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Research Article

PALEOECOLOGICAL APPRAISAL OF THE RAMTEK LAKE, NAGPUR DISTRICT, MAHARASHTRA, INDIA WITH SPECIAL EMPHASIS ON DIATOMS AND SEDIMENT GEOCHEMISTRY

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ABSTRACT
Sedimentary diatoms and geochemistry data recovered from the sediment core served as an important probe to investigate the paleoecological condition of the Ramtek Lake, Nagpur District, Maharashtra, India. The study of hydrochemistry and associated surface sediments of the lake revealed the recent ecological condition with the diatoms response. The geochemical contents like Calcium (Ca), Aluminum (Al), Potassium (K), phosphorous (P), Organic Matter (OM) etc. were used to investigate the anthropogenic influence throughout the sediment core (0 – 50cm length) representing Unit I (bottom) to Unit V (top). The overall trend of the sediment core of the Ramtek Lake signify the increased rate of soil erosion and enhanced nutrient concentrations in the recent units at the top owing to accelerated anthropogenic activities in the watershed and likely to be multiplied in coming years with severe modifications in the landscape patterns.

Keywords: *Paleoecology, Productivity, Diatoms, Geochemistry, Hydrochemistry, Ramtek Lake*

INTRODUCTION
The Ramtek town is situated about 58 km from at NE side of the Nagpur city and well connected to Nagpur by road (NH-7) and rail. The study area falls in the latitude 21°18'29" N and 21°23'56" and the longitude 79°21'26" E and 79°21'01" E. The Ramtek Lake (locally also called as the Mahar Lake) is small and about 500m in length and 300m in width with semicircular shape.
The continental water varies greatly due to variability of lithology, climate, vegetation and the mineral composition. The Anthropogenic activities have direct impact on the soil erosion, irrigation, impute of industrial material, municipal or agricultural waste into surface water bodies and often increase the mineral content (Mey and Helmer, 1989). Diatoms are the eukaryotic, unicellular algae which show the filamentous colonies and good indicator of environmental change (Dixit *et al.*, 1992) and classified under the division Chrysophyta (Round *et al.*, 1991). They are very sensitive to limnological variables such as nutrient concentration, pH, and conductivity etc. So, it can be used as a powerful tool of environmental change in aquatic ecosystem and often used to monitor changes in ionic content and composition (Mey and Helmer, 1989; Dixit *et al.*, 1992).
Physiography and Drainage: The study area in general is gently undulating plain with isolated positive landforms. Average elevation is about 300 m above Mean Sea Level (MSL). The area is extensively covered with soil and remains under thick cultivation. A few laterite exposures in the form of capping are also seen scattered in the area. Rock exposures are few and restricted only to nala cuttings and old workings. The area is drained by southerly flowing small nalas, which joins at the southern part of the area. There are two prominent canals, viz., the Ramtek canal originating from Khindsi Lake in the north and the other from the Sur River which passes through the eastern end of the area.
Review of previous work: Most of the rivers and Lakes in India are polluted due to human activity, chemical nutrients like phosphorus, nitrogen, and other industrial waste material. Gwalani *et al.,* (1988) have studies the environmental geology of the Nagpur and adjoining areas. Diatoms have been widely applicable to infer the past epilimnetic phosphorus concentration in Lake (Hall and Smol, 1992). Since last decade, most of the worker like Bennion *et al.,* (1995), Marchetto and Betlinetti (1995), Hall *et al.,* (1997), Rippey *et al.,* (1997), Lotter (1998), Alfers and Muller (1999) have worked on various aspects of

lake environment and verified the Total Phosphorus (TP) model and their inferences in the entire length of core. Humane *et al.,* (2009, 2010a) have studied the tropic status of the Lakes such as Phutala Lake and Ambazari Lake using sedimentary diatoms. Humane *et al.,* (2010b) have shown the circumneutral to alkaliphilous water condition of the Vena River based on the diatom studies. Rahul Mohan *et al.,* (2010) have studied the diatoms morphometry and elucidated their application to decipher the past climatic changes which deals with the paleoceanography. The present work is focused on the detailed investigation of a sediment core and surface (grab) sediments of the Ramtek Lake to divulge the past eutrophication trends and anthropogenic influence since past several decades.

Geological Setting and Lithology of A Sediment Core

Geologically, the Nagpur area has been represented by the rocks of the Archean age, the Lower Gondwanas, the Lametas, the Deccan Basalt associated with Intertrappeans and alluvium (Gwalani *et al.*, 1988; Deshpande, 1998). The Ramtek Lake is surrounded by the granitic gneiss with migmatite and granite of the Tirodi Gnessic Complex Group of the Archean to Paleoproterozoic age and quartzite and quartz muscovite schist of the Sausar Group of the Mesoproterozoic age (DRM, 2000; Figure 1; Table 1).

A collected sediment core was cut into two equal halves for the lithological and paleolimnological studies (Figure 2). These sections were further cut and subdivided into five units from top to bottom as given below.

(1) 0-10cm Top (Unit V): a) Colour- Grayish Black; b) Sorting- Fine; c) Grain size –fine; d) Fossils- Gastropod Shells; e) Others- Roots. (2) 10-20cm (Unit IV): a) Colour: dark Grayish Black; b) Sorting: Fine- Medium; c) Grain size –comparatively finer than MLC_3; d) Fossils- Gastropods Shells; e) Others- Roots. (3) 20-30cm (Unit III): a) Colour: Yellowish Brown; b) Sorting: Fine – Medium; c) Grain size: Medium- Coarse; d) Fossils- Absent; e) Others: Roots absent. (4) 30-40cm (Unit II): a) Colour: Reddish Brown; b) Sorting: Medium- Coarse; c) Grain size: Coarse; d) Fossils: Absent; e) Others: Roots absent. (5) 40-50 cm Bottom (Unit I): a) Colour: dark Reddish Brown; b) Sorting: Medium- Course; c) Grain size: Coarse; d) Fossils: Absent; e) Others: Roots absent.

MATERIALS AND METHODS

Methodology

A systematic sampling at the Ramtek Lake was done in the month of May, 2011 to collect the sediment samples (surface and core) along with water samples. The sample locations of the Ramtek Lake were as follows: 1) RMLG1 (Surface)**:** 21°23'14.86''N, 79°19'46.94''E; 2) RMLG2 (Surface): 21°23'14.57''N, 79°19'50.83''E; 3) RMLG3 (Surface): 21°23'14.38''N, 21°23'14.38''N; 4) RMLC (Core): 21°23'16.40''N, 79°19'49.04''E. The sample locations were noted using GPS (Garmin e-Trex Hx).

Water Sampling: The water samples were collected in the plastic bottles at the three different locations (RMLW1, RMLW2 and RMLW3). The conductivity and pH of the lake water were measured during the sampling. These samples were further sent to the laboratory for further hydro chemical analysis.

Water Analysis: The various elemental parameters of the water samples such as pH, Electrical conductivity, Alkalinity, Chloride, Calcium, Magnesium, Nitrogen, Iron, Total Phosphorous, Aluminum, and Manganese were measured using the equipment as given below: pH meter (model-101E), Digital Conductivity Meter (Model-601), UV-Visible Spectrophotometer (Make - Systronics, Model No.118) from the Water Quality Lab Level –II, Hydrology Project Division, Government of Maharashtra, Nagpur. Some of the parameters were analyzed by the titration methods.

Surface Sediment Sampling: The surface sediment samples were collected at the three different places from where water samples were collected and labeled as RMLG1, RMLG2 and RMLG3 respectively.

Core Sampling: The core sediments were collected with the help of 80cm long PVC pipe of 4” diameter. A 50cm long core was recovered from this lake (Figure 2) and sub sampled into five units and named as $RMLC_1$ to $RMLC_5$.

Geochemical Analysis: The sub sectioned sediment core samples were dried at 105^{o}C using the Hot Air Oven. The estimation of the Loss on Ignition (LOI) was done by burning the sediment samples at 450^{o}C for 5 hours and finally heated at 950°c for 2 hour in the furnace to measure the organic matter and carbonates respectively. The sediment samples were analyzed using K_2O, P_2O_5, Al_2O_3, MgO, CaO and SiO_2 by XRF spectrometry, Model: PW2403-MAGIX, Manufacture: PANlytical, Netherland from the Indian Bureau of Mines (IBM), Pilot Plant, Nagpur.

Maceration of Sediment Samples: The maceration of the sediments was done using the standard procedures given by Battarbee (1986).

Preparation of Diatom Slides: The macerated samples were used to prepare the diatom slides using the polyvinyl alcohol and the cover slips were mounted on the slides using the D.P.X. mounting medium. The identification and enumeration of the diatoms were done using Carl Zeiss Biological Microscope at 400x and 1000x magnification in the Apllied Micropaleontology Laboratory of the department.

RESULTS AND DISCUSSION

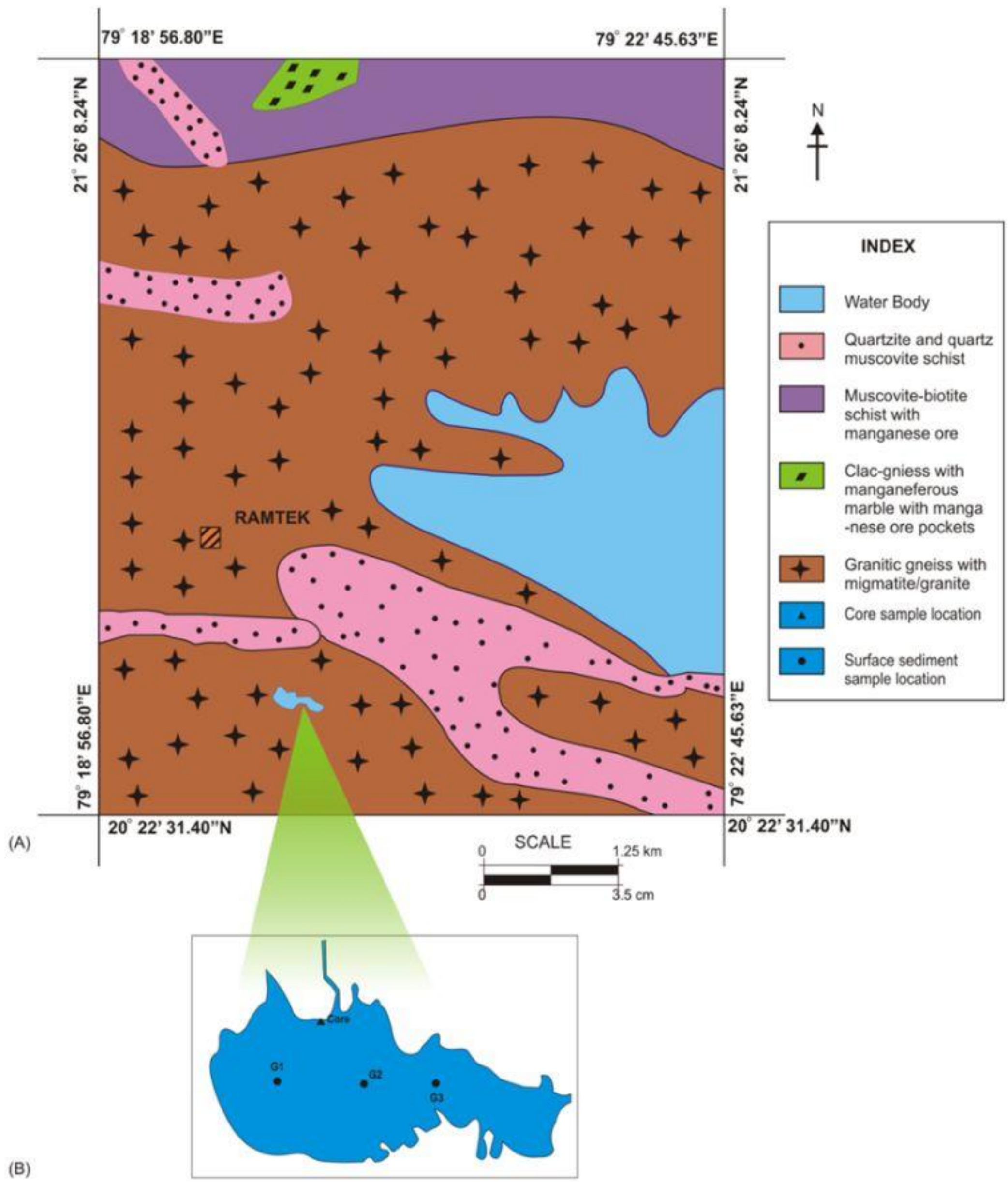

Figure 1: A. Geological map of the Ramtek Lake. B. Diagram of the Ramtek Lake showing sample location (Core and surface)

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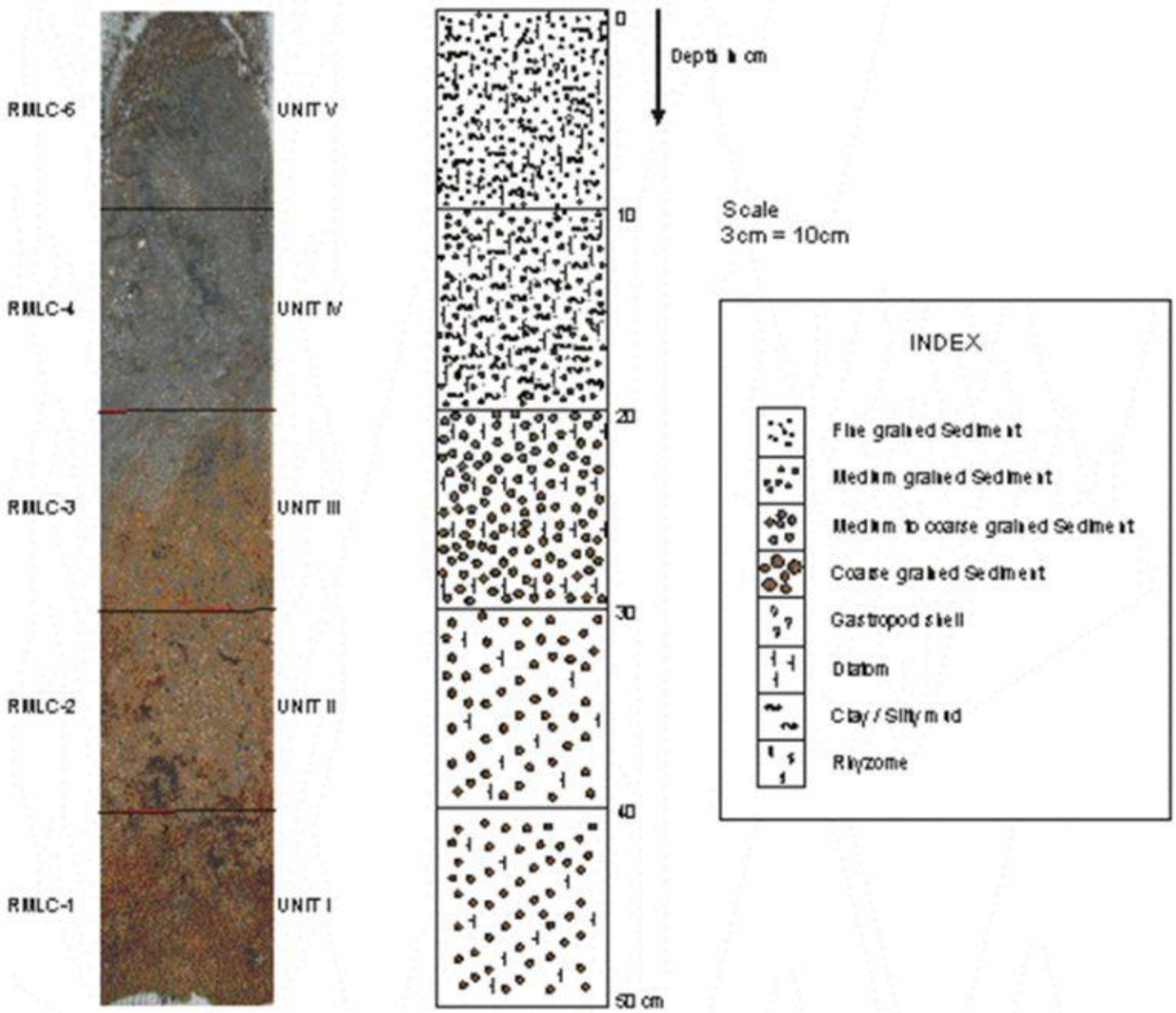

Figure 2: A sediment core Section of the Ramtek Lake with its Schematic diagram

Analyses of the Hydrochemistry: The results of the water analyses are shown in the Table 2. These results were compared with the standard values of the BIS (1991) and the common alkalinity and the common total phosphorous values of the Wisconsin Lakes (NLS, 2008; Tables 3, 4). The pH of the Ramtek Lake was 7.9, which falls in the desirable range of the BIS (1991).

The decomposition of organic matter and enhanced level of photosynthesis may be responsible for higher value of pH (Singh and Mahajan, 1987). This pH supports a typical range of the water quality for the healthy fish population (Robert *et al.*, 2004).

The Electrical conductivity (EC) was 967 µmhos /cm. The liberation of ions from the decomposed organic matter may be responsible for the higher value of the EC (Kumar *et al.,* 2008). The alkalinity of the lake water was 276 CaCO3 mg/l.

The high alkalinity may be solely due to presence of bicarbonates (Kumar *et al.,* 2008). The lake is rich in nutrition owing to > 100 mg/l alkalinity. The alkalinity value suggests presence of very hard water when compared with common alkalinity values of Wisconsin Lake (Table 3).

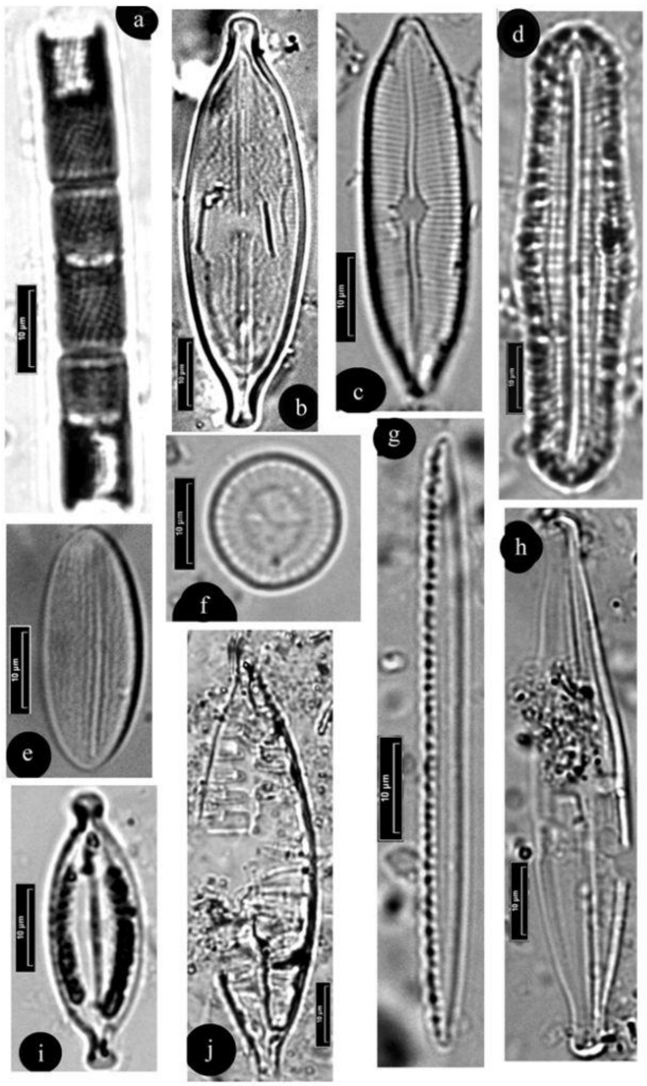

Figure 3

a) ***Aulacoseira granulata*** **($RMLC_3$)**
b) ***Anomoneis sphaerophora*** **($RMLG_3$)**
c) ***Neidium affine*** **($RMLG_3$)**
d) ***Rhopalodia gibba*** **($RMLC_4$)**
e) ***Cocconeis placentula*** **($RMLC_4$)**
f) ***Cyclotella ocellata*** **($RMLG_3$)**
g) ***Nitzschia dissipeta*** **($RMLC_3$)**
h) ***Stauroneis anceps*** **($RMLC_4$)**
i) ***Mastogloia braunii*** **($RMLG_3$)**
j) ***Surirella ovalis*** **($RMLC_2$)**

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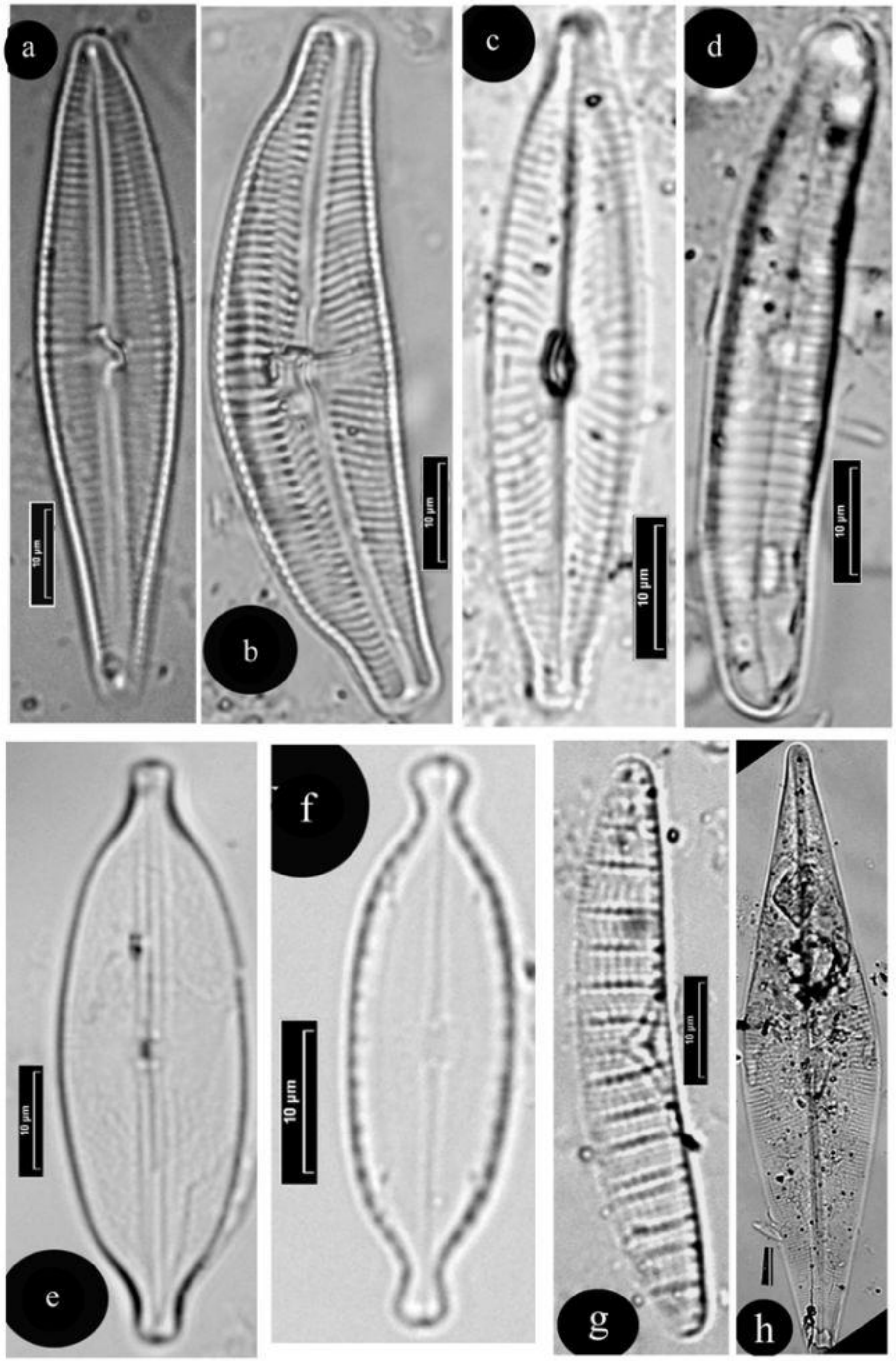

Figure 4

a) ***Gomphonema pseudoaugur*** **(RMLC$_1$)**
b) ***Cymbella tumida*** **(RMLC$_4$)**
c) ***Navicula viridula*** **(RMLC$_2$)**
d) ***Eunotia formica*** **(RMLC$_5$)**
e) ***Anomoeoneis sphaerophora*** **(RMLG$_2$)**
f) ***Aneumastus tusculus*** **(RMLG$_1$)**
g) ***Epithemia turgida*** **(RMLG2)**
h) ***Craticula cuspidata*** **((RMLC$_2$)**

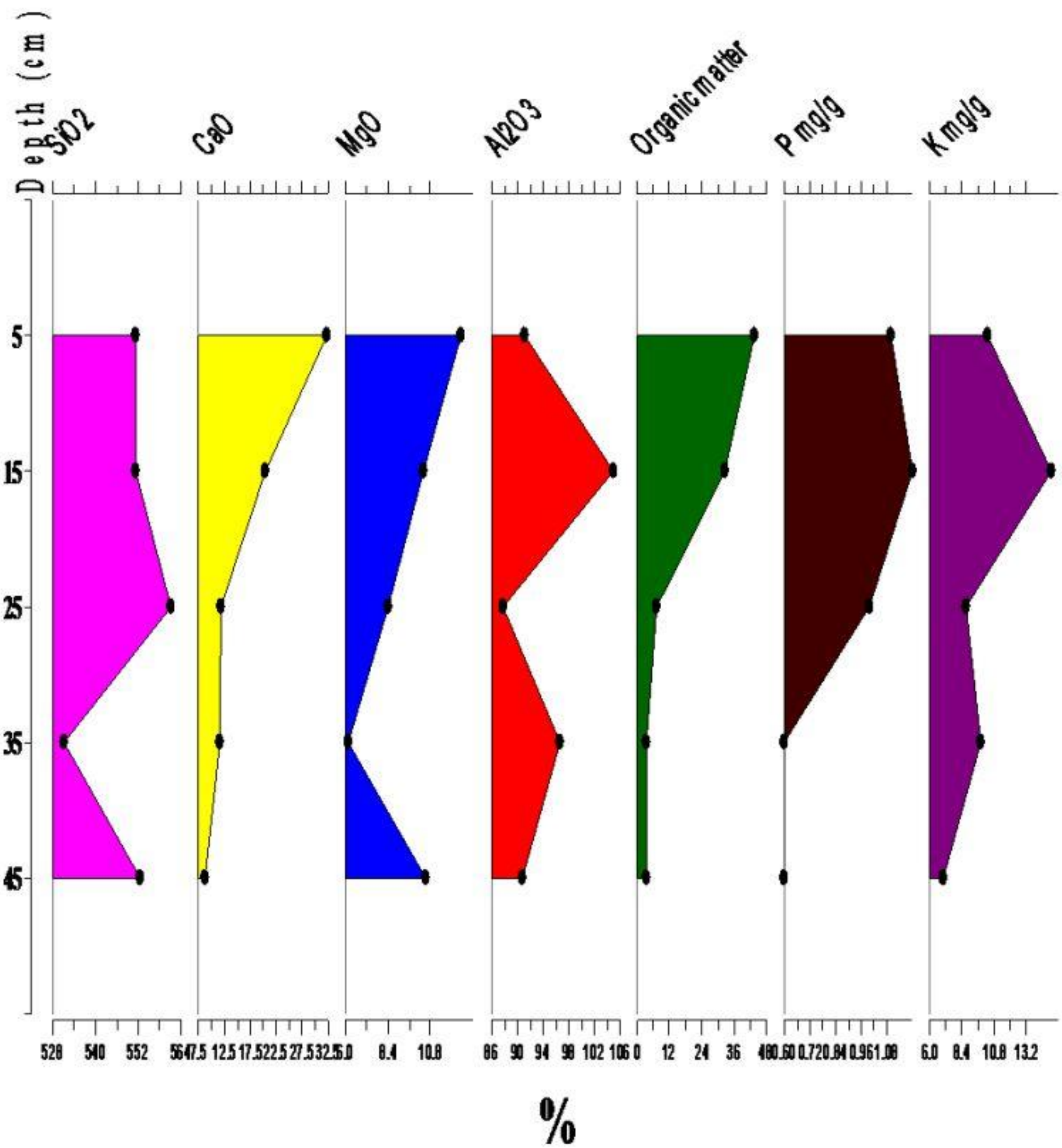

Figure 5: Profiles of (% and mg/g) distribution of selected geochemical elements in the Sediment core of the Ramtek Lake

The concentration of Chloride in water was 165 mg/L and falls under the desirable range of BIS (1991). The high concentration of chloride may be due to more house hold activities near lake. The concentration of calcium was 28.9 mg/l lower than the desirable range BIS (2003).

The value of magnesium was 41.8 mg/l which was slightly higher than the desirable value. The higher Mg might be added by the weathering of soil around the lake (Table 2).

The phosphorous and nitrate are very important nutrients for the growth of aquatic plant and algae. On the basis of BIS Standard Total Nitrogen content observed in the lake was 1.48 mg/L while iron goes slightly beyond the desirable limit which shows the value 0.38 mg/L.

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The total Phosphorus concentration is 0.124 mg/l. and indicates very poor water condition (WLS, 2008, Table 4) owing to excessive growth of algae and aquatic plants.

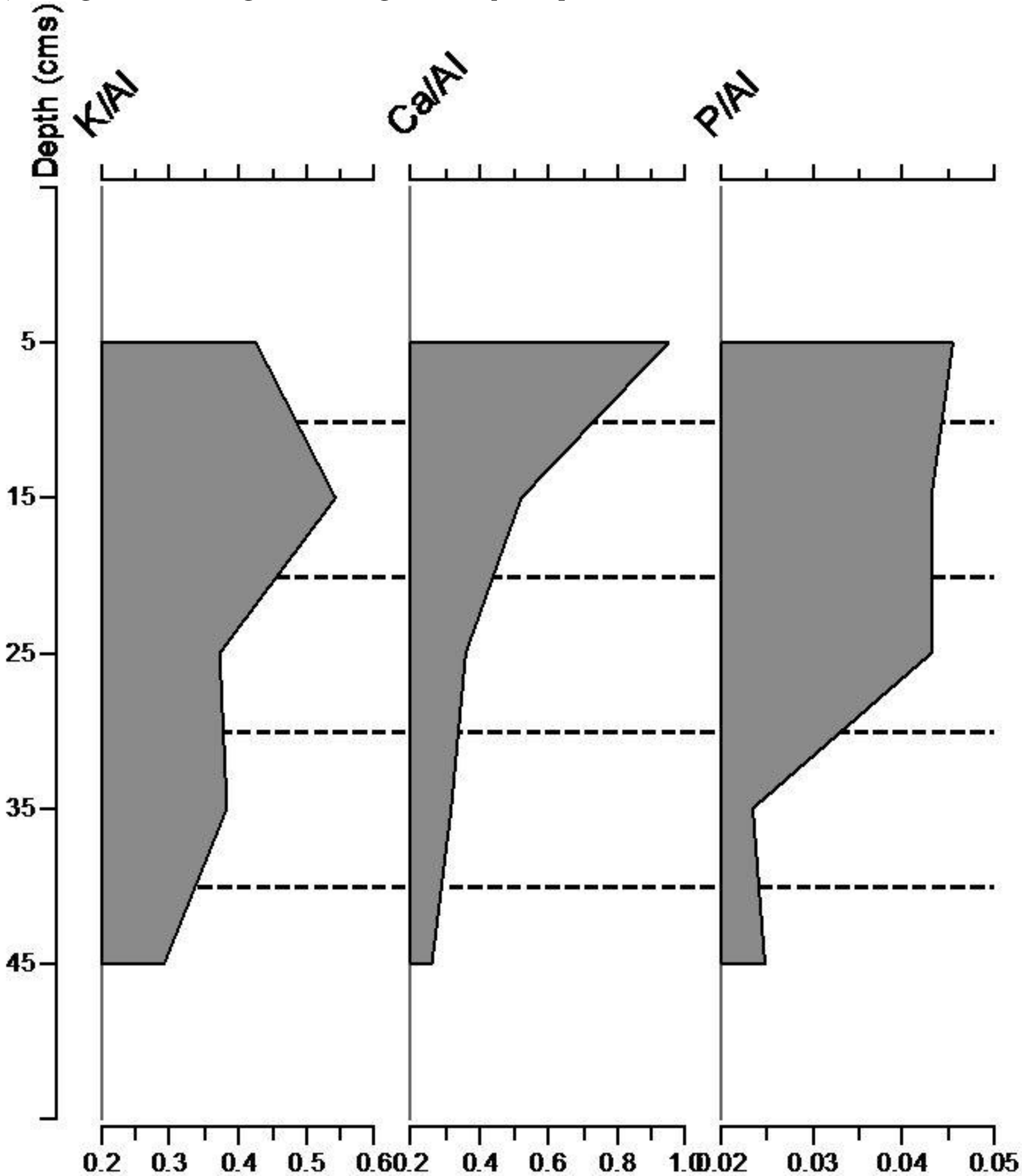

Figure 6: Profiles of ratios of selected geochemical elements in the Sediment core of the Ramtek Lake

The concentration of Aluminum was 0.08 mg/l which was slightly higher than the desirable range (BIS, 2003). The Al content is generally derived from weathering of adjacent soils. The silica content in the water was 0.46 mg/l. It may also be derived from weathering of soils in the watershed.

Analyses of surface Sediments: The average concentration of SiO_2 in the surface sediments (RML) was 531mg/g. The CaO content was 32.2 mg/g. The concentration of MgO in sample was 12.5mg/g, while, Al_2O_3 content was 91.2mg/g. The concentration of Phosphorous and Organic Matter was 0.01 mg/g and 43.9 mg/g respectively. The potassium content in the surface sediments of the lake was 4.1 mg/g (Table 5).

Analyses of Core Sediments: The analyses of the core sediments were carried out by XRF and wet chemical methods. Analytical results of geochemical studies of core sediments are shown in the Tables 5. The maximum concentration of SiO_2 was in RMLC- 3 (561.1 mg/g) and minimum in RMLC - 5 (531.0 mg/g). The CaO content ranges from 8.8mg/g (RMLC- 1) to 32.2 mg/g (RMLC- 5). The value of MgO was maximum at RMLC- 5 (12.5 mg/g) and minimum at RMLC - 2 (6.2 mg/g). The concentration of Al_2O_3 was less in RMLC - 3 (87.8 mg/g) and the maximum in RMLC- 4 (105 mg/g). The concentration of P was minimum in RMLC- 1(0.6 mg/g) and maximum in RMLC- 4 (1.2 mg/g). The quantity of Organic Matter was minimum in RMLC - 1 and RMLC- 2 (3.5 mg/g) and maximum in RMLC- 5 (43.9 mg/g). The value of Potassium (K) ranges from 7.0 mg/g (RMLC- 1) to 15.1 mg/g (RMLC-4) (Table 5). The impact of various watershed activities on the lake was estimated by studying the geochemical variables (Table 6). Aluminum (Al) and Titanium (Ti) are derived from detrital alumino-silicates present in soil (Garrison and Laliberte, 2010).

Table 1: Stratigraphic Succession of the Nagpur Region (DRM, 2000)

Quaternary **Cenozoic**	**Alluvium** **Laterite**		
Cretaceous To palaeogene	Sahyandri Group (Deccan Trap)	Karanja Formation	18 Simple flow of Basalt
		Chikhli Formation	6 Flow of Basalt (3 Simple and 3 Compound)
		Intertappean Bed.	
		Undiffrantiated Basalt.	
Cretaceous	Lameta Group	Conglomerate, Sandstone, shele. Limestone.	
Permian – Triassic	Gondwana Super Group	Kamthi Formation	Sandstone , Ferruginous Sandstone,
Carboniferous - Permian		Talchir Formation	Boulder Bed, Sandstone, shele.
Meso-proterozoic	SAUSAR GROUP	Granite, pegmatite.	
		Bichua Formation	Crystalline limestone , Dolomite. Granite, pegmatite.
		Junewani Formation	Muscovite-biotite- schist, Quartzite-Biotite-Granulite
		Charbaoli Formation	Quartzites and Quartz- Muscovite Schist.
		Mansar Formation	Muscovite-biotite- schist with manganese ore horizon,
		Lohangi Formation	Calc-Gneiss Manganiferous Marbles with Manganese Ore Pocket.
		Sitasaongi Formation	Quartz- Muscovite Schist, Feldspar- Muscovite Schist, and intercalated Quartzite.
	Silicified Zone of Quartz Reef.		
	SAKOLI GROUP	Meta Rhyolite, Tuff, Felsic Volcanics and associated Tuff	
		Mica Schist.	
		Phyllite , Carbonaceous Phyllite.	
		Turmalinite ,Cotical	
		Metabasalt with associated Tuff	
Archean to Paleozoic	AMGAON GNEISSIC COMPLEX.	Amphibolite	
		Ultramafic Rock.	
		Quartzite along with same amount of Kynite and sillliminite	
		Calc- Silicate Rock	
		Granitic Gneiss with Migmatite Gneisss	
	TIRODI GNEISSIC COMPLEX	Granite gneisses with Migmatite / Granite	

Therefore, the modification in Al content will reflect variation in the rate of soil erosion.
The synthetic fertilizers and soil particles do contain Potassium (K). Hence, the addition of K in the lake watershed either from synthetic fertilizers or from soil erosion will be clearly distinguished in its profile. The plant growth particularly algae and aquatic plants, is being control by the nutrients like phosphorus and nitrogen contents (Garrison and Lalibert, 2010). The organic matter content in the profile of the lake core indicates the general lake productivity (Garrison and Lalibert, 2007).
The vertical profile of the sediment core of the Ramtek Lake clearly shows three distinct zones in the entire five units. The concentration of Potassium (K) in Unit I (depth 40-50cm) of a sediment core is lowest and increased in the Unit II (depth 30-40cm) and decreased in the Unit III (depth 20-30 cm) indicating rise in the soil erosion in the Unit II and further fall in erosion in the Unit III. Further top in the Unit IV, the soil erosion drastically increased with some fall in the topmost Unit V (Figure 5). The concentration of Phosphorus (P) was very important nutrient for the growth of aquatic plants. The concentration of sedimentary Phosphorus in Units I and II remains very low, whereas it shows continuous rise through Units III and IV with little decline at the top in the Unit V (Figure 5). Thus, the Units III, IV and V shows moderate to poor water quality of the lake. The organic matter (O.M.) content was also very high in the Units III, IV and V indicating increased lake productivity. Thus, the nutrient like P was closely associated with the Organic matter.

Table 2: Analysis of Water sample of the Ramtek Lake for various parameters (all units mg/l except pH, EC (μmhos/cm) and Alkalinity (mg CaCO3/l)

Parameters	pH	EC	Alkalinity	Cl	Ca	Mg	Si	Fe	TP	Al	Mn	Nitrate
Mean values	7.9	967	276	165	28.9	41.8	0.46	0.38	0.124	0.08	N.D.	1.48

Table 3: Common alkalinity value of Wisconsin Lakes (National Lake Survey, 2008)

Soft	0-60 mg/L
Moderately hard	61-120 mg/L
Hard	121-180 mg/L
Very hard	>180 mg/L

Table 4: Common total phosphorous values of Wisconsin Lakes (National Lake Survey, 2008)

Good	< 0.020 mg/L
Fair	0.020-0.050 mg/L
Poor	0.050-0.150 mg/g
Very Poor	0.150 mg/L

Table 5: Elemental composition of the core sediments of the Ramtek Lake

Sample code	SiO_2 mg/g	CaO mg/g	MgO mg/g	Al_2O_3 mg/g	P mg/g	O.M mg/g	K mg/g
MLC_1	552.6	08.8	10.5	90.7	0.6	03.5	07.0
MLC_2	531.3	11.6	06.2	96.7	0.6	03.5	09.8
MLC_3	561.1	11.8	08.4	87.8	01.0	07.2	08.7
MLC_4	551.1	20.4	10.4	105.0	01.2	32.7	15.1
MLC_5	551.1	32.2	12.5	91.2	01.1	43.9	10.3
$MLG_{(Grab)}$	531	32.2	12.5	91.2	0.01	43.9	4.1

Table 6: Showing selected chemical indicators of watershed or in lake processes (Garrison, 2005; 2006; 2008)

Process	Chemical Variable
Soil erosion	Aluminum, potassium, titanium
Synthetic fertilizer	Potassium
Urban	Zinc, copper
Ore smelting	Zinc, cadmium, copper
Nutrients	Phosphorous, nitrogen
Lake productivity	Organic matter

Table 7: The Checklist of diatom species from the surface sediments of the Ramtek Lake

SN	Name of the Species	Slide No.	SN	Name of the Species	Slide No.
01	*Amphora ovalis*	$RMLG_1$	20	*Gomphonema affine*	$RMLG_{1, 2, 3}$
02	*Anomoneis sphaerophora*	$RMLG_{1, 2, 3}$	21	*G. clevei*	$RMLG_3$
03	*Aneumastus tusculus*	RMG_1	22	*G. parvulum*	$RMLG_2$
04	*Aulacoseira granulata*	$RMLG_{1, 3}$	23	*G. pumilum*	$RMLG_{1, 3}$
05	*Caloneis ventricosa*	$RMLG_1$	24	*G. augur*	$RMLG_{1, 3}$
06	*Caloneis* sp.	$RMLG_1$	25	*G. undulatum*	$RMLG_{1, 3}$
07	*Cocconeis placentula*	$RMLG_3$	26	*G.* sp.	$RMLG_2$
08	*Craticula cuspidata*	$RMLG_1$	27	*Mastogloia elliptica*	$RMLG_1$
09	*Cyclotella ocellata*	$RMLG_3$	28	*M. smithii*	$RMLG_1$
10	*C. striata*	$RMLG_3$	29	*M. braunii*	$RMLG_{2, 3}$
11	*Cymbella tumida*	$RMLG_3$	30	*Navicula viridula*	$RMLG_{1, 3}$
12	*Cymbella* sp.	$RMLG_{1, 2}$	31	*Navicula* sp.	$RMLG_1$
13	*Diadesmis confervacea*	$RMLG_2$	32	*Nitschia palea*	$RMLG_2$
14	*Encyonema minutum*	$RMLG_2$	33	*Nitzschia* sp.	$RMLG_3$
15	*Epithemis adnata*	$RMLG_{1, 3}$	34	*Pinnularia subcapitata*	$RMLG_{1, 2, 3}$
16	*E. turgida*	$RMLG_{1, 2}$	35	*P. gibba*	$RMLG_{1, 3}$
17	*Eunotia pectinalis*	$RMLG_{2, 3}$	36	*Eunotia bilunaris*	$RMLG_1$
18	*E. minor*	$RMLG_2$	37	*Rhopaloidea gibba*	$RMLG_1$
19	*Eunotia* sp.	$RMLG_1$	-	-	-

Table 8: The Checklist of diatom species from the sediment core of the Ramtek Lake

SN	Name of the Species	Slide No.	SN	Name of the Species	Slide No.
01	*Achnanthidium binodis*	$RMLC_2$	34	*G. intricatum*	$RMLC_4$
02	*Achnanthidium* sp.	$RMLC_3$	35	*G. pumilum*	$RMLC_4$
03	*Amphora ovalis*	$RMLC_{1, 2,5}$	36	*G. augur*	$RMLC_{3, 5}$
04	*A. libyca*	$RMLC_{1, 2}$	37	*G. undulatum*	$RMLC_{3, 5}$
05	*A. veneta*	$RMLC_1$	38	*Gyrosigma kutzingii*	$RMLC_5$
06	*A. australienesis*	$RMLC_2$	39	*Mastogloia baltica*	$RMLC_{1, 2}$
07	*Aneumastis tusculus*	$RMLC_4$	40	*M. smithii*	$RMLC_{1, 3, 5}$
08	*Anomoneis sphaerophora*	$RMLC_{1, 2, 3}$	41	*M. braunii*	$RMLC_{3, 5}$
09	*Aulacoseira granulata*	$RMLC_{2, 3, 4}$	42	*Navicula cincta*	$RMLC_{1,}$
10	*Brachysira serians*	$RMLC_2$	43	*N. lanceolata*	$RMLC_{1,}$
11	*Cocconeis placentula*	$RMLC_4$	44	*N. viridula*	$RMLC_{2, 5}$
12	*Craticula cuspidata*	$RMLC_2$	45	*N. radiosa*	$RMLC_3$
13	*Cyclotella meneghiniana*	$RMLC_{1,}$	46	*N. cryptocephala*	$RMLC_5$

14	*C. ocellata*	RMLC1	47	*Navicula* sp.	RMLC$_{5}$
15	*C. atomus*	RMLC$_{2}$	48	*Neidium productum*	RMLC$_{1,}$
16	*C. striata*	RMLC$_{4}$	49	*N. affine*	RMLC$_{4,5}$
17	*C. helvetica*	RMLC$_{5}$	50	*Nitschia palea*	RMLC$_{2, 3, 4, 5}$
18	*Encyonema minutum*	RMLC$_{2, 3}$	51	*N. microcephala*	RMLC$_{5}$
19	*E. silesiacum*	RMLC$_{3}$	52	*N. denticula*	RMLC$_{5}$
20	*E. gracile*	RMLC$_{3}$	53	*N. dissipeta*	RMLC$_{3}$
21	*Epithemis adnata*	RMLC$_{1, 4}$	54	*Pinnularia viridis*	RMLC$_{2,5}$
22	*Eunotia pectinalis*	RMLC$_{1, 4, 5}$	55	*P. gibba*	RMLC$_{5}$
23	*E. minor*	RMLC$_{1, 2,4}$	56	*Pinnularia borealis*	RMLC$_{4}$
24	*E. formica*	RMLC$_{2, 3, 4, 5}$	57	*Pinnularia* sp.	RMLC$_{5}$
25	*E. mondon*	RMLC$_{4, 5}$	58	*Planothodium delicatum*	RMLC$_{3}$
26	*E. incisa*	RMLC$_{3}$	59	*Rhopaloidea gibba*	RMLC$_{1, 4, 5}$
27	*Eunotia* sp.	RMLC$_{5}$	60	*Sellaphora pupila*	RMLC$_{5}$
28	*Frustulia* sp.	RMLC$_{3}$	61	*Stauroneis anceps*	RMLC$_{4}$
29	*Gomphonema affine*	RMLC$_{1, 3, 4}$	62	*Stauroneis* sp.	RMLC$_{3}$
30	*G. gracile*	RMLC$_{1, 5}$	63	*Surirrela ovalis*	RMLC$_{2}$
31	*G. pseudoaugur*	RMLC$_{1,}$	64	*Synedra ulna*	RMLC$_{5}$
32	*G. parvulum*	RMLC$_{5}$	65	*Tryblionella victoriae*	RMLC$_{2, 5}$
33	*G. angustum*	RMLC$_{3,4}$	-	-	-

Table 9: Showing Diatoms inferred trophic status in various units of the Ramtek Lake (Hall *et al.*, 1992, 1996; Little *et al.*, 2000)

Unit	Most Common diatoms species	Diatom inferred trophic status.
Grab (Topmost)	*Gomphonema affine*	Cl- 1.39 m eq/l
	Epithemia turgida	TP-11.0 µg/l
Unit –V	*Gomphonema augur*	pH-6.9, Tp-18 µg/l,
	Gomphonema gracile	Cl-113 µeq/l
Unit –IV	*Gomphonema affine*	Cl- 1.39 m eq/l
	Rhopaloidea gibba	TP-11.0 µ g/l
	Gomphonema affine	Cl-1.39 meq/l
Unit –III	*Gomphonema angustum*	TP-8.6 µg/l
Unit –II	*Amphora ovalis*	pH-8.0, TP- 22 µg/l,
	Cyclotella atomus	Cl-118 µeq/l
	Encyonema minutum	
Unit -I	*Anomoneis sphaerophora*	pH-8.3, TP- 66 µg/,
	Cyclotella meneghianiana	Cl-1113 µeq/l

The concentration of Calcium (Ca) has been progressively increased from the lower unit I to the top most Unit V (Figure 5). The Ca profile clearly reflects the accelerated rate of soil erosion on the top of the core as compare to the lower units. The Mg profile also supports the above observations. The Si concentrations in the Unit I was 552.6 mg/g and slightly decreased in the Unit II indicating little decline in soil erosion. Its concentration was increased in the Unit III with small decline further in the Units IV and V. The concentration of aluminum (Al) in the Unit I was 90 mg/g with further rise in the Unit II and reached to its highest in the Unit IV (Figure 5). The increased concentrations of Al in these units indicate the accelerated rate of the soil erosion. The profile of the organic matter shows gradual increase in the productivity of the lake (Figure 5). The highest productivity of the lake was observed in the units IV and V. The selected geochemical elements were normalized to aluminum (Al) to discern anthropogenic inputs apart from the mineral sediments (Garrison and Laliberte, 2010; Figure 6). This analysis helps to determine trends that impact the lake apart from the input of soil from the watershed. The ratio of

CaO/Al_2O_3 shows the progressive increase indicating gradual rise in the rate of soil erosion from the lower units to the top (Figure 6). Thus, the calcium in the sediment core was mostly derived from the adjoining soils. The K/Al ratio similar values pointing the equal contribution of K as a source from the surrounding soils and the synthetic fertilizers (Figure 6). While, in the remaining units the K content was mostly derived from synthetic fertilizers used in the adjoining agricultural lands. The P/Al ratio was highest in the units III, IV and V (Figure 6). The P was derived from the soil particles in these units and suggests the increased rate of soil erosion.

Diatom Study: The morphological study of the sedimentary diatoms of the Ramtek Lake shows presence of 37 species belonging to 20 genera from the surface sediments and 65 species belonging to 28 genera from the sediment core. The diatoms are classified based on their frustules form and sculpture (Mann, 1999). The diatoms are mostly categorized into two types i.e. Centric and Pennate (Mann, 1999). The Check list of the diatoms discovered from core and surface sediments of the Ramtek Lake is given in the Tables 7 and 8.

Diatoms inferred trophic status: The most abundant species found in Unit I is *Anomoneis sphaerophora* and *Cyclotella meneghianiana*. The presence of these diatom species indicate the alkaline nature of the lake water in the unit I with pH value of 8.3, total phosphorous value of nearly 66 µg/l and Cl content 1113µ eq / l and meso to eutrophic status of lake. The Unit II was represented by the abundance of *Amphora ovalis, Cyclotella atomus and Encyonema minutum* (Dixit *et al.,* 1999). The presence of *Amphora ovalis* suggest the pH value of 8, TP value of 22 µ g/l and Cl value of 118 µ eq/l of the lake water during the Unit II. On the basis of diatom inferred trophic status of the Unit II, it can be interpreted that during this period the water quality was in between circumneutral to alkaline with the eutrophic status. The unit III was represented by the abundance of *Gomphonema affine* and *Gomphonema angustum,* which suggest the pH more than 7with TP of 8.6 µg/l and Cl would be 1390 µ eq/l (Hall and Smol, 1996). Thus, the overall quality of lake water of the Unit III was alkaline and oligotrophic suggesting nutrient deficient to optimum nutrient condition. In the unit IV, the most abundant diatom species were *Gomphonema affine* and *Rhopalodia gibba* having pH value more than 7 and TP of 11.0 µg/l suggesting alkaline, polytrophic nature of the lake water. The unit V shows abundance of *Gomphonema augur* and *Gomphonema gracile* with DI TP of pH value of 6.9, TP of about 18 µ eq/l and Cl of 113 µ eq/l. The DI TP indicates circumneutral eutrophic status of water. Whereas, the top most part of the unit V was represented by the surface sediments. It shows abundance of *Gomphonema affine* and *Epithemia turgida* which occurs at pH > 7 i.e. alkaline water with eutrophic status of the lake water.

Conclusion

The calcium concentrations shows gradual increase from the Unit I to highest in the topmost Unit V indicating periods of maximum soil amendments around the Ramtek Lake in the recent times. The Aluminum content shows three peaks in the Units I, II and IV pointing enhanced soil erosion. The Potassium concentration has increased from the Unit I and II with little fall in the Unit III and the top Unit V and its maximum peak in the Unit IV suggesting increased rate of the soil erosion associated with the addition of commercial fertilizers in the watershed. The gradual increase in the Phosphorous content from the Unit I to Unit V signify eutrophication in the recent time possibly due to excessive use of inorganic fertilizers in agricultural land around lake. Similarly, Organic Matter (OM) content also shows progressive increase from the bottom Unit I to the top Unit V suggests enhanced productivity of the lake. The productivity was highest in the recent time due to myriad human activities in the watershed particularly excessive use of fertilizers. The Diatom Inferred (DI) trophic status shows that the lake waters of the Unit I (RLC1) was alkaline, partially mesotrophic (poor in phosphorous status) and moderately hard. The Unit II (RLC2) indicates slightly alkaline, mesotrophic (fair in phosphorous status) to eutrophic and moderately hard waters. The Unit III (RLC3) points slightly alkaline, oligotrophic (poor in phosphorous status) and moderately hard waters. The Unit-IV (RLC4) indicates slightly alkaline, eutrophic (good in phosphorous status) to polytrophic staus and moderately hard waters. The diatom inferred trophic status of the topmost Unit-V (RLC5) indicates circumneutral to alkaline, eutrophic (good in phosphorous status), moderately hard waters of the lake water whereas the surface sediments shows eutrophic status in the recent times. Thus, the overall trend of the sediment core of the Ramtek Lake signify the increased rate of soil erosion and enhanced nutrient concentrations in the recent units at the top owing to accelerated anthropogenic activities in the watershed and likely to be multiplied in coming years with severe modifications in the landscape patterns.

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Repository

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

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