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Trophic Status and Water Quality Study Based On Diatoms from the Coastal Lakes of Palghar District, Maharashtra

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ABSTRACT

The physicochemical characters and diatoms of two coastal lakes i.e. the Khajuri Lake and the Babule Lake from the Palghar District Maharashtra were studied to ascertain the relationship between water quality and diatom diversity. The prevalent diatom assemblage from the Khajuri Lake indicates fresh to brackish, alkaliphilous water with mild pollution and mesotrophic to eutrophic status. Similarly, dominant diatom assemblage from the Babule Lake indicates alkalibiontic, eutrophic water with the impact of anthropogenic pollution. The pH values clearly indicate alkaline nature of both the lakes, but very high values of pH were noted for the Khajuri Lake (9.6). Thus, these pH values clearly point moderate to high alkaline nature of water. However, higher values of the pH for the Khajuri Lake suggest increased decomposition of organic matter in addition to elevated photosynthetic activities. The conductivity of these lakes varies from minimum at the Khajuri Lake (255µs/cm) to a maximum at the Babule Lake (620µs/cm). The highest conductivity in the Babule Lake may be due to release of ions from the decomposed organic matter during summer. The total dissolved solids (TDS) content was higher in the Babule Lake (326 mg/l), followed by the Khajuri Lake (125 mg/l), respectively. The low- medium levels of TDS in these lakes may be due to the presence of low to moderate content of potassium, chloride and sodium. The higher values of the total hardness in both these lakes may be due to the usages of excessive fertilizers from the adjoining agriculture fields. The Calcium hardness of both the lake may be categorized as rich lakes. The phosphorous and total nitrogen content suggest fair to poor, eutrophic to hyper-eutrophic water quality for both the lakes.

KEYWORDS: *Diatoms, Trophic Status, water quality, Khajuri Lake, Babule Lake*

INTRODUCTION

Lakes are vital ecosystems of great economic, cultural, scientific and educational values (Dudgeon et al, 2006). Despite the small fraction of the earth surface occupied by lakes, they play an important role in climate system, by exchanging heat and water with atmosphere and contributing to the global carbon cycle (Krinner, 2003). In recent years, intense human activities and climate change have exerted significant effects on freshwater ecosystem, eutrophication and loss of bio diversity and degradation of ecological function (Liu and Diamond, 2005). Limnology is continuously giving us a new horizon for

the study of diatoms. Past climates studies of the Indian subcontinent based on multiproxy data and correlation with the global data are being carried out (Seker and Bera, 1999; Phartiyal *et al*. 2019; Mishra *et al.* 2014; Thakur *et al*., 2018). Furthermore, global warming and eutrophication could also play a role leading to increase in autochthonous sediments due to enhanced productivity (Rose *et al.*, 2011).

The diatoms are microscopic, single celled algae that build complex, cell wall made up of silica (Saade and Bowler 2009). These algae range in size from 2 to 500 µm in length, but most of the species that encountered are in size range 10-200 µm (Winder *et al,* 2008). The diatoms are very sensitive to limnological variables. Diatoms are indicators for reconstruction of past and present ecological status John, 2012; Tripathi *et al.,* 2017; Mishra et al., 2015. Diatoms are the ideal tools for a wide a range of applications such as oil exploration, forensic examinations, environmental indications, bio-silica pattern generation, toxicity testing and eutrophication of aqueous ecosystem (Garrison, 2000; Fitzpatrick *et al.* 2003). Diatoms are also been studied as ecological and paleoecological indicators in rivers environment (Stone *et al*, 2010). Various workers have studied the diatoms and their relationship with the lake and river water quality in the different Indian regions, (Venkatachalapathy *et al*., 2014 and Logannathan et al., 2014 and Sharma et al. 2011) and present and past trophic status of lakes and reservoirs of the central India (Humane et al. (2009, 2015a, 2015b. 2016; Humane et al. 2010; Humane and Humane 2015a and b).

Geologically, both the Khajuri Lake and the Babule Lake occur above the Deccan Volcanic Province, which is practically horizontal surface with dips of almost 0.5^{o} in more or less circular kind of pattern forming a shallow dome (Bodas *et al.,* 1988; Cox 1989; Godbole *et al.,* 1996; Subbarao, 1999). Here, two lava flows with a thick sequence of intertrappeans are present. These lavas are believed to represent a younger phase of Deccan volcanic Province.

The aim of the present research is to evaluate the water quality of the Babule Lake and the Khajuri Lake of the Palghar District, Maharashtra using diatoms and an attempt had been made to evaluate the trophic status of these lakes and to estimate the possible source of pollution by comparing the water quality of both the lakes with the dominant diatoms.

MATERIALS AND METHODS

The present work deals with the investigations of the two lakes i.e. the Babule Lake and the Khajuri Lake, Dahanu Taluka, Palghar District, Maharashtra state (Figure 1). Both the lakes are present in the northernmost part of the Konkan lowlands of the Maharashtra state. The Khajuri Lake is situated between latitude of 19^{o}54'27.04" N and longitude of 72^{o}40'50.52" E. This lake is used for fishing during the rainy reason, however in summer, it dries completely. The lake seems to be polluted by various anthropogenic activities around it (Figure 1 C). While, the second lake i.e. Babule Lake is situated in between latitude of 19^{o}53'44.09" N and longitude of 72^{o}41'32.46"E is also polluted and used for fishing during rainy season (Figure 1 D).

The sediment samples (grab) from each lake along with the water samples were collected from the centres of these lakes during June 2018 (Table 1). The positions of collected samples were noted using the GPS and numbered systematically i.e. BLS1/ BLW1: Latitude- 19^{o}53'44.09" N, Longitude – 72^{o}41'32.46"E, and KLS1/KLW1: Latitude-19^{o}54'27.04" N and Longitude-72^{o}40'50.52" E. The collected sediment samples were kept in the zip locked bags with proper labelling. The rocks samples were also collected from the periphery of each lake and named as KLR1 and BLR1 for the Khajuri Lake and the Babule Lake, respectively. The epilithic diatoms were collected in the labelled zip lock bags by scrapping the rock surfaces.

For collection of water samples from lakes, air tight water bottles were used. Precaution was taken while collecting the water samples by opening the water bottle caps inside lake water to avoid the atmospheric contamination and same was closed inside the water surface. The parameters that were done during sampling itself includes pH (Make: Hanna; Model 601), TDS (Make: Hanna; Model 101E) and other parameters like alkalinity, chloride, sulphate, magnesium, calcium, total

phosphorous (TP), nitrogen, sodium, potassium, silica and chlorophyll A were analyzed from the Government of Maharashtra Water quality Lab, Level II, Hydrology Division, Ajni Nagpur by using UV spectrometer (Make: Systronics; Model: 118).

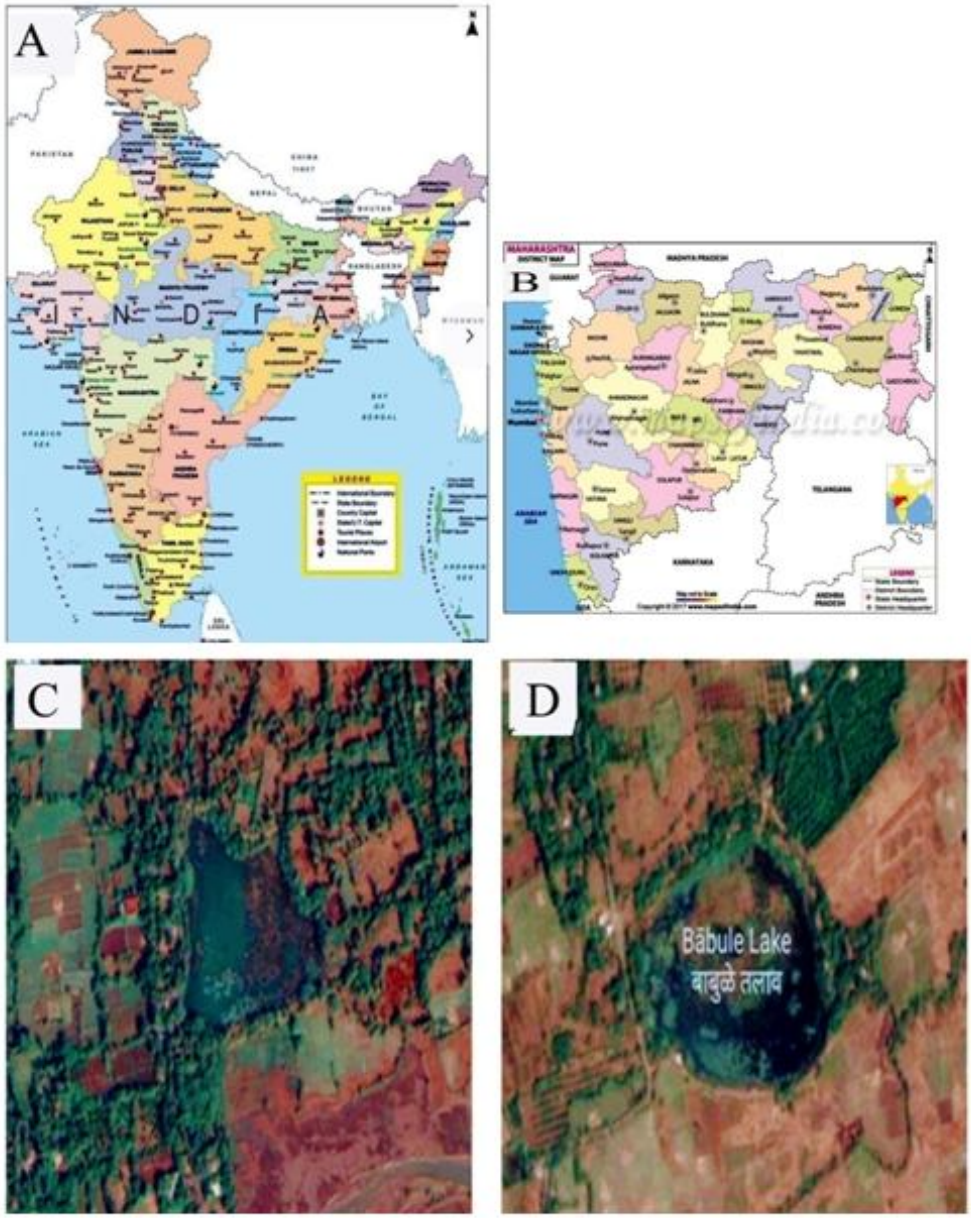

Figure 1: A) Map of India B) Map of Maharashtra C) Location map of Khajuri Lake D) Location map of Babule Lake, Palghar District, Maharashtra

Table 1: Sample locations of major lakes of Palghar district

Sr. No.	Lake	Sample no.	Lattitude	Longitude
1	Babule lake	BLS1	19° 53' 44.09" N	72° 41' 32.46"E
2	Khajuri lake	KLS1	19° 54' 27.04" N	72° 40' 50.52" E

About 0.2 -0.5 grams of the dry sample (1-2 grams wet sample) were taken in 100-200 ml beaker and 20 ml hydrogen peroxide (H_2O_2) was added to it. All the organic matter was removed by heating the sample with H_2O_2 on hot Plate (Battarbee, 1986). The process was repeated till the dark organic material gets removed (lighter colour appears). Few drops of Hydrochloric Acid HCl (30-50% normal) were added to remove carbonates from the samples. The supernatant solution was decanted and the washing process was repeated for two to four times. Clay was removed in the final wash by adding few drops of very weak ammonia solution (1%) to the processed samples. The diatom suspension was diluted to suitable concentration were allowed to settle, overnight in the cover slips. Thus, the finally processed samples were used to prepare the diatom slides by mounting dried cover slips on the glass slides using the mounting medium Naphrax. These slides were observed under the microscope at 40X and 100X magnification using Olympus Microscope and photomicrographs were taken for Identification of diatoms (Battarbee, 1986). The identification of the diatoms was done after John (2014a, b), Round *et al.* (1990), Mann (1996) and https://diatoms.org/genera/guide.

RESULTS AND DISCUSSION

The result of the hydrochemistry and sedimentary diatoms study of the major lakes of the Palghar District are discussed and significant conclusions are drawn.

(A) Hydrochemistry

Various physicochemical parameters were analysed from the collected water samples of the Khajuri and Babule Lakes (Figures. 2-4). The pH of water of the Khajuri Lake was 9.6 with 125 mg/l of TDS and 256 µs conductivity at 35° C temperature. According to WHO (2011) Standards values of pH, conductance, TDS, chloride, calcium, sodium, phosphorous of Khajuri Lake were not within the desirable limits (Table 2), whereas the pH of water from the Babule Lake was observed as 8.2 with 326 mg/l of TDS and 620µs/cm conductivity at 40° C. According to WHO (2011), the standard values of pH, conductance, TDS, chloride, calcium, sodium, phosphorous were within desirable limits of drinking water (Table 2).

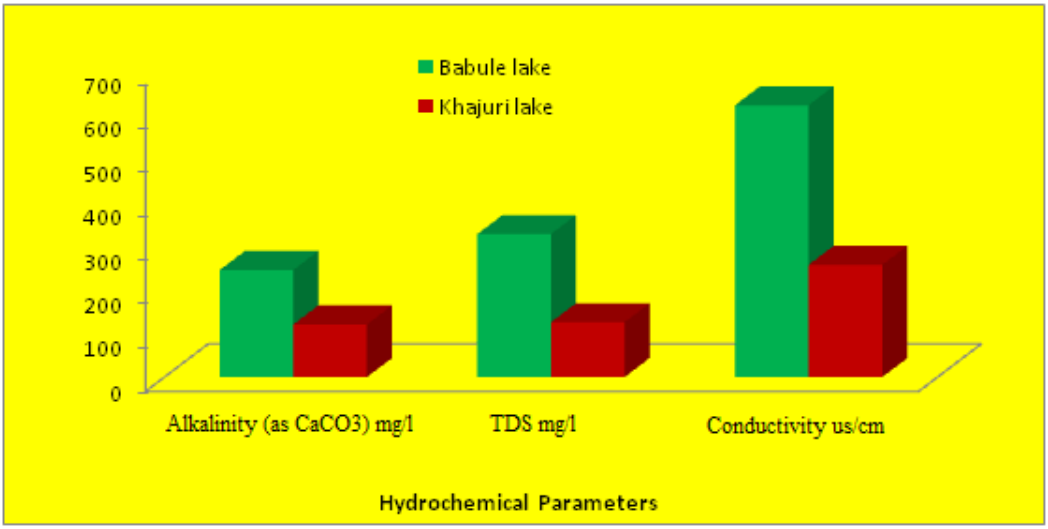

Figure 2: Graph showing variation in Alkalinity, TDS and Conductivity from the Babule Lake and the Khajuri Lake

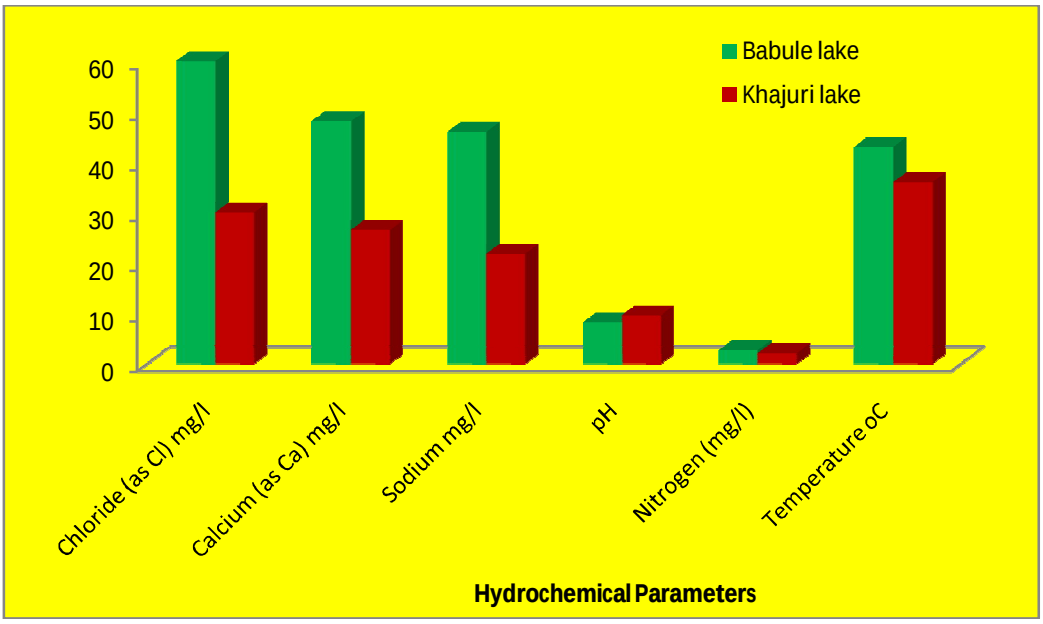

Figure 3: Graph showing variation in Cl, Ca, Na, pH, N and Temperature from the Babule Lake and the Khajuri Lake

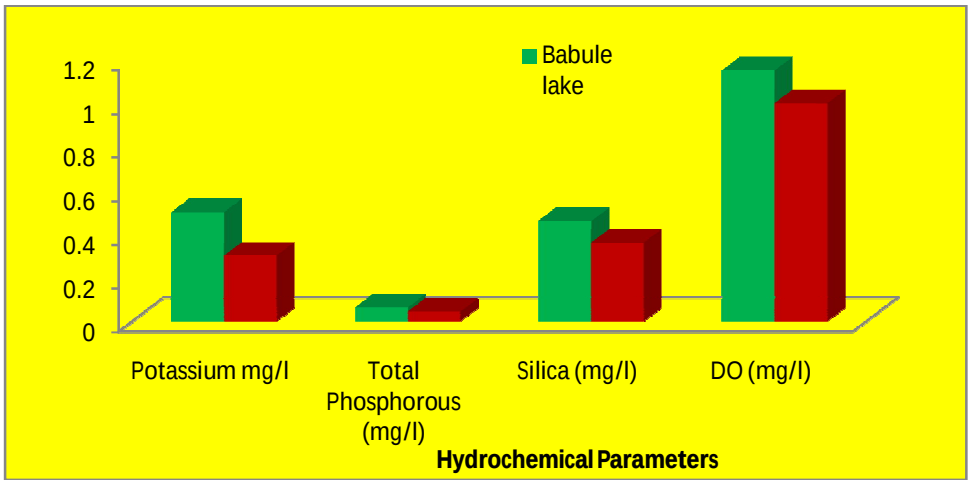

Figure 4: Graph showing variation in K, Total P, Silica and DO from the Babule Lake and the Khajuri Lake

The conductivity was 256 µs in the Khajuri Lake and 620 µs in the Babule Lake of the Palghar district. The values of Dissolved Oxygen (DO) were ranging between 1- 1.15 mg/l in both the lakes. The value of DO was high in the Babule Lake as compared to the Khajuri Lake. The total Phosphorus concentration in the Babule Lake was 0.062 mg/l and 0.045 mg/l in the Khajuri Lake. The values of chloride ranges from 30 mg/l to 60 mg/l for the Khajuri and the Babule Lakes, respectively. Sodium concentrations for the Khajuri and the Babule Lakes were 21.8 mg/l and 46 mg/l, respectively. The sodium concentration below 20 mg/l was permissible for the drinking purpose; hence water of these two lakes is not suitable for drinking purpose. Potassium concentrations for the Khajuri and the Babule Lakes were 0.3 mg/l and 0.5 mg/l, respectively. The potassium concentrations of the two lakes fall under the permissible level of drinking water (WHO, 2011). The chlorophyll content of the Khajuri and the Babule Lakes was below the detection limit

and hence consider as zero (WHO, 2011; Table 2). Temperature values of both the lakes vary from 30-45^{o}C. The surface water temperature of these two lakes were slightly different i.e., 36^{o}C and 40^{o}C for the Khajuri Lake and the Babule Lake, respectively. The pH observed from both the lakes was above the neutral value i.e. above 7, which indicates alkaline nature of water. The hydrogen ion concentration i.e., pH is high in the Khajuri lake (9.6) and comparatively less in the Babule Lake (8.2). These pH values clearly indicate moderate to high alkaline nature of water. However, higher values in the pH of these lakes suggest increased alkalinity due to anoxic bacterial activity (Schindler *et al*. 1980; Cook, 1981) during decomposition of organic matter in addition to photosynthetic activity (Kumar *et al* 2008). The bicarbonate present in the water decides the alkalinity of the lake (Kumar *et al*. 2008). The water bodies having alkalinity less than 1000 mg/l may be categorized as nationally rich (Pearsall, 1930). Thus, the investigation clearly reveals that lakes can be categorised as nutritionally rich water bodies making them eutropic in nature.

Table 2: Physiochemical parameters of the water samples recorded during the sampling.

Parameter	Unit	Khajuri Lake	Babule Lake
Alkalinity (as $CaCO_3$)	mg/l	120	244
Chloride (as Cl)	mg/l	30	60
Calcium (as Ca)	mg/l	26.5	48.1
Sodium	mg/l	21.8	46
Potassium	mg/l	0.3	0.5
Total Phosphorous	mg/l	0.045	0.062
K jeldahl Nitrogen	mg/l	2.1	2.7
Chlorophyll	µg/l	Nil	Nil
Temperature	^{o}C	35	41.5
pH	-	9.6	8.2
TDS	mg/l	125	326
Conductivity	µs/cm	256	620
Dissolved oxygen	mg/l	1	1.15

The total dissolved salt shows higher concentration in the Babule Lake (326 mg/l), and less in the Khajuri Lake (125 mg/l), respectively. Most often, low to medium levels of TDS are caused by the presence of low amount of potassium, chloride and sodium. These ions have little or no short time effects on water quality of lakes. The conductivity of the lakes varies from minimum at the Khajuri Lake i.e. 256µs to a maximum at the Babule Lake i.e. 620µs. The highest conductivity in the Babule Lake may be due to release of ions from the decomposed organic matter during summer (Kumar *et al.* 2008). Chloride concentration ranges between 30 mg/l to 60 mg/l in the two lakes under investigation indicating the low level of chloride concentration in the water bodies. The values of the water bodies having more than 58 mg/l of chloride are categorized as nutrient rich (Spence, 1964). Thus, both the lakes are classified as nutrient rich water bodies. The Calcium hardness more than 25 mg/l is categorized as rich water bodies. The Khajuri and the Babule Lakes have the calcium hardness values more than 25 mg/l. Thus, these two lakes can be categorized as rich lakes. Calcium and Magnesium in association with bicarbonate and carbonates, chlorides etc., decide the hardness of the water (Kumar *et al.* 2008). The higher values of the total hardness in the Khajuri and Babule Lake may be attributed to the addition of fertilizers in the agriculture fields. These two lakes show low concentration of dissolved oxygen suggesting the increase level of organic matter (Tsuda, 1965). The total phosphorous content in both the lakes lies in between 0.045 to 0.062 mg/l. The main source of the phosphorus may be through the sediments or may be due to the excessive use of fertilizers, detergents and municipal sewage entering into the water body (Kumar *et al.* 2008). Total Nitrogen ranges from 2.1 mg/l and 2.7 mg/l for the Khajuri and Babule Lakes, respectively. Nitrogen and Phosphorous are the important

nutrients for synthetic, autotrophs in the lake (Prakash, 1994). The low level of nitrogen content indicates minimal use of fertilizers around the Khajuri Lake, whereas, the input of cow dung from the cattle around the Babule Lake possible could have raised the values of nitrogen.

(B) Interpretation of diatoms from both Khajuri Lake and Babule Lake

The Babule Lake shows dominance of 14 types of diatoms species, which are from 11 different genera in which most dominant one is *Rhopalodia gibba* (19.90%) indicating mainly anthropogenic pollution with eutrophic trophic status of the lake (Hall, and Smol, 1992; Dixit et al., 1999). The Khajuri Lake shows dominance of 17 types of diatoms species, which are from 15 different types of genera in which *Diploneis ovalis* is the most dominant one (24.28%). All different diatoms from both the lakes are shown with their abundance in % (Tables 3 and 4).

Table 3: No. of occurrences of diatoms and their percentage from Khajuri Lake

Sr. no.	Name of Species	Number of Occurrence	Percent
1.	*Diploneis ovalis*	135	24.28
2.	*Amphora ovalis*	85	15.28
3.	*Eunotia* sp.	53	9.53
4.	*Pinnularia subcapitata*	52	9.35
5.	*Rhopaloidia gibba*	45	8.09
6.	*Aulacoseira granulata*	25	4.49
7.	*Gomphonema affine*	25	4.49
8.	*Encyonema minutum*	20	3.59
9.	*Gyrosigma spencerii*	15	2.69
10.	*Anomoeneis sphaerophera*	14	2.51
11.	*Amphora* sp.	13	2.33
12.	*Surirella* sp.	10	1.79
13.	*Nitzchia* sp.	10	1.79
14.	*Gomphonema* sp.	8	1.43
15.	*Pinnularia gibba*	7	1.25
16.	*Diploneis smithii*	7	1.25
17.	*Navicula sp.*	2	0.35
	Total	556	

Table 4: **No. of occurrences of diatoms and their percentage from Babule Lake**

Sr. No.	Name of Species	Number of Occurrence	Percent
1.	*RhopaloIdia gibba*	88	19.90
2.	*Encyonema minutum*	82	18.55
3.	*Pinnularia subcapitata*	52	11.76
4.	*Eunotia pectinalis*	48	10.85
5.	*Gomphonema undulatum*	32	7.23
6.	*Amphora ovalis*	28	1.4440
7.	*Navicula cryptocephala*	20	4.52
8.	*Mastogloia smithii*	20	4.52
9.	*Stauroneis anceps*	18	4.07
10.	*Cymbella similis*	18	4.07
11.	*Eunotia curvata*	17	3.84
12.	*Surirellla* sp.	12	2.71
13.	*Navicula tripuncata*	4	0.90
14.	*Eunotia incisa*	3	0.67
	Total	442	

The Principal Component Analysis (PCA) is performed on the uncorrelated variables by multiplying the original correlated variables with Eigen vector (loadings; PAST, Version, 2015). The Eigen values of the PCA are the measure of their related variance. The environment of the original variables in the PCA is provided by loadings (Helena et.al 2000). The contribution of each factor for both the lakes was calculated and score plots of first two PCA (PCA1 and PCA2) were constructed. The PCA was performed in order to understand the compositional variations among different physicochemical parameter with variation in water quality of both lakes and impact of anthropogenic activities. The result of PCA was produced by using software PAST (version 2015). PCA 1 of the 99.747% variation shows both positive and negative loadings for both Khajuri and Babule Lakes (Figure 5). *Diploneis ovalis* and *Amphora ovalis* are dominating diatom species in the Khajuri Lake, which is mainly controlled by Alkalinity and TOC in the Khajuri Lake. The high alkalinity (pH=9.6) of the Khajuri Lake positively signifies dominance of *Diploneis ovalis* and *Amphora ovalis* (Figure 6), similarly, *Rhopalodia gibba* and *Encyonema minutum* are dominating diatom species in the Babule Lake, which can be mainly correlated with total nitrogen concentration, phosphorous, Si, TDS and DO (Fig. 7). PCA 2 of 0.2527% variation is also characterized by positive and negative loadings for both the lakes (Fig. 8). Positive loading and negative loading may be due to different water chemistry during the present time. The geochemical analysis and PCA shows similar results. PCA 1 shows negative loadings i.e. -45.039 and PCA 2 shows 9.6166 for *Amphora ovalis* in the Khajuri Lake, similarly second most dominant diatom species is *Diploneis ovalis* representing PCA 1 showing negative loading i.e. -47.256 and PCA 2 shows positive loading 21.106. PCA 1 and PCA 2 show both the negative loadings i.e. -35.302 and -2.8273 for *Rhopalodia gibba* in the Babule Lake, similarly, second most dominant diatom species is *Encyonema minutum* representing PCA 1 and PCA 2 factor with the negative loadings i.e. -38.437 and -6.8376.

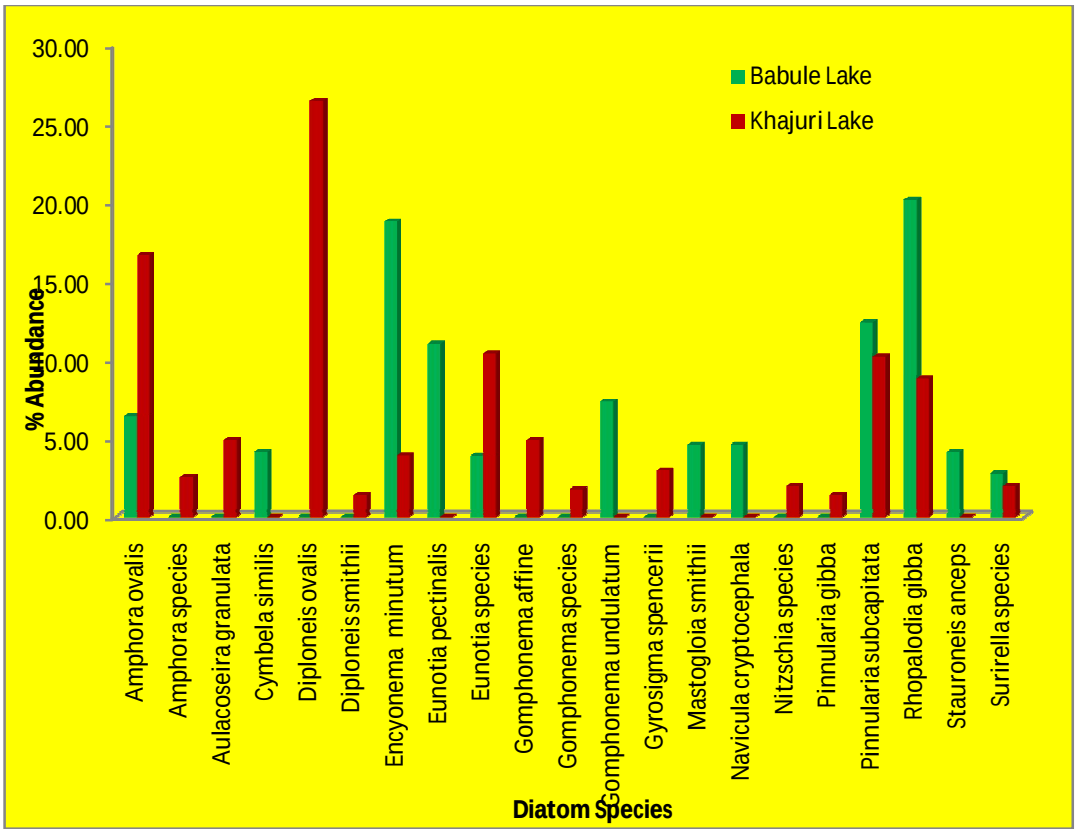

Figure 5: Abundance of Diatoms species in the Babule Lake and the Khajuri Lake

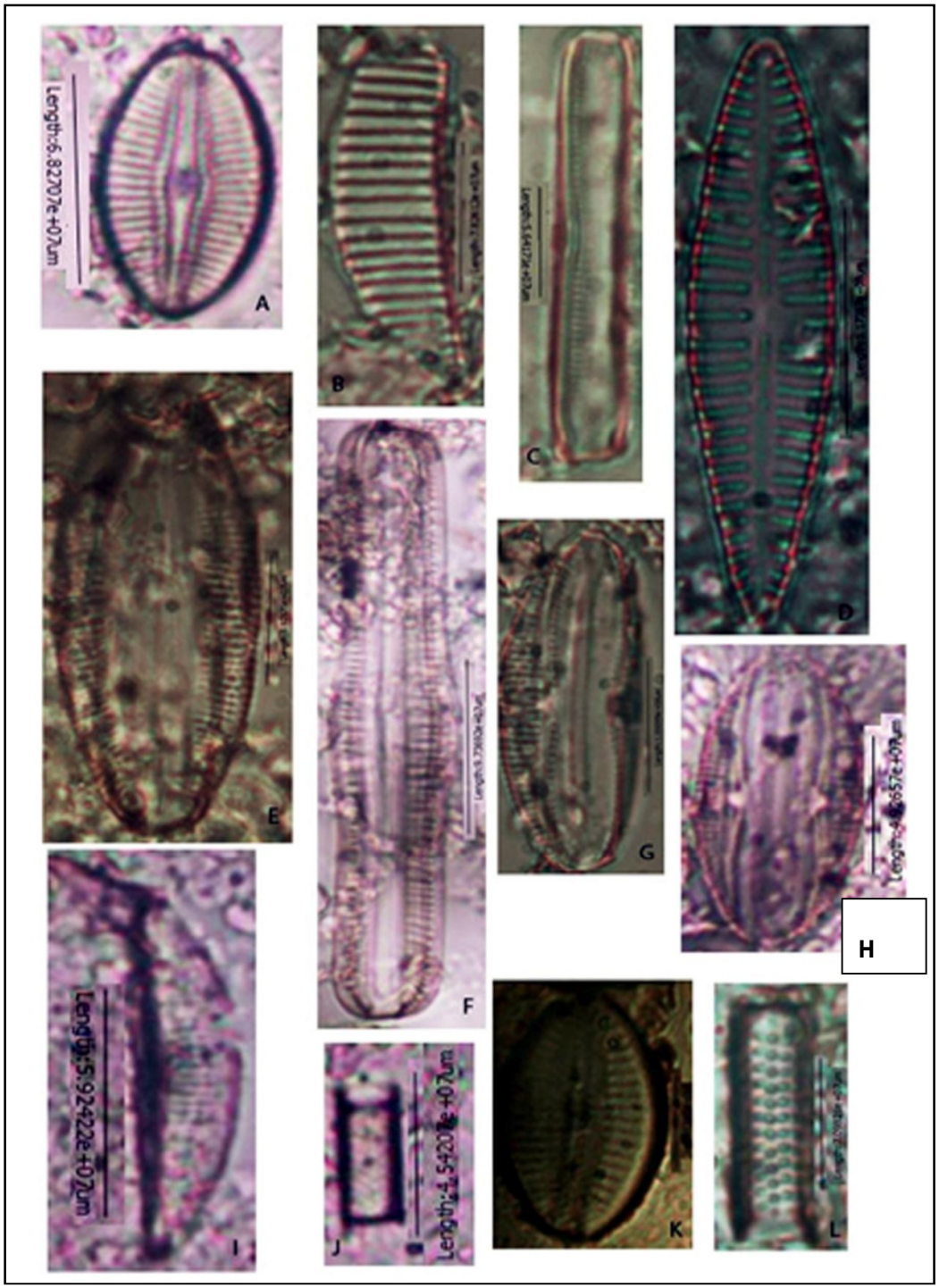

Figure 6: Microphotographs of dominant diatom species from the Babule Lake and the Khajuri Lake.

(A) *Diploneis ovalis* Rabenhorst, 1864 (KLS1); (B) *Eunotia* sp. (KLS1) ; (C) *Pinnularia subcapitata* Gregory, 1856 (KLS2); (D) *Gomphonema affine* Patrick, 1975 (KLR1); (E) *Amphora ovalis* Kutzing, 1884 (KLR2); (F) *Rhopalodia gibba* Muller, 1895 (KLR2); (G) *Amphora ovalis* Kutzing, 1884 (KLS1); (H) *Amphora ovalis* Kutzing, 1884 (KLS1); (I) *Encyonema* sp. (KLS1); (J) *Aulacoseira granulata* Rabenhorst, 1864 (KLR2); (K) *Diploneis ovalis* Rabenhorst, 1864 (KLR1); (L) *Aulacoseira granulata* Rabenhorst, 1864 (KLR1)

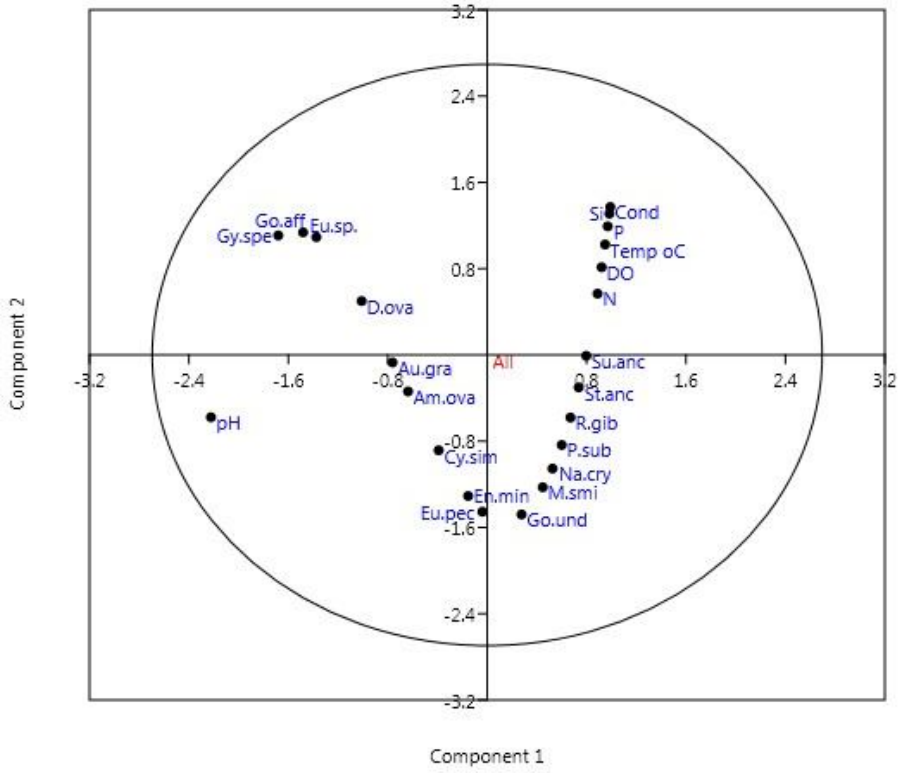

Figure 7: Principal Component Analysis of the Babule Lake and the Khajuri Lake

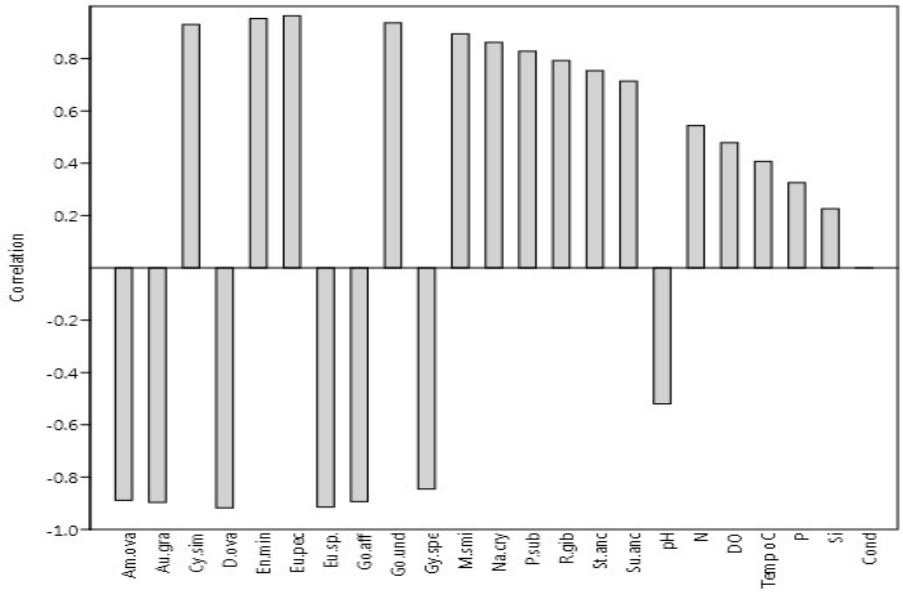

Figure 8: Loadings of physicochemical parameters

CONCLUSIONS

Both, the Khajuri and the Babule Lakes exhibit highly alkaline conditions i.e. pH- above 8, which may be due to discharge of detergents, soaps and animal waste in the lakes. The pH of lake water also indicates their alkaline status. Both these lakes are categorized as rich lake and their water is not suitable for drinking purpose. Total nitrogen content in both these lakes points increased anthropogenic activity such as use of fertilizers and detergent etc around the lakes. The Khajuri and the Babule Lakes reflect hyper-eutrophic condition on the basis of nitrogen concentration. On the basis of dominant diatom assemblage, it can be surmised that the Babule Lake was alkalibiontic (pH 8.2) and eutrophic in nature, while the Khajuri Lake indicates fresh to brackish, alkaliphilous water with pH above 7 and tolerant to mild pollution.

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