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Paleo-alluvial deposit of Nag River at Mahalgaon, Nagpur District, Maharashtra: significance of sediment chemistry anddiatoms

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ABSTRACT

Assessment of paleo-alluvial deposit of Nag River at Mahalgaon area of the Nagpur district was undertaken based on the study of sediment chemistry and dominant diatom assemblages. The aim of the present investigation was to analyze the major and trace oxide contents for the understanding of the changes in the sediment and trace metal accumulation patterns during the different periods. The historical profiles for SiO_2, MgO, Al_2O_3, Fe_2O_3 and $TiO_2$of the section MS-A and MS-B show a gradual increasing trend from bottom to top indicating the progressive rise in weathering and erosion of adjoining soils and lithology in the catchment area of the Nag River. The organic matter and carbonate content profiles also indicate cyclic variations in the flooding/high rainfall and low rainfall /dry period in the study area.The diatom inferred water quality also suggests cyclic changes in the trophic status of the Nag River at the MahalgaonSections. The increased diversity of various species of *Nitzschia*at the Mahalgaon Sections implies the high level of organic pollution in the Nag River since the last several decades.

KEYWORDS: Paleo-alluvial sediments, organic matter, diatoms, Mahalgaon

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INTRODUCTION:

Water is very important for the survival of life on the earth. However, growing industrialization and urbanization have created the perturbanceand started polluting many freshwater bodies like lakes and rivers. These water bodies are mainly impacted by the anthropogenic activities such as industrial waste, excessive use of in-organic fertilizers like phosphates, nitratesetc. The past epilimnetic phosphorous concentration in lakes had been studied on the basis of the inference models using diatoms[1]. The record of thepastwater quality is inferred based on the diatomsas they remain preserved in the natural archives like lakes, alluvial deposits, flood plains etc.Moreover, diatoms are very sensitive to these environmental transformations. Therefore, they have been widely used worldwide to assess the pollution in the lakes and rivers. Diatomsare usedto evaluate the past and present water quality and environmental conditions[2]. The freshwater diatoms have been used to study the historical developments of water bodiesdivulging the effect of changing acidity and climate on it[3,4]including the pollution caused by the anthropogenic impact. Diatoms have also been used as an indicator for the reconstruction of the past and present ecological status due to their responsiveness to limnological parameters like nutrient concentrations, pH, conductivity and their excellent sustenance in fossil deposits[5].The unknown historical records can be reconstructed using paleolimnological techniques especially using diatoms as bio-indicators of aquatic transformations[6,7,8.9]. Various workers have effectively employed diatoms to appraise water quality patterns developed because of acidificationand eutrophication of lakes, concentrations of dissolved organic carbon (DOC), salinitylinked with climatic changes[10,11,12]. Attempts have also been made in central Indian lakes to establish the relationship of diatoms with water quality Changes[13, 14,15,16,17]in addition to the few lakes of southern India[18].

The Nag River carries huge sediment load during monsoon seasons, which deposits along its flanks every year developing the thick paleo-alluvial deposits. The present work has mainly dealt with the investigation of the paleo-alluvial sediments(deposits) of the Nag River formed at Mahalgaon of the Nagpur district to infer the extent of anthropogenic impact based on sediment chemistry and to reconstruct the diatom inferred past water quality status.

Study area description:

The present study area lies on the outskirts at about 20km of the Nagpur city of the Maharashtra state near Mahalgaonvillage on National Highway number 6 and falls under the toposheet number 55 O/4[19].This area is connected well with the developed road and accessible by the local and government transport (Fig. 1). The paleo-alluvial sediments studied at two sections along Nag-River at Mahalgaon, Nagpur District are shown in the figure 1. The sample locations of the alluvial sediment-sections, MS-A is Latitude: N 21^{o}8' 15",Longitude: E 79^{o}12' 45" and MS-B Latitude:N 21^{o}8' 15", Longitude: E 79^{o}12' 15". A systematic sampling was done before pre monsoon season by collecting sediment samples (sediment-section) from the Mahalgaon area along Nag-River in May 2014 (Fig.3a, 3b).

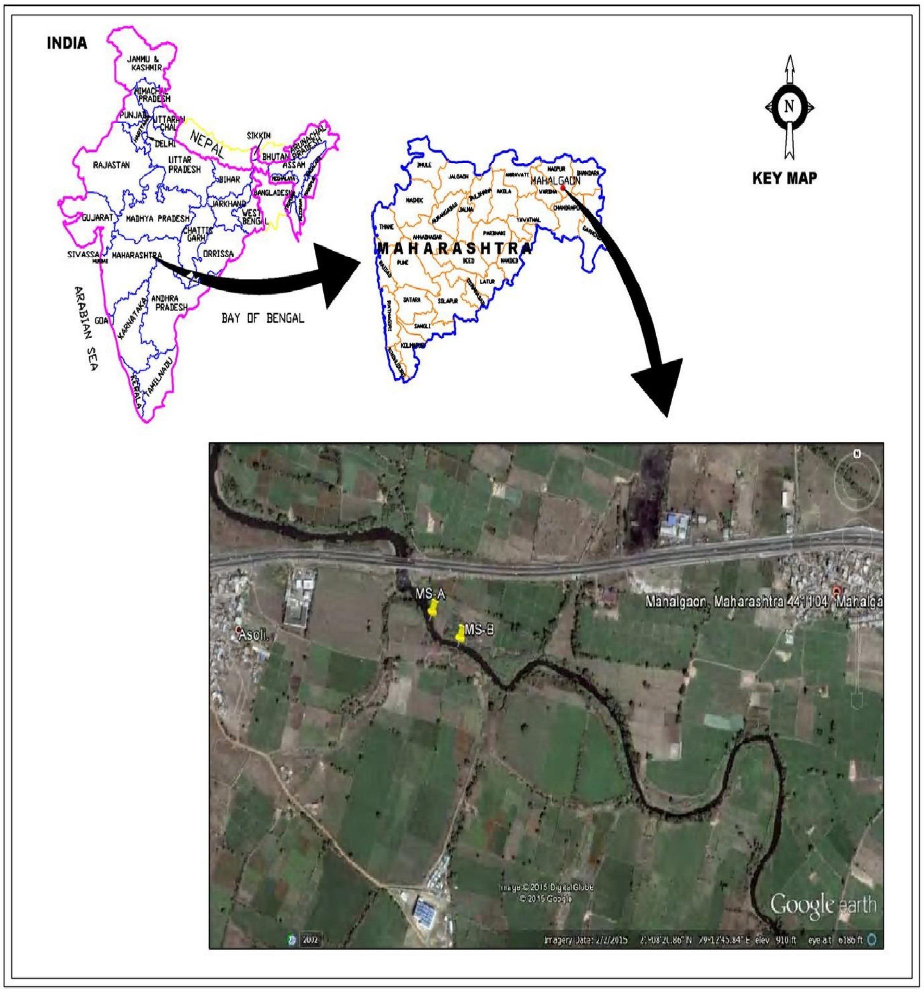

Fig. 1: Location map of the Sediment-sections(Pins) along Nag-River at Mahalgaon

Geology of the study area

The Nagpur district is geologically comprised of the rocks belonging to the theArcheans, the Lametas and the intertrappean beds associated with Deccan Traps. The Archeans of this district are represented by metamorphic and crystalline rocks and are often hidden beneath a considerable thickness of alluvium and soil deposited by the tributaries of the Kanhan and Wainganga Rivers[20]. Geologically, the study area is mainly composed of the Granitic Gneisses with Migmatiteof the Tirodi Gneissic Complex Groupbelonging to theArcheanandPalaeo Proterozoic age (Fig. 2; Table 1). These rocks are covered with the thick layers of the alluvium belonging to the Quaternary age.

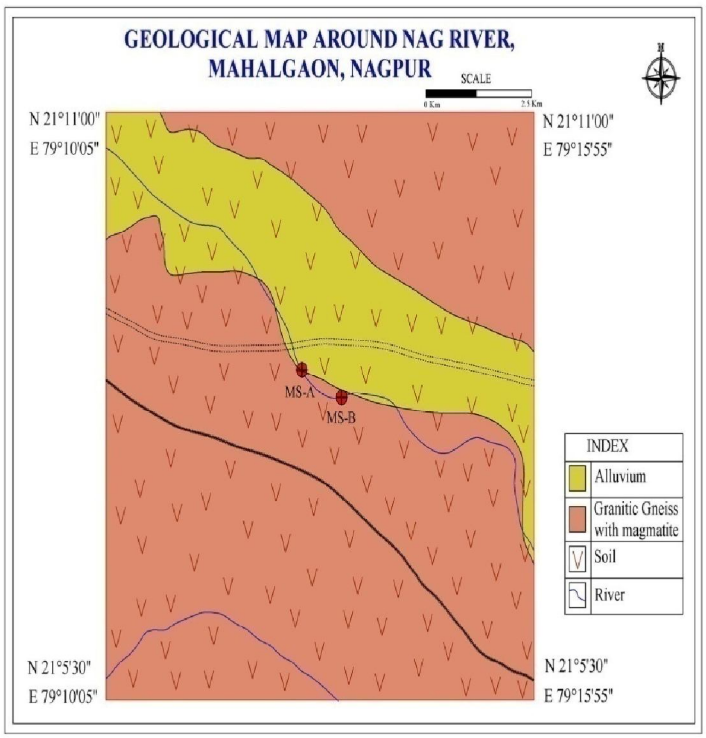

Fig. 2: Geological Map around the Nag-River Mahalgaon, Nagpur (DRM, 2000)

Table 1: Geology around the of Mahalgaon area(DRM, 2000)

Lithology	Formation	Age
Alluvium	Recent	Quaternary
Granitic Gneisses with Migmatite	Tirodi Gneissic Complex	Archean or Palaeo Proterozoic
Granitic Gneisses with Migmatite	Tirodi Gneissic Complex	Archean or Palaeo Proterozoic

MATERIAL AND METHODS

Sediment sampling from paleo-alluvial sections

The completely well preserved paleo-alluvial sections along the Nag River of the Mahalgaon area of the Nagpur district ware selected for the sampling in the present work. The paleo-alluvial sediment sections were collected in the sample bags from the bottom to top at the interval of ten centimetres each and proper labelling was done. The two sediment sections in the Mahalgaon area along the Nag-River were selected and named as the Mahalgaon Section A (MS-A) andthe Mahalgaon Section B(MS-B). The 10 samples of representing 10 centimetre interval each were collected from the 100cm long MS-A section (Fig. 3a).The second section i.e. MS-B was 210cm long (Fig. 3b). Total 21 sediment samples with the interval of the 10cm each were collected. The following numbering was given to the subsections of the section **MS-A:MS-A-1, MS-A-2, - - - - , MS-A-10** and for the section **MS-B:MS-B-1, MS-B-2, - - - - , MS-B-21**.

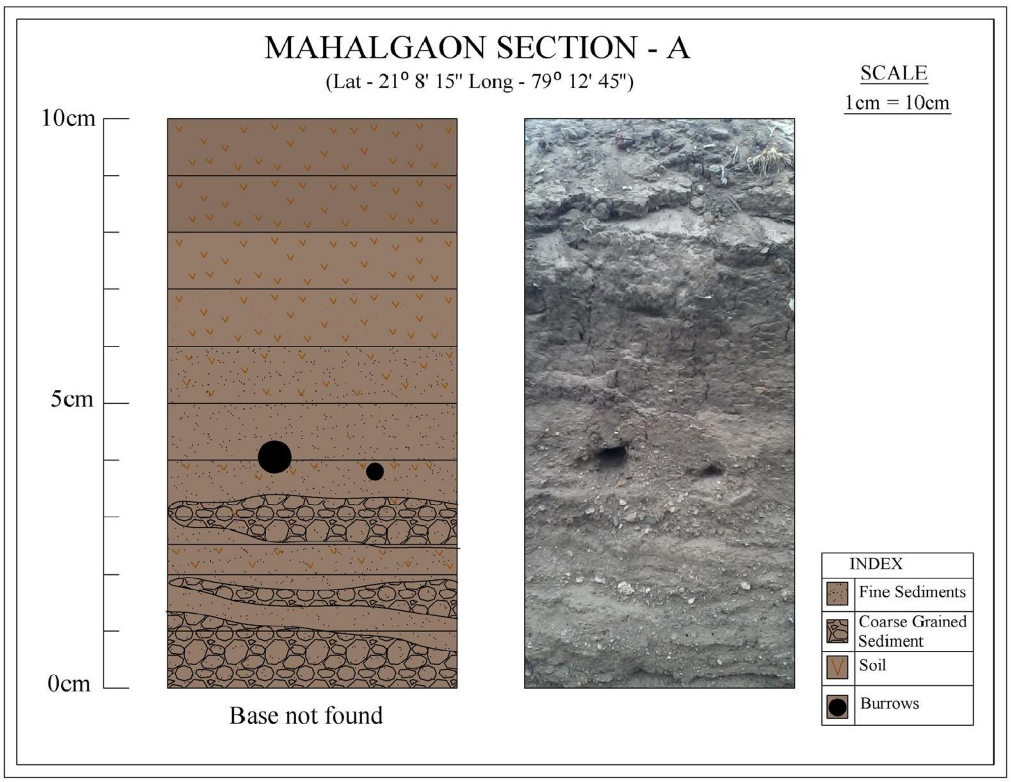

Fig.3 Sediment profile (MS-A) along the Nag-River at Mahalgaon, Nagpur

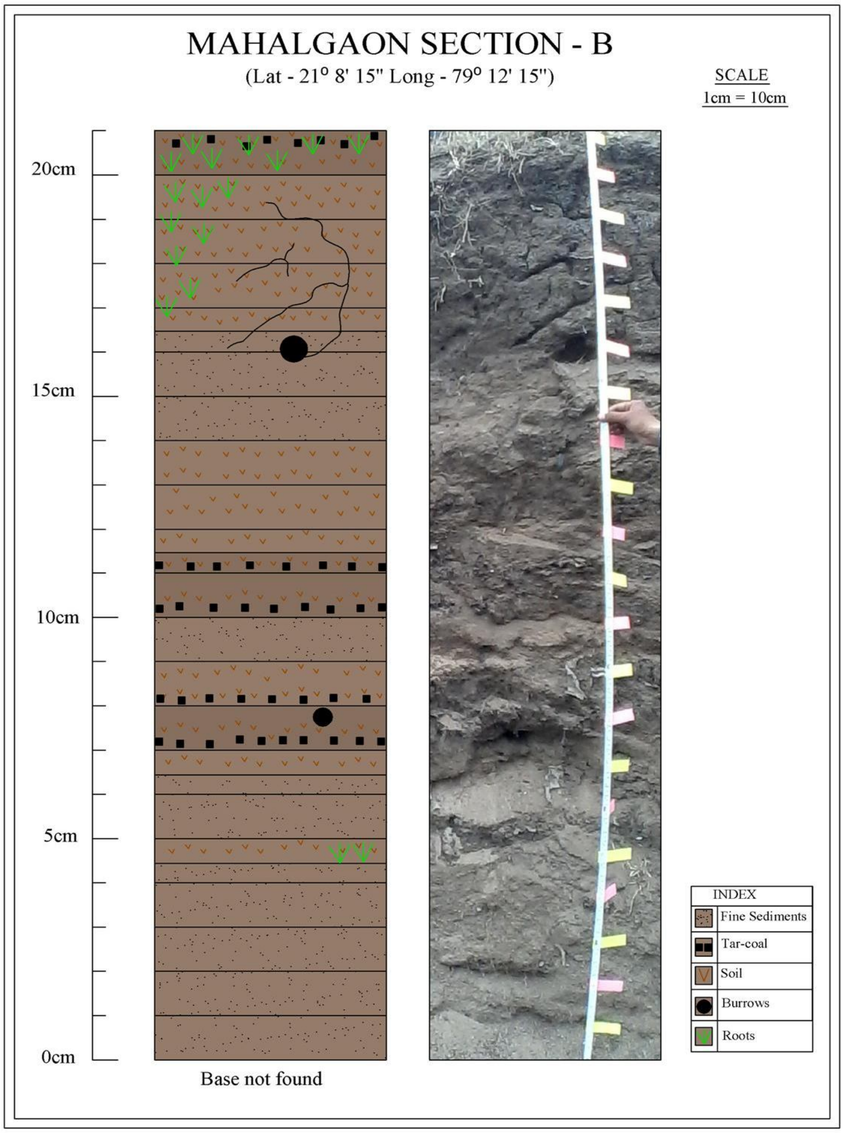

Fig. 3b: Sediment profile (MS-B) along the Nag-River at Mahalgaon, Nagpur

Laboratory analysis

The collected sediment samples were first dried in the oven at 110°C to measure the water content. These dried samples weresubsequently crushed and sieved to remove the rock fragments and shells pieces from the sediments. After the crushing, the samples were sieved for about 150 mesh size. This mesh size was selected as these mesh size particles provide more surface area for chemical reaction which is necessary for appropriateoutcome. The powdered samples were packed in the small zip-lock pockets and marked with the proper identification number and sent for further analysis.

Maceration of sediment samplesand preparation of diatom slides

The conning and quartering of allthe samples were done initially.About 5 gm of sediment sample representing each subsection were taken into the separate beaker. About 5 ml of HCl (10%) was added into each beakerto remove carbonate content and poured distilled water to wash the solution. This procedure was repeated 3 to 4 times at 4 hours intervals till effervescences seizes. Subsequently, about 10 ml of H_2O_2(Hydrogenperoxide; 30%) was added into the each beaker to remove the organic material. These samples were boiled for 5 minutes to expedite the process of dissolution. The acidified samples were repeatedly washed with the distilled water till all the traces were removed[21].

The slides were prepared using these macerated samplesto study diatoms and other siliceous forms.01-02 drops of polyvinyl alcohol were addedonto the slides.Put 01 drop of macerated sample on each cover slip and spread it gently by needle and allowed it to dry. The dried cover slips were gently released on the slides where drops of polyvinyl alcohol were already added. These mounted slides were further observed under the microscope at 600X to 1000X followed by the identification and microphotgraphy[21].

Geochemicalanalysis

The methods used in chemical analysis are as follows-

The determination of weight percent of the organic matter and carbonate content in sedimentsamples was done by the process of Loss on Ignition(LOI), which is based on the sequential heating of sediment samples using muffle furnace[22]. The estimation of the LOI of dried samples (110^{o}C) was done by weighing the samples in silica crucibles. In first step, the samples were heated at 530^{o}C for 5 hours to remove the organic matter. The organic matter was combusted to ash and carbon dioxide in the first step. The weight of silica crucibles filled with samples was noted down. In the second step, the crucibles filled with samples were heated at 950^{o}C for 2 hours. In this step carbon dioxide was evolved from carbonate, leaving oxide. After the second step, the crucibles were again weighted and measured the weight loss and finally the LOI was calculated[23].

These samples are kept in small zip-lock packet and properly labelled with appropriate number for the identification using the permanent marker pen. These samples were sent to the analytical laboratory of the Indian Bureau of Mines (IBM), Pilot Plant, Nagpurfor the X-Ray Fluorescence (XRF) analysis. The XRF analysis was done using the Model- PW2403-MAGIX and Manufacturer-PANlytical (Netherland).

RESULTS

The results of the geochemical analysis are presented in the figures 4a, b; 5a, b and Tables 2a and 2b.

Sediment Chemistry of MS-A Section

The mean concentrations of CuO, Fe_2O_3, MnO, ZnO and MgOwas 0.027 %, 10.33 %, 0.24%, 0.02% and 0.24%, respectively (Fig. 4a; Table 2a). The minimum and maximum concentrations of P_2O_5 were 0.46 % (MS-A-10) and 0.56 % (MS-A-7), respectively. The Na_2O concentration was 0.88 %. The TiO_2 concentration shows variation from 1.81 % to 2.31 % (Fig. 4a). The value of Al_2O_3 ranges from 12.79 % to 14.7%. The silica content varies from 42.99 % (MS-A-1) to 47.72 % (MS-A-10). The K_2O concentration was 1.25 %. The CaO concentration varies from minimum 5.67 % (MS-A-10) and maximum 10.56 % (MS-A-1). The concentration of NiO,Rb_2O and BaO was 0.01 %, 0.0057 % and 0.0275 %, respectively.The SiO_2 shows highest concentration in the entire profile with mean value of 40.50% (Fig. 4a). The trace elemental concentrations of MS-A was meager with decline in concentrations of RB_2O Y_2O_3 and ZnO at 80 cm depth (Fig. 4b). Similarly, CuO,Cr_2O_3 and BaO content remained uniform up to 40cm depth and subsequently declined at the top (Fig. 4b).

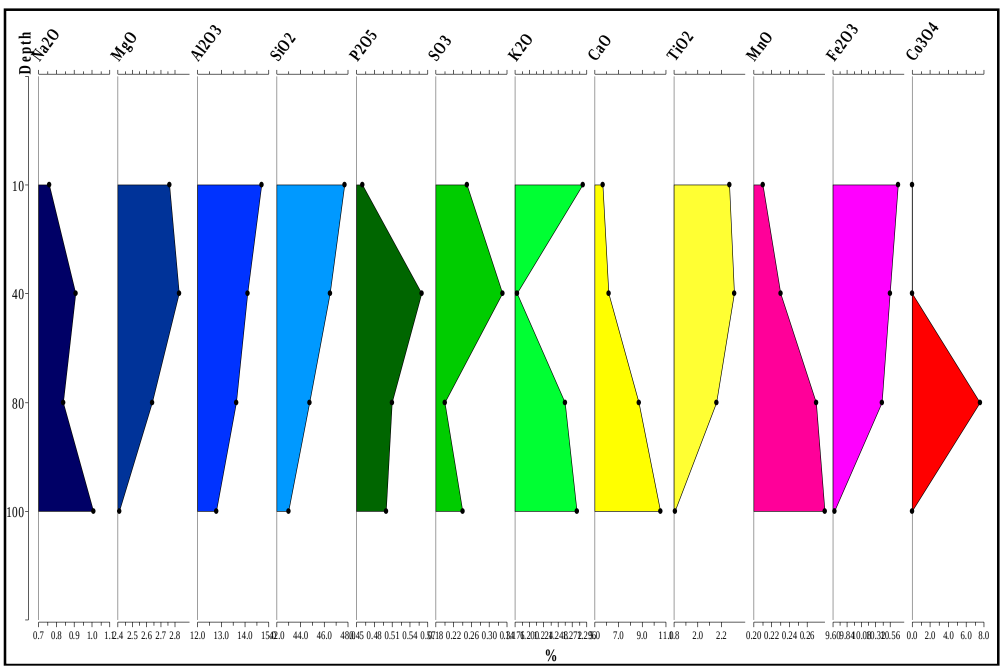

Fig. 4a: Profiles showing distribution of geochemical elements in section MS-A

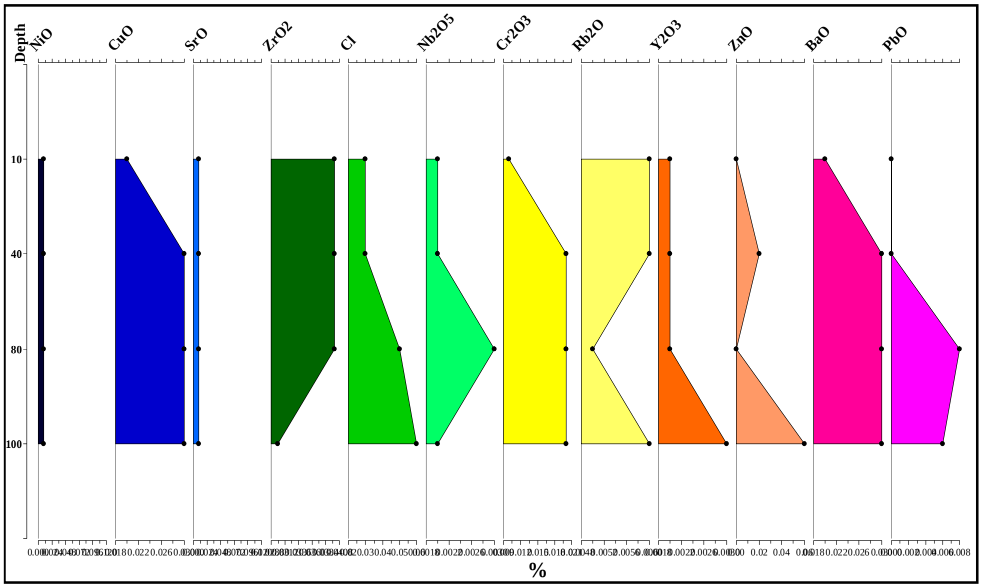

Fig. 4b: Profiles showing distribution of geochemical elements in section MS-A

Table 2a) Result of XRF analysis of MS-A

Sample no.	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3	Co_3O_4
	%	%	%	%	%	%	%	%	%	%	%	%
MS-A-1	1.01	2.41	12.79	42.99	0.5	0.24	1.28	10.56	1.81	0.28	9.63	0.01
MS-A-3	0.84	2.64	13.63	44.78	0.51	0.2	1.26	8.74	2.16	0.27	10.43	7.57
MS-A-7	0.91	2.83	14.12	46.52	0.56	0.33	1.18	6.2	2.31	0.23	10.56	0.009
MS-A-10	0.76	2.76	14.7	47.72	0.46	0.25	1.29	5.67	2.27	0.21	10.7	0.01
MEAN	0.88	2.66	13.81	45.5025	0.5075	0.255	1.2525	7.7925	2.1375	0.2475	10.33	1.89975

Sample no.	NiO	CuO	SrO	ZrO_2	Cl	Nb_2O_5	Cr_2O_3	Rb_2O	Y_2O_3	ZnO	BaO	PbO
	%	%	%	%	%	%	%	%	%	%	%	%
MS-A-1	0.01	0.03	0.01	0.03	0.06	0.002	0.02	0.006	0.003	0.06	0.03	0.006
MS-A-3	0.01	0.03	0.01	0.04	0.05	0.003	0.02	0.005	0.002	-	0.03	0.008
MS-A-7	0.01	0.03	0.01	0.04	0.03	0.002	0.02	0.006	0.002	0.02	0.03	-
MS-A-10	0.01	0.02	0.01	0.04	0.03	0.002	0.01	0.006	0.002	-	0.02	-
MEAN	0.01	0.0275	0.01	0.0375	0.0425	0.00225	0.0175	0.00575	0.00225	0.02	0.0275	0.0035

Sediment Chemistry of MS-B Section

The mean concentration of CuO, Fe_2O_3, MnO, ZnO and MgO is found to be 0.0283 %, 9.62%, 0.3 %, 0.01% and 2.40%, respectively (Fig. 5a; Table 2b). The minimum and maximum concentration of P_2O_5 was 0.26 % (MS-B-2) and 0.67% (MS-B-8). The Na_2O concentration is 0.71%. The TiO_2 concentration shows variation from 0.81% (MS-B-2) to 2.06 % (MS-B-20). The value of Al_2O_3 ranges from 6.22% (MS-B-2) to 14.51% (MS-B-10). The silica concentration varies from 23.43 % (MS-B-2) to 45.76 % (MS-B-20). The K_2O concentration is 1.95 %. The CaO concentration varies from minimum 6.63 % (MS-B-20) and maximum 34.81 % (MS-B-2; Fig. 5a). The SiO_2 content ranges from 23.43% to 45.76 % with an average value of 41.02 %. The concentration of NiO, Rb_2O and BaO was 0.0133 %, 0.0055 % and 0.033%, respectively (Fig. 5b).The NiO content was low at 50-110cm depth on the contrary to Rb_2O content (Fig. 5b). The CuO and ZrO_2concentration show more or less uniform values throughout the section (Fig. 5b).

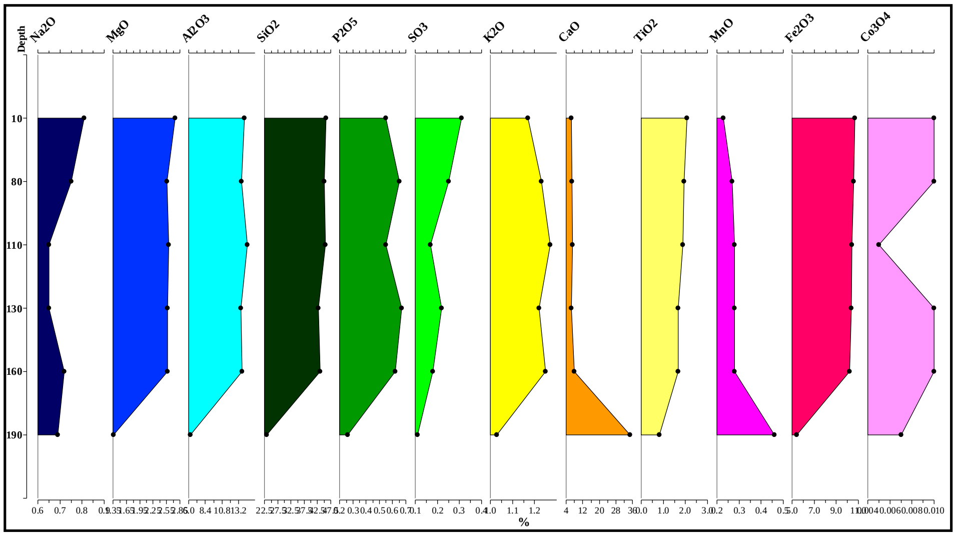

Fig. 5a: Profiles showing distribution of geochemical elements in section MS-B

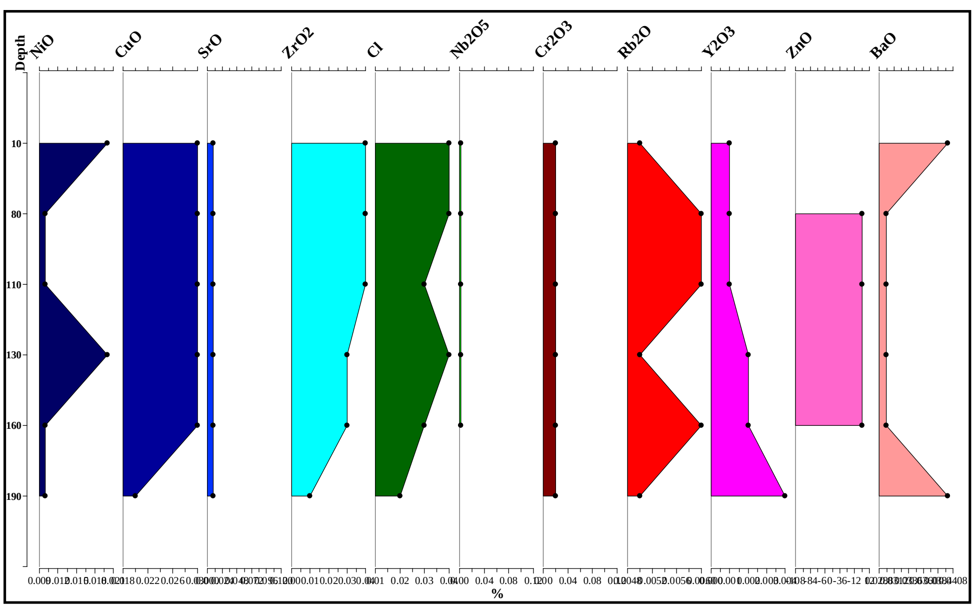

Fig. 5b: Profiles showing distribution of geochemical elements in section MS-B

Table 2 b) Result of XRF analysis of MS-B

Sample no.	Na_2O %	MgO %	Al_2O_3 %	SiO_2 %	P_2O_5 %	SO_3 %	K_2O %	CaO %	TiO_2 %	MnO %	Fe_2O_3 %	Co_3O_4 %
MS-B-2	0.69	1.36	6.22	23.43	0.26	0.11	1.03	34.81	0.81	0.46	5.43	0.007
MS-B-5	0.72	2.57	13.76	43.56	0.62	0.18	1.25	8.01	1.67	0.28	10.23	0.01
MS-B-8	0.65	2.57	13.55	42.82	0.67	0.22	1.22	6.63	1.67	0.28	10.37	0.01
MS-B-10	0.65	2.6	14.51	45.51	0.55	0.17	1.27	7.15	1.88	0.28	10.44	0.005
MS-B-13	0.75	2.56	13.63	45.06	0.65	0.25	1.23	6.97	1.93	0.27	10.59	0.01
MS-B-20	0.81	2.75	14.06	45.76	0.55	0.31	1.17	6.63	2.06	0.23	10.68	0.01
MEAN	0.71167	2.40167	12.6217	41.0233	0.55	0.20667	1.195	11.7	1.67	0.3	9.62333	0.00867

Sample no.	NiO %	CuO %	SrO %	ZrO_2 %	Cl %	Nb_2O_5 %	Cr_2O_3 %	Rb_2O %	Y_2O_3 %	ZnO %	BaO %	PbO %
MS-B-2	0.01	0.02	0.01	0.01	0.02	-	0.02	0.005	0.004	-	0.04	-
MS-B-5	0.01	0.03	0.01	0.03	0.03	0.002	0.02	0.006	0.002	0.01	0.03	-
MS-B-8	0.02	0.03	0.01	0.03	0.04	0.002	0.02	0.005	0.002	-	0.03	0.006
MS-B-10	0.01	0.03	0.01	0.04	0.03	0.002	0.02	0.006	0.001	0.03	0.03	-
MS-B-13	0.01	0.03	0.01	0.04	0.04	0.002	0.02	0.006	0.001	0.02	0.03	-
MS-B-20	0.02	0.03	0.01	0.04	0.04	0.002	0.02	0.005	0.001	-	0.04	-
MEAN	0.01333	0.02833	0.01	0.03167	0.03333	0.00167	0.02	0.0055	0.00183	0.01	0.03333	0.001

Diatoms study

The diatom analysis of the paleo-sediment samples from MS-A section reveals the presence of total 38 species of diatoms belonging to 17 genera out of which five species are centric and rest are pennate (Table 3a), whereas the MS-B section divulged the occurrence of 45 species belonging to 20 genera out of which 4 species are centric and rest are pennate (Table 3b). Both the sections contain noticeable concentrations of phytoliths, algal cysts and spicules (Tables 3a, b).

Table 3a: Diatom species abundance in sediment-section MS-A

Diatom species	No. ofOccurrences	% Abundance
Achnanthidium minutissimum	10	2.164502165
Aulacoseiraambiqua	1	0.216450216
Aulacoseira granulata	1	0.216450216
Achnanthidium sp.	1	0.216450216
Amphora holastica	7	1.515151515
Cocconeis placentula	2	0.432900433
Craticulacuspidate	1	0.216450216
Cyclotella ocellata	44	9.523809524
Cyclotellastraiata	1	0.216450216
Cymbellatumida	1	0.216450216
Diadesmisconfervacea	2	0.432900433
Discotellastelligera	3	0.649350649
Gomphonemalanceolatum	1	0.216450216
Gomphonema parvulum	2	0.432900433
Gomphonema sp.	1	0.216450216
Naviculacari	3	0.649350649
Naviculacryptotenella	2	0.432900433
Navicula sp.	1	0.216450216
Nitzschiaacicularia	2	0.432900433
Nitzschiacapitellata	149	32.25108225
Nitzschiafiliformis	1	0.216450216
Nitzschiafonticola	6	1.298701299
Nitzschiamicrocephala	7	1.515151515
Nitzschiapalea	23	4.978354978
Nitzschiapaleacea	61	13.2034632
Nitzschia sp.	3	0.649350649
Pinnulariaappendiculata	2	0.432900433
Pinnularia gibba	1	0.216450216
Pinnularia sp.	1	0.216450216
Planothidiumdelicate	1	0.216450216
*Psammothidium*sp.	1	0.216450216
Pleurosigma sigmoid	1	0.216450216
Synedra ulna	9	1.948051948
Tryblionella apiculata	1	0.216450216
Tryblionellahungerica	14	3.03030303
Algal cysts	42	9.090909091
Phytoliths	2	0.432900433
Spicules	1	0.216450216

TOTAL	462	100

Table 3b Diatom species abundance in sediment-section MS-B

Diatom species	No. of Occurrences	% Abundance
Achnanthidium minutissimum	18	2.627737226
Achnanthidium sp.	3	0.437956204
Amphora holsatica	4	0.583941606
Cocconeis placentula	4	0.583941606
Cyclotella meneghiniana	1	0.145985401
Cyclotella ocellata	68	9.927007299
Cyclotella sp.	1	0.145985401
Cymbella sp.	1	0.145985401
Cymbellatumida	2	0.291970803
Diadesmisconfervacea	1	0.145985401
Discotellastelligera	5	0.729927007
Encyonema minutum	1	0.145985401
Encyonemasilesiacum	2	0.291970803
*Eunotia*sp. (girdle view)	1	0.145985401
Fallaciaarticulata	1	0.145985401
Gomphonemalanceolatum	1	0.145985401
Gomphonema parvulum	14	2.04379562
Gomphonema sp.	5	0.729927007
Hantzschia amphioxys	1	0.145985401
Hantzschiavirgata	2	0.291970803
Mastogloia sp.	1	0.145985401
Naviculacari	3	0.437956204
Naviculacryptotenella	3	0.437956204
Navicula radiosa	2	0.291970803
Navicula sp.	4	0.583941606
Neidiumproductum	1	0.145985401
Nitzschiaacicularia	1	0.145985401
Nitzschia amphibian	6	0.875912409
Nitzschiaangustata	118	17.22627737
Nitzschiacapitellata	157	22.91970803
Nitzschiadenticulate	1	0.145985401
Nitzschiafiliformis	8	1.167883212
Nitzschiamicrocephala	6	0.875912409
Nitzschiaobtuse	1	0.145985401
Nitzschiapalea	17	2.481751825
Nitzschiapaleacea	10	1.459854015
Nitzschia sp.	2	0.291970803

Pinnulariaappendiculata	8	1.167883212
Pinnularia gibba	4	0.583941606
Pinnularia subcapitata	1	0.145985401
Psammothidiumoblongellum	2	0.291970803
Sellaphora pupila	1	0.145985401
Synedra ulna	24	3.503649635
Tryblionellahungerica	46	6.715328467
Tryblionella sp.	1	0.145985401
Algal cysts	92	13.43065693
Phytoliths	29	4.233576642
TOTAL	685	100

DISCUSSION

The sediment samples from MS-A and MS-B sections were analyzed for the major and traceelemental (oxide) contents to know the changes in the sediment and trace metal accumulation patterns since the historical past. The historical profiles for MgO, Al_2O_3, SiO_2, Fe_2O_3 and TiO_2 show a gradual increasing trend from bottom to top indicating the progressive rise in weathering and erosion of adjoining soils and lithology in the catchment area of the Nag River of the section MS-A and MS-B (Fig. 4a and 5a). The vertical profiles of Na_2O, CaO and MnO shows a decliningpattern in the section MS-A (Fig. 4a) whereas the profile of Na_2O reflects a fluctuating trend. Similarly, the profiles of CaO and MnO show a diminishing trend in section MS-B (Fig. 4b). The MnO profile in the MS-A indicates the possibility of the existing of the reducing environment in the Nag River at Mahalgaon since last few decades till recent time[23]. The profile of P_2O_5 and SO_3 shows nearly same pattern with respect to each other during the course of deposition of these sediments in sections MS-A and MS-B. The profile of MnO and SO_3 shows slight declining concentration of these elements from ~100 - 80 cm and increased at ~ 79 – 40 cm. The MnO and SO_3 content again showed a declining trend from ~39 – 0 cm (top) in section MS-A (Fig. 4a). However, the MnO and SO_3content shows slight increase in their concentrationsat ~ 190 - 130 cms, which was subsequently declined at ~ 130 – 110 cm and again rise at ~ 109 – 0 cm (top) in section MS-B (Fig. 5a). These variations in the P_2O_5 and SO_3 profile can be attributed to the use of synthetic fertilizers in the adjoining watershed and their subsequent deposition from the surface runoff to river followed by into the sediments. The historical profiles of trace elements(oxides) such as NiO, CuO, SrO, ZrO_2, Cl, Nb_2O_5, Cr_2O_3, Rb_2O, Y_2O_3, ZnO and BaO do not show any significant change in the entire sections (Fig. 5b).

The organic matter and carbonate profile of MS-A section represents three major cycles of changes viz. i) at ~100 – 80 cm exhibiting nearly constant supply of organic matter but decreasing carbonate content points moderate rainfall and moderate erosion during that time. ii) ~79 – 50 cm shows constant supply of organic matter with the increased carbonate content indicates declining rate of erosion which in turn reflects dry period[24] and iii) ~49-0 cm depth shows increased content of organic matter and carbonate content suggesting high productivity and high rainfall (Fig. 6a).On the other hand, the organic matter and carbonate profile of MS-B section represents one major and three minor cycles of changes from a depth at ~ 200 to 100 cm followed by nearly constant trend from ~100 to 40 cm and again rise in their content at ~ 40 to 10 cm.The Nag River may have brought the excessive carbonate during the high rainfall period. The four peaks of organic matter and carbonate content at the depth of ~ 200 to 100 cm indicate increased productivity and more constant supply of nutrients/ organic matter. From ~ 99 to 40 cms,the three minor periods of high rainfall are observed, which was followed by the period of moderate rainfall/dry season from. The depth range ~39 - 0 cm (top) represents increased rainfall and increased organic matter content(Fig. 6b).

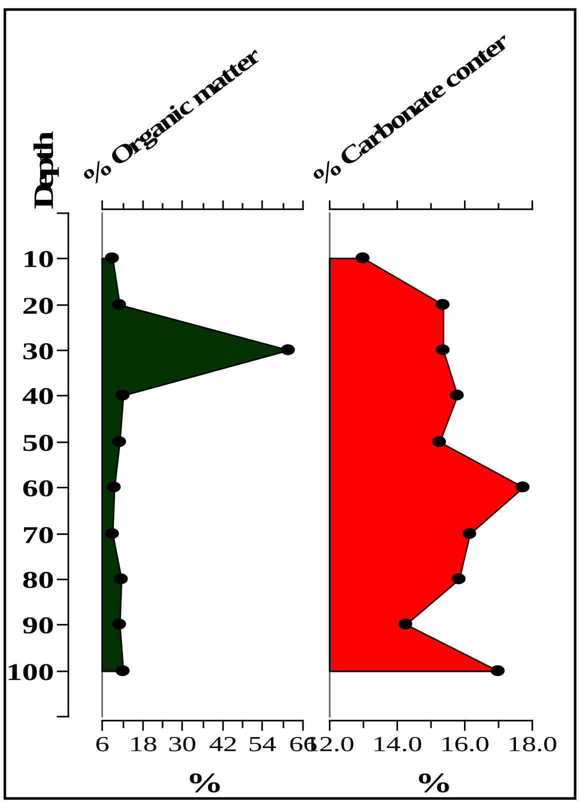

Fig. 6a Vertical profile of organic matter and Carbonate content in MS-A

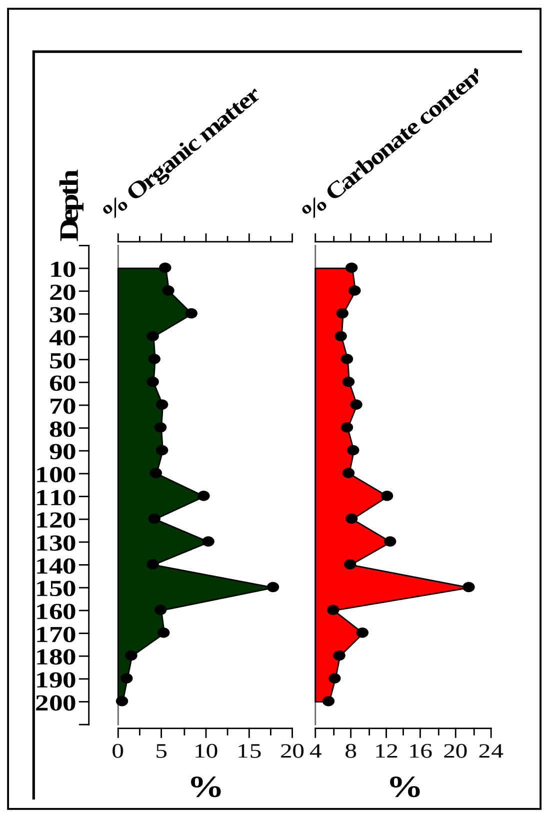

Fig. 6b Vertical profile of organic matter and Carbonate content in MS-B

The surface water quality of the Nag River and its relationship with the abundant diatoms were followed from Dahat[25] to interpret diatom inferred water quality status of the paleo-alluvial deposits at Mahalgaon(Tables 4a, b; 5a, b).Both the paleo-alluvial sediment sections at Mahalgaon overall very distinctly depicts the dominance of *Nitzschiacapitellata* (32%);*Nitzschiaangustata* (17%) and*Cyclotella* *ocellata* (10%) can be used to know their diatom inferred past water quality status and supports the water quality parameter studied by Dahat[25] (Tables 4a,b; 5a,b).

Table 4a: Physicochemical parameters of Nag River (NGS-2) with dominant diatom species (Dahat[25])

Most abundant diatom species	Physiochemical parameters							
	Alklalinity mgCaCo$_3$/l	Ca mg/l	Mg mg/l	Cl mg/l	SO_4 mg/l	P mg/l	Na mg/l	K mg/l
Nitzschiaangustata								
Nitzschiacapitellata	308	50.5	20.4	71	18.4	0.04	54.6	0.5

Table 4b: Physicochemical parameters of Nag River (NGS-2) with dominant diatom species (Dahat[25])

Most abundant diatom species	Physiochemical parameter							
	Al mg/l	Fe mg/l	Mn mg/l	Si mg/l	pH	Conductivity µs	TDS ppm	Temp ^{o} C
Nitzschiaangustata								
Nitzschiacapitellata	0.16	0.58	NA	4.5	7.1	847	442	34

Table 5a: Physicochemical parameters of Nag River (NGS-10) with dominant diatom species (Dahat[25])

Most abundant diatom species	Physiochemical parameters							
	Alklalinity mg CaCo$_3$/l	Ca mg/l	Mg mg/l	Cl mg/l	SO_4 mg/l	P mg/l	Na mg/l	K mg/l
Cyclotella ocellata								
Tryblionellahungarica	252	52.1	21.4	71.0	17.2	0.037	55.1	0.5

Table 5b: Physicochemical parameters of Nag River (NGS-10) with dominant diatom species (Dahat[25])

Most abundant diatom species	Physiochemical parameter							
	Al mg/l	Fe mg/l	Mn mg/l	Si mg/l	pH	Conductivity µs	TDS ppm	Temp ^{o}C
Cyclotella ocellata								
Tryblionellahungarica	0.15	0.26	NA	4.48	7.3	884	465	35

The vertical profile of abundant diatom species including *Cyclotellaocellata, Synedra ulna, Achnanthidiumminutissum, Naviculacari., Amphora holastica, Nitzschiaangustata, Nitzschiacapitellata, Nitzschiamicrocephala, Nitzschiapalea, Nitzschiapaleacea, Nitzschiafonticola, Nitzschialeibetruthi, Tryblionellahungerica* and algal cysts recovered from sediment core of MS-A section has been divided into 3 units i.e. 100-79cm –Zone I, 80-40 cm - Zone II and 39-0 cm- Zone III. The Zone I is marked by increased abundance of *Cyclotellaocellata, Synedra ulna, Naviculacari., Amphora holastica, Nitzschiamicrocephala, Nitzschiapaleacea, Tryblionellahungarica* which indicates alkaliphilous, hypertrophic condition of the water and occurs at the physicochemical conditions as shown in table 4a,b; figure 6a[25]. The Zone II is marked by abundance of *Cyclotellaocellata*, *Naviculacari.*, *Amphora holastica, Nitzschiaangustata, Nitzschiacapitellata, Nitzschiamicrocephala, Nitzschiapaleacea*, *Nitzschiafonticola*, *Nitzschialeietruthi*, *Tryblionellahungerica*pointcircumneutral to alkaliphilous and hypertrophic condition of water[25]. While, the Zone III is represented by the abundance of *Achnanthidiumminutissum, Cyclotellaocellata, Synedra ulna, Naviculacari., Amphora holastica, Nitzschiaangustata, Nitzschiacapitellata, Nitzschiapaleacea*, *Nitzschiafonticola*, *Nitzschialeibetruthi*and algal cyst indicating circumneutral, mesotrophicwater condition[25].

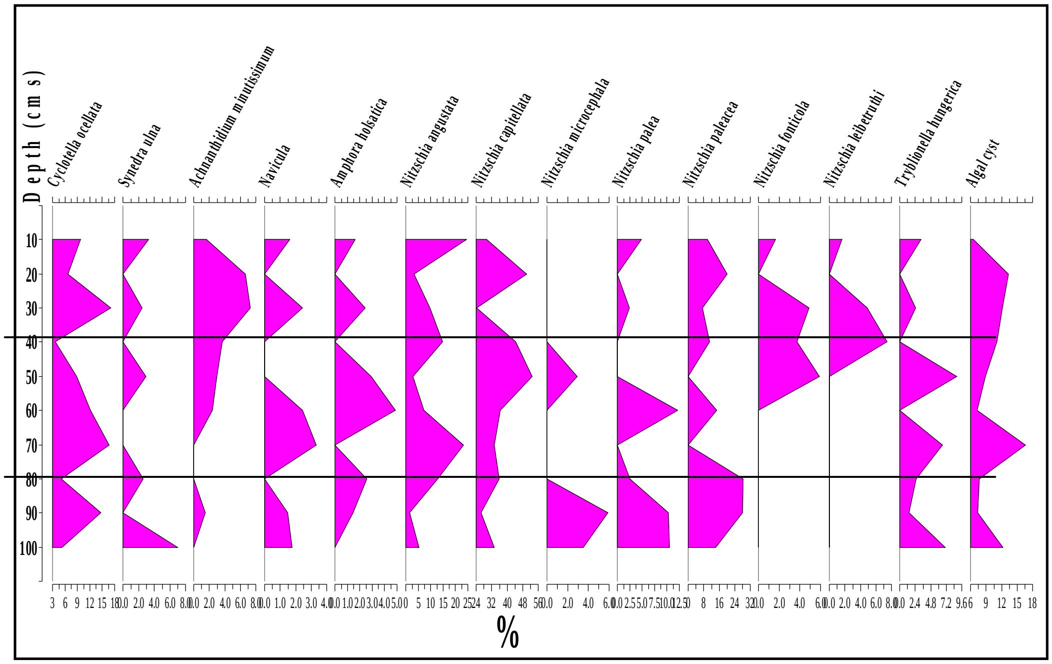

Fig. 6a Percentage occurrence of abundant diatom taxa along the vertical profile of MS-A section

The vertical profile of abundant diatom species from the MS-B sectiondivulges presence of *Cyclotellaocellata*, *Discostellastelligera*, *Synedra ulna*, *Achnanthidiumminutissimum,Cocconeisplacentula*, *Naviculacryptonella*, *Navicula*sp., *Pinnulariaappendiculata, Gomphonemaparvulum, Gomphonema*sp.,*Amphora holastica*, *Nitzschia amphibian*, *Nitzschiaangustata*, *Nitzschiacapitellata*, *Nitzschiamicrocephala*, *Nitzschiapalea*, *Nitzschiapaleacea*, *Nitzschiafiliformis*, *Tryblionellahungerica,*phytolith and algal cystsand categorized into 3 zonei.e.Zone I from 210 - 130 cm, Zone II from 129- 70 cm and Zone I from 69-0 cm (Fig. 6b). The Zone I is marked by increased abundance of *Nitzschiacapitellata, Nitzschiaangustata*, *Tryblionellahungerica*, *Cyclotellaocellata*indicating alkaliphilous hypertrophic waters during this period tables 5a, b; figures 6b.The Zone II is represented by the abundance of*Nitzschiacapitellata*, *Nitzschiaangustata*, *Tryblionellahungerica*, *Cyclotellaocellata*, *Discostellastelligera*, *Synedra ulna*,*Pinnulariaappendiculata*, *Gomphonemaparvulum*, *Nitzschiapalea*and algal cyst indicating circumneutral to alkaliphilous hypertrophic water conditions with high nutrient concentration,while Zone III is marked by the dominance of *Tryblionellahungerica*, algal cyst, *Nitzschiaangustata*, *Nitzschiacapitellata*, *Gomphonemaparvulum*, *Cyclotellaocellata*, *Discostella stelligera* indicating increased eutrophication in this zone. The enhanced diversity of various species of *Nitzschia* very explicitly indicates the rise in the level of organic pollution of the Nag River owing to the release of sewage, excessive use of fertilizers along the banks of the river for the cultivation of vegetables and cultivation of crops in the agricultural land present in its catchment area.

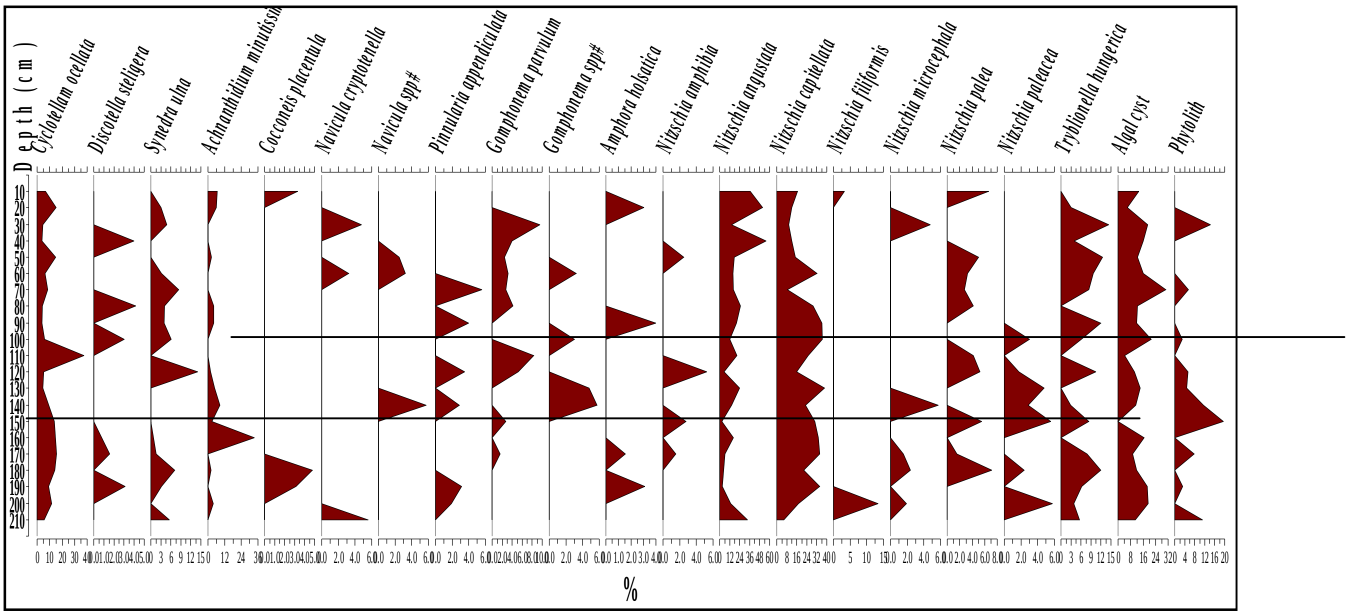

Fig. 6b Percentage occurrence of abundant diatom species along the vertical profile of MS-B section

CONCLUSION

The geochemical analysis has revealed the impact of organic pollutants of the river water since last several decades. The higher concentration of indicators of erosion such as Al_2O_3 and TiO_2 indicates that recent years have witnessed increased rate of soil erosion in the region. The organic matter and carbonate profile shows that at the depth of about 100 – 80 cm, nearly constant supply of organic matter was there with the declining carbonate content. This points the presence of moderate flooding and rainfall with fair soil erosion during that time. However, at about 79 – 50 cm,the organic matter supply was more or less constant but carbonate content went on increasing leading to decline in the rate of erosion and prevalence of low rainfalli.e. may be dry period. Similarly, at about 49- 0 cm depth, the organic matter and carbonate content shows their increase concentration indicating high productivity and high rainfall/ flooding in the study area.The Nag River may have brought the excessive carbonate during the high rainfall period. The four peaks of organic matter and carbonate content at the depth of about 200-100 cm indicate increased productivity and more constant supply of nutrients/ organic matter. From about 99- 40 cm,the three minor periods of high rainfall are observed, which was followed by the period of moderate rainfall/dry season from. The depth range ~39- 0 cm (top) represents increased rainfall and increased organic matter content.

The diatom inferred water quality of the MS-A section broadly reflects three cyclic changes i.e. Zone I: indicates alkaliphilous, hypertrophic condition, Zone II:circumneutral to alkaliphilous and hypertrophic condition and Zone III:indicatescircum-neutral, mesotrophic water condition. Similarly, the diatom inferred water quality of the MS-B section broadly indicates three major cycles of changes i.e. Zone I: alkaliphilous to hypertrophic waters, Zone II: indicatescircumneutral to alkaliphilous hypertrophic water conditions with high nutrient concentration and Zone III: increased eutrophication.The increased diversity of various species of *Nitzschia* suggests the high level of organic pollution in the Nag River.

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