

Removal of Dyes from Wastewater using Adsorption - A Review

Sivamani S, Leena Grace B

Department of Biotechnology, School of Biochemical Engineering, VMKV Engineering College, Vinayaka Missions University, Salem, INDIA

dr_sivamani@rediffmail.com

ABSTRACT:

The adsorption process is being extensively used for the removal of dyes from synthetic dyehouse effluents by various researchers. The most widely used adsorbent is commercially available activated carbon. Despite the frequent use of adsorption in wastewater treatment systems, commercially available activated carbon remains an expensive material. In recent years, the safe and economical methods are required for the treatment of dyehouse effluents, which involved researchers to focus towards the preparation of low cost adsorbents from cheapest sources. Therefore, in this review article, the different cheapest sources of preparing adsorbent are discussed and their feasibility in treating dyehouse effluents is studied.

INTRODUCTION

Dyeing industry is one of the largest water consuming industries. The effluent coming out of the dyeing industries contains various chemicals and colouring compounds and the effluent requires proper treatment before it is discharged into any water body. But, the dyehouse effluents are very difficult to treat satisfactorily because they are highly variable in composition [1].

In most situations, the use of a combination of different methods of treatment is necessary in order to remove all the contaminants present in the wastewater [2, 3 and 4]. Therefore, adsorption became one of the most effective methods to remove colour from textile wastewater [5, 6 and 7].

Despite the frequent use of adsorption in wastewater treatment systems, commercially available activated carbon remains an expensive material.

The cheapest sources of preparing adsorbents include sewage treatment plant biosolids (sludge) [8], magnetically modified brewer's yeast [9], cassava peel activated carbon [10], tapioca peel activated carbon [11], soil [12], fly ash [12, 18], jack fruit peel activated carbon [13, 17], groundnut shell activated carbon activated with Zinc chloride solution [14], neem leaf powder [15], kaolinite [16], montmorillonite [16], hazelnut activated carbon [16], bagasse pith [19], natural clay [19], maize cob [19], rice bran based activated carbon [20], guava seeds activated with Zinc chloride solution followed by pyrolysis [21] etc.

They are used for the removal of dyes from synthetic dyehouse effluents by various researchers. The two methods of processing adsorbents are physical and chemical methods.

Physical method of treating adsorbent involves activation by heating in an oven. Chemical method of treating adsorbent involves activation by adding acid or alkali.

Since the addition of inorganic acids make the method polluted and expensive, recently, researchers started to use organic acids for the acid treatment of adsorbents. Sometimes, combination of both methods may also be used.

Cost is an important factor for comparing the feasibility of adsorbents in treating dyehouse effluents. However, in any report, cost analysis is not stated and the expense of adsorbents varies depending on the method of processing and availability of source materials.

In general, an adsorbent is said to be low cost if it requires little processing, abundant in nature with high adsorption capacity [22].

The objective of this study is to contribute in the search for low cost adsorbents and their utilization possibilities to remove dyes from synthetic dyehouse effluents.

LITERATURE

Reviews on low cost adsorbents for the removal of dyes from wastewater are presented as follows.

Fly ash

Fly ash is a residue that results from the combustion of coal in thermal power plants. The major components of fly ash are alumina, silica, iron oxide, calcium oxide, magnesium oxide and residual carbon.

One of the main advantages of fly ash over the other adsorbents is that it is in abundance and easily available to make it a strong choice in the investigation of an economic way of dye removal. Other advantage is that it could easily be solidified after the pollutants are adsorbed because it contains pozzolanic particles that react with lime in the presence of water to form cementation calcium-silicate hydrates [12].

The fly ash adsorbent was prepared for the adsorption process by the following procedure [23]: The fly ash sample was received from nearby thermal power plant and then washed with distilled water to remove surface dust and was dried in sun. Fly ash samples were stored in the laboratory in airtight plastic container. The fly ash adsorbent was characterised using standard procedures to determine the physical and physicochemical parameters.

After analysis, the fly ash adsorbent is found to contain 60.10% SiO₂, 18.60% Al₂O₃, 6.40% Fe₂O₃, 6.30% CaO, 3.60% MgO. The values of surface area, porosity, and bulk density of the adsorbent are 40.16 m²/g, 0.43 and 3.51 g/cm³ respectively. However, the constituents of fly ash vary according to the type of coal used and degree of combustion.

The fly ash adsorbent was used for the removal of various dyes like Methylene blue, Malachite green and Rhodamine – B, from aqueous solutions [12]. The high colour removal percentages are 93%, 89% and 77% for the dyes, Methylene blue, Malachite green and Rhodamine – B, respectively.

The adsorption on dyes, Malachite green and Methylene blue was studied on two different samples of fly ash, fly ash I and II [18]. They have concluded that the maximum color removal was attained with fly ash containing high carbon content.

Bagasse Pith

Bagasse pith is a waste product produced from sugar refining industry. It is the name given to the residual cane pulp remaining after sugar has been extracted. Bagasse pith is composed largely of cellulose, pentosan and lignin [24].

The research was carried out on adsorption of dyes, Astrazone blue, Maxillon red and Telon blue using bagasse pith [19]. Based on cost analysis, they showed that the bagasse pith is economically attractive than commercially available activated carbon.

Other low cost adsorbents

The sewage treatment plant biosolids (sludge) was used as adsorbent in removing basic dyes, Basic blue 3, Basic red 22 and Basic black 9 from aqueous solutions [8].

Batch mode adsorption experiments are carried out, by varying contact time, initial dye concentration, initial adsorbent dosage, agitation rate, temperature and pH. The results revealed that the adsorption capacity of basic dyes was higher (22-24 mg/g) with the lower values of the temperature (25-30°C), adsorbent dosage (0.5-0.75% w/v), higher values of the initial pH (8-9) and agitation rate (150-200 rpm). The equilibrium in the solution was observed within 2 h of operation.

The magnetically modified *Saccharomyces cerevisiae* subsp. *uvarum* cells was studied as adsorbent in removing water soluble dyes, Aniline blue, Congo red, Crystal violet, Naphthol blue black and Safranin – O from aqueous solutions [9].

The results revealed that the maximum adsorption capacity of the magnetic cells differed substantially for individual dyes; the highest value was found for aniline blue, 220 mg/g. The dyes removal by activated carbon prepared from cassava (*Manihot esculenta*) peel was studied [10]. Cassava peel is an agricultural waste from the food processing industry.

Activated carbons prepared from waste cassava peel employing physical and chemical methods were tested for their efficiency in the removal of dyes and metal ions from aqueous solution. They have reported that the material impregnated with H₃PO₄ showed higher efficiency than the heat treated materials while both of these were efficient as adsorbents for dyes and metal ions. The removal of a basic dye, Rhodamine – B, by using tapioca peel activated carbon as an adsorbent was also studied [11].

The soil was used as adsorbent for removal of dyes, Methylene blue, Malachite green and Rhodamine – B, from aqueous solutions [12]. At optimal conditions, the colour removal percentages are 89.18%, 83.20% and 71.56% for the dyes, Methylene blue, Malachite green and Rhodamine – B, respectively.

The jack fruit peel activated carbon was used as adsorbent in removing a basic dye, Rhodamine – B, from aqueous solution [13]. Batch mode adsorption experiments are carried out, by varying initial dye concentration, initial adsorbent dosage, and pH.

The results revealed that the optimal adsorption capacity of the basic dye was 121.47 mg/g, adsorbent dosage (1.2 g/L), and the influence of pH on dye removal was not significant. The maximum colour removal percentage achieved was 96%.

The jack fruit peel activated carbon was also used as adsorbent in removing a dye, Malachite green, from aqueous solution [17]. Batch mode adsorption experiments are carried out by varying initial dye concentration, temperature and pH. They reported that the maximum adsorption capacity attained was 166.37 mg/g at an initial pH of 6.0 and at 32 ± 0.5°C.

Table 1. Various types of adsorbents for dye removal by adsorption

Adsorbent	Percentage removal of dye (%)													Reference
	Acid blue 16	Acid red 183	Aniline blue	Basic black 9	Basic blue 3	Basic red 22	Brilliant green	Congo red	Crystal violet	Malachite green	Methylene blue	Rhodamine - B	Safranine - O	
Sewage treatment plant biosolids	-	-	-	90.1	83.4	86.7	-	-	-	-	-	-	-	[8]
Modified brewer's yeast	-	-	91.2	-	-	-	-	95.2	83.4	-	-	-	93.2	[9]
Tapioca peel activated carbon	-	-	-	-	-	-	-	-	-	-	-	85.9	-	[11]
Jack fruit peel activated carbon	-	-	-	-	-	-	-	-	-	82.6	-	88.2	-	[13 and 17]
Groundnut shell activated carbon	82.6	-	-	-	-	-	-	-	-	-	-	-	-	[14]
Neem leaf powder	-	-	-	-	-	-	93.4	87.4	-	-	91.5	-	-	[15]
Kaolinite	-	65.2	-	-	-	-	-	-	-	-	-	-	-	[16]
Montmorillonite	-	72.3	-	-	-	-	-	-	-	-	-	-	-	[16]
Hazelnut activated carbon	-	81.4	-	-	-	-	-	-	-	-	-	-	-	[16]
Guava seeds activated carbon	-	-	-	-	-	-	-	-	-	-	76.3	-	-	[21]

The removal of acid dyes by using groundnut shell powder activated by Zinc chloride solution was studied as an adsorbent [14]. The results revealed that the maximum adsorption capacity was found to be 55.5 mg/g of the adsorbent for 100 ppm initial concentration of dye solution.

The neem leaf powder was used to remove three water-soluble dyes, viz., brilliant green, congo red and methylene blue from aqueous medium [15]. The adsorptive interactions were tested under varying conditions of concentration of the dyes, amount of adsorbent, pH, and temperature.

The removal of acid red 183 from aqueous solution was studied by activated carbon, raw kaolinite and montmorillonite using an agitated batch adsorber [16]. The results revealed that the adsorption capacity was 1495, 111, 29 and 19 mg/g for CAC (commercial activated carbon), HAC (activated carbon obtained from hazelnut), KC (raw kaolinite) and MC (montmorillonite) at 25°C respectively.

Rice bran based activated carbon and guava seeds activated carbon, followed by pyrolysis were also used as adsorbents to remove dyes from aqueous solutions [20 and 21].

The comparative performance study of various adsorbents for the removal of dye by adsorption was highlighted in Table 1.

CONCLUSION

A review of various adsorbents presented shows a good potential for the removal of dyes from wastewater. The adsorption capacity depends on the type of adsorbent and the nature of wastewater.

The expensive adsorbents can be replaced by the low cost adsorbents for the removal of dyes from wastewater. More research should be carried out to treat other industrial effluents for the exploration of low cost adsorbents and to demonstrate the technology effectively. As presented in table 1, various adsorbents show a good adsorption capacity for the removal of dyes.

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