Removal of Dyes from Textile Industrial Wastewater using Sugarcane Bagasse

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Abstract
The use of eco-friendly adsorbent has always been an alternative substitution of activated carbon for the treatment of waste water. Sugarcane bagasse acts as a perfect adsorbent and can be used to remove components dissolved in water. In this paper, the potential use of sugarcane bagasse for the removal of dyes from wastewater has been discussed. Dyes are usually present in trace quantities in the treated effluents of many industries. The effectiveness of adsorption for dye removal from wastewaters has made it an ideal alternative to other expensive treatment methods. The result showed that as the amount of adsorbent increase, the percentage of dye removed from the water also increased. Sulphuric acid treated sugarcane bagasse and burnt sugarcane bagasse showed a better performance compared to formaldehyde treated sugarcane bagasse and raw bagasse, thus making it an interesting option for dye removal from industrial effluents.
Keywords: Sugarcane bagasse, dyes, effluent, adsorption

1. Introduction

Dyes are usually present in trace quantities in the treated effluents of many industries due to their good solubility. However, the discharge of dye-bearing wastewater into natural streams and rivers possess a severe problem, as dyes impart toxicity to aquatic life and are damaging the aesthetic nature of the environment [3]. Wastewater containing dyes is very difficult to treat, since the dyes are recalcitrant organic molecules, resistant to aerobic digestion, and are stable to light, heat and oxidizing agents due to their structure and molecular size. Due to low biodegradation of dye, a convectional biological treatment process is not very effective in treating a dye wastewater [7]. It is usually treated with either by physical or chemical processes. However, these processes are very expensive and cannot effectively be used to treat the wide range of dyes waste. Amongst the numerous techniques of dye removal, adsorption is the procedure of choice and gives the best results as it can be used to remove different types of coloring materials [15]. The effectiveness of adsorption for dye removal from wastewaters has made it an ideal option for other expensive treatment methods. The use of cheap and ecofriendly adsorbents have been studied as an alternative substitution of activated carbon for the removal dyes from wastewater.

2. Review of Literature

Mahmoud El-Latifa M., Mozarei Ibrahim A., (1994) utilized activated carbons prepared from oak sawdust, a timber industry waste to examine theremoval of remazol brilliant blue (RB) dye from aqueous solutions through batch adsorption technique. Tai-Lee Hu (1996) stated that adsorption of reactive dyes by bacterial cells is significant particularly under acidic conditions. Mohan, S.V.and Karthikeyan, J., (2004) observed that at lower pH the surface of the adsorbents becomes positively charged and this would facilitate sorption of the colour cation probably by exchange sorption. Ali Rıza Dinc et al., (2007) Compared activated carbon and bottom ash for removal of reactive dye from aqueous solution and observed that the dye uptake by GAC was higher at lower pH. Nevine Kamal Amin , (2008) utilized Bagasse pith, which is the main waste from sugarcane industry in Egypt,as a raw material for the preparation of different activated carbons in order to remove the reactive dyes. Antonio R. Cestari et al (2009)., successfully employed the three-parameter Sips adsorption model to modeled equilibrium adsorption data of a yellow and a red dye onto a mesoporous aminopropyl-silica, in the presence of the surfactant sodium dodecylbenzenesulfonate (DBS) from 25 to 55 ◦C. Yongjie Xue et al.,(2009) carried out the utilization of treated basic oxygen furnace slag (BOF slag) to remove three synthetic textile dyes (Reactive lue 19 (RB19), Reactive Black 5 (RB5) and Reactive Red 120 (RR120)) by adsorption from aqueous solutions. Franciele Regina Furlan et al., (2010) used coagulation–flocculation–sedimentation tests to determine the best pH and dosage of coagulant and alkalizer in the aqueous solution. Kongliang Xie et al., (2011) stated that nano-cellulose macromolecules have numerous aminos, which impart positive charge on cellulose. They could form numerous new adsorptive positions for reactive dyes. Magdalena Greluka et al., (2013) described the treatment efficiency of Amberlite IRA-900 to model wastewaters and showed that the polystyrene anion exchanger Amberlite IRA-900 can be effectively used as a adsorbent for the removal of C.I. Reactive Black 5, C.I. Reactive Red 2 and C.I. Reactive Red 120 from aqueous solutions. P. V. Thitame, S. R. Shukla (2015) observed that the maximum dye adsorption capacity shown by the activated carbon produced from coir pith was 2022.9 mg/g for C.I. Reactive Red 2 and 1694.3 mg/g for C.I. Reactive Yellow 145A with initial concentration of 1000 mg/L.

3. Methodology

Sugarcane waste was collected from the sugarcane juice vendor. The waste was washed with water to remove the sugary content from it. It was then dried under sunlight for 2-3 days, so as to evaporate the moisture. This process was repeated twice in order to remove all the sugar content from the bagasse. The dried waste was grinded to get fine powder. The powdered waste was sieved to -80 to +230 mesh size and was divided into four equal parts.

A. Formaldehyde treated Sugarcane Bagasse

Prepare 1% formaldehyde solution by adding 10 ml of Conc. Formaldehyde in 1000 ml of distilled water. Stir well the solution. To immobilize the color and water soluble substances, the ground powder was treated with 1% formaldehyde in the ratio of 1:5 (bagasse: formaldehyde, w/v) at 50ºC for 4 hrs. The sugarcane bagasse was filtered out, washed with distilled water to remove free formaldehyde and activated at 80ºC in hot air oven for 24 hrs. The material was placed in an airtight container for further use.

B. Sulphuric acid treated sugarcane bagasse

One part of dried sugarcane bagasse was mixed with one part of concentrated sulphuric acid and heated in a muffle furnace for 24 hrs at 150ºC. The heated material was washed with distilled water and soaked in 1% sodium bicarbonate solution overnight to remove residual acid. The material was dried in an oven at 105ºC for 24 hrs and sieved in the size range of 80-230 mesh and is kept under airtight container.

C. Powdered Activated Carbon prepared from Burnt Sugarcane Bagasse

One part of dried sugarcane bagasse was burnt under the gauze plate so as to convert it into ash form and was placed in desiccators for overnight. Then this ash was kept into muffle furnace at 150ºC for 48hrs in order to activate the adsorbent capacity of the bagasse. After 48 hrs, this ash was again kept in desiccators for cooling. All adsorbents were dried at 110ºC overnight before the adsorption experiments.

D. Untreated Sugarcane Bagasse

The fine powder of the Bagasse was kept in an air tight container and was directly introduce in order to remove the dyes present in waste water.

Treatment of wastewater:

Industrial wastewater was collected from Pratibha Syntax (Plot No 4, IGC, Sector 1, Kheda, Pithampur, Dhar – 454775). This wastewater sample was equally divided into 4 parts. One part of the wastewater sample was treated with Formaldehyde treated Sugarcane Bagasse. Second part of the wastewater sample was treated with Sulphuric acid treated Sugarcane Bagasse. Third part of the wastewater sample was treated with Burnt Sugarcane Bagasse. Fourth part of the wastewater sample was treated with untreated sugarcane bagasse. In each adsorption experiment, 100 ml of dye solution of known concentration and pH was added to 400 mg of adsorbents (untreated, formaldehyde treated, sulphuric acid treated sugarcane bagasse and burnt sugarcane bagasse) in a 250 ml round bottom flask. This was done at a room temperature (29±1ºC). The mixtures were then stirred on a magnetic stirrer at 160 rpm. Treatment period was 36-48 hrs. After 48 hrs, take out the magnetic stirrer out of the bottle and left the solution for 5-6 hrs so that all the suspended sugarcane bagasse gets settle down onto the base of the flask. Now, each of these solutions was filtered by whatman (grade 1) filter paper so as to obtain the treated solution only and kept in airtight bottles. Tests were applied on these solutions so as to determine certain parameters.

4. Results

Results for the dosage of 1:5 ratio (W:V ratio) of bagasse and effluent at 42ºC for both the samples are shown below:

Table 1 Results for Sample A (Wastewater of Direct Dye Solution)

Samples / Parameters	Original (A)	IA	IIA	IIIA	IVA
BOD (mg/l)	85.35	71.65	41.5	32.89	32.87
COD (mg/l)	432.06	398.54	252.15	247.54	246.64
DO (ppm)	3.2	5.8	7.5	5.5	6.8
Free Chlorine content	5	1.95	0.65	0.48	0.4
Chloride content	7	2	1.57	0.98	0.58
TDS (ppt)	10.6	9.87	8.53	5.11	5.56
Salinity	25.9	15	0	0	0
Alkalinity (ppm)	5665.7	5248.35	689.655	4207.692	874.59
Conductivity (mS)	11.3	9.5	7.46	12.6	5.65
Temperature (^{0}C)	41.3	42	42	42	42

pH	11.97	10.68	0.67	9.34	7.6
Hardness (mg/l)	148	135.26	79.65	88.47	71.25
Colour change	Dark Orange	Light Orange	Transparent	Lightest Orange	Transparent

Table 2 Results for Sample B (Wastewater of Acid Dye Solution)

Samples / Parameters	Original (B)	IB	IIB	IIIB	IVB
BOD (mg/l)	80	68.5	40.24	35.14	29.05
COD (mg/l)	485	398.6	275.6	280	240.58
DO (ppm)	6.9	7.52	8	6.4	9.56
Free Chlorine content	2.98	2.25	1.65	1.47	1.5
Chloride content	3.56	2.57	1.520	0.25	1.24
TDS (ppt)	6.75	4.58	1.25	3.29	1.54
Salinity	0	0	0	0	0
Alkalinity (ppm)	1220.12	1035.5	892.85	476.19	678.57
Conductivity (mS)	7.45	6.57	0.02	9.17	2.65
Temperature (^{0}C)	41.8	40	40	40	40
pH	3.42	4.5	0.39	4.35	6.6
Hardness (mg/l)	108.65	100.54	87.58	75.68	79.24
Colour change	Dark Blue	Light Blue	Transparent	Lightest Blue	Transparent

Note:
I : Wastewater with Raw Sugarcane Bagasse
II: Wastewater with Sulphuric Acid treated Sugarcane Bagasse
III: Wastewater with Formaldehyde treated Sugarcane Bagasse
IV: Wastewater with Powdered Activated Carbon (Prepared from Burnt Sugarcane Bagasse)

5. Discussion

Effect of Initial dye concentration: The Paper had shown that for the powdered activated carbon (PAC), the percentage of dye removal was very high, nearly 100% for all initial dye concentration and agitation time. The lowest dyes removal was for raw sugarcane bagasse, which was measured for initial dye concentration of 250 mg/L and 15 min contact time. The efficiency of dye removal was increased as the agitation time increased and lowers initial dye concentration. For the treated sugarcane bagasse (undergo physical and chemical treatment), it had shown an increment in the percentage of dye removal. Also, it was found that an increasing in the dye concentration had caused the decreasing in the percentage of dye removal, even though the amount of dye being adsorbed is increased. As a comparison, sugarcane bagasses which undergo the chemical treatment (sulphuric acid treatment) had shown better result in the dye adsorption compared to sugarcane bagasse treated with physical treatment. The process was rapid initially and a large fraction of the total amount of dye was removed within a few minutes.
The effect of pH: For the powdered activated carbon, it was found that the percentage of dye removal was not affected by pH variation. The uptake of the dyes was nearly 100% for all pH values. For the sulphuric acid treated bagasse (PCSB), the dyes adsorption was significantly change over the pH value of 4 to 7. The lowest percentage of dye removal was recorded at pH 2 (52.2%). At the pH range 7 to 10, the percentage of removal was almost remains constant. As the pH of the solution decrease (more acidic), the number of negatively charged adsorbents site increased. This will not favor the adsorption of the positively charge dyes. This, however didn't apply to the PAC, as it was remained almost 100% for all pH values. There might be another mode of adsorption, such as ion exchange. As the pH value increased from 9 to 13, the efficiency of the dye removal is slightly become lessened.

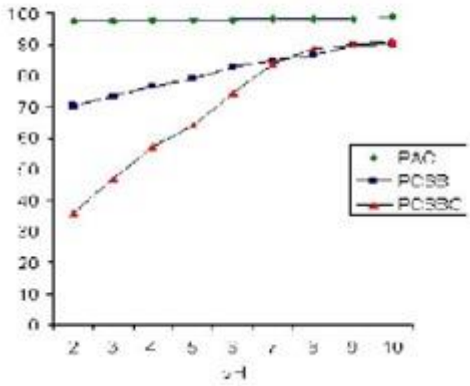

Fig. 3: Effect of pH on methyl red removal by PAC, PCSB and PCSBC (initial dye concentration 250 mg L¯1, adsorbent dosage=0.4 g 100 mL¯1, temperature 26°C, contact time=120 min.

The nearly same pattern was obtained for the formaldehyde treated sugarcane bagasse (PCSBC). The minimum percentages of removal were recorded at pH 2 (78.5) and the highest percentage recorded at pH 10 (98.7%). Figure 2 shows the variation of dye removal for different adsorbents at various pH values. The effect of adsorbance dosage: For the powdered activated carbon (PAC), it was found that the percentage of dye removal was increased with the increment of absorbance dosage. For the adsorbent dosage of 1.0 g 100 mL¯1, it was found that after 45 min agitation time, the amount of dye being adsorbed was nearly 100%. As for sulphuric acid treated bagasse (PCSBC), the percentage of dye removal was increased from 54.9% to 96.5%, as the adsorbent dosage increased from 0.2 to 1.0 g/100 mL after the equilibrium time. Also, the increment from 17.5 to 74.5% was obtained for PCSB for the same increment of adsorbent dosage. This is due to increase in adsorbent dosage attributed to increase in surface area and availability of adsorption site.

6. Conclusion

The removal of dyes from simulated wastewater by using PAC, PCSB and PCSBC has been investigated for different variables viz. contact time, adsorbent dosage pH and initial dye concentration. From this study, it was found that PCSB and PCSBC has a comparatively lower adsorption efficiency compared to powdered activated carbon (PAC), and raw bagasse has very poor adsorption capacity compared to others, at the any given initial dye concentration. The adsorption efficiency can be arranged in the following order PAC>PCSBC>PCSB. The work shows that PCSB and PCSBC have a lower adsorption efficiency compared to PAC at any given pH value. Initial dyes concentration over the range of 2 to 6, decreased the efficiency of the dyes removal. While, the pH range 7 to 10 is optimum for the dye removal for both adsorbents, PCSB and PCSBC. As sugarcane bagasse is easily available in the countryside, it can be used by the small scale industries which produced dyes as their effluent, after being pretreated with formaldehyde and sulphuric acid. The data may be useful for designing and fabrication of an economically cheap treatment process using a batch or stirred tank flow reactors for the removal of dyes from diluted industrial effluent.

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