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Environmental Impact Assessment Using Diatoms in Thamirabarani River, Tirunelveli District, Tamil Nadu, India

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Abstract

The present study provides a detailed report on the occurrence and record of diatom taxa from the Thamirabarani River. A total number of 55 diatom taxa belonging to 25 genera were identified. The result shows the abundance of diatom genera *viz. Amphora, Aulacoseira, Cyclotella, Cymbella, Eunotia, Gomphonema, Melosira* and *Ulnaria* in the study area indicated varying pollution levels and pristine conditions. The diversity of diatom taxa in Site 1 and Site 3-7 indicate that the river water is not polluted in these locations. Domestic waste input in the river at Site 2 area may responsible for the dominant occurrence of moderate pollution tolerant diatoms taxa. The abundance of pollution tolerant diatom taxa *in* Site 8, Site 9 and Site 10 areas of the river indicates high pollution. The Canonical Correspondence Analysis (CCA) results also show that the concentration of diatom taxa and physico-chemical parameters suggest the release of industrial effluents and anthropogenic activity. The proper waste water treatment methods need to be implemented along the catchment areas of the river to ratify pollution levels.

Keywords: Diatoms, Thamirabarani River, Pollution, Water Quality, Anthropogenic Impact

Introduction

Diatoms are unicellular microalgae, primary producers, plays an important role in the food web structure and biogeochemical cycles of aquatic ecosystems (Smucker and Morgan, 2011).They are present in all aquatic environments and are important biological indicators. Each diatoms taxa has its specific water quality requirements and responds quickly to changes in environmental conditions and anthropogenic activities (Pandey *et al*., 2017; Srivastava *et al*., 2016). Diatoms are beneficial environmental indicator and many trophic indices for water quality monitoring due to their abundance in many lotic systems (Kamble *et al*., 2014). In recent years, the study of aquatic pollution and monitoring of environmental conditions have been carried out using the occurrence, diversity and dominance of diatoms. Diatoms are also used in paleolimnological and paleoecological studies (Dalu and Froneman, 2016). There are currently over 260 genera of living diatoms with over 1,00,000 diatom taxa present in a marine and freshwater ecosystem (Round *et al*., 1990). They are diverse and identified by their unique siliceous cell wall (Jain, 2020). The possession of a siliceous cell wall, also known as 'frustule', is the predominant characteristic feature for diatom identification. The decomposition of silica cell walls does not occur in the diatom, so they are the essential tool for identification and application in fossils and living organisms. Even though diatoms occupy 1% of the photosynthetic biomass of the earth, they contribute 45% of our planet annual net primary productivity. Diatoms play a significant role in the ecosystem because they exhibit a high correlation with water parameters (Hill *et al*., 2001). The diatom assemblages are good indicators for understating the water quality change by nutrient enrichment, acidification and pollution (Pajunen *et al*., 2016). They have a short life cycle and are easily susceptible to water quality change. Diatoms show a narrow ecological tolerance due to their rapid change in physico-chemical characteristics depending on the surrounding ecosystem and therefore useful as an ecological indicator (Solak *et al*., 2020). Diatoms indices can be used as monitoring tools, rather than other monitoring tools, because of their uniqueness in their occurrence, diversity and dominance for water quality. Their data can be calculated easily using Omnidia software or ecological data available in software programs (Karthikeyan and Venkatachalapathy, 2018). Diatom research has a long history, with notable work on the diatom taxonomy in recent years (Kumar *et al*., 2009; Karthick *et al*., 2013; Singh *et al*., 2010). Water is essential for domestic, agricultural, industrial activities, navigation, fisheries and water-power generation (Espinosa *et al*., 2020). Using the river water for these purposes may lead to anthropogenic activity affecting the water quality and biotic communities (Smol, 2008). Diatoms study and their diversity has been recorded in some rivers in Cauvery river (Karthikeyan and Venkatachalapathy, 2016), Sakarya river (Solak *et al*., 2020), Patagonian river (Chen *et al*., 2020), Lepenci river basin (Bytyqi *et al*., 2019). The river is an essential drinking water source in Tamil Nadu, southern districts.This paper focuses on the

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abundance of diatom taxa and the distribution of diatoms in macrophytic and epiphytic samples from the river. Hence, the Thamirabarani River is selected to investigate the occurrence of diatom taxa and diversity, besides analyzing physico-chemical parameters of river water to understand the water quality changes in the course of a river due to anthropogenic and industrial activity.

Materials and Method

Study Area

The Thamirabarani River is one of the Perennial River in Tamil Nadu, originates from the peak of the Pothigai Hills on the eastern slopes of the Western Ghats at an elevation of 1,725metres (5,659ft) above sea level. It flows eastward for about 128kilometers before its confluence with the Bay of Bengal at Punnaikayal (Fig. 1). The Thamirabarani River is the primary source of potable water supply, irrigation, domestic usage and industrial processes in Tirunelveli and Thoothukudi districts of Tamil Nadu, with a population of more than 50 Lakhs.

Sample Techniques

A total of Ten (10) samples each of macrophytes, epilithic and surface water samples were collected from 10 different locations in the Thamirabarani River, Tirunelveli District, Tamil Nadu. The samples were collected from epilithic (stone) and epiphyte (plant) to study diatom taxa. The samples were analyzed using standard methods (Karthick *et al*., 2010). The diatom samples were preserved by adding 3-4 % formalin solution for colonial structure and chloroplasts can be retained. The stone surface were scrubbed using a toothbrush. Diatom frustules were cleaned using 10% Nitric acid and 30% concentrated Hydrogen Peroxide. The diatom samples were boiled to oxidize the organic materials and then the acid washed by distilled water. The permanent diatom slides were mounted with D.P.X. mounting medium and placed on the hot plate until the solvent evaporated. Then the slides were cooled immediately by removing the hotplate and the diatoms slides thus obtained are permanent. Microscopic observations were made using Euromax Holland ME 2885 microscope, slides are observed under 40X and the photomicrographs were taken using CMEX DC 5000 camera. The surface water samples were collected in 1(L) Polly lab bottle. The water quality parameters like pH, Electrical conductance (Ec) and Temperature (˚C) were measured. The parameters like Biological Oxygen Demand (BOD) and Total Dissolved Solids (TDS) were analyzed by using standard methods for the assessment of water quality.

Results and Discussion

The water samples were analyzed for physico-chemical parameters like pH, EC, TDS, BOD and Temperature. The analysis result shows that the pH values vary between 6.63 to 7.8 with an average of 6.88. The temperature varies between 27°C to 30°C with an average of 28°C. The Ec varies between 270 mho/cm to 380 mho/cm with an average of 326 mho/cm. The TDS varies between 190mg L^{-1} to 287 mg $L^{-1}$with an average of 244.5mg L^{-1}.The BOD varies between 5.9 mg L^{-1} to 8.3 mg L^{-1} with an average of 6.8mg L^{-1}.The present study results have been compared with previous work

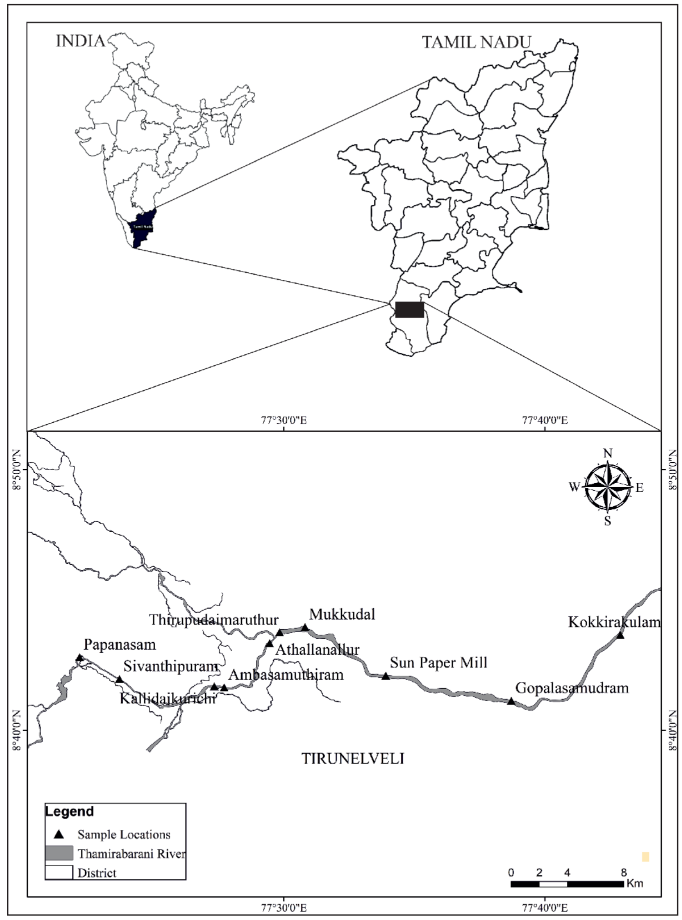

Fig.1. The study area location map

to evaluate the distribution of diatom taxa in different rivers worldwide (Table 1).

In the present study, the minimum value of pH 6.63 was recorded at the river Site 2 and observed the dominance of diatom taxa *Gomphonema augur, Gomphonema lanceolatum* and *Gomphonema parvulum*, whereas the highest value of pH 7.8 was recorded at Site 1 with the dominant presence of diatom taxa *Aulacoseira distans, Eunotia pectinalis* and *Melosira moniliformis*. The dominance of diatom taxa *Cyclotella meneghiniana, Gomphonema undulatum* and *Gomphonema affine* was found in the river at Site 3 where the temperature of the surface water was 27°C; however with the increase of temperature 30°C at Site 5 the taxa *Surirella tenera* and *Gomphonema gracile* were recorded as dominant diatom taxa. An increase and decrease value of Ec has an

Table 1: Assessment study of diatom taxa from different rivers

S. No.	Name of the rivers	No of taxa	No. of genera	Reference
1	Thamirabarani	55	25	Present study
2	Amba	35	24	Karthik *et al.*, 2020
3	Karaj	128	48	Kheiri *et al.*, 2019
4	Wutong	122	29	Xue *et al.*, 2019
5	Balikhli	110	49	Mirzahasanlou *et al.*, 2019
6	Chambal	102	40	Grover *et al.*, 2017
7	Shivna	33	17	Mitra and Reddy, 2015
8	Cauvery	60	21	Venkatachalapathy and Karthikeyan, 2014
9	Ganga	23	23	Kumar *et al.*, 2022

effect on the occurrence and distribution of diatom taxa. In the study area, lower values of Ec 270 mho/cm were reported at Site 1 with the dominance of diatom taxa *Aulacoseira distans, Eunotia pectinalis* and *Melosira moniliformis*. Whereas the maximum values of Ec 380 mho/cm recorded at Site 10 with the dominance of diatom taxa *Cyclotella atomus* and *Ulnaria ulna.* The minimum value of TDS 190mg $L^{-1}$was recorded at the river Site1 and observed the dominance of diatom taxa *Aulacoseira distans, Eunotia pectinalis* and *Melosira moniliformis* were recorded. Whereas the maximum value of TDS 287 mg L^{-1}at Site 10 with the dominant presence of diatom taxa *Cyclotella atomus* and *Ulnaria ulna* were recorded. The BOD analyses in the study area reveal the fluctuation in BOD values between 5.9 to 8.3 mg/l. The dominance of diatom taxa *Surirella tenera* and *Gomphonema gracile* were noticed at Site 5 where the minimum concentration of BOD value 5.9 mg $L^{-1}$was recorded. Whereas, the maximum value of BOD 8.3 mg $L^{-1}$was recorded at Site 10 signifies low water quality. The present study records the dominant presence/ increase of tolerant diatom taxa *Cyclotella atomus* and *Ulnaria ulna* may be due to the combined influence of industrial effluents and anthropogenic activity in Thamirabarani River.

The present analysis of the diatom samples from the Thamirabarani River shows the presence of 55 diatom taxa belonging to 25 genera, they are *Achnanthes brevipes, A. inflata, Amphora ovalis, Aulacoseira distans, A. granulata, Cocconeis placentula, Cyclotella atomus, C. meneghiniana, Cymbella tumida, C. turgidula, Discostella stelligera, Encyonema minutum, Eunotia formica, E. flexuosa, E. minor, E. pectinalis, E. rhomboidea, Fragilaria capucina, F. rumpens, F. tenera, F. ulna, Frustula vulgaris, Gomphonema affine, G. augur, G. gracile, G. lacusrankala, G. lanceolatum, G. parvulum, G. truncatum, G. undulatum, Gyrosigma acuminatum, G. balticum, Hantzschia distinctepunctata, Mayamaea atomus, Melosira moniliformis, M. varians, Nitzschia obtusa, N. palea, Pinnularia acrosphaeria, P. subcapitata, P. divergens, P.viridis, P. gibba, Placoneis clementis, P. placentula, Rhopalodia gibba, Sellaphora pupula, Surirella angusta, S. linearis, S. ovalis, S. splendida, S. tenera, Synedra rumpens, Tryblionella victoriae* and *Ulnaria ulna.* The analyses show that the diatom taxa such as *Aulacoseira distans, Cyclotella meneghiniana, Cymbella tumida, Eunotia pectinalis, Gomphonema affine, Gomphonema gracile, Gomphonema undulatum, Melosira moniliformis* and *Surirella tenera* dominantly recorded in Site 1 and Site3-7. The diatom taxa such *Gomphonema augur, Gomphonema lanceolatum* and *Gomphonema parvulum* are dominantly recorded in Site 2 (Fig.2). The dominant taxa, such as *Cyclotella atomus* and *Ulnaria ulna* are recorded in Site 8, Site 9 and Site 10.

Certain diatom taxa like, *Cyclotella atomus* and *Ulnaria ulna* are indicate high pollution (Venkatachalapathy *et al*., 2014; Faustino *et al*., 2016; Maraslioglu *et al*., 2020). The diatom taxa such *Gomphonema augur, Gomphonema lanceolatum* and *Gomphonema parvulum* suggest moderate pollution (Karthikeyan and Venkatachalapathy, 2016). The diatom taxa such as *Aulacoseira distans, Cyclotella meneghiniana, Cymbella tumida, Eunotia pectinalis,Gomphonema affine,Gomphonema gracile, Gomphonema undulatum, Melosira moniliformis* and *Surirella tenera* indicates pristine condition (Karthick *et al*., 2013; Karthikeyan and Venkatachalapathy, 2016). The composition of the diatom assemblage is then affected by environmental factors that can be found utilizing multivariate direct gradient analysis techniques. Such data are frequently analyzed using Canonical Correspondence Analysis (CCA). The CCA was analyzed by using Paleontological Statistics (PAST) software (Hammer *et al*., 2001). The Canonical Correspondence Analysis (CCA) was applied to analyze the influence of environmental factors and diatom assemblages. The results of CCA are presented in the ordination diagram and values *i.e.*, Eigen value and cumulative percentage variance are compared (Table 2). The Eigen values and cumulative percent variance of environmental data obtained for the study area reveals the species-environment relationship. The Eigen values range from 0.14 to 2.87, whereas the cumulative percentage ranges from 1.0% to 51.06% with 5 physico-chemical variables. The CCA diagram indicates the effects of environmental variables on the occurrence and distribution of diatom taxa shown in the 1st and 2nd axes (Fig. 3-4).

The CCA plot was developed to understand the inter-correlation relationship between the diatom taxa and physico-chemical parameters, this CCA was expressed with variables and taxa that had maximum coefficients of variation. The CCA axis 1 and 2 reveals that dominant diatom taxa occur in Site 2, Site 8 and Site 9 locations, such as *Cyclotella atomus, Gomphonema augur, Gomphonema lanceolatum, Gomphonema parvulum* and *Ulnaria ulna.* That is directly associated with high TDS 287 mg L^{-1}, Ec 380 mho/cm, BOD 8.3mg L^{-1} that respective sampling locations are affected due to domestic wastage and industrial effluents (Karthikeyan and Venkatachalapathy, 2016). The CCA diagram

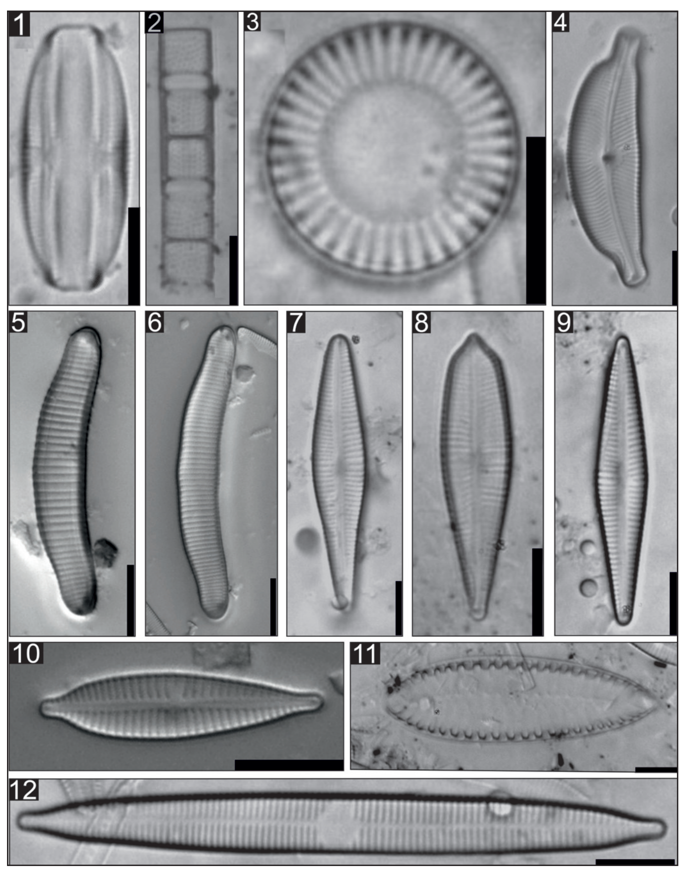

Fig.2. Illustration of the most dominant diatom taxa: (1) *Amphora ovalis*, (2) *Aulacoseira granulata* (3)*Cyclotella meneghiniana,* (4) *Cymbella tumida,* (5)*Eunotia minor*, (6) *Eunotia pectinalis* (7) *Gomphonema affine,* (8) *Gomphonema augur,* (9) *Gomphonema gracile,* (10) *Gomphonema parvulum* (11) *Surirella tenera,* (12) *Ulnaria ulna*

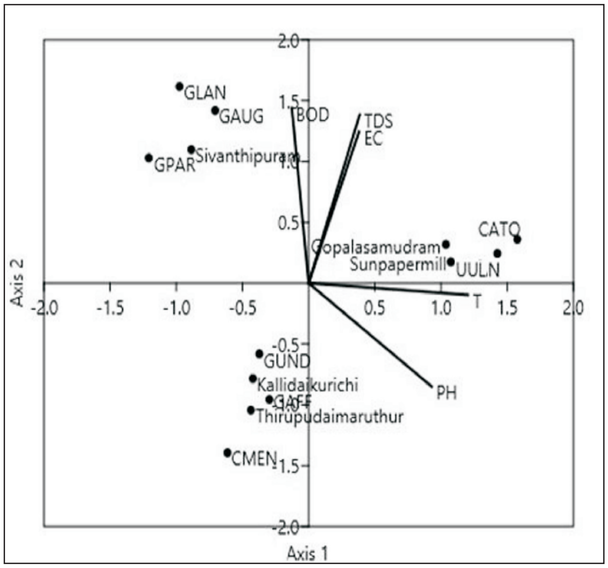

Fig. 3. Ordination diagram is based on CCA of most frequently occurring diatom taxa composition in five sampling sites with respect to five environmental variables (Temperature, EC, TDS, pH and BOD). CATO-*Cyclotella atomus*, CMEN-*Cyclotella meneghiniana*, GAFF-*Gomphonema affine*, GAUG-*Gomphonema augur*, GLAN-*Gomphonema lanceolatum*, GPAR-*Gomphonema parvulum*, GUND-*Gomphonema undulatum*, UULN-*Ulnaria ulna*.

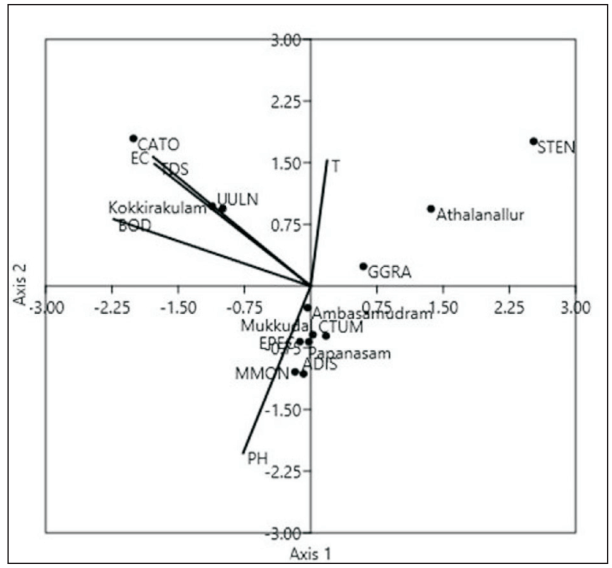

Fig. 4. Ordination diagram is based on CCA of most frequently occurring diatom taxa composition in five sampling sites with respect to five environmental variables (Temperature, EC, TDS, pH and BOD). ADIS- *Aulacoseira distans*, CATO- *Cyclotella atomus*, CTUM-*Cymbella tumida*, EPEC- *Eunotia pectinalis*, GGRA-*Gomphonema gracile*, MMON-*Melosira moniliformis*, STEN-*Surirella tenera*, UULN-*Ulnaria ulna*.

showing the simultaneous effects of environmental variables on the most frequently occurring diatom taxa in the ordination space of the 1st and 2nd axes show in (Fig. 3). The pollution level has completely declined because of the good flowing of water at the Site 1 and Site 3-7, their diatom taxa such, as *Aulacoseira distans, Cyclotella meneghiniana, Cymbella tumida, Eunotia pectinalis, Gomphonema affine, Gomphonema gracile, Gomphonema undulatum, Melosira moniliformis* and *Surirella tenera* were dominant flora found in the above sampling locations. CCA diagram shows environmental variables on most frequently occurring diatom taxa (Fig. 4).

Conclusions

The Thamirabarani River is one of the perennial and pristine rivers in India and has revealed moderate to high diatom diversity with 55 taxa belonging to 25 genera. The study of diatoms and analysis of water samples from river provide valuable evidence on the status of river health. The CCA results show high assemblages of diatom taxa *Aulacoseira distans, Cyclotella meneghiniana, Cymbella tumida, Eunotia pectinalis, Gomphonema affine, Gomphonema gracile, Gomphonema undulatum, Melosira moniliformis* and *Surirella tenera.* The respective locations, like Site 1 and Site 3-7, indicate the absence of pollution due to the good flowing of water. The dominant presence of moderate pollution tolerant taxa *Gomphonema augur, Gomphonema lanceolatum* and *Gomphonema parvulum* in the Site 2 area is indicative of the presence of the domestic waste, whereas pollution level at Site 8, Site 9 and Site 10 locations indicate high pollution due to the influence of industrial effluents and anthropogenic activity in the river and represented by the abundance of diatom taxa *Cyclotella atomus* and *Ulnaria ulna*. Besides, it is supported by analyzing water samples where these diatom taxa are directly associated with physico-chemical parameters. The present study report reveals that the Thamirabarani River water is getting polluted due to domestic waste and industrial effluents need the attention of authorities and the general public to protect the river health in its flow regime.

Table 2: Canonical Correspondence Analysis Results

Axis	Eigen value	Variance (%)
(I) CCA Results (Fig. 2)		
1	0.66	51.06
2	0.61	47.91
3	0.06	0.48
4	2.87	2.24
(II) CCA Results (Fig. 3)		
1	0.54	44.92
2	0.52	43.32
3	0.14	11.76
4	1.21	1.00

Authors' Contributions

Raju Venkatachalapathy: Conceptualization, Investigation, Supervision, Writing- Reviewing and Editing, Formal Analysis. **Madhu Madhankumar:** Conceptualization, Investigation, Writing- Reviewing and Editing, Software.

Conflict of Interest

The authors declare no conflict of interest.

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