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EFFECT OF WATER QUALITY ON THE ALGAL DIVERSITY; A CASE STUDY FROM TANDA DAM AND SELECTED STREAMS OF DISTRICT KOHAT AND HANGU, PAKISTAN

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Abstract

In this study, 94 algae taxa were isolated and identified from 137 samples collected from 6 sampling stations along the banks of 1 river, 4 streams and 1 dam in District Kohat and Hangu. The algal taxa comprised 39 genera, 31 families, 18 orders, 7 classes, and 4 phyla. 15 genera and 32 species represented Bacillariophyta, Charophyta 7 genera and 33 species, Chlorophyta 10 genera and 15 species and Cyanophyta 7 genera and 14 species. The highest number of species were contributed by *Cymbella* (7 sp.), *Spirogyra* (15 sp.), *Ulothrix* (4 sp.) and *Merismopedia* (4 sp.). In the sampling sites, the highest number of species were found in Tanda Dam (79 sp.), followed by Kohat River (73 sp.), Jabi Toi (67 sp.), Khanki Toi (65 sp.) and Alizai Toi (64 sp.). However, the lowest number of species (3) were found in Shanga Toi (61). Diversity analysis indicated that the highest species richness (Margalef Index), species dominance (Simpson Index) and species evenness (Brillouin Evenness Index) were found in Tanda Dam (13.99, 0.988 and 3.804, respectively). Assessment of physicochemical parameters of water quality showed that water temperature ranged from 21.3ºC to 22.5ºC, pH from 7.63 to 8.25, Oxidation Reduction Potential (mV) from 73.3 to 89.4, Electrical Conductivity (µS/cm) from 493 to 752, Resistivity (Ω-cm) from 1326 to 2028, Total Dissolved Solids (ppm) from 246 to 377, Salinity (psu) from 0.24 to 0.37, Dissolved Oxygen (mg/L) from 23.76 to 45.31, Chloride (mg/L) from 184 to 284, Sodium (mg/L) from 28.4 to 84.7, Carbonic Acid (mg/L) from 7.1 to 9.2 and Total Hardness (mg/L) from 168 to 280. Canonical Correspondence Analysis (CCA) indicated that Electrical Conductivity (EC) negatively influenced the diversity of *Charophyta* species. In contrast, Carbonic Acid and Total Hardness positively influenced the diversity of *Bacillariophyta* species. Temperature, Resistivity and Dissolved Oxygen (DO) also negatively influenced the diversity of *Chlorophyta* species.

Key words: Water quality, Algal diversity, Tanda Dam, Kohat, Hangu, Pakistan.

Introduction

Algae is one of the most important varied groups of living organisms. Algae are considered the base of food web and food chain in aquatic life and play a significant role in sustaining aquatic ecosystems. They are found across rivers, oceans, lakes and ponds, on walls and soil (Ianora *et al.*, 2006). According to Bhaskar *et al.*, (2015) freshwater algal species were categorized by their habitats as benthos (attached to sediments), planktons (free-floating) and algae attached to stones, hydrophytes, mud, sand, lakes, reservoir rocks and sand. Khan *et al*., (2016) reported 73 freshwater algal flora related to 34 genera and 25 families and investigated the taxonomy and morphology of algal species in Mardan region. Similarly, Yaseen *et al*., (2016) conducted a thorough examination of the freshwater algal species from the Charsadda and Peshawar regions that belonged to the *Xanthophyta*, *Charophyta, Chrysophyta, Cyanophyta* and *Chlorophyta*. Din *et al*., (2017) reported various algal species from Peshawar Valley. Harsha *et al*., (2017) studied algal communities in four pond ecosystems from Southern Assam, North East India. A total of 74 non-filamentous and filamentous algal species related to *Chlorophyceae, Euglenophyceae, Bacillariophyceae* and *Cyanophyceae* were reported. Generally, the species of diatoms were recorded to be the maximum. Jaffer *et al*., (2018) taxonomically investigated the diversity of freshwater algae from some areas of Nasir Bagh and Lahore city up to the specie level. According to Mursaleen *et al*., (2018) algae play a significant part in human life and the formation of the environment. Khuram *et al*., (2019), have studied green algal species belonging to the division Chlorophyta in various areas of Pakistan. The study of Ullah *et al*., (2019) indicated that algae are a good source of nourishment and vigor for aquatic organisms. Among them, many unicellular algal species are of great significance. Previous investigations have revealed that algae play an essential role in material circulation, information transmission and energy flow in food webs of water bodies (Jia *et al*., 2019). Agha *et al*., (2020) reported 109 species of algae belonging to 54 in the agricultural fields of Balochistan, Pakistan.

Water quality can be measured by the dissolved carbon dioxide concentration and dissolved Oxygen. It can also be measured by the amount of its turbidity and the concentration of salts, Salinity in water. To determine water quality, microscopic algae, heavy metals, pesticides, and other contaminants may also be measured. The quality and quantity of water are influenced by the most important natural influences, i.e. climatic, hydrological and geological factors. A wide range of human and natural influences affects water quality. Human activities have a wide range of impacts on water quality, and they disrupt the environment. According to Jiang & Shen, (2007) algae are one of the best markers of water quality. Among other aquatic species inhabiting various depths, the benthic and planktonic algal community is significant because the water environment influences it. The ascendency of green algae and diatoms exists in comparatively clean and oligotrophic aquatic bodies, while blue-green algal bloom development specifies that the aquatic body is eutrophic or contaminated. Few survey report based on the assessment of water quality as an ecological parameter are available for India (Kumar & Pal, 2012).

Knowing how algal variety is impacted by variables including electrical conductivity, carbonic acid, total hardness, temperature, resistivity, and dissolved oxygen. It would be beneficial to gain ecological insights into why these factors influences particular species. Various chemical and physical aspects distress the growth of algae and community structure, like; pH, grazing and seasonality, carbonates, bicarbonates, magnesium, organic nutrients, Temperature, and light and calcium contents in water and are responsible for changes in morphology (Uddin *et al*., 2015). Some algal species can face stress, and certain species cannot assume themselves in stressful environments. Diverse species appear at different temperatures; for example, thermal blue-green algae propagate at 74ºC. Green algae propagate at less than 47ºC. Diatoms can propagate in temperatures up to 60 ℃. Light quality also produces variations in the persistence and growth of algal species. Alteration in pH can also disturb algae growth (Prescott, 1962). Members of *Cyanophyceae* can propagate above a pH8 and they cannot propagate at a pH less than 4. The diversity of algal species from low to high temperatures was also verified (Krupa, 2019).

The purpose of measuring algal diversity in an ecosystem is to judge a community's relationship with its members and the prevailing environmental conditions (Mateo-Cid *et al*., 2019). High species diversity is related to high community composition, environmental stability, predictability, and productivity. In the present study, we aimed to evaluate the effect of water quality and characterize the algal species in the diverse aquatic habitats across Tanda Dam, Kohat and Hangu regions of Pakistan.

Material and Methods

Collection, preservation and storage of algal samples: Algal specimens were collected with the help of forceps and by hand picking from water and squeezing and scrapping the aquatic vegetation and stones from the freshwater of Tanda Dam and Jabi Toi, Khanki Toi, Shanga Toi, Alizai Toi and Kohat River of District Kohat and Hangu (Fig. 1). The collected specimens were preserved in 4% formaldehyde solution to avoid degradation and stored in plastic bottles.

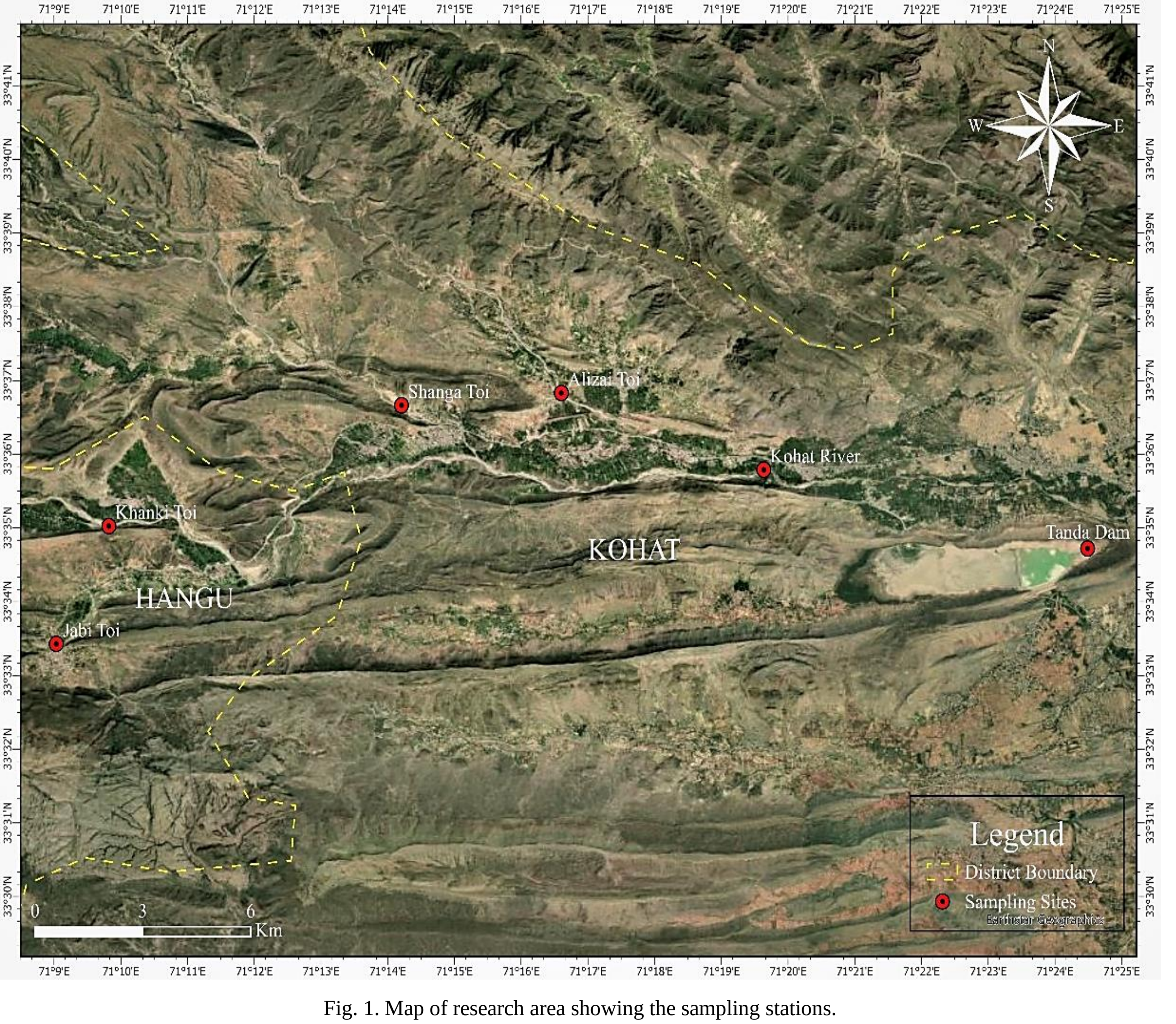

Fig. 1. Map of research area showing the sampling stations.

Laboratory processing and taxonomic identification: Slides of the collected algae were prepared and observed under the 10×, 20×, 40× and 100× objectives of the Microscope. Micromorphology of the algae was studied by the wet-mount method described by Edler & Elbrächter (2010). Standard literature of previous researchers were followed for their taxonomic identification (Matthews, 2016 a; b; Bellinger & Sigee, 2015; Wehr *et al*., 2015; Urbaniak & Gąbka, 2014; Prescott, 1962; Desikachary, 1959; Tiffany & Britton, 1952).

Diversity measurement: Abundance scores of algal species were recorded according to the six scores scale of Korde (1956), followed by Barinova *et al*., (2006). PAST V. 4.1 software was used for the evaluation of algal diversity. Species richness was measured by using the Margalef index. Species dominance was measured by using Simpson's Index. Species evenness was measured by using Brillouin Evenness Index.

Collection and determination of physicochemical properties of water: Water was collected in the bottles, and their Temperature, pH, Oxidation-reduction Potential, Electrical Conductivity, Resistivity, Total Dissolved Salts, Salinity, and Dissolved Oxygen were measured using HANNA HI98190 portable meter. Chloride, Sodium, Carbonic Acid and Total Hardness were measured using the standard method of Rice *et al*., (2012). The identification of specific factors influencing the diversity of algal species, such as Electrical Conductivity, Carbonic Acid, Total Hardness, Temperature, Resistivity, and Dissolved Oxygen, adds valuable insights for evaluating algal diversity.

Canonical correspondence analysis (CCA): Algal species and water quality data were subjected to CANOCO version 4.5 software for canonical correspondence analyses to assess the effect of water quality on algal diversity (ter Braak & Barendregt 1986).

Results

Making informed decisions about the conservation and management of aquatic ecosystems is made easier for researchers and environmental managers when they are aware of these ecological implications. It also sheds light on the potential effects that alterations in environmental factors, such as those brought on by human activity or climate change, may have on algal communities and, in turn, the larger ecosystem. A total of 94 algae taxa were isolated and identified from 137 samples collected from 6 sampling stations along the banks of 1 river, 4 streams and 1 dam in districts Kohat and Hangu. The algal taxa comprised of 39 genera, 31 families, 18 orders, 7 classes, and 4 phyla. The 4 phyla were: *Bacillariophyta*, *Charophyta*, *Chlorophyta* and *Cyanophyta* (Table 1).

Bacillariophyta was represented by 2 classes, 6 orders, 11 families, 15 genera and 32 species. *Charophyta* was represented by 2 classes, 3 orders, 5 families, 7 genera and 33 species. *Chlorophyta* was represented by 2 classes, 5 orders, 8 families, 10 genera and 15 species. *Cyanophyta* was represented by 1 class, 4 order, 7 family, 7 genera and 14 species (Fig. 2). In *Bacillariophyta*, the highest number of species were contributed by *Cymbella* (7 sp.), followed by *Navicula* (4 sp.), *Gyrosigma* (3 sp.), *Nitzschia* (3 sp.), *Achnanthidium* (2 sp.), *Gomphonema* (2 sp.), *Placoneis* (2 sp.), *Synedra* (2 sp.), *Cyclotella* (1 sp.) *Cocconeis* (1 sp.), *Fragilaria* (1 sp.), *Hantzschia* (1 sp.), *Neidium* (1 sp.), *Pinnularia* (1) and *Pleurosigma* (1). In Charophyta, the highest number of species were contributed by *Spirogyra* (15 sp.) followed by *Cosmarium* (8 sp.), *Zygnema* (4 sp.), *Chara* (2 sp.), *Mougeotia* (2 sp.), *Closterium* (1 sp.), and *Gonatozygon* (1 sp.). In *Chlorophyta*, the highest number of species were contributed by *Ulothrix* (4) followed by *Scenedesmus* (3 sp.), *Ankistrodesmus* (1 sp.), *Cladophora* (1 sp.), *Chlamydomonas* (1 sp.), *Desmodesmus* (1 sp.), *Monoraphidium* (1 sp.), *Oedogonium* (1 sp.), *Oocystis* (1 sp.) and *Tetraëdron* (1 sp.). In Cyanophyta, the highest number of species were contributed by *Merismopedia* (4 sp.) followed by *Chroococcus* (3 sp.), *Oscillatoria* (3 sp.), *Cyanothece* (1 sp.), *Phormidium* (1 sp.), *Spirulina* (1 sp.), and *Woronichinia* (1 sp.). The highest number of Bacillariophyta species were found in Kohat River (27 sp.), followed by Tanda Dam (26 sp.), Khanki Toi (23 sp.), Alizai Toi (21 sp.), Jabi Toi (19 sp.) and Shanga Toi (18 sp.) (Fig. 3).

The highest number of Charophyta species were found in Tanda Dam (29 sp.), followed by Jabi Toi (27 sp.), Khanki Toi (25 sp.), Alizai (24 sp.), Kohat River (23 sp.) and Shanga Toi (21 sp.) (Fig. 4). The highest number of Chlorophyta species were found in Kohat River (13), followed by Jabi Toi (12 sp.), Shanga Toi (11 sp.), Tanda Dam (11 sp.), Khanki Toi (10 sp.) and Alizai Toi (9 sp.) (Fig. 5). The highest number of Cyanophyta species were found in Tanda Dam (13 sp.), followed by Shanga Toi (11 sp.), Alizai Toi (10 sp.), Kohat River (10 sp.), Jabi Toi (9 sp.) and Khanki Toi (7 sp.) (Fig. 6). The highest number of algal species were found in Tanda Dam (79 sp.), followed by Kohat River (73 sp.), Jabi Toi (67 sp.), Khanki Toi (65 sp.) and Alizai Toi (64 sp.). However, the lowest number of species (3 sp.) were found in Shanga Toi (61 sp.) (Fig. 7).

According to the Margalef Index highest species richness was found in Tanda Dam (13.99) followed by Kohat River (13.15), Jabi Toi (12.45), Khanki Toi (11.92) and Alizai Toi (11.80). The lowest species richness was seen in Shanga Toi (11.35). The scores of the Margalef Index fluctuated between 11.35 to 13.99 (Fig. 8). According to Simpson Index highest species dominance was found in Tanda Dam (0.988) followed by Kohat River (0.987), Jabi Toi (0.986), Khanki Toi (0.985) and Alizai Toi (0.985). The lowest species dominance was seen in Shanga Toi (0.984). The scores of the Simpson Index fluctuated between 0.984 to 0.988 (Fig. 9). According to the Brillouin Evenness Index highest species of evenness was found in Tanda Dam (3.804) followed by Kohat River (3.731), Jabi Toi (3.607), Khanki Toi (3.605) and Alizai Toi (3.580). The lowest species evenness was seen in Shanga Toi (3.538). The scores of the Brillouin Evenness Index fluctuated between 3.538 to 3.804 (Fig. 10).

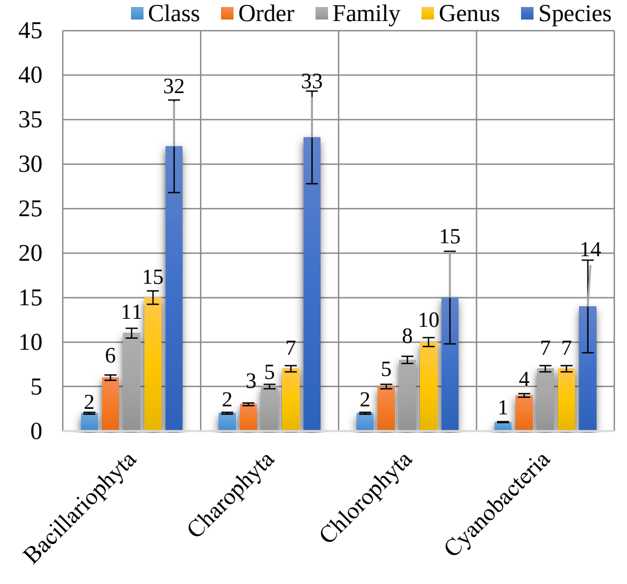

Fig. 2. Distribution of Algae in taxonomic groups.

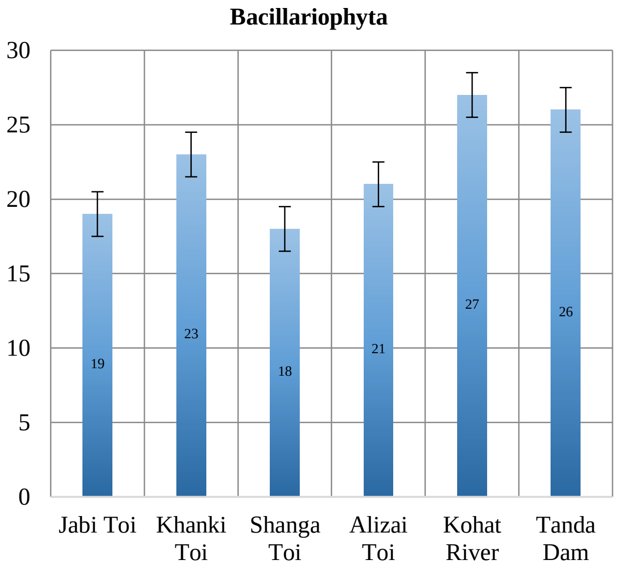

Fig. 3. Distribution of Bacillariophyta species over sampling sites.

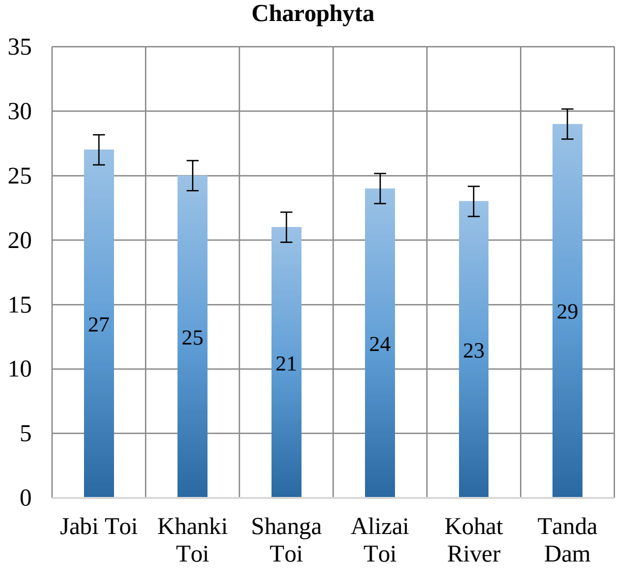

Fig. 4. Distribution of Charophyta species over sampling sites.

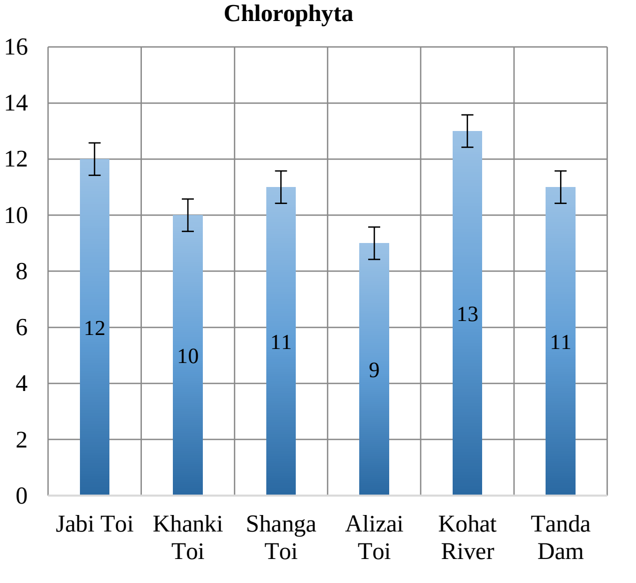

Fig. 5. Distribution of Chlorophyta species over sampling sites.

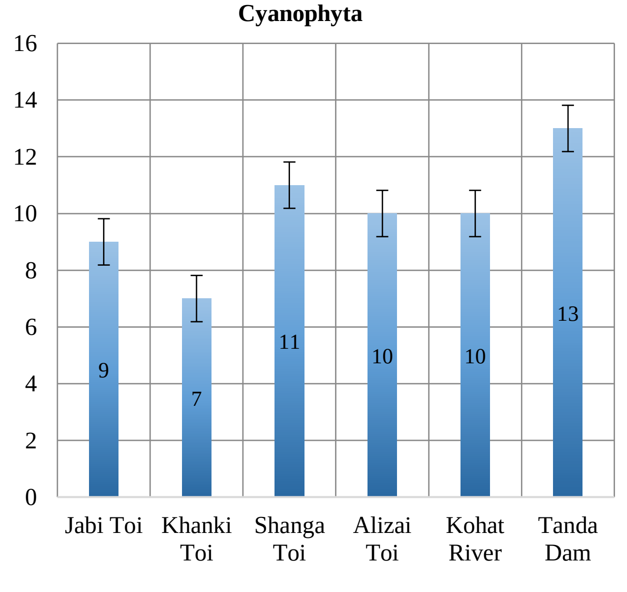

Fig. 6. Distribution of Cyanophyta species over sampling sites.

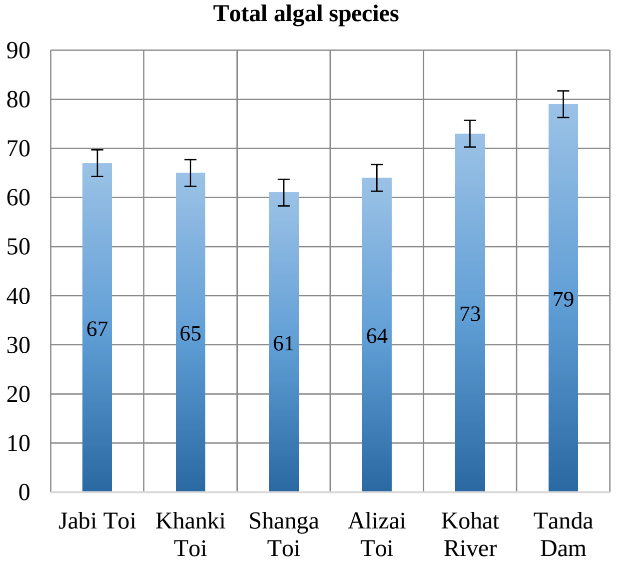

Fig. 7. Distribution of Algal species over sampling sites.

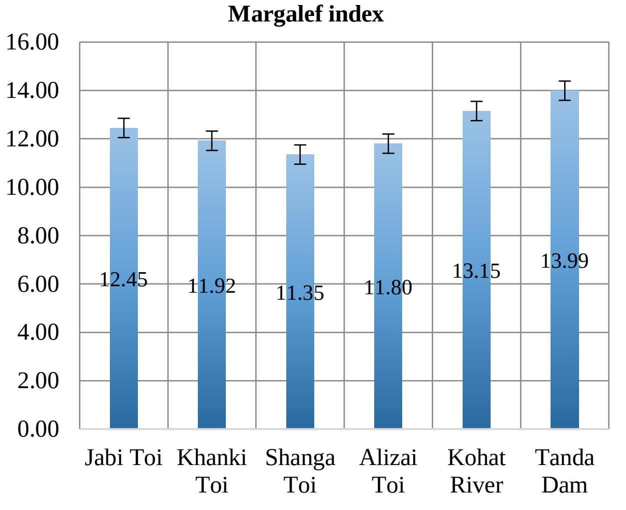

Fig. 8. Species richness according to Margalef index.

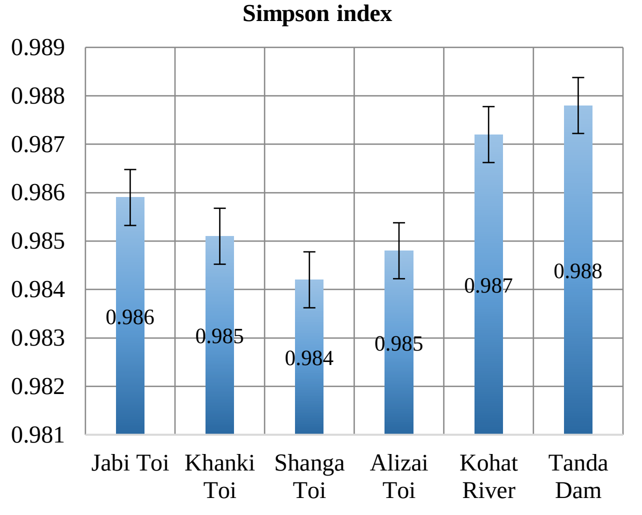

Fig. 9. Species dominance according to Simpson index.

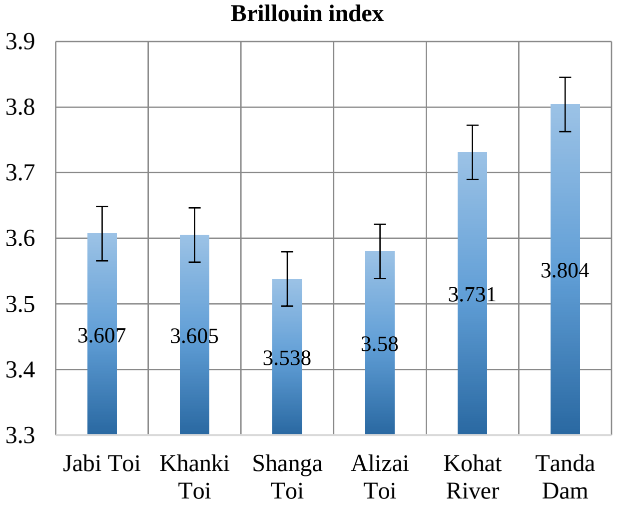

Fig. 10. Species evenness according to Brillouin evenness index.

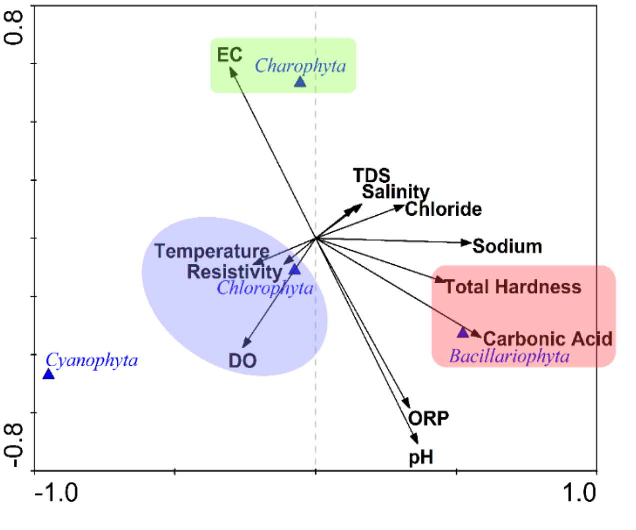

Fig. 11. Effect of physicochemical parameters of water on algal diversity.

Table 1. Distribution of algae in taxonomic groups.

S. No.	Phylum	Class	Order	Family	Genus	Species
1	Bacillariophyta	2	6	11	15	32
2	Charophyta	2	3	5	7	33
3	Chlorophyta	2	5	8	10	15
4	Cyanobacteria	1	4	7	7	14
Total	**4**	**7**	**18**	**31**	**39**	**94**

Table 2. Physicochemical parameters of water.

S. No.		Jabi Toi	Khanki Toi	Shanga Toi	Alizai Toi	Kohat River	Tanda Dam
1.	Temperature	22.5	21.3	22.1	22.5	22.4	21.3
2.	pH	7.64	8.05	8.12	7.63	8.25	7.84
3.	ORP	78.6	73.3	74.2	77.3	89.4	77.6
4.	EC	752	502	493	672	533	628
5.	Resistivity	1326	1988	2028	1634	1428	1782
6.	TDS	377	251	246	314	356	267
7.	Salinity	0.37	0.25	0.24	0.31	0.35	0.26
8.	DO	31.34	34.17	41.89	23.76	35.87	45.31
9.	Total Hardness	200	280	256	198	245	168
10.	Chloride	284	234	224	213	276	184
11.	Sodium	28.4	84.7	45.3	38.9	47.2	63.8
12.	Carbonic Acid	7.1	9.2	8.3	7.8	8.4	8.1

Water temperature (ºC) ranged from 21.3ºC to 22.5ºC (Table 2). The highest water temperature was recorded in Alizai Toi and Jabi Toi (22.5ºC) followed by Kohat River (22.4ºC), Shanga Toi (22.1ºC), Khanki Toi (21.3ºC) and Tanda Dam (21.3ºC). pH of the water ranged from 7.63 to 8.25 (Table 2). The highest pH of water was recorded in Kohat River (8.25) followed by Shanga Toi (8.12), Khanki Toi (8.05), Tanda Dam (7.84), Jabi Toi (7.64) and Alizai Toi (7.63). The oxidation Reduction Potential (mV) of water ranged from 73.3 to 89.4 (Table 2). The highest ORP (mV) of water was recorded in Kohat River (89.4) followed by Jabi Toi (78.6), Tanda Dam (77.6), Alizai Toi (77.3), Shanga Toi (74.2) and Khanki Toi (73.3).

Electrical Conductivity (µS/cm) of water ranged from 493 to 752 (Table 2). The highest Electrical Conductivity (µS/cm) of water was recorded in Jabi Toi (752) followed by Alizai Toi (674), Tanda Dam (628), Kohat River (533), Khanki Toi (502) and Shanga Toi (493). The resistivity (Ω-cm) of water ranged from 1326 to 2028 (Table 2). The highest Resistivity (Ω-cm) of water was recorded in Shanga Toi (2028) followed by Khanki Toi (1988), Tanda Dam (1782), Alizai Toi (1634), Kohat River (1428) and Jabi Toi (1326). Total Dissolved Solids (ppm) of water ranged from 246 to 377 (Table 2). The highest Total Dissolved Solids (ppm) of water was recorded in Jabi Toi (377), followed by Kohat River (356), Alizai Toi (314), Tanda Dam (267), Khanki Toi (251) and Shanga Toi (246).

The Salinity (psu) of water ranged from 0.24 to 0.37 (Table 2). The highest Salinity (psu) of water was recorded in Jabi Toi (0.37) followed by Kohat River (0.35), Alizai Toi (0.31), Tanda Dam 90.26), Khanki Toi (0.25) and Shanga Toi (0.24). Dissolved Oxygen (mg/L) of water ranged from 23.76 to 45.31 (Table 2). The highest Dissolved Oxygen (mg/L) of water was recorded in Tanda Dam (45.31) followed by Shanga Toi (41.890, Kohat River (35.87), Khanki Toi (34.17), Jabi Toi (31.34) and Alizai Toi (23.76). Chloride (mg/L) of water ranged from 184 to 284 (Table 2). The highest Chloride (mg/L) of water was recorded in Jabi Toi (284) followed by Kohat River (276), Khanki Toi (234), Shanga Toi (224), Alizai Toi (213) and Tanda Dam (184). Sodium (mg/L) of water ranged from 28.4 to 84.7 (Table 2). The highest Sodium (mg/L) of water was recorded in Khanki Toi (84.7) followed by Tanda Dam (63.8), Kohat River (47.2), Shanga Toi 945.3), Alizai Toi (38.9) and Jabi Toi (28.4). Carbonic Acid (mg/L) of water ranged from 7.1 to 9.2 (Table 2). The highest Carbonic Acid (mg/L) of water was recorded in Khanki Toi (9.2) followed by Kohat River (8.4), Shanga Toi (8.3), Tanda Dam (8.1), Alizai Toi (7.8) and Jabi Toi (7.1). Total Hardness (mg/L) of water ranged from 168 to 280 (Table 2). The highest Total Hardness (mg/L) of water was recorded in Khanki Toi (280) followed by Shanga Toi (256), Kohat River (245), Jabi Toi (200), Alizai Toi (198) and Tanda Dam (168).

Altogether 12 water quality variables and algal species richness represented by four phyla were subjected to Canonical Correspondence Analysis (CCA) to evaluate the effect of water quality on algal diversity. The total inertia or variation in species data was 0.011. The eigenvalue of axis-I was 0.005, axis-II (0.004), axis-III (0.002) and axis-IV (0.000). The species environment correlation of axis-I was (1), axis-II (1), axis-III (1) and axis-IV (0). The cumulative percentage variance of species with axis-I was (43.7), axis-II (77.6), axis-III (100) and axis-IV (0). While the cumulative percentage variance of species-environment relation with axis-I was (43.7), axis II (77.6), axis III (100) and axis IV (0) (Table 2). pH (r=0.3634), ORP (r=0.3341), TDS (r=0.1364), Salinity (r=0.165), Chloride (r=0.3156), Sodium (r=0.5525), Carbonic Acid (r=0.588) and Total Hardness (r=0.4614) were positively correlated with axis-I while Temperature (r=-0.2226), EC (r=-0.3052), Resistivity (r=-0.1137) and DO (r=-0.2591) were negatively correlated with axis-I. EC (r=0.5889), TDS (r=0.1054), Salinity (r=0.1173) and Chloride (r=0.1139) were positively correlated with axis-II while Temperature (r=-0.0904), pH (r=-0.7065), ORP (r=-0.5834), Resistivity (r=-0.0895), DO (r=-0.3767), Sodium (r=-0.0161), Carbonic Acid (r=-0.34090 and Total Hardness (r=-0.1512) were negatively correlated with axis-II.

Canonical Correspondence Analysis (CCA) indicated that Electrical Conductivity (EC) negatively influenced the diversity of Charophyta species. In contrast, Carbonic Acid and Total Hardness positively influenced the diversity of Bacillariophyta species. Temperature, Resistivity and Dissolved Oxygen (DO) also negatively influenced the diversity of Chlorophyta species (Fig. 11).

Discussion

Various studies have reported algal species from aquatic environments in Pakistan, including Hussain *et al*., (2010), Shuaib *et al*., (2014) and Jang *et al*., (2014). Pattanaik & Adhikary, (2002) revealed 16 taxa under 8 genera of *Cyanophyceae* from monuments and archeological locations of India. Thirty-one taxa of *Bacillariophyceae*, *Cyanophyceae* and *Chlorophyceae* from Nainital, Uttaranchal reported by Srivastava, (2010). All these studies revealed a great resemblance to our research work. The most common genus in terms of species was Spirogyra 15 species belonging to division Charophyta. Our results are in accordance with the results of Zaman *et al*., (2009), they surveyed different freshwater habitats of the Peshawar Valley and reported 17 species of Spirogyra. We reported *Cosmarium* 8 species belonging to Division *Charophyta*. Our results are accordance with the work of Ghazala *et al*., (2012), where they recognized diverse species of *Cosmarium* taxonomically. Ten species of *Cosmarium* (*Desmidiophyceae*) were recorded for the first time from diverse freshwater localities of Dera Ghazi Khan, a district of Southern Punjab.

Among members of *Bacillariophyta,* Acnanthidium has 2 species; *Acnanthidium crassum* and *Acnanthidium exigum. Acnanthidium crassum* have been reported from the moderately deep and wide streams of the Himalayas by Juttner *et al*., (2001). Simalrly, Potapova & Ponader, (2004) reported *Acnanthidium crassum* showing resemblance to our work. *Fragilaria*, *Hantzchia*, *Neidium*, *Pinnularia*, *Pleurosigma cocconies*, *cyclotella* belonging to Division *Bacillariophyta* has one specie each. *Gomphonema*, *Placonies* and *Synedra* have 2 species each, Gyrosigma, Nitzchia, and Navicula 3 species each, and *Cymbella* has 7 species. Ali *et al*., (2009b) reported twenty-nine genera of algae related to the phylum Bacillarophycota, including Pinnularia, Nitzschia, Cymbella and Navicula species, resembling our results. Additionally, Ghazala *et al*., (2012) described *Bacillariophyta* from diverse freshwater, supporting our results. In our research work Algal members belonging to Division Chlorophyta include *Ankitrodesmus*, *Chlamydomonas*, *Desmodesmus*, *Monoraphidium*, *Oedogonium*, *Oocystis* and *Tetraedron* one species. Scenedesmus 3 species. *Ulothrix* and *Zygnema* has 4 species. *Mougeotia* 2 species. The genus *Chara* was characterized by two species *Chara contraria* and *Chara vulgaris*. *Chara vulgaris* was also reported by Imtiaz *et al*., (2018) from Peshawar Valley, Khyber Pakhtunkhwa. Furthermore, Minhas *et al*., (2023) reported freshwater green filamentous alga belonging to class Chlorophyceae from ponds and lakes of Sindh. They discovered 31 types of Chlorophycean members from Riverin lakes and new waters. Among Cyanophyta *Chroococcus* 3 species, *Cyanotheca*, *Phormidium*, *Spirulina* and *Woronichinia* with one specie each, *Merismopedia* 4 species, *Oscillatoria* 3 species. Shahnaz *et al*., (2009) reported filamentous blue-green algae (Class *Cyanophyceae*) from different freshwater habitats containing nine genera. Zarina *et al*., (2010) also reported 211 species of blue-green algae from freshwater habitats in NWFP and Punjab of Pakistan. Results related to our three divisions are similar to the work of Khattak *et al*., (2005), who recorded 50 species of algae from the running water of Dandot Cement Company and identified 20 genera belonging to Bacillariophyceae, Chlorophyceae and Cyanophyceae. Barkatullah *et al*., (2013) explored 63 algal samples from rocks of Batkhela, including algal specimens belonging to Divisions *Bacillariophyta Chlorophyta* and *Cyanophyta*, supporting our results. Din *et al*., 2017 investigated many algal species from the Peshawar Valley. Ali *et al*., (2009a) verified freshwater algae of Karachi and his work was conceded to add evidence to the existing information about some members of Class *Bacillariophyceae*, *Chlorophyceae* and *Cyanophyceae* from fresh waters of Peshawar Valley.

Physicochemical parameters; Temperature, pH, oxidation-reduction potential, electrical Conductivity, total dissolved solids, Salinity, dissolved Oxygen, Chloride, Sodium, total Hardness and carbonic Acid were observed during the study period. The study of Jiang and Shen, (2007) support our results, where they revealed that water quality could be indicated with the help of algae because they respond rapidly to changes in the environmental conditions. The physicochemical properties of aquatic areas play a significant part in recurrent variations and algal diversity (Prakash *et al*., 2014). According to Misra *et al*., (2001), algal communities' existence was correlated with water's physicochemical properties. Altaf *et al*., (2019) studied the classification and identification of algal species relative to physicochemical parameters in Samanabad, Lahore, Pakistan, showing a resemblance to our work. In the present investigation, results showed that the temperature (21.3-22.5ºC) of water of both aquatic environments was tolerable and suitable for the growth of algal species. For the evaluation of pH, water samples were collected from a freshwater stream of Hangu and Tanda Dam Kohat varied 7.63-8.25, more or less alkaline. Borkar, (2015) stated that the ideal pH of water and soil that consistently helps aquatic life's growth ranged from 6.5-9.5 and 6.5 to 8.4. High pH is positively correlated with algal growth. No water body of the study area was acidic. pH up to 8.25 was noted, and the pH of water samples collected from Tanda Dam Kohat and the Freshwater stream in Hangu is slightly alkaline. Shah *et al*., (2016) reported different species belonging to Chlorophyta, Bacillariophyta and Cyanophyta from river Jindi and water quality's effect on District Charsadda's algal diversity. In the present study, dissolved oxygen was noted higher range 23.76-45.32 mg/L or above in both study sites, indicating low pollution and high productivity rates. The Salinity ranged between 0.24-0.37 psu in both research sites. These different ranges of Salinity showed variations in the diversity of the algal species.

Fresh water stream has salts ranging 0.37 psu, whereas the water sample of the Dam has 0.26 psu. Salinity stress may have essential effects on the growth of algal species. Algal diversity can be better understood by looking at variables including electrical conductivity, carbonic acid, total hardness, temperature, resistivity, and dissolved oxygen. Effective ecological management of aquatic ecosystems depends on knowing how these elements affect different algae species favorably or unfavorably. The electrical conductivity varied from 493-752 µS/cm at Tanda Dam Kohat and Freshwater streams in Hangu. Total Hardness ranged 168-280 mg/L in the selected research areas. Total dissolved solids in the research sites were 246-377mg/L, having little or no effect on algal growth as described by Brady *et al*., (2002). A rapid or great change in TDS can kill aquatic life, including algal species. The concentration of Chloride ions in water samples ranged between 284-284 mg/L, showing that water samples had unacceptable chloride levels that have also been reported in earlier studies (Khan *et al*., 2016). The concentration of Sodium in the water sample ranged between 28.4-84.7 mg/L. The standards of sodium concentrations were found within the acceptable limit in samples. Sodium is a nontoxic metal and has no negative effect on algal growth. These results are supported by the literature published by Khan *et al*., (2008) and Farid *et al*., (2012). Correspondence Analysis (CCA) indicated that Charophyta species' diversity were negatively influenced by Electrical Conductivity (EC), while Carbonic Acid and Total Hardness positively influenced the diversity of Bacillariophyta species. Temperature, Resistivity and Dissolved Oxygen (DO) also negatively influenced the diversity of Chlorophyta species.

Conclusion

The present study extensively cataloged and characterized the algae in diverse aquatic habitats across the Kohat and Hangu regions of Pakistan. Identifying 94 algal taxa spanning multiple phyla and their distribution patterns among various sampling locations provides crucial insights into the region's aquatic biodiversity. The dominance of certain genera such as *Cymbella*, *Spirogyra*, *Ulothrix*, and *Merismopedia* emphasizes their ecological significance within these aquatic environments. The interplay between algal diversity and physicochemical parameters underscores the complex relationship between these organisms and their environment. Our analysis highlights the varying influences of different parameters on specific algal groups. These findings not only advance our understanding of local ecosystems but also emphasize the importance of maintaining suitable water quality conditions for the preservation of these intricate algal communities.

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