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**Ш. ФАХАД**,
Університет Науки та Інформаційних Технологій Куртуби,
Пешавар, Пакистан
e-mail: botanistsf@gmail.com

**Ф. ХУССАІН**,
Ісламський коледж,
Пешавар, Пакистан

**І. ХУРАМ**,
Коледж Єдварда, відділення біології,
Пешавар, Пакистан

# ОЦІНКА ВОДОРОСТЕВИХ УГРУПОВАНЬ У НИЖНЬОМУ КАНАЛІ Р. СВАТ ТА ЙОГО ПРИТОКАХ В РАЙОНІ ЧАРСАДДА, ПАКИСТАН

*Для оцінки водоростевих угруповань нижнього каналу р. Сват та його приток дослідження проводили на різних станціях, що відрізнялись за ступенем забруднення. Одночасно визначали фізико-хімічні параметри води. Обстеження проводили навесні (з березня по травень) 2021 р. Загалом знайдено 81 вид водоростей, що належать до 40 родів. Bacillariophyta, представлені 52 видами та 26 родами, переважали. Їхня частка у таксономічному багатстві водоростей становила 64,2 %. Chlorophyta нараховували 22 види та 10 родів (27,2 %), а Cyanophyta — 7 видів та 4 роди (8,6 %). Вплив чинників навколишнього середовища на структуру угруповань водоростей визначали з використанням канонічного аналізу відповідності (CCA). Встановлено, що температура, електропровідність, солоність, вміст міді та натрію, загальна мінералізація, pH, твердість води та інші чинники суттєво впливають на формування водоростевих угруповань. На станції, розташованій нижче за течією, водоростеві угруповання характеризувалися більшим різноманіттям, що свідчить про високу здатність екосистеми р. Сват до самоочищення. Зафіксовані фізико-хімічні параметри показали, що рівень біогенних речовин у каналі сприяє розвитку водоростевих угруповань.*

***Ключові слова**: водорості, різноманіття, фізико-хімічні параметри води, канонічний аналіз відповідності (CCA), нижній канал р. Сват.*

## Introduction

Algae are considered as biological indicators of aquatic ecosystem state. An assessment of aquatic ecosystems can be done using algae, because they are rather sensitive to huge numbers of contaminants, which maybe the cause for

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ecosystem diminishing. Both unicellular and multicellular algal species are very sensitive to even insignificant deviations in the physiochemical characteristics of the water resulting in prominent changes in the entire aquatic ecosystem food web [15]. Algae play a key role in food chain as primary producers [22]. They use different ways to utilize and fix carbon dioxide and transform it into valuable biomass [17].

The metabolism and diversity of microorganisms are affected by active toxic heavy metals; consequently, these organisms can adapt resistance to metal ions stress by converting their active form into an inactive stage. Several microalgae and bacteria are capable of absorbing the inorganic compounds containing heavy metals due to their affinity [23].

In polluted and unpolluted waters, algae inhabit different substrates. Because of this feature they are considered as a very useful tool in water quality determination. During the nineteenth century this thought that algal communities are the best mean of biomonitoring and bioindication had been accepted and acknowledged. Thus, a system of compatibility of algae with aquatic environment pollution was developed [4] and considered for different water bodies such as streams and rivers [3].

The objective of the present work was to compare algal communities occurring at various sites of the lower Swat canal and its tributaries differing in the degree of contamination.

## Material and Methods

*Description of study area.* The Charsadda district is a part of the Khyber Pakhtunkhwa province of Pakistan. The district position is between 34°03' to 34°38' N and 71 28' to 71°53' E with the total area of 996 $km^2$ and the altitude of 282 m above sea level [14].

Tehsil Tangi is a part of the Charsadda district covering an area of 347 $km^2$ with GPS coordinates of 34°8'43" N and 71°43'51" E and mean elevation of 358 m above sea level [12].

*Sampling and laboratory processing.* On the whole 60 algal samples were collected during the spring season of 2021 from the two different sites of the Lower Swat canal and its tributaries in the Charsadda district. Algal samples were collected mostly from different places like river banks, shallow water beds, moist soil and stones near river banks, partially or fully submerged hydrophytes, running and stagnant waters, etc. by the following methods [1, 10, 11, 13].

Forceps were used for the collection of filamentous algae. Slides and knifes were used for Cyanophyta or blue green algae collection. Toothbrushes were used to brush the stones containing diatoms, which were then collected into utensil by pouring the water over the stone; pipettes were used for desmid flora collection. Epilithic flora was scratched from rocks using toothbrushes and knifes [1].

The samples were preserved in 4 % formalin solution in bottles [5, 10, 13]. The taxonomic assessment of algal specimens was carried out in the Qurtuba University of Science and Information Technology, Peshawar campus. For identification, the glass slides mounted with the specimens were examined under a compound microscope and identified following [6—10, 16, 19, 20]. The species composition of algal communities found at different sites was compared using the Sorensen coefficient of community similarity [18].

Temperature, pH, electrical conductivity, total dissolved solids, salinity, and dissolved oxygen were measured at the sampling sites using a Multiparameter water quality meter (HANNA HI 98194). For more detail physiochemical properties of the water, samples were analyzed by the standard method for the examination of fresh water and wastewater [2] in the Environmental laboratory, Jail road, GHSS Mohabbat abad, Mardan, KP, Pakistan (Table 1).

## Results and Discussion

In the current study, algal samples were collected at site 1 (Shakh N 1-2) and site 2 (Shakh N 5-6) of the lower Swat canal and its tributaries in the Charsadda district. A total of 81 algal species belonging to 40 genera were identified, in which Bacillariophyta (64.2 %) with 52 species and 26 genera were the dominant group. They were followed by Chlorophyta (27.2 %) with 22 species and 10 genera and Cyanophyta (8.6 %) with 7 species and 4 genera.

The leading families represented by the largest number of species were Naviculaceae (13 species), Bacillariaceae (7 species), Zygnemataceae (6 species), Cymbellaceae (5 species), Gomphonemataceae, Oedogoniceae, Fragilariaceae, Oscillatoriaceae, and Scenedesmaceae (4 species in each family), Closteriaceae, Surirellaceae, Merismopediaceae, and Pinnulariaceae (3 species in each family), and Amphipleuraceae, Rhopalodiaceae and Cladophoraceae (2 species in each family). Other families included only one species (Figure 1).

The genera with the largest number of species were *Nitzschia* Hassall and *Navicula* Bory (7 species in each genus), *Spirogyra* Link (6 species), *Cymbella* C. Agardh (5 species), and *Oedogonium* Link ex Hirn, *Gomphonema* Ehrenberg, and *Gyrosigma* Hassall (4 species in each genus). They were followed by *Closterium* Nitzsch ex Ralfs, *Scenedesmus* Turpin, and *Merismopedia* Meyen (3 species), *Frustulia* Rabenhorst, *Fragilaria* Lyngbye, *Pinnularia* Ehrenberg, *Surirella* Turpin, and *Oscillatoria* Vaucher ex Gomont (with 2 species in each genus). Other genera were represented only by one species (Table 2).

The studied sites differed in the number of algal species. On the whole, 41 species were identified at site 1, whereas 65 species — at site 2.

The species composition of algae also differed, which is supported by low values of the Sorensen coefficient of community similarity (47.2 %) registered in comparing the studied sites. The species composition of Chlorophyta (42.8 %) and Bacillariophyta (47.0 %) differed most significantly. In this case, the species composition of Cyanophyta was rather similar (60.0 %).

The studied sites differed in the taxonomic structure of the algal flora. At site 1, the genera with the largest number of species were *Navicula* (7 species), *Nitzschia*, and *Cymbella* (4 species in each genus), *Merismopedia* and *Spirogyra* (3 species), and *Gomphonema*, *Gyrosigma*, *Pinnularia*, *Frustulia* (2 species in each genus). At site 2, the leading genera were *Nitzschia* (7 species), *Spirogyra* (6 species), *Oedogonium*, *Navicula* (4 species in each genus), *Cymbella*, *Gomphonema*, *Gyrosigma*, *Scenedesmus*, *Merismopedia*, *Closterium* (3 species in

*Table 1*

**Physiochemical parameters of the water in the Lower Swat Canal and its tributaries**

| Parameters | Method number | Units | Site 1 | Site 2 | Method used | NDWQS Standard 2017 (Drinking limits) |
|---|---|---|---|---|---|---|
| Temperature | | °C | 28 | 29 | Hanna digital meter | |
| pH | 4500H+B | — | 7.98 | 7.71 | Hanna digital meter | 6.5—8.5 |
| EC | 2510.B | µS/cm | 306 | 1031 | Hanna digital meter | NGVS |
| TDS | 2540.C | mg/L | 150 | 566 | Hanna digital meter | 1000 mg/L |
| Resistivity | | [ -cm] | 3546 | 4000 | Hanna digital meter | |
| Salinity | | [PSU] | 0.13 | 0.11 | Hanna digital meter | |
| Total hardness as $CaCO_3$ | 2340.C | mg/L | 75 | 140 | Titration based method | <500 mg/L |
| Calcium as $CaCO_3$ | 3500-Ca.B | mg/L | 34.4 | 75.3 | Multiparameter photometer | 250 |
| Magnesium as $CaCO_3$ | 3500-Ca.B | mg/L | 23.2 | 73.2 | Multiparameter photometer | 250 |
| Color 2120.B | 2120B/C | — | Colorless | 0.0 | Multiparameter photometer | <15 TCU |
| Odor 2150.B | 2150B/C | — | Objectionable | Objectionable | Sensory evaluation | Odorless |
| Taste 2160.A | 2160A/C | — | Tasteless | Objectionable | Sensory evaluation | Tasteless |
| Total alkalinity as $CaCO_3$ | 2320.B | mg/L | 139 | 478 | Multiparameter photometer | <500 |
| Sodium | 3500-Na | mg/L | 45 | 97 | Sodium meter | 200 mg/L |
| Sulfate | 4500-So2.B | mg/L | 10 | 88 | Multiparameter photometer | 250 mg/L |
| Chlorides | 4500-Cl.B | mg/L | 30 | 67 | Kit based method | 250 mg/L |

*Table 1 (continued)*

| Parameters | Method number | Units | Site 1 | Site 2 | Method used | NDWQS Standard 2017 (Drinking limits) |
|---|---|---|---|---|---|---|
| Nitrates | 4500-No 2.b | mg/L | 0.4 | 23.2 | Multiparameter photometer | 50 mg/L |
| Copper | 3111 Cu. B | mg/L | 1.74 | 1.91 | Multiparameter photometer | 2 mg/L |
| Turbidity | 2130.B | mg/L | 1.04 | 0.97 | 2100P HACH | 1000 mg/L |

each), and *Oscillatoria*, *Fragilaria*, *Surirella* (2 species in each) (Table 2). The predominance of the genus *Nitzschia* at site 2 more contaminated compared to site 1 can be conditioned by its ecological characteristics. In particular, it has been known [21] that many taxa of the genus *Nitzschia* have an affinity for brackish and/or organically polluted waters which are rich in nutrients and poor in oxygen.

It is likely that the increase in the number of algal species, and also changes in algal species composition and taxonomic structure, registered at site 2 were conditioned by changes in the physiochemical parameters of the water, primarily in the content of nutrients, due to anthropogenic and agricultural runoff into the river (Table 1).

The CCA analysis showed that copper had a positive effect on Bacillariophyta species and negative effect on Chlorophyta species. Salinity, turbidity,

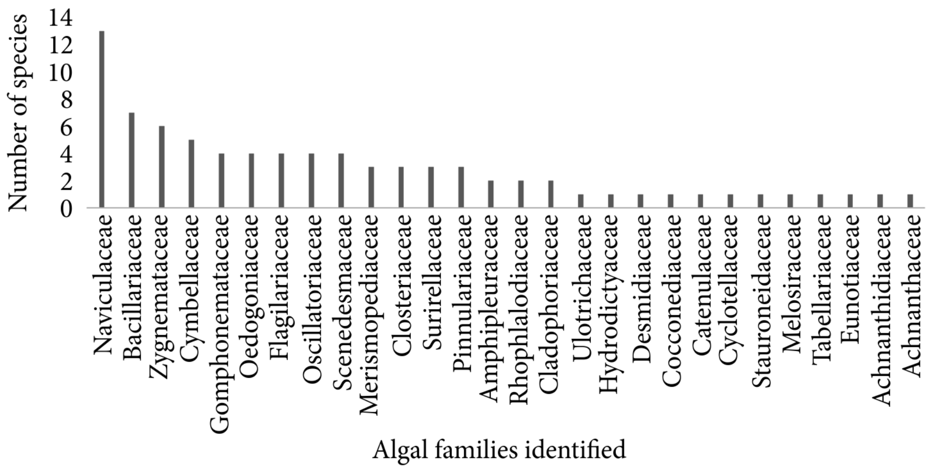


***Figure 1.*** Number of algal species in the families identified

*Table 2*

**List of algal species found at different sites of the Lower Swat Canal and its tributaries**

| Species | Site 1 | Site 2 |
|---|---|---|
| **Cyanophyta** | | |
| *Merismopedia elegans* A. Braun ex Kützing | + | + |
| *Merismopedia glauca* (Ehrenberg) Kützing | + | + |
| *Merismopedia tenuissima* Lemmermann | + | + |
| *Oscillatoria princeps* Vaucher ex Gomont | — | + |
| *Oscillatoria tenuis* C. Agardh ex Gomont | — | + |
| *Phormidium nigrum* (Vaucher ex Gomont) Anagnostidis & Komárek | — | + |
| *Spirulina subsalsa* Oersted ex Gomont | — | + |
| **Bacillariophyta** | | |
| *Achnanthes inflata* (Kützing ) Grunow | — | + |
| *Amphora copulata* (Kützing) Schoeman & R.E.M. Archibald | — | + |
| *Caloneis bacillum* (Grunow) Cleve | + | — |
| *Cocconeis placentula* Ehrenberg | + | + |
| *Craticula accomoda* (Hustedt) D.G. Mann | — | + |
| *Cyclotella meneghiniana* Kützing | — | + |
| *Cymatopleura solea* (Brebisson) W. Smith | — | + |
| *Cymbella affinis* Kützing | + | + |
| *Cymbella aspera* (Ehrenberg) Cleve | — | + |
| *Cymbella kappii* (Cholnoky) Cholnoky | + | — |
| *Cymbella tumida* (Brebisson ) van Heurck | + | + |
| *Cymbella turgidula* Grunow | + | — |
| *Diatoma vulgaris* Bory | — | + |
| *Diploneis elliptica* (Kützing) Cleve | — | + |
| *Epithemia adnata* (Kützing) Brebisson | + | — |
| *Eunotia minor* (Kützing) Grunow | + | + |
| *Fragilaria acus* (Kützing) Lange-Bertalot | — | + |
| *Fragilaria* sp. | — | + |
| *Frustulia saxonica* Rabenhorst | + | + |
| *Frustulia vulgaris* (Thwaites) De Toni | + | — |
| *Gomphonema affine* Kützing | — | + |
| *Gomphonema geminatum* (Lyngbye) C. Agardh | + | — |
| *Gomphonema laticollum* E. Reichardt | — | + |

*Table 2 (continued)*

| Species | Site 1 | Site 2 |
|---|---|---|
| *Gomphonema minutum* (C. Agardh) C. Agardh | + | + |
| *Gyrosigma acuminatum* (Kützing) Rabenhorst | — | + |
| *Gyrosigma attenuatum* (Kützing) Rabenhorst | + | — |
| *Gyrosigma scalproides* (Rabenhorst) Cleve | — | + |
| *Gyrosigma rautenbachiae* Cholnoky | + | + |
| *Melosira varians* C. Agardh | + | + |
| *Navicula capitatoradiata* H. Germain ex Gasse | + | — |
| *Navicula cryptocephala* Kützing | + | + |
| *Navicula gregaria* Donkin | + | + |
| *Navicula rhynchocephala* Kützing | + | — |
| *Navicula riediana* Lange-Bertalot & Rumrich | + | + |
| *Navicula rostellata* Kützing | + | + |
| *Navicula tripunctata* (O.F. Muller) Bory | + | — |
| *Nitzschia clausii* Hantzsch | — | + |
| *Nitzschia dissipata* (Kützing) Rabenhorst | + | + |
| *Nitzschia draveillensis* Coste & Ricard | + | + |
| *Nitzschia gracilis* Hantzsch | — | + |
| *Nitzschia hantzschiana* Rabenhorst | + | + |
| *Nitzschia recta* Hantzsch ex Rabenhorst | + | + |
| *Nitzschia sinuata* (Thwaites ex W. Smith) Grunow | — | + |
| *Pinnularia viridiformis* Krammer | + | — |
| *Pinnularia viridis* (Nitzsch) Ehrenberg | + | — |
| *Pleurosigma salinarum* (Grunow) Grunow | + | — |
| *Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot | — | + |
| *Rhopalodia gibba* (Ehrenberg) O. Muller | — | + |
| *Staurosira elliptica* (Schumann) D.M.Williams & Round | — | + |
| *Surirella didyma* Kützing | — | + |
| *Surirella patella* Kützing | — | + |
| *Ulnaria ulna* (Nitzsch) Compere | — | + |
| **Chlorophyta** | | |
| *Cladophora glomerata* (Linnaeus) Kützing | + | — |
| *Closterium acerosum* Ehrenberg ex Ralfs | — | + |

*Table 2 (continued)*

| Species | Site 1 | Site 2 |
|---|---|---|
| *Closterium karnakense* Koesel | — | + |
| *Closterium moniliferum* Ehrenberg ex Ralfs | — | + |
| *Cosmarium cataractarum* (Raciborski) Eichler | + | — |
| *Hydrodictyon reticulatum* (Linnaeus) Bory | + | — |
| *Oedogonium capillare* Kützing ex Hirn | — | + |
| *Oedogonium pringsheimii* C.E. Cramer ex Hirn | + | + |
| *Oedogonium subsetaceum* Kützing | — | + |
| *Oedogonium vaucheri* A. Braun ex Hirn | — | + |
| *Rhizoclonium tortuosum* (Dillwyn) Kützing | + | + |
| *Scenedesmus armatus* (Turpin) Brebisson | — | + |
| *Scenedesmus dimorphus* (Turpin) Kützing | — | + |
| *Scenedesmus quadricauda* (Turpin) Brebisson | + | + |
| *Spirogyra communis* (Hassall) Kützing | + | + |
| *Spirogyra crassa* (Kützing) Kützing | + | + |
| *Spirogyra pratensis* Transeau | — | + |
| *Spirogyra rivularis* (Hassall) Rabenhorst | + | + |
| *Spirogyra scrobiculata* (Stockmayer) Czurda | — | + |
| *Spirogyra tenuissima* (Hassall) Kützing | — | + |
| *Tetradesmus obliquus* (Turpin) M.J. Wynne | — | + |
| *Ulothrix zonata* (F. Weber & Mohr) Kützing | — | + |
| On the whole 81 | 41 | 65 |

chloride, nitrate, sulphate, calcium as $CaCO_3$, total alkalinity as $CaCO_3$ and magnesium as $CaCO_3$ had a positive effect on Chlorophyta species and a negative effect on Bacillariophyta species. Temperature, pH, total dissolved solids, sodium and total hardness as $CaCO_3$ had a positive effect on Cyanophyta species. Resistivity and electrical conductivity had a negative effect on Cyanophyta species (Figure 2).

## Conclusion

On the whole, 81 algal species were found during the period of investigations of the lower Swat canal and its tributaries. Bacillariophyta were highly diverse in their species composition (52 species) followed by Chlorophyta (22), and Cyanophyta (7).

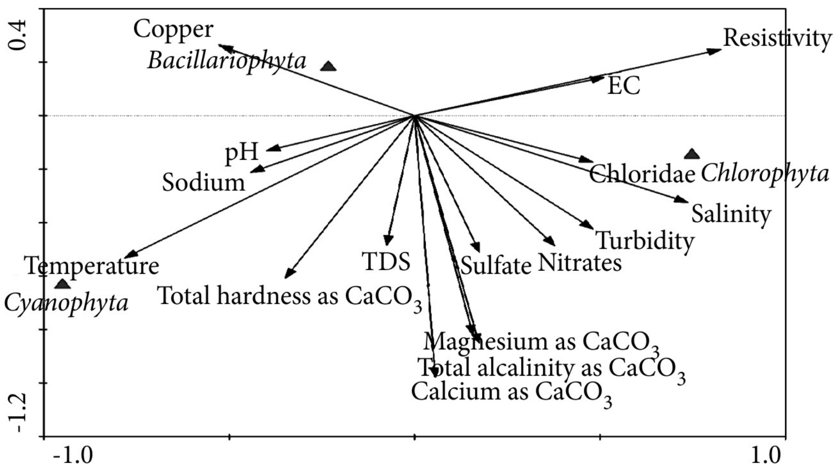


***Figure 2.*** CCA analysis of the influence of environmental factors on the algal communities

The study of the lower Swat canal and its tributaries revealed the fact that water physiochemical parameters have a great effect on the distribution and types of algal communities in the riverine system. The studied sites located upstream and downstream differed in the level of water contamination, primarily in the content of nutrients, TDS, chloride, sulfate, etc. At site 2, their content was essentially higher.

The studied sites significantly differed in the number of algal species, their species composition and taxonomic structure. At site 2 more contaminated compared to site 1, the number of algal species was higher (65) than that at site 1 (41), probably due to a higher content of nutrients incoming with anthropogenic and agricultural runoff. At site 1, the genus *Navicula* was represented by the largest number of species, whereas the genus *Nitzschia* more resistant to contamination predominated at site 2. Most of the algal species were reported from the slow running and standing shallow waters. Less number of algal species was reported from fast moving waters.

The CCA analysis showed that copper had a positive effect on Bacillariophyta species and negative effect on Chlorophyta species. Salinity, turbidity, chloride, nitrate, sulphate, calcium as $CaCO_3$, total alkalinity as $CaCO_3$ and magnesium as $CaCO_3$ had a positive effect on Chlorophyta species and a negative effect on Bacillariophyta species. Temperature, pH, total dissolved solids, sodium and total hardness as $CaCO_3$ had a positive effect on Cyanophyta species. Resistivity and electrical conductivity had a negative effect on Cyanophyta species.

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*Shah Fahad*,
Qurtuba University of Science and Information Technology,
Peshawar, Pakistan
e-mail: botanistsf@gmail.com
*Fida Hussain*,
Islamia College University,
Peshawar, Pakistan
*Izaz Khuram*,
Department of Biology, Edwards College,
Peshawar, Pakistan

ASSESSMENT OF ALGAL COMMUNITIES OF THE LOWER SWAT CANAL AND ITS TRIBUTARIES IN THE CHARSADDA DISTRICT, PAKISTAN

To assess the algal communities of the Lower Swat canal and its tributaries of Tehsil Tangi of the Charsadda district, samples were taken at various sites differing in the level of contamination. The physiochemical parameters of the river water were also determined. Investigations were carried out during the spring season (March to May) of 2021. A total of 81 species belonging to 40 genera were identified, among which Bacillariophyta (64.2 %) with 52 species and 26 genera were the dominant group. They were followed by Chlorophyta (27.2 %) with 22 species and 10 genera, and Cyanophyta (8.6 %) with 7 species and 4 genera. To evaluate the influence of environmental factors on the algal communities, canonical correspondence analysis (CCA) was performed. The CCA revealed water temperature, resistivity, electrical conductivity, salinity, copper and sodium content, total dissolved solids, total alkalinity as $CaCO_3$ and magnesium as $CaCO_3$, and total hardness as $CaCO_3$ as significant factors influencing freshwater algal communities. Higher algal diversity was registered downstream, which showed that the aquatic ecosystem of the Swat River has high self-purification capability with reported algal communities. The recorded physiochemical parameters of the water showed that the nutrients present were sufficient for the growth of algal communities.

***Keywords:*** *algae, diversity, physiochemical parameters, water, canonical correspondence analysis (CCA), the lower Swat canal.*