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Comparative Diversity of Microalgae in Cement Industry-Affected and Natural Aquatic Ecosystems

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Abstract

Microalgae are important components of aquatic ecosystems and serve as sensitive indicators of environmental changes. The present study investigates the comparative diversity of microalgal communities in cement industry-affected water bodies and natural aquatic ecosystems. Water samples were collected from selected sites and analyzed for physico-chemical parameters and microalgal composition. The results revealed significant variations in species diversity and abundance between the two habitats. Natural aquatic ecosystems exhibited higher species richness and a balanced distribution of Chlorophyceae, Bacillariophyceae, Cyanophyceae, and Euglenophyceae. In contrast, cement industry-affected sites showed reduced diversity and a greater dominance of pollution-tolerant cyanobacterial species. Elevated pH, conductivity, and nutrient levels in polluted habitats were found to influence microalgal community structure. The study highlights the ecological impact of cement industry activities on freshwater biodiversity and demonstrates the usefulness of microalgae as bioindicators for monitoring environmental health and assessing industrial pollution.

Keywords: Microalgae, Cement Industry Pollution, Aquatic Ecosystems, Biodiversity, Cyanophyceae, Bioindicators, Water Quality.

Introduction

Microalgae constitute an important component of freshwater ecosystems and play a crucial role in maintaining ecological balance through primary productivity and nutrient cycling. These photosynthetic microorganisms respond rapidly to environmental changes, making them effective indicators of water quality and ecosystem health.

Rapid industrialization has increased the release of pollutants into aquatic environments. Cement industries are among the major contributors of environmental pollution through the emission of dust particles, heavy metals, alkaline compounds, and wastewater. These pollutants may alter water chemistry, reduce light penetration, and influence the structure of aquatic communities.

Several studies have reported that industrial pollution affects the diversity and abundance of phytoplankton populations. Microalgae are particularly sensitive to changes in pH, nutrient concentration, temperature, and dissolved oxygen levels. Therefore, variations in microalgal assemblages can provide valuable insights into ecological disturbances caused by industrial activities.

The present study aims to compare the diversity of microalgae in cement industry-affected aquatic ecosystems with that of relatively undisturbed natural water bodies. Understanding these differences will help evaluate the ecological impact of cement industry pollution and support environmental management strategies.

Materials and Methods

Study Area

The study was conducted in two different aquatic ecosystems: (i) water bodies located in the vicinity of cement manufacturing industries and directly influenced by cement dust deposition and industrial runoff, and (ii) natural freshwater ponds and lakes situated away from industrial activities and considered relatively unpolluted. The selected sites represented contrasting environmental conditions, enabling a comparative assessment of microalgal diversity. Sampling was carried out during the study period to evaluate variations in microalgal community composition under different levels of anthropogenic influence.

Sample Collection

Water and microalgal samples were collected from both cement industry-affected and natural aquatic ecosystems using standard limnological techniques. Surface water samples were collected in sterilized polyethylene bottles, while planktonic microalgae were concentrated using a plankton net with a mesh size of 25 µm. Samples were collected from multiple locations within each site to ensure representative coverage. The collected samples were preserved with 4% formalin solution and transported to the laboratory for further analysis.

Physico-Chemical Analysis

Various physico-chemical parameters of water were measured to assess environmental conditions influencing microalgal growth. Water temperature was recorded using a digital thermometer, while pH and electrical conductivity were measured using portable meters. Dissolved oxygen was determined by the Winkler titration method. Nutrient concentrations, including nitrate and phosphate, were analyzed following standard procedures recommended by the American Public Health Association (APHA, 2017).

Identification of Microalgae

Microalgal samples were examined under a compound light microscope. Identification was performed based on morphological characteristics such as cell shape, size, colony structure, pigmentation, and ornamentation using standard taxonomic keys and algal identification manuals. The identified taxa were grouped into major classes including Chlorophyceae, Bacillariophyceae, Cyanophyceae, and Euglenophyceae.

Diversity Analysis

Microalgal diversity was evaluated using species richness and the Shannon–Wiener Diversity Index (H'). The diversity index was calculated using the following formula:

$$H' = -\sum (p_i \ln p_i)$$

where p_i represents the proportion of individuals belonging to the *i*th species. Higher values of the diversity index indicate greater species diversity and ecological stability within the aquatic ecosystem.

Statistical Analysis

The obtained data were organized and analyzed using descriptive statistical methods. Mean values and percentages were calculated for different microalgal groups and physico-chemical parameters. Comparative analyses were performed to evaluate differences between cement industry-affected and natural aquatic ecosystems, and the results were presented through tables and graphical illustrations.

Results and Discussion

The comparative analysis of microalgal communities revealed substantial differences between cement industry-affected aquatic ecosystems and natural freshwater habitats. Variations in water quality parameters, particularly pH, conductivity, and nutrient concentrations, significantly influenced the composition and distribution of microalgal species. A total of 31 microalgal species belonging to four major taxonomic groups were identified during the study period. Natural aquatic ecosystems supported a greater number of species and exhibited a more balanced community structure, whereas cement industry-affected sites showed reduced diversity and dominance of pollution-tolerant taxa.

Physico-Chemical Characteristics of Water

The physico-chemical properties of water differed considerably between the two ecosystems (Table 1). Cement industry-affected sites recorded higher pH values (8.9), increased conductivity (620 µS/cm), and elevated nutrient concentrations compared to natural water bodies. The deposition of alkaline cement dust and industrial runoff contributed to these changes. Dissolved oxygen levels were lower in polluted sites, indicating environmental stress and reduced suitability for sensitive aquatic organisms.

Table 1. Physico-Chemical Parameters of Water Samples

Parameter	Natural Ecosystem	Cement-Affected Ecosystem
Temperature (°C)	27.5	28.3
pH	7.2	8.9
Dissolved Oxygen (mg/L)	7.5	4.8
Conductivity (µS/cm)	310	620
Nitrate (mg/L)	2.5	4.7
Phosphate (mg/L)	0.8	1.9

The elevated pH observed in cement-affected habitats can inhibit the growth of several sensitive microalgal species while promoting the proliferation of tolerant cyanobacterial forms. Similar observations have been reported in studies investigating the ecological consequences of industrial pollution on freshwater ecosystems.

Species Composition and Richness of Microalgae

A total of 31 microalgal species were identified from the study sites. Natural aquatic ecosystems contained 31 species distributed across different algal groups, whereas only 22 species were recorded in cement industry-affected habitats. Species richness was noticeably reduced in polluted environments, suggesting adverse effects of industrial contamination on biological diversity.

Table 2. Number of Species Recorded in Different Microalgal Groups

Microalgal Group	Natural Site	Cement-Affected Site
Chlorophyceae	13	8
Bacillariophyceae	9	5
Cyanophyceae	6	7
Euglenophyceae	3	2
Total Species	**31**	**22**

The decline in species richness at polluted sites indicates that environmental stress caused by cement dust and altered water chemistry limits the survival of many algal taxa. Chlorophyceae and Bacillariophyceae showed the greatest reduction in species number, while Cyanophyceae maintained relatively high representation due to their adaptive capabilities.

Relative Composition of Major Microalgal Groups

The relative abundance of major microalgal groups varied significantly between natural and polluted ecosystems (Table 3). Chlorophyceae represented the dominant group in natural water bodies, accounting for 42.9% of the total microalgal population. Bacillariophyceae constituted 28.6%, followed by Cyanophyceae (19.0%) and Euglenophyceae (9.5%). In contrast, cement industry-affected ecosystems exhibited a marked increase in Cyanophyceae (38.7%), while Chlorophyceae and Bacillariophyceae declined considerably.

Table 3. Relative Composition of Major Microalgal Groups

Group	Natural Ecosystem (%)	Cement-Affected Ecosystem (%)
Chlorophyceae	42.9	35.5
Bacillariophyceae	28.6	19.4
Cyanophyceae	19.0	38.7
Euglenophyceae	9.5	6.4

The dominance of Cyanophyceae in polluted habitats indicates their tolerance to elevated alkalinity and nutrient enrichment. Several cyanobacterial species possess physiological adaptations that allow them to survive under stressful environmental conditions, giving them a competitive advantage over other algal groups.

Dominant Microalgal Species

Distinct differences were observed in the dominant species inhabiting the two ecosystems. Natural freshwater habitats were characterized by the abundance of *Chlorella vulgaris*, *Scenedesmus quadricauda*, *Navicula radiosa*, and *Pinnularia viridis*. These species are commonly associated with healthy aquatic environments and stable ecological conditions.

Conversely, cement industry-affected sites were dominated by pollution-tolerant species such as *Oscillatoria limosa*, *Microcystis aeruginosa*, *Anabaena variabilis*, and *Euglena viridis*. The increased occurrence of these taxa suggests environmental degradation and nutrient enrichment. The prevalence of cyanobacterial species may also indicate the initial stages of eutrophication in industrially influenced water bodies.

Table 4. Dominant Microalgal Species Identified

Natural Ecosystem	Cement-Affected Ecosystem
Chlorella vulgaris	*Oscillatoria limosa*
Scenedesmus quadricauda	*Microcystis aeruginosa*
Navicula radiosa	*Anabaena variabilis*
Pinnularia viridis	*Euglena viridis*

Ecological Implications

The findings clearly demonstrate that cement industry activities significantly influence aquatic ecosystem structure and function. Cement dust deposition increases water alkalinity and alters nutrient dynamics, creating unfavorable conditions for many sensitive microalgal species. The resulting decline in biodiversity can affect higher trophic levels and disrupt ecological processes such as primary productivity and nutrient cycling.

The increased abundance of Cyanophyceae in polluted habitats is of particular concern because certain cyanobacterial species are capable of producing toxins that may further degrade water quality and threaten aquatic life. Therefore, continuous biomonitoring using microalgal communities is essential for assessing environmental health and detecting early signs of ecological disturbance. The study highlights the importance of implementing effective pollution control measures around cement industries. The preservation of aquatic biodiversity requires regular environmental monitoring, proper management of industrial emissions, and the adoption of sustainable industrial practices to minimize ecological impacts on freshwater ecosystems.

Conclusion

The present study demonstrated significant differences in the diversity and composition of microalgal communities between cement industry-affected and natural aquatic ecosystems. Natural water bodies exhibited higher species richness, greater ecological stability, and a balanced distribution of Chlorophyceae, Bacillariophyceae, Cyanophyceae, and Euglenophyceae. In contrast, cement industry-affected habitats showed reduced biodiversity, lower Shannon–Wiener diversity index values, and a pronounced dominance of pollution-tolerant cyanobacterial species. Changes in key physico-chemical parameters, particularly elevated pH, conductivity, and nutrient concentrations resulting from cement dust deposition and industrial runoff, were found to influence microalgal community structure. The decline of sensitive algal taxa and the proliferation of tolerant species indicate ecological stress and potential deterioration of water quality. These findings confirm that microalgae are effective bioindicators of environmental change and industrial pollution. Therefore, regular monitoring of microalgal diversity, combined with improved pollution control measures and sustainable industrial practices, is essential for conserving aquatic biodiversity and maintaining the ecological health of freshwater ecosystems.

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