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ASSESSMENT OF WATER QUALITY OF THE GANGA RIVER AT VARANASI USING TROPHIC DIATOM AND WATER QUALITY INDEXES

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The purpose of this study is to assess the water quality of the river Ganga at Varanasi using the Trophic Diatom Index (TDI). Samples were taken from June to December 2006 at four sites and analyzed for different physico-chemical characteristics. The difference in water quality was reflected by different diatom communities. Generally, species belonging to genera such as Nitzschia and Navicula were more abundant at the polluted sites. TDIs were significantly correlated with phosphate and nitrate. A negative correlation was found with the Water Quality Index (WQI). Biological properties of periphyton including biomass, chlorophyll-a concentration, and the taxonomic composition assemblages, were also analyzed to characterize the pollution level. The sensitivity of TDI and other parameters supports the use of this index for monitoring the water quality of rivers.

INTRODUCTION

The Ganga River, one of the most sacred rivers in India, is being polluted by many sources. The main sources at Varanasi are industrial effluents, domestic sewage and cremation of dead bodies (Tripathi et al., 1991). At Varanasi, 190 MLD of domestic sewage and 80 MLD untreated sewage and industrial effluent along with excreta from human beings and various warm blooded animals are directly or indirectly discharged into the river. This has adversely affected the physicochemical and biological quality of the river.

The sensitivity or tolerance of algae to eutrophication and other forms of pollution has led to the creation of many indicator systems and indices for water quality in rivers. Tolerance indices typically summarize the relative abundances of species weighted by their sensitivity to specific stressors (Prygiel and Coste, 1993; Kelly and Whitton, 1998; Stevenson and Pan, 1999). Biological communities are good indicators of water quality (Whitton and Rott, 1996; Hill et al., 2000). Monitoring of river water quality with biological communities is better than physical and chemical measurements of water quality. Diatoms are a good indicator of pollution levels. Several diatom based indices have been adapted to estimate river water quality (Sladecek, 1986; Prygiel and Coste, 1993; Kelly and Whitton, 1995; and Kelly et al., 1998). In the past two decades benthic diatoms were used to rapidly evaluate the water quality in fresh water habitats in Europe (Kelly et al., 1998; Prygiel and Coste, 1993), Australia (Chessman et al., 1999), North America (Lowe and Pan, 1996; Stevenson and Pan, 1999). Several studies have linked changes in the algal community, particularly diatoms, to changes in water chemistry such as pH, phosphorus and nitrogen (Pan et al., 1996). The present study assesses the river Ganga water quality in Varanasi using the Trophic Diatom Index (TDI) (Kelly, 1995) and its relationship with physical and chemical variables.

MATERIAL AND METHODS

Study Site

The holiest of all the rivers in India, the Ganga (or Ganges) is a perennial river with its source in the Himalayas, at Gaumakh in the southern Himalayas on the Indian side of the Tibetan border. From Devprayag to the Bay of Bengal, and the vast Sundarbans Delta, the Ganga flows some 1,550 miles, passing and giving life to some of the most populous cities of India, including Kanpur, Allahabad, Varanasi, Patna, and Kolkatta. Dacca, the capital of Bangladesh is on a tributary of the Brahmaputra, just before it joins the Ganga to form Padma. A large number of tributaries join and flow to the Ganga to drain the Northern part of India and Bangladesh.

The study area covers the urban fringe of Varanasi city, situated in the eastern Gangetic plain (82^o 15'E to 84^o 30'E and 24^o 35 'N to 25^o 30'N) of northern India. A total four sites, namely Raj Ghat (site 4), Assi Ghat (site 3), Harischandra Ghat (site 2), and Samne Ghat (site 1) were selected for river quality monitoring. Each site was reasonably represented the water quality of the river system. The first site is most polluted and receives much of the sewage of the town. Sites 2 and 3 fall in the midstream region. Site 4 is located in an area of relatively low river pollution and upstream of Varanasi city.

Sample collection

Algal and water samples were collected in June, July, August, September, November, and December across in the river width at all four sites with a view to monitor changes caused by anthropogenic sources. Sampling, preservation and transport of the water samples to the laboratory were as per standard methods (APHA, 1998). All samples were transported in cold packs to the laboratory and were analyzed within 7 hours of collection. Periphyton was randomly collected from stratum throughout the sampling site by rinsing the algae suspension into a collecting bottle.

Sample analysis

Different physicochemical properties were analyzed by prescribed standards. The pH was determined by a portable pH meter at a collection site immediately after sampling since the biological and chemical reactions between the atmosphere and the sample could readily alter the pH (Hutton, 1983). Temperature was measured by an accurate thermometer. Analysis of nitrate, phosphate, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biological oxygen demand (BOD) followed the APHA (1998). There are various water quality indices (WQI) used to compare various physicochemical and biological parameters such as the Bhargava Method, Horton's Method, ambient water quality, the Delphi Method, etc. Brown et al. (1970) presented a WQI, which varied from zero to 100. The water quality index (WQI) was determined according to the Bhargava method. The simplified model for WQI for a beneficial use is given by

$$\mathrm{WQI} = \sum_{i=1}^{n} (f_i P_i)^{1/n} 100 \tag{1}$$

where n is the number of variables considered more relevant to the use and $f_i(P_i)$ is the sensitivity function of the ith variable which includes the effect of weighting of the ith variable in the use. WQI is a number between 0 and 1000 with high values indicating clean water (Sharifi, 1990).

Filamentous algae were magnified by 200 times using a counting chamber to estimate the ratio between filamentous algae and diatoms. To identify the diatoms, a suspension was boiled in a 2:1 mixture of concentrated HNO_3 and H_2SO_4 for 2-4 hours. Permanent slides were prepared. Diatoms were identified and enumerated with a microscope with a 1000× oil immersion objective. An average of 265 valves were identified using Tiffany and Britton (1971) and Pentecost (1984).

For estimation of dry mass, samples were scraped from pebbles, dried for 24 hours at 60 ^{0}C and weighed. Periphyton samples were dissolved in 10 ml of 95% ethanol (Nusch, 1980) for chlorophyll estimation. Samples were stored overnight in a freezer and the allowed to return to room temperature. The absorbance of the supernatant at 665 nm was determined by spectrophotometer. The Nusch (1980) equation was used for determine the chlorophyll a concentration.

The biovolume for each taxon was estimated following Litteral et al. (1995). To obtain mean cell dimension, 20 cells of all common species were measured using an ocular micrometer at 1000× (Hill and Knight, 1987). Calculation of biovolumes of taxa by formula was based on the geometric shape appropriate for each taxon. Cell counts were then converted to cell density (cells×cm^{-2}) and subsequently diatom cell densities were converted to diatom biovolume ($\mu m^3 cm^{-2}$). Biovolume is the calculation of density with each taxon by the estimated mean volume per cell.

The Trophic Diatom Index was calculated using Kelly et al. (2000). The diversity of each sample was estimated using Shannon and Wiener's diversity index (Shannon and Weaver, 1949), whilst the Simpson's index (Simpson, 1949) was calculated to indicate the extent to which one species dominated the assemblage.

RESULTS AND DISCUSSION

The physicochemical analysis carried out at the different sites during different seasons is shown in Table 1. Temperature is the most important factor which influences chemical, physical and biological characteristics of water bodies. The study showed that temperature varied from 21.3 to 26.5 ^{o}C, with a maximum at site 4 and minimum at site 1. A similar pattern was observed for electric conductivity. The pH values did not show remarkable differences between sampling sites and ranged between 7.5-8.1. The value of DO is an indicator of the water quality of an aquatic system. In the system where the rates of respiration and organic decomposition are high, the DO values usually remain lower than those of the system, where the rate of photosynthesis is high. The mean value of the dissolved oxygen ranged between 1.5 - 8.5 mg/L. Highest DO was found at the site 1 where there is minimum discharge of sewage effluent and human activities. Lowest DO was found at the site 4 where maximum discharge of sewage effluent comes from the town. BOD is a minimum at site 1 and maximum at site 4 followed by sites 3 and 2. The nitrate concentrations were high ranging from 1.2 - 4.5 mg/L. Highest mean concentration was observed at sampling site 3 and 4 (2.6 and 5.8 mg/L respectively). Plotting the monthly values of nitrate concentration verses time, maxima at the end of winter and during the summer are obtained. The highest concentration was probably partially a result of rainfall, washing out nitrate from fertilizers. The same pattern was also observed for phosphate. PO_4 values in the Ganga River ranged between 0.6 to 1.5 mg/L, where the maximum value was at sampling site 4, followed by sites 3, 2 and 1. The average concentration of PO_4 is 3.9, which is considered the lower limit for river waters to pose a risk of eutrophication. At site 3 and 4, the value of WQI was very low, which indicates a significant level of pollution (Table 1).

Table 2 shows the taxonomic composition of diatoms and number of taxa present in Ganga River. Taxonomic change is a powerful tool for detecting environmental change (Dixit et al., 1992; Gasse et al., 1995). The composition of the diatom assemblage changed from site to site and in different months. At sites 1 and 2 the dominant species were *Amphipleura pellucida*, *Diatoma vulgare*, *Cocconeis placentula*, while at sites 3 and site 4 the dominant species were *Amphora ovalis*, *Cylidrotheca closterium*, *Melosira borreri*, *Surirella ovata*, *Navicula lanceoleta*, *Synedra ulna*, and *Fragilaria crotonensis*. Generally, species belonging to genera such as *Nitzschia* and *Navicula* were more abundant at the polluted sites (3 and 4) while species belonging to genera such as *Achanthus* and *Fragilaria* were more abundant in less polluted sites.

A remarkable significant positive correlation with phosphate and nitrate was found which is shown in Figures 1 and 2. Negative correlations were found between TDI and WQI as shown by

Table 1. Physical and chemical characteristics at different sites along the Ganga River.

Parameters	Site 1	Site 2	Site 3	Site 4
pH	8.1	8.0	7.8	7.5
Temperature(^{0}C	21.3	23.4	24.5	26.5
Conductivity(μ Scm^{-1})	625	690	789	810
DO(mg/l)	8.5	6.5	2.8	1.5
BOD(mg/l)	3	8	185	250
TDS(mg/l)	98	125	250	320
TSS(mg/l)	130	250	290	550
Nitrate(mg/l)	1.2	1.5	2.6	4.5
Phosphate(mg/l)	0.6	0.8	1.1	1.5
Turbidity(NTU)	17	35	43	57
WQI	69	58	50	35

Table 2. The taxonomic composition of diatoms and number of taxa present in the Ganga River.

Genus	No of Taxa	Genus	No of Taxa
Amphipleura	3	*Diatoma*	4
Amphora	5	*Fragilaria*	8
Bacillaria	1	*Herridiscus*	2
Bacteriastrum	1	*Gyrosigma*	1
Beddulphia	1	*Navicula*	21
Chaethoceros	1	*Nitzschia*	19
Cocconeis	3	*Melosira*	2
Coscindiscus	1	*Surirella*	3
Cylidrotheca	2	*Syndera*	3
Diatomella	1	*Shelitonema*	2
		Ditylium	1
Total			85

Figure 3. The Trophic Diatom Index (TDI) values for site 4 in different months are shown in Figure 4. The TDI (Kelly and Whitton, 1995) is one of a number of diatom based tools developed to evaluate nutrient conditions in fresh waters (Rott et al., 1999). This study presents the TDI in reference to water quality in the Ganga River using different water quality parameters and the WQI. These trends are due to abundant phosphate and nitrate in polluted sites (sites 3 and 4) which increase the growth of the diatom community and decrease the water quality index. Indices used in this study focus on taxonomic change as a measure of the impact of nutrients on ecosystems, in contrast to studies on the effect of eutrophication on lake plankton which tend to focus on change in biomass (OECD, 1982). Average measures of community productivity are shown in Figures 5, 6 and 7. Biomass value (chlorophyll a concentration, dry mass, and biovolume) at different sites are shown in Table 3, with the highest concentration of chlorophyll at site 4 and lowest at site 1. The same pattern for dry mass and biovolume was observed at site 4 where there is a maximum discharge of wastewater which increases the concentration of phosphate and nitrate and causes eutrophication. Light, temperature and nutrient together define the potential for primary production while water velocity and grazing influence the development of biomass (Kelly and Whitton, 1995). Different diversity indexes at different sites are shown in Figure 8.

Table 3. Average concentration of chlorophyll-a (mg m^{-2}), dry mass (mg cm^{-2}), biovolume ($\times 10^8$ $\mu m^3 cm^{-2}$) at different sites.

Sites	Chlorophyll-a (mg m^{-2})	Dry Mass(mg cm $^{-2}$)	Biovolume ($\times 10^8$ $\mu m^3 cm^{-2}$)
Site1	91.3	8.5	31.9
Site2	99.6	9.5	41.8
Site 3	125.8	12.9	53.5
Site 4	105.8	11.8	55.6

CONCLUSION

This study suggests that the use of diatom indices, especially the TDI, could and should be accepted and applied to monitor rivers in India. The evaluation of water quality using the diatom community and their biomass is good ecological approach.

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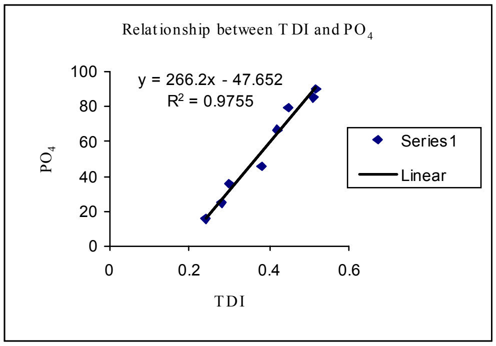


Figure 1

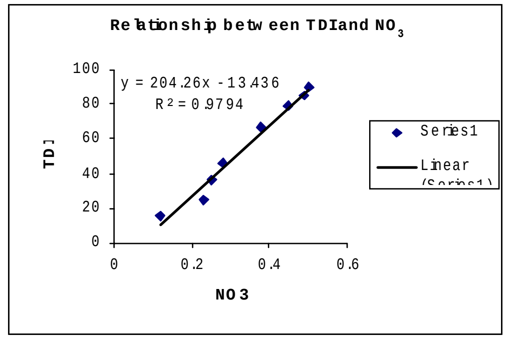


Figure 2

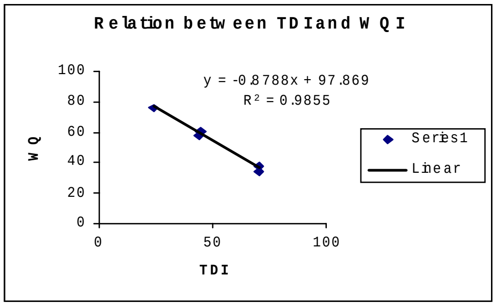


Figure 3

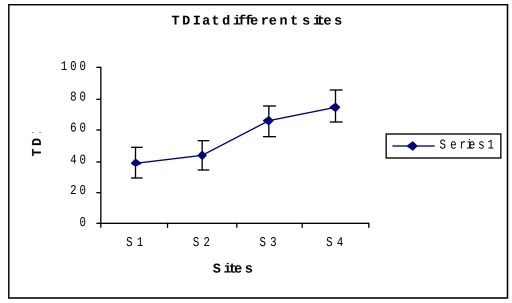
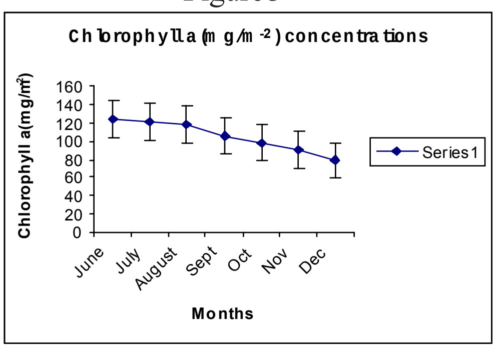


Figure 4



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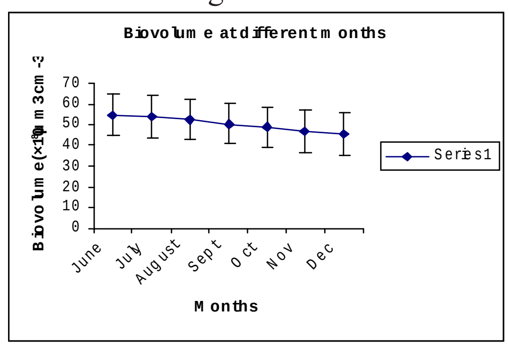

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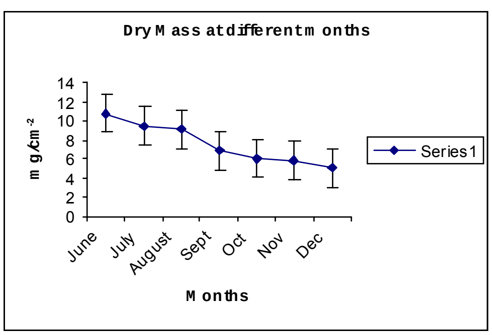

Figure 7

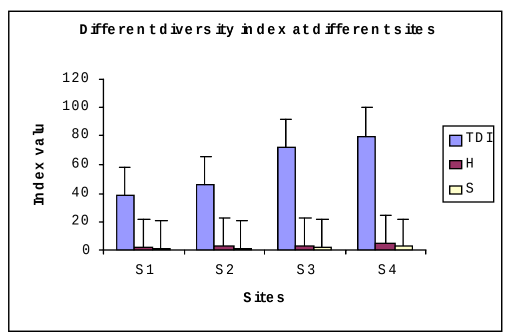

Figure 8

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