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Research Article

Abiotic factors modulate algal diversity in contaminated water of Cuttack, Odisha, India

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Abstract: Cuttack, one of Odisha's oldest district, is known as the Millennium City and located at 20.4625° N latitude and 85.8830° E longitude. It was selected for our research due to its high pollution levels and the prevalence of algae in contaminated water. In this regards, four collection sites were chosen viz. S1 (Badambadi), S2 (Jagatpur), S3 (Nischintakoili), and S4 (Salipur). Samples were collected in sterilized falcon tubes and analysed for physicochemical parameters viz. DO, pH, and temperature in the laboratory. Using a Leica dm 750 microscope and Leica ICC50 HD camera, we identified algal species based on their morphological characteristics with the help of monographs and algal databases. The study revealed a significant algal diversity of 30 species under 5 divisions (Cyanobacteria, Bacillariophyta, Charophyta, Chlorophyta, Euglenophyta), 15 orders including 19 families, and 22 genera. Moreover, the present study revealed that Bacillariophyta showed the highest diversity among others. Specifically, we found 6 species of Cyanobacteria, 16 of Bacillariophyta, 2 of Charophyta, 5 of Chlorophyta, and 1 of Euglenozoa. Notably, the present study revealed that five species were recorded for the first time from Odisha namely *Kamptonema cortianum*, *Halamphora veneta*, *Tabularia fasciculata, Micractinium pusillum*, *Navicula sacrophagus*. Furthermore, our study suggested that these algal species may be exploited as a promising feedstock for future biofuels and biodiesel production as well as phycoremediation and therapeutic intervention in the future.

Keywords: Algae, Contaminated water, Cuttack, Diversity

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1. INTRODUCTION

Algae, belonging to the Protista kingdom, are nucleus-bearing, photosynthetic, eukaryotic organisms. They are existing in different types such as Colonial, Capsoid, Coccoid, Palmelloid, filamentous, and parenchymatous. Planktons are floating, mostly unicellular algae living in the water. Those algae which adhere to the surface are called benthic algae, grow on sludge, rocks, plants, and creatures (Adl et al., 2005; Andersen, 2013). Algae can survive on land as well fresh and marine water (Maharana et al., 2019; Behera et al., 2020; Dash et al., 2020; Behera et al., 2021a, 2021b; Dash et al., 2021; Pradhan et al., 2022; Bhuyan et al., 2023a, 2023b) and in symbiotic relationships with non-photosynthetic organisms like sponges, ciliates, fungi, and Mollusca. They are classified into Rhodophyta (red algae), Phaeophyta (brown algae), and Chlorophyta (green algae) based on their pigments, and chemical composition (Asmida et al., 2017; Øverland et al., 2019). It also found in moist environments, lack true roots, stems, and leaves but play a crucial role in aquatic ecosystems, supporting 80% of the world's plant and animal species. Approximately 150,000 algal species inhabit intertidal zones and tropical waters were identified (Rathwa & Patel, 2020; Ramakrishnan et al., 2025).

Algal diversity spans various taxonomic ranks and habitats, with significant ecological roles in nutrient cycling and wastewater treatment (Duffy, 2006). They can consume carbon dioxide, produce oxygen, and remove nutrients and pollutants from water. The ecological place of algae at the base of the aquatic food chain and their roles in nitrogen and phosphorus cycling are dangerous to aquatic ecosystems. Some phytoplankton like *Stigeoclonium tenue*, *Nitzschia palea,Gamphonema parvulum, Coccinea chamaesiphon, Navicula accomoda*, and microalgae such as *Microspora amonea* and *Ulothrix zonata* have ability to absorb nutrients and removes heavy metals, inorganic and organic toxic substances, and pesticides from aquatic environments (Ahalya et al., 2003; Rath, 2012).

Water pollution, caused by physical, chemical, biological, or radiological contaminants, which makes them unusable for cooking, drinking, swimming, cleaning, and other activities (Juneja et al., 2013). Wastewater originates from sources such as toilets, sewage systems, laundries, industrial activities, fertilizers, and mining operations. When it mixes with cleaner water bodies like canals, rivers, and ponds, it leads to contamination. In these polluted environments, algal species grows such as *Chlamydomonas*, *Euglena*, *Oscillatoria*, and *Phormidium* (Ramakrishnan et al., 2010; Abdel-Raouf et al., 2012).

Different kinds of harmful diseases occur due to contaminated water such as cholera, diarrhoea, hepatitis, typhoid, polio, dysentery and many more. Different kinds of health impacts such as hair loss, renal failure, liver cirrhosis and neural disorder caused by metal-contaminated water. The sewage of local and hospitals includes various dangerous germs, and they are discarded into the water without adequate treatment can result in an eruption of deadly diseases like cholera and typhoid. Approximately, 50 kinds of diseases are caused and 50% of child deaths and 80% diseases are related to poor drinking water quality in all over the world (Lin et al., 2022).

Aquatic ecosystems are dynamic environments where the interaction between biotic and abiotic factors determines the structure and function of resident communities (Jackson et al., 2001). Among these, algae play a pivotal role as primary producers, contributing significantly to nutrient cycling, oxygen production, and food web stability (Jackson et al., 2001). However, algal diversity and distribution are highly sensitive to changes in abiotic parameters such as temperature, pH, dissolved oxygen, turbidity, and nutrient concentrations (Barinova et al., 2017; Al-Hasawi et al., 2022). In contaminated water bodies, these factors often undergo substantial alterations due to anthropogenic activities, leading to shifts in algal community composition and abundance. In this regards, Abiotic factors like temperature, pH, dissolve oxygen, salinity, nutrients, sunlight, and minerals influence algal growth in contaminated water (Juneja et al., 2013; Chowdury et al., 2020).

Cuttack district, one of Odisha's oldest and largest City with a population of 600,000 and hosts numerous industries, factories, and medical facilities, leading to water contamination. Cuttack, a major urban center in Odisha, India, is characterized by dense population, industrial growth, and extensive agricultural practices. These activities contribute to the contamination of local water bodies through the discharge of domestic sewage, industrial effluents, and agricultural runoff (Parwin et al., 2024). Such contamination not only degrades water quality but also exerts selective pressure on algal communities, favoring the proliferation of tolerant species while suppressing sensitive taxa (Ramakrishnan et al., 2010). Understanding how abiotic factors modulate algal diversity in these polluted waters is crucial for assessing ecological health, predicting ecosystem responses, and developing effective management strategies. This study aims to investigate the relationship between abiotic parameters and algal diversity in contaminated water bodies of Cuttack. By analysing the influence of physicochemical factors on algal assemblages, the research seeks to provide insights into ecological resilience, potential bioindicators of pollution, and the broader implications for aquatic ecosystem sustainability in urban landscapes.

In the coming decades, commercial fuel will be finished and we have to find an alternative source of fuel. In this regard, algae can be minimising the rationale. Moreover, algae contribute the dual role such as removal of heavy metal contaminants and biodiesel production. Although there was less amount of work done about the algal biodiversity of contaminated water and algae have the power to produce more than 30% biodiesel than land plants. Hence, an attempt has been made to document the information about algal biodiversity in the contaminated water of Cuttack and their future prospects for the exploration of biodiesel production. The study of algal biodiversity in contaminated water of Cuttack may highlights their potential for biofuel production and environmental remediation.

2. MATERIAL AND METHOD

2.1. Study Area

Cuttack district, located at 20.4625° N latitude and 85.8830° E longitude, hosts numerous industries, factories, and medical facilities. These establishments contribute to water contamination, which supports algal growth. Four collection sites were selected for sampling in Cuttack district viz. S1 (Badambadi), S2 (Jagatpur), S3 (Nischintakoili), and S4 (Salipur). The 4 collection sites were selected for sampling of Cuttack district are displayed (Map 1). The site S1 (Badambadi) is known for its vibrant markets, palaces, and forts. S2 (Jagatpur) is an industrial area. S3 (Nischintakoili) surrounds houses the tahsil office. S4 (Salipur) is a town, situated on the bank of the Chitrotpala river.

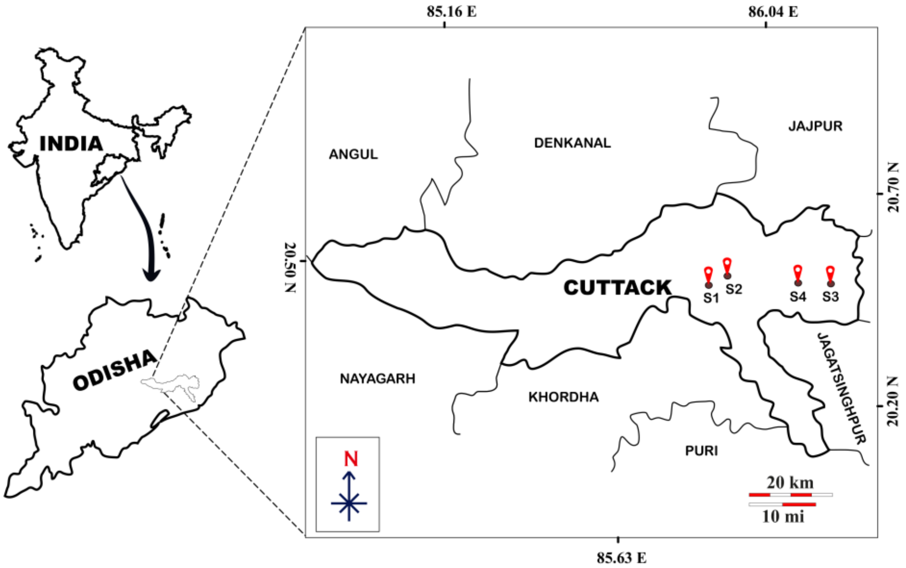

Figure 1. Map showing the location of sampling sites in Cuttack district

2.2. Sampling and Preservation

A total of four samples were collected in sterilized falcon tubes. The physicochemical parameters of the water samples, including DO, pH, and temperature, were recorded in the laboratory by using a water analysis kit. Additionally, the collected samples were preserved in 4% formaldehyde for further microscopic analysis.

2.3. Microscopy and Morphological Identification

The preserved samples were observed under a Leica dm750 microscope. The morphological characteristics of the algal species were identified with the assistance of monographs, published literature, and algal databases.

2.4. Statistical Analysis

This process involves collecting and analysing extensive data to identify trends and develop valuable insights in biological research. In this context, the statistical analysis of algal samples was conducted using the Species Richness Index, also known as Margalef's Index and is calculated by the following formula.

$$\text{Margalef's index } (D_{mg}) = \frac{(S-1)}{ln\,(N)}$$

(where S= number of species (species richness), and N= total number of individuals and ln= natural logarithm)

3. RESULTS

3.1. Physicochemical Parameters

The samples were collected from four sites, labelled as S-1, S-2, S-3, and S-4. The temperatures of the samples taken from the collection sites were observed to be 30.8 °C, 30.3 °C, 30.5 °C, and 30.7 °C, respectively. The highest temperature was 30.8 °C in S-1, and the lowest was 30.3 °C in S-2. The pH values of the samples were 6.37, 6.28, 8.22, and 10.8, respectively. The highest pH was 10.8 in S-4, and the lowest was 6.28 in S-2. The dissolved oxygen (DO) levels were 296.1 ppm, 276.7 ppm, 242.2 ppm, and 244.6 ppm, respectively. The highest DO content was 296.1 ppm in S-1, and the lowest was 242.2 ppm in S-3. Maximum algal growth was observed in S-3, which was basic, while minimum growth in S-1, which was acidic.

Table 1. Physicochemical parameters of 4 different sites of Cuttack district Badambadi, Jagatpur, Nischintakoili, Salipur.

Collection sites	Temperature (°C)	pH	DO (ppm)
S-1	30.8	6.37	296.1
S-2	30.3	6.28	276.7
S-3	30.5	8.22	242.2
S-4	30.7	10.8	244.6

3.2. Distribution of Algal Species

A total of 30 algal species belonging from 22 genera, 15 orders, and 19 families were identified from four different sites (S-1, S-2, S-3, and S-4) in Cuttack district are displayed (Table 2). These 30 species were categorized into five divisions viz. Cyanobacteria, Bacillariophyta, Charophyta, Chlorophyta, and Euglenophyta. Among them, 6 species belong to Cyanobacteria, 16 from Bacillariophyta, 2 from Charophyta, 5 from Chlorophyta, and 1 from Euglenophyta. The site wise distribution of algal species found in Site-1 (S-1) accounted for 20% of the algal species, Site-2 (S-2) for 27%, Site-3 (S-3) for 30%, and Site-4 (S-4) for 23%. The highest percentage of algal species was found at Site-3, while the lowest was at Site-1.

The distribution of Cyanobacteria of 6 species namely *Kamptonema cortianum*, *Nostoc hatei, Oscillatoria acuminata*, *Oscillatoria curviceps*, *Oscillatoria irrigua*, *Phormidium nigrum* belongs to 3 family, 2 order, and 4 genera. Similarly, the distribution of Bacillariophyta includes 16 species such as *Cymbella lange-bertalotii*, *Cocconeis placentula*, *Cocconeis placentula* var. *australica*, *Fragilaria crotonensis*, *Halamphora veneta*, *Navicula halophila, Navicula sacrophagus*, *Navicula salinarum*, *Neidium affine*, *Nitzschia filiformis*, *Nitzschia liebethruthii*, *Nitzschia* sp., *Nitzschia sigmoidea*, *Pinnularia braunii*, *Synedra ulna*,

Table 2. List of algal species recorded from four different sites of Cuttack

Microalgal division	Sl. No.	Names of identified algal taxa	S1	S2	S3	S4
Cyanobacteria	1	*Kamptonema cortianum* (Meneghini ex Gomont) Strunecký, Komárek & J. Smarda	+	-	-	-
	2	*Nostoc hatei S.C. Dixit*	+	-	-	-
	3	*Oscillatoria acuminata* f. *longe-attenuata* Geitler & Ruttner	-	-	+	-
	4	*Oscillatoria curviceps* C. Agardh ex Gomont	+	-	-	-
	5	*Oscillatoria irrigua* Kützing ex Gomont	-	-	+	-
	6	*Phormidium nigrum* (Vaucher ex Gomont) Anagnostidis & Komárek	-	-	-	+
Bacillariophyta	7	*Cymbella lange-bertalotii* Krammer	-	+	-	-
	8	*Cocconeis placentula* Ehrenberg	-	-	+	-
	9	*Cocconeis placentula* var. *australica* Playfair	-	-	-	+
	10	*Fragilaria crotonensis* Kitton	-	+	-	-
	11	*Halamphora veneta* (Kützing) Levkov	-	+	-	-
	12	*Navicula halophila* (Grunow) Cleve	-	-	+	-
	13	*Navicula sacrophagus* H.P. Gandhi, nom. inval.	-	+	-	-
	14	*Navicula salinarum* Grunow	-	-	+	-
	15	*Neidium affine* var. *amphirhynchus* (Ehrenberg) Cleve	-	-	+	-
	16	*Nitzschia filiformis* var. *conferta* (P.G. Richter) Lange-Bertalot	+	-	-	-
	17	*Nitzschia liebethruthii* Rabenhorst	+	-	-	-
	18	*Nitzschia sp.* Hassall,	-	-	-	+
	19	*Nitzschia sigmoidea* (Nitzsch) W. Smith	-	-	-	+
	20	*Pinnularia braunii* Cleve, nom. illeg.	-	-	-	+
	21	*Synedra ulna* var. *oxyrhynchus* (Kützing) O'Meara	-	+	-	-
	22	*Tabularia fasciculata* (C. Agardh) D.M. Williams & Round	-	-	+	-
Charophyta	23	*Cosmarium impressulum* Elfving	-	-	-	+
	24	*Spirogyra spreeiana* Rabenhorst	-	+	-	-
Chlorophyta	25	*Actinastrum Lagerheim*	+	-	-	-
	26	*Chlamydomonas angulosa* O. Dill	-	-	-	+
	27	*Closterium parvulum* Nägeli	-	-	+	-
	28	*Microspora amoena* (Kützing) Rabenhorst	-	+	-	-
	29	*Micractinium pusillum* Fresenius	-	-	+	-
Euglenophyta	30	*Trachelomonas teres Maskell*	-	+	-	-

Tabularia fasciculata, belons to 9 family, 6 order, 10 genera. The distribution of Charophyta includes 2 species namely *Cosmarium impressulum*, and *Spirogyra spreeiana* from 2 family namely Desmidiaceae, and Spirogyraceae of 2 orders i.e. Desmidiales and Spirogyrales, of 2 genera (*Cosmarium* and *Spirogyra*). Moreover, the distribution of Chlorophyta included 5 species such as *Actinastrum Lagerheim, Chlamydomonas angulosa*, *Closterium parvulum*, *Microspora amoena*, and *Micractinium pusillum*), 4 family (Chlorellaceae, Chlamydomonadaceae, Closteriaceae, Microsporaceae), 4 orders (Chlorellales, Chlamydomonadales, Desmidiales, Sphaeropleales), of 5 genera (*Actinastrum, Chlamydomonas, Closterium, Microspora, Micractinum*). Aditionally, 1 species of Euglenophyta namely *Trachelomonas teres* Maskell belongs to Euglenaceae, of order Euglenales of *Trachelomonas* genus. Furthermore, the percentage (%) of species distribution in different sites of Cuttack district, Site-1 contains 6 species constitutes 20%, site-2 contains 8 species of 27%, site-3 contains 9 species of 30%, site-4 contains 7 species of 23% (Figure 2).

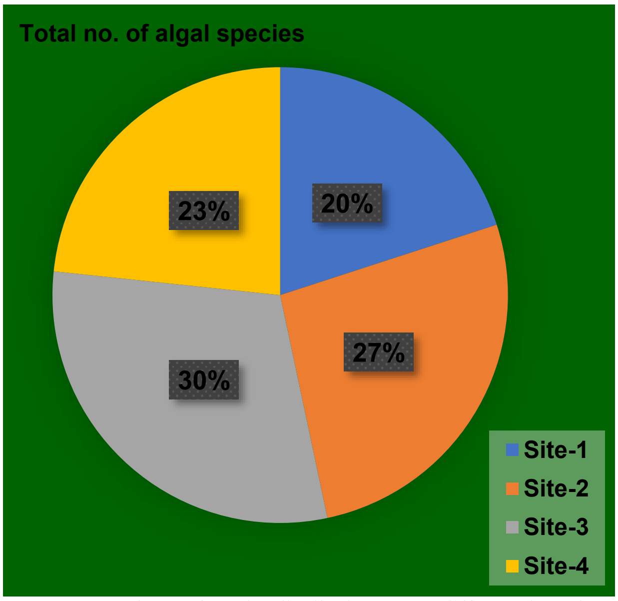

Figure 2. The % of species distribution among different sites of Cuttack district.

3.3. Species Richness Index/ Margalef's Index

Margalef's index is a species richness index which stands for the effect of sample size through dividing the number of species in a sample by the natural log of the number of collected organisms. The graphical representation of Margalefs index of the collected sites are displayed (Figure 3). The Margalef's index of S-1, S-2, S-3, and S-4 was calculated to be 1.47, 2.06, 2.35, and 1.76 respectively.

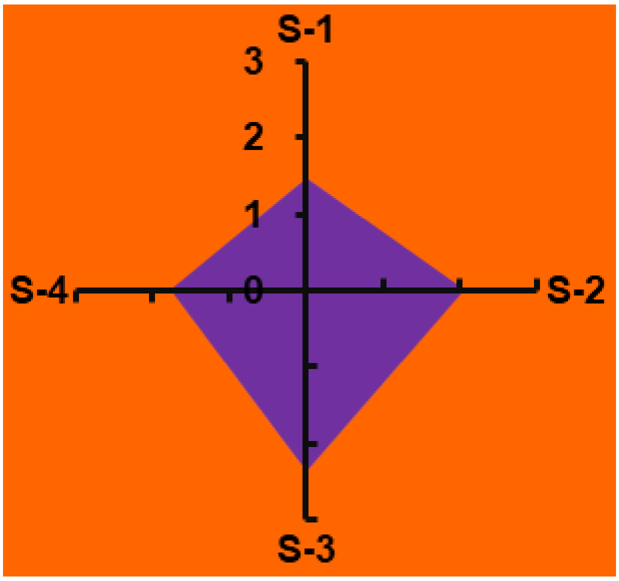

Figure 3. Indicates the graphical representation of Margalef's index of different collection sites of Cuttack district.

4. DISCUSSION AND CONCLUSION

A total of 30 algal species belonging to Cyanobacteria, Bacillariophyta, Charophyta, Chlorophyta, and Euglenophyta were recorded from different contaminated sites in Cuttack district. Among the five divisions, Bacillariophyta was found to be the most dominant. The physical parameters measured included temperature, turbidity, solids, and electrical conductivity, while the chemical parameters included pH, acidity, alkalinity, and dissolved oxygen (DO) which are responsible for the algal growth (Patil et al., 2012). These abiotic factors are crucial for the aquatic ecosystem. The effects of the physicochemical parameters of the four collected sites are discussed in Table 1.

Potential of Hydrogen (pH) is the negative logarithm of H^+ ion concentration, indicating the strength or power of hydrogen. Generally, the optimal algal growth occurs in pH ranges of 8.2-8.7 (Hansen, 2002; Nys et al., 2016), which is alkaline. However, in our study, algal growth occurred in the pH range of 6.28-10.8, encompassing both acidic and alkaline conditions. The algal diversity of S-2 had the lowest pH of 6.28 (acidic), while S-4 had the highest pH of 10.8 (alkaline), which is well supported by Tweed et al. (Tweed et al., 2011).

Temperature, a physical quantity measured with a thermometer, indicates the direction of heat energy flow from hotter to colder bodies. The optimal temperature for algal growth is 20°-30°C (Bouterfas et al., 2002; Singh & Singh, 2015). In our study, algal growth occurred between 30.3°-30.8°C. The algal diversity in S-2 had the lowest temperature of 30.3°C, while S-1 had the highest temperature of 30.8°C, supported by Ananthi et al. (Ananthi et al., 2021).

Dissolved oxygen (DO) measures the amount of oxygen dissolved in water, which is essential for the growth and development of living organisms (Wetzel & Likens, 2000). Oxygen enters water through direct absorption from the atmosphere, enhanced by turbulence and is released by aquatic plants during photosynthesis (Bryant et al., 2010). In our study, algal growth occurred between 242.2 ppm and 296.1 ppm. The algal distribution in S-3 had the lowest DO of 242.2 ppm, while S-1 had the highest DO of 296.1 ppm and supported by previously literature (Mangal et al., 2020).

The distribution of algal species at the four collection sites is presented in Table 2. The highest occurrence of algal species was recorded at Site-3, while the lowest was at Site-1. The algal diversity of different sites in India was reviewed in this study. However, there were minimal similarities between the algal diversity of different sites in India and the present study. Moreover, five algal species were recorded for the first time from Odisha in the present study namely *Kamptonema cortianum, Halamphora veneta,* and *Tabularia fasciculata, Micractinium pusillum,* and *Navicula sacrophagus*. The study found six species of Cyanobacteria, 16 species of Bacillariophyta, two species of Charophyta, five species of Chlorophyta, and one species of Euglenophyta from different sites in Cuttack district, Odisha.

From our present study, Cyanobacteria such as *Nostoc hatei, Oscillatoria acuminata, Oscillatoria curviceps, Oscillatoria irrigua,* and *Phormidium nigrum,* Chlorophyta such as *Chlamydomonas angulosa, Closterium parvulum,* and *Micractinium pusillum,* and Euglenozoa such as *Trachelomonas teres* Maskell, contribute to biodiesel production. Microalgae are favourable for biodiesel production due to their high lipid content, CO_2 emission mitigation, rapid growth rate, and non-arable land use for cultivation (Schenk et al., 2008). They are an environmentally friendly renewable resource. Our results are well supported by previously published literature (Hong et al., 2018; El Shafay et al., 2021; Munir et al., 2023; Mathimani et al., 2024).

Margalef's index is a biodiversity metric that emphasizes species richness (the number of species present) relative to the total number of individuals in a sample (Sina & Zulkarnaen, 2019). In contaminated waters, pollution often reduces richness by favoring pollution-tolerant species. The index helps quantify this loss. A low Margalef's index value usually indicates stressed or polluted environments where only a few tolerant algal species dominate. A high value suggests healthier ecosystems with diverse algal communities (Mahanandia & Singh, 2023). In Cuttack's polluted water bodies, this index can highlight the ecological impact of abiotic stressors like pH, dissolved oxygen, heavy metals, and nutrient loads. By comparing Margalef's index values across sites with different abiotic conditions (e.g., stagnant vs. flowing water, high vs. low contamination), researchers can correlate pollution levels with algal diversity (Devi & Antal, 2013). This helps identify which abiotic factors most strongly modulate algal community structure. Margalef's index provides a simple yet powerful metric for monitoring water quality (Mahanandia & Singh, 2023). In Cuttack, where industrial and domestic pollutants enter water bodies, the index can serve as a bioindicator for long-term ecological management and pollution monitoring. Since our study also touches on algae for biodiesel production, Margalef's index helps identify pollution-tolerant but productive algal species. This bridges ecological monitoring with applied biotechnology. Margalef's index is crucial because it quantifies algal species richness, reveals the impact of abiotic stressors on diversity, and serves as a bioindicator of pollution levels in contaminated waters of Cuttack. It connects ecological health assessment with practical applications like biodiesel potential.

Algae serve as vital components of ecosystems, contributing significantly to photosynthesis, providing fodder, and aiding in waste management. The Cuttack district, with its numerous water sources, many of which are stagnant or contaminated, hosts a diverse range of diatoms and filamentous algae. Cuttack is among the most polluted regions in Odisha, its water bodies receive substantial pollutants. These findings underscore the need for continuous monitoring of environmental parameters to protect ecological health of Cuttack and establish baseline data which is essential for the sustainable management of algal biodiversity. Moreover, our research highlights the potential of certain algal species in bioremediation potential as well as biodiesel production potential, presenting a promising avenue for dual role such as cleaner environment and sustainable energy in the future.

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PPB: Manuscript design, Writing, Draft checking.
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SRD: Reading, Formal analysis
BP: Writing, Draft checking, Reading, Editing.
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Statement on the Welfare of Animals
Ethical approval: For this type of study, formal consent is not required.

Statement of Human Rights
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Data Availability Statements
The authors confirm that the data supporting the findings of this study are available within the article.

REFERENCES

Abdel-Raouf, N., Al-Homaidan, A., & Ibraheem, I. (2012). Microalgae and wastewater treatment. *Saudi journal of biological sciences*, *19*(3), 257-275.

Adl, S. M., Simpson, A. G., Farmer, M. A., Andersen, R. A., Anderson, O. R., Barta, J. R., Bowser, S. S., Brugerolle, G., Fensome, R. A., & Fredericq, S. (2005). The new higher level classification of eukaryotes with emphasis on the taxonomy of protists. *Journal of Eukaryotic Microbiology*, *52*(5), 399-451.

Ahalya, N., Ramachandra, T., & Kanamadi, R. (2003). Biosorption of heavy metals. *Res. J. Chem. Environ*, *7*(4), 71-79.

Al-Hasawi, Z. M., Hariri, M. S., & Touliabah, H. E. (2022). Physico-chemical factors and biodiversity of microalgal flora in Rabigh Lagoon under Global Climate Change.". *Fresenius Environmental Bulletin*, *31*(8), 7646-7658.

Ananthi, V., Brindhadevi, K., Pugazhendhi, A., & Arun, A. (2021). Impact of abiotic factors on biodiesel production by microalgae. *Fuel*, *284*, 118962.

Andersen, R. A. (2013). The microalgal cell. *Handbook of microalgal culture: applied phycology and biotechnology*, 1-20.

Asmida, I., Akmal, N., Ahmad, I., & Sarah Diyana, M. (2017). Biodiversity of macroalgae in Blue Lagoon, the Straits of Malacca, Malaysia and some aspects of changes in species composition. *Sains Malaysiana*, *46*(1), 1-7.

Barinova, S., Krupa, E., & Kadyrova, U. (2017). Spatial dynamics of species richness of phytoplankton of Lake Balkhash in the gradient of abiotic factors. *Transylvanian Review of Systematical and Ecological Research*, *19*(2), 1.

Behera, C., Dash, S. R., Pradhan, B., Jena, M., & Adhikary, S. P. (2020). Algal diversity of Ansupa lake, Odisha, India. *Nelumbo*, 207-220.

Behera, C., Dash, S. R., Pradhan, B., Jena, M., & Hembram, P. (2021a). Coccoid green algae genus Coelastrum and some desmids from coastal region of Odisha, India. *The Journal of the Indian Botanical Society*, *101*(03), 182-188.

Behera, C., Pradhan, B., Panda, R. R., Nayak, R., Nayak, S., & Jena, M. (2021b). Algal Diversity of Saltpans, Humma (Ganjam), Odisha, India. *The Journal of Indian Botanical Society*, *101*(1and2), 107-120.

Bhuyan, P., Pradhan, B., Nayak, R., Jena, M., Hansdah, B., & Bastia, A. (2023a). Taxonomic Enumeration of Subaerial Cyanobacterial Flora of Similipal Biosphere Reserve, Odisha, India. Ecol. *Environ. Conserv*, *29*, S70-S80.

Bhuyan, P. P., Behera, S. K., Bhakta, S., Pradhan, B., Jena, M., Hansdah, B., & Bastia, A. K. (2023b). Subaerial algal flora of Similipal biosphere reserve, Odisha, India. *Journal of the Indian Botanical Society*, *103*(1), 1-12.

Bouterfas, R., Belkoura, M., & Dauta, A. (2002). Light and temperature effects on the growth rate of three freshwater [2pt] algae isolated from a eutrophic lake. *Hydrobiologia*, *489*(1), 207-217.

Bryant, L. D., Lorrai, C., McGinnis, D. F., Brand, A., est, A. W., & Little, J. C. (2010). Variable sediment oxygen uptake in response to dynamic forcing. *Limnology and Oceanography*, *55*(2), 950-964.

Chowdury, K. H., Nahar, N., & Deb, U. K. (2020). The growth factors involved in microalgae cultivation for biofuel production: a review. *Computational Water, Energy, and Environmental Engineering*, *9*(4), 185-215.

Dash, S. R., Pradhan, B., Behera, C., & Jena, M. (2020). Algal Diversity of Kanjiahata Lake, Nandankanan, Odisha, India. *The Journal of Indian Botanical Society*, *99*(1and2), 11-24.

Dash, S. R., Pradhan, B., Behera, C., Nayak, R., & Jena, M. (2021). Algal Flora of Tampara Lake, Chhatrapur, Odisha, India. *The Journal of Indian Botanical Society*, *101*(1and2), 1-15.

Devi, A., & Antal, N. (2013). Variation in Phytoplankton Diversity and Its Relationship with Abiotic Environment of a Temple Pond in Birpur (J&K) India. *Universal Journal of Environmental Research & Technology*, *3*(2).

Duffy, J. E. (2006). Biodiversity and the functioning of seagrass ecosystems. *Marine Ecology Progress Series*, *311*, 233-250.

El Shafay, S. M., Gaber, A., Alsanie, W. F., & Elshobary, M. E. (2021). Influence of nutrient manipulation on growth and biochemical constituent in Anabaena variabilis and Nostoc muscorum to enhance biodiesel production. *Sustainability*, *13*(16), 9081.

Hansen, P. J. (2002). Effect of high pH on the growth and survival of marine phytoplankton: implications for species succession. *Aquatic microbial ecology*, *28*(3), 279-288.

Hong, J., Kim, O., Jo, S., Kim, H., Jeong, M., & Yoon, H. (2018). Characterization of alkane-producing Nostoc sp. isolated from a summer bloom for biofuel potential. *Journal of Biobased Materials and Bioenergy*, *12*(3), 244-251.

Jackson, D. A., Peres-Neto, P. R., & Olden, J. D. (2001). What controls who is where in freshwater fish communities the roles of biotic, abiotic, and spatial factors. *Canadian journal of fisheries and aquatic sciences*, *58*(1), 157-170.

Juneja, A., Ceballos, R. M., & Murthy, G. S. (2013). Effects of environmental factors and nutrient availability on the biochemical composition of algae for biofuels production: a review. *Energies*, *6*(9), 4607-4638.

Lin, L., Yang, H., & Xu, X. (2022). Effects of water pollution on human health and disease heterogeneity: a review. *Frontiers in environmental science*, *10*, 880246.

Mahanandia, S., & Singh, L. (2023). Subaerial cyanobacteria on the monuments and exterior surface of building facades of Odisha state, India. *Taiwania*, *68*(2).

Maharana, S., Pradhan, B., Jena, M., & Misra, M. (2019). Diversity of phytoplankton in Chilika lagoon, Odisha, India. *Environ. Ecol*, *37*(3), 737-746.

Mangal, V., Phung, T., & Guéguen, C. (2020). An estimation of sulfur concentrations released by three algae (Chlorella vulgaris, Chlamydomonas reinhardtii, Scenedesmus obliquus) in response to variable growth photoperiods. *Environmental Science and Pollution Research*, *27*(11), 12491-12498.

Mathimani, T., Alshiekheid, M. A., Sabour, A., Le, T., & Xia, C. (2024). Appraising the phycoremediation potential of cyanobacterial strains Phormidium and Oscillatoria for nutrient removal from textile wastewater (TWW) and synchronized biodiesel production from TWW-tolerant biomass. *Environmental Research*, *241*, 117628.

Munir, N., Samad, M., Sharif, N., Haq, R., & Naz, S. (2023). Effect of mutagens on biomass and lipid content of Ulothrix sp. and Oscillatoria sp. for improved biodiesel production. *JAPS: Journal of Animal & Plant Sciences*, *33*(1).

Nys, C., Janssen, C. R., Van Sprang, P., & De Schamphelaere, K. A. (2016). The effect of pH on chronic aquatic nickel toxicity is dependent on the pH itself: Extending the chronic nickel bioavailability models. *Environmental Toxicology and chemistry*, *35*(5), 1097-1106.

Øverland, M., Mydland, L. T., & Skrede, A. (2019). Marine macroalgae as sources of protein and bioactive compounds in feed for monogastric animals. *Journal of the Science of Food and Agriculture*, *99*(1), 13-24.

Parwin, N., Dixit, S., Sahoo, S., Sahoo, R. K., & Subudhi, E. (2024). Assessment of the surface water quality and primary health risk in urban wastewater and its receiving river Kathajodi, Cuttack of eastern India. *Environmental Monitoring and Assessment*, *196*(6), 551.

Patil, P., Sawant, D., & Deshmukh, R. (2012). Physico-chemical parameters for testing of water–A review. *International journal of environmental sciences*, *3*(3), 1194-1207.

Pradhan, B., Maharana, S., Bhakta, S., & Jena, M. (2022). Marine phytoplankton diversity of Odisha coast, India with special reference to new record of diatoms and dinoflagellates. *Vegetos*, *35*(2), 330-344.

Ramakrishnan, B., Megharaj, M., Venkateswarlu, K., Naidu, R., & Sethunathan, N. (2010). The impacts of environmental pollutants on microalgae and cyanobacteria. *Critical Reviews in Environmental Science and Technology*, *40*(8), 699-821.

Ramakrishnan, R., Singh, K. S., John, M. A., Krishna P, A., & Imchen, T. (2025). Seasonal variations in phytoplankton community and the impact of physico-chemical variables in the estuaries of the central west coast of India. *Diatom Research*, 1-16.

Rath, B. (2012). Microalgal bioremediation: current practices and perspectives. *Journal of Biochemical Technology*, *3*(3), 299-304.

Rathwa, S. D., & Patel, V. A. (2020). Study on algal biodiversity in and around Patan (North Gujarat), India. *Journal of Multidisciplinary Educational Research*, *9*(3), 128-137.

Schenk, P. M., Thomas-Hall, S. R., Stephens, E., Marx, U. C., Mussgnug, J. H., Posten, C., Kruse, O., & Hankamer, B. (2008). Second generation biofuels: high-efficiency microalgae for biodiesel production. *Bioenergy research*, *1*(1), 20-43.

Sina, I., & Zulkarnaen, I. (2019). Margalef Index, Simpson Index and Shannon-Weaiver Index calculation for diversity and abudance of beetle in tropical forest. *Statmat: jurnal statistika dan matematika*, *1*(2).

Singh, S. P., & Singh, P. (2015). Effect of temperature and light on the growth of algae species: A review. *Renewable and sustainable energy reviews*, *50*, 431-444.

Tweed, S., Grace, M., Leblanc, M., Cartwright, I., & Smithyman, D. (2011). The individual response of saline lakes to a severe drought. *Science of the Total Environment*, *409*(19), 3919-3933.

Wetzel, R. G., & Likens, G. E. (2000). Dissolved oxygen. In *Limnological analyses* (pp. 73-84). Springer.