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Short research article

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Adsorption and desorption of methylene blue dye from waste water using multiple biosorbent technology

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Abstract

Dyes are intensely coloured complex organic compounds. The most significant industrial use of dye is in the textile dyeing process. Increased usage of dyes in the industrial scale is sequentially associated with the release of processed dye wastes in the water resources. These dye pollutants in waste water are the principle sources of aqueous contamination, since they are designed to be chemically and photolytically stable and are highly resistant in natural environment. The toxicological aspects of these dyes include, allergic reactions, prevention of oxygen binding and carcinogenic activity. Hence, the treatment of waste water to remove these contaminating dyes is inevitable and such treatment can be accomplished by physical, chemical and biological methods. Accordingly, our current research work focuses on the removal of such basic dye called methylene blue from industrial waste water by physical adsorption methodology using biological materials as adsorbents (biosorbents). The first part of our study involves the analysis of different biosorbent materials derived from sawdust, banana fibres and coconut fibres on removal of methylene blue dye. The biosorbents were characterised for their dye adsorbing efficiency and analysed for various parameters, such as adsorbing temperature, dye concentration, etc. The second part of our study involves the usage of combination of biosorbents for an effective removal of methylene blue dye. The results of this two-part study indicated that, the mixed biosorbents have more adsorption capacity than the individual biosorbent material. In addition, the desorption of dye was also performed to make the re-use of biosorbents.

Keywords
Effluents; *Adsorption*; *Biosorbents*; *Methylene blue*; *Desorption*

Introduction

Dyes, which are controversial agents released as industrial waste water are coloured complex substances that impart colour to a variety of materials, such as textiles, leather, paper, food substances, etc. The application of these dye stuffs is most significantly seen in the textile industries. The increased application of commercial dyes that are chemically and photolytically stable, in the textile industries have a greater impact on water bodies. They act not only as principle sources of aqueous contamination, but also are potential enough to induce problems in cardiovascular, dermatological, gastro-intestinal, genito-urinary, haematologic and central nervous system.[1,2] Also, a number of dyes have been found to be mutagenic, carcinogenic and known to produce allergic reactions and prevention of oxygen binding.[3]

These ill effects of dyes prioritise the treatment of waste water released from the dye-based industries in order to remove the contaminating dyes from polluting the environment. Hence, the treatment of waste water could be carried out by any of the processes, such as physical, chemical and biological.[4,5] But few reports suggest the adsorption process to be more efficient and better choice in terms of effective decolourisation, design and operation.[6,7]

The removal of dye in this process is based on the principle of adsorption, where the dissolved dye gets adsorbed by the sorbent as a result of which dye-free water could be obtained. In comparison to biodegradation, photodegradation, reverse osmosis and ion-exchange methods, the adsorption process is fast and inexpensive too.

Studies on microbes on the removal of dyes have revealed the fact that, microbial degradation takes 3–4 weeks minimally and also poses technical constraints, and also they have not given satisfactory colour elimination with current conventional biodegradation processes.[5] But reportedly, the physical process involving the usage of biosorbents was found to consume comparatively less time to eliminate about 90% of dye from the industrial waste water. Biosorbents for adsorption can be obtained from the vast agricultural or forest wastes. And in this study, sawdust, banana fibres and coconut fibres were selected as biosorbents. There are more than 100,000 dyes that are commercially available[8,9] but our current research focuses on the removal of a basic dye called methylene blue from industrial wastewater by adsorption using biomaterials and its desorption from those adsorbents to make their re-use. Methylene blue is regarded as a very dangerous pollutant into the environment even if it exists in small quantities.[10] Methylene blue may result in many adverse reactions in the human body systems, such as hypertension, pericardial pain, dizziness, mental confusion, headache, fever, decolouration of urine, bladder irritation, anaemia, nausea, vomiting, abdominal pain, staining of skin, etc. This dye contamination in water resources would disturb aquatic flora and fauna; hence, the treatment of effluents containing this dye particularly is of great interest.

Materials and Methods

Preparation of dye solution

Stock

The stock was prepared by mixing 1 g of methylene blue in 200 ml of distilled water (i.e. approximately 5 mg/ml). The concentration of 0.10 mg/ml of dye was prepared by mixing 2 ml of stock in 198 ml of distilled water (this concentration was used throughout the study).

Preparation of biosorbents

The biosorbents used for the study, such as coconut fibre, banana fibre and sawdust were collected from the nearby area. The samples collected were washed, ground and sun dried. The materials were then soaked overnight in water to remove the soluble particles and were used throughout the study as biosorbents.

Screening of biosorbents for their potency in dye removal

Screening was performed to check the potential of biosorbents in adsorption of dye. Stirring and stagnant methodologies were performed.

Stirring method

This method was performed by adding 4% of each biosorbent (sawdust, banana fibre and coconut fibre) separately to the dye solution for about 1 h in shaker. The samples were taken at every 15 min time interval. The OD values of the corresponding samples were observed at 700 nm using calorimeter. With the obtained values, a graph was plotted and analysed.

Stagnant method

This method was performed by adding 4% of each biosorbent (sawdust, banana fibre and coconut fibre) separately to the dye solution for about 1 h without shaking. The samples were taken at 15 and 60 min. The OD values of the corresponding samples were observed at 700 nm using calorimeter. With the obtained values, a graph was plotted and analysed.

Comparison of batch, fed-batch and continuous processes
Batch process:

In this process, about 4% of sawdust was added at the beginning and stirred for about 1 h. The samples were taken at every 15 min time intervals. The OD values of the corresponding samples were observed at 700 nm using calorimeter. With the obtained values, a graph was plotted and analysed.

Fed-batch process:

In this process, about 1% of sawdust was added every 15 min without removing the product. This was accomplished by stirring for about an hour. The samples were taken at every 15 min time intervals. The OD values of the corresponding samples were observed at 700 nm using calorimeter. With the obtained values, a graph was plotted and analysed.

Continuous process:

In this process, about 1% of sawdust was added every 15 min and at the end of every 15 min, the previously added biosorbent was removed. This was accomplished by stirring for about an hour. The samples were taken at every 15 min time intervals. The OD values of the corresponding samples were observed at 700 nm using calorimeter. With the obtained values, a graph was plotted and analysed.

Optimisation of dye removal using different dye concentrations

In order to test the efficiency of adsorption at higher concentration, a dye solution of 0.20 g/l, 0.30 g/l and 0.40 g/l was prepared from the stock solution. In this method, the sawdust of about 1% was added every 15 min and at the end of every 15 min time interval, the previously added biosorbent was removed.

This was accomplished by stirring for about an hour. The samples were taken at the 60^{th} min. The OD values of the corresponding samples were observed at 700 nm using calorimeter. With the obtained values, a graph was plotted and analysed.

Use of mixed biosorbents for dye removal

Mixed biosorbent could be used to achieve maximum adsorption in minimum time with minimum usage of biosorbent material. Based on the results from individual biosorbent's ability, the constituents of mixed biosorbent were determined. The mixed biosorbent was employed by continuous process and stirring method. In this process, 1% of sawdust was added and after every 15 min, the sample was taken and the sawdust was removed. Then 0.5% of banana fibre was added and at the 20^{th} min i.e. after 5 min of its addition, the sample was taken and the banana fibre was removed. Then 0.5% of coconut fibre was added and at the 30^{th} min i.e. after 10 min of its addition, the sample was taken and the coconut fibre was removed. Then again, 0.5% of coconut fibre was added and at the 45^{th} min i.e. after 15 min of its addition, the sample was taken and the coconut fibre was removed. The OD values of the corresponding samples were observed at 700 nm using calorimeter. With the obtained values, a graph was plotted and analysed.

Desorption

The desorption process was performed using 1% NaOH solution to the used biosorbent materials for 24 h. The dye thus removed by NaOH can be removed from the biosorbents and re-used.

Results
Screening of biosorbents for their potency in dye removal

Table 1. Adsorption rates of dye by stirring method

Biosorbents	Time (min)	Dye removal (%)
Sawdust	15	97.50
	30	98.50
	45	99.00
	60	99.00
Banana fibre	15	91.00
	30	97.50
	45	98.00
	60	98.00
Coconut fibre	15	99.00
	30	99.50
	45	99.50
	60	99.50

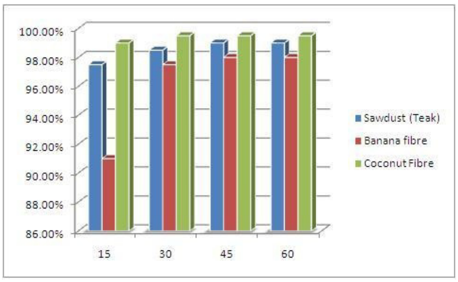

Fig. 1. The graph represents the adsorption rates of sawdust, banana fibre and coconut fibre at every 15 min intervals

Table 2. Adsorption rates of dye by stagnant method

Biosorbents	Time (min)	Dye removal (%)
Sawdust	15	91.50
	60	99.50
Banana fibre	15	70.00
	60	99.00
Coconut fibre	15	50.00
	60	98.50

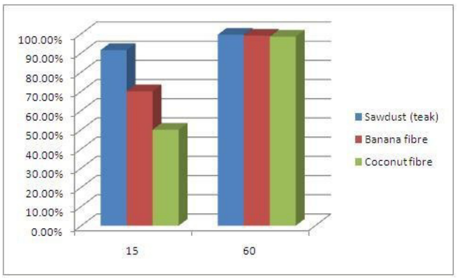

Fig. 2. The graph represents the adsorption rates of dye by sawdust, banana fibre and coconut fibre at 15 and 60 min

Comparison of dye removal between batch, fed-batch and continuous process (using sawdust)

Table 3. Comparison of dye removal by three processes

Biosorbent (sawdust)	Time (min)	Dye removal (%)
In batch process	15	96.50
	30	98.50
	45	98.50
	60	98.50
In fed-batch process	15	91.50
	30	96.50
	45	97.50
	60	99.00
In continuous process	15	91.50
	30	99.00
	45	99.50
	60	99.50

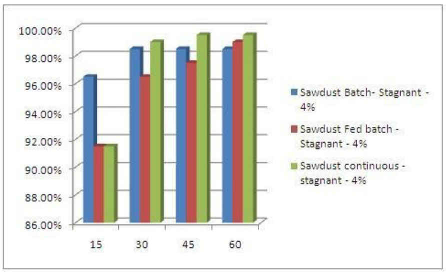

Fig. 3. The graph represents the comparison of dye removal by three processes

Dye removal using different dye concentrations

Table 4. Dye removal by different concentrations of dye

Concentration of dye (g/l)	Time (min)	Dye removal (%)
0.1	60	99.50
0.2	60	99.50
0.3	60	99.00
0.4	60	98.50

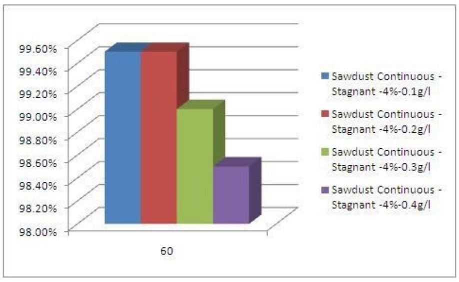

Fig. 4. The graph represents the dye removal by different concentrations of dye

Dye removal by mixed biosorbent

Table 5. Mixed biosorbent's effect on removal of dye

Mixed biosorbent	Time (min)	Dye removal (%)
Mixed sawdust, banana and coconut	15	92.50
	20	96.50
	30	98.50
	45	99.00

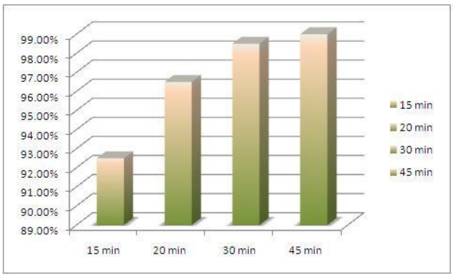

Fig. 5. The graph represents the mixed biosorbent's effect on removal of dye

Desorption

Table 6. Desorption of used biosorbents

Used biosorbent	Time (h)	Dye removal (%)
Sawdust	24	98.20
Banana fibre	24	86.70
Coconut fibre	24	12.40

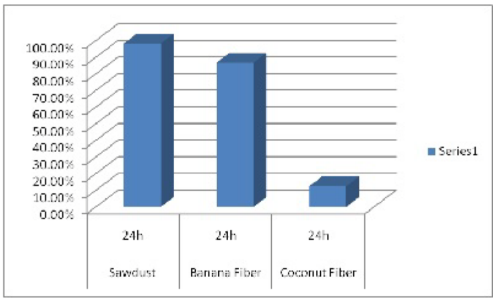

Fig. 6. Graph representing the desorption of used biosorbents

Discussion

Recently textile industries were enhanced with high modern colour textures to build good appearance. In course of time, huge effluents were discharged by the industries, those are especially composed of dyes which are non-degradable in the atmosphere. They may lead to depletion in the fauna and flora of the environment. They more often cause oxygen demand and are highly toxic because they have a tendency to reduce the light penetration into the water system for the survival of living beings.[11] Many efforts have been taken to identify a suitable adsorbing material, which can neglect the high ratio of dyes from the environment. Adsorbent materials mainly taken from the natural sources, such as banana fibres, coconut fibres, sawdusts are often called as biosorbents. In this study, these biosorbents were processed for dye removal under different conditions. In the stirring method, the sawdust was found to adsorb about 99% of dye, the banana fibres have adsorbed 98%; whereas, the coconut fibres have shown 99.5% of dye adsorption. The adsorption rates are represented in Table 1 and Fig. 1. In stagnant method, the sawdust had shown adsorbtion of about 99.5% of dye, banana fibre had adsorbed about 99% and coconut fibre was found to adsorb about 98.5%. These adsorption rates are represented in Table 2 and Fig. 2. In batch process, about 98.5% of adsorption was achieved; whereas, in fed-batch and continuous process, it was observed to be 99% and 99.5%. The values obtained are shown in comparison in Table 3 and Fig. 3. The efficiency of adsorbance was studied for different concentrations by sawdust as adsorbent in which 99.5% of adsorption was achieved by 0.10 g/l concentration of dye solution, 99.5% of adsorption was acheived by 0.20 g/l concentration of dye solution, 99% of adsorption was acheived by 0.30 g/l concentration of dye solution and 98.5% of adsorption was achieved by 0.40 g/l concentration of dye. These values are represented in Table 4 and Fig. 4. For maximum adsorption, the mixed biosorbent was performed. The mixed biosorbent was employed by continuous process and stirring method, where 92.5% of adsorption was achieved by sawdust initially, then by banana fibre, up to 96.5% of adsorption was achieved. Further, adsorption by coconut fibre had resulted up to 98.5% of dye removal and finally again its treatment with coconut fibre resulted in up to 99% of adsorption. Thus, with the mixed biosorbent technology, maximum adsorption in a shorter period with minimum biosorbents was achieved. These values are represented in Table 5 and Fig. 5. The desorption process was performed using 1% NaOH solution to the used biosorbent materials for 24 h. The dye has been found to be effectively removed from the used materials as represented in Table 6 and Fig. 6.

Conclusion

Different biosorbent materials were employed to remove the methylene blue dye under different concentrations. Coconut fibre had shown a predominant effect on adsorbing the dye on an average when compared with other biosorbent materials, such as sawdust and banana fibre; whereas, mixed absorbent technology was found to be of greater advantage when it was treated along with coconut fibre, since the description property of these biosorbent materials when treated along with NaOH was very challenging when they were used independently. So our work concluded that, the effective use of biosorbent material did phenomenal role in the dye adsorption.

Hence, it can be applied in waste water processing treatment to prevent the sediments of dye.

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