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Assessment of River health of Chambal River based on Biological Communities, India

Amit Kumar[1*] M.P. Sharma[2] and Naresh Singh Yadav[3]

[1,2]*Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, 247667, India*
[3]*Deputy Conservator, Department of Forest, Government of Madhya Pradesh, 462023, India*

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**Corresponding author: E-mail: amit.agl09@gmail.com, Mobile: +91-9045939559*

Abstract
Local biota and their ecological attributes is an indicator of varying conditions in aquatic ecosystems. Biological diversity was used to calculate pollution index of Chambal River, in National Chambal sanctuary in Madhya Pradesh (M.P). The Biotic species present in the areas provides robust physico-chemical interaction between terrestrial and aquatic ecosystems. The present paper focused on the biological community to assess the pollution status of Chambal River, M.P, during June 2012 to May 2013. The average Simpson diversity index and Shannon's diversity index was found as 0.66–0.81 and 1.58–1.72 respectively indicating moderate health of Chambal River. Similarly, the average richness indices i.e. Margalef and Menhinick richness indices were found as 0.61–0.73 and 0.35–0.51 respectively indicating again the moderate health of the river. The diversity and richness indices is an indication of moderate river health which can be taken care by taking appropriate corrective measures to keep the water quality in good condition. The study indicates that water of the stretch is not fit for drinking but can be used for irrigation, bathing, aquaculture etc.

Keywords: Biodiversity**,** River, Pollution, index, Biotic

1. Introduction
Water is the most important element for all life forms on the earth. The living forms require water for almost all the vital metabolic activities. It is believed that life originated on the earth in shallow warm water. Even after millions of years of evolution of life, the importance of water has not changed for the living forms. Life still thrives in plenty both in freshwater & marine environment. Though, some life forms evolved and moved to land during their evolutionary course, the importance of water still remained the same for their survival. The biological properties of freshwater ecosystem is defined by the whole complex of animals and plants inhabiting water bodies and interrelations between living organisms and the physic-chemical conditions of water body and its catchments. These conditions are mainly influenced by climate, geographical location and type of water bodies. The River Chambal is the most significant water resource of the state of Madhya Pradesh (M.P) catering to the demand of a large number of cities and towns situated on its banks. Apart from the supply of potable water, the river is also ecologically very important as it harbours very rich biodiversity [1-2]. The Chambal River is considered pollution free [3-7] and hosts an amazing riverine faunal assemblage including 2 species of crocodilians viz. Mugger and Gharial, 8 species of freshwater turtles, smooth-coated otters, Gangetic river dolphins, skimmers, black-billed terns, sarus cranes and black-necked storks, amongst other large number of migratory birds. It is observed that in order to conduct extensive studies on aquatic flora and fauna, very little significance is given to tropical biota in the context of water quality classification and its managements. Though tropical biota are often the essential part of aquatic ecosystems that anti-pollution programmes are targeted to protect, however the local biota and their ecological components may be used to provide information on changing conditions in freshwater ecosystem. Among various available water resources, Lakes & Rivers are very significant segment of aquatic ecosystem. Unfortunately, most of the water bodies especially the major

rivers in India are contaminated due to large number of anthropogenic activities. The problem of water quality deterioration is mainly due to human activities such as disposal of dead bodies, discharge of industrial and sewage wastes and agricultural runoff which are major cause of ecological damage and poses serious health hazards [8]. River pollution in India has now reached to a point of crisis due to unplanned urbanization and rapid growth of industrialization [9]. The entire array of life in water is affected due to pollution in water. The River Chambal which is a major river in Central India is no exception. The river has been reported to be polluted at many places due to discharge of industrial effluent and domestic sewage. The discharge of waste water not only degrades the water quality of the river but also affects the biodiversity in it. The present study evaluates the health of the Chambal River based on Macrophytes, Macrobenthos, Phytoplankton and Zooplankton using species diversity and richness indices. Consequently, different indices of diversity were taken into account to highlight their importance with respect to river health assessment.

2. Material and Methods

2.1. Study Area

The River Chambal originates near the Janapao temple at about 24 km south-west away from Mhow in M.P at an elevation of 854.35 m. At the origin, there are three minor streams which are 1.6 to 2.4 km in length around the temple. These streams meet the river Chambal. The Chambal is a perennial river in M.P. The stretch of river contained in the National Chambal sanctuary ($25^{o}23'52''N$, $76^{o}28'15''$ E) extends upto a distance of 600 km downstream from Kota (Rajasthan) to the confluence of the Chambal with the Yamuna river (Etawah) a major tributary of river Ganga. In fact, this river forms the boundary between Rajasthan and M.P and M.P and Uttar Pradesh (U.P). Within the sanctuary (river length of approximately 600 km), the river flows through the areas of deeply eroded alluvium, Stony rapid, sand banks and gravel bars which are in abundance, and there are many steep banks and bends, where the depth of water exceeds even 10 m. The field study was conducted in an entire stretch of 59 kms from Rajghat to Kussidghat. Details of sampling point and its location has been given in our previous paper [6].

2.2 Methodology

For the qualitative and quantitative analysis, the seasonal water samples were collected from 100 m upstream, centre and 100 m downstream of the river near National Chambal sanctuary during the period June 2012- May 2013. For the collection of plankton samples (both Phytoplankton & Zooplankton), plankton net (Nylon bolt No: 22) of mesh size 25µm was used. During sampling, 10 litres of water samples were collected by Ruttner Water Sampler (a type of Niskin type water sampler) which was filtered through the plankton net and concentrated to 50 ml sub- sample. The collected sample was then preserved with 5% formaldehyde solution and iodine for analysis of zooplankton and phytoplankton sample respectively. Plankton was studied under compound microscope and was identified with the help of standard references [10]. The results are expressed in organism /litre. In order to find out the relationship between macrophytic and macrobenthic fauna, macrophyte was collected with the help of iron hook from different locations of the study stretch and was kept in bucket so as to isolate the attached fauna. Then they were segregated using sieve no. 40 mesh size sieve. The organisms retained were then identified as per the macrobenthic invertebrates. The special adaptations and texanomic details of macrophytes were identified with the help of pertinent literature APHA [11] and Adoni [12]. To understand a particular biotic community, it is important to work out certain indices such as Diversity indices *viz.*, Shannon and Simpson diversity index (1949) and Menhinik (1964) and Margalef index (1967). These were computed by following equations which have been discussed in Table 1.

3. Results

It is established fact that pollution of any river drastically reduces the number of species of the aquatic system (i.e., Species Diversity) while frequently creating a conducive environment that is favorable to only few species (i.e., pollution-tolerant forms). Thus, in a polluted river, there are normally large numbers of few species, while

in a pristine river there are moderate numbers of many useful species. The change in total number of biological communities at different sampling locations during the period June 2012 to May 2013 has been illustrated in Table 2-4.

Table 1: Details of Species Richness and Species Diversity indices

Items	**Species Richness Indices**		**Species Diversity Indices**	
Name of Index	Margalef's richness index (MARI)	Menhinik richness index (MERI)	Simpson's diversity index (SDI)	Shannon-Weiner diversity index (SWDI or H)
Equations	$MARI = \frac{S-1}{\ln(N)}$	$MERI = \frac{S}{\sqrt{N}}$	$SDI = \sum_{i=1}^{s} \frac{ni(ni-1)}{n(n-1)}$	$H = -\sum_{i=1}^{s} (pi \ln(pi)$
Range of indexes and its description	$(0-\infty)$ (0-ln(S))	0-1 0 indicates all taxa are equally present and 1 indicates one taxon dominates the community completely.	0-1 Where, 0 represents infinite diversity and 1 no diversity.	0-5 Where, 0 represents for communities with only a single taxon and 5 for communities with many taxa.
River health	Larger the index, more healthy the river, is/or vice versa.	Larger the index, more healthy the river, is/or vice versa.	Low: the environment is quite stressful with relatively few ecological niches and only a few organisms are well adapted to that environment. High: a greater number of successful species and a more stable ecosystem.	H> 4: Very good H = 3-4: Good H= 2-3: Moderate H= 1-2: Poor H<1: Very poor
References	[15-16]	[14]	[13]	[17]
Where, *S*= the number of species in a sample, *N*= the number of individuals in a community, *n* = the number of individuals in a sample from a population, *ni* = the number of individuals in a species *i* of a sample from a population, *pi* is the proportion of i^{th} species in the total sample.				

Table 2: Average number of Biological species found in Chambal River during June 2012- May 2013 at Upstream

Sl. No	**Macrophytes**	**Macrobenthos**	**Phytoplankton**	**Zooplankton**
	Azolla pinnata	*Bellamya bengalensis*	*Amphora sp*	*Alona sp*
	Ceratophyllum demersum	*Bellamya dissimilis*	*Ankistrodesmus falcatus*	*Alonella sp*
	Chara branchypus	*Thiara scabra*	*Arthrospira sp*	*Amoeba sp*
	Cyperus articulatus	*Thiara tuberculata*	*Asterionella sp*	*Anuraeopsis sp*
	Hydrilla verticillata	*Tarebia lineata*	*Botryococcus brauni*	*Arcella discoides*
	Hydrocharis dubia	*Lymnaea*	*Caloneis sp*	*Arcella sp*

		acuminata		
	Ludwigia adscendens	*Pila globosa*	*Characium limneticum*	*Arcella vulgaris*
	Myriophyllum spathulatum	*Unio species*	*Chlorella humicola*	*Asplancha sp*
	Najas minor	*Corbicula striatella*	*Chlorella vulgaris*	*Bosmina sp*
	Spirodella polyrhiza	*Gyraulus convexiusculus*	*Chlorococcum humicola*	*Brachionus angularis*
	Utricularia flexuosa	–	*Chlorococcum sp*	*Brachionus bidentata*
	Vallisneria spiralis	–	*Closteriopsis sp*	*Brachionus calyciflorus*
	–	–	*Closterium reticulatum*	*Brachionus caudatus*
	–	–	*Closterium cambrium*	*Brachionus falacatus*
	–	–	*Coelastrum microporum*	*Brachionus patalus*
	–	–	*Coelastrum recticulatum*	*Calanoides sp*
	–	–	*Cosmarium quinarium*	*Centrocypris sp*
	–	–	*Cosmarium sp*	*Centropyxis aculeata*
	–	–	*Crucigenia sp*	*Ceriodaphnia sp*
	–	–	*Cyclotella sp*	*Chydorus sp*
	–	–	*Cymbella sp*	*Cyclops sp*
	–	–	*Denticulla sp*	*Cypris sp*
	–	–	*Diatoma sp*	*Daphnia sp*
	–	–	*Diatomella sp*	*Diaptomus sp*
	–	–	*Elkatothrix denticulatum*	*Difflugia sp*
	–	–	*Elkatothrix viridis*	*Filina longistata*
	–	–	*Epithemia turgida*	*Filina sp*
	–	–	*Euastrum bidentatum*	*Hexarthra sp*
	–	–	*Eudorina elegans*	*Keratella tropica*
	–	–	*Filmente sp*	*Lacrymaria sp*
	–	–	*Fragillaria sp*	*Lecane sp*
	–	–	*Frustula sp*	*Lepadella*
	–	–	*Gloeotrichia sp*	*Mesocyclops*
	–	–	*Gomphonema sp*	*Moina sp*
	–	–	*Hanzchia sp*	*Monostyla sp*
	–	–	*Kirchneriella contorta*	*Mytilina sp*
	–	–	*Melosira granulata*	*Paramecium sp*
	–	–	*Melosira varians*	*Phyllodiaptomus*
	–	–	*Merismopedia sp*	*Polyarthra*
	–	–	*Microcystis aeruginosa*	*Stenocypris sp*
	–	–	*Navicula sp*	–
	–	–	*Nitzschia sp*	–
	–	–	*Oedogonium sylvaticum*	–
	–	–	*Oocystis lacustris*	–
	–	–	*Oscillatoria maxima*	–
	–	–	*Oscillatoria sp*	–
	–	–	*Oscillatoria tenius*	–

	–	–	*Pediastrum duplex*	–
	–	–	*Pediastrum simplex*	–
	–	–	*Peridinium sp*	–
	–	–	*Pinnularia sp*	–
	–	–	*Rhopalodia sp*	–
	–	–	*Scenedesmus alterans*	–
	–	–	*Scenedesmus sp*	–
	–	–	*Schroederia sp*	–
	–	–	*Selenestrum sp*	–
	–	–	*Spirogyra elongota*	–
	–	–	*Spirogyra sp*	–
	–	–	*Synedra ulna*	–
	–	–	*Tabellaria sp*	–
	–	–	*Tetradon sp*	–
	–	–	*Trachelomonus sp*	–
	–	–	*Treubaria sp*	–
	–	–	*Ulothrix sp*	–
	–	–	*Volvox sp*	–
Total	**12**	**10**	**65**	**41**

Table 3: Average number of Biological species found in Chambal River during June 2012- May 2013 at Centre

Sl. No	**Macrophytes**	**Macrobenthos**	**Phytoplankton**	**Zooplankton**
1.	*Azolla pinnata*	*Bellamya dissimilis*	*Amphora sp*	*Alonella sp*
2.	*Ceratophyllum demersum*	*Thiara tuberculata*	*Asterionella sp*	*Bosmina sp*
3.	*Chara branchypus*	*Lymnaea acuminata*	*Caloneis sp*	*Brachionus bidentata*
4.	*Cyperus articulatus*	*Pila globosa*	*Chlorella humicola*	*Brachionus patalus*
5.	*Hydrilla verticillata*	*Unio species*	*Chlorococcum humicola*	*Ceriodaphnia sp*
6.	*Ludwigia adscendens*	–	*Closterium reticulatum*	*Chydorus sp*
7.	*Myriophyllum spathulatum*	–	*Coelastrum recticulatum*	*Cyclops sp*
8.	*Najas minor*	–	*Cosmarium quinarium*	*Daphnia sp*
9.	*Vallisneria spiralis*	–	*Crucigenia sp*	*Diaptomus sp*
10.	–	–	*Denticulla sp*	*Mesocyclops sp*
11.	–	–	*Diatoma sp*	–
12.	–	–	*Elkatothrix viridis*	–
13.	–	–	*Epithemia turgida*	–
14.	–	–	*Eudorina elegans*	–
15.	–	–	*Filmente sp*	–
16.	–	–	*Fragillaria sp*	–

17.	–	–	*Frustula sp*	–
18.	–	–	*Hanzchia sp*	–
19.	–	–	*Kirchneriella contorta*	–
20.	–	–	*Melosira granulata*	–
21.	–	–	*Melosira varians*	–
22.	–	–	*Merismopedia sp*	–
23.	–	–	*Navicula sp*	–
24.	–	–	*Nitzschia sp*	–
25.	–	–	*Oedogonium sylvaticum*	–
26.	–	–	*Oscillatoria maxima*	–
27.	–	–	*Pediastrum simplex*	–
28.	–	–	*Pinnularia sp*	–
29.	–	–	*Scenedesmus alterans*	–
30.	–	–	*Spirogyra elongota*	–
31.	–	–	*Spirogyra sp*	–
32.	–	–	*Synedra ulna*	–
33.	–	–	*Tabellaria sp*	–
34.	–	–	*Tetradon sp*	–
35.	–	–	*Ulothrix sp*	–
36.	–	–	*Volvox sp*	–
Total	**9**	**5**	**36**	**10**

Table 4: Average number of Biological species found in Chambal River during June 2012- May 2013 at Downstream

Sl. No	Macrophytes	Macrobenthos	Phytoplankton	Zooplankton
	Ceratophyllum demersum	*Bellamya bengalensis*	*Amphora sp*	*Alona sp*
	Chara branchypus	*Thiara tuberculata*	*Asterionella sp*	*Alonella sp*
	Cyperus articulatus	*Lymnaea acuminata*	*Chlorella humicola*	*Amoeba sp*
	Hydrilla verticillata	*Unio species*	*Chlorococcum humicola*	*Anuraeopsis sp*
	Hydrocharis dubia	*Corbicula striatella*	*Closterium reticulatum*	*Arcella discoides*
	Ludwigia adscendens	*Gyraulus convexiusculus*	*Closterium cambrium*	*Arcella sp*
	Myriophyllum spathulatum	–	*Coelastrum recticulatum*	*Arcella vulgaris*
	Najas minor	–	*Cosmarium quinarium*	*Asplancha sp*
	Utricularia flexuosa	–	*Crucigenia sp*	*Bosmina sp*
	Vallisneria spiralis	–	*Cyclotella sp*	*Brachionus bidentata*
	–	–	*Cymbella sp*	*Brachionus calyciflorus*
	–	–	*Diatomella sp*	*Brachionus caudatus*
	–	–	*Epithemia turgida*	*Brachionus falacatus*
	–	–	*Eudorina elegans*	*Calanoides sp*
	–	–	*Fragillaria sp*	*Centrocypris sp*

	–	–	*Frustula sp*	*Centropyxis aculeata*
	–	–	*Gomphonema sp*	*Ceriodaphnia sp*
	–	–	*Kirchneriella contorta*	*Chydorus sp*
	–	–	*Melosira granulata*	*Cyclops sp*
	–	–	*Navicula sp*	*Cypris sp*
	–	–	*Nitzschia sp*	*Daphnia sp*
	–	–	*Oedogonium sylvaticum*	*Diaptomus sp*
	–	–	*Oscillatoria maxima*	*Difflugia sp*
	–	–	*Pediastrum duplex*	*Filina sp*
	–	–	*Pediastrum simplex*	*Hexarthra sp*
	–	–	*Pinnularia sp*	–
	–	–	*Rhopalodia sp*	*Mesocyclops*
	–	–	*Scenedesmus alterans*	*Moina sp*
	–	–	*Selenestrum sp*	–
	–	–	*Spirogyra elongota*	–
	–	–	*Synedra ulna*	–
	–	–	*Tabellaria sp*	–
	–	–	*Tetradon sp*	–
Total	**10**	**6**	**33**	**28**

At upstream, 12 number of macrophyte species of different groups were identified while number of macrobenthos observed at this station was 10. Among plankton communities, 65 phytoplankton species were observed at this station whereas, number of zooplankton species recorded was 41 (Table 2). Similarly, at centre of the river, total 9 number of macrophyte species of different groups were observed while macrobenthos recorded at this station was 5 (Table 3). The plankton community's on the other hand depicted 36 phytoplankton species and10 zooplankton species whereas, at downstream of the river, total 10 macrophyte species of different groups were observed while number of macrobenthos recorded at this station was 6. The plankton communities on the other hand depicted 33 phytoplankton species and 28 zooplankton species (Table 4). The variation of biotic community at various stretches of Chambal River, as shown in figure 1 and the calculation of various diversity indices, ranges and its health status at all sampling site of Chambal River in National Chambal Sanctuary have been shown in Table 5.

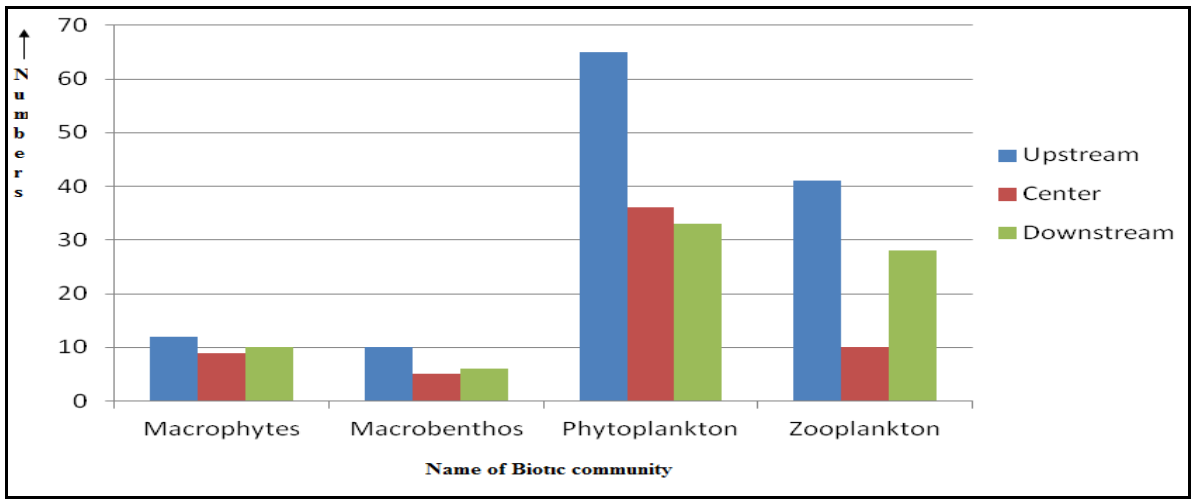

Figure 1: Variation of biological community at different locations in Chambal

Table 5: Calculation of diversity indices for sampling site in Chambal River

Items	**Margalef's richness index**			**Menhinik index**			**Shannon's diversity index**			**Simpson diversity index**		
	U/s	Centre	D/s	U/s	Centre	D/s	U/s	Centre	D/s	U/s	Centre	D/s
	0.618	0.732	0.69	0.353	0.516	0.455	1.63	1.58	1.724	0.74	0.814	0.66
Ranges	**(0−∞)**			0-1			0-5			0-1		
River health	****	****	****	****	****	****	****	****	****	****	****	****

Where; U/s means upstream location of river**;** D/s means downstream location of river**;** **** means moderately polluted river

4. Discussions

The analysis of the river health associated with the biotic community in the study stretch was quantitatively rich. According to the results of present investigation, it is concluded that the biological community in Chambal River changes frequently with the change in locations owing to the changing environmental factors mainly temperature and humidity observed in such shallow Chambal River. Similar pattern of changes in phytoplankton community in different freshwater bodies were recorded by Sharma (1980); Sharma *et al.* (1982) and Deorari (1993) [18-20]. During present study, it was seen that at different locations diversity indices vary. The Margalef and Menhinik richness indices were high at centre i.e. 0.73 and 0.51 as compared to other locations. The Shannon's diversity index is maximum (1.72) at downstream and lower (1.58) at centre. A community becomes more divergent as the stress increases and accordingly species diversity diminishes with poor water quality. A community dominated by relatively few species indicates environmental stress [21]. The Shannon's index (1.58-1.72) obtained during this study indicates moderate pollution in the Chambal River. The Simpson index (0.66-0.81) indicates an increase in dominance of fewer species at downstream due to high variation in water quality. According to this range, the Chambal River is moderately polluted. The Margalef and Menhinick richness indices ranged from 0.61 to 0.69 and from 0.35 to 0.51 respectively, which indicate moderate richness of the organisms. The moderate health of the study stretch of Chambal River can also be authenticated by the results of our published work [4-6] based on water quality and riparian vegetations. To bring about the improvement in the river health, the corrective conservation measures may be appropriately taken by concerned authorities so that river pollution is reduced in future.

Conclusions

The present study was conducted based on the Macrophytes, Macrobenthos, Phytoplankton and Zooplankton, the diversity and richness indices were assessed in 58 km study stretch in U/s, D/s and Centre of Chambal River during June 2012 to May 2013. The average Simpson diversity index and Shannon's diversity index was found as 0.66-0.81 & 1.58-1.72 respectively indicating moderate health of Chambal River. Similarly, the richness indices i.e. Margalef and Menhinick richness indices were found as 0.61 -0.73 & 0.35-0.51 respectively indicating again the moderate health of the river. The diversity and richness indices is an indication of moderate river health which can be taken care by taking appropriate corrective measures to keep the water quality in good condition. The study concludes that water of the stretch is not fit for drinking but can be used for irrigation, bathing, aquaculture etc. In order to improve the river health, it is suggested that proper conservation plan to be implemented to provide favourable habitat for the aquatic fauna/flora.

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