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Seasonal variation of physico-chemical characteristics of water, using diatoms as a bio-indicator and diversity index of water quality, district Mardan, KP, Pakistan

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Key words: Diatoms, Bio-indicator, Mardan, Diversity indices, Physicochemical properties.

Abstract

The present research work was conducted to study the impact of water on diatoms growth in different seasons. Diatoms are excellent indicators and used for the assessment of water quality of district Mardan, KP, Pakistan. Algal and water samples were collected in different seasons during the year 2016. A total of 78 species and 27 genera of diatoms were isolated. Results revealed that maximum number of diatoms (49 species) were recorded in winter followed by autumn (39 species) summer (22 species) to the minimum (17 species) in spring. This may be attributed to the presence of favourable nutrients requirement in winter, autumn and summer than spring resulted in maximum number of diatoms. This fact may revealed that water in winter and autumn receiving more effluents from residential areas and industries than summer and spring that positively promoted the diatoms growth. Most dominant species of diatoms were reported for the genera *Navicula, Nitzschia, Cymbella, Gyrosigma* and *Ghomphonema*. Water was analysed for their physicochemical properties: temperature (12.5–31.7˚C), pH (8.7–9.2), turbidity (59.6–156 NTU), TDS (158.6–414 mg/l), TSS (100–212 mg/l) and electrical conductivity (341–435 µS/cm) were calculated. Diversity of the diatoms species was calculated through Margalef index (d), Pielou's evenness index (*J′*), Simpson's index (*D*) and Shannon-Wiener index (*H′*). Statistical analysis showed that temperature and total dissolved solids were highly significant while pH was only significant in diatoms growth. The growth of diatoms showed positive correlation with total dissolved solids, electrical conductivity and total suspended solids.

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Introduction

Most parts of the district Mardan face scarcity of clean water due the addition of wastes, as a result of different anthropogenic activities. The extent of water pollution increases with every passing day. Major causes of wastewater in the district are houses, sewages and industrial effluents. Diversity of the algal species in the research area was strongly influenced by the physicochemical properties of the water such as light availability, temperature, turbidity, concentration of dissolved oxygen and nutrients. Water of the research area contains large quantity of organic matter, dissolved oxygen, phosphate, nitrate, domestic sewages and all other effluents discharges from residential area, cities and factories. All these effluents have positive impact on algal growth and diversity. Algae act as a bioindicator of the environment in a particular area (Jafari and Gunale, 2006). Under favourable environmental conditions, some of the genera of algae are selected as indicators to measure the level of organic pollution (Palmer, 1969). Algae are good pollutants indicator as they quickly respond to environmental changes and used in water quality monitoring programs (WQMP) (pollution) (Addy and Linda, 1996; Gupta and Kumar, 2014). Algae recognise and qualify the pollutants effects on the aquatic environment. It indicate the combined effect of various pollutants and its persistency in the ecosystem (Sen *et al.*, 1927). Diatoms along with some other algae are consider to be the most suitable indicators of the aquatic environment. It indicate the overall status of the ecosystem in which they occurred (Hosmani, 2013). As compared to other organisms, diatoms are more suitable indicator because of their seeming ubiquity, short time from generation to generation, more sensitive to changes in the nutrient levels and vast assemblages (De la Rey, 2004). In aquatic environment, the study of algal community give signal about the pollution (like changing pH, addition of oil, heavy metals, increase of organic matter and chemical fertilizers) (Buragohain and Yasmin, 2014). Thus it can act as an early warning signals and indicate the 'health' status of different water bodies (Jafari and Gunale, 2006).

Cystoseira sp. (brown algae), *Ulva sp.* and *Enteromorpha sp.* (green algae) are widly used as biondicator for trace metals (Akcali and Kucuksezgin, 2011). Water quality reduces by pollution, thus it becomes unfit for consumption. Organic pollutants (domestic sewages, urban run off, industrial effluents and farm water) worsely effect the quality of water (Sen *et al.*, 1927). Therefor the present research work was conducted to study the impact of water on diatoms growth and diversity in different seasons of the year, as diatoms are reliable indicator and used in the monitoring of water quality.

Materials and methods

Site selection

To assess the water quality, sampling was carried out randomly in different seasons from three sites (Mardan, Takht Bhai and Katlang) of district Mardan. Water of these sites become polluted by every coming day receiving pollutants from different sources. Flow of water is occurred in the direction of north to south and west to east.

Water and algal sampling

Algal and water samples were collected in different seasons for the year 2016. A total 30 samples were collected during the entire period of study. Algal specimens were collected with the help of forceps, tooth brush and net mesh regularly from the water of floating habitat, attached with stones and submerged plants and on side walls of pond, stream and river. The collected specimens were kept in plastic bottles of 50ml and brought to the Laboratory, Department of Botany, Islamia College University, Peshawar. The specimens were preserved in 4% formaldehyde solution after washing carefully.

Laboratory method

The Diatomaceous algae were washed by using peroxide (H_2O_2) technique (Swift, 1967). The organic matter in the sample get oxidize in the presence of peroxide and the silica cell walls of diatoms remain undisturbed and study for their morphology under microscope viewed at 10×, 40× and 100× Nikon Lambda E2000 microscope objectives. Images of the diatoms were taken with a digital camera.

Standard references of (Collins, 1909; Transeau, 1951; Prescott, 1962; Bellinger and Sigee, 2010) were used for identification. Micrometric measurement (length and width) for each algal specimen has taken with the help of stage and ocular micrometres.

Ecological diversity of algal species in the research sites of different seasons were calculated as follows:

Species richness

Margalef index (1958) was used to measured species richness.

Margalef index (d) = (S-1) / ln N

Where S = number of ecorded species, N = total recorded individuals in the sample and In = natural logarithm.

Species evenness

Pielou's evenness index (1966) can be used to measure the species evenness of a community.

Shannon-Wiener index

Pielou's evenness index (J') = H' *(observed)* / $H'max$ and H' is Shannon-Wiener index

$H'max$ = ln (S)

Value for J' ranges between 0 and 1. The higher the value for J, there will be less variation in communities between the species.

Spices dominance

Simpson's index (D) was used to measure the species dominance.

Simpson's index of diversity: D = 1- [Σ n (n-1)/ N (N-1)]

Shannon-Wiener index (H') was used to measure the combined index.

$H' = \Sigma\, pi\, (ln * pi)$ *or* H = $-\Sigma\, pi\, (ln * pi)$

Where pi is the proportion of species relative to the total number of species.

Analysis of physico-chemical parameters of water

Temperature and pH of water were determine with the help of portable pH meter-8414 on the spot, while electrical conductivity was measured with the help of HANNA HI98192 conductivity meter, turbidity with HANNA HI98703 turbidity meter, total dissolved solids with HANNA HI98192 meter and total suspended solids with HACH TSS meter in the laboratory.

Statistical analysis

Statistical analysis of the data for the species diversity and water quality parameters for correlation was counted by distance-weighted least squares using the *Statistica 7.1* Program.

Results

Physicochemical parameters of the collected water samples were temperature (12.5˚C–31.7 5˚C), pH ranged (8.7–9.2), turbidity ranged (59.6–156 NTU), total dissolved solids (158.6–414 mg/l), total suspended solids (100–212 mg/l) and electrical conductivity (341–435 µS/cm) in different seasons. A total of 77 species of diatoms were reported in different seasons. Out of which 49 species were reported in winter, 39 species in autumn, 22 species in summer and 17 species reported in spring. Diversity of diatoms in the research sites in different season were calculated with the help of standard diversity indices. Species richness was ranged (1.2–.4.59 points), species evenness was (0.93 –0.95 points), species dominance was (0.02– 0.09 points) and combine index was (2.32–3.01 points).

Discussion

Physico-chemical parameters of the collected water samples from the research sites showed variation with changing seasons. As it can be seen (Fig. 1) fluctuation in temperature (12.5˚C –31.7˚C) occurred in the entire period of study. Average recorded pH in summer was (8.7), in winter was (9), in autumn was (9.2) and in spring was (8.9) in the research sites. This indicated that water of the research sites in all seasons was of alkaline nature.

Average turbidity that recorded in summer (156 NTU), in winter (64.6 NTU), in autumn (61.6 NTU) and in spring (59.6 NTU) and for total suspended solids recorded in summer (100 mg/l), in winter (212 mg/l), in autumn (185 mg/l) and in spring (151 mg/l) in the research sites. Average value for conductivity recorded in summer (341 µS/cm), in winter (435 µS/cm), in autumn (424 µS/cm) and in spring (427 µS/cm) the research sites.

Table 1. Diversity of diatoms in different season on the basis of standard diversity indices.

S. No.	Diversity Indices	Summer	Winter	Autumn	Spring
1	Margalef index (d).	4.59	1.95	2.73	3.81
2	Pielou's index (*J'*).	0.95	0.93	0.93	0.94
3	Simpson's index (*D*)	0.04	0.02	0.03	0.09
4	Shannon-Wiener index (*H'*)	3.0	2.32	2.64	2.9

Key: M= Mardan, T= Takht Bhai, K= Katlang

Table 2. Diversity and seasonals variation of diatoms in district Mardan.

S. No.	Diatoms	Seasons			
		S	W	A	Sp
1	*Amphora normani* Rabenhorst	–	–	+	–
2	*Amphora ovalis* (Kutz.) Kutz	–	–	+	–
3	*Cyclotella meneghiniana* Kutz	–	–	+	–
4	*Cyclotella quillensis* L.W.Bailey	–	–	–	+
5	*Melosira* granulate (Ehrenb.) Kütz	–	+	–	–
6	*Melosira varians* C. Agardh	–	+	–	–
7	*Cocconeis placentula* Ehrenb	–	–	+	–
8	*Cocconeis lineata* Ehrenberg	–	–	+	–
9	*Cocconies placentula* var. *lineata* (Ehrenb.) van Heurck	+	–	–	–
10	*Diploneis puella* (Schumann)	–	+	+	–
11	*Diploneis scutellum* (O'Meara) F.W. Mills	–	+	–	–
12	*Diatoma vulgare* Bory var. *vulgare*	–	+	+	+
13	*Fragilaria crotonensis* Kitton	–	+	+	–
14	*Fragilaria capunica* Desmazières	+	+	–	+
15	*Synedra pulchella* (Ralfs) Kuetz.	–	–	+	–
16	*Synedra ulna* (Nitzsch) Ehrenberg	+	+	–	+
17	*Synedra acus* Kützing	–	–	–	+
18	*Asteionella formosa* Hassall	–	–	+	–
19	*Rhizosolenia longiseta* O.Zacharias	–	–	+	–
20	*Meridion circulare* (Greville) C. Agardh	–	–	–	+
21	*Cymbella affinis* Kuetz	–	+	–	–
22	*Cymbella prostrata* (Berkeley) Cleve	–	+	+	–
23	*Cymbella neocistula* Krammer	–	–	+	–
24	*Cymbella laevis* Naeg.	–	–	+	–
25	*Cymbella tumida* (Breb.) V. H.	–	+	+	–
26	*Cymbella cymbiformis* (Kuetz.) Breb.	–	+	+	–
27	*Cymbella cuspidata* Kuetz.	–	+	+	–
28	*Ghomphonema parvulum* (Kütz.) Kütz.	–	+	+	–
29	*Gomphonema gracile* Ehrenb.	–	–	+	–
30	*Gomphonema clavatum* Ehrenb.	–	–	+	–
31	*Gomphonema truncatum* (jon kinross) Ehrenb.	–	–	+	+
32	*Gomphonema angustatum* (Kütz.) Grunow	+	–	–	+
33	*Frustulia vulgaris* (Thwaites) De Toni	–	+	–	–
34	*Frustulia rhomboids* Ehrenb.	+	+	+	+
35	*Gyrosigms kuetzingii* (Gronow) Cleve	–	+	+	–

36	*Gyrosigma acuminatum* (Kutz.) Rabenh.	–	+	+	–
37	*Gyrosigma spencerii* (W. Sm.) Cl. Griffith	–	+	+	–
38	*Gyrosigma wormleyi* (Sullivant) Boyer	–	+	+	–
39	*Gyrosigma scalproides* Rabenhorst	–	+	+	+
40	*Gyrosigma attenuatum* (Kutz.) Cleve	–	+	+	–
41	*Mastogloia smithii* Thwaites	+	–	–	–
42	*Mastogloia dansei* (Thwaites) Thwaites ex W. Smith	+	–	–	–
43	*Navicula gastrum* Ehrenb.	–	+	+	+
44	*Navicula trivialis* L.-B.	+	+	+	–
45	*Navicula cuspidata* Kütz.	+	+	–	–
46	*Navicula rhyncocephala* Kütz.	+	+	–	–
47	*Navicula radiosa* Kütz.	+	–	–	–
48	*Navicula cincta* (Ehrenb.) Ralfs	–	+	–	–
49	*Navicula confervacea* (Kutz.) Grunow	–	+	–	–
50	*Navicula tripunctata* (O. Mu¨ ll.) Bory	–	+	–	–
51	*Navicula veneta* Kütz	–	+	–	–
52	*Navicula viridula* Kütz	–	+	–	–
53	*Stauroneis anceps* Ehrenb.	+	–	+	+
54	*Stauroneis acuta* Wm. Smith	–	+	–	–
55	*Neidium dubium (*Ehrenb.) Cl.	+	–	–	–
56	*Neidium silvatica*	+	–	–	–
57	*Neidium ampliatum* (Ehrenberg) Krammer	–	+	–	–
58	*Anomoeoneis exilis* (Grunow) Ross	–	+	+	+
59	*Anomoeoneis variabilis* (Grunow) Ross	+	+	+	–
60	*Pinnularia viridis* (Nitzsch) Ehrenb.	–	+	+	+
61	*Pinnularia major* Kutz.	–	+	–	–
62	*Nitzschia scalaris* (R.Creran)	–	–	+	–
63	*Nitzschia vermicularis* (Kütz.) (Bemersyde)	–	+	–	–
64	*Nitzschia linearis* (C. Ag.) W. Sm.	+	+	+	–
65	*Nitzschia constricta* (Kutzing) Ralfsin	+	+	+	–
66	*Nitzschia palea* (Kütz.) W. Sm.	+	+	+	–
67	*Nitzschia sigmoidea*(Nitzsch) W. Sm.	–	+	–	–
68	*Nitzschia commutata* Grunow	–	+	–	–
69	*Nitzschia hungarica* Grunow	+	+	+	–
70	*Nitzschia scalpelliformis* Cleve & Grunow	+	+	–	–
71	*Cymatopleura solea* (Brébisson) W. Smith	–	+	+	+
72	*Cymatopleura solea var; vulgaris* Meister	–	–	–	–
73	*Stenopterobia sigmatella* (R.Creran)	+	–	–	–
74	*Surirella ovalis* Bréb.	–	–	–	–
75	*Surirella robusta* Ehrenb.	–	–	–	–
76	*Ulnaria ulna* (Nitzsch) P. Compere	+	–	–	–
77	*Denticulata tenuis* Kuetz.	–	–	–	+

Key: S= Summer, W= Winter, A= Autumn, Sp= Spring.

It was concluded that apart from summer all other seasons have total suspended solids, turbidity and conductivity values beyond the permissible limit of WHO. This might be attributed to the increased concentration of industrial and agricultural effluents in the water (Surubaru *et al.*, 2012). Average value for total dissolved solids recorded in summer (158.6 mg/l), in winter (382 mg/l), in autumn (414 mg/l) and in spring (226 mg/l) research sites and within permissible limits (500 mg/l) suggested by WHO (Fig. 1).

A total of 77 species of diatoms belonged to 27 genera were recorded. Maximum number (49 species) were reported in winter followed by autumn (39 species) summer (22 species) to the minimum spring (17 species). Variation occurred in diatoms diversity in different seasons (Table 1). This seasonal variation in algal diversity was also studied by Mahadik and Jadhav (2013). It may be attributed that a rapid accumulation of organic wastes and other pollutants in the water.

This results in increasing the number of diatoms species in these two seasons. In summer, the genera contributing most of the species in summer were *Nitzschia* followed by *Navicula* (Table 2). Other species occurred one to two in numbers in the research sites in summer were *Neidium dubium*, *N. sylvatica*, *Mastogloia smithii*, *M. dansei*, *Cocconies placentula* var. *lineata*, *Fragilaria capunica*, *Synedra ulna*, *Gomphonema angustatum*, *Frustulia rhomboides*, *Stauroneis anceps*, *Anomoeoneis variabilis*, *Stenopterobia sigmatella* and *Ulnaria ulna*.

Table 3. Correlation of diatoms species in different seasons.

Seasons	Seasons			
	Summer	Winter	Autumn	Spring
Summer	-	0.68ns	-0.89ns	0.98*
Winter	-	-	-0.27ns	0.80ns
Autumn	-	-	-	-0.79ns
Spring	-	-	-	-

In winter, the genera contributed maximum number of species were *Navicula* followed by *Nitzschia*, *Gyrosigma* and *Cymbella*. Genera shared two species per genus were *Melosira*, *Diploneis*, *Frustulia*, *Fragilaria*, *Pinnularia*, *Cymatopleura* and *Surirella* (Table 1). Singly occurred species in winter were *Diatoma vulgare*, *Synedra ulna*, *Ghomphonema parvulum*, *Stauroneis acuta*, *Neidium ampliatum* and *Stenopterobia sigmatella*. Genera contributing maximum number of species during winter were *Cymbella* followed by *Nitzschia*, *Gyrosigma* and *Gomphonema*. Genera contributing two species per genus were *Amphora*, *Cocconeis*, *Navicula* and *Anomoeoneis* (Table 1). Singly occurred species were *Frustulia rhomboides*, *Cyclotella meneghiniana*, *Diploneis puella*, *Diatoma vulgare*, *Fragilaria crotonensis*, *Synedra pulchella*, *Asterionella formosa*, *Rhizosolenia longiseta*, *Stauroneis anceps*, *Pinnularia viridis* and *Cymatopleura solea*.

In spring, neither of the species showed their dominancy but occurred one to two in number per genus. These genera were *Synedra*, *Gomphonema*, *Cyclotella*, *Diatoma*, *Fragilaria*, *Meridion*, *Frustulia*, *Gyrosigma*, *Navicula*, *Stauroneis*, *Neidium*, *Anomoeoneis*, *Pinnularia*, *Cymatopleura* and *Denticulata* (Table 2). Results revealed that in all seasons, most of the dominant species were found for *Navicula* (10 species), *Gomphonema* (5 species), *Nitzchia* (9 species) *Cymbella* (8 species) each, *Fragillaria* 2 species), *Synedra* 3 species), *Pinnularia* (2 species) *Gyrosigma* (6 spscies) can tolerate and inhibited the water containing pollutants (Table 2). Species of *Nitzschia*, *Fragilaria* and *Gyrosigma* were dominant (Mahadik and Jadhav, 2013). Species of *Cyclotella*, *Gomphonema* and *Synedra* showed quick responses to environmental pollution (Hosmani, 2013). It can be attributed that species of these genera have the capacity to inhibit the water loaded with pollutants. Species of *Navicula*, *Fragillaria* and *Nitzchia* occurred in water containing organic pollutants (Nadan and Aher, 2005; Jafari and Gunale, 2006; Palmer, 1969). Epiphytic algae (*Gomphonema*) was an excellent indicator of water pollution (Round, 1965). *Synedra ulna* was the most tolerable species for organic pollution (Hosmani, 2013). Jafari and Gunalem (2006), Gunale and Balakrishnan (1981) reported that *Navicula*, *Nitzchia*, *Gomphonema* and *Synedra* inhibited the water loaded with pollutants. Pennales diatoms (*Navicula*, *Nitzchia*, *Gomphonema etc.*) were the dominant diatoms that can tolerate a wide range environmental pollution (Kadhim, 2014). *Cymbella*, *Nitzchia*, *Gomphonema*, *Navicula*, *Fragillaria*, *Cocconeis* and *Synedra* were extensively used as indicators of environmental changes and can tolerate many environmental variables (Kadhim, 2014). Kumar (1990), Agar and Ghosh (2006), Jafari and Gunale (2006) reported species of *Melosira* was confined to aquatic medium loaded with nutrients. Species of *Cocconeis, Amphora, Navicula* and *Cymbella* were inhibited the water of alkaline nature (Polge, 2010; Round 1956a).

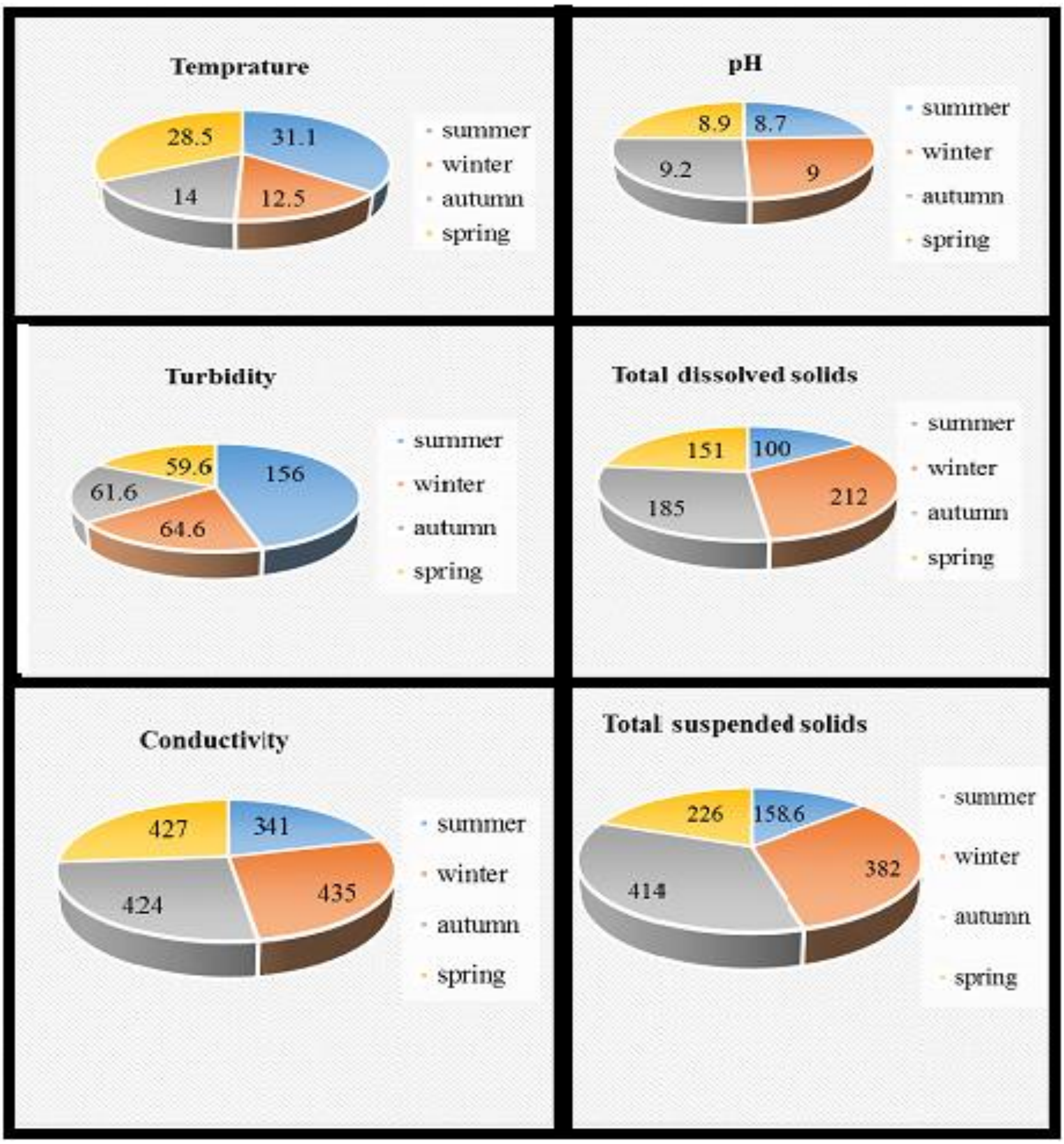

Fig. 1. Physico-chemical parameters of water in different seasons in the research sites.

Diversity of diatoms were measured on the basis of standard diversity indices. These diversity indices were Margalef index, Pielou's evenness index, Simpson's index and Shannon-Wiener index. In four seasons, maximum species richness (4.59 points) was recorded in summer followed by spring with value (3.81 points) while minimum species richness (1.29 points) was recorded in spring followed by autumn with value (2.73 points).

Species evenness (0.95 points) was maximum in summer followed by spring with value (0.94 points) while it was minimum (0.93 points) in both winter and autumn. Maximum species dominance (0.09 points) was recorded in spring followed by summer with value (0.04 points) while minimum species dominance (0.03 points) was recorded in autumn followed by winter with value (0.02 points).

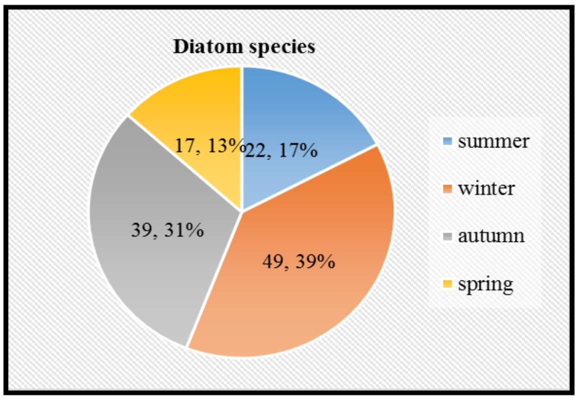

Fig. 2. Diversity of diatoms in different seasons in the research sites.

The highest diversity indices in summer and spring may attributed to lack or the presence small quantity of pollution in these two seasons. Al-Jizani (2005) stated that diversity of algal species decreases with pollution. Shannon-Wiener index value of the algal species can be used to monitor the pollution status of the water. Value < 1 indicated highest pollution, value ranged 1–3 indicated moderate pollution while value > 3 suggested that the water would be clean. Shannon-Wiener index value for the water of district Mardan was ranged from 2.32 to 3 points indicated that it was moderately polluted. Highest value (3.01 points) for Shannon-Wiener index was recorded in summer followed by spring with value (2.9 points) while lowest value (2.32 points) for Shannon-Wiener index was recorded in winter followed by autumn with value (2.64 points). This may be attributed to the increased concentration of industrial and agricultural effluents in the water that rich with nutrients (Table 1).

Statistical analysis showed that the species of diatoms in summer represent non-significant relationship with that of winter and autumn and significant relationship with species occurred in spring (Table 3). They showed positive correlation with species of winter and in spring and negative correlation with species occurred in autumn. Similarly, the species present in winter showed non-significant relationship with that of autumn and spring. They showed positive correlation with species of spring and negative correlation with species occurred in autumn. The diatoms species present in autumn showed non-significant relationship and negative correlation with diatoms occurred in spring.

Factors like temperature and total dissolved solids were highly significant while pH have only a significant effect on the growth of diatoms. While all other factors had non-significant effect on their growth. They showed positive correlation with total dissolved solids, electrical conductivity and total suspended while negatively correlated with temperature, pH and turbidity.

Conclusion

Physicochemical parameters and diatoms characteristics in the research area showed seasonal variation. Distribution of the diatoms species in the water bodies was strongly influenced by the physicochemical properties of the water, such as light availability, temperature, turbidity, concentration of dissolved oxygen and nutrients etc.

Maximum number of diatoms species were reported in winter followed by autumn. It was concluded that there was a rapid accumulation of organic wastes and other pollutants in the water of these two seasons there by increasing the number of diatoms species. By comparing the diversity of diatoms species in different seasons, in summer and spring lesser number of species were reported. This fact may be attributed to the presence of large number of sediments in the water causing turbidity, reduced light penetration by limiting the developing of diatoms species.

Recommendations

Water of the district Mardan did not consider to be potable and fit for consumption. Therefore, it should be subjected to suitable control measurements before it can be used for consumption.

The main causal agent that loading the water with nutrients is human being making it unfit for other consumption. If proper care is not taken, water of district Mardan is very soon dominated only by algal species making it unfit for the consumption of other phytoplankton.

Diatoms are excellent indicators of the water quality especially for nutrients of organic nature, dissolved oxygen and pH concentrations.

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