Research Article

Effect of water quality on algal diversity in various sites of district Charsadda, Khyber Pakhtunkhwa (KPK)-Pakistan

Zahir Shah¹, Syed Zahir Shah¹, Muhammad Shuaib^{2*}, Khan Niaz Khan³, Tahir Khan⁴ and Fida Hussain^{3,5}

1. Department of Botany, Islamia College Peshawar, KP-Pakistan

2. School of Ecology and Environmental Science, Yunnan University, Kunming, Yunnan-China

3. Department of Biology, Edwards College Peshawar, KP-Pakistan

4. School of Life Sciences, Department of Botany, Yunnan University, Kunming-China

5. Department of Botany, Qurtaba University Peshawar-Pakistan

*Corresponding author's email: zeyadz44@yahoo.com

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Abstract

Seasonal distribution of algae determined in three research sites of river Jindi, Pakistan. Samples of 5 classes having 46 families, 54 genera, 107 spp., out of 107 spp. 46.72% collected in winter, 53.27% in summer seasons. The most abundant class *Bacillariophyta* with 24 genera, 46 spp. (46.9%), followed by *Chlorophyceae* with 18 genera, 33 spp. (30.8%), *Cyanophyceae* with 8 genera, 20 spp. (18.69%), *Euglenophyceae* with 3 genera, 6 spp. (5.60%), *Charophyceae* with 1 genus, 1 spp. (0.93%) in both seasons. In winter season, abundant class *Bacillariophyceae* with 14 genera, 24 spp. (48.97%), followed by *Chlorophyceae* with 11 genera, 22 spp. (44.89%), *Euglenophyceae* 2 genera, 1 spp. *Charophyceae* with 1 genus, 1 spp. (2.04%). In summer season, abundant class *Bacillariophyceae* with 10 genera, 22 spp. (38.59%), followed by *Cyanophyceae* 7 genera, 19 spp. (33.33%), *Chlorophyceae* 7 genera, 11 spp. (19.29%), *Euglenophyceae* 2 genera, 5 spp. (8.77%). The genus *spirogyra* is abundant among all sites, shows wide range ecological amplitude, thus found in different habitats. The diatom, bluegreen algae dominated, summer season (38.59%), and (33.33%) respectively, followed by green algae 19.29%). The diatoms registered high numbers in summer (48.97%), winter (38.59%) respectively. The pH of water samples varied 7.35-8.89, more or less alkaline in nature. High pH is positively correlated with algal growth. Turbidity ranged from 5-18 NTU. High turbidity decreases oxygenation, high penetration. TDS, TSS were positively correlated with number of species. TDS were 212.9-297.9 mg/L. The amount of TSS varied from 17-37 mg/L, EC value 365-812 μ S/cm. The optimum amount of EC favours growth, distribution of algae. Salinity value 0.5-2.1 mg/L suitable for the growth, distribution of algae. The total CO₂ in water was 7.04-54.08 shows more respiration, results algal growth. The amount of DO varied from 2.5-3.8 mg/L. Nitrate as N₂ content 0.05-1.8 mg/L, Phosphate as TP range from 0.5-1.4 mg/L and Ca Hardness as CaCO₃ 227-440 mg/L.

Keywords: Algae; Dissolved CO₂; DO; EC; TSS; TDS

Introduction

Algae are the simplest autotrophic plants without roots stem or leave and exist in

variable sizes. Algae are abundant in every aquatic ecosystem in this biosphere [1]. As primary producers, they are inhabitants of

moist, freshwater; brackish water and marine environments [2]. There are microscopic algal cells which cause water to look green, while some of the algae are macroscopic with longer and branchy structures which make them visible to the naked eye. In lake ecosystems, planktonic algae live in the open water and periphytic algae live in the littoral (benthic) areas usually attached to rock substrates. Algae possess chlorophyll-a as their primary photosynthetic pigment. Their sexual organs are not enclosed within sterile protective coverings [1, 3]. Algal flora is also considered a good indicator of water pollution [4]. Phytoplankton inhabiting the water body reflects the average ecological condition and may be used as an indicator of water quality [5]. Ohashi, [6] reported the harmful effect of nitrogen, DO, PO and pH increases due to the algal flora attached to the bottom of Shife River in Japan. Hall, [7] reported the effect of wastewater containing nitrogen on the aquatic community composition and variation with land settlement and concentration of nitrogen in sewage with urbanization. The extensive use of pesticides on agricultural land and industrial effluents may lead to their presence in fresh waters environments [8]. Consequently increased water temperatures are associated with both eutrophication and Cyanobacteria blooms [9, 10]. One main cause of the eutrophication, defined as organic matter production enhancement, is high dissolved nutrient concentration [11, 12]. The algal distribution and organic pollution in fifteen sites in rural and temple pond in Balrampur were studied for algae belonging to *Chlorophyceae*, *Cyanophyceae*, *Euglenophyceae*, and *Bacillariophyceae* [13]. When the water is alkaline and minerals are in abundance it increased the algal growth. Filamentous algae were found more prevailing during the spring season, while diatoms were four out of five in epilithic species. The variation in water quality is mainly responsible for the communities' determination [14].

Water quality is a term used to express the suitability of water to sustain various uses or processes. Any particular use will have certain requirements for the physical, chemical or biological characteristics of water, and can be measured by several factors such as the concentration of dissolved O₂, and CO₂, the amount of salt, or the amount of material suspended in water (turbidity). In some water bodies, the concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants may also be measured to determine water quality. Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic since these affect the quantity and the quality of water available [12, 15, 16]. A variety of physical and chemical variables will control the level of stratification. Thermal stratification then has a direct impact on the spatial and temporal distribution of the algae and the remainder of the biology of the lake [17, 18]. Taxonomic groups with a small upper size range are also likely to be regulated strongly in lakes with intermediate and high nutrient levels, which support herbivorous zooplankton populations [18]. It is also known that many of the dinoflagellates such as *Ceratium* and *Phormidium* with their amour plate-like exterior are less prone to grazing than many other species [19]. The current paper aims to cover the algal diversity, water qualities, EC, Dissolved CO₂, DO, TSS and TDS in local area district Charsadda, KPK, Pakistan.

Materials and methods

The present study comprises of the Identification, classification, and relative distribution of algal flora with respect to the effect of water quality from three different sites of the river Jindi, District Charsadda Khyber Pakhtunkhwa in two seasons (summer and winter). The study aims to explore algal diversity found in three different sites in two different seasons of the year with different physioco-chemical

parameters of water of river Jindi, in which existent algal flora was inhibited. The study of algal flora was based on comparative bases. The comparative investigations of algal flora of different sites were mainly the nature and location of different sites as less

polluted water, slightly polluted water and highly polluted water. Three main sites of river Jindi which were selected for the present study was Harichand Ziam Bridge, Sherpao Kanever Bridge, and Umerzai Cheena site (Figure 1).

Figure 1. Map Showing collection site of river Jindi, District Charsadda, Pakistan

Sampling of species

Samples of algae and water were collected from the research sites/ locations. For this purpose, visits were made to collect the algae in summer and winter seasons. The collections were made by hand picking, squeezing and scraping the aquatic flora by the planktonic net, knife, glass slides, handpicking, squeezing and scratching of stones/ wood/plant material in selected sites of river Jindi. Seasonal distributions of algae within and among the site were determined by recording the presence of species in 10 samples from each site. The collected samples of algae and water from

collection sites were brought to the laboratory of Botany Department Islamia College Peshawar in standard size bottles.

Preservation of species

The collected algal samples were transferred to collect plastic bottles and immediately preserved in 4% formalin solution. Temperature and pH of water samples were noted on spot of research areas with the help of digital portable pH cum temperature meter at the time of collection.

Identification of the species

Various groups of algae were identified using floristic literature. Identification was

made with the help of Prescott, [20], Tiffany and Britton, [21], Faridi, [22], Shah, [23] and Shameel, [2]. Pictures were taken with the help of camera fixed on a microscope (Model Olympus BH₂). Water samples were collected from research sites in clean bottles and were analyzed for physico-chemical Parameters at PCSIR Laboratories, Peshawar. Algal specimens were stored in the Herbarium of the Department of Botany, Islamia College Peshawar. Algae type, counts and species identification in addition to the physiochemical parameters (pH, Temperature Turbidity, EC, Dissolve CO₂, DO, TSS, TDS, Nitrogen content, TP, Total Hardness as CaCO₃) were conducted according to the Standard Methods of Examination of Water and Waste Water

Results

A total of 107 species of different groups of algae were isolated both in winter and summer seasons from the research sites. Out of 107 species, 50 species were isolated in winter season which constitutes 46.72 percent of the total number while 57 species were isolated in the summer season; this constitutes 53.27 percent of the total species isolated. The most abundant class in both seasons was *Bacillariophyceae* with 24 genera and 46 species (46.9%), *Chlorophyceae* with 18 genera and 33 species (30.8%), class *Cyanophyceae* with 8 genera and 20 species (18.69%), class *Euglenophyceae* with 3 genera and 6 species (5.60%), class *Charophyceae* with one genus and one species (0.93%) (Table 1).

In winter season the most abundant class was *Bacillariophyceae* with 14 genera and 24 species (48.97%) followed by *Chlorophyceae* with 11 genera and 22 species (44.89%), *Euglenophyceae* and *Charophyceae* with 1 species each (2.04%).

In the summer season, the most abundant class was *Bacillariophyceae* with 10 genera and 22 species (38.59%), followed by *Cyanophyceae* with 7 genera and 19 species (33.33%), *Chlorophyceae* with 7 genera and 11 species (19.29%) and *Euglenophyceae* with 2 genera and 5 species (8.77%) (Table 1).

The genera which were found in both seasons were *Spirogyra*, *Euglena*, *Cymatopleura*, *Nitzschia*, *Diatoma*, *Synedra*, *Navicula*, *Hydrodictyon*, *Gomphonema* and *Fragillaria*. The most abundant genus among them was *Spirogyra* found at all sites is an apparent justification that this genus may have wide ecological amplitude and therefore occurs in different habitats.

The genera which were only found in summer season were *Oscillatoria*, *Anabaena*, *Phormidium*, *Merismopodium*, *Aphanocapsa*, *Gloecapsa*, *Spirulina*, *Oedogonium*, *Ankistrodesmus*, *Haematococcus*, *Chlorococcum*, *Basiciadia*, *Pinnularia*, *Achanthes*, *Phacus*, and *Euglena*. The most abundant genus was *Oscillatoria* with 6 species followed by *Anabaena* with 4 species (Table 1).

The result of the summer collection *Cyanophyceae*

A total of 7 genera with 19 species of *Cyanophyceae* were identified from the collection sites samples from Jindi river of district Charsadda during the summer season of 2014. The most common genus was *Oscillatoria* with 7 species (36.84%) of the total algal flora identified. the other genera were *Anabaena* with 4 species (21.05%). The other genera were *Phormidium*, *Merismopedia*, and *Gleocapsa* with 2 species each (10.52%) while *Spirulina* and *Aphanocapsa* with 1 species each (5.26%) (Figure 2, Table 2).

Table 1. Various genus occurrences at three selected sites with the different water quality of winter season

S. No.	Genus	Species	Occurrence / sites		
			1	2	3
1	<i>Spirogyra</i>	<i>S. pseudoforidiana</i>	—	+	+
		<i>S. daedaleoides</i>	+	+	+
		<i>S. funtiformis</i>	+	—	+
		<i>S. tetrapla</i>	+	+	—
		<i>S. weberii</i>	+	+	+
		<i>S. pratensis</i>	+	+	—
2	<i>Closterium</i>	<i>Closterium diana</i>	+	+	—
		<i>C. leibleinii</i>	+	+	+
		<i>C. littoralis</i>	+	+	+
		<i>C. moniliferum</i>	+	+	+
3	<i>Cladophora</i>	<i>Cladophora glomerata</i>	+	—	—
		<i>C. crispata</i>	+	—	—
4	<i>Ulothrix</i>	<i>Ulothrix subconstricta</i>	+	+	—
		<i>U. tenuissima</i>	+	+	—
5	<i>Hyalotheca</i>	<i>Hyalotheca mucosa</i>	+	+	+
6	<i>Hydrodictyon</i>	<i>H. reticulatum</i>	+	+	—
7	<i>Schizomeris</i>	<i>S. leibleinii</i>	+	+	—
8	<i>Chlorella</i>	<i>Chlorella vulgaris</i>	+	—	+
9	<i>Tetraedron</i>	<i>Tetraedron muticum</i>	+	—	+
		<i>T. constitutum</i>	+	+	+
10	<i>Chlamydomonas</i>	<i>C. pyreneideum</i>	+	+	—
		<i>C. sphagnicola</i>	+	—	+
11	<i>Diatoma</i>	<i>Diatoma anceps</i>	+	+	—
		<i>D. elongatum</i>	—	+	—
		<i>D. hiemale</i>	+	+	—
12	<i>Synedra</i>	<i>Synedra ulna</i>	+	+	+
		<i>S. ulna ver aequalis</i>	—	+	—
		<i>S. ulna ver danica</i>	+	+	—
		<i>S. rumpens</i>	+	+	—
13	<i>Cymbella</i>	<i>Cymbella turgid</i>	+	—	+
		<i>C. cistula</i>	—	+	+
		<i>C. tumida</i>	+	+	—
14	<i>Gyrosigma</i>	<i>G. eximium</i>	+	—	+
		<i>G. kuetzingii</i>	—	+	+
		<i>G. spencenii</i>	+	+	—
15	<i>Cocconeis</i>	<i>C. placentula</i>	+	+	—
16	<i>Stauroneis</i>	<i>S. anceps</i>	+	+	—
17	<i>Melosira</i>	<i>M. granulata</i>	—	+	—
18	<i>Gomphonema</i>	<i>G. alivaceum</i>	—	+	—
19	<i>Nitzschia</i>	<i>N. linearis</i>	+	+	—
20	<i>Cymatopleura</i>	<i>C. solea</i>			
21	<i>Rhoicosphenia</i>	<i>R. currata</i>	—	+	+
22	<i>Euglena</i>	<i>E. viridis</i>	+	+	—
23	<i>Chara</i>	<i>C. vulgaris</i>	+	—	—

Figure 2. Genera wise percentage of Cyanophyceae in river Jindi, Charsadda District during summer season-2014

Table 2. A total number of algae, their %age and total no. of species collected in summer from three different sites of river Jindi at Charsadda KP-Pakistan

S. No.	Class	Order	Family	Genus	No of Spp	Spp%age
1	Cyanophyceae	Hormogonales	Oscillatoriaceae	<i>Oscillatoria</i>	6	9.75
		//	//	<i>Phormidium</i>	2	4.87
		//	//	<i>Spirulina</i>	1	2.43
		Synechoccales	Merismopodiaceae	<i>Aphanocapsa</i>	1	2.43
		//	//	<i>Merismopedia</i>	2	4.87
		Hormogonales	Nostacaceae	<i>Anabaena</i>	4	7.31
		Chroococcales	Chroococcaceae	<i>Gloeocapsa</i>	2	2.43
2	Bacillariophyceae	Surirealales	Surirellaceae	<i>Cymatopleura</i>	3	4.87
		Bacillariales	Bacillariaceae	<i>Nitzschia</i>	3	7.31
		Fragilariales	Fragilariaceae	<i>Fragilaria</i>	2	4.87
		//	//	<i>Synedra</i>	2	4.87
		Naviculales	Naviculaceae	<i>Navicula</i>	2	4.87
		Achanthales	Cocconeidaceae	<i>Cocconeis</i>	1	2.43
		Naviculales	Pinnulariaceae	<i>Pinnularia</i>	3	7.31
		Fragilariales	Fragilariaceae	<i>Diatoma</i>	3	7.31
		Cymbellales	Gomphonemataceae	<i>Gomphonema</i>	2	4.87
		Mastogloiales	Achanthaceae	<i>Achanthes</i>	1	2.43
3	Chlorophyceae	Chlorococcales	Hydrodictyaceae	<i>Hydrodictyon</i>	1	2.43
		Oedogoniales	Oedogoniaceae	<i>Oedogonium</i>	1	2.43
		//	Oosystaceae	<i>Ankistrodesmus</i>	1	2.43
		Chlamydomonales	Haematococcaceae	<i>Haematococcus</i>	1	2.43
		Chlamydomonales	Chlorococcaceae	<i>Chlorococcum</i>	1	2.43
		Cladophorales	Cladophoraceae	<i>Basicladia</i>	1	2.43
		Conjugales	Zygnemaceae	<i>Spirogyra</i>	5	4.87
4	Euglenophyceae	Euglenales	Euglenaceae	<i>Phacus</i>	2	4.87
		//	//	<i>Euglena</i>	3	2.43
	Grand Total	18	21	26	57	99.78

Bacillariophyceae

A total of 10 genera with 22 species of Bacillariophyceae were reported from the collected samples of river Jindi district Charsadda during the summer season of 2014. The most common genera were *Cymatopleura*, *Nitzschia*, *Pinnularia* and

Diatoma with 3 species each (13.63%) followed by *Fragilaria*, *Synedra*, *Navicula* and *Gomphonema* with 2 species each (9.09%). While the less frequent genera were *Cocconeis* and *Achanthes* with 1 species each (4.54%) (Figure 3, Table 2, 3).

Figure 3. Genera wise percentage of Bacillariophyceae in river Jindi, Charsadda District during summer season-2014

Table 3. Various Genus occurrences at three selected sites with the different water quality of summer season

S. No.	Genus	Species	Occurrence / Site		
			1	2	3
1	<i>Oscillatoria</i>	<i>Oscillatoria chlorine</i>	—	+	+
		<i>O.formosa</i>	—	+	+
		<i>O. curviceps</i>	—	+	—
		<i>O. granulate</i>	—	+	+
		<i>O. terebriformis</i>	—	+	+
		<i>O. chlorine</i>	—	+	—
2	<i>Diatoma</i>	<i>Diatoma anceps</i>	—	—	—
		<i>D. elongatum</i>	—	+	+
		<i>D.hiemale</i>	—	+	—
3	<i>Synedra</i>	<i>Synedra ulna</i>	+	+	+
		<i>S. aequalis</i>	—	+	+
4	<i>Fragilaria</i>	<i>Fragilaria cupusina</i>	—	+	+
		<i>F. virscens</i>	—	+	—
5	<i>Ankistrodesmus</i>	<i>A. falcatus</i>	—	+	—
6	<i>Gomphonema</i>	<i>G. constrictum</i>	—	+	+
		<i>G. capitatum</i>	—	—	+
		<i>G. oleacea</i>	+	+	+
7	<i>Navicula</i>	<i>N. scoliopleuroids</i>	+	+	—
		<i>N. crucicula</i>	—	+	+
8	<i>Basicladiacoccurrences</i>	<i>B. chelonum</i>	—	+	+
9	<i>Merismopedia</i>	<i>M. convoluta</i>	+	—	+
		<i>M. glauca</i>	—	—	+

10	<i>Cocconeis</i>	<i>Cocconeis placentula</i>	+	+	+
11	<i>Chlorococcum</i>	<i>C. humicola</i>	—	+	—
12	<i>Hormidium</i>	<i>H. klebesii</i>	—	+	+
13	<i>Nitzschia</i>	<i>Nitzschia vermicularis</i>	—	—	+
		<i>N. acicularis</i>	+	+	—
		<i>N. obtusa</i>	—	+	+
14	<i>Haematococcus</i>	<i>H. lacustris</i>	—	—	+
		<i>S. pseudoforidiana</i>	+	+	—
		<i>S. daedaleoides</i>	+	+	+
		<i>S. funtiformis</i>	—	+	+
		<i>S. tetrapla</i>	+	—	—
		<i>S. weberi</i>	—	+	+
16	<i>Achanthes</i>	<i>Achanthes minutissima</i>	—	+	—
17	<i>Aphanocapsa</i>	<i>A. richteriana</i>	—	+	—
18	<i>Spirulina</i>	<i>Spirulina major</i>	—	+	+
19	<i>Hydrodictyon</i>	<i>H. reticulatum</i>	+	+	—
20	<i>Gloecapsa</i>	<i>G. crepidium</i>	—	+	+
		<i>G. pleurocapsoides</i>	—	+	+
		<i>A. variabilis</i>	—	—	+
		<i>A. unisporea</i>	—	+	+
22	<i>Euglena</i>	<i>Euglena viridis</i>	+	—	+
		<i>P. fragile</i>	—	—	+
		<i>P. foveolarum</i>	—	+	+
		<i>C. ellipticavern spiralis</i>	—	+	+
		<i>C. solea</i>	—	+	—
		<i>C. spiralis</i>	—	+	+
		<i>P. acuminatus</i>	—	+	+
		<i>Phacus</i>	—	+	+
		<i>N. mutica</i>	+	+	—
		<i>N. scoliopleuroides</i>	+	+	—
		<i>P. gibba</i>	—	+	+
		<i>P. divergens</i>	—	—	+
		<i>P. appendiculata</i>	—	+	+
38	<i>Oedogonium</i>	<i>O. prinshemii</i>	+	+	+

Chlorophyceae

A total of 7 genera with 11 species of Chlorophyceae were identified from the collection sites from collected samples of river Jindi district Charsadda during the summer season of 2014. The most common genus was *Spirogyra* of family Zygnemaceae with 5 species (45.45%) followed by Hydrodictyaceae, Oedogoniaceae, Oosystaceae, Haematococcaceae with 1 species each (9.09%). While other genera were Chlorococcaceae and Cladophoraceae, also with 1 species each (9.09%) (Figure 4, Table 2 & 3).

Euglenophyceae

Sum of 2 genera with 5 species of Euglenophyceae was identified from the collection sites from collected samples of river Jindi district Charsadda during the summer season of 2014. The 2 genera were *phacus* with 2 species (40%) followed by *Euglena* with 3 species (60%) (Figure 5).

Chlorophyceae

Sum of 11 genera with 22 species of Chlorophyceae was identified from the collection sites from collected samples of river Jindi district Charsadda during the winter season of 2014. The most abundant genera were *spirogyra* (22.72%) and *Closterium* (18.1%) with 5 and species respectively while *Cladophora* (9.09%),

Ulothrix (9.09%), *Chlamydomonas* (9.09%) and *Cosmarium* (9.09%) with 2 species each while *Hyalotheca*, *Chlorella*,

Schizomeris, *Tetraedron* and *Hydrodictyon* with 1 species each having same percentage (4.54%) (Figure 6, 7).

Figure 4. Genera wise percentage of Chlorophyceae in River Jindi, Charsadda District during summer season-2014

Figure 5. Genera wise percentage of Euglenophyceae in river Jindi, Charsadda District during summer season-2014

Figure 6. Seasonal variation of algae in summer season results of the winter collection

Figure 7. Genera wise percentage of Chlorophyceae in river Jindi, Charsadda District during winter season-2014

Bacillariophyceae

Sum of 14 genera with 24 species of Bacillariophyceae was identified from the collection sites from collected samples of river Jindi district Charsadda during the winter season of 2014. The most abundant genera were *Synedra* (16.6%) with 4 species followed by *Diatoma* (12.5%),

Gyrosigma (12.5%), *pinnularia* (12.5%) and *Cymbella* (12.5%) with 3 species each while other were *Fragilaria*, *Gomphonema*, *Rhoicosphenia* with 2 species each and *Navicula*, *Stauroneis*, *Cymatopleura*, *Cocconeis*, *Melosira*, *Cyclotella*, and *Nitzschia* (4.16%) with 1 species each (Figure 8).

Figure 8. Genera wise percentage of Bacillariophyceae in river Jindi, Charsadda district during winter season-2014

Charophyceae

Genus *Chara*, family Characeae with only 1 species (100%) was collected from river Jindi during winter 2014 (Figure 9).

Cyanophyceae

Genus *Rhabdoderma* family

Synechococcaceae with only 1 species (100%) was collected (Figure 9).

Euglenophyceae

Genus *Euglena*, family Euglenaceae with only 1 species (100%) was collected during winter 2014 from river Jindi (Figure 9).

Figure 9. Seasonal variation of algae in the winter season

Chemical Analysis of the three types of water

Measurements and results

The range of pH is 7.35-8.84 (favorable for the growth of Chlorophyceae and Bacillariophyceae), The range of temperature 24-27 (favorable for algal growth), Turbidity 13-23 (high turbidity decreases light penetration and oxygenation), TSS (total suspended salts) 17-60) high TSS favoures algal growth, TDS (total dissolved solids) 254.2-327.4 number of algal species increases with increase in TDS. DO (dissolved oxygen) more oxygen in water favorable algal growth, Free CO₂: luxurious algal growth favors more co₂ release, High total N/P accelerate algal growth (Figure 10 (a,b), Table 4).

Site information, species collected and chemical analysis of water of river Jindi during summer 2014

Less polluted water

The Less polluted water is mainly present in Harichand Ziam, the total recorded species of this various site are; Total 6 genera with 11 species of unicellular and filamentous green algae and 5 genera and 11 species of *Bacillariophyceae* and only 1

species of genus *Euglena* of *Euglenophyceae* were identified from the collected samples of Harichand Ziam bridge.

The prevalent genus was *Spirogyra* with 5 species followed by *Hydrodictyon*, *Oedogoniaceae*, *Oosystaceae*, and *Haematococcaceae* with 1 species each. While other genera were *Chlorococcaceae*, *Cladophoraceae*, and *Zygnemaceae* also with 1 species each. In *Bacillariophyceae*, the most abundant genera were *Cymatopleura* with 3 species followed by *Synedra*, *Nitzschia*, *Cocconeis*, and *Gomphonema* with 2 species each. While genus *Euglena* with 1 species.

The chemical analysis at Less polluted water revealed that total hardness as CaCO₃ is 227 mg/L, phosphorus content is 1.4 mg/L and Nitrogen content is 0.78 mg/L, Free CO₂ is 54.08 mg/L, Dissolve Oxygen is 3.8 mg /L and TDS is 451.9 mg/L, TSS is 17 mg/L, Turbidity of water is 7 NTU, Salinity is 0.5 ppt, Electrical Conductivity is 812 µS/cm, Temperature of water is 27 0C, pH of water is 8.84 (Table 4).

Slightly polluted water

Near Sherpao village at Kanever bridge over Jindi river the water is slightly

polluted, the total recorded Species from this site are; Total genera 10 with 22 species of *Bacillariophyceae* were identified from the collected samples near Kanever bridge Sherpao.

The most common genera were *Cymatopleura*, *Nitzschia*, *Pinnularia*, and *Diatoma* with 3 species each followed by *Fragilaria*, *Synedra*, *Navicula* and *Gomphonema* with 2 species each. While the less frequent genera were *Cocconeis* and *Achanthes* with 1 species each. The Chlorophyceae were represented by 8 genera and 8 species that is *Ankistrodesmus*, *Basycladia*, *Hormidium*, *Achanthes*, *Aphanocapsa*, *Hydrodictyon* and *Oedogonium* each with one species each.

The chemical analysis at slightly polluted water revealed that total hardness as CaCO_3 is 277 mg/L, phosphorus content is 0.8 mg/L and Nitrogen content is 0.56 mg/L, Free CO_2 is 35.06 mg/L, Dissolve Oxygen is 2.7 mg/L and TDS is 381.1 mg/L, TSS is 20 mg/L, Turbidity of water is 10 NTU, Salinity is 0.3 ppt, Electrical Conductivity is 730 $\mu\text{S}/\text{cm}$, Temperature of water is 24 $^\circ\text{C}$, pH of water is 8.41 (Table 4).

Highly polluted water

Water is highly polluted as the river passes through the villages of district Charsadda like Sherpao, Umerzai, Turangzai samples were collected from Umerzai Cheena Bridge over Jindi river.

The total recorded algae which were identified from the collection sites were 9 genera with 24 species belonging to *Cyanophyceae* and *Euglenophyceae*.

The most common and prevalent genus was *Oscillatoria* with 7 species of the total algal flora identified. The other genera were *Anabaena* with 4 species. The other genera were *Phormidium*, *Merismopedia*, and *Gloeocapsa* with 2 species each while *Spirulina* and *Aphanocapsa* with 1 species each. *Euglenophyceae* was recorded with 2 genera and 5 species, *Phacus* with 2 species followed by *Euglena* with 3 species.

The chemical analysis at slightly polluted water revealed that total hardness as CaCO_3 is 337 mg/L, phosphorus content is 1.2 mg/L and Nitrogen content is 1.8 mg/L, Free CO_2 is 50.03 mg/L, Dissolve Oxygen is 2.5 mg/L and TDS is 437.9 mg/L, TSS is 25 mg/L, Turbidity of water is 18 NTU, Salinity is 0.2 ppt, Conductivity is 606 $\mu\text{S}/\text{cm}$, Temperature of water is 25.5 $^\circ\text{C}$, pH of water is 7.35.

Figure 10. (A) Seasonal variation of pH value of summer season (B) Seasonal variation of Temperature of the summer season

Chemical Analysis of the three types of water

Measurements and results

The range of pH is 7.35-8.84(favorable for the growth of Chlorophyceae and

Bacillariophyceae), The range of temperature 24-27(favourable for algal growth), Turbidity 13_23(high turbidity decreases high penetration and oxygenation), TSS(total suspended

salts)17-60)high TSS favoures algal growth, TDS(total dissolved solids)254.2-327.4 number of algal species increases with increase in TDS, DO(dissolved oxygen)more oxygen in water favorable algal growth, Free CO₂:luxurious algal growth favors more CO₂ release, High total N/P accelerate algal growth.

Site information, species collected and chemical analysis of water of river Jindi during winter 2014

Less polluted water

The Less polluted water is mainly present in Harich and Ziam bridge up to Kanever Sherpao Tehsil Tangi, the total recorded species of these various sites are; Total 11 genera with 22 species of unicellular and filamentous algae belonging to *Chlorophyceae* were identified from the collected samples of Harichand Ziam. The most abundant genera were *Spirogyra* and *Closterium* with 5 and 4 species respectively while *Cladophora*, *Ulothrix*, *Chlamydomonas*, and *Cosmarium* with 2 species each while *Hyalotheca*, *Chlorella*, *Schizomeris*, *Tetraedron* and *Hydrodictyon* with 1 species each having the same percentage. The chemical analysis at slightly polluted water revealed that total hardness as CaCO₃ is 227 mg/L, phosphorus content is 1.4 mg/L and Nitrogen content is 0.07 mg/L, Free CO₂ is 7.04 mg/L, Dissolve Oxygen is 2.5mg /L

and TDS is 297.9 mg/L, TSS is 23 mg/L, Turbidity of water is 5 NTU, Salinity is 0.3 ppt, Electrical Conductivity is 812 µS/cm, Temperature of water is 15 0C,pH of water is 8.89.

Slightly polluted water

Near Sherpao village at Kanever bridge over Jindi river the water is slightly polluted, the total recorded species from this site are; Total genera 15 with 24 species of *Bacillariophyceae* and genus *Chara* with one species were identified from the collected samples near Kanever bridge Sherpao.The most abundant genera were *Synedra* with 4 species followed by *Diatoma*, *Gyrosigma*, *Pinnularia* and *Cymbella* with 3 species each while other were *Fragilaria*, *Gomphonema*, *Rhoicosphenia* with 2 species each *Navicula*, *Stauroneis*, *Cymatopleura*, *Cocconeis*, *Melosira*, *Cyclotella*, and *Nitzschia* with 1 species each and genus *Chara* with one species.The chemical analysis at slightly polluted water revealed that total hardness as CaCO₃ is 423 mg/L, phosphorus content is 1.2 mg/L and Nitrogen content is 1.5 mg/L, Free CO₂ is 7.04 mg/L, Dissolve Oxygen is 2.9 mg /L and TDS is 281.1 mg/L,TSS is 29 mg/L, Turbidity of water is 7 NTU, Salinity is 0.3 ppt, Electrical Conductivity is 730 µS/cm, Temperature of water is 12 0C,pH of water is 8.45 (Table 5).

Table 5. Chemical Analyses of three types of water of winter season Method Used: Standard Methods for the Examination of water and wastewater 20th Edition, 2005

Parameters	Method	Units	1 Site	2 Site	3 Site	Mean SD±	Water Q standards
pH	4500-(H+B)	mol/L	8.89	8.45	7.95	8.43 0.470319	6.5-8.5
Temperature		(0C)	15	12	13	13.3 1.527525	16-40
Conductivity	2510-(B)	µS/cm	517	445	365	442.3 76.03508	1000 µS/cm
Salinity		Ppt	0.4	0.2	0.2	0.3 0.11547	<0.5-1
Turbidity	Nephelometric Method	NTU	5	7	12	8 3.605551	90 NTU(Standardized)
TSS	2540-(D)	mg/L	23	29	37	29.6 7.023769	<80
TDS	2540-(C)	mg/L	297.9	281.1	212.9	263.9	<400

						45.0157	
DO(Dissolved Oxygen)	4500-OG	mg/L	2.5	2.9	2.8	2.73 0.208167	>5
Free CO ₂	4500-CO ₂ G	mg/L	14.02	7.04	10.56	10.54 3.490043	<20-<60
Nitrogen Content	4500-N	mg/L	0.05	0.07	1.1	0.04 0.600528	<103 as N gas
Phosphorus Content/TP	4500-PD	mg/L	0.5	0.4	0.7	0.53 0.152753	
Total Hardness as CaCO ₃	2540-(D)	mg/L	440	423	327	396.66 60.92892	500

Highly polluted water

Water is highly polluted as the river passes through the main villages of District Charsadda like Sherpao, Umerzai, Turangzai Utmanzai and Rajjar because of the addition of household and agricultural polluted water which badly affect the Chemistry of water. The total recorded algae which were identified from the collection sites were 10 genera with 14 species belonging *Bacillariophyceae*, *Cyanophyceae*, and *Euglenophyceae*. The most abundant genera were *Synedra* with 4 species followed by *Diatoma Gyrosigma*, *Pinnularia* and *Cymbella* with 3 species each while other were *Fragilaria*, *Gomphonema*, *Rhoicosphenia* with 2 species each.

Both Genus *Rhabdoderma* and Genus *Euglena* have only 1 species each

The chemical analysis at slightly polluted water revealed that total hardness as CaCO₃ is 337 mg/L, phosphorus content is 1.7 mg/L and Nitrogen content is 1.1 mg/L, Free CO₂ is 10.56 mg/L, Dissolve Oxygen is 2.8mg /L and TDS is 212.9 mg/L, TSS is 37 mg/L, Turbidity of water is 12 NTU, Salinity is 0.02 ppt, Electrical Conductivity is 606 µS/cm, Temperature of water is 13 0C, pH of water is 7.35.

Discussion

In the set of samples from research sites 5 classes having 46 families, 54 genera and 107 species were recorded belonging to *Chlorophyta*, *Bacillariophyta*, *Cyanophyta* while the least were *Euglenophyta* and *Charophyta* with fewer species in two seasons, winter and summer. The diatoms

and the blue-green algae dominated the summer season (38.59%) and (33.33%) respectively, followed by green algae (19.29%). The diatoms registered the highest number in seasons, summer and winter, (48.97%) and (38.59%) respectively. The diversity and abundance of the diatoms and blue-green algae showed a polluted environment, which is similar to the study conducted by Venkateswarlu, [24], Vijayakumar *et al.* [25] they suggested that *Cyanophyceae* (blue-green algae) grow luxuriantly with great variety and abundance in water with less DO and oxidizable organic matter. The wastewater from municipality water and agricultural wastes showed a considerable amount of nitrates and phosphates, with an increased level of BOD and COD along with very low DO and turbidity. This could be the reason for the flourishing growth of *Cyanophyceae*.

Genus *Chara* was only found at site two (Sherpao Kanever bridge) at high pH, high CaCO₃ level and high water conductivity because of effluents discharge from nearby marble factory directly added to a water body where the luxurious growth of *Chara* can be seen as a justification of favorable growth condition for *Chara*. The genus *Chara* represented only by one species *C. vulgaris*, it was only confined to winter season [26, 27].

Bacillariophyta was the most dominant class having 46 species which is similar to the reports of Salim and Khan, [28] who reported 102 species of river water diatoms from whole Peshawar Valley. The

difference between our results in the number of species was that because our algal study was confined only to winter and summer seasons of only District Charsadda of Peshawar valley.

Chlorophyta and *Cyanophyta* were the second dominant classes in our findings as they together included 52 species, 33 species of *Chlorophyta* and 19 species of *Cyanophyta*. Our results are similar to the observation of Sarim et al. [29] they also reported 39 species of *Chlorophyceae* from Peshawar Valley. The variation in collection points and the difference in localities could be one of the apparent reason for justification. Nawaz and Sarim, [30], who studied 33 species of *Chlorophyta* from Peshawar valley including district Charsadda. The result was further supported by Zaman and Sarim, [31] who also listed 47 species of *Chlorophyta* from Peshawar Valley. Anjum and Hussain, [32] reported 30 species of *Cyanophyta* (blue Green algae) including by our present study and this agreed with our result. *Cyanophyta* was the most prominent and abundant class in highly polluted points. *Oscillatoria* was the most abundant and represented genus in the present study investigation represented by 6 species, followed by *Anabaena* with 4 species, *Merismopedia*, *Phormidium* and *Gloecapsa* with 2 species each. The same study was conducted by Anjum and Hussain, [33] regarding the phylum *Cyanophyta* as the genera and species are the same. Nishat et al. [34] reported 4 species of *Euglena* and *Phacus* with 4 species each from Swat and Peshawar valley respectively whereas our study included that of 4 species of *Euglena* and 2 species of *Phacus*. The results correlate with the findings of Sarim in this respect of the reason for less number of species. The abundance of *Cyanophyceae* suggests highly polluted water condition. Moreover the high water pH and Temperature favors the luxurious growth of blue-green algae. A high count of *Anabaena* is due to high temperature and

the pH reached 7.35 which cause the bad odor to water.

Hussain, [35] reported 36 species among 26 genera, *Cyanophyceae* was represented by 6 genera and 10 species represented by *Gloecapsa*, *Oscillatoria* and *Phormidium* with 2 species further strengthened our findings which suggest the presence of *Cyanophyceae* represented by 4 genera and 19 species represented by *Oscillatoria* with 7 species, *Anabaena* with 4 species and *Merismopedia*, *Gloecapsa*, *Phormidium* with 2 species each, while *Spirulina* and *Aphanocapsa* with 1 species each. *Chlorophyceae* was represented by 5 genera and 7 species but in our findings, *Chlorophyceae* was represented by 18 genera and 33 species, *Bacillariophyceae* was represented by 14 genera and 18 species but in our findings, *Bacillariophyceae* was represented by 24 genera and 46 species. The difference is due to seasonal variations and localities, moreover, our study was confined to two seasons summer and winter.

These different species have been reported from various localities from Jindi river during two season summer and winter. The difference in a number of algal species was due to the difference in location of sites and prevailing local conditions of the water bodies [36].

The pH of water samples varied from 7.35 to 8.89 and was more or less alkaline. In the present study, the pH of Harichand Ziam bridge site –1, Sherpao Kanever bridge site – 2 were abundant and had more species diversity as compared to other sites. Results similar to Nishat, [34] investigated that high and suitable required level of pH accelerates and favor the growth of desmids and other aquatic plants respectively while low pH was toxic for them. For chemical parameters, the alkalinity reaches their highest in summer than winter. For pH the highest value in summer, autumn and then winter (8.84, 7.35, 7.7). High turbidity decreases high penetration of light and oxygenation, hence causes a decreased level of species growth and number in our

study turbidity range from (5-18 NTU). A parameter such as Total Dissolved Solids and Total Suspended Solids positively correlated and affected the growth and number of species. The number of species increased with increasing total dissolved solids and total suspended solids in the water. In the present investigation, the total dissolved solids (212.9 – 297.9mg/L) showing the concentration of Total Dissolved Solids of water which affects the distribution of algae. The number of TDS varied from (212.9 – 437.9mg/L) and TSS varied from (17-37 mg/L) which suit the distribution of algae. It was observed that as with the increase in TSS and TDS, algal species promoted. The present findings are similar to those of Leghari *et al.* [37] who observed the similar relationship. The higher value of TSS indicates the high concentration of various nonliving particulates matters originate as catchments, derived salts, clayey mud, organic matter of plants and animals etc are present in the water. It increases the turbidity of water. EC (365-812 $\mu\text{S}/\text{cm}$) shows the presence of soluble salts in the water body. The optimum amount of EC favors growth and distribution of algal species.

The similar studies were conducted by Leghari *et al.* [38] who studied and compared

The electrical conductivity of both freshwater with marine water(brackish water) to find out their effect on growth relation of algal flora. The result was observed that in freshwater optimum conductivity level accelerates algal growth and had 45 species, in comparison to marine water which has 9 species with high conductivity. Low level of salts mainly NaCl in terms of Salinity (0.5– 2.1 mg/L) was the most suitable level for the growth and distribution of algae, in our findings, the recorded salinity value was (0.2-0.4). Results are similar to those of Lealand *et al.* [39] reported that minute amount of NaCl promote the algal growth while high value causes growth retardation. The decreasing

CO_2 (7.04 –54.08), nitrate as Nitrogen content (0.05-1.8 mg/L), phosphate as TP (0.5-1.4 mg/L) and calcium hardness (227–440mg/L) increased the number of algal species which correspond to Leghari *et al.* [38] concluded that high CO_2 level, phosphates nitrates, and Total hardness as CaCO_3 generally enhanced the algal species and does support the present findings.

The amount of DO (Dissolved Oxygen varied from 2.5– 3.8mg/L indicate more Oxygen in water hence favorable for algal growth. The present study correlates with reports of Sarim and Ali [31] who observed the high DO promote the algal growth. The Turbidity among the various points was recorded from 5–18 NTU. Most commonly, low level of Turbidity favors the growth and distribution of algae while high value was not suitable for the growth and distribution of algal flora by decreasing light penetration and oxygenation. Similarly, oxygen decreases with high temperature. The seasonal variation of algal species, counts and that mostly depends on the pH value, clarity of water, sunlight transmission, amount of nutrients and the nature of water, Also the algae distribution patterns were increased because the type of physical and chemical variables affect the quality of water body that in turn influencing algal diversity.

Conclusion and recommendations

A comprehensive and thorough collection not only of algae but Limnology of river Jindi round the year for a better understanding of the relationship of Algae to water bodies can be conducted. Medicinal studies of these algal species can be conducted for their nutrient value, toxicants, and antimicrobial activities. A limnological profile of various water bodies can be made.

Authors' contributions

Conceived and designed the experiments: Z Shah Performed the Fields work and experiments: Z Shah, Analyzed the data: T Khan, K Niaz, M Shuaib Contributed reagents/ materials/ analysis tools: M

Shuaib F Hussain, Wrote the paper: Z Shah, SZ Shah, M Shuaib & F Hussain.

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