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Application of *Canna Indica* for Removal of Methylene Blue using Phytoremediation Techniques

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***Abstract*: India's rapid urbanization and industrialization have released industrial effluents comprising dyes and heavy metals into the environment, significantly contaminating the ecosystem and water bodies. The traditional physicochemical methods for dye removal were sometimes costly and inefficient, especially when used at lower concentrations. For removing pollutants from wastewater, phytoremediation has become a popular and affordable solution. The use of *Canna indica* as a biosorbent for the phytoremediation of textile wastewater containing Methylene Blue (MB) dye is studied in this work. After immobilizing *Canna indica* root tubers with calcium chloride and sodium alginate, batch adsorption experiments were conducted to study several variables, including pH, temperature, and contact duration. The results demonstrated that following treatment, important wastewater quality measurements such as total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), and biochemical oxygen demand (BOD) were significantly reduced. With notable improvements in colour, pH, and other pollutant levels, *Canna indica* was used in phytoremediation to reduce the concentration of Methylene Blue from 10 ppm to 1 ppm and to meet regulatory standards set by the Central Pollution Control Board (CPCB). The Phyto-bed's ability to remove dye was also much improved when the dye concentration was lowered to 1156.7 mg/L. As India's industrialization and environmental degradation accelerate, this study emphasizes *Canna indica's* ability as an eco-friendly method of treating wastewater contaminated by dyes, providing a suitable solution to the problems associated with cleaning wastewater from the textile industries.**

***Keywords*: Biosorption, *Canna indica*, Immobilization, Methylene blue, Phytoremediation, Wastewater**

I. INTRODUCTION

India's population growth, urbanization, and industrialization are all accelerating, making people more sensitive to environmental issues (Malika, M. et al., 2023). Plant-based remediation of heavy metal-contaminated soils and rivers has grown in become an affordable, environmentally friendly remedy during the last 20 years Ozonation, chemical precipitation, photocatalysis, membrane separation, and adsorption are some of the conventional techniques used to remove colours from industrial effluents (Bethi, B. et al., 2017). Biosorption is unique among these techniques because it is inexpensive, simple to use, requires little energy, is eco-friendly, and has high dye removal efficiency. This approach is increasingly being used to combat pollution from industrial dyes (Gujar J. et al, 2023; Katole, A. et al., 2016).

Dye removal from industrial wastewater has been accomplished using a variety of adsorbent materials, such as microbes and agricultural waste (Kale, P. et al., 2023, Dronkar, M., & Gujar, J. G. 2018; Mahmoodi, et al., 2011). However, there are disadvantages to traditional techniques such as membrane electrolysis and electrochemical oxidation, including their high expense, inefficiency at low dye concentrations, and inability to satisfy EPA regulations (Sonawane, S. H. et al., 2020). The environmental impact of dye particles <1 ppm on aquatic ecosystems is addressed by phytoremediation, a green and eco-friendly method that uses plants to efficiently remove dyes and heavy metals from wastewater (Wagh, S. et al., 2012; Sonawane, S. S. et al., 2022). Since it increases BOD and decreases DO, dye pollution negatively impacts the aquatic life. (Sonawane S. S. et al., 2009; Malkapuram, S. T. et al., 2021). Since they are extremely persistent to non-biodegradable, and resistant to standard treatment techniques, synthetic dyes such as Methylene Blue (MB) present serious risks to human health and the environment. (Imron et al., 2019; Jadhav, A. et al., 2023). Although Methylene Blue is widely used in paper, textile, and cosmetic industries, it is hazardous as it is toxic and not biodegradable in water streams (Gavali, A. et al., 2024; Malika M and Sonawane S S., 2021). The use of plants like *Canna indica* in phytoremediation offers an environment-friendly approach to the solution of dye removal (Shah, et al., 2024). The immobilized *Canna indica* root tubers, which were made using calcium chloride and sodium alginate, helped as the biosorbent material in this investigation (Khandare et al., 2021; Mzinyane, 2024). In batch adsorption studies, variables such as temperature, pH, contact time, and dye concentration were all adjusted. The equilibrium and nature of the adsorption process were revealed by adsorption isotherms and thermodynamic studies ($\Delta S°$, $\Delta H°$, and $\Delta G°$) (Rafatullah et al., 2010; Verma et al., 2012). This method demonstrates *Canna indica* potential for environmentally friendly wastewater colour removal (Patil, et al., 2022). To remove the Methylene Blue dye from textile wastewater, this study presents a unique method of phytoremediation that uses *Canna indica* as a biosorbent (Cheng et al., 2007). Focusing on a native species makes it possible to use native plants to restore the habitat, which encourages sustainability and reduces the costs to associated with importing alien species. This is one of the research's main features (Bañuelos et al., 1997). The study also uses cutting-edge immobilization methods, such as calcium chloride and sodium alginate, to improve the plant material's stability and biosorption capability, increasing its efficacy in the treatment of wastewater. Additionally, the study provides a thorough evaluation of the effects of many operational factors on dye removal effectiveness, including pH, temperature, and contact duration, offering insightful information for improving phytoremediation procedures (Buthale, R. & Gujar, J. 2018; Patil P, et al., 2022). By evaluating several aspects of water quality.

The technique known as phytoremediation was used to remove harmful materials from soil and water. "Phyto-remediation Technique" refers to the living interactions between bacteria, soil, water, sunlight, and wetland plant roots (Bharathiraja et al., 2018). Phytoremediation, which comes from the words "phyto" (plant) and "remedium" (cure), is the process of using plants to clean up or purify soil, water, or air of contaminants. By converting harmful materials into non-toxic forms, this environmentally beneficial in-situ technique improves fertility, decreases soil erosion, and regenerates ecological equilibrium (Malika, M. & Sonawane S. 2022). Together with bacteria-enhanced plants, aquatic plants like *Canna indica* and Phragmites australis increase pollution clearance by addressing pollutants including metals, hydrocarbons, and industrial waste (Mao et al., 2023; Venkatesh & Arutchelvan, 2020; Kadam, S. et al., 2023). When compared to traditional approaches, constructed wetlands that use plants like Typha are an 80% more affordable secondary and tertiary wastewater treatment option. According to studies, phytoremediation may reduce the levels of TDS, TSS, BOD, and COD by around 15%, 40%, 65%, and 60%, respectively. These systems are a sustainable wastewater management option since they also exceed tertiary treatment standards, improve landscapes, offer bird homes, remove smells, and need little maintenance (Olawale et al., 2021; Roondiwala et al., 2017).

There is growing research on treating textile dyes like Methylene Blue using plants. Research has demonstrated the efficacy of plants, such as *Canna indica*, in phytoremediation, an environmentally friendly method of purifying wastewater that contains dyes. The capacity to eliminate impurities from dye solutions in hydroponic systems has been shown by *Canna indica* and other species, including *Trachyspermum ammi, Tagetes erecta, Hibiscus rosa-sinensis, Chrysanthemum indicum, Bryophyllum fedtschenkoi, and Catharanthus roseus*. The dyes were phytotreated for a maximum of forty hours at Methylene Blue dye concentrations (10 & 20 mg L). Experiments estimating dye removal and plant development at different time intervals were conducted to investigate *Canna indica's* ability to remove Methylene Blue. *Canna indica* at a maximum wavelength of 665 nm, the absorbance values were recorded at 1,2,3,4,5,6,7, and 24 hours based on concentration. The percentage of dye removal and the relative growth rate of *Canna indica* were assessed during Methylene Blue exposure. It may be possible to use *Canna indica* as a phytoremediation agent to eliminate wastewater dyes. Its potential as a phytoremediation agent was demonstrated by the results, which showed a considerable removal of dye in this process.

II. MATERIALS AND METHODS

The plant that is most widely available, *Canna indica*, is the subject of the current study on phytoremediation of textile wastewater. In this work, the plastic tank is used as a photo-bed. Brickbats, aggregates, sand, and soil make up the filter media. Green in colour, *Canna indica* is a medium-sized species plant that grows locally. It is also known in Marathi as "Kardal." The plant has a single-leaf stalk. A *Canna indica* plant can reach a height of 0.5 to 2.5 meters. It can also survive on wastewater; in fact, numerous studies have shown that *Canna indica* is an extremely efficient way to treat waste water (Kore, P.S. et al. 2017).

The initial parameters measured for the wastewater were colour, pH, temperature, total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), and biochemical oxygen demand (BOD). A step-by-step methodology was employed.

1. Waste water was intended to be properly settled and separated using a phytoremediation bed (tank).
2. The chosen plants, such as *Canna indica*, were planted.
3. The flow rate of waste water was consistently 1 lit/hr.
4. The treated water was collected following a 24-hour period of confinement. Phytoremediation can be broadly categorized according to the type of contamination, applicability, and basic processes.

Phytodegradation: Using enzymes released from plant tissue, pollutants are taken up, stored, and broken down during this process.

Phytoextraction: This process involves storing harmful substances in the roots, stems, and leaves of plants.

Rhizodegradation, also known as phytostimulation, breaks down pollutants by utilizing symbiotic soil microorganisms found in the rhizosphere.

Phytovolatilization: This process involves pollutants being taken up from the plant growth matrix and then released into the atmosphere as volatilized pollutants.

Rhizofiltration: This process involves plant roots absorbing pollutants that have been stored in an aqueous growth matrix.

Phytostabilization: By precipitating or absorbing pollutants through their roots, plants immobilize them in the soil. This process reduces the bioavailability of pollutants by preventing controlled migration of pollutants from soil and water erosion.

Experimental Setup

Four pots were filled with red and black dirt, and on the bottom of each pot, and then placed a few small bricks in a methodical pattern on the bottom of each pot. Additionally, PVC pipes measuring 0.30 meters in diameter were fastened to the side of the pots. Additionally, the other end of the pipe was equipped with take-up and cock plants arranged vertically in each pipe, and larger holes, each with a diameter of 0.20 m, have a small rubber packing attached to it. Wastewater was able to enter through the top section of another pot and exit at the bottom of the feed tank, which is positioned at the top and filled with Methylene Blue solution. *Canna indica* was discovered to be one of the plants that could decolourize textile dyes in the initial trials that were carried out in this regard (Yadav et al., 2023). Using running tap water, adherent soil was first removed from the roots of these plants. After that, distilled water was used to thoroughly clean the plants. For hydroponic treatment (without soil), plants were submerged in distilled water, and growth was observed for up to three days. The effluent was treated with Methylene Blue dye solution, a particular dye, at concentrations of 10 and 20 L over three days, and then placed inside a potted plant containing Cannabis indica plants. All plants are kept open to allow atmospheric free oxygen to enter. The upper pot was connected to a container whose inlet was used to add synthetic solution. The plants were moved to prepare dye solutions with varying concentrations after they became adapted to their surroundings. Additionally, both abiotic controls remained in place. The inanimate plants in the dye solution were removed, but the plants in the water were retained for biotic regulation. Up to seven hours of decolorization were observed (1, 2, 3, 4, 5, 6). The absorbance of each solution was measured at its absorption maxima (λmax (MB) – 665 nm) using UV-visible spectroscopy. The formula will be applied to calculate the decolourization percentage. The dye concentration will be increased from the starting point of 10 ppm to 10, 20, 30, or 40 ppm.

Fig. 1(a) shows the *Canna indica* plant that is frequently utilized in phytoremediation research because of its capacity to absorb toxins while improving the surrounding environment. Fig. 1 (b) shows a photograph of the experimental setup for phytoremediation with *Canna indica* plants in each of the indicated pots (Pots 1 through 4). To collect the treated water from the pots, a collecting chamber is positioned at the foot of the stairway that holds these pots. This experiment shows an innovative attempt to look into the efficacy of using plants in a controlled environment to remove the dye.

Fig. 1. Treatment of *Canna indica* plant, (a) Photograph of *Canna indica* Plant (b) Removal of Methylene Blue dye by *Canna indica*

Analysis

The absorption spectrum of the MB shows absorbance in the range of 640-680 nm with an absorbance peak at 665 nm. The standard MB aqueous solution covering the range 1-40 mg L^{-1} was made by adding distilled water. The UV spectrophotometer (UV-1800) was used to determine the concentration of MB in the current work.

TABLE 1
Characteristics of Methylene Blue

Parameters	Properties
Molecular formula	$C_{16}H_{18}N_3SCl$
Molecular weight	319.85
Colour index number	52015
Density	1.0
Melting Point	190

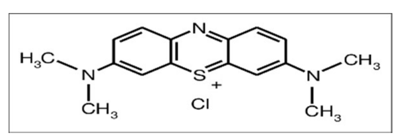

Fig. 2. Chemical Structure of Methylene Blue

Removal of Methylene Blue dye

Methylene Blue dyes are one of the most extensively used dyes in the textile industry and are produced in huge quantities every year (Gürses, et al., 2006; Khan, et al., 2022). One can be found in Methylene Blue dyes, the majority of which are intractable. There are three main ways in which Methylene Blue dyes cause cancer. The first mechanism involves the covalent binding of DNA in the metabolically oxidized state via the release of aromatic amines resulting from the cleavage of the Methylene blue bond. Free aromatic amine groups, which are commonly present in Methylene Blue dyes with structures, are the second mechanism. The most effective method is to activate

Methylene dyes by directly oxidizing the dye bond with electrophilic diazonium salts (Niveditha et al., 2019). This produces an oxidized form that is metabolically produced without requiring dye reduction (Karungamye, 2022). Biological treatment techniques are less successful because microorganisms were unable to degrade Methylene Blue dye. Because of this, azo-dye decolourization has become a major area of study for researchers. Wastewater containing Methylene Blue dye, toxicity, and salinity all prevent microorganisms from growing and activating metabolically. Treatment for dye removal includes phytoremediation, which is based on plants' ability to cause biodecolorization.

III. Results and Discussion

Effect of Various Parameters

In the current work, the effect of various parameters for the removal of Methylene Blue was studied.

Effect of Various Parameters at 10ppm Concentration

At the initial stage, 5 L of Methylene Blue solution are added to the feed chamber to begin the process. After 2 hours, the process is finished, and 5 L of clear, colourless water were removed from the collection chamber; the remaining water was absorbed by the soil and the *Canna indica* plant.

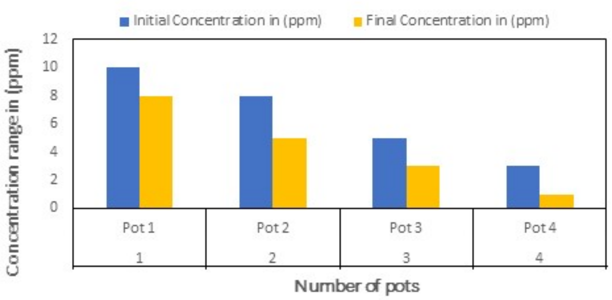

Fig. 3. Effect of concentration on removal of Methylene blue

Fig. 3 shows the decrease in pollutant concentration across four pots, which represents the efficacy of phytoremediation. The starting concentration of the pollutant varied from 10 ppm in Pot 1 to 3 ppm in Pot 4. The final values dropped to 8 ppm, 5 ppm, 3 ppm, and 1 ppm, respectively, following treatment. This demonstrates the steady decline in pollutants, indicating the effectiveness of the remediation procedure under various concentration conditions.

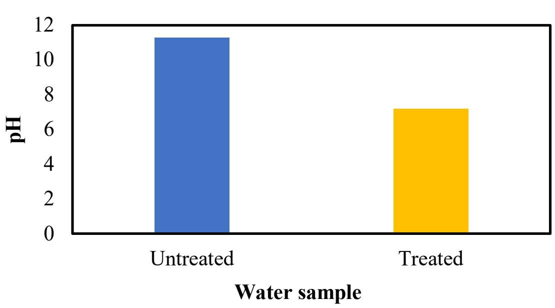

Fig. 4. Effect of pH on adsorption of Methylene Blue

Fig. 4 shows the initial pH of Methylene Blue solution is up to 11.28 and after treatment it decreases when passes through *Canna indica* bed it is decreased up to 7.2. Such a high pH is often undesirable for a variety of environmental and biological systems since it can have negative consequences such as reduced nutrient solubility, harm to aquatic habitats, and material corrosion. However, after passing the fluid through a *Canna indica* bed, a substantial pH drop was seen. This treatment reduced the pH of the fluid to a more neutral or slightly alkaline level.

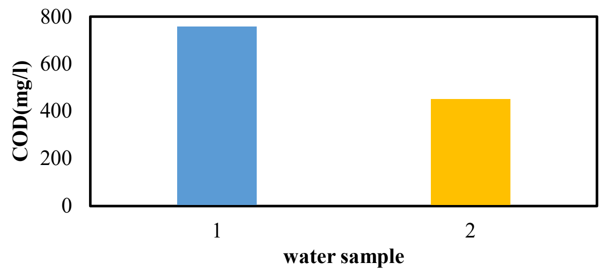

Fig. 5. Effect of COD on the adsorption of Methylene Blue

Fig. 5 shows the Methylene Blue solution had an initial COD of 756.7 mg/L, which indicates significant pollution levels typical of untreated wastewater. After treatment with a *Canna indica* bed, the COD level dropped to 451.3 mg/L, representing a 40% reduction. This demonstrates the efficiency of the *Canna indica* bed as a natural and sustainable remediation solution for organic and inorganic contaminants.

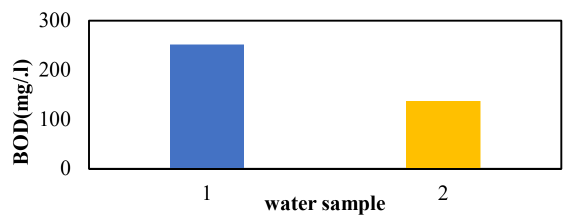

Fig. 6. Effect of BOD on the adsorption of Methylene Blue

According to the experiment, the feed tank's initial BOD for the Methylene Blue solution was 251.25 mg/L, suggesting a significant level of organic contamination. Treatment with a *Canna indica* bed decreased the BOD to 136.4 mg/L. By encouraging biological and microbiological processes, *Canna indica* effectively eliminates organic materials, as evidenced by this noteworthy decline. To ensure safe disposal or reuse, the BOD must be further reduced to satisfy CPCB standards, which are normally below 30 mg/L for treated effluents. By reducing oxygen decrease in water bodies, this mechanism aids in the protection of aquatic ecosystems.

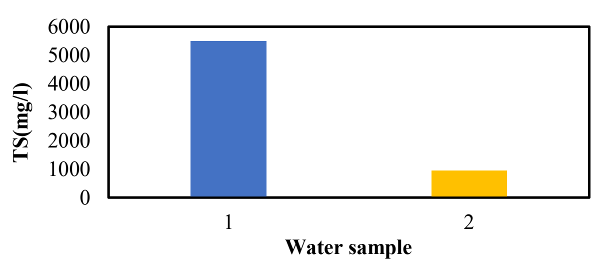

Fig. 7. Effect of TS on the adsorption of Methylene Blue

Fig. 7 shows the total solids (TS) levels of the Methylene Blue solution before and after it was run through a bed of *Canna indica*. The initial TS of 5500 mg/L indicated significant suspended and dissolved solids pollution. Following treatment, the TS intensely dropped to 950.01 mg/L, indicating that the *Canna indica* bed is efficient in eliminating contaminants through adsorption, sedimentation, and biological activity.

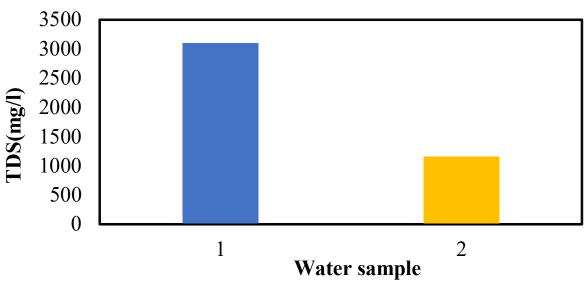

Fig. 8. Effect of TDS on the adsorption of Methylene Blue

Fig. 8 shows the total dissolved solids (TDS) levels in the Methylene Blue solution before and after treatment using a Canna indica bed. Initially, a significant quantity of dissolved contaminants was indicated by the TDS measurement of 3105.8 mg/L. The TDS dramatically decreased to 1156.7 mg/L following treatment, demonstrating the Canna indica bed's efficiency in eliminating dissolved solids by adsorption and biological absorption. To achieve CPCB standards and safe water quality for disposal or reuse, more reduction is required.

IV. Conclusion

Industrial effluents comprising dyes and heavy metals have been released as a result of India's fast urbanization and industrialization, seriously contaminating the ecosystem, especially in water bodies. Because conventional physicochemical dye removal techniques are frequently expensive and ineffective, particularly at lower concentrations, new alternatives have been investigated.

This study shows the substantial reduction in pH, COD, BOD, TS, and TDS of synthetic Methylene Blue dye solution by phytoremediation techniques using *Canna indica*. Plants' root systems typically absorb pollutants from the environment and protect it from their toxicity. The *Canna indica* is a cost-effective and environmentally friendly way to combat the pollution that textile effluents generate, and its use is consistent with sustainable environmental standards. Future studies might concentrate on assessing long-term performance in the field, improving the phytoremediation process, and investigating *Canna indica's* potential for remediating additional contaminants.

It can considerably reduce the dye concentration while also assisting in environmental restoration. In addition to addressing the crucial problem of industrial dye pollution, this innovative method highlights the applications of native plant species for ecological balance and economical wastewater treatment.

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