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Original Research Paper

Algal Studies in a Polluted Site of Krishna River at Wai, Maharashtra (India)

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ABSTRACT

Krishna River is one of the 14 major rivers of India, which originates from Mahabaleshwar and flows all across southwestern Maharashtra covering several important towns like Wai, Satara, Karad and Sangli. The present study was made in the Krishna River at two sites, mainly Eksar and Wai. The Eksar site is before entering of the river at Wai. The Wai is holy city and comparatively a polluted city due to religious and cultural activities. The purpose of taking Eksar site was mainly for comparison purpose. A total number of 42 species was recorded in the Krishna River belonging to four major classes, Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenophyceae. Algal species recorded at Wai are highly tolerant to organic pollution, while the species obtained in the untainted section before water enters in Wai have comparatively several sensitive species. This indicates that the water is non-polluted or relatively less polluted at Eksar. The Palmer's algal index shows very low organic pollutants at Eksar and probable organic pollution at Wai. Shannon's diversity index reveals that the human activity at Wai has made the river highly polluted, which at a glance looks like of no direct use. Simpson's index is used to assess the dominance of algal species. According to the Simpson's index, species are not evenly distributed in both the sites. Environmental Gini index also shows the Wai as comparatively a polluted site.

INTRODUCTION

The rivers are long ecosystems which are known to have diverse stretches due to changing boundary conditions and catchment area. The water characteristics and the associated flora and fauna change from one section to other. Industrial wastes, agricultural runoff and sewage are the main cause of the river pollution (Chetna et al. 1997, Singh & Rai 1999, Ganguly et al. 1999, Goel & Bhosale 2001). Due to the flowing nature of rivers, they usually have higher self purification capacity than other aquatic ecosystems. The organic matter tends to degrade faster owing to higher reaeration of water due to flowing nature and high turbulence.

As rivers are often important source of community water supply and irrigation, their water quality has to be monitored regularly. The quality of water can also be monitored by the types of organisms present in water (Javaid & Pandit 2013). Numbers of algal species are sensitive as well as tolerant to organic pollution. Several workers have used algae as indicators of water quality (Sudhakar et al. 1994, Trivedy 1986, LiLi 2010). Algae are used to assess the water quality because they have very sensitive and have short life cycle. Algae are easily cultured in the laboratory and samplings are easy, inexpensive and create minimal impact on resident biota. Relatively standard methods exist for the evaluation of functional and non-taxonomic structural characteristics of algal communities (Round 1991, Van Dam et al. 1994, McCormick & Cairns 1994, Stevenson & Pan 1999). Alterations and shifts in the species composition and productivity of algal assemblages in response to anthropogenic stresses should be considered in order to predict the effects on food web interactions and other ecosystem components (McCormick & Cairns 1994). Algae affect the taste and smell of water, and forecasting the movement and growth of algae in river systems is important for operational managers responsible for the distribution and supply of potable water (Whitehead & Hornberger 1984).

Krishna River is the major river in Satara district of Maharashtra and has a number of tributaries. It originates from Mahabaleshwer in Western Ghats of Maharashtra and flows towards southern Maharashtra covering several important towns like Wai, Satara, Karad and Sangli. Wai is an ancient and religious city having large number of small and large temples at the bank of the Krishna River.

The present study deals with the changes in the algal population in Krishna river at Wai where it is highly polluted due to cultural and religious activity (Pawar & Vaidya 2012). For this purpose the various algal based biotic and diversity indices have been used. During months of summer the quality of river water is usually at the lowest due to less flow and high evaporation rate. A number of indices including Shannon & Weaver (1949) species diversity index have been used to assess the pollution status of aquatic bodies (Islam 2008). Palmer's algal biotic index, Simpson's index, Shannon diversity index, Margalef index and Environmental Gini index have been calculated and they have been compared with the non-polluted stretch of the river (Eksar) before it enters the Wai town. The present survey was undertaken during the period of September 2014 to August 2015.

MATERIALS AND METHODS

Study area and sampling sites: Satara district lies in south-western Maharashtra, between 17°7' to 18°11' North latitude and 73°33' to 74°54' East longitude. The annual average temperature varies from minimum of 11.6°C to maximum of 37.5°C. Two sampling sites of Krishna River were selected for algal study.

Site 1-Wai: This is first major town where river enters in non-polluted form. Many famous temples are situated at the bank of the river. Due to high religious and cultural activities and visits of devotees the river suffers with high pollution. The washing of cloths and vehicles are common practices at the ghats of river at Wai.

Site 2-Eksar: This village is situated at the bank of Krishna River before Wai. Washing of cloths, cattle, and bathing are the common practices at this site.

Collection of samples for chemical and algal studies The water samples were collected in 2-litre polyethylene containers during the noon time. These containers were brought to the laboratory and kept in a refrigerator for further analysis.

Analysis of water quality: Water temperature was recorded at the time of sample collection by using a mercury thermometer. While other parameters like pH, alkalinity, dissolved oxygen, TDS, chlorides, phosphate, nitrate and electrical conductivity were estimated in the laboratory by using standard methods of APHA (1996) and Trivedy & Goel (1986).

Algal analysis: For the study of algae, the samples were concentrated 10 times by centrifugation and preserved with 4% formalin for further analysis. The qualitative study for algal identification was made under a high resolution trinocular microscope (Olymps, Model- CH20iBIMF) attached with an electronic eyepiece directly connected to computer for the study of finer details and capturing photographs. The identification of algae was made with the help of standard floras and monographs (Desikachary 1959, Prescott 1951, Sarode & Kamat 1984, Randhava 1959). The density of algae was calculated by using a haemocytometer. The calculation of the Palmer's genus index was made according to the Palmer (1969). The diversity indices were calculated by using PAST software and Biodiversity calculator.

RESULTS AND DISCUSSION

Chemical quality of water: Physicochemical parameters of water in the selected sites are given in Table 1. The range of temperature varied from 21°C to 30°C at Eksar and 20°C to 31°C at Wai. The minimum value is recorded in the winter season and maximum in summer season. The pH of water in Wai ranges from 6.5 to 7.7 and in Eksar from 6.5 to 8.5. The range of electrical conductivity at Eksar was 85.2µS/cm to 312µS/cm and at Wai it was 98.4 µS/cm to 561µS/cm. Correspondingly, the range of TDS was 65mg/L to 165mg/L at Eksar and 63.96mg/L to 262mg/L at Wai. Dissolved oxygen, while it ranges from 4.4mg/L to 8.2mg/L at Eksar, it got reduced to 0.8mg/L to 5.22mg/L at Wai, indicating

Table 1: Range of physicochemical characteristics of River Krishna (2014 to 2015).

Sr. No.	Parameters	Site 1	Site 2
1	Temperature (°C)	21-30	20-31
2	pH	6.5-7.7	6.5-8.5
3	Electrical conductivity (µmho/cm)	85.2-312	98.4-561
4	TDS (mg/L)	65-165.1	63.9-262
5	Alkalinity (mg/L)	60-270	105-335
6	Hardness (mg/L)	28-166	82-226
7	Chlorides (mg/L)	4.26-19.88	14.2-39.8
8	Calcium (mg/L)	7.21-44.08	20.04-52.9
9	Magnesium (mg/L)	2.43-13.14	7.79-32.14
10	Dissolved oxygen (mg/L)	4.4-8.2	0.8-5.22
11	Phosphate-P (mg/L)	0.08-0.79	0.083-1.25
12	Nitrate-N (mg/L)	0.055-2.42	0.098-2.838

Note: Site 1-Eksar, Site 2-Wai

Table 3: Density ($\times 10^3$ units/mL) of algal species in Krishna River (2014-2015).

Sr.No.	Name of Algae	Site 1	Site 2
CHLOROPHYCEAE			
1	*Cosmarium quadratum*	Nil	95.541-127.388
2	*Cosmarium venustum*	Nil	95.541-127.388
3	*Cosmarium tumidum*	Nil	0-159.236
4	*Closterium pritchardianum*	0-95.541	0-127.388
5	*Pediastrum tetras*	Nil	0-127.388
6	*Pediastrum integrum*	Nil	0-95.541
7	*Pediastrum boryanum*	Nil	95.541-127.388
8	*Scenedesmus arvernensis*	Nil	127.388-254.777
9	*Scenedesmus armatus*	159.236-254.777	95.541-254.777
10	*Scenedesmus acuminatus*	Nil	159.236-382.166
11	*Scenedesmus incrassatulus*	Nil	95.541-127.388
12	*Scenedesmus quadricauda*	Nil	127.388-350.319
13	*Spirogyra hyaline*	Nil	127.388-191.083
14	*Spirogyra occidentalis*	0-254.777	95.541-286.624
CYANOPHYCEAE			
1	*Arthrospira khannae*	0-95.541	Nil
2	*Chroococcus caudatus*	Nil	0-95.541
3	*Chroococcus turgidus*	63.694-95.541	95.541-318.472
4	*Merismopedia tenuissima*	Nil	191.083-318.472
5	*Oscillatoria nigra*	191.083-318.472	127.388-382.166
6	*Oscillatoria curviceps*	222.930-382.166	318.472-382.166
7	*Oscillatoria limosa*	0-318.472	Nil
8	*Spirulina gigantea*	Nil	95.541-191.083
9	*Spirulina major*	95.541-127.388	63.694-254.777
BACILARIOPHYCEAE			
1	*Cymbella affinis*	95.541-445.852	95.541-382.166
2	*Cymbella gracilis*	Nil	0-382.166
3	*Cymbella tumidula*	0-254.777	Nil
4	*Eudorina elegans*	Nil	0-63.694
5	*Fragilaria construens*	0-254.777	Nil
6	*Fragilaria capucina*	159.236-509.555	69.694-254.777
7	*Fragilaria pinnata*	222.930-382.166	127.388-350.319
8	*Gomphonema gracile*	63.694-318.472	95.541-254.777
9	*Gyrosigma attenuatum*	95.541-318.472	0-222.930
10	*Gonium pectorale*	Nil	0-191.083
11	*Navicula minuta*	286.624-573.249	191.083-796.180
12	*Navicula disjuncta*	159.236-573.249	382.166-605.096
13	*Navicula pupula*	222.930-445.852	Nil
14	*Surirella robusta*	Nil	127.388-286.624
15	*Surirella tenera*	63.694 - 95.541	Nil
16	*Staurastrum triangularis*	Nil	0-95.694
17	*Synedra ulna*	63.694 -286.624	95.541-254.777
EUGLENOPHYCEAE			
1	*Phacus caudatus*	Nil	63.694-254.777
2	*Euglena acus*	Nil	0-63.694
Total number of genera		21	36

Note: Site 1-Eksar, Site 2-Wai

presence of higher quantities of organic matter and reduction by microbes. Hardness, calcium and magnesium were higher in Wai as compared to Eksar. Phosphorus was low in the study sites, ranging from 0.08mg/L to 0.79mg/L at Eksar and 0.083mg/L to 1.25mg/L at Wai. The range of nitrate was recorded from 0.055mg/L to 2.42mg/L at Eksar and 0.098 mg/L to 2.838 mg/L at Wai.

Algal Study: Twenty one species of algae were reported from the river water at Eksar while at Wai the number of species increased to 36. Higher number of species and density of algae indicate the pollution of Krishna river water as it enters into the City Wai. The stream algae usually show a great range of variety. Streams also do not show usually any precise assemblage of algae, which are usually found in

Table 3: Different biotic and diversity indices in Krishna River (2014 to 2015).

Sr. No.	Biotic and Diversity indices	Site 1	Status of Site 1	Site 2	Status of Site 2
1	Palmer index	3-12	Very low organic pollution	11-19	Probable evidence of high organic pollution
2	Simpson index	0.79-0.88	Stable community	0.88-0.89	Stable community
3	Shannon index	1.65-2.49	Moderate pollution	1.648-2.489	Moderate pollution
4	Margalef index	0.6993-1.161	Less polluted	0.9245-1.717	More polluted than Site 1
5	Gini index	0.125-0.2917	Less polluted	0.1324-0.4065	More polluted than Site 1

Note - Site 1-Eksar, Site 2-Wai

lentic waters. The algae in streams are subjected to extreme fluctuation in quantity and constitution due to fast changing of current and other characteristics of water (Palmer 1980). In the current study, the algae *Oscillatoria curviceps*, *Navicula minuta, Scenesdesmus armatus* and *Navicula anidium* were quite dominant at Eksar. In Wai also the dominance of algae was made by *Navicula minuta, Navicula disjuncta* and the species of *Oscillotoria*. However, a few tolerant species like *Euglena*, *Pediastrum* sp., *Phacus* and *Scenedesmus* also appeared at Wai.

The Palmer's algal biotic index indicates the quality of water at Eksar with low organic pollution and at Wai with high organic pollution. It ranged from 3-12 at Eksar and 11-19 at Wai. Higher values of Palmer index indicate organic pollution. A value above 20 is polluted water, and 15-19 as moderate pollution.

The diversity indices indicate the quality of water in stressed aquatic ecosystems. They are dependent upon number of species, number of individuals from all species, biological interactions between species, competition, mutualism, symbiosis, availability of food supply/amount of energy reaching the ground, human impact and climate/ temperature sensitivity. The diversity usually decreases in stressed conditions and increases in non polluted conditions. In moderate eutrophic systems, as the waters are quite rich in algal diversity, the diversity indices sometimes fail to indicate the quality of water. In such conditions, both sensitive and tolerant species may be present in different numbers according to the level of eutrophication (Goel et al. 1988). Sometimes, the chemical indices also do not correlate with the diversity indices as the chemical changes are much faster than the biological changes.

In the present study Shannon's diversity index ranged from 1.65 to 2.45 at Eksar and 1.64 to 2.49 at Wai indicating that there are not much differences in the level of algal diversity. According to Goel et al. (1988), relatively better conclusions can be made if lowest value of the annual ranges is taken into consideration, which can predict the pollution level better in a water body. On the basis of this study it is evident that both the sites are moderately polluted. Usually a value of Shannon index more than 3 indicates non-polluted water. If the values are in the range of 1 to 3, the water can be moderately polluted and if values are less than 1, the water is considered to be heavily polluted. At the time of blooms, the algal diversity suddenly falls, while after that it increases sharply. For comparison of pollution level of different sites, the difference between maximum and minimum values can also work as a good indicator (Goel et al. 1988).

Simpson's index uses to quantify biodiversity of a habitat and takes into account the number of species present and the relative abundance of each species. It represents the probability that two randomly selected individuals from the habitat will not be from the same species. Simpson's index ranges from 0 to 1. The lower value of Simpson's index indicates high diversity, and more values a lower diversity. According to Simpson indices the diversity of algae is slightly higher at Wai and lower at Eksar. The range at Eksar was from 0.79 to 0.88 and at Wai it was 0.88 to 0.89. In both the sites Simpson index increases towards the higher value, it means that these two sites have mature and stable community.

Margalef diversity index is used for small community (Margalef 1956), it has no limit value and show a variation depending upon the number of species. The range of Margalef index was from 0.6993-1.161 at Eksar and 0.9245-1.171 at Wai. The Margalef index can be used for comparison of pollution levels.

Gini Coefficient index was originally used to measure income inequality, but can be used to measure any form of uneven distribution. It has number between 0 and 1, where 0 corresponds with perfect inequality and 1 corresponds with perfect equality (Bosi & Seegmuller 2006). Moreover, Gini coefficient has also been used to study environmental inequality. For instance, Saboohi (2001) used Gini coefficient to analyse the distribution of energy consumption and also used it to study the inequality between urban and rural neighborhoods in Iran. Here, we have used the Gini coefficient for observing the diversity of algae. A value near to 0 will indicate more diversity, while near to 1 will be less diversity. In this study we observed the range from 0.125 - 0.2917 at Eksar and 0.1324-0.4065 at Wai. It indicates that the water at Wai is slightly more polluted than Eksar.

CONCLUSION

Industrial waste, agricultural runoff and sewage are the main sources of river pollution. The study indicated that the cultural activities have their significant role in changing the quality of water in rivers adversely. This is amply indicated by quantitative and qualitative presence of algae as well as some indices developed based on them. The Wai site with high cultural and religious activity is more polluted than the Eksar site before entry of river in Wai. Here, we suggest avoiding throwing garbage in the river, washing of vehicles and cloths and discharging drainage in the river directly.

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REFERENCES

APHA, 1996. Standard Methods for Examination of Water and Wastewater. American Public Health Association, AWWA, WPCF, Washington DC.

Bosi, S. and Seegmuller, T. 2006. Optimal cycles and social inequality: What do we learn from the Gini index? Research in Economics, 60(1): 35-46.

Chetana Suvarna, A. and Somashekar, R.K. 1997. Ecological study on the river in ecosystem of Karnataka. II. Physico-chemical characteristics of River Cauvery. J. Environ. and Polln., 4(1): 57-63.

Desikachary, T. V. 1959. Cyanophyta. ICAR, Monographs on Algae. New Delhi, pp. 686.

Ganguly, T., Kumar, B., Sen, A.K. and Bhunia, A.B. 1999. Assessment of water quality of Damodar river through comparative analysis of bioindicators and physico-chemcial determinants. J. Environ. and Polln., 6(2 & 3): 189-196.

Goel, P.K., Kulkarni, A.Y. and Khatavkar, S.D. 1988. Species diversity in phytoplankton communities in a few freshwater bodies in southwestern Maharashtra. Geobios, 15: 150-156.

Goel, P.K. and Bhosale P.M. 2001. Studies on the river Panchaganga at Kolhapur with special reference to human inpact on water quality. In: Current Topics in Environment Sciences (Eds. G. Tripathy and G. C. Pandey), ABD Publishers, Jaipur.

Islam, M.S. 2008. Phytoplanktonic diversity index with reference to Mucalinda Sarovar, Bodh-Gaya. In Proceeding of Taal 2007: The 12th World Lake Conference, 462-463.

Javaid, A.S. and Pandit, A.K. 2013. Application of diversity indices to Crustacean community of Wular lake, Kashmie Himalaya. Inter. Jour. Of Biodiversity and Conservation Vol.5(6), pp.311-316.

LiLi, Binghui, Zhery and Lusen Liu, 2010. Biomonitoring and bioindicators used for river ecosystem, definitions, approaches and trends. Procedia Environmental Science, Elsevier, pp.1510-1524.

Margalef, R. 1956. Diversidad de species enlas commundades naturals. Publ. Inst.de Biol.Apl.,9:5-28.

McCormick, P.V. and Jr. J. Cairns 1994. Algae as indicators of environmental change. Journal of Applied Phycology, 6(5-6): 509-526.

Pawar, S. and Vaidya, R. 2012. Studies on physico-chemical characteristics and level of sewage pollution in Krishna River at Wai, Dist. Satara. Proceeding of Inter. Conf. SWRDM.

Palmer, C.M. 1969. A composite rating of algae tolerating organic pollution. J. Phycol., 5: 78-82.

Palmer, C.M. 1980. Algae and Water Pollution. Castle Housing Publications Ltd.

Prescott, G.W. 1951. Algae of the Western Great Lakes Area. Pub. Otto Koeltz Science Publisher, Michigan University, pp. 977.

Randhawa, M.S. 1959. Zygnemaceae. ICAR, New Delhi, 478 pp.

Round, F.E. 1991. Diatoms in river water-monitoring studies. Journal of Applied Phycology, 3: 129-145.

Saboohi, Y. 2001. An evaluation of the impact of reducing energy subsidies on living expenses of households. Energy Policy, 29(3): 245-252.

Sarode, P.T. and Kamat, N.D. 1984. Freshwater diatoms of Maharashtra. Saikripa Prakashan.

Singh, S.N. and Rai, Seema 1999. Physico-chemical studies of Ganga river at Varanasi. J. Environ and Polln., 6(1): 43-46.

Stevenson, R. J. and Pan, Y. 1999. Assessing ecological conditions in rivers and streams with diatoms. In E. F. Stoemer and J. P. Smol (eds.). The diatom: Applications to the environmental and earth science. Cambridge, UK: Cambridge University Press, 11-40.

Sudhakar, G. Joyothi, B. and Venkateswarlu, V. 1994. Role of diatom as indicators of polluted gradients. Environ. Moni. and Assessment, 33: 85-99.

Shannon, C.E. and Weaver, W. 1949. Mathematical Theory of Communication. Urbans III: Uniersity of Lllinois Press.

Trivedy, R. K. 1986. Role of algae in biomonitoring of water pollution. Asian Environ., 8(3): 31-42.

Trivedy, R.K. and Goel, P.K. 1986. Chemical and Biological Methods for Water Pollution Studies. Environmental Publications, Karad.

Van, Dam. H, Mertens, A. and Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Aquatic Ecology 28(1): 117-133.

Whitehead, P.G. and Hornberger, G.M. 1984. Modelling algal behaviour in the River Thames. Water Research, 18(8): 945-953.