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Original Article

A Study of Physico-Chemical Characteristics of Effluent Collected from an Industrial Area in Boisar and Its Treatment Using Algal Bioadsorbent

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Abstract

Rapid industrialization has intensified the discharge of untreated or partially treated effluents containing toxic organic and inorganic pollutants, causing significant deterioration of water quality and posing serious risks to aquatic ecosystems and human health.[1] Heavy metals, dyes, nutrients, and other refractory contaminants are of particular concern due to their persistence, bioaccumulation, and toxicity.[1] Conventional wastewater treatment methods such as ultrafiltration, coagulation, ion exchange, electrochemical processes, ozonation, and reverse osmosis can be effective but are often constrained by high capital and operational costs, energy demand, and secondary pollution.[3] In this study, locally available marine algal biomass from the Dahanu coastal region (Maharashtra, India) was converted into a low-cost bio-adsorbent and evaluated for the treatment of industrial effluent collected from Tarapur M.I.D.C., Boisar. Key physico-chemical parameters including pH, turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total acidity, total alkalinity, salinity, inorganic phosphate, nitrate, nitrite, and free CO_2 were analyzed before and after treatment. Batch biosorption experiments were conducted by contacting 1 g of prepared algal bio-adsorbent with 100 mL of effluent under continuous agitation for up to 5 days. The algal bio-adsorbent achieved substantial reductions in COD, BOD, acidity, turbidity, salinity, and inorganic phosphate, while shifting pH from acidic toward near-neutral. These results demonstrate that marine algal biomass can be effectively utilized as a sustainable, cost-efficient, and eco-friendly bio-adsorbent for industrial wastewater treatment and supports its potential integration into scalable effluent management systems.[3]

Keywords: *Algal biomass, bio-adsorbent, industrial effluent, wastewater treatment.*

Introduction

Industrial development has become central to economic growth but has simultaneously intensified pressure on water resources through the discharge of complex wastewater containing heavy metals, dyes, organic pollutants, nutrients, and emerging contaminants.[1] Heavy metals are particularly critical because they are non-biodegradable, persistent, and capable of bioaccumulation and biomagnification, leading to carcinogenic, neurotoxic, nephrotoxic, and cardiovascular effects in humans and other organisms.[3] Water, as an excellent solvent, readily dissolves and transports such contaminants, compromising aquatic ecosystems, altering community structure, and reducing biodiversity.[2]

Rapid urbanization and industrial clustering, as seen in industrial estates such as Tarapur M.I.D.C., generate a mixture of effluents from chemical, textile, pharmaceutical, and other manufacturing units, often containing high loads of organic matter, salts, nutrients, and metals.[6] The release of inadequately treated effluents into surface water bodies and groundwater systems degrades water quality, reduces availability of safe drinking and domestic water, and disrupts ecosystem homeostasis.[2] Industrial effluents can broadly be categorized into metal-bearing, organic-rich, and mixed streams, with organic and mixed effluents posing particular treatment challenges due to the presence of refractory compounds and high salinity.[1] Conventional physico-chemical treatment methods (e.g., coagulation–flocculation, activated carbon adsorption, ion exchange, membrane processes, and advanced oxidation).

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often provide good removal efficiencies but suffer from drawbacks such as high cost, energy consumption, chemical usage, and sludge generation.[3] These limitations have driven interest in low-cost, sustainable alternatives such as biosorption using natural biomaterials. Algal biomass microalgae and macroalgae has emerged as a promising biosorbent due to its high surface area, abundance of reactive functional groups, renewable nature, and potential for post-treatment valorization into value-added products.[1] Therefore, this study focuses on the conversion of marine algal biomass into an effective bio-adsorbent for treating industrial effluent.

Objectives:

1. To prepare a marine algal bio-adsorbent from locally available algal biomass.
2. To analyse the physico-chemical characteristics of industrial effluent collected from Tarapur M.I.D.C., Boisar, before treatment.
3. To evaluate the treatment efficiency of the algal bio-adsorbent in improving effluent quality through batch experiments.

Materials and Methods:

Study Area and Effluent Collection

Industrial effluent samples were collected from a selected discharge point within the Tarapur M.I.D.C. industrial zone, Boisar, Maharashtra, India, which hosts a variety of chemical and manufacturing industries. Effluent was collected in pre-cleaned, high-density polyethylene containers, transported to the laboratory and stored at 4 °C prior to analysis and treatment experiments to minimize changes in composition.

Algal Biomass Collection and Preparation

Marine algal biomass was collected from Ambewadi, Chikhala old bridge, near Dahanu, along the Maharashtra coastline, where macroalgae are naturally abundant.[7] The collected algae were thoroughly washed with tap water followed by distilled water to remove adhering sand, salts, and debris. Clean biomass was air-dried at ambient conditions for approximately three days, followed by oven drying at 90 °C for two hours to remove residual moisture. The dried algal biomass was then ground to a fine powder and sieved to obtain a relatively uniform particle size fraction, which was stored in airtight containers as the prepared bio-adsorbent for subsequent experiments.[4][7]

Physico-Chemical Characterization of Effluent

Before treatment, the raw effluent was characterized using standard water and wastewater analysis procedures for the following parameters: pH, turbidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total acidity, total alkalinity, salinity, free CO_2, nitrate, nitrite, and inorganic phosphate. Measurements were performed using appropriate instruments: pH meter for pH, turbidimeter for turbidity, titrimetric methods for acidity, alkalinity, and selected colorimetric or instrumental methods for nutrients and COD/BOD as per standard guidelines.[2]

Batch Experiments

Batch experiments were conducted to evaluate the performance of the algal bio-adsorbent. A defined mass of bio-adsorbent (1.0 g) was added to 100 mL of raw effluent in 250 mL flasks, resulting in a biosorbent dose of 10 g/L. [3] The flasks were placed on a rotary shaker at 200 rpm to ensure uniform mixing and adequate contact between the algal particles and effluent. Experiments were carried out over contact times of 1, 3, and 5 days to assess the influence of exposure duration on pollutant removal. At the end of each contact time, the mixture was filtered and the clear supernatant was collected for post-treatment analysis.

Optical Density Measurement

Optical density (OD) of the untreated and treated effluent samples was monitored at an appropriate wavelength in the visible region using a colorimeter, with distilled water as the blank (OD = 0.00).[4] OD values provided a simple indicator of changes in colour and turbidity during treatment.

Observation

Fig.1. Algal bioadsorbent

Fig.2. Treatment of effluent by algal bioadsorbent

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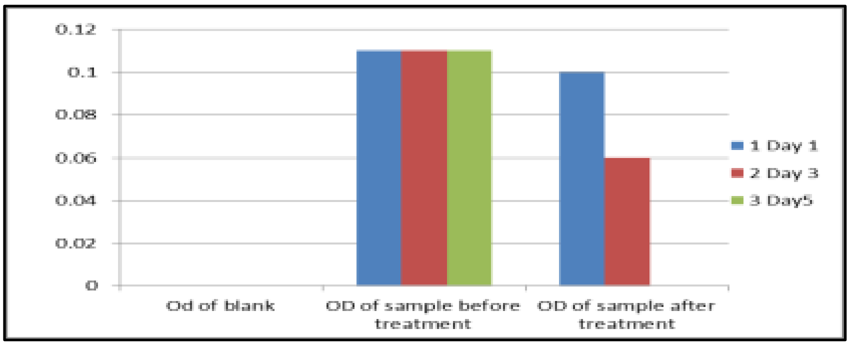
Fig.3. Comparison of untreated sample with treated sample

Fig.4. Turbidity- before and after treatment with bioadsorbent

Treatment of effluent by using bio-adsorbent

Sr. No	Day	OD of blank	OD of sample before treatment	OD of sample after treatment
1.	1	0.00	0.11	0.10
2.	3	0.00	0.11	0.06
3.	5	0.00	0.11	0.00



Results

	Parameter	Effluent before treatment	Effluent after treatment
1.	pH	4.76 pH	6.21 pH
2.	Turbidity	13.9 TU	4.6 TU
3.	BOD (Biochemical oxygen demand)	4.16 mg/L	1.6 mg/L
4.	COD (Chemical oxygen demand)	480 mg/L	224 mg/L
5.	Total alkalinity $CaCO_3$/L	200 mg	2250 mg
6.	Total acidity $CaCO_3$/L	13000 mg	2250 mg
7.	Salinity	3370.43 mg/L	1742.93 mg/L
8.	Inorganic phosphate	2050 mg/L	520 mg/L
9.	Nitrite	420 mg/L	320 mg/L
10.	Nitrate	820 mg/L	740 mg/L
11.	Free CO_2	352 mg/L	1100 mg/L

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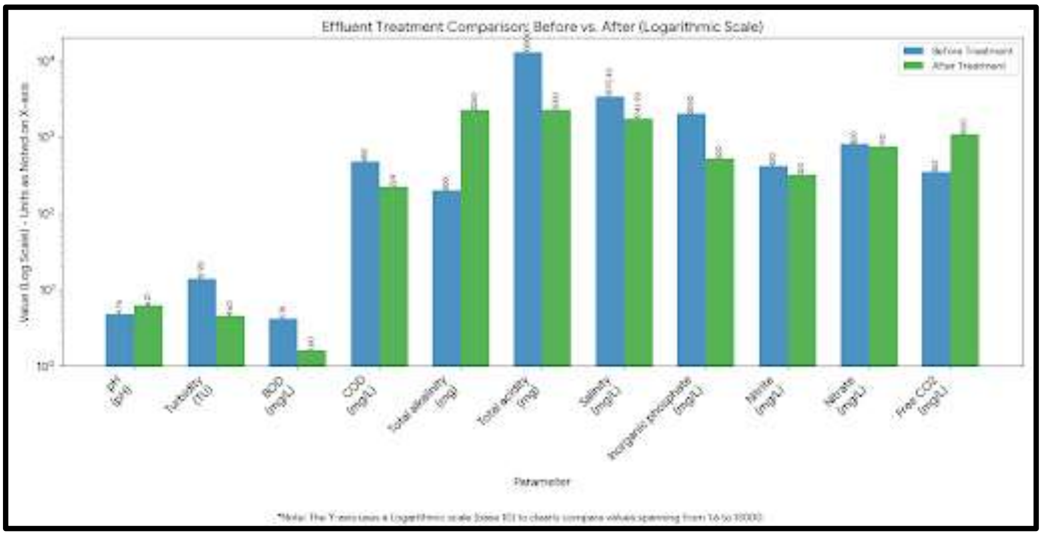

Effluent Quality Before and After Treatment

Key parameter changes included: pH increased from 4.76 to 6.21; turbidity decreased from 13.9 to 4.6 TU; BOD decreased from 4.16 to 1.6 mg/L; COD decreased from 480 to 224 mg/L; total acidity decreased from 13,000 to 2,250 mg $CaCO_3$/L; total alkalinity increased from 200 to 2,250 mg $CaCO_3$/L; salinity decreased from 3,370.43 to 1,742.93 mg/L; inorganic phosphate decreased from 2,050 to 520 mg/L; nitrite and nitrate decreased from 420 to 320 mg/L and from 820 to 740 mg/L, respectively; and free CO_2 increased from 352 to 1,100 mg/L, reflecting changes in carbonate equilibria.

Optical Density

OD measurements showed progressive improvement in clarity: OD of the untreated effluent was 0.11, while OD decreased to 0.10 on day 1, 0.06 on day 3, and 0.00 on day 5, indicating a near-complete reduction in colour and suspended material with increasing contact time.

Discussion

- Mechanisms of Pollutant Removal: The combined reduction in COD, BOD, turbidity, salinity, and nutrients reflects multiple mechanisms of pollutant removal by the algal bio-adsorbent. Biosorption onto functional groups on the algal cell wall likely contributed to the binding of dissolved organics, while bioaccumulation and subsequent biochemical transformation may have further reduced dissolved organic and nutrient load.[3][5] The substantial decrease in COD and BOD indicates that the algal biomass effectively removed a significant fraction of the oxygen-demanding organic compounds, which is critical for preventing oxygen depletion in receiving water bodies.[2] The pronounced reduction in inorganic phosphate and partial removal of nitrate and nitrite suggests that algae efficiently captured nutrient species from the effluent, aligning with reports that microalgae and macroalgae can remove 45–65% of BOD/COD and substantial amounts of nitrogen and phosphorus from wastewater.[11] The reduction in turbidity and OD can be attributed to adsorption and entrapment of suspended solids and colloidal particles on the algal surface, leading to improved water clarity.[4]
- Neutralization and Stabilization of Effluent: The shift in pH from 4.76 to 6.21, a large reduction in total acidity, and a marked increase in total alkalinity demonstrate the buffering capacity of the algal bio-adsorbent and partial neutralization of aggressive components in the effluent.[2] These changes are favorable for downstream biological treatment processes and for reducing the corrosive and toxic nature of the effluent if discharged. The decrease in salinity is particularly relevant for industrial regions where high salt concentrations can limit the performance of conventional biological treatment systems.[16]
- Advantages over Conventional Treatment: Compared with conventional physico-chemical methods, algal bio-adsorbents offer several advantages, including low material cost, minimal chemical additives, reduced sludge generation, and the potential to recover and reuse the biosorbent or convert it into biofuels and fertilizers.[1][3] This aligns with circular economy principles and supports sustainable wastewater management in industrial clusters like Tarapur M.I.D.C.

Conclusion

This study confirms that marine algal biomass sourced from the Dahanu coastal region can be successfully converted into an efficient bio-adsorbent for the treatment of industrial effluent from Tarapur M.I.D.C., Boisar. The algal bio-adsorbent achieved significant reductions in COD, BOD, turbidity, salinity, and inorganic phosphate, and shifted the effluent pH from acidic toward near-neutral, thereby improving overall water quality and reducing toxicity. The process is cost-effective, environmentally friendly, and compatible with resource recovery strategies, as the spent biomass can potentially be valorized into biofuels, fertilizers, or animal feed.[4] Overall, algae-based bio-adsorbents represent a promising alternative or complementary technology to conventional treatment methods for sustainable industrial effluent management.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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