



A Green approach for Removal of Dyes using Biodegradable Waste

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ABSTRACT

One of the most affected sources of pollution is water. The textile dyeing process is one of the many factors that lead to water pollution. Some of the compounds like dyes and other chemicals if left untreated poses significant environmental pollution and health risk. Amongst the various existing methods adsorption technique is highly effective for removing such substances. In this study we have investigated, using of rice husk and corn husk as an eco-friendly and sustainable bioadsorbents for removal of dyes. Rice husk due its porous structure and active functional group, and corn husk rich in cellulose shows promising adsorption potential.

In our study, we assessed dye removal by measuring changes in absorbance noting a significant decrease as dyes were adsorbed. Further we analyzed the combined effect of rice husk and corn husk which enhanced adsorption with a declined in optical density confirming their binding. The optimal bioadsorbent blend offers a sustainable solution for treatment of textile water. This optimal bioadsorbents were further used in sample obtained from textile industry. Parameters like COD and chromatographic technique validates the findings highlighting the broader application of agricultural based waste in dye removal and offers viable alternative for wastewater treatment.

Keywords: Bioadsorbents, wastewater treatment, removal of dyes, adsorption.



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INTRODUCTION

Water is a limited natural resource and preserving its purity is a growing global problem. It is crucial for achieving the UN sustainable Developmental Goals, notably goal 14: Life underwater, that this effluent is treated before being discharged into natural resources. Water is one of the essential components and that is heavily polluted. Large amounts of wastewater are generated daily from the textile, cosmetics, paper, rubber, leather, and printing industries (Shamsollahi. Z., & Partovinia. A, 2019). It has been reported that textile industry utilizes large amounts of water during the process of textile processing (Prasad S.S, Aikat K 2014). The chemical manufacturing industry is also a significant source of wastewater pollution

Various constituents are found in textile wastewater such as acids and alkalis, dyes, print pigments, hydrogen peroxide, starch, surfactants, dispersing agents and soap of metals (Sihotang, 2021). The percentage of toxic and hazardous dyes present in the wastewater system ranges from 5 to 10% (Prasad and Aikat, 2014). Some of these components are toxic and thereby difficult to treat which can hence pollute the environment and cause harm to human life. As most dyes are aromatic in nature their structure makes it hard for their degradation (Akbari, et al, 2002). These dyes, when discharged into water bodies, can cause irreversible damage to ecosystems. The presence of these chemicals in wastewater is concerning, as many of them are carcinogenic or toxic, leading to long-term contamination of aquatic ecosystems.

The textile industry needs environmentally friendly and sustainable purification technology is needed. Given limited natural resources and increased sustainability awareness, finding effective and economical alternatives has become crucial. To date many efforts are made to remove organic dye/pollutants. Physical methods like adsorption, coagulation, flocculation and chemical methods like ozonation, photocatalysis are used (Bal & Thakur, 2022).

Adsorption is the adhering of substances from gases or liquids onto the interface of two phases, mainly onto solids. In water and used water purification, adsorption is applied for the removal of dissolved impurities (Pillai, 2020). Recently, agricultural and food wastes have also been widely used as biosorbent for biosorption (Royer, et al, 2009) This technique is generally a fast process and uses relatively inexpensive materials such as cellulose based agricultural waste from agriculture which is abundant in nature, low cost, highly biodegradable, environmentally friendly and high stability for most organic solvents.

The cellulose-based rice agricultural waste rice husk has been shown to enhance the degradation of synthetic dyes. The newly born rice husk has also been proven to be effective in removal of cationic dyes such as methylene blue from textile effluent. (unmodified rice husk) (Moeinian and Mehdinia, 2019). Rice husk has granular structure, chemical stability. Corn husk that can be used as adsorbent since it has a fairly high cellulose content of 36.81% (Bawa et al, 2023). The OH

group contained in the cellulose and hemicellulose on corn husk can bind to the adsorbate as vinyl sulfone groups from reactive dyes so that the adsorbent can absorb the adsorbate in the form of dyes (Bawa, et al 2023).

The color methylene blue with the chemical formula ($C_{16}H_{18}N_3S$) is a heterocyclic aromatic compound. Moreover, it is one of the most widely used cationic colors in the textile industry. The color methyl orange is a synthetic, water soluble, azo dye with the chemical formula ($C_{14}H_{14}N_3NaO_3S$). It is used in fiber, textile, paint, and cosmetic industries. It is used in textile industries to color fabrics. Methyl orange when released into the environment can have significant negative effects including toxicity to aquatic life, disruption of photosynthesis due to reduced light penetration etc.

The purpose of this study was to determine the optimum condition of the adsorbent for the combination of rice husk and corn husk including contact time, pH of the solution and weight of adsorbent as well as to determine the ability of the adsorbent to adsorb methylene blue and methyl orange dyes. Therefore, this study investigates the capability of rice husk, corn husk and combined effect of rice husk and corn husk for the removal of textile dyes.

MATERIAL AND METHODS

The materials used in this project was Rice husk, Corn husk, Methylene blue dye powder, Methyl orange dye powder, Textile wastewater, NaOH, HCL, Distilled water. Rice husk and corn husk were obtained from local vendor and then used further. Instruments used were Analytical balance, Ph mete80 mesh sieves, Colorimeter, Filter paper, an oven, Set of glass wares.

Methods

Production of Rice Husk as Bioadsorbent:

Rice husk was procured from a local vendor for use in the bioadsorbent production process. The rice husk was initially subjected to a thorough washing process to remove any impurities or residual particles. Following this, the rice husk was placed in an oven set at a constant temperature of 60°C for a drying duration of 24 hours. The drying process was carefully monitored to ensure that all moisture was completely removed from the husk, ensuring its suitability for

further processing. After the drying period, the rice husk was sieved to achieve uniformity in particle size, ensuring consistent quality and effectiveness for use as a bioadsorbent material.

Production of Corn Husk as Bioadsorbent:

Corn husk was sourced as a waste material from a local corn seller, ensuring its availability for use in bioadsorbent production. The corn husks were first thoroughly washed and cleaned to remove any dirt, dust, or unwanted particles. After cleaning, the husks were cut into smaller, more manageable pieces to facilitate the drying and sieving processes. These smaller pieces of corn husk were then placed in an oven set at a temperature of 60°C for a period of 24 hours, allowing the husks to dry completely.

Activation of Corn Husk:

To enhance the efficiency and increase the adsorption capacity of the corn husk, an activation process was employed using a 0.5 N sodium hydroxide (NaOH) solution. The corn husk, after being thoroughly cleaned and dried, was immersed in the 0.5 N NaOH solution. The husks were left in the solution for a period of one hour to allow for effective activation. The washing continued until a neutral pH was achieved, indicating that no alkaline solution remained on the husk and then dried.

Preparation of Standard Stock Solutions of Methylene Blue and Methyl Orange:

- **Methylene Blue**

To prepare the standard stock solution of methylene blue, precisely 0.1 grams of the pure methylene blue powder was carefully weighed. 1000ml of Distilled water was measured, thereby preparing 0.1M Methylene Blue stock solution. This was further used as untreated stock solution

- **Methyl Orange**

For the preparation of the standard stock solution of methyl orange, 0.5 grams of the pure methyl orange dye was accurately weighed. The methyl orange powder was then added to another 1000 mL volumetric flask. This resulted in 0.5M of stock solution of Methyl Orange.

Determination of Optimum Adsorbent Conditions:

To determine the optimum conditions for adsorption using both rice husk and corn husk, three different weights of the adsorbent were selected for each material: 0.5g, 0.75g, and 1g. These varying amounts. Each individual adsorbent, either rice husk or corn

husk, was placed into separate bottles, with each bottle containing 30 mL of methyl orange dye solution at a concentration of 500 mg/L. After the adsorption process, the optical density of the solution was measured using a colorimeter set at a wavelength of 505 nm, which is the specific absorption peak for methyl orange and a similar process was carried out for Methylene Blue at a maximum wavelength of 495nm. The optical density readings were used to assess the efficiency of adsorption for each weight of the adsorbent.

Optimum Weight:

To determine the optimum weight of the adsorbent, three different weights of the adsorbent materials were selected: 0.5g, 0.75g, and 1g. These varying weights were chosen to assess how the quantity of the adsorbent impacts the dye adsorption process. The selected amounts of adsorbent were each placed in contact with a dye solution for a specific, variable period to allow for sufficient interaction between the adsorbent and the dye molecules. After the designated contact time, the solution was carefully filtered using filter paper to separate the adsorbent from the dye solution. By analyzing the adsorption capacity for each weight variation, the optimum weight of the adsorbent could be identified, providing valuable insight into the most efficient amount of material required for effective dye removal.

Determination of Optimum Contact Time:

Once the optimum weight of the adsorbent had been identified, the next step was to determine the optimum contact time for the adsorption process. The experiments were conducted with varying contact times to assess how the duration of interaction between the adsorbent and the dye solution affects the adsorption efficiency. The contact times tested were 24 hours, 48 hours, 72 hours, and 96 hours. During each trial, the mixture containing the bioadsorbent was allowed to interact with the dye solution for the designated time. After the respective contact periods had passed, the mixtures were filtered to separate the adsorbent from the solution. Through this process, the ideal contact time could be selected, ensuring that the adsorbent achieved the highest possible adsorption capacity.

Determination of Optimum pH

To determine the optimum pH for the bioadsorbents under the previously identified optimum conditions,

experiments were conducted using 30 mL of the respective dye solutions. The pH of each dye solution was adjusted to various levels, specifically pH values of 4, 5, 7, and 11, to assess how the pH of the solution influences the adsorption process. These absorbance readings were then used to calculate the concentration of the dye absorbed by the bioadsorbent at each pH level. By comparing the concentration of the absorbed dye at each pH value, the adsorption capacity of the bioadsorbent could be determined for each variation in pH.

Determination of Optimum Composition Ratio:

After determining the optimum contact time, pH, and weight of the adsorbent, the next step was to identify the optimum composition ratio of the two bioadsorbent materials: corn husk and rice husk. To explore the best combination, different ratios of corn husk to rice husk were tested. The ratios used for the mixture were 1:1, 1:2, and 2:1, with each mixture containing a total of 0.75g of the combined adsorbent. These different ratios were chosen to evaluate how the proportion of each material in the blend affects the overall adsorption capacity. The recorded absorbance values were used to calculate the concentration of the dye that had been absorbed by the bioadsorbent, and from this, the adsorption capacity for each composition ratio could be determined. The adsorption capacity (Q_e) was calculated using the following formula:

$$Q_e = (C_0 - C_e) V / m$$

Where,

Q_e = Adsorption capacity

C_0 = Initial concentration of solution (mg/l) C_e = Final concentration of solution (mg/l) V = Volume of solution taken (ml)

M = Mass of adsorbent used.

Application in textile wastewater:

The textile industry is known to leave 20% of the dye in the wastewater and will be discharged into the environment as waste. In textile industry the synthetic dyes that are often used are reactive of the vinyl sulphone group. The dye powder containing 1-amino pHenyl-4-beta hydroxy ethyl sulphone sulfate ester with the chemical formula ($C_8H_{11}NO_6S_2$).

and molecular weight 281. was obtained from Maruti Syntex Textile factory in Botad area, Gujrat. The dye

solution containing 1-amino pHenyl-4-beta hydroxy ethyl sulphone sulfate was prepared in the laboratory by dissolving 0.5g of dye powder in 100ml of distilled water. Then the waste was adsorbed using a combined adsorbent in optimum mass ratio of 1:1, 1:2 and 2:1 and the adsorption process was carried out to adsorb 30ml of the prepared dye solution at optimum contact time of 2 days.

In the final step the mixture was filtered and the absorbance of the adsorption filtrate was measured using a UV-vis spectrophotometer at the maximum wavelength of the dye which was 254nm. The absorbance value obtained was then used to determine the absorbed dye's concentration to determine the adsorbents adsorption capacity.

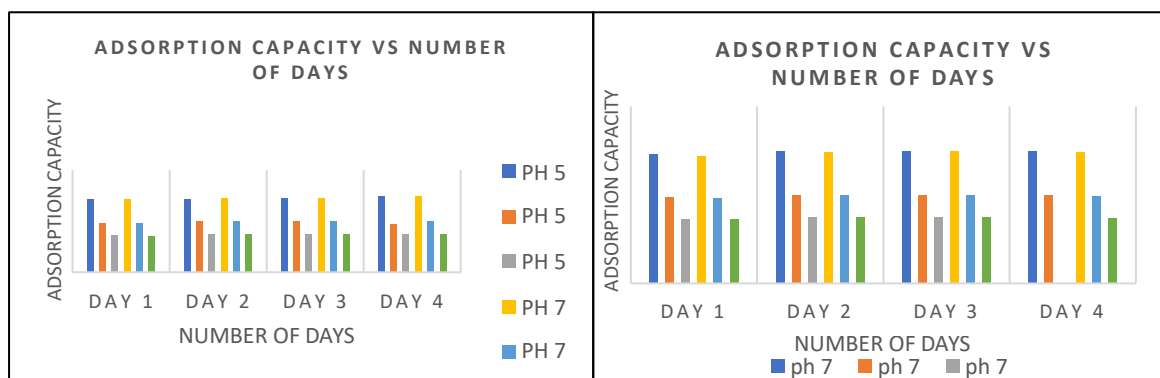
RESULTS AND DISCUSSION

Rice husk obtained was 300 grams which was cleaned and sieved as required. Corn husk obtained from local vendor were dried and ground, it was activated using 0.5M Sodium hydroxide.

Determination of adsorbent optimum conditions

Determination of optimum weight: The optimal weight of the adsorbent was determined through a series of experiments using varying amounts of bioadsorbent, specifically 0.5g, 0.75g, and 1g. The purpose of testing these different weights was to evaluate the adsorption efficiency at each level. In the case of methyl orange, the results showed a clear trend: as the weight of the adsorbent increased, the adsorption capacity decreased. As shown in the graph, the maximum adsorption occurred at 0.5g for both rice husk and corn husk. On day 1, the adsorption capacity for corn husk was 28.70%, while on day 2, it slightly decreased to 28.49%. This pattern can be explained by the fact that, as the quantity of the adsorbent rises, the surface area available for adsorption sites becomes less effective.

Corn husk demonstrated better adsorption performance than rice husk, which suggests that corn husk has more favourable properties for adsorbing methyl orange. On day 1, the adsorption capacity for corn husk was 28.70%, while on day 2, this value slightly decreased to 28.49%. In general, lower weights tend to offer higher adsorption efficiencies due to greater surface area per unit mass, which facilitates more efficient interactions between the dye molecules and the bioadsorbent's binding sites.



Graph 1 : Adsorption capacity Vs Number of days

Determination of optimum contact time: For methyl orange the adsorption capacity of the adsorbents tends to increase with the increase of contact time from 24 to 48 hours. The adsorption process within 48 hours that is on 2nd day shows the highest adsorption capacity compared to other variations which was 28.70% for rice husk. The highest adsorption capacity for corn husk obtained was 29.9%. with varying weight of adsorbents, the optimum contact time is seen to be 48 hours.

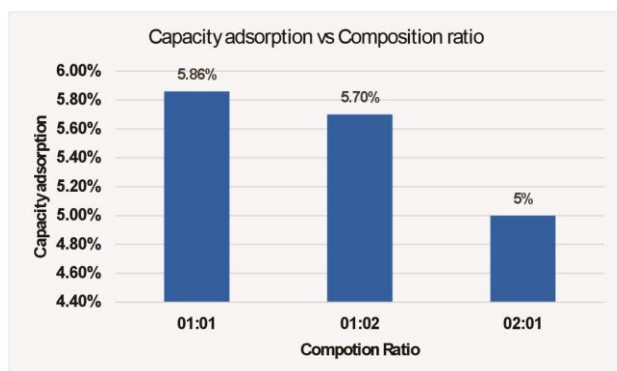
For methylene blue the adsorption capacity of the adsorbents tends to increase with the increase of contact time from 48 to 72 hours. The adsorption process within 72 hours that is on 3rd day shows the highest adsorption capacity compared to other variations which was 5.81% for rice husk. The highest adsorption capacity for corn husk obtained was 29.2%. with varying weights of adsorbents, the optimum contact time is seen to 72 hours.

Determination of optimum pH: In methyl orange use of both rice husk and corn husk shows maximum pH capacity at pH 7 This can be owed to electrostatic

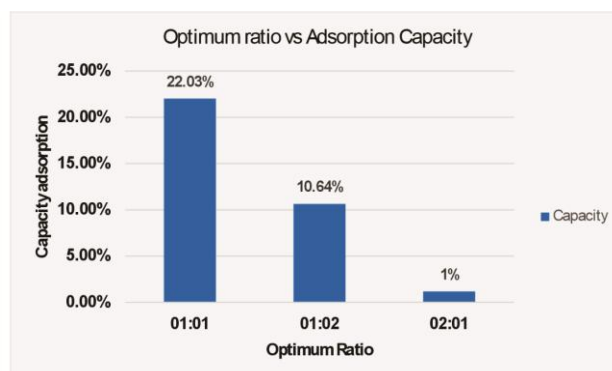
interactions between adsorbent and dye molecules which causes increase or decrease in adsorption capacity. For methylene blue in case of pH 5 there was precipitation occurring due to which their improper readings. The variability in pH and its correlation with adsorption capacity maybe hindered due to certain undesirable interactions.in conclusion pH 7 proved to be optimum for adsorption of methylene blue while using bioadsorbents-rice husk and corn husk.

Determination of optimum composition ratio:

Optimum composition ratio for methylene blue: The optimal adsorbent composition was determined using the previously established ideal weight of 0.5 grams. This study evaluated combined rice husk and corn husk adsorbents at ratios of 1:1, 2:1, and 1:2 (rice husk to corn husk). Results showed that corn husk had superior adsorption capacity. The 1:2 ratio achieved the highest removal at 5.86%, followed by 1:1 at 5.70%, while the 2:1 ratio showed the lowest at 5.00%. This trend highlights corn husk's effectiveness, likely due to its negatively charged functional groups that enhance binding with cationic methylene blue dye.



Graph 2: Adsorption Capacity Vs Optimum composition ratio



Graph 3: Adsorption capacity v/s Optimum composition ratio

Optimum composition ratio for Sample dye: For a known dye concentration, the optimal adsorbent composition was determined using the standardized ideal weight of 0.5 grams, which proved most effective for both rice husk and corn husk. Various rice husk to corn husk ratios were tested using this fixed weight. The 1:1 ratio showed the highest adsorption capacity at 22.03%, indicating the most efficient dye removal. In contrast, the 1:2 and 2:1 ratio resulted in lower performance, with the 2:1 ratio showing the least capacity at just 1%.

HPLC Analysis: LC-2010 HT Shimadzu HPLC was run on both: the initial solution containing 1-amino pHenyl-4-beta hydroxy ethyl sulphone sulfate ester with the chemical formula (C₈H₁₁N₀S₂) and the treated solution with corn husk and rice husk. The absorption peak for this dye was found to be at 254 nm. The retention time was 1.87 with a peak area of 97.34% indicating a high purity of the desired sample in the solution.

Once the treated solution is run for 40 minutes there is a decline in the retention time of samples. Maximum reduction is seen in the sample treated with rice husk and corn husk where the area peak is 3.670% which indicates a decrease of around 95% of the initial sample. In case of rice husk and corn husk the area, peak was observed at 59% and at 12.31%. This indicates that the corn husk has better adsorption capacity than rice husk.

DISCUSSION

Novel bioadsorbents are being explored for their potential to remove Methyl Orange dye from industrial wastewater. Materials like rice husk and corn husk are abundant, biodegradable, and cost-effective, making them promising candidates. Rice husk, rich in silica and lignocellulosic material, offers high surface area and porosity, while corn husk also shows strong adsorption potential. Combined, they enhance dye removal efficiency and support sustainable treatment. Adsorption capacity can be further improved through surface modifications, such as functional group alteration, increasing selectivity and binding strength. Reusability through solvent-based desorption (e.g., ethanol, chloroform) enables multiple-use cycles, reducing waste. Studying adsorption kinetics helps shorten treatment time, boosting efficiency for large-scale applications. Improper disposal can lead to

environmental contamination and harm to ecosystems. Further research is needed to understand the desorption process and ensure the safe disposal of biological adsorbents without causing environmental harm.

CONCLUSION

Biological adsorbents—derived from plants, animals, or microbes—are gaining attention for their ability to remove contaminants from wastewater through adsorption. Their abundance, renewability, low cost, and eco-friendliness make them ideal alternatives to synthetic adsorbents. Common examples include agricultural wastes like rice husk, corn husk, coconut husk, and plant-based materials such as Moringa powder and walnut peels. These materials have high surface areas and functional groups (hydroxyl, carboxyl, amine) that effectively bind pollutants like dyes, heavy metals, and organic compounds. Microbial adsorbents, including algae and fungi, also offer high selectivity and capacity. In this study, various bioadsorbents were tested. While Moringa powder, walnut peels, and coconut husks showed potential, rice husk and corn husk outperformed them in dye removal. Both demonstrated high adsorption efficiency due to their porous structure and complementary chemical properties. Rice husk is rich in silica and effective for dyes like Methyl Orange and Methylene Blue, while corn husk, with high cellulose content, enhances adsorption further. Their combination improved overall performance through synergistic interaction. Optimal conditions were established: 0.5 g adsorbent weight, neutral pH (7), and a 1:2 rice husk to corn husk ratio yielded the best results. The increased surface area and varied functional groups in the combined husks enhanced dye binding beyond what each could achieve individually. Compared to conventional adsorbents like activated carbon, rice and corn husks are more sustainable, affordable, and widely available. This makes them promising eco-friendly solutions for wastewater treatment.

Conflict of interest

The authors declare no competing interests.

Data Availability Statement: Not applicable.

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