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DIVERSITY AND DISTRIBUTION OF DIATOMS IN BAGMATI RIVER, KATHMANDU, NEPAL

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ABSTRACT

Diversity and distribution of diatoms in different seasons from different localities and habitats of Bagmati River, Kathmandu was studied. Samples were collected as epilithic forms using a toothbrush, epipelic forms using a dropper, and epiphytic forms by squeezing aquatic macrophytes and were preserved in FAA solution. The dominant diatom taxa of Bagmati river were *Achnanthes crenulata, Gomphonema pseudoaugur, Nitzschia linearis, N. palea, Pinnularia cf divergens* and *Surirella linearis*. Out of 48 taxa reported, maximum taxa (87.5%) were found at Mulkharka site whereas taxa were minimum (39.58%) at Pashupati-Guheshwori site. The sizes of diatom cell, from largest to smallest, also followed the same pattern as above. Ten diatom taxa were common in all three sites. Seasonal and habitat diversity of diatom studied in Mulkharka site showed that the maximum number of taxa was reported during summer (92.85%) and least during winter (23.8%), and maximum taxa were found as epilithic (85.71%) followed by epipelic (38.09%) and epiphytic (33.33%).

Key words: Algae, bacillariophyceae, epilithic, pashupati temple, seasonal variation

INTRODUCTION

Diatoms (Bacillariophyceae) are the unique algae as their cell wall (frustule) is made up of two overlapping pieces of silica. They are microscopic, unicellular (sometimes colonial and filamentous), aflagellated, uninucleated, diploid organisms with generally two major types of morphological shapes i.e., centric (valve circular) and pinnate (valve elongated). Chloroplast contains chlorophyll-c and chlorophyll-a, together with fucoxanthin, diatoxanthin, and diadinoxanthin pigments. Reserved foods are oil and chrysolaminarin but never starch. Reproduction is primarily by binary fission, sometimes by statospores (cysts or endospores), auxospores, and uni- or bi-flagellate microspores. In binary fission, one daughter cell receives larger frustules (or epitheca) and another daughter cell receives small frustules (or hypotheca) from the parent cell. Vegetative cells also divide by meiosis, producing male and female gametes which then fuse to form a zygote. In centric diatoms, small male gametes have one flagellum while female gametes are large and non-motile. In pennate diatoms, both the gametes lack flagella (isogamous) (Grethe *et al*., 1996). The zygote sheds its silica theca and grows into a large spherical auxospore. A new diatom cell of the maximum size, as the initial cell, forms within the auxospore thus beginning a new generation. Diatoms are distributed in all short of aquatic habitats throughout the world. All diatom species are not cosmopolitan in distribution. Though there are many species with global distributions, a significant number of species have distinct regional or local distributions; particularly in the polar Antarctic region and ancient lakes

(Vyverman *et al*., 2010). The endemic species of diatom of Nepal is *Gomphonema turris* var. *nepalensis* Hirano (Baral, 1999). The number of diatoms species described in the world is between 25,000 and 30,000; in India is around 14,700 taxa (Karthick *et al.*, 2013); and in Nepal is 192 species (Baral, 1999).

The work on diatom flora of Nepal is still at an early stage. Sporadic records have been made by some foreign workers from different places along the route during their different expeditions to the Himalaya regions. Carter (1926) has reported *Navicula confervacea* from Makawanpur district which seems to be the first record of diatom from Nepal. A significant contribution was made by Hirano (1955) reporting 69 diatom species from Phewa lake, Kaski; Ankhu khola and Luitel bhanjyang, Gorkha; Tandi khola, Pisang and Thaple Himal, Manang; and Kali Gandaki and Tukuche moor, Mustang. Later on, contribution on diatom of Nepal was made by various workers (Hirano, 1969, 1984; Suxena and Venkateswarlu, 1968; Nakanishi, 1986; Aryal and Lacoul, 1996; Jüttner *et al.*, 1996, 2003, 2010, 2011; Habib, 1997; Cantonati *et al*., 2001; Van de Vijver, 2011; Krstić *et al.*, 2012, 2013).

Diatoms of Kathmandu valley was studied by Hirano (1963) and Hickel (1973). Few species of diatoms have been reported from Sundarijal, Bagmati River (Shrestha and Manandhar, 1983; Simkhada and Jüttner, 2006). The literature on diatoms of Bagmati river is least available. Thus, the present work aimed to study the diversity and distribution of diatoms at three localities of Bagamati river in three different seasons.

MATERIALS AND METHODS

Study sites

The Bagmati is a holly river, originated from Baghdwar, south of Shivapuri Hills and flows through Pashupatinath Temple, Kathmandu valley and leaves the valley at Chobhar. The climate of Kathmandu valley ranges from subtropical (88.2% area lies in 1,000 to 2,000 m asl) to temperate (11.8% area lies in 2,000 to 3,000 m asl). The average annual temperature and precipitation of Kathmandu are 18.3°C and 1343 mm, respectively.

Three diatom sampling sites were selected along the Bagmati river *viz*., site 1- Mulkharka (above Sundarijal), site 2- Gokarna, and site 3- Pashupati-Guheshwori (Fig. 1).

Fig. 1. Diatom collection sites along the Bagmati River: Mulkharka, Gokarna and Pashupati.

Site 1: Mulkharka lies about 1 km north from Sundarijal Water Reservoir, in Sundarijal Gokarneshwor Municipality (Shivapuri Nagarjun National Park), on the north western corner of Kathmandu. The river is surrounded by a dense forest of *Castonopsis* and *Schima*. This site was further divided into two parts; "up bridge" (27º46'45.02"N, 85º25'27.37"E, alt. 1674 m asl) and "down bridge" (27º46'44.19"N, 85º25'29.09"E, alt. 1662 m asl). This site was assumed to be the fresh and unpolluted site because there was no human disturbance observed around the area. The diatom sample collection of three seasons *viz*., summer, rainy and winter was made from this site.

Site 2: Gokarna (27º44'6.64"N, 85º24'17.83"E, alt. 1325 m asl) lies in Sundarijal Gokarneshwor Municipality where the river just enters into the

plain valley. The river is narrow, channel like, with slow running water. This site was taken as mildly polluted site as this is the semi urbanized area and human disturbance on the river area could be seen. Sample collection of the only rainy season was done in this site.

Site 3: Pashupati-Guheshwori (27º42'37.43"N, 85º21'15.99"E, alt. 1306 m asl) area lies in Kathmandu Metropolitan City. It is the most important religious place for Hindus. This site lies at the centre of the Kathmandu city and surrounded by dense urbanization. This site was taken to be the heavily polluted site. The river flows slowly with thick and black water. Sample collection of the only rainy season was possible from this site.

Sample collection

The present study was conducted during the year 2014. For site 1, sample collection of three seasons (summer, rainy, winter) was made and for sites 2 and 3, sample collection of the only rainy season was performed. In every trip, 30 samples were collected from each site. A different set of materials (e.g., bottles, brush, dropper etc.) were used for each site so that contamination and mixing up of diatom species were avoided. The epilithic forms (present as a slippery coating on stones) were collected using a toothbrush, the epipelic forms (residing on sand/mud at the edge of river bed) were collected using a dropper, and the epiphytic forms (dwelling on the surfaces of other plants like moss) were collected by squeezing aquatic macrophytes. The collections were then preserved in FAA solution. The sampling number, locality site, collection date, method of collection, season and habitats for each collection were labeled. The nature of habitat, water pollution level, and surrounding vegetation were also noted in the field book. The geographical position of each collection site was noted using GPS Garmin e-Trex. Photographs of the locality were captured using Canon Digital Camera. All diatom samples were carried to the Phycological Research Lab, Department of Botany, PG Campus, Biratnagar for further study.

Preliminary screening of samples was done. Permanent slides of diatom were made according to the modified method of PCER, ANSP (1988). Microphotograph of each species was taken using an Olympus CH20i microscope with a camera attached. Diatoms were identified up to species and variety levels following Lange-Bertalot (2001), Krammer and Lange-Bertalot (1991), Krammer (2002), Mann *et al*. (2004), Metzeltin *et al*. (2009), Lange-Bertalot *et al*. (2011), and Karthick *et al*. (2013). The collected samples and permanent slides have been deposited in the Phycological Research Lab, Department of Botany, PG Campus, Biratnagar.

RESULTS AND DISCUSSION

A total of 48 diatom taxa were reported from Bagmati river belonging to 12 families and 25 genera (Rai and Khadka, 2017). Out of which, 42 taxa (87.5%) were recorded from Mulkharka, 20 taxa (41.66%) from Gokarna and only 19 taxa (39.58%) from Pashupati site throughout all the three seasonal collections. Similarly, diatom size was also variable in three different sites as large sized were restricted to Mulkharka, medium sized were found in Gokarna and small sized were rich in Pashupati site. This decrease in the number of diatom species and size from Mulkharka to Gokarna to Pashupati sites may be due to the increase in pollution level and the decrease in water current in three different sites of the river. Growth and development may be less in highly polluted and nearly stagnant water at Pashupati site, but clean and running water stream of Mulkharka site influence well growth and development of diatoms.

In general, frequently observed diatoms of

Bagmati River were *Achnanthes crenulata, Gomphonema pseudoaugur, Nitzschia linearis, N. palea, Pinnularia cf divergens* and *Surirella linearis*. Second frequent species were *Gomphonema gandhii, G. parvulum, Navicula radiosa, N. rostellata* and *Planothidium lanceolatum*. Rarely present species were *Amphora ovalis, Aulacoseira granulata, Cymbella aspera, C. tumida, Diploneis ovalis, Encyonema ventricosum, Epithemia adnata, E. sorex, Eunotia bidens, E. botuliformis, E. minor, Fragilaria vaucheriae, Frustulia rhomboides var. saxonica, Gomphonema acidoclinatum, Gyrosigma kuetzingii, Meridion circulare var. constrictum, Pinnularia grunowii, Stauroneis gracilis* and *S. smithii*.

Diatom diversity in three different sites (Mulkharka, Gokarna, Pashupati) of Bagmati River in the rainy season

When observed only on rainy season, a total of 35 diatoms were reported from three different sites, out of which a maximum number of diatom taxa were reported from Mulkharka (68.57%), then followed by Gokarna and Pashupati sites with 57.14% and 54.28% taxa, respectively (Fig. 2, Table 1). Diatoms common to all three sites were *Achnanthes crenulata, Cymbella turgidula, Gomphonema Gandhii, G. parvulum, G. pseudoaugur, Gyrosigma scalproides, Navicula radiosa, Navicula rostellata, Sellaphora capitata* and *Ulnaria ulna*. Diatoms reported only from Mulkharka site in rainy season were *Cocconeis placentula, Diploneis ovalis, Epithemia adnata, Eunotia minor, Frustulia rhomboides* var. *saxonica, Gyrosigma kuetzingii, Pinnularia microstauron, Planothidium lanceolatum* and *Surirella linearis*. Diatoms *viz*., *Amphora ovalis, Aulacoseira granulata, Cymbella aspera, Encyonema ventricosum, Eunotia bidens, Eunotia botuliformis, Gomphonema acidoclinatum, Gomphonema rhombicum, Meridion circulare var. constrictum, Neidium ampliatum, Stauroneis gracilis, Stauroneis smithii* and *Surirella splendida* were also found only in Mulkharka but during summer and winter seasons. Similarly, diatoms reported only from Gokarna site were *Cymbella tumida, Pinnularia grunowii* and *Surirella angusta* and only from Pashupatinath were *Epithemia sorex*, *Fragilaria vaucheriae* and *Navicula escambia*.

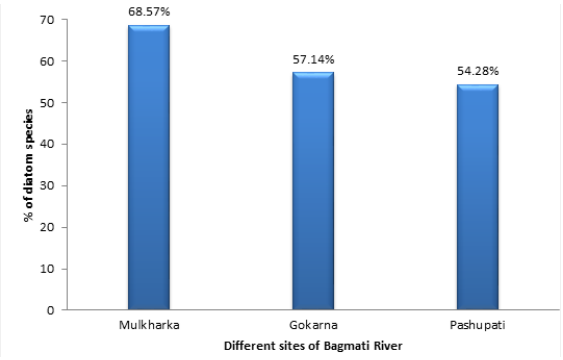

Fig. 2. Presence of diatoms at different sites of Bagmati river in the rainy season.

Table 1. Diatoms diversity at different sites of Bagmati river in the rainy season.

SN	Diatoms	Sampling sites in Bagmati river		
		Mulkharka	Gokarna	Pashupati
1	*Achnanthes crenulata* Grunow	++++	+	+
2	*Achnanthes inflate* (Kützing) Grunow	+	-	+
3	*Cocconeis placentula* Ehrenberg	+	-	-
4	*Cyclotella meneghiniana* Kützing	+	-	+
5	*Cymbella tumida* (Brébisson) Van Heurck	-	+	-

6	*Cymbella turgidula* Grunow	++	+	+
7	*Diatoma hiemale* var. *mesodon* (Ehrenberg) Grunow	+	+	-
8	*Diploneis ovalis* (Hilse) Cleve	+	-	-
9	*Encyonema hustedtii* Krammer	-	+	-
10	*Epithemia adnata* (Kützing) Brébisson	+	-	-
11	*Epithemia sorex* Kützing	-	-	+
12	*Eunotia minor* (Kützing) Grunow	+	-	-
13	*Fragilaria vaucheriae* (Kützing) J.B. Petersen	-	-	+
14	*Frustulia rhomboides* var. *saxonica* (Rabenhorst) De Toni	+	-	-
15	*Frustulia vulgaris* (Thwaites) De Toni	-	+	++
16	*Gomphonema gandhii* Karthick et Kociolek	+++	+	+
17	*Gomphonema parvulum* (Kützing) Kützing	+	++	+++
18	*Gomphonema pseudoaugur* Lange-Bertalot	++	++++	++++
19	*Gyrosigma kuetzingii* (Grunow) Cleve	+	-	-
20	*Gyrosigma scalproides* (Rabenhorst) Cleve	+	+	+
21	*Navicula escambia* (R.M. Patrick) Metzeltin et Lange-Bertalot	-	-	++
22	*Navicula radiosa* Kützing	++	+++	+
23	*Navicula rhyncocephala* Kützing	-	-	+
24	*Navicula rostellata* Kützing	+	+++	+
25	*Nitzschia linearis* W. Smith	++	+	-
26	*Nitzschia palea* (Kützing) W. Smith	-	++	+++
27	*Pinnularia* cf *divergens* W. Smith	-	++++	++
28	*Pinnularia grunowii* Krammer	-	+	-
29	*Pinnularia microstauron* (Ehrenberg) Cleve	+	-	-
30	*Pinnularia viridis* (Nitzsch) Ehrenberg	+	+	-
31	*Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot	+	-	-
32	*Sellaphora capitata* D.G. Mann et S.M. McDonald	+	+	+
33	*Surirella angusta* Kützing	-	+	-
34	*Surirella linearis* W. Smith	++	-	-
35	*Ulnaria ulna* (Nitzsch) Compère	++	+	+
Total diatom taxa		24	20	19

++++ Dominant, +++ Frequent, ++ Common, + Occasional, - absent

Diatom diversity in different seasons at Mulkharka site, Bagmati River.

Diatom flora during summer, winter and rainy seasons observed at Mulkharka site showed that *Achnanthes crenulata, Nitzschia linearis* and *Surirella linearis* were dominant taxa throughout all three seasons. Out of 42 taxa, the maximum number of diatoms were reported during summer (92.85%) followed by rainy (57.14%) and least during winter (23.80%) (Fig. 3, Table 2). This variation in the number of taxa may be due to warm temperature that influences the growth and development during summer season.

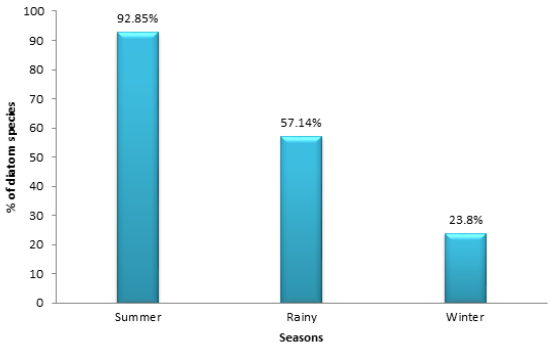

Fig. 3. Presence of diatoms in different seasons at Mulkharka, Bagmati river

Diatoms occurred in all three seasons were *Achnanthes crenulata*, *Diatoma hiemale* var. *mesodon, Gomphonema gandhii, G. parvulum, Navicula radiosa, Nitzschia linearis, Pinnularia viridis, Planothidium lanceolatum, Surirella linearis and Ulnaria ulna.* Diatoms reported only during summer season were *Amphora ovalis, Aulacoseira granulata, Cyclotella meneghiniana, Cymbella aspera, Encyonema hustedtii, E. ventricosum, Epithemia adnata, Eunotia bidens, E. botuliformis, Frustulia vulgaris, Gomphonema acidoclinatum, G. rhombicum, Gyrosigma kuetzingii, G. scalproides, Meridion circulare* var. *constrictum, Navicula rhyncocephala, N. rostellata, Neidium ampliatum, Nitzschia palea, Pinnularia* cf *divergens, Stauroneis gracilis, S. smithii* and *Surirella splendida.* Similarly, diatoms reported only during the rainy season were *Achnanthes inflata, Diploneis ovalis* and *Frustulia rhomboides* var. *saxonica*. All diatoms reported during winter were also observed during other seasons.

Diatom diversity on different habitats of Mulkharka site, Bagmati River

Diatom diversity studied on different habitats at Mulkharka site showed that maximum taxa were epilithic (attached on stone) (35) followed by epipelic (attached on mud and sand) (15) and epiphytic (attached on moss plant) (13) (Fig. 4, Table 2). Diatoms present in all three habitats were *Achnanthes crenulata, Diatoma hiemale* var. *mesodon, Navicula radiosa, Nitzschia linearis, Planothidium lanceolatum, Surirella linearis* and *Ulnaria ulna.* The following diatoms were inhabitated only on stones- *Aulacoseira granulata, Cocconeis placentula, Cyclotella meneghiniana, Cymbella turgidula, Encyonema hustedtii, E. ventricosum, Epithemia adnata, Eunotia bidens, E. botuliformis, E. minor, Gomphonema acidoclinatum, G. pseudoaugur, Gyrosigma kuetzingii, G. scalproides, Navicula rostellata, Pinnularia* cf *divergens, P. microstauron, Stauroneis gracilis* and *S. smithii.* Diatoms inhabited only on sand and mud were *Amphora ovalis* and *Meridion circulare* var. *constrictum* and only on moss plants were *Cymbella aspera* and *Navicula rhyncocephala.*

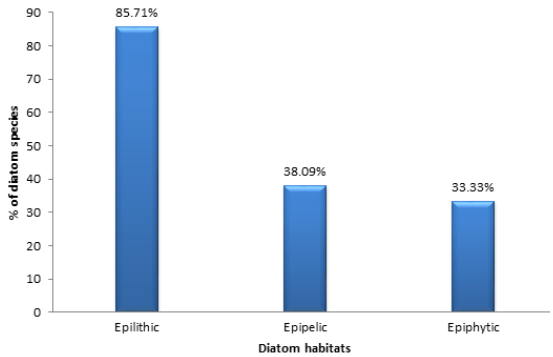

Fig. 4. Presence of diatoms on different habitats at Mulkharka, Bagmati river.

Table 2. Diatom diversity in different seasons and habitats at Mulkharka site, Bagmati river.

SN	Diatoms	Seasons			Habitats		
		Summer	Rainy	Winter	Epilithic	Epipelic	Epiphytic
1	*Achnanthes crenulata* Grunow	++++	++++	++++	++++	+	++++
2	*Achnanthes inflate* (Kützing) Grunow	-	+	-	-	-	+
3	*Amphora ovalis* (Kützing) Kützing	+	-	-	-	+	-
4	Aulacoseira granulata	+	-	-	+	-	-
5	*Cocconeis placentula* Ehrenberg	+	+	-	+	-	-
6	*Cyclotella meneghiniana* Kützing	++	+	-	++	-	-
7	*Cymbella aspera* (Ehrenberg) Simonsen	+	-	-	-	-	+
8	*Cymbella turgidula* Grunow	+	++	-	+	-	-
9	*Diatoma hiemale* var. *mesodon* (Ehrenberg) Grunow	++	+	++	++	++	+
10	*Diploneis ovalis* (Hilse) Cleve	-	+	-	-	+	-
11	*Encyonema hustedtii* Krammer	+	-	-	+	-	-
12	*Encyonema ventricosum* (C. Agardh) Grunow	+	-	-	+	-	-
13	*Epithemia adnata* (Kützing) Brébisson	+	+	-	+	-	-
14	*Eunotia bidens* Ehrenberg	+	-	-	+	-	-
15	*Eunotia botuliformis* G.-R. Wang	+	-	-	+	-	-
16	*Eunotia minor* (Kützing) Grunow	+	+	-	+	-	-
17	*Frustulia rhomboides* var. *saxonica* (Rabenhorst) De Toni	-	+	-	+	-	-
18	*Frustulia vulgaris* (Thwaites) De Toni	+	-	-	+	+	-
19	*Gomphonema acidoclinatum* Lange-Bertalot et Reichardt	+	-	-	+	-	-
20	*Gomphonema gandhii* Karthick et Kociolek	+	+++	+++	+++	+	-
21	*Gomphonema parvulum* (Kützing) Kützing	++	+	+	+	-	++
22	*Gomphonema pseudoaugur* Lange-Bertalot	+++	++	-	+++	-	-
23	*Gomphonema rhombicum* Fricke	+	-	-	++	+	+
24	*Gyrosigma kuetzingii* (Grunow) Cleve	+	+	-	+	-	-
25	*Gyrosigma scalproides* (Rabenhorst) Cleve	+	+	-	+	-	-
26	*Meridion circulare* var. *constrictum* (Ralfs) Van Heurck	+	-	-	-	+	-
27	*Navicula radiosa* Kützing	+++	++	++	+++	+++	++
28	*Navicula rhyncocephala* Kützing	+	-	-	-	-	+
29	*Navicula rostellata* Kützing	+++	+	-	+++	-	-
30	*Neidium ampliatum* (Ehrenberg) Krammer	+	-	-	+	-	+
31	*Nitzschia linearis* W. Smith	++++	++	++++	+++	++++	++++
32	*Nitzschia palea* (Kützing) W. Smith	+++	-	-	+++	-	++
33	*Pinnularia* cf *divergens* W. Smith	++++	-	-	++++	-	-
34	*Pinnularia microstauron* (Ehrenberg) Cleve	+	+	-	+	-	-
35	*Pinnularia viridis* (Nitzsch) Ehrenberg	+	+	+	+	+	-
36	*Planothidium lanceolatum* (Brébisson ex Kützing) Lange-Bertalot	+++	+	++	++	++	+++
37	*Sellaphora capitata* D.G. Mann et S.M. McDonald	++	+	-	++	+	-
38	*Stauroneis gracilis* Ehrenberg	+	-	-	+	-	-
39	*Stauroneis smithii* Grunow	+	-	-	+	-	-
40	*Surirella linearis* W. Smith	++++	++	++++	++++	++++	++++
41	*Surirella splendid* (Ehrenberg) Kützing	+	-	-	+	+	-
42	*Ulnaria ulna* (Nitzsch) Compère	++	++	++	++	+	+
Total diatom taxa		39	24	10	36	16	14

++++ Dominant, +++ Frequent, ++ Common, + Occasional, - absent

The dominant diatoms in epilithic habitat were *Achnanthes crenulata, Pinnularia* cf *divergens* and *Surirella linearis*. Similarly, dominant taxa in epipelic habitat were *Nitzschia linearis* and *Surirella linearis* and in epiphytic habitat were *Achnanthes crenulata, Nitzschia linearis* and *Surirella linearis*.

In general, dominant diatom taxa of Bagmati river were *Achnanthes crenulata, Gomphonema pseudoaugur, Nitzschia linearis, N. palea, Pinnularia cf divergens* and *Surirella linearis* and rarely present species were *Amphora ovalis, Aulacoseira granulata, Cymbella aspera, C. tumida, Diploneis ovalis, Encyonema ventricosum, Epithemia adnata, E. sorex, Eunotia bidens, E. botuliformis, E. minor, Fragilaria vaucheriae*. The poor representations throughout the study period were of following genera *viz*., *Amphora*, *Aulacoseira, Cocconeis, Cyclotella, Diatoma, Diploneis, Fragilaria, Meridion, Neidium, Planothidium, Sellaphora and Ulnaria*. These were represented by single taxa.

CONCLUSIONS

A total of 48 diatom taxa belonging to 25 genera and 12 families were enumerated in three seasons from three different sites of Bagmati River. The maximum number of diatom taxa (87.5%) was found in Mulkharka and minimum number (39.58%) was found in Pashupati sites. Thus, Mulkharka site favoured the luxuriant growth of diatoms with rich diversity. There were 10 common diatom taxa found in all three sites. Nine taxa occurred at Mulkharka only, 4 each occurred at Gokarna and Pashupati sites only. At Mulkharka, the maximum number of taxa was reported during summer (92.85%) and least during winter (23.8%). Diatom diversity studied on different habitats at Mulkharka showed that the maximum taxa were epilithic (85.71%) followed by epipelic (38.09%) and epiphytic (33.33%). Largest sized diatoms were observed in Mulkharka and smallest sized were observed in Pashupati sites. Further extensive studies are required for a better documentation and understanding of diatoms flora of Bagmati River.

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