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, Drake Dam and Rawalakot Nullah was affected from anthropogenic activities and needs to be managed.

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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
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, Presscott, 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 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: Chroococcales |                                      |
|           | 1. Chroococcus turgidus (Kutzing) Naegeli |                                      |
|           | 2. Chroococcus limneticus Lemmermann |                                      |
|           | Family: Microcystaceae |                                      |
|           | 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 mertensiya Meneghini ex Gomont |                                      |
|           | 8. Lyngbya majuscula 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 C.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: Merismopediae |                                      |
|           | 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 |                                      |
|           | Order: Chlorococcales |                                      |
|           | Family: Scenedesmaceae |                                      |
|           | 23. Schroederia setigera [Schroeder]/Lemmermann |                                      |
|           | Order: Sphaeropleales |                                      |
|           | Family: Scenedesmaceae |                                      |
|           | 24. Scenedesmus quadricauda (Turpin) Brebisson |                                      |
|           | 25. Scenedesmus apolensis Richter |                                      |
|           | 26. Scenedesmus protuberatus 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. longicuda G.M Smith |                                      |
|           | 32. Scenedesmus quadricauda var. maxima West & GS West |                                      |
|           | 33. Scenedesmus abundans var. Kirchner (Chodat) |                                      |
|           | 34. Tetradron regulare Kutzing |                                      |
|           | 35. Tetradron cautatum (Corda) Hansgirg |                                      |
|           | 36. Tetradron trigonum var. minus Reinich |                                      |
|           | 37. Trochidia aspera Reinisch |                                      |
|           | 38. Coelastrum microporum Nageli |                                      |
|           | 39. Coelosphaerium kuntzinginum |                                      |
|           | Order: Hydrodictyaceae |                                      |
|           | 40. Pediastrum duplex Meyen |                                      |
|           | 41. Pediastrum duplex var. gracilimum West & GS West |                                      |
|           | 42. Pediastrum simplex var. echunulatum Wittrock |                                      |
|           | 43. Pediastrum biaue var. ovatum (Ehrenberg) Tiffany |                                      |
|           | 44. Pediastrum simplex var. duodenarium (Bailey) Rabenhorst |                                      |
|           | 45. Pediastrum boryanum var. longicorne Raciborski |                                      |
|           | Order: Oedogoniales |                                      |
|           | Family: Oedogoniaceae |                                      |
|           | 46. Oedogonium macroandrium Wittrock |                                      |
|           | 47. Oedogonium carduncum (Hassall) Wittrock |                                      |
|           | 48. Oedogonium majus (Hansgirg) Tiffany |                                      |
|           | Order: Tetrasporales |                                      |
|           | Family: Sphaerocystidaceae |                                      |
|           | 49. Sphaerocystis Schroeteri R. Chodat |                                      |
|           | Order: Microspermales |                                      |

(continued on next page)
| Divisions | Class | Order, Family, Genus and Species name |
|-----------|-------|---------------------------------------|
| **Family: Microsporaceae** | | |
| 50. Microspora quadrata Hazen | | |
| 51. Microspora wilfekio Lagerheim | | |
| 52. Microspora tumidula Hazen | | |
| **Order: Chetophorales** | | |
| **Family: Chetophoraceae** | | |
| 53. Draparnaldia plumose (Vaucher) C.A. Agardh | | |
| 54. Chetophora lobata F.Schranks | | |
| 55. Chetophora 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 | | |
| **Zygmematophyceae** | | |
| **Order: Zygmematales** | | |
| **Family: Zygmemataceae** | | |
| 61. Spirogyra communis (Hassall) Kutzing | | |
| 62. Spirogyra biforis C.C.Jao | | |
| 63. Spirogyra maxima Link in C.C.Nees | | |
| 64. Spirogyra neglecta (Hassall) Kutzing | | |
| 65. Spirogyra subsalsa Link in C.C.Nees | | |
| 66. Spirogyra tetrapla Transeau | | |
| 67. Spirogyra elongata (Vaucher) Kutzing | | |
| 68. Spirogyra flaviatilis Hilse | | |
| 69. Spirogyra punctiformis Trascan | | |
| 70. Spirogyra rectangularis Transeau | | |
| 71. Spirogyra catenaeformis (Hassall) Kutzing | | |
| 72. Zygmena tenue Kutzing | | |
| 73. Zygmena sterile Transeau | | |
| 74. Zygmena insigni (Hassall) | | |
| 75. Zygmena aplanosporum Stacheva,J.D.Hall & Sheath | | |
| 76. Mougetia micropora Taft | | |
| 77. Mougetia viridis (Kutzing) Wittrock | | |
| **Order: Desmidiales** | | |
| **Family: Desmidaceae** | | |
| 78. Cosmarium formosulum Hoffmann | | |
| 79. Cosmarium botrytis Meneghini | | |
| 80. Cosmarium speciosum Lundell | | |
| 81. Cosmarium granatum Brebisson | | |
| 82. Cosmarium nitidulum Donoradis | | |
| 83. Cosmarium subtumidum Nordsted | | |
| 84. Staurastrum rorosae Meyen ex Ralfs | | |
| **Family: Closteriaceae** | | |
| 85. Closterium acutum (Lyngbye) Brebisson | | |
| 86. Closterium parvulum Naegeli | | |
| 87. Closterium leidlinii Kutzing | | |
| 88. Closterium lanceolatum Kutzing | | |
| 89. Closterium intermedium Ralfs | | |
| 90. Closterium littorale Gay | | |
| 91. Closterium lunula (Mueiller) Nitzch | | |
| 92. Closterium pseudolumula Borge | | |
| 93. Closterium acerorum var. elongatum Brebisson | | |
| 94. Closterium striolatum Ehrenberg | | |
| **Trebouxiophyceae** | | |
| **Order: Chlorellales** | | |
| **Family: Chlorallaceae** | | |
| 95. Chlorella conductrix Brandot | | |
| **Charophyta** | | |
| **Charophyceae** | | |
| **Order: Charales** | | |
| **Family: Characeae** | | |
| 96. Chara corallina Klein ex C.L.Willdenow | | |
| 97. Chara globular Thuiller | | |
| 98. Chara vulgaris Linnaeus | | |
| Division | Class   | Order, Family, Genus and Species name |
|----------|---------|----------------------------------------|
| **Bacillariophyta** | **Bacillariophyceae** | **Order:** Bacillariales  
**Family:** Anomoeoeidaceae  
99. *Anomoeoneis vitrea* Pfitzer  
100. *Anomoeoneis exilis* (Kutzing) Cleve  
101. *Anomoeoneis servanus* (Brebisson) Cleve  
**Family:** Catenulaceae  
99. *Amphora holsatica* Hustedt  
**Family:** Achnanthidiaceae  
100. *Achnanthus microcephalus* (Kutzing) Cleve  
**Family:** Cocconeidaceae  
101. *Cocconeis plancetula* Ehrenberg  
**Family:** Bacillariaceae  
102. *Denticula tennis* Kutzing  
103. *Nitzchia palea* (Kutzing) Wm. Smith  
104. *Nitzchia sublinearis* Hustedt  
105. *Nitzchia acicularis* (Kutzing) Wm. Smith  
106. *Nitzchia hungarica* Grunow  
107. *Nitzchia denticula* Grunow  
108. *Nitzchia palea* var. tenuirostris Grunow  
**Family:** Fragilariales  
109. *Diatom vulgare* Bory  
110. *Diatoma anceps* (Ehrenberg) Kirchner  
111. *Fragillaria viresecens* Ralfs  
112. *Fragillaria pinnota* Ehrenberg  
113. *Fragillaria capucina* Desmazieres  
114. *Fragilaria vaucheriae* (Kutzing) J.P. Peterson  
115. *Fragilaria intermedia* (Grunow) Grunow  
116. *Fragilaria crotonensis* var. prolongata Grunow  
117. *Fragilaria phoenicentron* (Nitzsch) Ehrenberg  
118. *Fragilaria acuta* Wm. Smith  
119. *Fragilaria amphicentra* var. amphilepta (Ehrenberg) Cleve  
120. *Fragilaria scalproides* Rabenhorst  
121. *Fragilariaatus* var. amphilepta (Ehrenberg) Cleve  
122. *Fragilaria denticula* var. amphilepta (Ehrenberg) Cleve  
123. *Synedra denticula* var. amphilepta (Ehrenberg) Cleve  
124. *Synedra denticula* var. amphilepta (Ehrenberg) Cleve  
125. *Synedra denticula* var. amphilepta (Ehrenberg) Cleve  
126. *Navicula tuscula* (Ehrenberg) Grunow  
127. *Navicula gracilis* Ehrenberg  
128. *Navicula protracta* (Grunow) Cleve  
129. *Navicula exigua* (Gregory) Muller  
130. *Navicula viridula* Kutzing  
131. *Navicula cuspidata* Kutzing  
132. *Caloneis bacillum* (Grunow) Mereschkowsky  
133. *Gyrosigma amnicum* (Kutzing) Cleve  
134. *Gyrosigma wormleyi* (Sullivant) Boyer  
135. *Gyrosigma Kaetzingii* (Grunow) Cleve  
136. *Navicula rotundata* (Ehrenberg) Cleve  
137. *Navicula gracilis* Ehrenberg  
138. *Navicula protracta* (Grunow) Cleve  
139. *Navicula exiguus* (Gregory) Muller  
140. *Navicula veneta* Kutzing  
141. *Navicula salinarum* Grunow  
142. *Navicula rhynocephala* Kutzing  
143. *Navicula radiosa* Kutzing  
144. *Navicula viridula* Kutzing  
145. *Navicula pusilla* Kutzing  
146. *Navicula grimmel Kraskeh  
147. *Navicula denticula* (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. *Ephelidium adnatum* (Kutzing) Brebisson  
153. *Ephelidium argus* (Ehrenberg) Kutzing  
**Family:** Pinnulariaceae  
154. *Pinnularia nobilis* Ehrenberg  
155. *Pinnularia braunii* (Grunow) Cleve  
156. *Pinnularia angulata* (Quekett) Wm. Smith  
157. *Pinnularia salinarum* (Grunow) Grunow  
**Family:** Neidaceae  
158. *Nedium iridis* (Ehrenberg) Pfitzer  
(continued on next page)
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.

| Divisions | Class | Order, Family, Genus and Species name |
|-----------|-------|--------------------------------------|
| *Nedium dubium* (Ehrenberg) Pfitzer | Family: Sellaphoraceae | |
| *Sellaphora capitata* D.G.Mann & S.M. McDonald | Family: Amphipleuraceae | |
| *Sellaphora pupilla* (Kutzing) Meresckowsky | Family: Stauroneidaceae | |
| *Frustulia rhomboids* (Ehrenberg) DeToni | Family: Sellaphoraceae | |
| *Frustulia viridula* (Brebisson) DeToni | Family: Amphipleuraceae | |
| *Craticula cuspidata* (Kutzing) D.G.Mann | Order: Surirellales |
| *Frustulia viridula* (Brebisson) DeToni | Order: Mastogloiales |
| *Surirella linearis var. constricta* (Ehrenberg) Grunow | Order: Euglenales |
| *Surirella ovata* Kutzing | Order: Euglenales |
| *Surirella minutu* Kutzing | Order: Gomphonemataceae |
| *Surirella patella* Kutzing | Order: Euglenales |
| *Surirella saronica* Auerswald | Order: Cymbellales |
| *Surirella didyma* Kutzing | Order: Cymbellales |
| *Surirella splendida* (Ehrenberg) Kutzing | Family: Gomphonemataceae |
| *Surirella linearis* var. | |
| *Surirella linearis* var. | |
| *Surirella minuta* Kutzing | |
| *Surirella patella* Kutzing | |
| *Surirella saronica* Auerswald | |
| *Surirella didyma* Kutzing | |
| *Surirella splendida* (Ehrenberg) Kutzing | |
| *Surirella linearis* var. | |
| *Surirella minuta* Kutzing | |
| *Surirella patella* Kutzing | |
| *Surirella saronica* Auerswald | |
| *Surirella didyma* Kutzing | |
| *Surirella splendida* (Ehrenberg) Kutzing | |
| *Surirella linearis* var. | |
| *Surirella minuta* Kutzing | |
| *Surirella patella* Kutzing | |
| *Surirella saronica* Auerswald | |
| *Surirella didyma* Kutzing | |
| *Surirella splendida* (Ehrenberg) Kutzing | |
| *Surirella linearis* var. | |
| *Surirella minuta* Kutzing | |
| *Surirella patella* Kutzing | |
| *Surirella saronica* Auerswald | |
| *Surirella didyma* Kutzing | |
| *Surirella splendida* (Ehrenberg) Kutzing | |
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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
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 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      | Chlamydomonas | 3     | Stigeoclonium| 2    |
| 9      | Anacystis     | 2     | Micractinium| 1    |

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        | 1                       |
| Euglena         | 1            | –            | –          | 1        | 1                       |
| Gomphonema      | 1            | 1            | 1          | 1        | 1                       |
| Chlorella       | –            | 1            | 1          | –        | –                       |
| Navicula        | 3            | –            | –          | 3        | 3                       |
| Cyclotella      | –            | –            | –          | –        | –                       |
| Chlamydomonas   | –            | –            | –          | –        | –                       |
| Nitzchia        | 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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