.5	Slight Pollution	B
Betwa River near Satlapura	1 <sup>st</sup> Quarter	3.5	0.7	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	4.8	0.8	Moderate Pollution	C
	3 <sup>rd</sup> Quarter	5.7	0.6	Moderate Pollution	C
	4 <sup>th</sup> Quarter	5.4	0.6	Moderate Pollution	C
	5 <sup>th</sup> Quarter	6.7	0.7	Slight Pollution	B
	6 <sup>th</sup> Quarter	5.5	0.5	Moderate Pollution	C
	7 <sup>th</sup> Quarter	6.4	0.7	Slight Pollution	B
	8 <sup>th</sup> Quarter	6.0	0.6	Slight Pollution	B
Betwa River near road bridge Bhojpur	1 <sup>st</sup> Quarter	5.6	0.7	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	5.4	0.7	Moderate Pollution	C
	3 <sup>rd</sup> Quarter	6.7	0.7	Slight Pollution	B
	4 <sup>th</sup> Quarter	6.1	0.7	Slight Pollution	B
	5 <sup>th</sup> Quarter	7.1	0.6	Slight Pollution	B
	6 <sup>th</sup> Quarter	6.0	0.5	Moderate Pollution	C
	7 <sup>th</sup> Quarter	6.1	0.7	Slight Pollution	B
	8 <sup>th</sup> Quarter	5.9	0.6	Moderate Pollution	C
<b>Zone-II Vidisha Region</b>					
Betwa river near road bridge Pagneshwar, Raisen	1 <sup>st</sup> Quarter	5.1	0.7	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	5.8	0.5	Moderate Pollution	C
	3 <sup>rd</sup> Quarter	6.6	0.7	Slight Pollution	B
	4 <sup>th</sup> Quarter	Sampling not done due to drought	Sampling not done due to drought	Sampling not done due to drought	Sampling not done due to drought
	5 <sup>th</sup> Quarter	6.1	0.6	Slight Pollution	B
	6 <sup>th</sup> Quarter	5.7	0.5	Moderate Pollution	C
	7 <sup>th</sup> Quarter	6.6	0.6	Slight Pollution	B
	8 <sup>th</sup> Quarter	6.8	0.5	Slight Pollution	B
Betwa river near road bridge Vidisha	1 <sup>st</sup> Quarter	5.6	0.6	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	6.0	0.7	Moderate Pollution	C
	3 <sup>rd</sup> Quarter	5.8	0.7	Moderate Pollution	C
	4 <sup>th</sup> Quarter	5.2	0.5	Moderate Pollution	C
	5 <sup>th</sup> Quarter	7.2	0.5	Slight Pollution	B
	6 <sup>th</sup> Quarter	5.2	0.6	Moderate Pollution	C

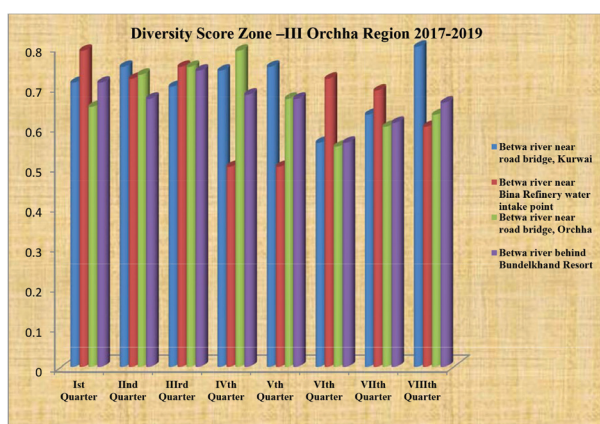
Table 5. Continued ...

## Water Quality on the Basis of BWQC Score 2017-19

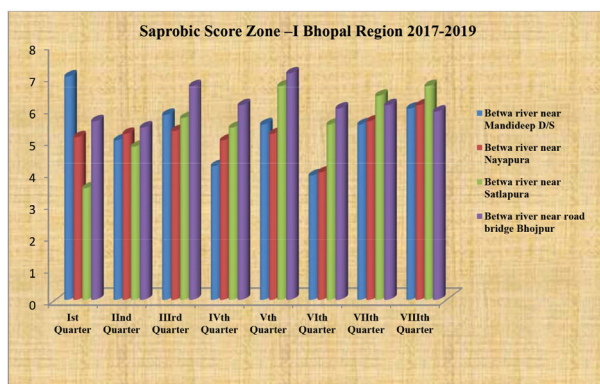
Sampling Location	Quarter	Saprobic score	Diversity score	Water Quality	Water Quality Class
Betwa river near water intake point Vidisha	7 <sup>th</sup> Quarter	5.8	0.6	Moderate Pollution	C
	8 <sup>th</sup> Quarter	7.3	0.6	Slight Pollution	B
	1 <sup>st</sup> Quarter	5.0	0.7	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	6.7	0.7	Slight Pollution	B
	3 <sup>rd</sup> Quarter	7.5	0.7	Slight Pollution	B
	4 <sup>th</sup> Quarter	5.6	0.5	Moderate Pollution	C
	5 <sup>th</sup> Quarter	5.4	0.5	Moderate Pollution	C
	6 <sup>th</sup> Quarter	5.5	0.6	Moderate Pollution	C
Betwa river near Barighat road bridge, Ganjbasoda	7 <sup>th</sup> Quarter	5.9	0.7	Moderate Pollution	C
	8 <sup>th</sup> Quarter	6.1	0.5	Slight Pollution	B
	1 <sup>st</sup> Quarter	7.5	0.8	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	5.5	0.7	Slight Pollution	B
	3 <sup>rd</sup> Quarter	6.3	0.7	Slight Pollution	B
	4 <sup>th</sup> Quarter	6.7	0.5	Slight Pollution	B
	5 <sup>th</sup> Quarter	6.2	0.6	Slight Pollution	B
	6 <sup>th</sup> Quarter	5.7	0.5	Moderate Pollution	C
Zone-III Bina/Orchha Region	7 <sup>th</sup> Quarter	5.9	0.5	Moderate Pollution	C
	8 <sup>th</sup> Quarter	6.1	0.6	Slight Pollution	B
Betwa river near road bridge, Kurwai	1 <sup>st</sup> Quarter	7.0	0.7	Moderate Pollution	C
	2 <sup>nd</sup> Quarter	7.5	0.7	Slight Pollution	B
	3 <sup>rd</sup> Quarter	6.0	0.7	Moderate Pollution	C
	4 <sup>th</sup> Quarter	5.1	0.7	Slight Pollution	B
	5 <sup>th</sup> Quarter	7.5	0.7	Slight Pollution	B
	6 <sup>th</sup> Quarter	6.5	0.5	Slight Pollution	B
	7 <sup>th</sup> Quarter	5.9	0.6	Moderate Pollution	C
	8 <sup>th</sup> Quarter	5.7	0.8	Moderate Pollution	C
Betwa river near Bina Refinery water intake point	1 <sup>st</sup> Quarter	5.2	0.7	Slight Pollution	B
	2 <sup>nd</sup> Quarter	5.0	0.7	Slight Pollution	B
	3 <sup>rd</sup> Quarter	5.8	0.7	Moderate Pollution	C
	4 <sup>th</sup> Quarter	6.0	0.5	Slight Pollution	B
	5 <sup>th</sup> Quarter	6.5	0.5	Slight Pollution	B
	6 <sup>th</sup> Quarter	6.0	0.7	Slight Pollution	B
	7 <sup>th</sup> Quarter	6.2	0.6	Slight Pollution	B
	8 <sup>th</sup> Quarter	6.0	0.6	Slight Pollution	B
Betwa river near road bridge, Orchha	1 <sup>st</sup> Quarter	7.0	0.6	Slight Pollution	B
	2 <sup>nd</sup> Quarter	6.3	0.7	Slight Pollution	B
	3 <sup>rd</sup> Quarter	5.1	0.7	Moderate Pollution	C
	4 <sup>th</sup> Quarter	5.7	0.7	Moderate Pollution	C
	5 <sup>th</sup> Quarter	7.2	0.6	Slight Pollution	B
	6 <sup>th</sup> Quarter	5.6	0.5	Moderate Pollution	C
	7 <sup>th</sup> Quarter	5.8	0.6	Moderate Pollution	C
	8 <sup>th</sup> Quarter	6.2	0.6	Slight Pollution	B
Betwa river behind Bundelkhand Resort	1 <sup>st</sup> Quarter	6.8	0.7	Slight Pollution	B
	2 <sup>nd</sup> Quarter	6.8	0.6	Slight Pollution	B
	3 <sup>rd</sup> Quarter	6.5	0.7	Slight Pollution	B
	4 <sup>th</sup> Quarter	6.3	0.6	Slight Pollution	B
	5 <sup>th</sup> Quarter	6.8	0.6	Slight Pollution	B
	6 <sup>th</sup> Quarter	6.2	0.5	Slight Pollution	B
	7 <sup>th</sup> Quarter	5.1	0.6	Moderate Pollution	C
	8 <sup>th</sup> Quarter	7.0	0.6	Slight Pollution	B



Graph 2. Diversity Score Zone – II Vidisha Region



Graph 3. Diversity Score Zone – III Orchha Region

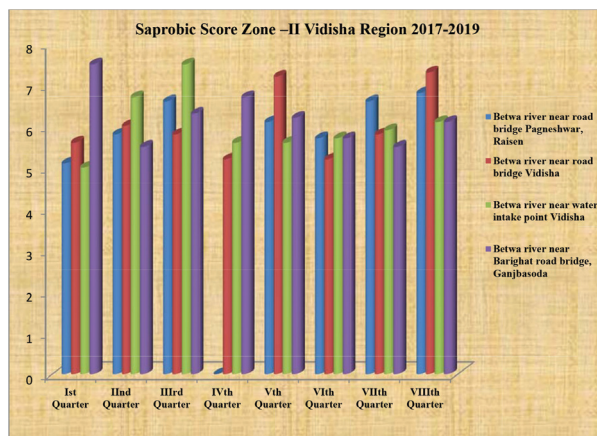


Graph 4. Saprobic Score Zone – I Bhopal Region

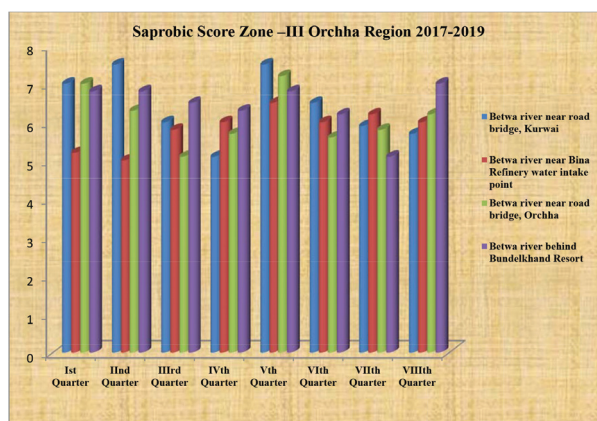
Zone-III, water quality of river Betwa based on BWQC classified class B to C.

## Conclusion

This study provides an information and data to evaluate the water quality of river Betwa in different cycles at different sampling locations by biological



Graph 5. Saprobic Score Zone – II Vidisha Region



Graph 6. Saprobic Score Zone – III Orchha Region

components. Biologically, the water quality of river Betwa based on BWQC classified as class B to C. The quality of water at most of the places having slight pollution [Class B] whereas at some places water quality of river was observed deteriorated due to influx of domestic, industrial effluents into the river and other human activities along the banks of the river at different places.

The tool of Bio-Monitoring is the use of benthic macro-invertebrates for categorization of rivers by different color maps which show several classes according to classification of water quality at different sampling locations in terms of clean, slight pollution, moderate pollution and severe pollution. Betwa River has distinctive diversity of benthic macro invertebrates throughout its stretch. The presence, absence, frequency of appearance, disappearance and abundance of these organisms act as *biomonitoring tool* in pollution load assessment. Water quality of River Betwa favored virtually 45 num-

bers of families of macro zoo benthos invertebrates identified during study period from April 2017 to March 2019. The benthic macro invertebrate fauna exhibit an enormous range of diversity in river bed and are highly sensitive or tolerant to changes in water quality. The presence, absence, frequency of appearance, disappearance and abundance of these organisms act as *biomonitoring tool* in pollution load assessment.

In Zone-I Mandideep region at subsequent sampling locations 21 families of macro zoo benthos were identified, the water quality class at most of the locations of zone-I was Class C based on BWQC score. At some sampling locations degradation of water quality was observed mainly due to merging of domestic and industrial effluent within and around the river bed of Mandideep region. In this region water quality remains same throughout the study period. Water quality of Betwa River near road bridge Bhojpur was Class C during 1<sup>st</sup> and 2<sup>nd</sup> cycle whereas Class B during 3<sup>rd</sup> and 4<sup>th</sup> cycle.

In Zone-II Vidisha Region, about 23 families were identified. Water quality at most of the sampling locations was slightly to moderately polluted, i.e. Class B to C. The reasons for the degradation of water quality in some locations are mainly due to human activities which include idol immersion cattle influence affecting the water quality of river. However, at Betwa river near Barighat road bridge, Ganjbasoda water quality Class B was observed.

In Zone III Bina/Orchha region water quality was mostly of Class B ie. Slightly polluted but 3<sup>rd</sup> cycle the water quality degrades due to anthropogenic activities, the cause for the deprivation of water quality at some sampling sites is basically due to human influence and religious activities.

## References

- Anderson, James, E. 1979. A Theoretical Foundation for the Gravity Equation. *American Economic Review, American Economic Association*. 69(1) : 106-116, March.
- Gooderham, G. J. and Tyrslin, T. E. 2002. *The Waterbug Book: A Guide to the Freshwater Macroinvertebrates of Temperate Australia*, 2<sup>nd</sup> ed. pp. 1-3, CSIRO Publishing, Australia.
- Hallawell, J. M. 1986. Biological Indicator of fresh water pollution and environment management. Pollution monitoring series, Advisory Editor; Kenneth Mellanby, England 1986; 546.
- Honda, 1986. Spatial and Seasonal distribution of phytoplankton in the Cross River estuary, Nigeria. In: Paper delivered at the 6<sup>th</sup> Annual Conference of the Nigerian Society for Botany, 46-49.
- Needham, J.G. and Needham, P.R. 1962. *A Guide to the Study of the Freshwater Biology*. Holden-Dey Inc Francisco: 108.
- Pennak, R.W. 1953. Freshwater invertebrates of United States. The Ronald Press Company, New York.
- Resh, V.H. 2008. Which group is best? Attributes of different biological assemblages used in freshwater biomonitoring programs. *Environment Monitoring and Assessment*. 138 : 131-138.
- Rosenberg, D. M. and Resh, V. H. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates; In: *Freshwater Biomonitoring and Benthic Macroinvertebrates* (eds) Rosenberg, D. M., and Resh, V. H., (New York: Chapman and Hall), 1-9.
- Sampath, V., Sreenivasan, A. and Ananthanarayan, R. 1981. In: *Proceedings of a workshop, Cent. Bd. Prev. Cout. Water Pol. Osm. University, Hyderabad*, 149-16.
- Victor, R. and Ogbeibu, A.E. 1985. Macrobenthic invertebrates of a stream flowing through farmland in Southern Nigeria. *Environmental Pollution Series A*. 39: 333-347.
- Wilhm, J. F. 1975. *Biological Indicator of Pollution*. London: Blackwell Scientific Publications.