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Limnological Study of Gadchiroli Lake, Maharashtra, India using hydro-Sediment Chemistry and Sedimentary Diatoms

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ABSTRACT

Diatom assemblages are indicators of lake condition and may be used to evaluate past lake water quality changes. The surface sediment samples along with the water samples were collected from the Gadchiroli Lake covering the complete stretch and were analyzed for the physicochemical parameters, geochemistry and sedimentary diatom assemblages. The spread of diatom species was strongly linked to various environmental parameters. The Total Alkalinity (TA), total dissolved salt, calcium hardness and magnesium hardness values evidently specify that currently the lake water is moderately hard to hard. The calcium concentration shows that the good portion of calcium has been deposited from the soil erosion. The concentrations of carbonates in the Gadchiroli Lake could have been increased due to enhanced human activities in and around the lake such as rapid urbanization, washing the clothes using the detergents etc. The concentrations of the Total Phosporous indicates fair to poor quality of the lake water. The total Nitrogen content points eutrophic condition of the lake. The other physicochemical parameters were well within the permissible limit. The overall hydrochemical analysis suggests that the lake water is deteriorated due to the increased anthropogenic activities. The higher concentration of SiO_2, Al_2O_3 and Fe_2O_3 may be mainly due to the enhanced weathering of these rocks and soil in the watershed for the Gadchiroli Lake. The dominance of the centric diatoms such as *Aulacoseira granulata* and *Cyclotella meneghiniana* indicates that water from the Gadchiroli Lake was more eutrophic with increased productivity and high conductivity.

Keywords: Sedimentary Diatoms, Water Quality, Trophic State, Gadchiroli Lake, *Cyclotella meneghiniana* , *Aulacoseira granulata*

I. INTRODUCTION

In the world, there is immense need of water, particularly for the drinking water purpose. As the population is increasing, the industries and agricultural activities are also enhanced leading the rise in the higher use of water as compared to its replenishment. Similarly, the release of the industrial and anthropogenic effluents into the lakes and rivers create the myriad water related problems. Therefore, the monitoring of such situations is highly needed considering the importance of the source of the fresh water. Diatoms are sensitive to environmental changes and therefore used as good indicators of the environment contamination (Hall and Smol, 1999). They are commonly used to monitor the environmental conditions including the past and present water quality as they are almost ubiquitous and found in aquatic environments, soils etc. (Round, 1961).

The diatoms are the single celled microscopic eukaryotic algae having a range of size between 2μm to 500 μm in length/diameter. They are among the main photosynthetic producer on the earth, occurring in almost all aquatic, marine and fresh water habitats and thus playing a major role in the global carbon and silica cycle (John, 1987). They are the major photosynthetic producers and many a times live in colonies like filaments, fans, zigzags or stars (John, 2014a, b). Their cell walls are composed of silica (i.e. hydrated silicon dioxide) and referred as frustules. They were originated somewhere during the early Jurassic or before and only the male gametes of centric diatoms were able to move with the help of flagella (Brassier, 1980).

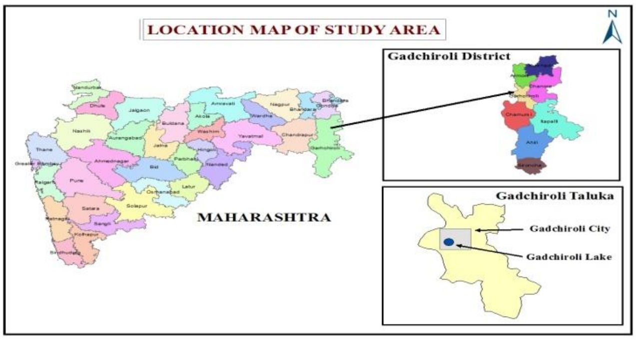


Figure 1. Location map of Gadchiroli Lake

The study area i.e. Gadchiroli Lake is present in the Gadchiroli district headquarter on the easternmost part of the Maharashtra State and approximately 170 km away from the Nagpur city (Fig. 1). The lake is easily accessible by tar roads throughout the year. The study area i.e. the Gadchiroli Lake (N- 20^{o} 11' 12.0" and N- 20^{o} 11' 3.6"; E- 79^{o} 59' 46.2" and E- 80^{o} 00' 5.9") falls in the survey of India toposheet no. 55p/16 of the Gadchiroli district. The lake is mostly surrounded by the urban settlements (Fig. 2). The Gadchiroli district is bounded by the Bhandara district in the North, Chandrapur district in the West, Adilabad and Karimnagar district of the Andhra Pradesh in the West and South, respectively and Rajnandgaon and Baster district of the Chhattisgarh State border in the East.

Figure 2. A panaromic view of the Gadchiroli Lake

The total watershed area of the Gadchiroli Lake is about 10 sq. km. The highest temperature is usually reached up to 46^{o} C in the months of May and June. The Gadchiroli district receives maximum rainfall during monsoon months June, July, August, and September excluding the summer months, when extremely hot weather prevails with very scanty rainfall consequential to the recurrent water storage. The maximum, minimum and average rainfall received by the Gadchiroli Taluka since 2004 to 2015 was 2005.6mm, 846.2mm, 1366.32mm, respectively (gadchiroli.gov.in-enmraingad8). The climate of the study area follows a seasonal monsoon weather pattern with the dry tropical weather.

Various workers have studied the diatoms and their relationship with the lake and river water quality in the different Indian regions (Venkatachalapathy et al., 2013, 2014 and Logannathan et al., 2014). Similarly, Humane et al. (2009, 2010b, 2012a, 2012b, 2015a, 2015b. 2016), Humane et al. (2010) and Humane and Humane (2015a, b and c) have particularly worked on the sedimentary diatoms, present and past trophic status of lakes and reservoirs of the central India.

The Gadchiroli Lake is surrounded by the urban settlement leading to increased anthropogenic impact on it. Therefore, the present study has mainly dealt with the investigations of the anthropogenic impact on the water quality of the Gadchiroli Lake on the basis of the hydrochemistry, geochemistry and the sedimentary diatoms.

II. GEOLOGICAL SETTINGS

Geologically, the Gadchiroli district is mainly comprised of the rocks such as the Archean Basement Complex, the Gondwana, the Deccan Trap along with the intertrappeans and the alluvium and soil of the quaternary age (Deshpande, 1998). The geology around the Gadchiroli Lake and its catchment area is mainly comprised of rocks such as granitic gneisses, migmatite with the enclaves of hornblende schists and amphibolites belonging to the Amgaon Gneissic Complex of Archean to Paleoproterozoic age (DRM, 2000; Figure 3).

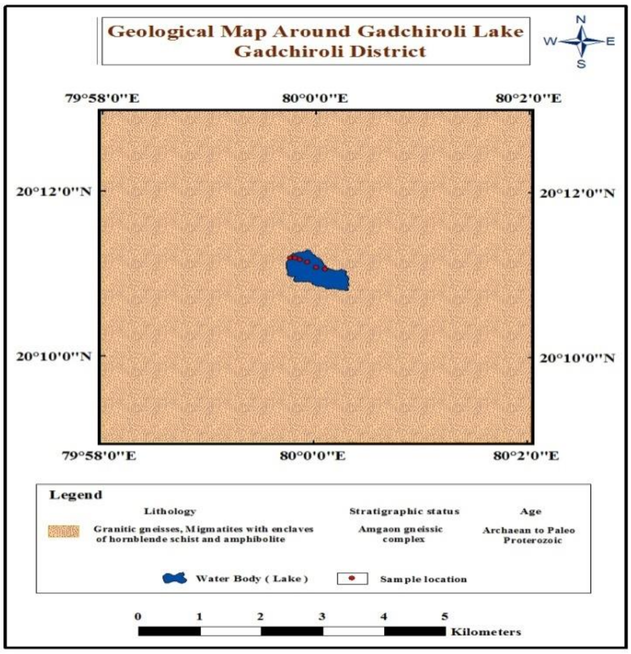


Figure 3. Map showing geology around Gadchiroli Lake

III. METHODS AND MATERIAL

The following methods have been used for the sampling of grab sediment and water samples:

A systematic sampling was done during Pre Monsoon season by collecting sediment samples (Grab) along with water samples from the Gadchiroli Lake in June 2013. The different equipment using during the field work were as follows: the Global Positioning System (GPS) (Garmin, e-trex Hx), pH meter, Conductivity meter, water bottles (06 in quantity), zip-lock plastic bags, rope, measuring tape; medium size bucket and plastic mug etc.

Overall, the six sediment (grab) samples along with the six water samples were collected from the Gadchiroli Lake at different intervals covering its complete stretch. The positions of collected samples were noted using the GPS Instrument and numbered systematically i.e. GLG-1/ GLW1: Latitude- N 20° 11' 12", Longitude - E 79° 59' 46.2"; GLG-2/ GLW2: Latitude - N 20° 11' 11.7", Longitude - E 79° 59' 48.9"; GLG-3/ GLW3: Latitude - N 20° 11' 10.5", Longitude - E 79° 59' 51"; GLG-4/ GLW4: Latitude - N 20° 11' 8.9", Longitude - E 79° 59' 55.8"; GLG-5 / GLW5: Latitude - N 20° 11' 4.8", Longitude - E 080° 00' 1.1" and GLG-6 / GLW6: Latitude – N 20° 11' 3.6", Longitude - E 80° 00' 5.9" (Fig. 4).

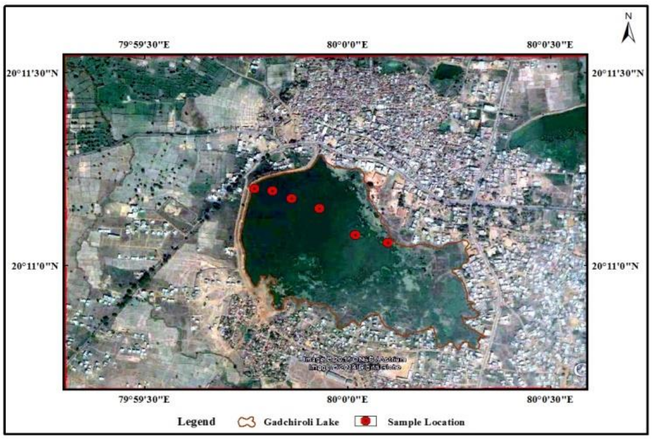


Figure 4. Satellite image of the Gadchiroli Lake showing sample locations

The water samples were collected in the air tight plastic bottles from the six different parts of Gadchiroli Lake during pre monsoon season by following the standard water sampling techniques. The physicochemical parameters such as Conductivity and pH of the lake water and depth of the lake at the six different locations were measured during sampling itself. Similarly, the sediment samples were collected in the air tight zip lock plastic bags. These water and sediment samples were subsequently moved to the laboratories for hydrochemical, geochemical and diatom analyses.

The various physicochemical parameters of the water samples such as pH, Electrical Conductivity, Alkalinity, Chloride, Calcium, Magnesium, Nitrate-Nitrogen, Iron, Phosphorous, Aluminum, Manganese, Silica, Sodium and Potassium were measured using different equipment such as: pH meter (Model-101E), Digital conductivity meter (Model-601), Titrimetric analysis, UV spectrometer (make- Systronics, Model-118), UV- visible spectrometer, from the Water Quality Lab, level II, Hydrology Project Division, Ajani, Nagpur.

The collected sediments samples were first dried in the oven at 110°C. These dried samples were then crushed and sieved for using -170 mesh size particles to provide more surface area for chemical reaction and needed for the good results. The powdered sediment samples were packed in the small zip-lock bags with the proper numbering and used for the further analysis.

These samples were kept in the small labelled Zip-Lock packets. These samples were then sent to the analytical laboratory of the Indian Bureau of Mines (IBM), Nagpur for the X-Ray Fluorescence analysis (Model- PW2403, MAGIX and Manufacturer-PANlytical, Netherland).

About 01g wet sediment samples from the each location were taken into the six different beakers. Few drops of dilute HCl were added to it to remove the carbonates. The solution was washed with the distilled water at about 3 hours interval to remove the traces of HCl. This process was repeated for three to four times wherever required. Then, about 05 ml of H_2O_2 (Hydrogen peroxide, 30%) was added to each sample to remove the organic matters. The samples were boiled for 5 minutes to speed up the process. The acidified samples were repeatedly washed with the distilled water till all the traces were removed (Battarbee, 1986). The macerated samples were used to prepare the diatom slides following the procedure given by Batterbee (1986). The identification of the diatoms was followed after John (2014a, b); Round et al. (1990), Mann (1999) and www.environment_agency. gov. uk.

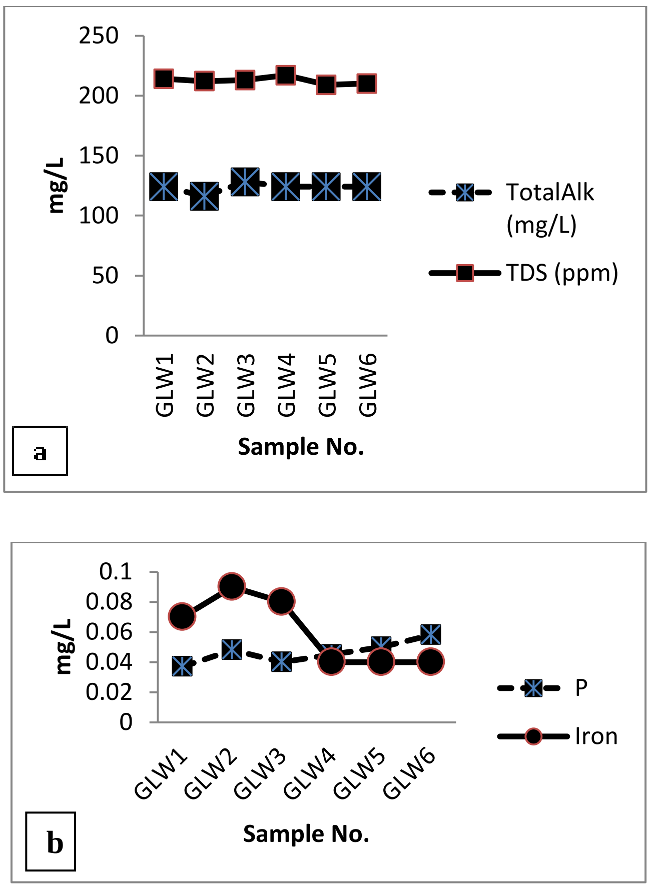
IV. RESULTS AND DISCUSSION

The different physicochemical parameters wee used for the lake water analysis such as Total Alkalinity, Chloride, Calcium, Magnesium, Nitrate- Nitrogen, Total Phosphorous, Iron, Aluminum, Manganese, Silica, Sodium, Potassium, and Dissolved Oxygen (DO). The result of analysis is represented in the figures 5a-f. The pH of lake water was 7.7 to 7.8 and its temperature was about 26.6^{o} C at the time of sampling. The electrical conductivity of the lake water was ranging from 412 μhos /cm - 427 μhos/cm, with an average were 421 μhos/cm.

The sodium content of water ranges from 27.5 mg/l to 33 mg/l (Fig. 5c). The potassium concentration changes from 0.4 – 0.8 mg/l. There is slight variation in CaCO3 content from 116 mg/l to 124 mg/l and the NO_3-N content lies between 0.64 -0.76 mg/l (Fig. 5d).The Iron content in lake water also shows small fluctuation with its mean values is 0.09 mg/l and the Phosphorous value ranges from 0.037 to 0.058 mg/l (Fig. 5b). The concentration of calcium and magnesium ranges from 28.9 -30.5 mg/l and Mg ranges from 8.2 mg/l to 9.2 mg/l respectively (Figs. 5e-f). The hardness of water is mainly based on its Ca and Mg content. The calcium and magnesium hardness also suggest the comparatively hard quality of the lake waters. The total dissolved salt content was also high in the entire lake (Fig. 5a) leading to rise in its hardness.

The Total Alkalinity (TA) values were varying from 116 mg/l to 128 mg/l, with a mean value was 123 mg/L (Fig. 5a), which clearly indicates that currently the lake water is moderately hard to hard and may have the impact on the fishes and the aquatic plants. The calcium concentration shows that the good portion of calcium has been deposited from the soil erosion. The abundance of carbonates in lake water makes it alkaline (Kumar et al. 2008). Thus, the concentrations of carbonates in the Gadchiroli Lake could have been increases due to myriad anthropogenic activities in and around the lake including washing the clothes using the detergents etc. The high level of alkalinity is also due to the more suspended carbonate particles withdrawn from plant and other organic content from the nearest environment. The chloride ion content ranges from 41.5 to 44.5 mg/l with its maximum concentrations in the sample GLG1 (Fig. 5F). The chloride content indicates that there are other sources of its origin in the lake than the rainfall and seepage (Dixit et al., 1999). The excessive use of detergents along the lake shore may also be the reason of its rise. The TDS of the water falls under the permissible limit of the BIS (2003). The concentrations of the Total Phosporous (TP) ranges from 0.037-0.058 mg/l (Fig. 5b) indicating fair to poor quality of the lake water. Nitrogen is the second most important parameter other than Phosphate and essential nutrient for the plant and algal growth. The total Nitrogen content in the lake water is between 0.64 mg/l to 0.76 mg/l (Fig. 5d), which indicates eutrophic condition of the lake. The source for nitrate to the lake may also be due to the various human activities such as washing clothes, movement of cattle along the lake shore etc. The Silica content in the lake water varies from 2.88 - 4.90 mg/l (Fig. 5e), which is very much important for the growth of the cell walls of the aquatic algae such as diatoms and other siliceous forms. The Iron, Aluminium, Sodium and Potassium content were well within the permissible limit (APHA, 1985).

Thus, the overall hydrochemical analysis of lake water suggests the lake is polluted in the recent time by the increased anthropogenic activities.



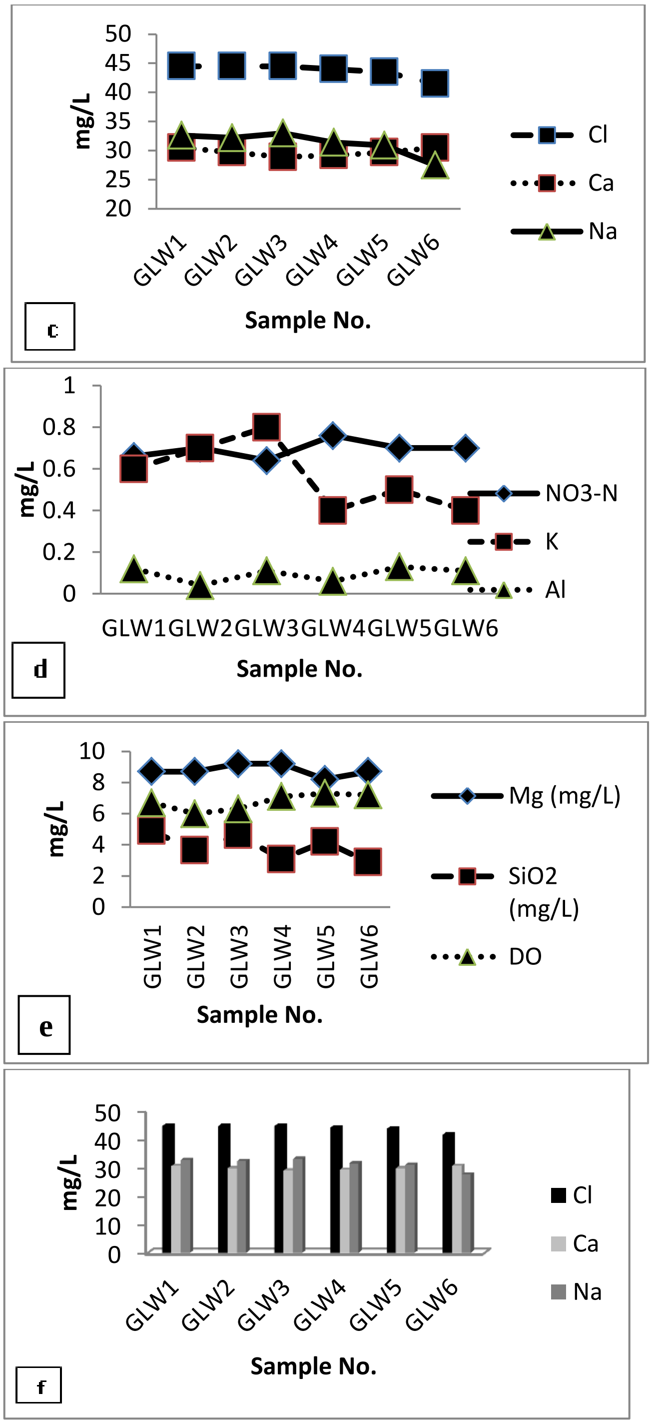
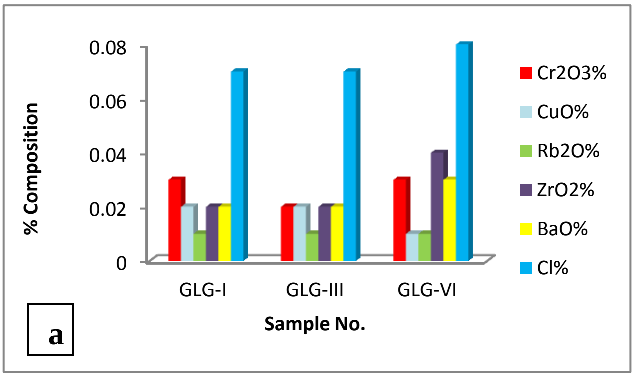
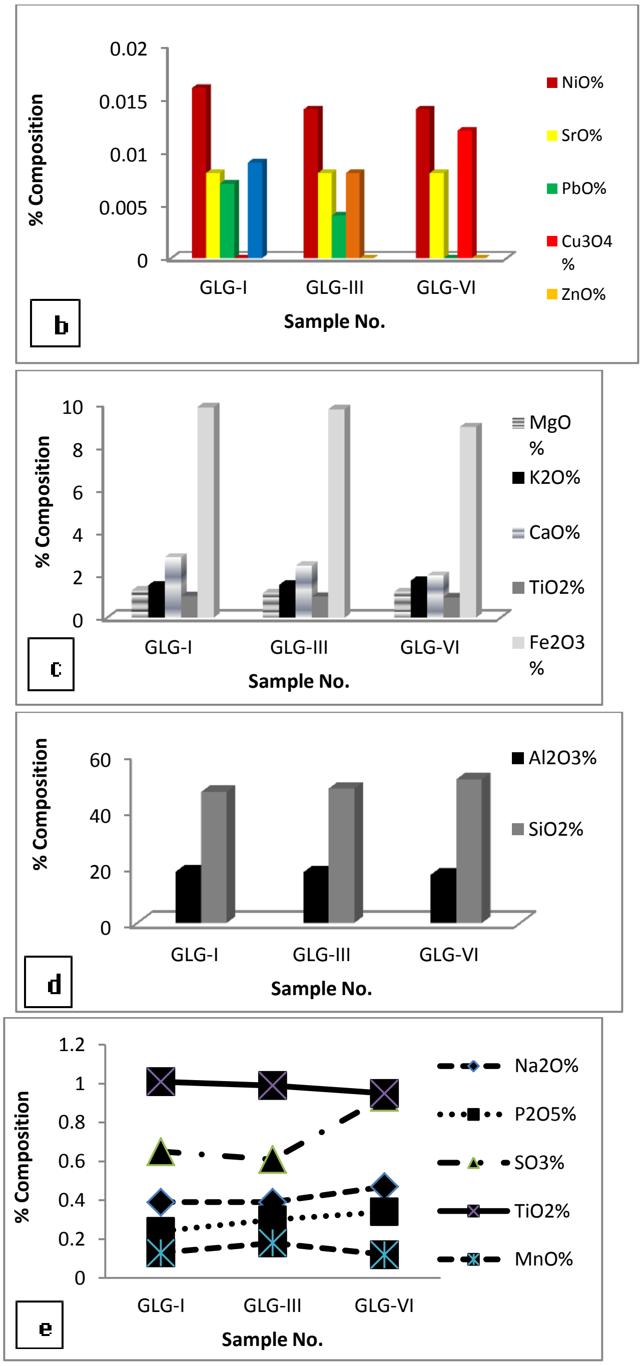


Figure 5 (a-f): Distribution of Physicochemical parameters in lake water

The surface sediment (grab) samples were analysed to understand the different elemental concentrations such as Na_2O, MgO, Al_2O_3, SiO_2, P_2O_5 ,K2O, TiO_2, MnO, Fe_2O_3 (major oxides) and Sc, Co ,Ni, Cu, Zn, Pb, Th, Rb, Sr, Zr, Nb, Cr (trace elements). The results of geochemical analysis of the grab sediments were shown in the figures 6a-e. The elemental concentration of copper shows very low peaks at the different locations of the lake (Fig. 6a). The sedimentary silica content varies from 46.61% to 51.12 %, with the mean value of silica is 48.52 % (Fig. 6d). The value of magnesium changes from 1.15% to 1.27%, with the mean value is 1.20 % (Fig. 6c). The calcium concentration ranges from 1.96% (GLG3) to 2.82% (GLG1) and mean value of calcium is 2.40% (Fig. 6c). The MgO content ranges from 1.20%-1.1.20% (Fig. 6c). The concentration of Na_2O varies from 0.39%-0.47% (Fig. 6e). The concentration of K_2O is very less and varies from 1.54% mg/g-1.72mg/g (Fig. 6c). The P_2O_5 ranges from 0.30%-0.34% (Fig. 6e). The maximum concentration of Al_2O_3 is in GLG1 (18.20%) and minimum in GLG-VI (17.16%), with the mean value of it is 17.78% (Fig. 6d). The concentration of Fe_2O_3 varies from 8.91% - 9.84% (Fig. 6c). The Silica content ranges from 47.61% - 51.12% in the surface sediments of the Gadchiroli Lake (Fig. 6d). The TiO_2 concentrations changes from 0.99% -1.01% (Fig. 6c). The Cr_2O_3 content varies from 0.02%-0.03% (Fig. 6a). The CuO content ranges from 0.01%-0.02% (Fig. 6a). The Cu_3O_4 content ranges from 0.012% - 0.008% (Fig. 6b) and the mean ZnO value was 0.009% (Fig. 6b). The ZrO_2 content ranges from 0.02%-0.04% (Fig. 6a). The MnO concentration ranges from 0.12% - 0.18% in the surface sediments of the lake (Fig. 6e). The NiO content from the grab sediments ranges from 0.014%-0.016% (Fig. 6b). The mean values of SrO and Rb_2O are 0.008% and 0.01, respectively (Figs. 6a-b). The PbO value ranges from 0.004%-0.007% (Fig. 6b). The BaO content varies from 0.02%-0.03% (Fig. 6a). The chloride (Cl) values ranges from 0.07%-0.08% (Fig.6a). The SO_3 content ranges from 0.65%-0.93% (Fig. 6e).

The Gadchiroli Lake is surrounded by the rocks such granitic gneisses, migmatite with the enclaves of hornblende schists and amphibolites belonging to the Amgaon Gneissic Complex and the soil developed out of it. Thus, the higher concentration of SiO_2, Al_2O_3 and Fe_2O_3 may be mainly due to the increased weathering of these rocks and soil in the watershed (Figs. 6C-d). The fluctuation in the Al_2O_3 content points the changing rate of soil erosion (Garrision and Lalibetre, 2007). The high content of the SiO_2 may also be due to the erosion of rocks and soils rich in silica. Similarly, the TiO_2 content is chiefly derived from the soil particles, particularly clays (Garrision, 2005). The higher Fe_2O_3 content in the lake may be due to increased soil erosion and the enrichment of iron in its deepest part. The CaO content of lake could primarily be derived from the soil erosion in the catchment area (Fig. 6c). The MgO content in the lake may be derived from soil erosion in addition to the anthropogenic activities such as urbanization around lake mainly the excess use cement etc (Fig. 5c). The concentrations of Na_2O, P_2O_5, SO_3 and MnO are very less in the lake sediments i.e. less than 1 (Fig. 6e). Similarly, the concentrations of Cr_2O_3, CuO, Rb_2O, ZrO_2, BaO and Cl (Fig.6a) and NiO, SrO, PbO, Cu3O4 and ZnO (Fig. 6b) are very meagre. However, the comparative study of the trace elemental concentrations from the sediments indicates that the lake is to some extent enriched in ZrO_2, Cr_2O_3 and NiO. The high percentage of CaO, SiO_2, Al_2O_3, and FeO indicate the increase rate of erosion in the lake watershed.

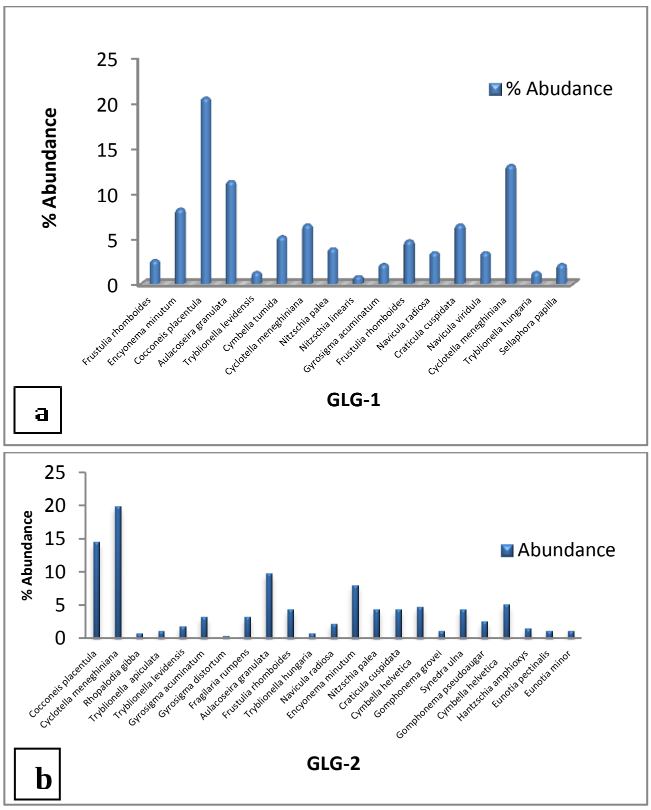


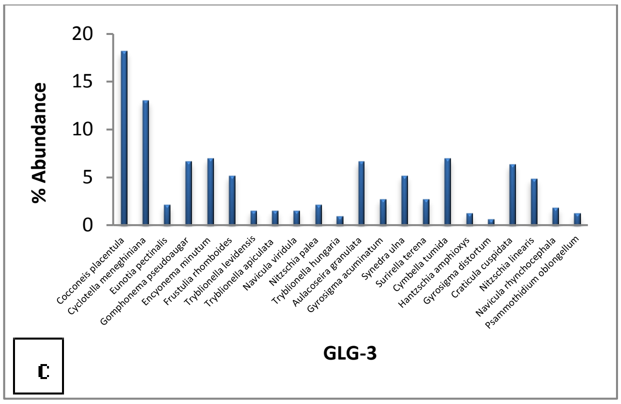


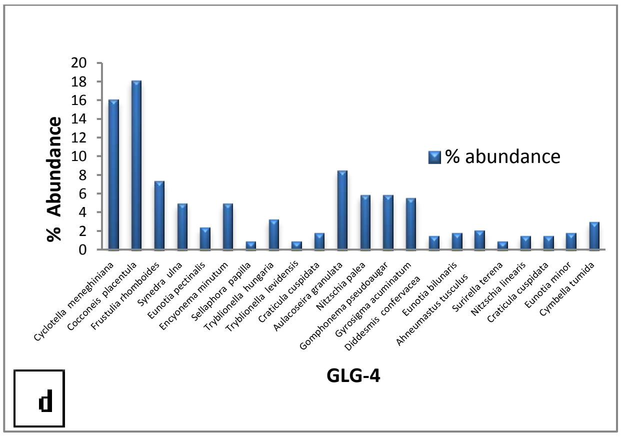
Figures 6 a-e: The results of the geochemical analysis of grab sediments

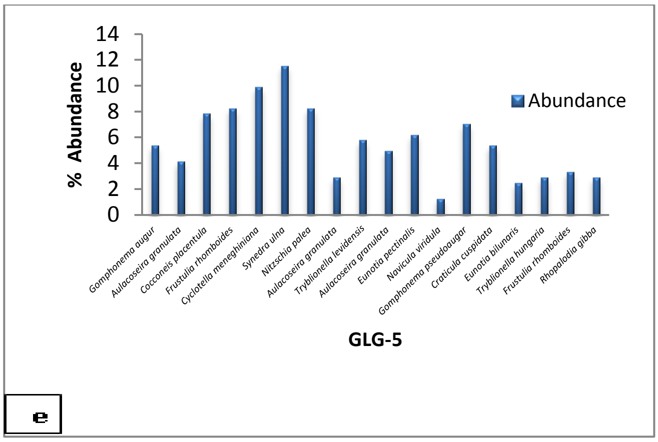
The overall study of surface sediments of Gadchiroli Lake reveals the presence of 44 species belonging to 27 genera (Table 2; Fig. 7g). The sedimentary diatom assemblage is represented by 02- Centric, 03- Pennate Araphids, 34-Pennate Biraphid diatom species and 05-other diatoms. The abundance of diatom species found in the surface sediments are *Cyclotella meneghiniana* (14.54%) and *Aulacoseria granulata* (8.36%), *Cocconeis placentula* (14.48%) indicating high conductivity of water (Figs.7 a-f).

The physicochemical and geochemical variables are the important factors governing the abundance of diatoms in the Gadchiroli Lake. The higher values of pH in the Gadchiroli Lake point slightly alkaline nature. Thus, the pH values of the lake support the alkalibiontic diatom assemblages. *Aulacoseira granulata* always thrive in the more eutrophic waters with shallow depth (Stoermer et al., 1995). Similarly, *cyclotella meneghiniana* is commonly observed in the waters of high conductivity (www.craticula.ncl.ac.uk). The prevalence of the centric diatoms such as *Aulacoseira granulata*, *Cyclotella meneghiniana* indicates that water from the Gadchiroli Lake was more eutrophic with increased productivity along with high conductivity. The pH showed the significant positive correlation with SiO_2. The correlation of planktonic to benthic diatom species indicates eutrophic condition of the lake. The increased dissolved silica content also corroborates the rise in the diversity of the diatom species. The higher content of sedimentary silica also supports increased diatom diversity.









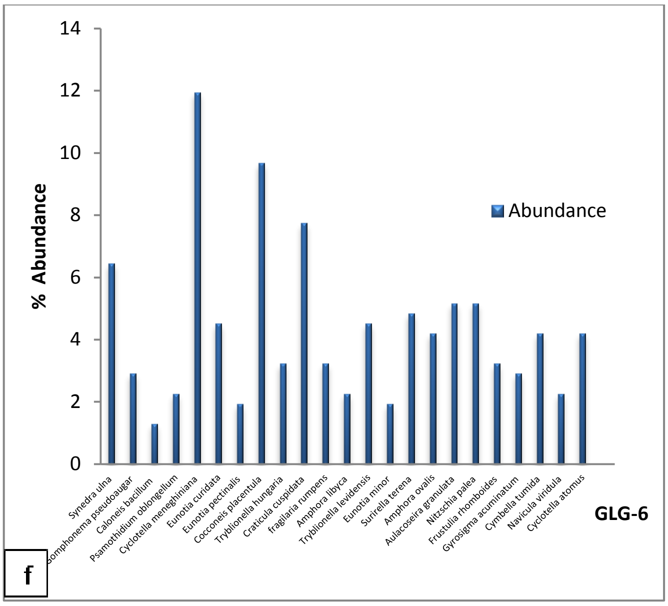


Figure 7a- f. Abundant diatom species from Grab sediments

(GLG1-GLG6)

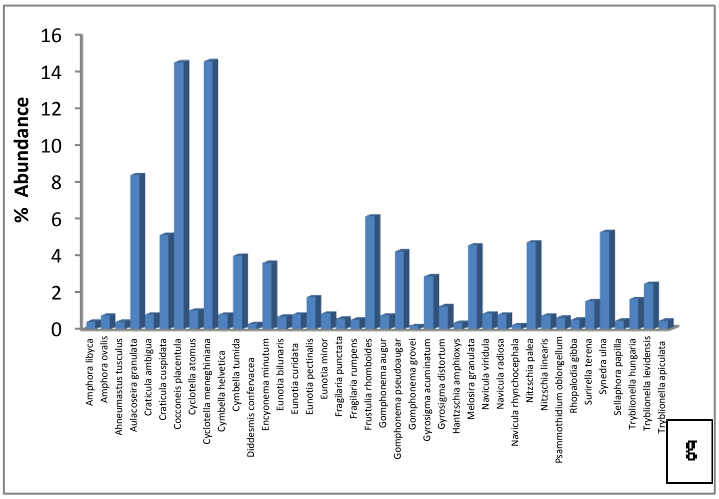


Figure 7g. Total abundant diatom species from Grab sediments

Name of species	occurrence	% abundance
Amphora libyca	7	0.393038
Amphora ovalis	13	0.729927
Ahneumastus tusculus	7	0.393038
Aulacoseira granulata	149	8.366086
Craticula ambigua	14	0.786075
Craticula cuspidata	91	5.109489

Cocconeis placentula	258	14.48624
Cyclotella atomus	18	1.010668
Cyclotella meneghiniana	259	14.54239
Cymbella helvetica	14	0.786075
Cymbella tumida	71	3.986524
Diddesmis confervacea	5	0.280741
Encyonema minutum	64	3.593487
Eunotia bilunaris	12	0.673779
Eunotia curidata	14	0.786075
Eunotia pectinalis	31	1.740595
Eunotia minor	15	0.842223
Fragilaria punctata	10	0.561482
Fragilaria rumpens	9	0.505334
Frustulia rhomboides	109	6.120157
Gomphonema augur	13	0.729927
Gomphonema pseudoaugar	75	4.211117
Gomphonema grovei	3	0.168445
Gyrosigma acuminatum	51	2.86356
Gyrosigma distortum	22	1.235261
Hantzschia amphioxys	6	0.336889
Melosira sp.	81	4.548007
Navicula viridula	15	0.842223
Navicula radiosa	14	0.786075
Navicula rhynchocephala	4	0.224593
Nitzschia palea	84	4.716451
Nitzschia linearis	13	0.729927
Psammothidium oblongellum	11	0.617631
Rhopalodia gibba	9	0.505334
Surirella tenera	27	1.516002
Synedra ulna	94	5.277934
Sellaphora papilla	8	0.449186
Tryblionella hungaria	29	1.628299
Tryblionella levidensis	44	2.470522
Tryblionella apiculata	8	0.449186
Total	1781	-

Table 2. Occurrences of diatom species in Grab sediments

V. CONCLUSION

The calcium and magnesium hardness also suggest the comparatively hard quality of the lake waters. The total dissolved salt content was also high in the entire lake leading to rise in its hardness. The Total Alkalinity (TA) values clearly indicate that currently the lake water is moderately hard to hard. The calcium concentration shows that the good portion of calcium has been deposited from the soil erosion.

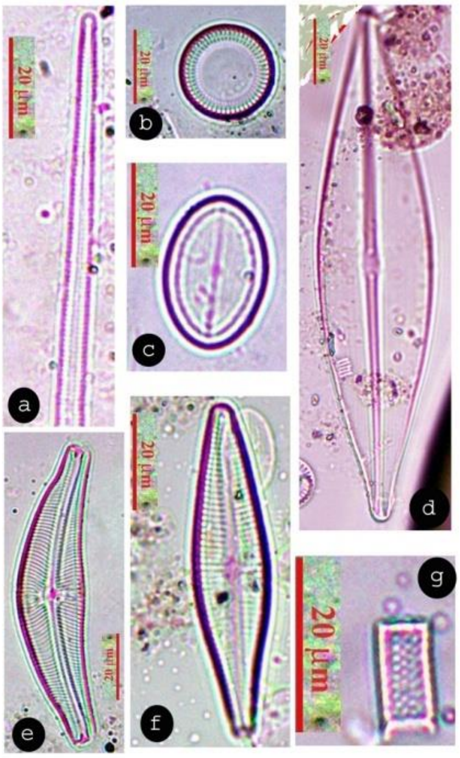


Figure 8. Dominant diatom species from grab sediments of Gadchiroli Lake (a- *Syndedra ulna*, b- *Cyclotella meneghiniana*, c- *Cocconeis placentula*, d- *Craticula cuspidata,* e- *Cymbella tumida,* f- *Gomphonema pseudoaugar* and g- *Aulacoseira granulata*)

The concentrations of carbonates in the Gadchiroli Lake could have been increased due to myriad anthropogenic activities in and around the lake including washing the clothes using the detergents etc. The high level of alkalinity is also due to the more suspended carbonate particles withdrawn from plant and other organic content from the nearest environment. The excessive use of detergents along the lake shore may also be the reason in the rise of the sulphide content. The concentrations of the Total Phosporous indicates fair to poor quality of the lake water. The total Nitrogen content points eutrophic condition of the lake. The source for nitrate to the lake may also be due to the various human activities such as washing clothes, movement of cattle along the lake shore etc. The Iron, Aluminium, Sodium and Potassium content were well within the permissible limit. The high silica content in the lake water could have also supported in the growth of the cell walls of the aquatic algae such as diatoms. Thus, the overall hydrochemical analysis suggests that the lake is polluted in the recent time by the increased anthropogenic activities. The higher concentration of SiO_2, Al_2O_3 and Fe_2O_3 may be mainly due to the increased weathering of these rocks and soil in the watershed for the Gadchiroli Lake. The comparative study of the trace elemental concentrations from the sediments indicates that the lake is to some extent enriched in ZrO_2, Cr_2O_3 and NiO. The pH values of the lake support the existence of the alkalibiontic diatom assemblages. The prevalence of the centric diatoms such as *Aulacoseira granulata* and *Cyclotella meneghiniana* indicates that water from the Gadchiroli Lake was more eutrophic with increased productivity and high conductivity.

VI. ACKNOWLEDGEMENTS

We are very much thankful to Indian Bureau of Mine (IBM), Nagpur for the X-Ray Fluorescence analysis (XRF) of grab sediments at the Pilot Plant, Hingna Road, Nagpur. Thanks are also due to the Director, Hydrology Project Division, Government of Maharashtra, Nagpur, for the Hydro-chemical analyses of water samples. We acknowledge the financial assistance to the department, under UGC SAP- DRS-II program.

VII. REPOSITORY

The diatoms slides studied in the present work are kept in the Applied Micropaleontology Laboratory, Post Graduate Department of Geology, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur.

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