Research Article

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Bioremediation of malachite green dye using *Sargassum wightii* seaweed and its biological and physicochemical characterization

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Abstract: Textile dye effluents and their contamination in aquatic environments is a serious risk pose of aquatic pollution. Degradation of such dyes using a biological treatment like microbe and plant-based remediation is an eco-friendly approach and more feasible than the physical and chemical treatment processes. In the present study, the biosorption of malachite green (MG) dye from aqueous solution using *Sargassum wightii* seaweed was evaluated. Using batch mode, several factors, including biosorbent concentration (1–6 g/L), pH (3–10), and temperature (25–60°C), that affected biosorption over a range of time intervals were determined. The absorption capacity was lowered as the temperature increased over 40°C. Similarly, at pH 3.0, the least adsorption of 23 mg/g was recorded. With a large elevation in pH, a gradual increment in adsorption was seen. At pH 7, a maximum uptake capacity of 78 mg/g was observed. The concentrations of dissolved oxygen demand and biological oxygen demand were much reduced in the treated dye-contaminated water. The BOD value decreased from 0.5 to 5,440 mg/L, and the COD value decreased from 20 to 2,080 mg/L as the biosorption time increased. *S. wightii*-mediated dye degradation resulted in reduced water toxicity level, which is ensured by seed germination when the dye-treated water was used using *S. wightii*. The dye-treated water exhibited no antimicrobial properties in terms of antifungal and antibacterial when compared to non-treated water. The biosorbent and adsorbent interactions were characterized using FTIR and SEM. FTIR interpretation revealed that the treated water reduces the dye concentration in water, which is evident through reduction of functional groups when compared with FTIR results of untreated water. Dye-treated water and its safe physicochemical and biological parameters were assessed using a green gram germination test and microbial toxicity assay using the treated water.

Keywords: malachite green, biosorption, seaweed, green gram, scanning electron microscope

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1 Introduction

Increased anthropogenic effect like industrialization and more urbanization imposes severe risks to an aquatic environment and aquatic pollution. Every year, the textile industry generates 7–105 tons of organic dye wastewater [1]. The primary composites in textile effluents include a

composite confluence of organic dyes, phosphates, nitrates, and heavy metals [2]. These industries generate water-mixed organic and inorganic waste as a result of their manufacturing processes, which changes the biological and chemical composition of the ultimate water sources. The textile sector employs a range of dyes to impart color to their goods, which results in dye effluent mixed wastewater that is distinguished by having a high color and organic content [3]. A dye-effluent-contaminated water body is a prime area that poses a red alert risk to humans, animals, and plants that consume contaminated water. Dyes are mostly used in the manufacturing sectors, such as tanneries, textiles, preservation, and cosmetic industries, with an annual global production of 1,000,000 tons [4,5]. Based on the chromophore, dyes are divided into ionic and non-ionic dyes, such as azo, triarylmethane, diarylmethane cyanine, anthraquinone, acridine, phthalein, xanthene, triphenylmethane dye, indigoid, oxazine nitro, etc. An Azo dye accounts for 60–70% of the dying material in most of the fabric and industrial components [6,7].

Malachite green (MG) is a basic dye that is used to color finished goods in a variety of sectors, including leather, textile, paper, etc. This dye is still used around the world despite being prohibited in some nations because of its accessibility, cost, efficacy, and lack of adequate substitutes [8]. Additionally, it acts as a toxin for respiratory enzymes, resulting in a delay in blood coagulation, an increase in hemoglobin, anemia, and leukocytosis after exposure to MG dye [9]. Several theoretical procedures, such as electrodialysis, froth flotation, adsorption, cloud point extraction, and coagulation, might be utilized to remove the color from fabric effluents (Vigneshpriya and Shanthi, 2006). Successful innovations have driven us to investigate biosorption that adsorbs organic dyes on biomass.

Seaweed serves as an effective biosorbent due to its high surface area and abundance of functional groups such as hydroxyl and carboxyl. For example, a study using the red seaweed *Pterocladia capillacea* showcased its ability to adsorb 98% of Crystal Violet dye from synthetic wastewater, proving its potential as a low-cost and eco-friendly adsorbent [10]. The development of optimized biosorption processes continues to highlight the versatility of seaweed in addressing dye pollution. The phycobioremediation potential of seaweeds is another noteworthy aspect. The ability of seaweed biomass to absorb and metabolically degrade toxic dyes provides a unique advantage over land-based plants [11]. Moreover, their cultivation can contribute to marine ecosystem sustainability while providing a resource for effective pollutant removal. Seaweeds are efficient biomass in reducing the dyes from the water environment. It is proven that seaweeds enriched with sulfate polysaccharides efficiently degrade the dyes present in the textile industry water discharge, making that water utilizable for human and agricultural usage [12]. The brown alga *Sargassum wightii* is one of the marine algal species that exhibit a wide range of organic properties. *S. wightii* is distributed abundantly on the Southeast coast of India, Sri Lanka, the Philippines, and Indonesia. Adsorption methods are broadly utilized to remove dyes that are not effectively biodegradable from wastewater. As a result, for the removal of colors from wastewater, the combination of organic treatment and adsorption is becoming increasingly popular [13].

There exists a gap in the literature regarding the practical applications of seaweed-derived materials in dye adsorption. Previous experimental studies involved the use of *Fucus vesiculosus* seaweed as a bioadsorbent in degrading dyes like methylene blue and rhodamine-B efficiently up to 96% [14]. Huge seaweed biomass aggregation in coastal environments has increased in recent years, and the management of such stockpiling seaweed aggregation is a serious concern in modern times. Utilizing such seaweeds for bioremediation in dye degradation is a novel approach for wastewater treatment. The present study explores the regeneration and reuse of seaweed *Sargassum wightii* as bio-adsorbents, emphasizing their sustainability and long-term viability as an environmental solution. This report illustrates the novel contributions of seaweed to dye degradation, particularly highlighting its role as a bioremediation agent that is both effective and environmentally friendly. Due to the toxicity of the dye employed in this experiment, marine macro alga *S. wightii* seaweed was utilized as an adsorbent to remove the malachite color from an aqueous solution. By using *in vitro* systems, the dye biosorption impact of *S. wightii* and its microbiological and phytotoxicity investigations were assessed. Utilizing FTIR and SEM analyses, the analytical characterization of *S. wightii* dye degrading impact was evaluated.

2 Methodology and materials

2.1 Reagents and dyes

All the chemicals and reagents used in the present study are of analytical grade (AR) (>99% purity) and were procured from Sigma Aldrich (India). Microbial strains used for microbial toxicity assay in the present study are of American-type cell culture (ATCC), which was purchased from Hi-Media Labs (Mumbai, India). The physicochemical parameters of MG dye are shown in Table 1.

Table 1: Phytotoxicity study (on 7th day) of control, untreated, and *S. wightii*-treated MG dye (n = 20) and its effect on seed germination (%), shoot length (cm), root length (cm), weight (g), vigor index, and tolerance index

Germination of seeds	Observation	Control	T_1	T_2
Green gram	Germination (%)	91	40	82
	Length of the shoot (cm)	12.43 ± 0.208[c]	3.10 ± 0.020[a]	12.50 ± 0.057[b]
	Length of the root (cm)	6.41 ± 0.152[c]	2.16 ± 0.020[a]	5.20 ± 0.0570[b]
	Fresh weight (g)	0.27 ± 0.020[c]	0.09 ± 0.005[a]	0.24 ± 0.005[b]
	Dry weight (g)	0.20 ± 0.010[c]	0.08 ± 0.005[a]	0.18 ± 0.005[b]
	Vigor index (VI)	558	82	410
	Tolerance index (TI)	—	0.333	0.822
	% phytotoxicity	—	−7.40	−78.80

[a]Significance level at $p > 0.1$; [b]significance at $p < 0.01$; and [c]significance at $p < 0.005$.

2.2 Adsorbent

Marine alga *S. wightii* was collected from the coastal region of Kanyakumari, Tamil Nadu, India (Lat: 98.28°N Long: 79.12°E). To get rid of contaminants, *S. wightii* was washed extensively with fresh water. The algal species was identified by Professor Anatharaman (Annamalai University, Parangipettai, India). A voucher specimen (AU:14584) was deposited at the marine museum of CASMB for future reference. The alga was transported to the lab and shade-dried for a week, and the dried seaweed was ground into a fine powder and sieved through a mesh size of 150 µm. The powdered and sieved seaweed sample was stored in a sealed bottle for further use.

2.3 Adsorbate

The MG dye solution was prepared for the biosorption investigation using the method of Gunduz and Bayrak (2017) with a few minor modifications. To prevent the decolorization brought through light, a series of concentrations of stock dye (0.25, 0.5, 1, 2, 3, 5 g/L) was prepared, and the dye stock solution container was covered with aluminum foil. The appropriate stock solutions were made using precise serial dilutions, and the absorbance was measured at 625 nm.

2.4 Batch mode study: Biosorption

S. wightii was used to determine the biosorption factors of MG dye in an aqueous solution. The tests were carried out in 250 mL Erlenmeyer flasks containing 100 mL of dye solution and the required amount of adsorbent. The experiment was conducted using the methods with a few minor modifications utilizing variable adsorbent dosages (0.1–0.6 g/100 mL), pH (3–10), and different temperatures (25–60°C). To change the pH of the solution, 0.1 N NaOH and 0.1 N HCl were added. Samples (5 mL) were taken during the experiment at different time intervals (0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, and 240 min) and centrifuged to determine the amount of color removed (%) and the amount of color uptake (qeq), which were then measured at 625 nm in a colorimeter (P Photo Colorimeter-1311). To obtain concordant results, all experiments were conducted in triplicate.

2.5 Analytical studies

The metabolites were extracted after biosorption of MG dye (100 g/L) under optimized conditions. The untreated dye solution at 0 h served as a control. A total of 100 mL of samples was centrifuged at 5,000 rpm for 10 min. The cell-free supernatant of control and treated samples were sequentially extracted with ethyl acetate (EtoAC) [15]. The extract was dried using a vacuum evaporator (Buchi, Switzerland). Decolorized samples were used for the characterization of functional groups using Fourier transform infrared spectroscopy (FTIR) (Shimadzu IR-Tracer-100, USA) analysis (800–4,000 cm^{-1}) using a Shimadzu 8400 S model spectrum (Perkin Elmer PE 1600), and the surface characterization of the biomass was examined by scanning electron microscopy (SEM) (Model JSM-6100) operated at 10 kV.

2.6 Physicochemical properties of MG dye solution

Both treated and untreated MG dye solutions were assessed for their physicochemical properties, according to APHA (2000).

2.7 Phytotoxicity study

Green gram (*Vigna radiata* L) seeds were procured from Tamil Nadu Agricultural University (TNAU, India). 1% $HgCl_2$ was used to surface-sterilize the seeds for 2 min.

Twenty seeds were used in each pot for the experiment, with T1 (untreated MG dye) and T2 (treated MG dye) serving as the treatments and tap water acting as the control. Triplicates of each treatment were employed [16]. On the seventh day, many indicators were measured, including the percentage of germination, fresh weight (g), vigor index, root length (cm), dry weight (g), shoot length (cm), tolerance index, and phytotoxicity. Additionally, the percentages of phytotoxicity, tolerance index, and vigor index were computed.

2.8 Antimicrobial activity

A microbial toxicity assay was carried out with both treated and untreated dye water [17] to assess the water toxicity level. The agar well diffusion technique was employed to assess the antimicrobial activity. Using sterile cotton swabs, 0.1 OD cultures of Gram-positive (three cultures) and Gram-negative (three cultures) bacteria were swabbed onto Muller–Hinton agar (MH) plates. Each Petri plate had a 6 mm well created using a sterile cork borer. In a separate well, 10 µL of treated and untreated dye were put into Petri plates, which were then incubated for 24 h at 37°C. After 24 h, the plates were checked for bacterial toxicity and the zone of inhibition. As a negative control, distilled water was added. The data were collated, and the zone of inhibition was measured in millimeters (mm).

Potato dextrose agar (PDA) was used to culture the fungal strains. To Petri plates containing fungal cultures, with 10 µL of untreated dye and treated dye, were added to a separate well and incubated at 37°C for 72 h. After 72 h of incubation latency time, the antifungal effect was determined using the zone of inhibition (mm) observed in Petri plates.

2.9 Statistical analysis

Using the STATISTICA Program (Version 10.0), an analysis of variance (ANOVA) was performed on the phytotoxicity results, and Duncan's numerous extend test (DMRT) was established for significant differences (P 0.05).

3 Results and discussion

3.1 Effect of the adsorbent dose

The effect of contact time between seaweed adsorbents and dye contaminants is critical for optimizing the biosorption

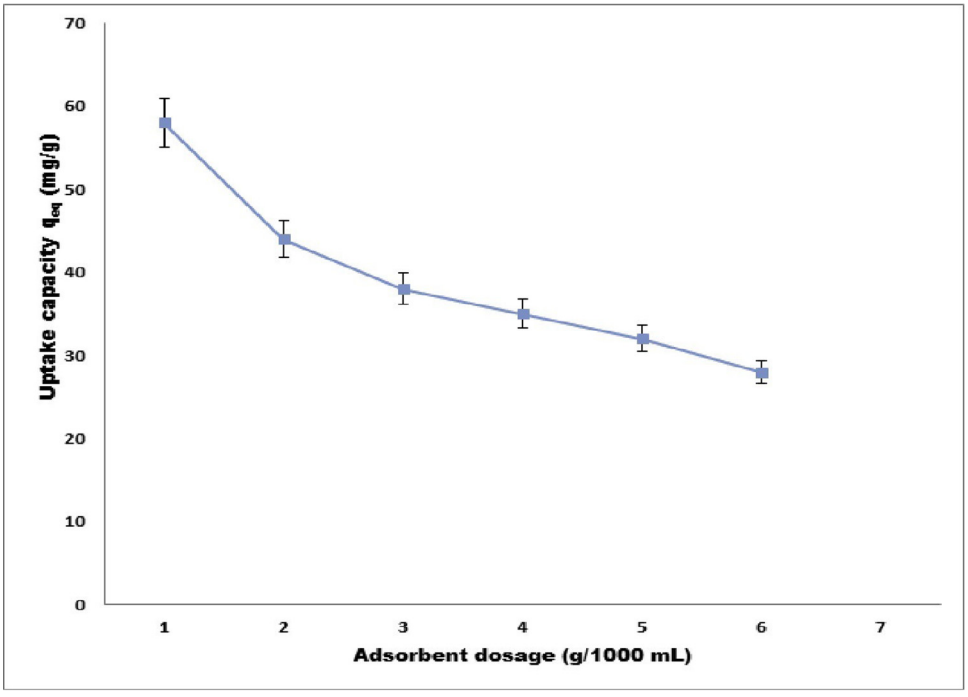

Figure 1: Effect of the adsorbent dose on the removal of MG dye (initial dye concentration: 70 mg/L, agitation: 180 rpm, and temperature: 30°C).

process. Research has shown that adsorption efficiency generally increases with contact time, highlighting the importance of allowing adequate interaction between the adsorbent and contaminant to achieve optimal dye removal [18]. In the present study, the contact time significantly influenced the adsorption capacity of seaweed adsorbents such as the MG dye. As time progressed, the interaction between the dye and the biosorbent enhanced, leading to higher adsorption efficiencies. Initially, rapid adsorption occurred; however, it slowed down as the available adsorption sites on the adsorbent became saturated. The studies indicate that longer contact times often result in greater removal percentages of dye contaminants. With an increase in biosorbent dose, it was observed that the equilibrium dye uptake capability decreased. The amount of dye adsorbed is proportional to the increase in the dye biosorbent dosage. At a dose of 1 g/1,000 mL adsorbent, the equilibrium dye absorption capacity was 58 mg/g (Figure 1). Previously, a similar result was observed for the elimination of Reactive red 2 dye and Reactive blue 81 dye using dried soya bean meal [19]. Apart from dye degradation, effective metal adsorption was also performed using plant-based phytoremediation as *Sesbania bispinosa* biochar (SBC) with copper oxide (SBC/CuO) and manganese oxide nanoparticles (SBC/MnO) used for the efficient and inexpensive removal of environmentally concerned contaminant heavy metal metal arsenic (As) from contaminated water at batch scale. Similar reports in earlier studies with *Phoenix dactylifera* leaf biochar (PBC) were prepared to adsorb the Congo red dye from water [20], and a green powder material from plants was used to remove rare earth elements like Praseodymium and Samarium effectively as biochar adsorbents [21].

3.2 Effect of pH

The pH influence on dye biosorption was detected by altering the pH level in the system from 3.0 to 10.00 (Figure 2). At pH 3.0, the least adsorption of 23 mg/g was recorded. With an increase in the pH, a gradual increase in adsorption was observed. At pH 7, a maximum uptake capacity of 78 mg/g was observed. At pH 10, the uptake capacity was found to be 59 mg/g, and the adsorption rate >pH 8 gradually decreased.

This might be a result of electrostatic interactions, as well as the distinctive qualities of the adsorbent and dye molecule structures. In color adsorption, color particles play essential roles. Figure 2 illustrates the impact of solution pH on the equilibrium absorption of MG dye using *S. wightii* at 30°C. The biomass will have a net positive charge at lower pH levels [22]. Changes in surface properties and charge can be the reasons for the decrease in dye absorption ability on *S. wightii* with increasing pH.

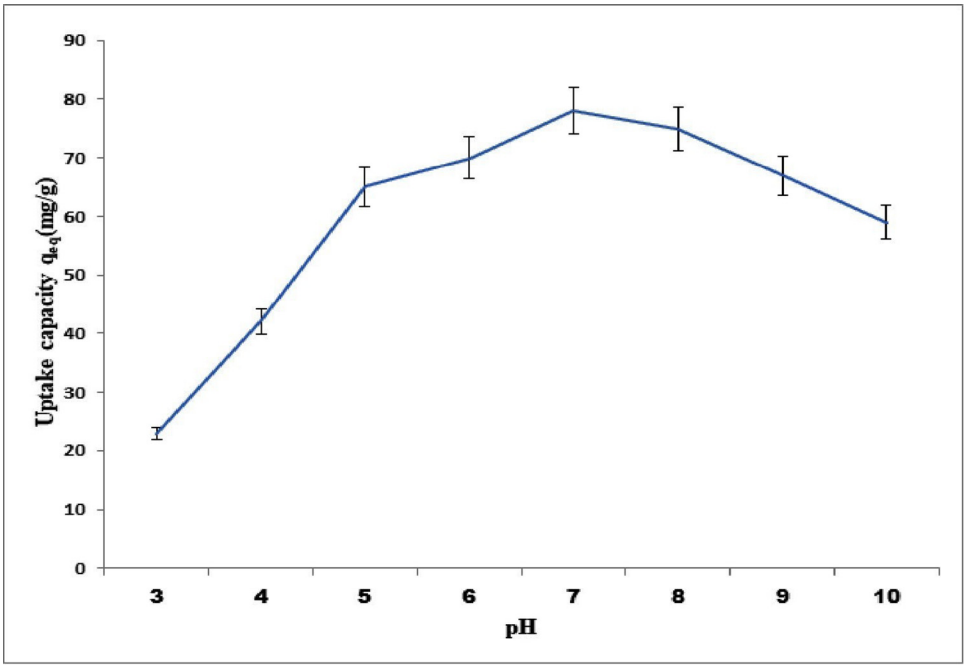

Figure 2: Effect of pH on the removal of MG dye (initial dye concentration: 70 mg/L, agitation: 180 rpm, temperature: 30°C, and biosorbent dosage: 0.1 g/100 mL).

Increasing the pH imparts the biomass with more negatively charged sites and decreases the positively charged sites. The biosorbent neutrally charged surface site promotes the pH-related adsorption processes. Likewise, our results follow earlier findings of MG dye removal of up to 73% at pH 7.0 using thiolated graphene nanostructures [23].

3.3 Effect of temperature

Figure 3 depicts the effect of temperature on uptake capacity. The ability for dye absorption was shown to increase with temperature from 25 to 40°C. At 40°C, the maximal absorption capacity was measured to be 98 mg/g. The absorption capacity was lowered as the temperature increased over 40°C, which literally coincided with similar earlier reports [24].

3.4 Physicochemical analysis

The physicochemical parameters of the treated and untreated dye were determined at a pH of 7.0 at 30°C. The concentrations of dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and total dissolved solids (TDS) all increased to 2.0, 23, 250, 95, 2,000, and 2,080 mg/L, respectively. It was observed that the untreated dye had a pH of 9.0 at 30°C. The concentrations of DO, BOD, COD, TSS, TDS, and TS were found to be 0.5, 90, 481, 260, 5,000, and 5,440 mg/L, respectively. When compared to the untreated dye, the overall physicochemical parameters of the treated dye significantly altered due to the decreased level of the organic level in water [25,26].

3.5 Phytotoxicity study of MG dye treated and untreated water on green gram

3.5.1 Seventh day of the experiment

Experimental studies have emphasized the high efficiency of seaweed in dye adsorption. For instance, *P. capillacea* achieved a remarkable removal percentage of over 98% in batch experiments under optimized conditions, underscoring the application of seaweeds as effective adsorbents in real-world wastewater management [27]. Textile dye that has been treated may be utilized in irrigation and industry. The most viable approach in this regard appears to be the reuse of textile wastewater for irrigation

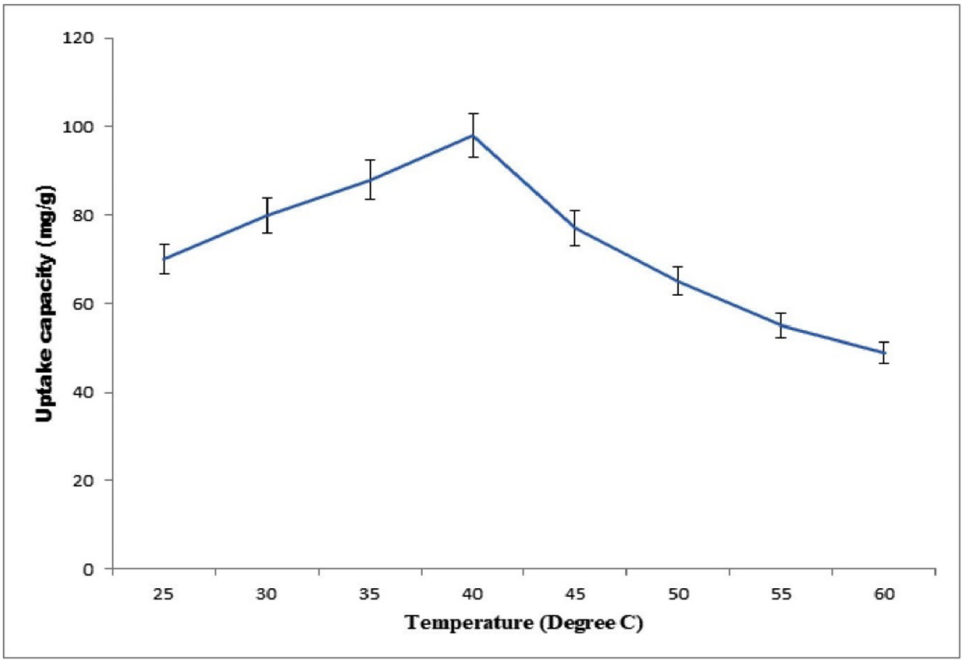

Figure 3: Effect of temperature on the removal of MG dye (initial dye concentration: 70 mg/L, agitation: 180 rpm, pH: 7, and biosorbent dosage: 0.1 g/100 mL).

purposes. As a result, the dye that has been processed might be used to supply irrigation water for farms. The purpose of the current study was to evaluate the treated MG dye that was used to irrigate *Vigna radiata* L.

Green gram *Vigna radiata* L was used to conduct phytotoxicity research comparing untreated (T1) and *S. wightii*-treated (T2) MG dye solutions to the control (tap water). The results are shown in Table 1. According to the analysis of variance, the *S. wightii*-treated MG dye had the highest fresh weight, germination percentage, dry weight, and seedling growth, whereas the untreated MG dye had the lowest. Untreated MG dye had a harmful impact (Figure 4a), but dye removal from treated dye solution improved seed germination and spontaneous plant development (Figure 4b). Controlled plant seedling growth (Figure 4c) is used as the standard reference. In a previous similar experiment, *Fucus vesiculosus* seaweed was used as a bioadsorbent in removing methylene blue, and rhodamine dye was effectively reused even after absorbing the dye [14]. In the present study, *S. wightii* was used after dye treatment and seemed to be alive without any physical and biological damage to the plants, which states that the seaweed as a bioadsorbent for dye degradation is environmentally friendly with efficient reusability.

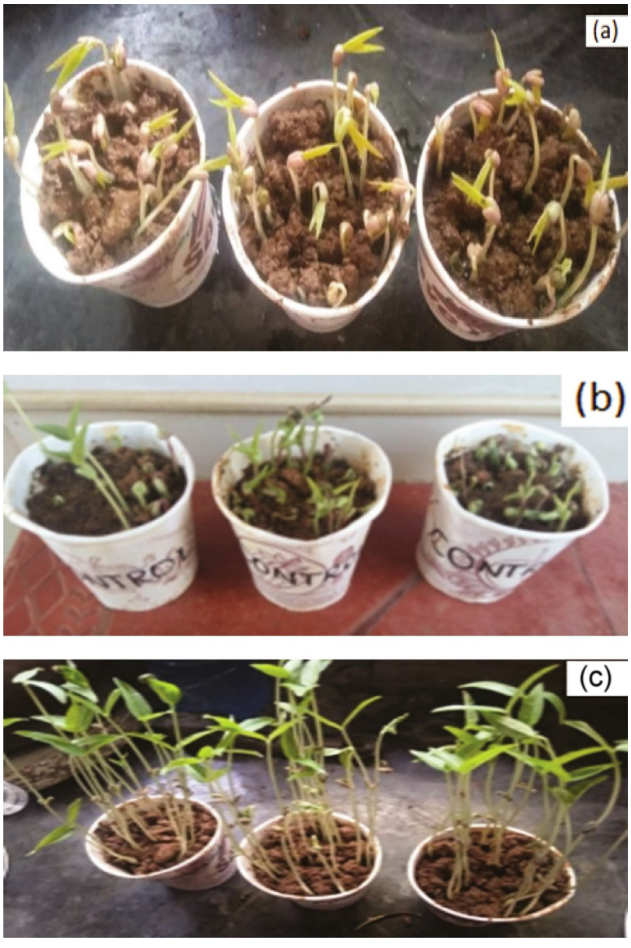

Figure 4: (a) Growth of green gram using untreated MG dye, (b) growth of green gram using treated untreated MG dye, and (c) growth of green gram in control water.

Due to its elevated level of sulfated polysaccharides, the brown alga *S. wightii* is renowned seaweed for its well-documented biomedical advantages, such as antioxidant and anti-inflammatory properties. The current results also support the findings of Phugare et al. [28], which described the harmful and nontoxic effects of both treated and untreated dye on the germination of *T. aestivum* and *P. mungo* seeds, respectively. *Triticum aestivum* and *Ervum lens* plants cultivated after decolorization had a greater germination rate than plants grown in dye, according to phytotoxicity research [29]. When compared to untreated dye, *Triticum* sp. growing in treated dye exhibited superior growth. The development of cowpea seedlings was aided by the reduced textile dye content [30].

Plants may be used to remove toxins from locations in different ways. By serving as filters or traps for soil, sediment, and/or water contaminants, plants can remove them. According to Otunola et al. [31], the root systems of plants often ingest toxins from the environment and protect the environment from their toxicity. Due to adaptability, plants' root systems take in additional pollutants as well as the vital nutrients needed for development. More photosynthetic activity and a better seed output result from improved plant development [32].

3.6 Microbial toxicity of the untreated and treated MG dye

3.6.1 Bacterial toxicity

Gram-positive and Gram-negative bacteria were used to investigate the bacterial toxicity of untreated and treated MG dye (Table 2 and Figure 5a–f). Untreated dye that had a substantial concentration of the dye showed sizable bacterial toxicity. *Streptococcus epidermis* (ATCC 12228) (A) and *Staphylococcus aureus* (ATCC 25923) (B) showed a prominent inhibition zone with a diameter of about 1.9 cm, followed by *Pseudomonas aeruginosa* (ATCC 47085) (C), *Bacillus cereus (*ATCC 9634) (D), *Vibrio cholera* (ATCC 14035) (E), and *Klebsiella pneumoniae* (ATCC 13882) (F) with diameters of 1.8, 1.5, and 1.2 cm, respectively. The untreated dye is harmful to biotic organisms, as seen by the toxicity it exhibits against bacteria. No inhibitory zones

Table 2: Bacterial toxicity of the untreated and treated MG dye

S. no.	Organism	Zone of inhibition (cm)	
		Untreated MG dye	Treated MG dye
1.	*Bacillus cereus* (Gram-positive)	1.6 ± 0.24	NIL
2.	*Streptococcus epidermis* (Gram-positive)	1.9 ± 0.15	NIL
3.	*Staphylococcus aureus* (Gram positive)	1.9 ± 0.15	NIL
4.	*Vibrio cholera* (Gram-negative)	1.5 ± 0.24	NIL
5.	*Klebsiella* sp. (Gram-negative)	1.2 ± 0.29	NIL
6.	*Pseudomonas aeruginosa* (Gram-negative)	1.8 ± 0.14	NIL

Results depict the mean values and significance levels achieved at $p < 0.05$.

were observed with the dye solution that had been treated, confirming the isolated metabolite's harmless nature. Similar experimental research employing various microbial cultures on the toxic effects of untreated dyes and the removal of their toxicity following biological treatment was reported [33].

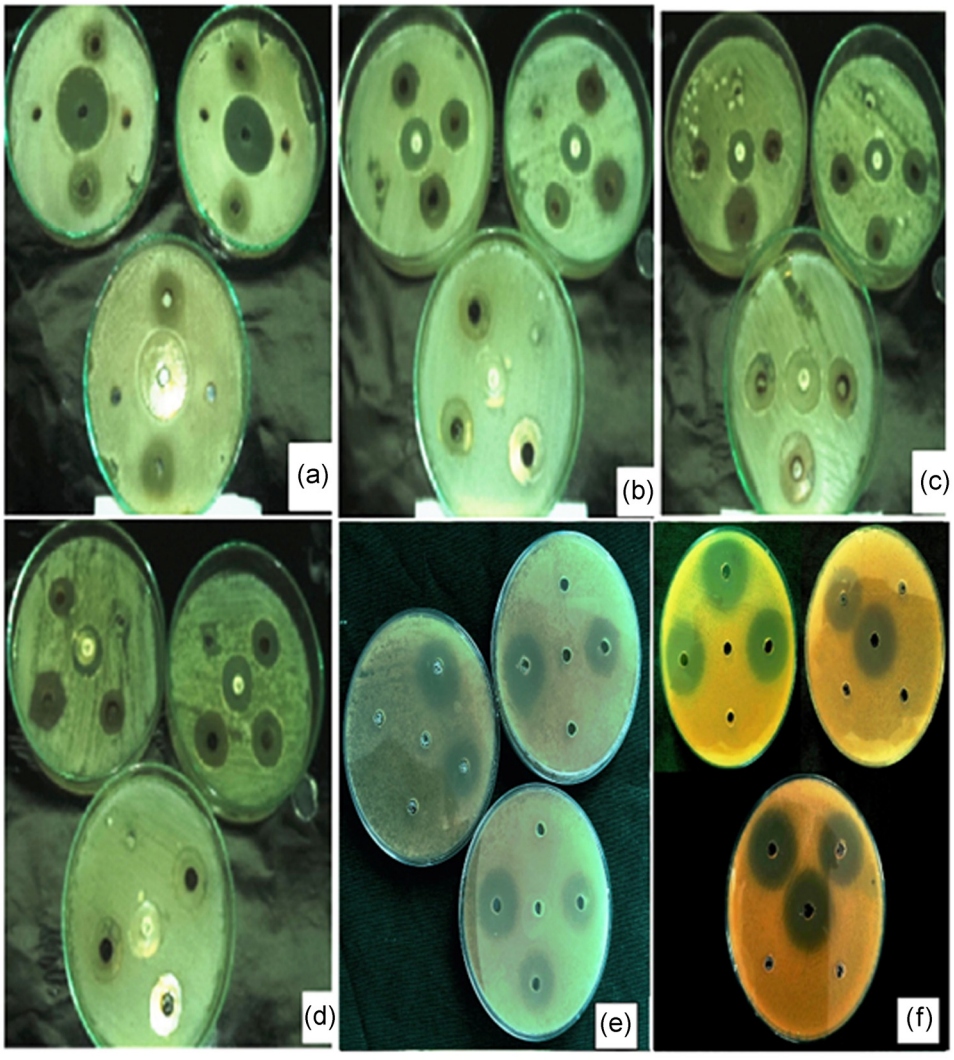

Figure 5: Bacterial toxicity of the untreated and treated dye samples against *Streptococcus epidermis.* (a) *Staphylococcus aureus,* (b) *Pseudomonas aeruginosa,* (c) *Bacillus cereus,* (d) *Vibrio cholera,* (e) *Klebsiella* sp., and (f) *Pseudomonas aeruginosa*.

Table 3: Fungal toxicity of the untreated and treated MG dye

S. no.	Organism	Zone of inhibition (in cm)	
		Untreated MG dye	Treated MG dye
1.	*Rhizopus* sp.	0.9 ± 0.53	NIL
2.	*Aspergillus flavus*	0.7 ± 0.38	NIL
3.	*Acremonium* sp.	0.7 ± 0.38	NIL
4.	*Aspergillus fumigates*	0.9 ± 0.53	NIL

Results depict the mean values and significance levels achieved at $p < 0.05$.

3.6.2 Fungal toxicity

The antifungal effects of pre- and post-treated dye were assessed against phytopathogenic fungal strains of *Rhizopus* sp. (ATCC 20577), *Aspergillus flavus* (ATCC 16883), *Acremonium* sp. (ATCC KY4917), *Aspergillus fumigates* (ATCC 13073), *and Aspergillus niger* (ATCC 16888) (Table 3 and Figure 6a–c). No zone of inhibition was observed in the dye group that had been treated, but it was observed in the dye group that had been treated. A moderate zone of inhibition with a diameter of 0.7 cm was observed against *Aspergillus flavus* (B) and *Acremonium* sp. (C), and a maximum zone of inhibition (0.9 cm) was recorded against *Rhizopus* sp. (A), and *Aspergillus fumigates* (D). MG dye that has been exposed to *S. wightii* lacked antifungal properties. Finally, a fungal growth bioassay indicated that dyes had been detoxified. In a previous investigation, *Saraca asoca* and *Albizia lebbeck* plants' ability to absorb dye was reported to be degraded, and the dye that had been treated had a considerable antifungal impact on the strains of phytopathogenic fungi [34,35].

3.7 Analytical studies (characterization of dye solution)

3.7.1 FTIR analysis

FTIR analysis was used to determine the vibrational changes in the peaks (the ranges from 4,000 to 800 cm^{-1}) of MG dye samples before and after adsorption using *S. wightii* (Figure 7). The spectrum of absorbance before adsorption can be detected at 3772.76, 3348.42, 3294.42, 2083.12, 1643.35, 1496.76, 1103.28, and 702.09 cm^{-1}. 3348.42, 3294.42, 1643.35, and 702.0 cm^{-1}, which are the main peaks.

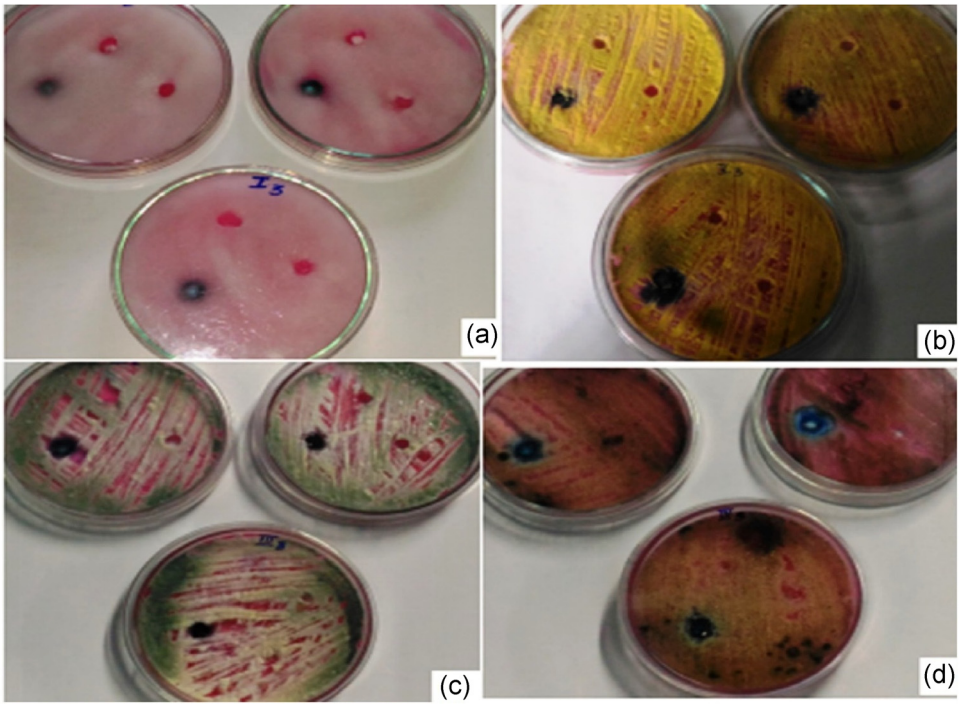

Figure 6: Antifungal activity of the untreated and treated dye samples against (a) *Rhizopus* sp., (b) *Aspergillus flavus*, (c) *Acremonium* sp., and (d) *Aspergillus fumigates.*

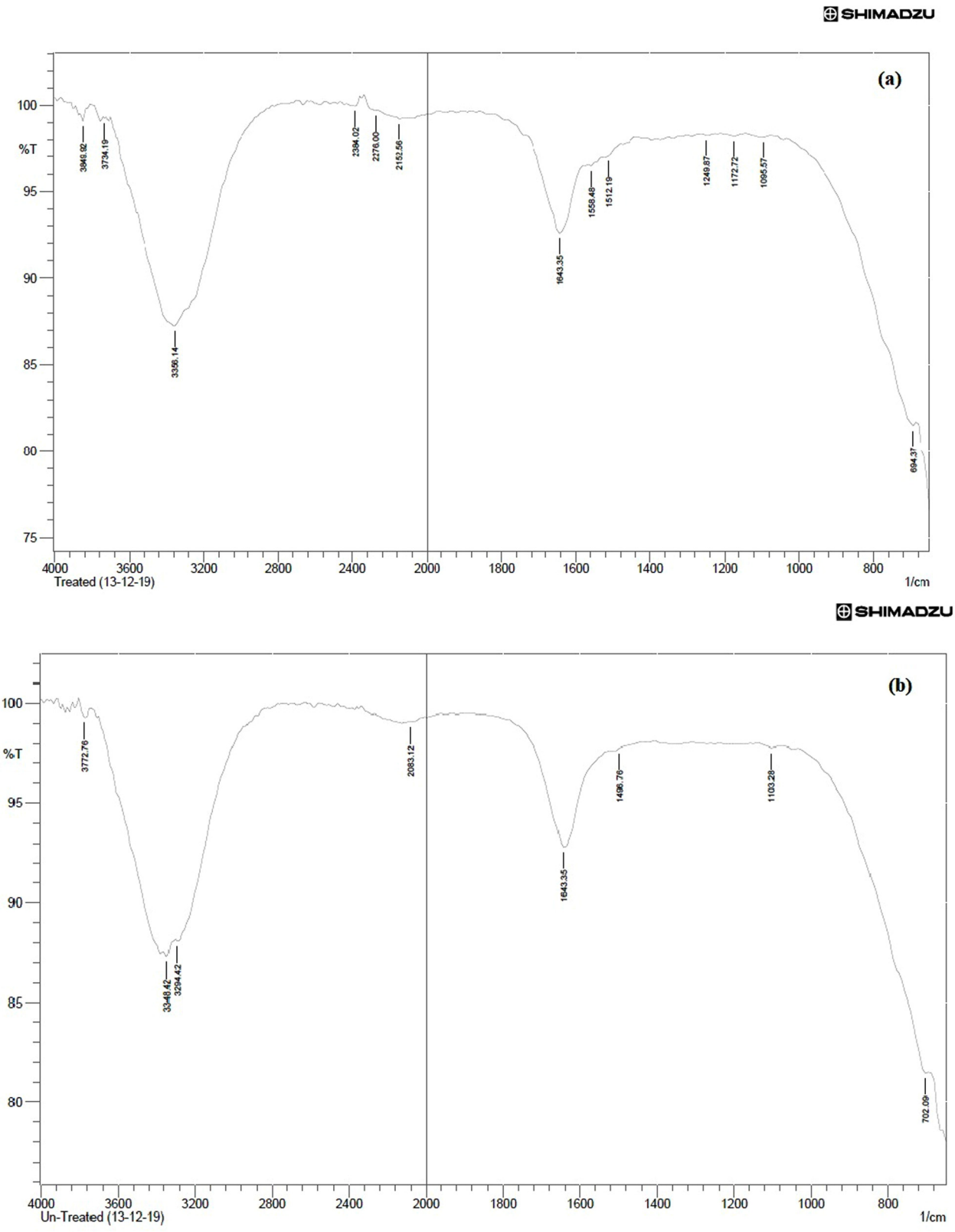

Figure 7: FTIR spectra of the dye particles: (a) before adsorption and (b) after adsorption.

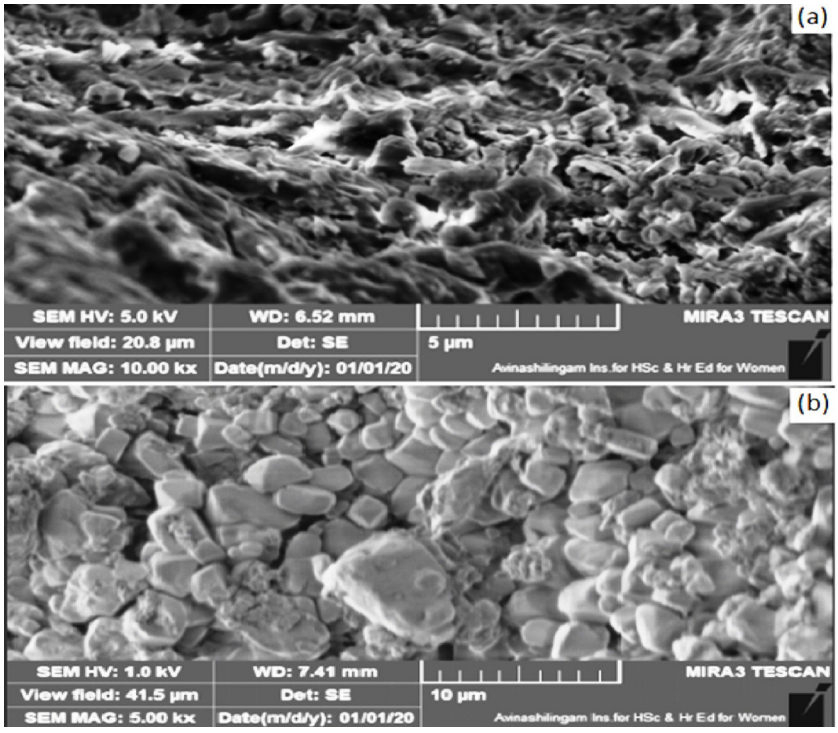

Figure 8: SEM micrograph of the biosorbents: (a) before adsorption and (b) after adsorption.

After adsorption, the absorbances of the dye samples were measured at 3849.92, 3734.19, 3356.14, 2384.02, 2276.00, 2152.56, 1643.35, 1558.48, 1512.19, 1249.87, 1172.72, and 1095.57 cm^{-1}. Many chemical components of the plant may be determined by using FTIR analysis. These findings suggest that the biosorbent surface also included other functional groups (hydroxyl, carboxyl, and amine) in addition to the MG dye.

3.7.2 SEM analysis

The images show the biosorbent's porous and fibrous structure, which has a high degree of variability and may aid in the biosorption of the dyes. Figure 8 depicts an SEM image of a biosorbent both before and after adsorption. The rough and uneven surfaces of the *S. wightii* sample were evident in the micrograph taken before dye adsorption, which may have contributed to the increased available area for dye adsorption. A considerable change in the surface of the adsorbent was observed after the MG dye was adsorbed on *S. wightii*, indicating that the homogeneous, uniform, fibrous structure of the biosorbent contributed to the biosorption of the dye on the surface of *S. wightii*. Additionally, the smoothness of the surface could be noticed. When methylene blue and rhodamine B dye were removed using the brown algae *Fucus vesiculosus*, a similar trend in the results was previously observed [14]. Since they have a regular surface and form, there is a good chance that the dye will become trapped by the adsorbent and be removed from the aqueous solution in a greater percentage.

4 Conclusion

In the present study, the dried biomass of *S. wightii* was studied in a batch method for the adsorptive capacity of the MG dye. The biosorbent dose of 0.1 g/L was determined to have the highest absorption capacity. Comparing the pH for the maximal absorption capacity with other pH values examined in this study, it was found that the pH for this capacity was at a pH value of 7. According to the findings of the most recent studies, using the seaweed *S.wightii* as a replacement for the present costly techniques for removing aqueous solution dye contamination would be the best option. Green gram growth may not be adversely affected by dye treatment with *S.wightii*. As a result, the toxicity level of MG dye treated with *S.wightii* reduces environmental harm.

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