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Original article

Exploration and determination of algal role as Bioindicator to evaluate water quality – Probing fresh water algae

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A B S T R A C T

Objectives: To explore the algal floral diversity and its role to determine water quality.
Methods: The regular monthly collection of algal and water samples was made during 2018. Unicellular algae were preserved in 2 to 3% formalin while macroalgae in 4% formalin. Microphotographs of algae were taken at the biotechnological Lab of PCSIR Lahore, Pakistan. Palmer pollution index was used to determine water quality.
Results: The study identified 201 algal species distributed among 57 genera, 42 families, 25 orders, 10 classes and 7 divisions. The total score of Algal Genus Pollution Index of Banjosa Lake, Ali Sojal Dam, Dothan Dam, Drake Dam and Rawalakot Nullah (city) were 14, 9, 10, 18 and 25 respectively. It was revealed that Banjosa Lake has probable organic pollution, Ali Sojal Dam and Dothan Dam showed lack of organic pollution, Drake Dam indicated moderate pollution while Rawalakot Nullah (City) indicated confirm high organic pollution.
Conclusion: We strongly recommend the conservation and managed status of algal species for sustainable resource of algal- derived products in future. It was revealed that the water quality of Banjosa Lake, Drak Dam and Rawalakot Nullah was affected from anthropogenic activities and needs to be managed.

1. Introduction

Algae are diverse and large group of simple, photosynthetic, unicellular and multicellular organisms. They have very simple body called thallus which cannot be differentiated into true roots, stems and leaves and lack vascular tissues. They are very diverse organisms in size, form, structure, color, habit and habitat. Algae occupy variety of habitats due to their vast ecological amplitude and distributed across the oceans, rivers, lakes, ponds and streams. They are present from the depth of ocean to the highest peaks of the world. Linnaeus for the first time coined the term 'Algae (Linnaeus, 1753).Fig. 1.

Algae are major source of food for aquatic organism and play an important role in aquatic food chain or food web (Galloway et al., 2012). They are good source of natural human diet (Gupta and Pandey, 2007). Microalgae are good source of biofuel and higher productivities than traditional crops (Khatoon and Pal, 2015). Many crucial antibiotics and medicines are obtained from these

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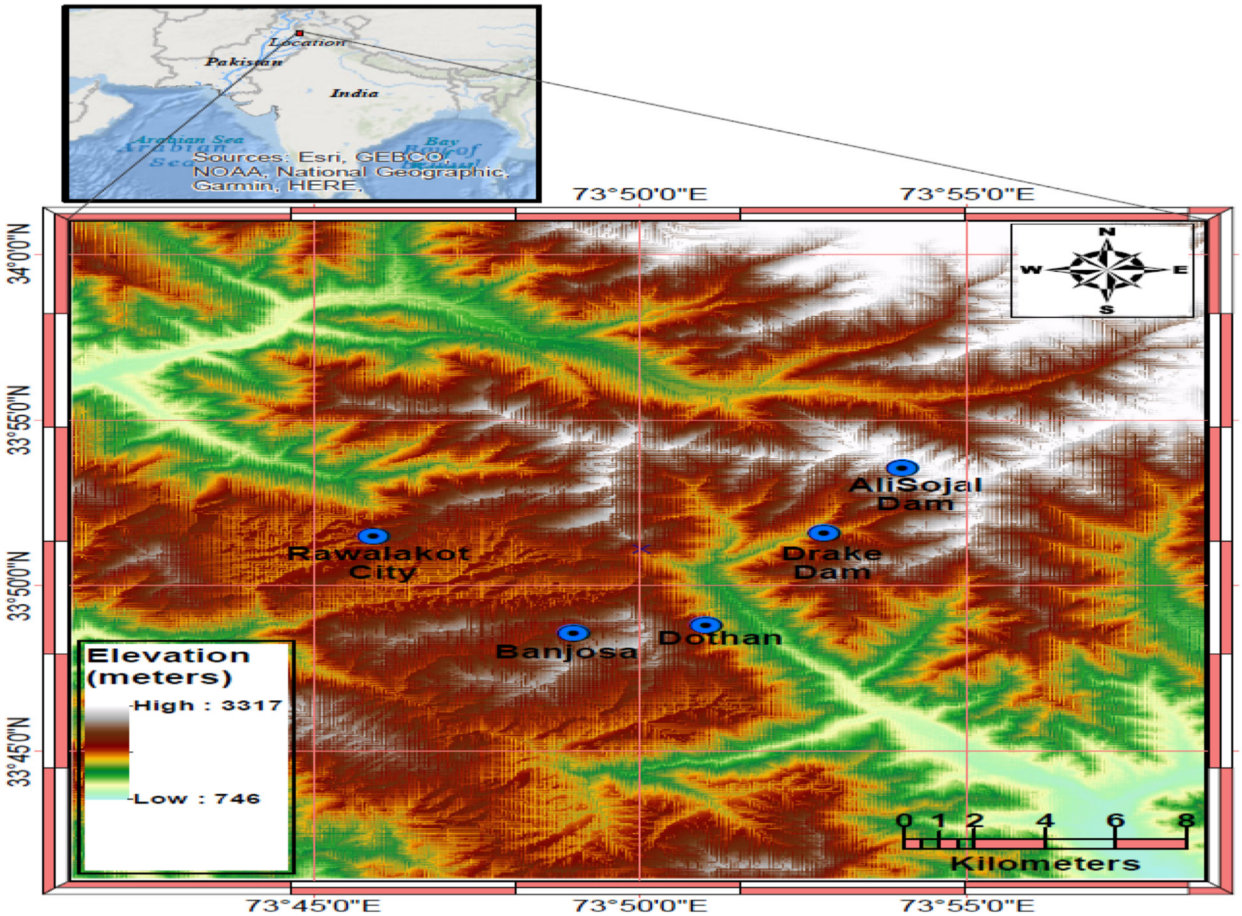


Fig. 1. Map of the study area.

organisms. They are used by pharmaceutical companies to prepare drugs which are used to treat various diseases like cancer, Acquired immune deficiency syndrome (AIDS), Arthritis, respiratory diseases and infections due to viruses, bacteria and fungi (V, Vadlapudi, 2012). Algae are involved in water purification from nutrients and pollutants (Biggs and Kilroy 2000). Algae are considered as very good bioindicator of water quality due to their rapid response to pollutants. Algae are important biological organism for purification of waters bodies because they absorb organic and inorganic pollutants, heavy metals and radioactive substances (Alp et al., 2012). Microalgae are bioindicators of eutrophication and effectively used to assess the quality of water (Kumar and Amit, 2012). The dominance of green algae and diatoms indicate the oligotrophic conditions while abundance of blue green algae indicate the eutrophic conditions of water bodies (Musharaf et al., 2011).

(Abdul Aziz et al., 2003) undertook algal study on the Arabian Gulf of the coastal waters of Saudi Arabia. They reported 35 genera of unicellular algae belonging to Bacillariophyta, Dinophyta and Cyanophyta and found that algae showed luxurious growth in summer due to nutrients status and temperature conditions. Similar algal studies were conducted by (Khomayis and Al- Harbi, 2003) on marine fouling area of Sharm Obhour, Saudi Arabia and recorded 22 species of Bacillariophyta and 2 species of Cyanophyta and Dynophyta each. An important study regarding algae of different groups at Batkhela, Malakand, Pakistan was carried out and total of 63 algal species belonging to Cyanophyta, Chlorophyta and Bacillariophyta were recorded (Barkatullah et al.,2013). An important study to explore fresh water algal flora of Jauharabad district, Pakistan was conducted and species were taxonomically described (Zarina et al., 2013). Some studies on algal flora were carried out in Azad Jammu & Kashmir (Khuhawari et al., 2009, Naz et al., 2009, Haq et al., 2012, and Ali et al., 2006).

Due to immense importance and contribution of algae and attempt was made to document the presence of valuable algal species. The objectives of this particular study were to conduct an extensive research for collection, identification and classification of algal flora to determine Phycological diversity and its role to determine water quality from the study area for the first time. This research work is significant because this is an up to date novel work. The paper should be of interest to readers in the areas of Botany, Ecology, Conservation biology, Agriculture and Environmental sciences etc.

2. Materials and methods

2.1. Study site

Rawalakot is headquarter of district Poonch Azad Jammu & Kashmir, Pakistan. It located in temperate region at an elevation of 5374 feet and the Latitude 33°51′32.18″N, Longitude 73°45′34.93″E. The climate of Rawala Kot can be divided into four seasons. Rawala Kot has mild and warm temperature during the spring and summer, while snow falls in the winter. Maximum and minimum temperatures can be 38 C and −1 C in summer and winter respectively.

2.2. Sampling sites

For present study, algal and water samples were collected from five randomly selected sampling Sites; Banjosa Lake, Ali Sojal Dam, Dothan Dam, Drak Dam and Rawalakot City (Nallah) were selected as sampling stations.

2.3. Sampling of algae

The regular monthly collection of algae was made from January 2018 to December 2018. Epiphytic algae and desmid flora were collected with pipette. Filamentous algal species were collected with the help of forceps. Tooth brush was used to collect diatoms while macro-algae were picked up with hands. The collected algal samples were transferred into bottles and were labelled.

2.4. Preservation of algae

Unicellular algae were preserved in 2 to 3% formalin while macro algae were kept in 4% formalin (Mason, 1967).

2.5. Laboratory studies and identification of algae

The algal samples were taken to molecular & biotechnological lab, food and biotechnological research Centre PCSIR, Lahore, Pakistan for microphotography. Microphotographs of algal species were taken with the camera attached with the microscope (MT5300H-Japan). The specimens of algal species were identified with the help of authentic literature upto species level or even up to variety level (Hustedt 1930, Majeed 1935, Smith 1950, Presscot, 1962, Tilden, 1910).

2.6. Analysis of algae

The collected material was assessed on the basis of morphological, cytological and reproductive characters during microscopic examination. After detail analysis, algae were documented and tabulated for evaluation of algal biodiversity from the study area.

2.7. Palmer pollution index

Palmer pollution index was used to evaluate water quality.

3. Results

The present study identified 201 algal species consisting of 57 genera, 42 families, 25 orders, 10 classes and 7 divisions from the study area during 2018. The maximum number of families (18) were contributed by division Bacillariophyta, followed by Chlorophyta (14) families and Cyanophyta (5) families. Euglenophyta contributed 2 while Glucophyta and Dinophyta contributed 1 family each. (Table.1). The Bacillariophyta showed dominancy with (47%) frequency followed by Chlorophyta and Cyanophyta 38% and 19% frequency respectively. The minor divisions Euglenophyta, Charophyta and Dinophyta showed poor representation with (2%), (1.5%) and (1%) frequency respectively (Fig. 2).

The highest number of species were represented by Naviculaceae and Fragillariaceae while minimum by Glucocystaceae (Table 1). Maximum number of species identified were 95 which were contributed by Bacillariophyta followed by Chlorophyta 76 species. Minimum number of species were represented by Glaucophyta and Dinophyta with one species each. Maximum number of genera (25) were contributed by Bacillariophyta followed by Chlorophyta and Cyanophyta by 21 and 6 genera respectively. Euglenophyta was represented by 3 genera while rest of the divisions were recorded with 1 genus each. The division with maximum number of orders was Chlorophyta which contributed 11 orders followed by Bacillariophyta 6 and Cyanophyta 4 orders while remaining divisions gave up 1 order each (Fig. 3). The largest genus was Navicula which was represented by 14 species followed by spirogyra and Cymbella with 11 species each. Minimum number of species were contributed by Troschia and Lyngbya (Fig. 4 and Table 1). The division Bacillariophyta showed dominancy with (47%) frequency followed by Chlorophyta and Cyanophyta 38% and 19% respectively. The minor divisions Euglenophyta, Charophyta and Dinophyta showed poor representation with (2%), (1.5%) and (1%) frequency respectively.Fig. 5.

3.1. Evaluation of organic pollution by Palmer's algal genus

Pollution of surface water has become major environmental problem. Organic pollution in water bodies leads to eutrophication which in turn accelerate the growth of certain type of algal species in water body. Algae are taken as natural indicator to environmental conditions because they form blooms in water bodies and show vigorous growth. There are many studies by various authors who showed strong relationship among algal species and polluted and unpolluted water. They are influenced by factors like mixing of water masses, light, temperature, salinity and nutrients. Bioindicator organisms can be used to identify the effects of pollutants in aquatic ecosystems.

Different environmental conditions affect the occurrence and distribution of algae. Cyanobacteria mass is influenced by the hydrogen ion concentration (pH) followed by temperature, light, soil type and available nutrients. Their mass can be recorded in the form of the frequency as well as the intensity of biotic community due to eutrophication. Various studies on algal species confirmed their role for the assessment of pollution in water bodies. (Kolkwitz and Marsson, 1950) defined five zones on the degree of pollution in water bodies and proposed the use of aquatic organisms as bioindicators to evaluate the water quality.

(Werner, 1977) proposed nine different zones on the basis of organic pollution in water bodies. Werner proposed zones were Coprozoic, Polysaprobic, Mesosaprobic, Oligosaprobic, and Katharobic. Each zones was found to be different on the basis of physico-chemico and biological characteristics. He listed the indicator species of these zones which showed changes in their growth pattern in response to pollutants in water bodies. Polysaprobic zone was characterized by the complete absence of algae except for blue green algae Spirulina and green algae *Euglena viridis*. Blue green algae showed dominancy in alpha-Mesozoic while diatoms and green algae were dominant in Beta-Mesozoic zones. Members of Dinophyta and Charophyta were found only in oligosaprobic zones.

Palmer (1969) proposed pollution index on the basis of algal genus and species present in water bodies. This pollution index which is effectively used to analyze the water quality for high or low organic pollution (Table 2). The pollution tolerant genera of algae were recorded from all the sites of the study area and a pollution index score was assigned to each algal genus. Pollution index score of 20 or more confirms high organic pollution within the water body. A score of 15–19 is an evidence of probable organic pollution. Pollution index scores from 10 to 14 indicates moderate organic pollution, while index score 0–10 indicates lack of organic pollution in waters.

During our present study algal genera were used to determine the water quality of freshwater bodies in the study area in which the total score of algal genus pollution index of Banjosa Lake, Ali Sojal Dam, Dothan Dam, Drake Dam and Rawalakot City (Nullah) were found to be 14, 9, 10, 18 and 25 respectively. It was concluded that Banjosa Lake has probable organic pollution while Ali Sojal Dam and Dothan Dam, showed lack of organic pollution, Drake Dam indicated probable organic pollution and Rawalakot Nullah indicated confirm high organic pollution (Table 3).

Table 1
Algal flora explored from freshwater bodies of the study area.

Divisions	Class	Order, Family, Genus and Species name
Cyanophyta	**Cyanophyceae**	
		Order: Chroococcales
		Family: Chroococcaceae
		1.*Chroococcus turgidus* (Kutzing) Naegeli
		2. *Chrococcus limneticus* Lemmermann
		Family: Microcystacae
		3. *Gleocapsa punctate* Nageli
		4. *Gleocapsa bituminosa* Kutzing
		Order: Nostocales
		Family: Nostocaceae
		5.*Nostoc muscorum* C.A. Agardh
		Order: Oscillatoriales
		Family: Oscillatoriaceae
		6. *Lyngbya birgei* G.M. Smith
		7. *Lyngbya martensiana* Meneghini ex Gomont
		8.*Lyngbya majuscule* Harvey ex Gomont
		9. *Oscillatoria tenuis* C.A. Agardh
		10. *Oscillatoria limosa* C.A. Agardh
		11.*Oscillatoria princeps* Vaucher
		12.*Oscillatoria sancta* (Kutzing) Gomont
		13.*Oscillatoria fracta* G.W.F.Carlson
		14.*Oscillatoria acuta* Bruhl
		15.*Oscillatoria chilkensis* Biswas
		16.*Oscillatoria obscura* Bruhl &Biswas
		17.*Oscillatoria curviceps* C.A. Agardh
		18.*Oscillatoria anguina* Bory ex Gomont
		Order: Synechococcales
		Family: Merismopediaceae
		19. *Merismopedia glauca* (Ehrenberg) Kutzing
Chlorophyta	**Chlorophyceae**	
		Order: Chlorococcales
		Family: Oocystaceae
		20.*Ankistrodesmus falcatus* var. *radiates* (Chod) Lemmermann
		Order: Chlamydomonadales
		Family:Volvocaceae
		21.*Volvox aureus* Ehrenberg
		22.Pandorina morum Bory
		Family: Chlorococcaceae
		23. *Schroederia setigera* (Schroeder)Lemmermann
		Order: Sphaeropleales
		Family: Scenedesmaceae
		24.*Scenedesmus quadricauda* (Turpin) Brebisson
		25.*Scenedesmus opoliensis* Richter
		26.*Scenedesmus protuberans* Fritsch and Rich
		27.*Scenedesmus longus* Meyen
		28.*Scenedesmus dimorphus* (Turpin) Kutzing
		29. *Scenedesmus carinatus* (Lemmermann) Chodat
		30.*Scenedesmus communis* E.Hegewald
		31.*Scenedesmus abundans* var.*longicada* G.M Smith
		32.*Scenedesmus quadricauda* var.*maxima West & GS West*
		33.Scenedesmus abundans (Kirchner) Chodat
		34.*Tetraedron regulare* Kutzing
		35.*Tetraedron caudatum* (Corda) Hansgirg
		36.*Tetradron trigonum* var.*minus* Reinch
		37.*Troschia aspera* Reinsch
		38. *Coelastrum microporum* Nacgeli
		39.*Coelosphaerium kuetzinginum*
		Family: Hydrodictyaceae
		40.*Pediastrum duplex* Meyen
		41.*Pediastrum duplex* var. *gracillimum West & GS West*
		42.Pediastrum simplex var echnulatum Wittrock
		43.*Pediastrum biwae* var. *ovatum* (Ehrenberg) Tiffany
		44.*Pediastrum simplex* var.*duodenarium* (Bailey) Rabenhorst
		45.*Pediastrum boryanum* var.*longicorne* Raciborski
		Order: Oedogoniales
		Family: Oedogoniaceae
		46.*Oedogonium macrandrium* Wittrock
		47.*Oedogonium cardiacum* (Hassall) Wittrock
		48.*Oedogonium majus* (Hansgirg) Tiffany
		Order: Tetrasporales
		Family: Sphaerocystidaceae
		49.*Sphaerocystis schroeteri* R.Chodat
		Order: Microsporales

(*continued on next page*)

Table 1 (*continued*)

Divisions	Class	Order, Family, Genus and Species name
		Family: Microsporaceae
		50.*Microspora quadrata* Hazen
		51.Microspora willeana Lagerheim
		52.Microspora tumidula Hazen
		Order: Chetophorales
		Family: Chaetophoraceae
		53.*Draparnaldia plumose* (Vaucher) C.A. Agardh
		54.*Chaetophora lobata* F.Schrank
		55.*Chaetophora elegans* (Roth) Agardh
	Ulvophyceae	
		Order: Ulvotrichales
		Family: Ulotrichaceae
		56.*Ulothrix gemilata* Kutzing
		57.*Ulothrix zonata* (Weber & Mohr) Kutzing
		58. Ulothrix aqualis Kutzing
		Order: Cladophorales
		Family: Cladophoraceae
		59.*Cladophora glomerata* (Linnaeus) Kutzing
		60.*Cladophora oligoclona* Kutzing
	Zygnematophyceae	
		Order: Zygnematales
		Family: Zygnemataceae
		61.*Spirogyra communis* (Hassall) Kutzing
		62.*Spirogyra biformis* C.C.Jao
		63.*Spirogyra maxima* Link in C.G.Nees
		64.*Spirogyra neglecta* (Hassall) Kutzing
		65.*Spirogyra subsalsa* Link in C.G.Nees
		66.*Spirogyra tetrapla* Transeau
		67.*Spirogyra elongata* (Vaucher) Kutzing
		68.*Spirogyra fluviatilis* Hilse
		69.*Spirogyra punctiformis* Trascan
		70.*Spirogyra rectuangularis* Transeau
		71.*Spirogyra catenaeformis* (Hassall) Kutzing
		72.*Zygnema tenue Kutzing*
		73.*Zygnema sterile* Transeau
		74.*Zygnema insigni* (Hassall)
		75.*Zygnema aplanosporum* Stancheva,J.D.Hall & Sheath
		76.*Mougetia micropora* Taft
		77.*Mougetia viridis* (Kutzing) Wittrock
		Order: Desmidiales
		Family: Desmidiaceae
		78.*Cosmarium formosulum* Hoffman
		79.*Cosmarium botrytis* Meneghini
		80.*Cosmarium speciosum* Lundell
		81.*Cosmarium granatum* Brebisson
		82.*Cosmarium nitidulum* Denotaris
		83.*Cosmarium subtumidum* Nordstedt
		84.*Staurastrum rzoskae* Meyen ex Ralfs
		Family:Closteriaceae
		85.*Closterium acutum* (Lyngbye) Brebisson
		86.*Closterium parvulum* Naegeli
		87.*Closterium leibleinii* Kutzing
		88.*Closterium lanceolatum* Kutzing
		89.*Closterium intermedium* Ralfs
		90.*Closterium littorale* Gay
		91.*Closterium lunula* (Mueller) Nitzch
		92.*Closterium pseudolunula* Borge
		93.*Closterium acerosum* var.*elongatum* Brebisson
		94.*Closterium striolatum* Ehrenberg
	Trebouxiophyceae	
		Order: Chlorellales
		Family: Chlorallaceae
		95.*Chlorella conductrix* Brandt
Charophyta		
	Charophyceae	
		Order: Charales
		Family: Characeae
		96.*Chara coralina* Klein ex C.L.Willdenow
		97.*Chara globular* Thuiller
		98.*Chara vulgaris* Linnaeus

Table 1 (*continued*)

Divisions	Class	Order, Family, Genus and Species name
Bacillariophyta		
	Bacillariophyceae	
		Order: Bacillariales
		Family:Anomoeneidaceae
		99.*Anomoeoneis vitrea* Pfitzer
		100.*Anomocoenis exilis* (Kutzing) Cleve
		101.*Anomoconies serianus* (Brebisson) Cleve
		Family:Catenulaceae
		102.*Amphora holsatica* Hustedt
		Family:Achnanthidiaceae
		103.*Achanthes microcephala* (Kutzing) Cleve
		Family:Cocconeidaceae
		104.*Cocconeis plancetula* Ehrenberg
		Family: Bacillariaceae
		105.*Denticula tennis* Kutzing
		106.*Nitzchia palea* (Kutzing) Wm. Smith
		107.*Nitzschia sublinearis* Hustedt
		108.*Nitzchia acicularis* (Kutzing) Wm. Smith
		109.*Nitzchia hungarica* Grunow
		110.*Nitzchia denticula* Grunow
		111.*Nitzchia palea* var.*tenuirostris* Grunow
		Order: Fragilariaales
		Family:Fragilariaceae
		112.*Diatom vulgare* Bory
		113.*Diatoma anceps* (Ehrenberg) Kirchner
		114.*Fragillaria viresecens* Ralfs
		115.*Fragillaria pinnota* Ehrenberg
		116.*Fragillaria capucina* Desmazieres
		117.*Fragilaria vaucheriae* (Kutzing) J.P.Peterson
		118.*Fragillaria intermedia* (Grunow) Grunow
		119.*Fragillaria crotonensis* var.*prolongata* Grunow
		120.*Stauroneis phoenicentron* (Nitzsch*)* Ehrenberg
		121.*Stauroneis acuta* Wm.Smith
		122.*Stauroneis phoenicentrum* var.*amphilepta* (Ehrenberg) Cleve
		123.*Stauroneis anceps* var.*birostris* (Ehrenberg) Cleve
		124.*Synedra dorsiventralis* Mueller
		125.*Synedra ulna* (Nitzsch) Ehrenberg
		126.*Synedra acus* Kutzing
		127.*Synedra parasitica* (Wm.Smith) Hustedt
		128.*Synedra amphicephala* Kutzing
		129.*Synedra affinis* Kuetz
		130.*Synedra crystalina* (C.A.Agardh) Kutzing
		Order:Naviculales
		Family:Naviculaceae
		131.*Caloneis bacillum* (Grunow) Mereschkowsky
		132.*Gyrosigma acuminatum* (Kutzing) Cleve
		133.*Gyrosigma wormleyi* (Sullivant) Boyer
		134.*Gyrosigma Kuetzingii* (Grunow) Cleve
		135.*Gyrosigma scalproides* Rabenhorst
		136.*Navicula tuscula* (Ehrenberg) Grunow
		137.*Navicula gracilis* Ehrenberg
		138.*Navicula protracta* (Grunow) Cleve
		139.*Navicula exigua* (Gregory) Muller
		140.*Navicula veneta* Kutzing
		141.*Navicula salinarum* Grunow
		142.*Navicula rhyncocephala* Kutzing
		143.*Navicula radiosa* Kutzing
		144.*Navicula viridula* Kutzing
		145.*Navicula cuspidata* Kutzing
		146.*Navicula grimmei* Krasske
		147.*Navicula dicephala* (Ehrenberg) Wm.Smith
		148.*Navicula reinhardtii* (Grunow) Van Heurek
		149.*Navicula gregaria* Donkin
		Family: Rhopalodiaceae
		150.*Rhopalodia gibba* (Kutzing) Mueller
		151.*Rhopalodia gibba* var.*ventricosa (Kutzing)* H.Peragallo & M. Peragallo
		152.*Epithemia adnata* (Kutzing) Brebisson
		153.*Epithemia argus* (Ehrenberg) Kutzing
		Family: Pinnulariaceae
		154.*Pinnularia nobilis* Ehrenberg
		155.*Pinnularia braunii* (Grunow) Cleve
		156.*Pleurosigma angulatum* (Quekett) Wm.Smith
		157.*Pleurosigma salinarum* (Grunow) Grunow
		Family: Neidiaceae
		158.*Nedium iridis* (Ehrenberg) Pfitzer

(*continued on next page*)

Table 1 (*continued*)

Divisions	Class	Order, Family, Genus and Species name
		159.*Nedium dubium* (Ehrenberg) Pfitzer
		Family:Sellaphoraceae
		160.*Sellaphora capitata* D.G.Mann& S.M. McDonald
		161.*Sellaphora pupilla* (Kutzing) Meresckowsky
		Family: Amphipleuraceae
		161.*Frustulia rhomboids (*Ehrenberg) DeToni
		163.*Frustulia viridula* (Brebisson) DeToni
		Family: Stauroneidaceae
		164.*Craticula cuspidata* (Kutzing) D.G.Mann
		Order: Surirellales
		Family:Surirellaceae
		166.*Cymatopleura solea* (Brebisson) Wm.Smith
		167.*Cymatopleura elliptica f.spiralis* (Chase) Boyer
		168.*Surirella linearis* Wm.Smith
		169.*Surirella saronica* Auerswald
		170.*Surirella didyma* Kutzing
		171.*Surirella splendida* (Ehrenberg) Kutzing
		172.*Surirella linearis* var.*constricta* (Ehrenberg) Grunow
		173.*Surirella ovata* Kutzing
		174.*Surirella minuta* Kutzing
		175.*Surirella patella* Kutzing
		Order: Mastogloiales
		Family:Mastogloiaceae
		176.*Mastogloia smithii* Tshwait
		177.*Mastogloia smithii* var.*amphicephala* Grunow
		Order:Cymbellales
		Family:Cymbellaceae
		178.*Cymbella tumida* (Brebisson) Van Heurck
		179.*Cymbella leptoceros* (Ehrenberg) Grunow
		180.*Cymbella laevis* Naegeli
		181.*Cymbella lanceolata* (Brebisson) Van Heurck
		182.*Cymbella prostrata* (Berkeley) Cleve
		183.*Cymbella turgida* Gregory
		184.*Cymbella acqualis* Wm.Smith
		185.*Cymbella affinis* Kutzing
		186.*Cymbella parva* (Wm.Smith) Cleve
		187.*Cymbella aspera* (Ehrenberg) Cleve
		188.*Cymbella brehmii* C.A.Agardh
		Family:Gomphonemataceae
		189.*Gomphonema ventricosum* Gregory
		190.*Gomphonema constrictum* Ehrenberg
		191.*Gomphonema micropus* Kutzing
		192.*Gomhonema sphaerophorum* Ehrenberg
		193.*Gomhonema angustatum* (Kutzing) Grunow
		194.*Gomhonema parvulum* (Kutzing) Grunow
Euglenophyta	**Euglenophycaea**	
		Order: Euglenales
		Family: Euglenaceae
		195.*Euglena limnophila* Ehrenberg
		196.*Euglena sociabilis* P.A. Dangeard
		197.*Euglenaformis proxima* (Dangeard) M.S.Bennett
		Family: Phacaceae
		198.Phacus longicauda (Ehrenberg) Dujardin
		199.*Astasia cylindrical* Fromental
Glaucophyta		
	Glaucophyceae	
		Order:Glaucocystales
		Family: Glaucocystaceae
		200.*Gloescystis ampla* Kutzing
Dinophyta	**Dinophyceae**	
		Order: Phytodiniales
		Family: Phytodinaceae
		201.*Cystodinium steinii* Transeau

4. Discussion

The algae have been an interesting group of plants due to their primitive nature and worldwide distribution because of their capabilities to exist in variety of environmental conditions. Algae are the primary producers in all kind of aquatic ecosystems due to their photosynthetic ability. They are very much important organism from ecological, commercial and medical aspects. In Pakistan, few algal studies have been conducted but little attention was given to explore algal flora of Azad Jammu & Kashmir. Our study in fresh water bodies showed rich diversity of algal species in which 3 species; *Phacus longicauda*, *Closterium leibeleinii*, and *Pediastrum duplex* var.*gracillimum* were new records for Azad Jammu & Kashmir. Our results are in agreement with the study on the diversity of algae carried out by Leghari et al., 2002 in which they identified 134 algal species from River Jhelum, Azad Jammu & Kashmir.

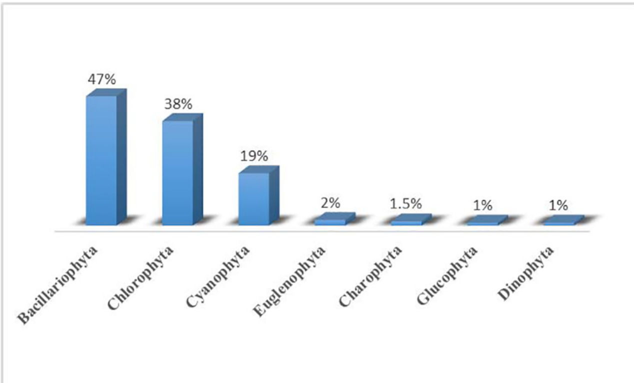


Fig. 2. Species percentage of identified taxa.

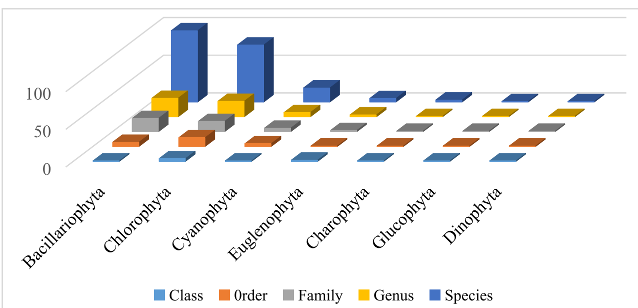


Fig. 3. Number of taxa within documented Divisions.

Similar algal research was undertaken and 195 algal species were documented from Punjab, Khyber Pakhtoonkhwa, Azad Kashmir, and north-eastern areas of Pakistan. The class Nostocophyceae was found to be more abundant which contributed 144 species as compared to the class Chlorophyceae which added 51 algal species. It was observed that these species appeared during spring and summer and disappeared in the autumn (Haq et al., 2012).

Previously some research work has been carried out on the algal diversity in Jauharabad District, Pakistan by Zarina et al., 2013. They identified four species of diatoms belonging to family Bacillariaceae, Gomphonemaceae and Nitzschiaceae. (Jang et al., 2014) investigated the algal diversity in fresh water bodies from different localities of Swabi District, Pakistan and identified 22 genera with 35 species. Our studies are in accordance with (Aliya et al.,2009) during which they explored the fresh water habitats of Karachi city, Pakistan and reported 6 division, 33 families, 86 genera and 214 algal species. The divisions Cyanophycota and Volvophycota showed dominancy with (74.8%) frequency while the Euglenophycota and Chrysophyta showed poor representation of (2.8%) frequency. Variations in algal composition and diversity was analyzed in Sangju weir, Gyeongsangbuk do-province and it was found that it was varied at bottom, middle and surface layers of water due to formation of thermocline in water body. Micro algae were dominated by diatoms followed by green algae and blue green algae.

Bioindicator organisms indicate the effects of different pollutants in aquatic ecosystems. Phytoplanktons are reliable tool to evaluate the water quality of wetlands (Crosseti et al., 2008). Freshwater bodies and lakes are characterized on the basis of dominant algal group. We characterized water bodies of our study area on the basis of algal genus and concluded that Banjosa Lake has probable organic pollution, Ali Sojal Dam and Dothan Dam showed lack of organic pollution, Drake Dam indicated probable organic pollution while Rawalakot Nullah indicated confirm high organic pollution. Species of Chlorophyta like Chlymdomonas and Euglena, members of Bacillariophyta like Navicula, Synedra, Gomphonema, and blue green algae such as Oscillatoria and Phormidium grow in organic polluted waters (Palmer, 1969). (Anand, 2000) investigated the ecology of a diatom species and noticed their role as an indication of water quality parameters. The dominance of green algae and diatoms indicate the oligotrophic conditions while abundance of blue green algae indicate the eutrophic conditions of water bodies (Musharaf et al., 2011). Our findings agree with palmer (1969) and Musharaf et al. (2011).

5. Conclusion

The water of the fresh water bodies of Rawalakot is used for domestic, industrial and agricultural purposes. It was revealed through the current study that Rawalakot Nullah, Drak Dam and Banjosa Lake are declining due to pollution. Conservation and management of these water bodies is required in order to avail them for long term in a proper way. Sustainable water use and management is recommended for the subsistence of the water bodies in the study area. It is recommended for future studies to carry out

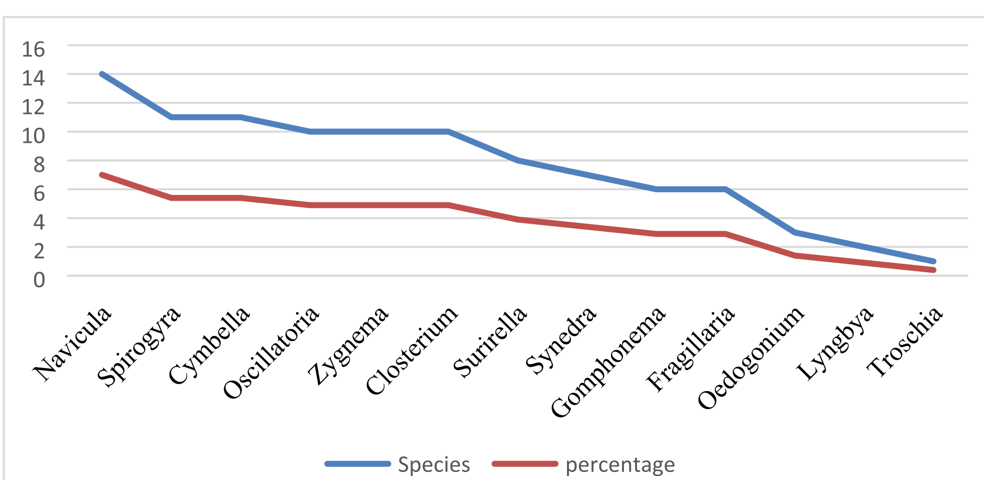
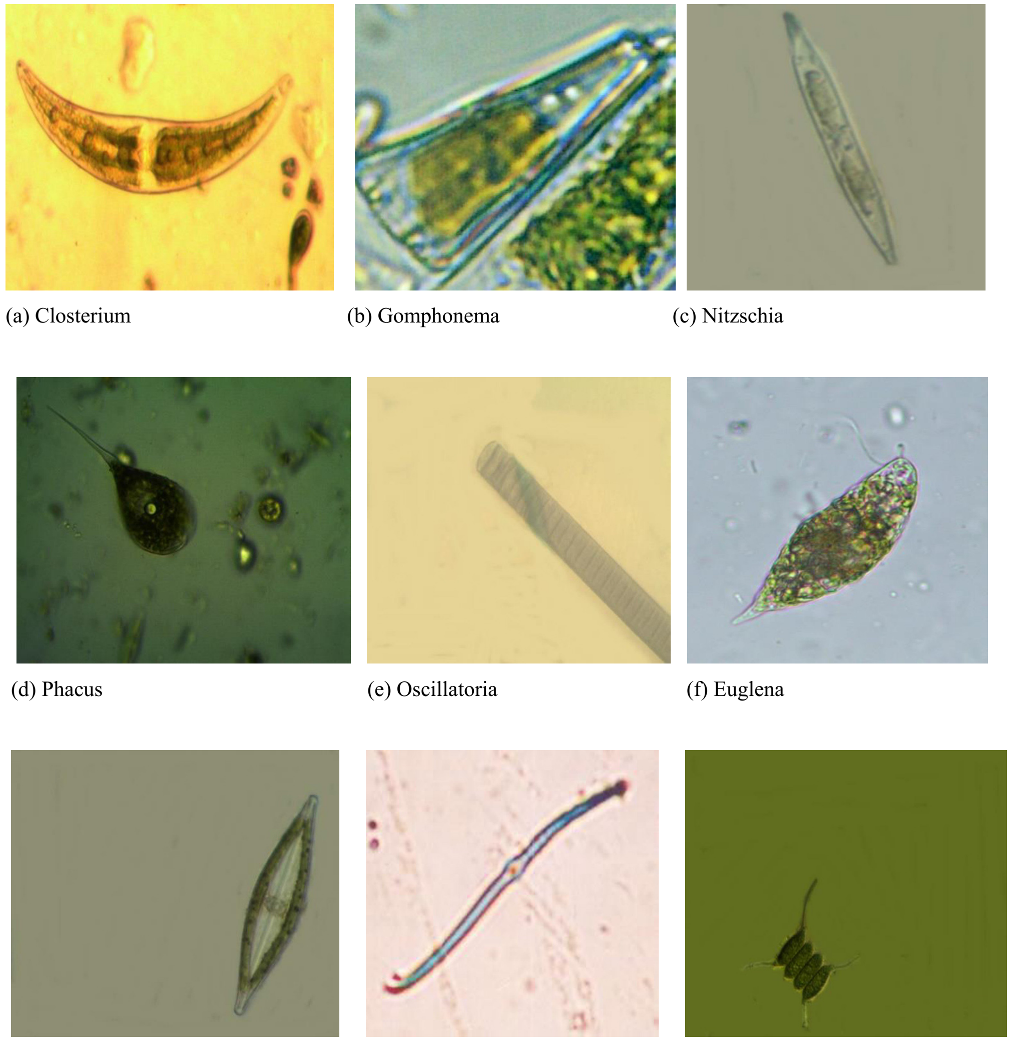


Fig. 4. Genera with their contribution for algal species.



(a) Closterium (b) Gomphonema (c) Nitzschia
(d) Phacus (e) Oscillatoria (f) Euglena
(g) Navicula (h) Ankistrodesmus (i) Scenedesmus

Fig. 5. (a-i) Pollution tolerating genera identified from the freshwater bodies of the study area.

Table 2
Palmer algal genus pollution index.

S. No.	Genus	Index	Genus	Index
1	Ankistrodesmus	4	Nitzchia	3
2	Closterium	1	Scenedesmus	4
3	Euglena	1	Syndra	2
4	Gomphonema	1	Pandorina	1
5	Chlorella	1	Oscillatoria	5
6	Navicula	3	Phacus	2
7	Cyclotella	5	Phormidium	1
8	Chlaymydomonas	3	Stigeoclonium	2
9	Anacystis	2	Micractinium	1

molecular studies of algae along with phylogeny of the representative genera. The algal use for bio-fuel, bioremediation, medicinal, human algal diet and fish flora should be studied for commercial and industrial applications and its advantages to the mankind.

Table 3
Pollution indicating algal genera from water bodies of the study area.

Algal Genus	Banjosa Lake	Alisojal Dam	Dothan Dam	Drak Dam	Rawalakot City (Nullah)
Ankistrodesmus	4	–	–	4	4
Closterium	1	–	1	1	1
Euglena	1	–	–	1	1
Gomphonema	1	1	1	1	1
Chlorella	–	1	1	–	–
Navicula	3	–	–	3	3
Cyclotella	–	–	–	–	–
Chlamydomonas	–	–	–	–	–
Nitzschia	3	3	–	3	3
Scenedesmus	–	–	4	–	4
Syndra	2	2	2	–	2
Pandorina	–	–	1	–	1
Oscillatoria	–	–	–	5	5
Phacus	2	2	–	–	–
Phormidium	–	–	–	–	–
Stigeoclonium	–	–	–	–	–
Total	**14**	**9**	**10**	**18**	**25**

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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