Green Coconut Shell Biosorbent for Dye Removal: Preparation to Applications

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Abstract:

Dyes are widely used in various industries, including textile, leather, and paper, and their effluent discharge poses a significant environmental threat. Biosorption is a promising technology for dye removal, and green coconut shell biosorbent has been proven to be an effective and sustainable option. We attempt to provide a review of the preparation, characterization, and applications of green coconut shell biosorbent for dye removal.

Introduction

Dye removal from wastewater has been significant environmental issue; traditionally methods such as coagulation, sedimentation, and biological treatment have been employed with limited effectiveness. Biosorption is a sustainable and cost-effective alternative for the removal of dyes from wastewater (Singh and Srivastava, 2022). Biosorbents help to biosorb dyes from waste water by an environment sustainable procedure (Saravanan *et al*, 2021). Biosorbent developed from green coconut shell have been identified as promising materials due to high adsorption capacity and low cost. Green coconut shells are mostly discarded as waste from food and oil processing industries. This adds to the problem of waste management. However, it has been found that green coconut shells can be processed to prepare low cost and efficient biosorbents. This helps to manage water pollution as well as converts waste to environment sustainable materials.

Green coconut shells

Green coconut shells are the hard, outer layer of coconuts that are harvested from coconut palms. They are typically removed and discarded as waste after the coconut meat and water have been extracted. Their high lignocellulosic content and porous structure makes them priority probables to prepare biosorbents (Abdelwahab *et al*, 2015). Their abundance in tropical country like India makes them a readily available and sustainable source of biosorbent material. They are also biodegradable and do not pose a threat to the environment, making them a more environmentally friendly alternative to synthetic adsorbents. The biosorbents developed in recent years have been found to be effective in removing various dyes from wastewater, including synthetic dyes such as methylene blue, crystal violet, and malachite green (Saravanan *et al*, 2021). The good adsorption capacity of green coconut shell is also promising for the treatment of industrial wastewater containing heavy metals such as lead, cadmium, nickel and chromium (Venkatachalam *et al*, 2019; Karthikeyan & Rajgopal, 2016). Overall, green coconut shell biosorbent has the potential to be a cost-effective and environmentally friendly alternative to synthetic adsorbents for various applications in the field of environmental remediation.

Preparation of Green Coconut Shell Biosorbent

The physical and chemical treatments are used to prepare green coconut shell biosorbent. The methods are mostly simple and cost effective (Madadgar *et al*. 2021; Munim *et al*, 2018; Adewuyi & Pereira, 2016). The green coconut shells are collected from local coconut farms or processing units. The preparation involves the following steps:

1. **Collection and cleaning**: Green coconut shells are collected and washed to remove any dirt or debris.
2. **Drying**: The cleaned green coconut shells are then dried to remove any moisture. This can be done using an oven, a sun-drying method, or any other suitable method.
3. **Grinding**: The dried green coconut shells are ground into small pieces or powder using a grinder or a mortar and pestle.
4. **Chemical treatment**: The ground green coconut shell particles are chemically treated with hydrochloric acid or sodium hydroxide, to remove any impurities and enhance the porosity of the material.

5. **Washing and drying**: The treated green coconut shell particles are washed with distilled water to remove any residual chemicals and then dried again.
6. **Activation**: The ground green coconut shells are activated by heating or treating them with an activating agent such as phosphoric acid, potassium hydroxide, or zinc chloride. This increases the surface area and porosity of the biosorbent, making it more effective for dye removal.
7. **Washing and drying**: The activated green coconut shell biosorbent is then washed thoroughly with water to remove any impurities and dried again.
8. The prepared biosorbent is packaged in airtight containers for storage until it is ready to be used for various applications.

Characterization of Green Coconut Shell Biosorbent:

The biosorbents should ideally have high adsorbent capacity and be inexpensive. The efficiency of green coconut biosorbent to remove dye is evaluated by various methods. The characters evaluated include physical and chemical properties like surface area, pore size, functional groups and morphology. These properties influence the adsorption capacity of the coconut shell biosorbent (Wong & Wu, 2017).

Brunauer-Emmett-Teller (BET) analysis gives a fair idea of the surface area available for dye adsorption. It measures the adsorption of gas molecules onto the surface of the biosorbent (Madadgar *et al*, 2021). Higher the surface area, higher is the adsorption efficiency of the biosorbent. The pore size distribution enables better dye adsorption deep inside the biosorbent (Senthil *et al*, 2011). Mercury intrusion porosimetry or nitrogen adsorption-desorption isotherms determine the pore size distribution in the biosorbent (Kalavathy *et al*, 2005). The adsorption capacity of biosorbent depends on the functional groups available on adsorption sites of the biosorbent (Nandi *et al*, 2007). The presence of hydroxyl, carboxyl or amino groups enhances the efficiency of biosorbent. Fourier transform infrared (FTIR) spectroscopy detects the available functional groups.

Morphological characterization of the biosorbent can be performed using techniques such as scanning electron microscopy (SEM) or transmission electron microscopy (TEM) to visualize the surface topography and structure of the biosorbent. This can provide information on the particle size, shape, and distribution, which can affect the adsorption capacity of the biosorbent (Saravanan *et al*, 2021; Harikrishnan & Anjali, 2018). Table 1 provides an overview of characteristics evaluated and the methods employed. The evaluation of characteristics of green coconut shell biosorbent helps to understand the physical, chemical properties and their effect on dye adsorption capacity (Ighalo & Adeniyi, 2020). The characterization helps to optimize the biosorption process and provides insight to develop more efficient and effective biosorbents for the treatment of dye-containing wastewater.

Table 1: Biosorbent characteristics and their methods of analysis

Characteristic	Definition	Method of Analysis	References
Surface area	Total area of the solid surface per unit mass or volume	BET analysis or gas adsorption isotherms	Madadgar *et al*, 2021; Ighalo & Adeniyi, 2020
Porosity	Fraction of the solid that is empty space or pores	Mercury porosimetry or nitrogen sorption	Rocha *et al*, 2019; Baseri *et al*, 2012
Particle size distribution	Range of particle sizes in the biosorbent	Sieve analysis or laser diffraction	Adewuyi & Pereira, 2016

Functional groups	Chemical groups on the biosorbent surface that are involved in adsorption	Fourier Transform Infrared Spectroscopy infrared spectroscopy (FTIR) or photoelectron spectroscopy (XPS)	Ighalo & Adeniyi, 2020; Adewuyi & Pereira, 2016
Zeta potential	Electric potential at the slipping plane near the surface of the biosorbent	Electrophoretic m obility measurements	Adewuyi & Pereira, 2016
Crystallinity	Degree of structural order in biosorbent	X-ray diffraction or Raman spectroscopy	Ighalo & Adeniyi, 2020; Munim *et al*, 2018 Adewuyi & Pereira, 2016
Biodegradability	Ability of the biosorbent to be broken down by biological processes	Incubation with microorganisms or analysis of degradation products	Moustafa, 2021; Taylor *et al*, 2021
Density	Mass per unit volume of the biosorbent	Gravimetric analysis or helium pycnometry	Adewuyi & Pereira, 2016
Moisture content	Amount of water present in biosorbent	Oven-drying or Karl Fischer titration	Mellin *et al*, 2019; Gao *et al*, 2013; Baseri *et al*, 2012
Ash content	Amount of inorganic material remaining after combustion of the biosorbent	Furnace or muffle furnace	Gao *et al*, 2013; Baseri *et al*, 2012
Carbon content	Amount of carbon present in biosorbent	Elemental analysis thermogravimetric analysis	Adewuyi & Pereira, 2016; Munim *et al*, 2018
Surface morphology	Surface features of the biosorbent	Scanning electron microscopy (SEM) or atomic force microscopy (AFM)	Ighalo & Adeniyi, 2020
pH point of zero charge	pH at which the biosorbent surface has no net charge	pH titration or potentiometric titration	Munim *et al*, 2018

The functional optimization evaluates the effect of pH, temperature, initial dye concentration, dye-biosorbent interactions, ions or compounds in the solution, the contact time between the biosorbent and the solution, and the size and shape of the biosorbent particles (Almohammadi & Mirzaei, 2016). The pH and temperature affect surface chemistry and the ability of biosorbent to bind the dye. The electrostatic interactions between the biosorbent and the dye molecules are affected by pH. Some biosorbents exhibit higher adsorption capacity at lower pH values, where the surface is positively charged, while others may have a higher adsorption capacity at higher pH values, where the surface is negatively charged.

Temperature is another important factor that can affect the adsorption capacity of a biosorbent (Saravanan *et al*, 2021). Generally, increasing the temperature of the solution can increase the rate of adsorption due to increased molecular motion and more collisions between the biosorbent and the dye molecules. However, at very high temperatures, the biosorbent can become denatured or degraded, reducing its adsorption capacity (Wong & Wu, 2018).

The initial dye concentration in the solution can also affect the adsorption capacity of the biosorbent (Singh and Srivastava, 2022; Saravanan *et al*, 2021). As the concentration the electrostatic interactions between the biosorbent and the dye molecules on of dye molecules increases, the number of available adsorption sites on the biosorbent becomes limited. Therefore, at higher dye concentrations, the adsorption capacity of the biosorbent may decrease.

Applications of Green Coconut Shell Biosorbent

Green coconut shell biosorbent has been successfully used for the removal of various dyes, including reactive, acid, and basic dyes, from wastewater. Table 2 provides a brief summary of the different applications of green coconut shell biosorbent for dye removal. This biosorbent can be used in batch and continuous modes away from affected site.

Table 2: Applications of Green Coconut Shell Biosorbent*

Applications	Dye	Adsorption Capacity	Reference
Textile dyeing	Acid Blue 113	16.3 mg/g	Yadav & Saini, 2013
Industrial effluent treatment	Reactive Red 120	27.8 mg/g	Abdelwahab *et al*, 2015
Food processing wastewater treatment	Brilliant Blue R	28.4 mg/g	Suresh *et al*, 2013
Dye wastewater treatment	Acid Blue 25	33.6mg/g	Moghaddam *et al*, 2016
Pharmaceuticals wastewater treatment	Basic Blue 3	41.5 mg/g	Suresh *et al*, 2014
Paper mill effluent treatment	Acid Blue 15	57.2 mg/g	Chockalingam *et al*, 2013a,b

*Adsorption capacity may vary depending on the experimental conditions and the properties of the biosorbent and the dye.

Regeneration and reuse

Green coconut shell biosorbent is an eco-friendly, sustainable material that can be used for the removal of dyes from waste water. They are preferred for their regenerative ability and can be recycled for multiple usages. Regeneration of the biosorbent involves desorbing the adsorbed dye molecules from the surface of the biosorbent. This can be done by chemical elution, thermal treatment, and biological regeneration (Moustafa, 2021; Taylor *et al*, 2021). Chemical elution involves using a desorbing agent, such as acid or base, to release the adsorbed dye molecules from the biosorbent. Thermal treatment involves heating the biosorbent to a high temperature to release the adsorbed dye molecules. Biological regeneration involves using microorganisms to break down and degrade the adsorbed dye molecules.

However, the process of regeneration decreases the ability of biosorbent to adsorb dyes. This is due to physical and chemical changes occurring on biosorbent surface. The regeneration and reuse are key areas of research and optimization processes are underway.

Conclusion

Green coconut shell recycling as biosorbent helps to mitigate a potential environmental pollutant. Additionally, it has been found to reclaim dye polluted waste waters efficiently and cost effectively. This chapter has provided an overview of the preparation, characterization, and applications of green coconut shell biosorbent. It offers a potential solution for reducing the environmental impact of industrial dyeing processes and for protecting water resources.

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