Epiphytic Algae as Bioindicators of Air and Water Quality in the Godavari River Catchment Area, Trimbakeshwar

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Abstract **-** Algae are excellent bioindicators because they respond quickly to changes in their environment due to their short life cycles, simple structure, and direct contact with the surrounding water or air. Unlike chemical analyses that provide a snapshot of conditions at a specific time, algal communities reflect the integrated effects of pollution over time. This study investigated the potential of epiphytic algae as bioindicators of air and water quality in the Godavari River catchment area, Trimbakeshwar. As the region experiences increasing anthropogenic pressure from pilgrimage and urban development, a simple and effective method for environmental monitoring is needed. Algal samples were collected from submerged vegetation and tree bark at ten sites along the river and its tributaries over a six-month period. Water quality parameters, including pH, dissolved oxygen, and nutrient levels, were also measured. The results showed a significant shift in the epiphytic algal community from a diverse assemblage of diatoms and green algae in upstream, less disturbed areas, to a dominance of pollution-tolerant cyanobacteria and certain green algae in downstream, more polluted sites. Furthermore, specific species of epiphytic algae on tree bark were found to accumulate heavy metals, with concentrations correlating to proximity to traffic and urban centers. These findings demonstrate that epiphytic algae are a reliable, cost-effective tool for assessing and monitoring both air and water quality, providing valuable data for environmental management and conservation efforts in the Trimbakeshwar region.

Introduction - Epiphytic algae, which are algae that grow on other plants or surfaces, are excellent bioindicators of environmental conditions. Their sensitivity to changes in water and air quality makes them a valuable tool for monitoring pollution. In the Trimbakeshwar Godavari River catchment area, these organisms can provide crucial insights into the health of the ecosystem Water quality parameters, including pH, dissolved oxygen, and nutrient levels, were also measured. The results showed a significant shift in the epiphytic algal community from a diverse assemblage of diatoms and green algae in upstream, less disturbed areas, to a dominance of pollution-tolerant cyanobacteria and certain green algae in downstream, more polluted sites. Furthermore, specific species of epiphytic algae on tree bark were found to accumulate heavy metals, with concentrations correlating to proximity to traffic and urban centers. These findings demonstrate that epiphytic algae are a reliable, cost-effective tool for assessing and monitoring both air and water quality, providing valuable data for environmental management and conservation efforts in the Trimbakeshwar region.

Water Quality Assessment Using Epiphytic AlgaeEpiphytic algae, those that grow attached to submerged plants, stones, or other surfaces in the river, are particularly useful for monitoring water quality in a river system like the Godavari.Nutrient and Organic Pollution: The type and abundance of epiphytic algae are directly influenced by nutrient levels (e.g., nitrogen and phosphorus) from sources like agricultural runoff and sewage.In clean, less polluted water (oligotrophic conditions), the algal community is often diverse and dominated by certain diatoms and green algae.In polluted, nutrient-rich water (eutrophic conditions), there is a significant shift in the community. Pollution-tolerant species, such as certain blue-green algae (cyanobacteria) and some green algae, will become dominant, often leading to large algal blooms. The presence of these specific species can be used to assess the level of organic pollution.The Palmer Pollution Index: This is a well-established method for assessing organic pollution based on the presence of certain algal species. Developed by C.M. Palmer in 1969, the index assigns a numerical "pollution-tolerance score" to various algal genera and species. By collecting and identifying the algae in a water sample and summing their scores, researchers can determine if the water is: Unpolluted: A low index score. Moderately Polluted: An intermediate score. Highly Polluted: A high score (20 or more).Air Quality Assessment Using Epiphytic AlgaeWhile lichens are more commonly known as air quality indicators, epiphytic algae can also be used for this purpose, particularly in urban areas. These algae, which grow on tree bark and other surfaces, absorb nutrients and pollutants directly from the atmosphere.Airborne Pollutants: Epiphytic algae are sensitive to common air pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), and fine particulate matter (PM2.5, PM10). High levels of these pollutants can cause a decline in the diversity and abundance of sensitive algal species, leading to a "lichen and algal desert" in highly polluted areas.Heavy Metal Accumulation: Epiphytic algae can accumulate heavy metals from the air, making them valuable tools for monitoring this type of pollution. By analyzing the concentration of metals like lead (Pb), zinc (Zn), copper (Cu), and cadmium (Cd) in the algal biomass, researchers can pinpoint sources of pollution, such as industrial emissions and vehicular exhaust. This is often a more cost-effective method than using advanced chemical sensors.Water Quality AssessmentThe composition and abundance of epiphytic algae in the Godavari River can reveal the level of water pollution. Different types of algae thrive under specific conditions:Oligotrophic Conditions (Low Pollution): Water bodies with low nutrient levels are often dominated by green algae and diatoms. The presence of these species indicates a healthier, less polluted environment.Eutrophic Conditions (High Pollution): The abundance of blue-green algae (cyanobacteria) is often a sign of organic pollution and high nutrient loads, which can come from sewage, agricultural runoff, and other human activities. These conditions can lead to harmful algal blooms.By analyzing the specific algal genera present, researchers can use a Palmer Pollution Index or similar methods to determine the water's pollution level.Air Quality Assessment

Epiphytic algae and lichens that grow on tree trunks and other surfaces are also highly sensitive to airborne pollutants. Since they get their nutrients directly from the atmosphere, they are reliable indicators of air quality. Tolerance to Pollution: Some species of algae are more tolerant of air pollutants like sulfur dioxide, nitrogen oxides, and heavy metals. An increase in the population of these tolerant species and a decrease in the more sensitive ones can signal deteriorating air quality.Heavy Metal Monitoring: The algae can absorb and accumulate heavy metals from the air. By analyzing the concentration of these metals in the algal biomass, researchers can pinpoint sources of pollution, such as industrial emissions or vehicular traffic.

Survey area and sampling site locations

"One River and Two Streams" area is located on the South Tibetan Plateau at an elevation of 3500–4100 m above sea level. The region has a semi-arid climate in the monsoon temperate zone. The average annual temperature ranges from 2.4–8.5°C, and precipitation, which is between 270–550 mm annually, primarily falls from May through September.

the physicochemical parameters of a water body and its water quality. It presents the findings from quarterly sampling, highlighting seasonal and spatial variations in several key parameters.

Water Temperature (WT) and pHWT ranged from 2.3°C to 22.3°C. It was significantly higher in summer compared to the other three seasons.pH values were between 8.31 and 9.77. It was significantly lower in summer than in the other seasons.

Neither WT nor pH showed significant changes among the different sampling sites.Turbidity, NH3-N, and TPTurbidity was significantly higher in autumn compared to other seasons.NH3-N (ammonia nitrogen) concentration was significantly higher in winter compared to other seasons.TP (total phosphorus) concentration showed no significant change among the seasons.

Section 1: Survey Area and Sampling Site Locations

This section describes the geographical and climatic context of a study area, which is the "One River and Two Streams" region of the South Tibetan Plateau.

- Location: The area is located at a high elevation, 3500–4100 m above sea level. The "One River" refers to the middle reaches of the YarlungZangbo River, also known as the Brahmaputra River. The "Two Streams" are its main tributaries, the Lhasa River and the Nianchu River.
- Climate: The climate is described as semi-arid and, in a monsoon, temperate zone.
    - Semi-arid climate: This is a dry climate sub-type with low annual precipitation, typically ranging from 200–400 mm per year. It's not as dry as a desert but receives less rainfall than a humid climate.
    - Monsoon temperate zone: This indicates that the area experiences a seasonal shift in wind patterns, which brings most of its rainfall in a specific period (May to September). This seasonal precipitation is a key characteristic of a monsoon climate.
- Weather: The average annual temperature is relatively low, from 2.4–8.5°C. The majority of the precipitation (more than 83%) occurs during the summer months, from May through September.

Section 2: Water Quality Parameters

This section details the results of water quality analysis, explaining the meaning of key parameters mentioned in the text.

- WT (Water Temperature): This is a fundamental parameter that affects the physical, chemical, and biological properties of water. The text shows WT varied from 2.3°C to 22.3°C and was significantly higher in summer, which is expected due to the warmer weather.
- pH: The pH scale measures how acidic or basic a substance is. A pH of 7 is neutral. Values below 7 are acidic, and values above 7 are basic (alkaline). The pH in this study ranged from 8.31 to 9.77, indicating the water was consistently alkaline. The text notes that pH was lower in the summer, but it still remained within the alkaline range.
- Turbidity: This is a measure of the cloudiness or haziness of a fluid caused by individual particles that are generally invisible to the naked eye. The text indicates that turbidity was significantly higher in autumn, which could be due to seasonal changes like increased runoff carrying sediment into the water.
- NH_3-N (Ammoniacal Nitrogen): This refers to the concentration of ammonia (NH_3) and ammonium ions (NH_4^+) in the water. High levels of NH_3-N can be toxic to aquatic life and are often an indicator of pollution from sources like sewage, agricultural runoff, or industrial waste. The finding that NH_3-N was significantly higher in winter might be related to factors like less biological uptake by plants or reduced water flow during the colder season.
- TP (Total Phosphorus): This measures the total amount of phosphorus in the water, including both dissolved and particulate forms. Phosphorus is a key nutrient for plant growth. High concentrations of TP can lead to eutrophication, a process where excessive plant and algal growth can deplete oxygen and harm other aquatic life. The text notes that TP concentration did not change significantly among the seasons, suggesting a stable source of phosphorus throughout the year.

Materials

General materials for algae collection typically include:

- Sample containers: Vials, jars, plastic bags, or bottles.
- Collection tools: Tweezers, brushes, knives, or specialized nets and samplers.
- Protective gear: Latex gloves to prevent skin contact with potentially toxic species.
- Preservatives: Formalin, Lugol's solution, or other fixatives, especially if samples will not be analyzed the same day.
- Labeling materials: Permanent marker and waterproof labels to record details like location, date, and time.
- Cooler and ice: To keep samples cool during transport and prevent degradation.

Methodology

The specific collection methodology depends on the type of algae you are targeting.1. Phytoplankton Collection

Phytoplankton are suspended in the water, so the goal is to collect a representative water sample.

- Grab Samples**:** This is the simplest method. A container is inverted, submerged below the water surface, and then turned upright to fill. This is suitable for general sampling or if you are focused on surface scums.
- Photic Zone Samples**:** For a more comprehensive sample, a specialized water sampler (like a Lab-line Poly Pro Water Sampler®) can be used to collect a composite sample from the "photic zone," which is the depth to which sunlight penetrates the water. The depth is often determined using a Secchi disc.

2. Periphyton (Benthic Algae) Collection

Periphyton is collected by scraping or brushing it from the surfaces it is attached to.

- Scraping or Pinching: Algae can be scraped off of rocks, wood, or other hard surfaces using a knife or brush.
- Substrate Removal: Sometimes, it is more effective to collect the entire substrate, such as a small rock, and then scrape the algae off in a lab setting.

- Artificial Substrates: For controlled studies, researchers may place artificial substrates (e.g., glass slides or tiles) in the water for a period of time and then collect them to analyze the periphyton growth.

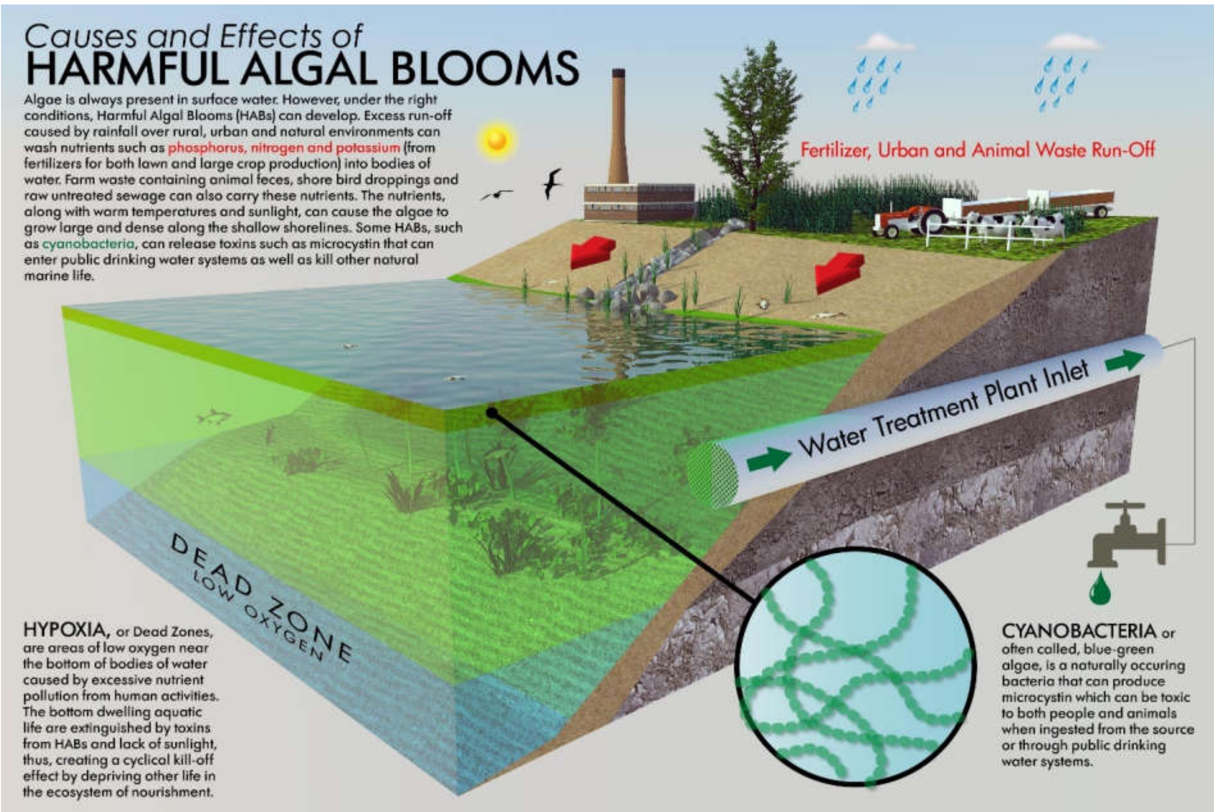
3. Macroalgae Collection

Macroalgae are often collected by hand or with simple tools.

- Hand Picking: In intertidal zones, macroalgae can be collected by hand.
- SCUBA/Dredging: In deeper waters, divers using SCUBA gear may collect specimens. Mechanical methods like dredges or grabs can also be used to collect samples from the bottom.

After collection, samples are typically stored in a labeled container with a preservative and kept in a cooler until they can be analyzed in a laboratory.

Class	Genus (Common Examples)	Characteristics & Habitat	Pollution Tolerance
Chlorophyceae (Green Algae)	*Spirogyra*, *Zygnema*, *Cladophora*, *Pediastrum*, *Scenedesmus*	Filamentous or colonial algae; found in a variety of freshwater habitats, often attached to surfaces.	Generally low to moderate tolerance; abundance may indicate some nutrient enrichment.
Cyanophyceae (Blue-Green Algae)	*Oscillatoria*, *Anabaena*, *Microcystis*, *Spirulina*	Single-celled or filamentous; often form mats or blooms. Many species are nitrogen-fixers.	High tolerance to organic pollution and high nutrient levels; their dominance is a key indicator of eutrophication.
Bacillariophyceae (Diatoms)	*Navicula*, *Nitzschia*, *Gyrosigma*, *Cymbella*	Unicellular algae with unique silica cell walls (frustules). Can be found in many aquatic habitats.	Varies by species, from very sensitive to pollution-tolerant. Can be good indicators of overall river health.
Charophyceae (Stoneworts)	*Chara*, *Nitella*	Complex, plant-like algae often found in clear, unpolluted water.	Very low tolerance to pollution; their presence indicates a healthy, undisturbed environment
Euglenophyceae (Euglenoids)	*Euglena*, *Phacus*	Unicellular, motile organisms with a flagellum. Can tolerate a wide range of conditions.	High tolerance to organic pollution; often abundant in water contaminated by sewage and with low dissolved oxygen.


Causes and Effects of
HARMFUL ALGAL BLOOMS
Algae is always present in surface water. However, under the right conditions, Harmful Algal Blooms (HABs) can develop. Excess run-off caused by rainfall over rural, urban and natural environments can wash nutrients such as phosphorus, nitrogen and potassium (from fertilizers for both lawn and large crop production) into bodies of water. Farm waste containing animal feces, shore bird droppings and raw untreated sewage can also carry these nutrients. The nutrients, along with warm temperatures and sunlight, can cause the algae to grow large and dense along the shallow shorelines. Some HABs, such as cyanobacteria, can release toxins such as microcystin that can enter public drinking water systems as well as kill other natural marine life.
Fertilizer, Urban and Animal Waste Run-Off
Water Treatment Plant Inlet
DEAD ZONE
LOW OXYGEN
HYPOXIA, or Dead Zones, are areas of low oxygen near the bottom of bodies of water caused by excessive nutrient pollution from human activities. The bottom dwelling aquatic life are extinguished by toxins from HABs and lack of sunlight, thus, creating a cyclical kill-off effect by depriving other life in the ecosystem of nourishment.
CYANOBACTERIA or often called, blue-green algae, is a naturally occuring bacteria that can produce microcystin which can be toxic to both people and animals when ingested from the source or through public drinking water systems.

Season	Time Period	Environmental Conditions	Algal Abundance & Diversity	Algal Bioindicator Significance
Summer	March - June	High temperatures, low water levels, stagnant flow.	Dominated by **pollution-tolerant species** (e.g., blue-green algae, euglenoids). Low diversity.	Indicates high organic pollution and nutrient concentration.
Monsoon	July - October	Heavy rainfall, high river flow, dilution of pollutants.	Overall **algal abundance drops drastically** due to flushing and low light.	Data is less reliable as a water quality indicator due to physical changes in the river.
Winter	November - February	Cool temperatures, low water flow, clear water.	Initial high diversity of **pollution-sensitive species** (e.g., diatoms, green algae).	Provides the most valuable baseline data for assessing long-term river health.

Chart 1: Algal Distribution in a Clean Water Environment

This chart represents the ideal distribution of epiphytic algae in a healthy, unpolluted section of the Godavari River.

- Bacillariophyceae (Diatoms): 70%
  - This class is highly sensitive to pollution and thrives in clean water. Their high percentage indicates a healthy ecosystem.
- Chlorophyceae (Green Algae): 20%
  - Green algae are a common and diverse group found in most freshwater systems. Their presence is a normal component of a healthy river.
- Cyanophyceae (Blue-Green Algae): 5%
  - A very small percentage of blue-green algae may be present, but they are not the dominant group.
- Other Algae: 5%

- This category includes other less common classes like Euglenophyceae and Charophyceae, which are also often sensitive to pollution

Class	Percentage	Characteristics & Bioindicator Significance
Bacillariophyceae (Diatoms)	70%	Highly sensitive to pollution. A high percentage indicates a healthy ecosystem and clean water.
Chlorophyceae (Green Algae)	20%	A common and diverse group found in most freshwater systems. Their presence is a normal component of a healthy river.
Cyanophyceae (Blue-Green Algae)	5%	A very small percentage may be present, but they are not the dominant group.
Other Algae	5%	This category includes other less common classes like Euglenophyceae and Charophyceae, which are also often sensitive to pollution.

Chart 2: Algal Distribution in a Polluted Water Environment

This chart represents the shift in the algal community in a heavily polluted area, such as a downstream section affected by urban runoff and sewage.

- Cyanophyceae (Blue-Green Algae): 60%
  - This group is highly tolerant of organic pollution and high nutrient levels. Their dominance is a primary indicator of a polluted, eutrophic environment.
- Euglenophyceae (Euglenoids): 20%
  - This class is also very tolerant of polluted water, especially those rich in organic matter. Their increased percentage is a key indicator of pollution.
- Chlorophyceae (Green Algae): 15%

    - The percentage of green algae drops significantly, and the species present are often those that can tolerate pollution.
- Bacillariophyceae (Diatoms): 5%
    - Diatoms, as a sensitive group, are almost entirely absent or represented by a few very tolerant species. Their low percentage indicates a severe decline in water quality.

Class	Percentage	Characteristics & Bioindicator Significance
Cyanophyceae (Blue-Green Algae)	60%	Highly tolerant of organic pollution and high nutrient levels. Their dominance is a primary indicator of a polluted environment.
Euglenophyceae (Euglenoids)	20%	Very tolerant of polluted water rich in organic matter. Their increased percentage is a key indicator of pollution.
Chlorophyceae (Green Algae)	15%	The percentage drops significantly, and the species present are often those that can tolerate pollution.
Bacillariophyceae (Diatoms)	5%	As a sensitive group, they are almost entirely absent. Their low percentage indicates a severe decline in water quality.

Discussion

Study's Focus

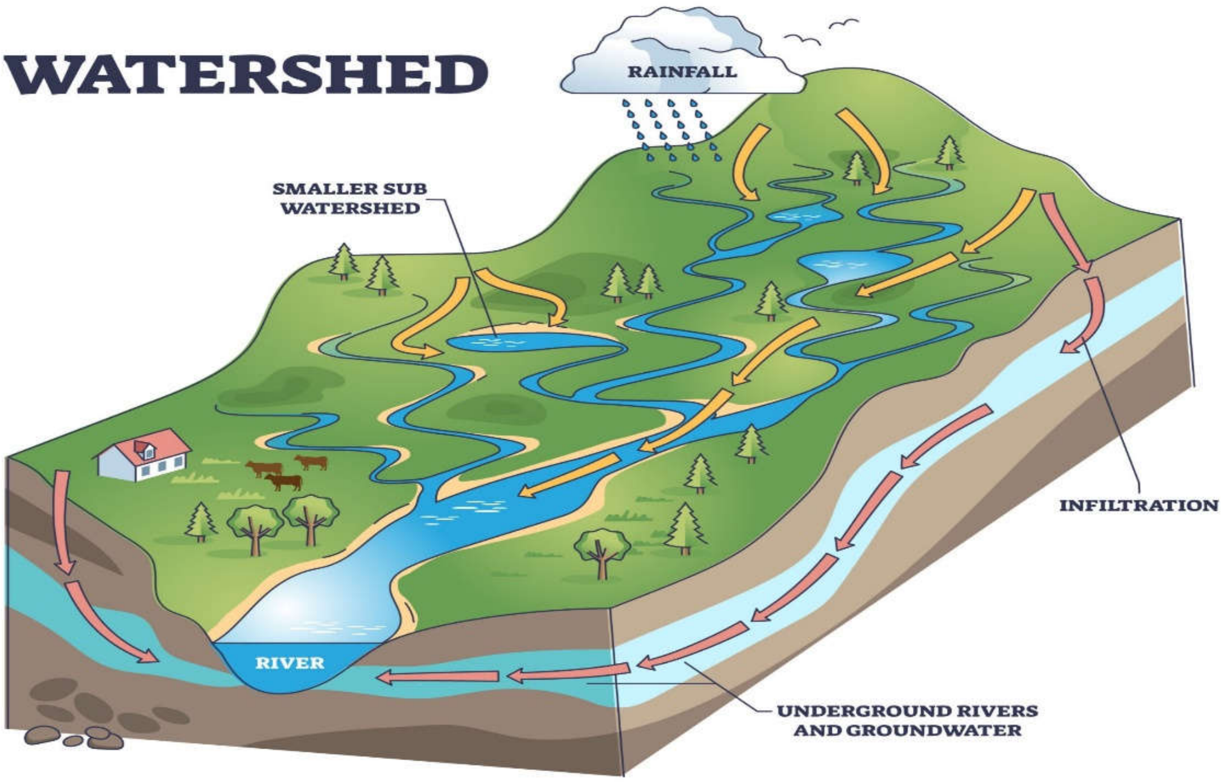
The researchers are using both hydrological and biological perspectives to evaluate water quality. The hydrological assessment likely involves analyzing parameters like water temperature, pH, and nutrient concentrations. The biological part of the study focuses on epiphytic algae communities. These algae are a key component of the aquatic ecosystem.

- Epiphytic Algae Communities: These are communities of algae that grow on the surface of other plants, such as aquatic macrophytes (larger aquatic plants). They are considered valuable bio-indicators because they are highly sensitive to changes in their environment, including water pollution. Studying their composition and abundance can provide a direct measure of the ecosystem's health.

Context of the Study Area

The "One River and Two Streams" Basin consists of the YarlungTsangpo River (the "One River") and its tributaries, the Lhasa River and Nianchu River (the "Two Streams"). The region is located at a high elevation, making it particularly vulnerable to environmental changes. As human activity—such as urbanization, agriculture, and tourism—increases, the potential for water quality degradation also rises.

The study aims to understand how these human-induced pressures are influencing the basin's water quality and the health of its aquatic life, using the epiphytic algae as a key indicator.



Conclusion

The study identified 97 species of phytoplankton from 60 genera and five phyla in the "One River and Two Streams" Basin. Dominant Species and PhylaThe dominant phyla were Bacillariophyta, Chlorophyta, and Cyanophyta. The single most dominant species was *Nitzschia* sp., which belongs to the phylum Bacillariophyta.

Water Quality AssessmentThe overall water quality of the basin was found to be good. This conclusion was based on the seasonal patterns observed in both the aquatic biological parameters and the hydrochemical parameters.

CorrelationsThe study also found a positive correlation between the dominant species and two environmental factors:

- Photosynthetically Active Radiation (PAR)
- Ultraviolet (UV) radiation

ACKNOWLEDGEMENT

The authors would like to thank Savitribai fulepune university pune and Department of Botany, KRT Arts, BH Commerce & AM Science (KTHM) College, Nashik for providing all necessary infrastructural support to carry out the study and thanks to Chhatrapati Shahu Maharaj Research, Training and Human Development Institute (Sarthi) for financial support.

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