



Biosorption of malachite green using marine macroalgae from aqueous solution

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Abstract

The present study has focused with its investigation on finding potential application of some seaweed (macroalgae) for biosorption of common dyes using batch culture process. The standard dyes were selected based on absorption potential. The result confirmed that, *Sargassum longifolium* did maximum removal of dyes such as green color dye, malachite green color and methyl violet color. *Ulva reticulata* was found removing red color dye, methyl yellow and methyl orange whereas *Gracilaria corticata* also showed maximum absorption for blue color dye, congo red and methyl blue dyes. In the present study, it was found that brown algal biomass showed highest affinity for removal of dye due to its fast binding, high affinity. The findings also indicated that marine algae can be used effectively for removal of toxic dye from the environment like any other biological systems.

Keywords: algal biomass, macroalgae, biosorption, dye

Introduction

The commercial dyes are toxic, mutagenic and of the most important threat to the environmental and mostly to the aquatic living organisms (Omar *et al.*, 2018) ^[13]. As commercial synthetic dyes are usually chemically designed which are also thermally stable, the wastewaters containing dye needs to be disposed accordingly and should be avoided to be discharged directly into water bodies (Kooh *et al.*, 2016) ^[10]. Basic malachite green dye has been widely used for the dyeing process in leather, wool, cotton, silk, jute, paper, detergent, distilleries as fungicide and antiseptic (Sartape *et al.*, 2017) ^[15]. Malachite green is environmentally persistent and acutely toxic to a wide range of aquatic and terrestrial animals (Kannan *et al.*, 2010) ^[7]. It is highly responsible for environmental threat and public hazard. Malachite green is a multiorgan toxin as the there are many evidence available at the level of clinical and experimental studies. It drastically decreases intake of food, growth, and fertility rates. The damage has been reported to the liver, spleen, kidneys, heart; skin, eyes, lungs, and bones (Omar *et al.*, 2018) ^[13]. Despite being debarred in several countries, malachite green is still being used in most part of the world due to a lack of an option. The proper discharge methods need to apply for removal of dye from waste water using various techniques.

There are various existing methods available for removing dye from wastewater. These includes conventional methods like ion exchange, adsorption, coagulation, flocculation, oxidation and electrochemical methods (Dutta *et al.*, 2021) ^[3] etc, which are not often economically feasible or appropriate because of their high costs and often generate other wastes that require further disposal (Dutta *et al.*, 2021) ^[4]. Due to these complications, an alternative method of removal of dyes which is economic and effective is of great importance. The increasing interest of using biological system for efficient removal of dyes from wastewaters is the need of the environment. The method has been highly selective and efficient based on the outcome reported for removal of dye. Macroalgae or seaweeds belong to one of several groups of multicellular algae: red algae, green algae, and brown algae. They are fast growing benthic plants, some species able to grow up to 60 m in length (McHugh, 2003) ^[12]. Due to their changeable intrinsic features, seaweeds are used in a variety of industrial applications, including ecosystem balancing, eutrophication for nutrient management or as a bioremediation (Holdt *et al.*, 2014; Kim *et al.*, 2017) ^[6, 9]. Macroalgae can be used to remove various commercial textile dyes. Hence, macroalgae are nontoxic, low-cost, and easily available biomaterials for the treatment of colored effluents with different degrees of success. In this context, an attempt was made to evaluate the dye adsorbing capacity of three different sea weeds (*Sargassum longifolium*, *Ulva reticulata*, and *Gracilaria corticata*) isolated from different coastal region of Tamil Nadu.

Materials and methods

- a. **Collection of seaweeds:** The macroalgae (seaweeds) were collected from Mandapam coast of Tamil Nadu, India. After being washed twice with deionized (DI) water, were dried at 60 °C over night in an oven. The seaweeds were also identified based on their characteristic features.
- b. **Preparation of dye solution:** In the current study, commercially available malachite green dye (C₅₂H₅₄N₄O₁₂) was obtained from Merck, and were used for the adsorption. The purity of the dye was approximately

90% (Fig. 1). The molecular weight of the dye was 927.02. The stock solution of the dye was prepared dissolving one gram in 1 L of deionized water (1 gL^{-1}). They were further diluted to obtain different dye concentrations (5, 10, 15, 20, 25, 30, and 35 mgL^{-1}).

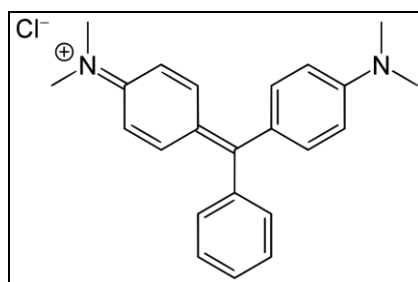


Fig 1: Structure of Malachite Green

- c. Batch procedure for dye removal:** The adsorption experiment was carried out by weighing the constant biomass of different seaweed (0.5 g) in 100 mL of the malachite green solution in 250 mL of conical flask in triplicates. The solution was vigorously shaken in rotary shaker at 200 rpm at room temperature for 24 h at specific pH 7 by measuring the absorbance between 250– 650nm. Likewise, different concentration of dye was also studied. The biomass was discarded using centrifugation process at 7000 rpm for 15 min and the dye concentration was determined in the solution before and after removal of the dye by measuring the absorbance at 650 nm using a UV spectrophotometer (Shimadzu, UV 2500, Japan).

Results

Looking into the adsorption of dyes by seaweed in the current study, it was noticed that the dye adsorbing capacity of the selected seaweeds varies among themselves. This may be mainly due to the presence of active functional groups, such as hydroxyl, carboxyl, carbonyl, amine, and sulfate, which participated in the biosorption process. In all the cases, standard dye solution was compared to the selected seaweeds. *Sargassum longifolium* showed the maximum bioremoval of malachite green dye in comparison to other seaweeds, *Ulva reticulata* and *Gracilaria corticata*. *Ulva reticulata* showed maximum bioremoval compared to *Gracilaria corticata* (Fig. 2).

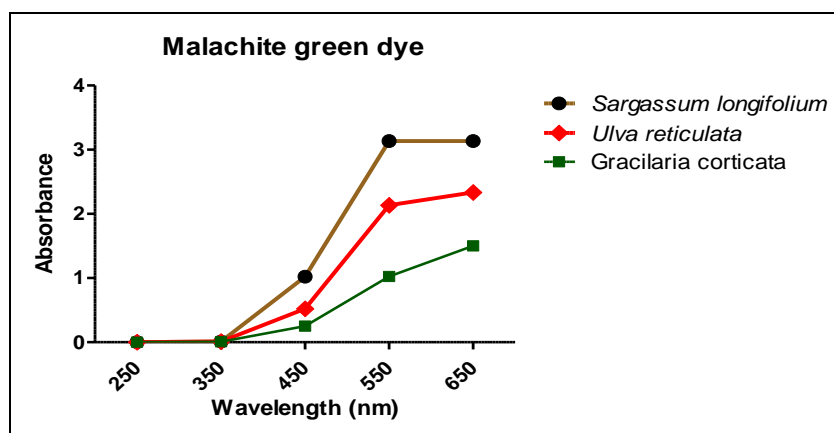


Fig 2: Bioremoval of malachite green dye by *Sargassum longifolium*, *Ulva reticulata* and *Gracilaria corticata*.

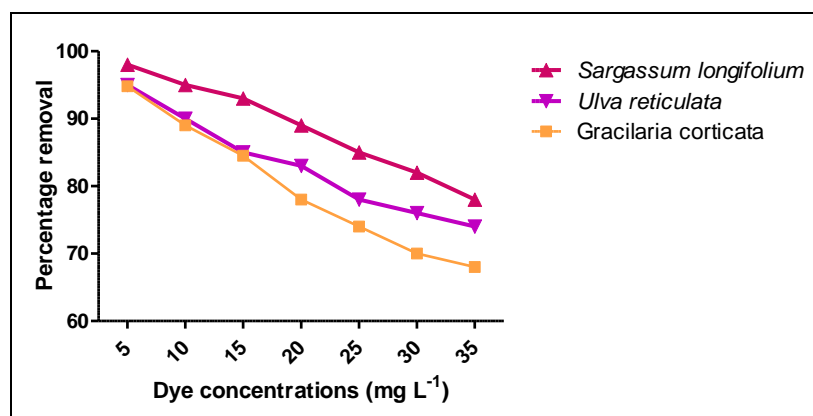


Fig 3: Bioremoval of malachite green dye using marine macroalgae biomass of *Sargassum longifolium*, *Ulva reticulata* and *Gracilaria corticata*.

Studies on reaction kinetic dealing with concentration of dye disclosed that data fitted well with the pseudo-second-order kinetic model, indicating that the chemisorption mechanism took part in removing dyes from wastewater using seaweeds. The effect of different dye concentrations (5–35 mg L⁻¹) on the removal of malachite green dye at the optimum conditions of pH (7.0), and at room temperature is illustrated in Figure 3. The results showed that the removal percentage of dye by algae decreased with increasing dye concentration. The minimum dye removal rates at highest concentration was 78.1%, 74% and 68.0% respectively using *Sargassum longifolium*, *Ulva reticulata* and *Gracilaria corticata*.

Discussion

In the present study, we made an attempt to use some of the easily available seaweeds for biosorption of commonly used dye malachite green at laboratory scale. The findings revealed that, all the marine macroalgae had the adsorbing capacities towards the dye. Macroalgae have been the smart choice for removal of pollutant from water bodies basically because of their potential as suitable biosorbent, fast and easy growth and wide availability. It has been reported that, decolonization effectiveness was highly dependent on its initial dye concentration, amount of algal biomass, pH, reaction time and temperature (Khataee *et al.*, 2010) [8].

The removal percentage of dye using algal biomass decreased with increasing concentration of dye. Mansour and El-Soud (2017) [11] reported from their studies that an increase in the removal of the dye takes place with varying concentration. They also observed that the adsorption was highly dependent on dye initial concentration. This result could be due to the increase in the mass gradient pressure between the algal biomass and the dye solution as also supported by Hameed (2009) [5]. The gradient force that act and separates the dye molecules from the solution on the surface of the biomass. The adsorption capacity reduced with increasing dye concentration could be due to the high concentration of the dye compared to the biomass dosage. The available sites for adsorption decreased sharply with high dye concentrations, and consequent result helped in the removal of dye related to the initial dye concentration.

The dead algae *Chlorella* biomass rapidly removes malachite green in agitated batch experiment as reported by Tsai and Chen (2017) [16]. Brown seaweed *Sargassum hemiphyllum* dead biomass was used for the removal of phenanthrene (PHE) under different parameters (Chung *et al.*, 2007) [1]. In general, biosorption of dyes is pH dependent as reported by previous investigations (Peta *et al.*, 2009) [14]. It has been reported that in case of metals, low pH has shown low adsorption capacity which might be due to the competition of hydrogen ions with metal ions on the sorption sites (Congeevaram *et al.*, 2007) [2].

Conclusion

Thus from the current study it can be concluded that the macroalgae biomass of brown, green and red would have facilitated the removal of malachite green from polluted water bodies. The dye removal was totally dependent on the dye concentration, fixed algal concentration, optimum temperature, and pH. The experimental data obtained were in correlation with the Langmuir and Freundlich adsorption pattern. The macroalgae was observed to have potential as adsorbents for the removal of dye. Because of the promising benefit of the macroalgae could serve for commercial purposes in future. The finding gives a step to treat wastewater from industry as naturally existing raw material has higher efficiency with a low-cost investment.

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Conflicts of Interest

The authors claim no conflicts of interest because none financial support was received from any government, non-government agency or organization to conduct this research work.

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