Asian Journal of Advances in Agricultural Research

3(3): 1-9, 2017; Article no.AJAAR.37246
ISSN: 2456-8864

Decolourisation of the Textile Dye Methyl Red from Aqueous Solution Using Sugarcane Bagasse Pith

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Authors' contributions

This work was carried out in collaboration between both authors. Author MA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MP managed the analyses of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAAR/2017/37246
Editor(s):
(1) Tancredo Souza, Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Portugal.
Reviewers:
(1) Hasan Aydogan, Selcuk University, Turkey.
(2) Dal Singh Kharat, India.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/21703

Short Communication

Received 6th October 2017
Accepted 31st October 2017
Published 2nd November 2017

ABSTRACT

The present study investigates the potential of sugarcane bagasse pith, an agro waste as an effective adsorbent for the removal of methyl red. Physicochemical parameters like concentration of dye, amount of adsorbent, temperature, pH and contact time were optimized to develop faster decolourization process. The spectrophotometric technique was adopted for the estimation of the concentration of dye before and after the adsorption. The results showed that the maximum decolourization (86%) of methyl red by sugarcane bagasse pith was found in 10 mg/L dye, 500 g/L of the adsorbent dose at pH 5 with temperature 30°C for 5 days. UV-vis spectral analysis showed a new peak at 781 nm which confirms the degradation of methyl red. The surface structure of the adsorbent treated with dye showed a significant difference when compared with control. The earlier results justify the applicability of the bagasse in removal of methyl red from textile wastewaters and their safe disposal.

Keywords: Adsorption; sugarcane bagasse pith; methyl red; optimisation parameters.

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1. INTRODUCTION

The rapid development of industries, population explosion and discharge of pollutants from various industries results in environmental pollution. Among various types of environmental pollution, water pollution is the major distress to the community, because of the existence of dye stuff in the wastewater which are released from the dyeing industries [1].

Almost all the industrial sectors are responsible for the environmental pollution [2]. Among them, textile industry plays a vital role in the release of effluents with a huge amount of additives, surfactants, detergents, suspended solids, carcinogenic amines and dyes that poses environmental threats to aquatic bodies [3]. Without any proper treatment, the bleached wastewaters from textile industries are directly released into water bodies. It makes a severe problem to aquatic life, reduces photosynthetic activity and also has an adverse effect on human health and causes toxicity turbidity problems [4]. Hence most of the dyes are toxic, mutagenic and carcinogenic in nature [5]. Elimination of colour from textile wastewater is one of the major environmental problems and its removal seems to be difficult by treating it with conventional method because the dyes are stable and to heat and oxidizing agents [6].

The physicochemical treatment methods such as adsorption, sedimentation, flocculation, floatation, coagulation, osmosis, neutralization, reduction, oxidation, electrolysis, ion-exchange are employed for dye removal. But, these methods are expensive and in addition, most of them produce the large quantity of sludge which needs further disposal. Therefore, economically and eco friendly techniques are needed for the degradation of dye from textile effluent [7-10].

Recently, a number of low costs, easily available and effective adsorbents were used for the removal of different dyes from aqueous solution. Many studies have been focused on the use of non-conventional low-cost adsorbents such as sugarcane bagasse, coconut husk, groundnut shell, banana pith, clay, rice husk, maize cob, coir pith, orange peel and wheat straw dust in wastewater treatment. Instead of disposing of the sugarcane bagasse as a waste material, it has been used as an adsorbent for the removal of dyes from the wastewater. It mainly consists of cellulose (45%), hemicellulose (28%) and lignin (18%) and also it has carboxylic and hydroxyl groups, which are responsible for the uptake of dyes from wastewater [11-13]. The aim of the present study is to determine the optimum conditions for the removal of methyl red by sugarcane bagasse pith.

2. MATERIALS AND METHODS

2.1 Sugarcane Bagasse Pith

The adsorbent, sugarcane bagasse pith was collected from a local juice market in Coimbatore, Tamilnadu. The bagasse was washed with water to remove the dirt and then it was dried under shade for 5 days for the removal of moisture. The dried bagasse was ground and sieved to the desired particle size of about 50 µm and used for adsorption studies.

2.2 Methyl Red Dye

Methyl Red, 2-[4-(dimethylamino)phenylazo] benzoic acid, used as an adsorbate for the study was purchased from the local dye market, Coimbatore, Tamilnadu. It is an azo dye pH indicator a dark red crystalline powder with molecular formula – $C_{15}H_{15}N_3O_2$, molar mass - 269.3 g mol^{-1}, density - 0.791 g cm^{-3}, Colour Index Number - 13020, EC Number 212-682-9, MDL number MFCD00002426 and melting point - 179-182°C.

2.3 Batch Adsorption Experiment

The effect of dye concentration, adsorbent dosage, pH, temperature and contact time were studied for the effective removal of colour. The batch adsorption studies was conducted at different dye concentration (10-50 mg/L), adsorbent dose (100-700 g/L), pH (2-10), temperature (20-60°C) and contact time (1-10 days). The control experiments were maintained without adsorbent. The pH of the solution was adjusted using 0.1N NaOH and 0.1 N HCl. Under optimised conditions, the untreated and treated dye solutions were filtered and centrifuged at rpm for 10mins. The absorbance of the supernatant was determined by the decolourisation percentage. After the 5^{th} day of contact time, the untreated and treated dye solutions were centrifuged at 5000 rpm/10mins. The absorbance of the supernatant was determined by the decolourisation percentage

$$\text{Decolourisation percentage} = C_i – C_o / C_i \times 100$$

C_i=initial absorbance, C_o = absorbance at 5^{th} day of incubation time

2.4 UV-Vis Spectroscopic Analysis

Decolourisation was monitored by UV- visible spectroscopic analysis. The spectrum was recorded using Shimadzu UV-1800 at the range of wavelength 200-800 nm. The initial and final absorbance values of untreated and treated peaks of methyl red were used to determine the dye decolourisation.

2.5 Scanning Electron Microscopic Analysis

The surface morphology of treated and untreated sugarcane bagasse pith was investigated using Scanning Electron Microscopy (SEM) Model HITACHIS3400N at an accelerating voltage of 15 kV. Before the examination, the surface of the untreated and treated samples was coated with a thin layer of gold approximately 30 nm using Sputter Coater Polaron SC 515.

3. RESULTS

3.1 Physicochemical Parameters

The adsorbent dose is an important parameter in adsorption studies because it determines the capacity of the adsorbent for a particular dye concentration. The dye removal from methyl red by sugarcane bagasse pith was studied by varying a amount of adsorbent doses (100-700 g/L). The percentage of colour removal was increased from 14% to 87%, as the adsorbent dosage increased from 100 to 500 g/L after that the equilibrium was attained (Fig. 1).

The experiment was carried out at different concentrations of methyl red (10-50 mg/L). Fig. 2 shows that the dye removal was reduced from 72% to 19% as concentration was increased from 10 to 50 g/L. It was evident that the percentage of dye adsorption by sugarcane bagasse pith decreased with the increase in initial dye concentration.

pH plays a significant role in decolourisation process and mainly on the adsorption capacity. Variation in solution pH leads to change the degree of ionization and the surface properties of the adsorbent [14,15]. In this view, the experiments were performed in different pH ranges (2-10) to attain the optimum pH for dye decolourisation. The results showed in the Fig. 3 reveal that the maximum of 83% decolourisation was found at pH 4 which decreased to 13% at pH (10).

A study on the temperature dependence of adsorption reactions gives valuable knowledge about the enthalpy and entropy changes [16]. The effect of temperature on decolourisation methyl red by sugarcane bagasse pith was studied at five different temperatures (20-60°C). In Fig. 4, the maximum decolourisation of methyl red by bagasse pith was noticed at 30°C.

The effect of contact time on methyl red decolourisation by sugarcane bagasse pith was investigated on different days (1-10 days). A rapid decolourisation was found at the initial stages of the adsorption and equilibrium was attained from 5th day onwards (Fig. 5). Such uptakes specify a high degree of affinity towards the dye molecules through chemisorptions [17]. The minimum colour removal efficiency was obtained at the 10th day which shows that the aggregation of dye molecules decreased with increase in contact time and makes it almost impossible to diffuse deeper into the adsorbent structure at highest energy sites [18]. The results of the present study coincide with Wong et al. [19] who stated that 85% of the RO16 dye was removed within 180 mins of contact time when treated with sugarcane bagasse.

Thus the optimum conditions for removal of methyl red from an aqueous solution by sugarcane bagasse pith were successfully identified (Table 1). Under the above-optimised conditions, the maximum adsorption (86**%**) was achieved.

3.2 UV-visible Spectral Analysis

Adsorption was further confirmed by UV-vis spectra in which the untreated dye showed characteristic absorbance peaks at 586, 393, 315 and 259 nm. After adsorption, the decrease of peak intensity at 781 nm in treated dye indicates the complete adsorption of the dye by sugarcane bagasse pith (Fig. 6). Naveenprasad et al. [20] reported that the absorbance peaks of methyl red dye were found to be 530 nm before adsorption and after adsorption, the peak intensity decreases which signifies the maximum adsorption of dye.

3.3 Scanning Electron Microscopic (SEM) Analysis

SEM is a primary tool for characterizing the surface morphology and fundamental physical properties of the adsorbent surface and it is also useful for determining the surface shape of particle and the appropriate size distribution of the adsorbent. Fig. 7 showed the SEM images of the sugarcane bagasse before and after adsorption. SEM micrograph of untreated sugarcane bagasse pith formed aggregates whereas the treated bagasse looks like a fiber with flake shape. Pham et al. [21] showed that the surface images of sugarcane bagasse had a smooth and less porous texture, after the adsorption of cadmium.

4. DISCUSSION

Increase in the adsorption with the increase of adsorbent dose can be attributed to the increase in adsorbent surface area and availability of more adsorption sites [22]. Subramanian and Ponnusamy [23] stated that the increase in dye removal with increasing adsorbent dose was due to the split in the concentration gradient between solute concentrations in the surface of the adsorbent. Asoka and Inamdar [24] reported that 76% of methyl red dye was removed by sugarcane bagasse from aqueous solution with 500g/L adsorbent dose which supports the present study. It was also observed by Raymundo et al. [25] that 500 g/L of sugarcane bagasse removed 80% of congo red dye in aqueous solution.

Natarajan et al. [26] stated that, at lower dye concentration, the ratio of dyes to the available surface area is low subsequently the fractional adsorption become independent of initial concentration. However, at high

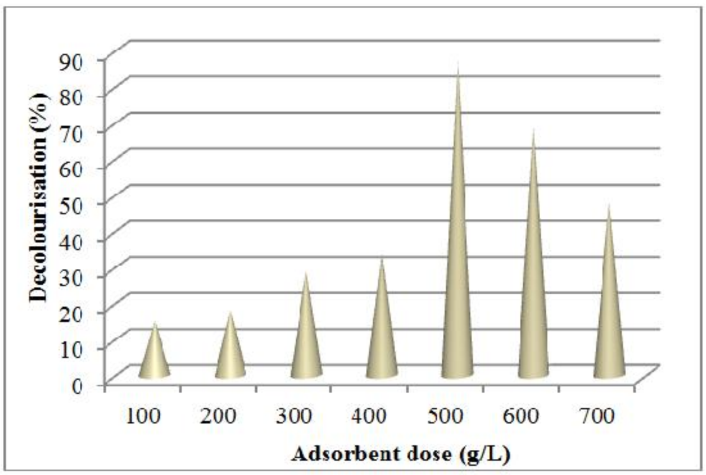


Fig. 1. Effect of adsorbent dose

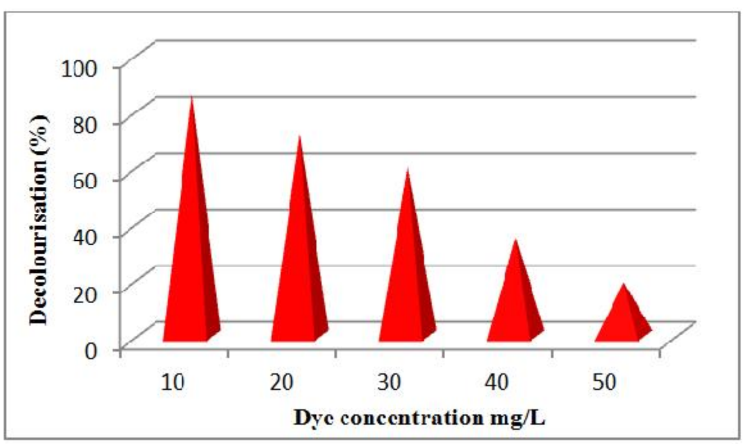


Fig. 2. Effect of dye concentration

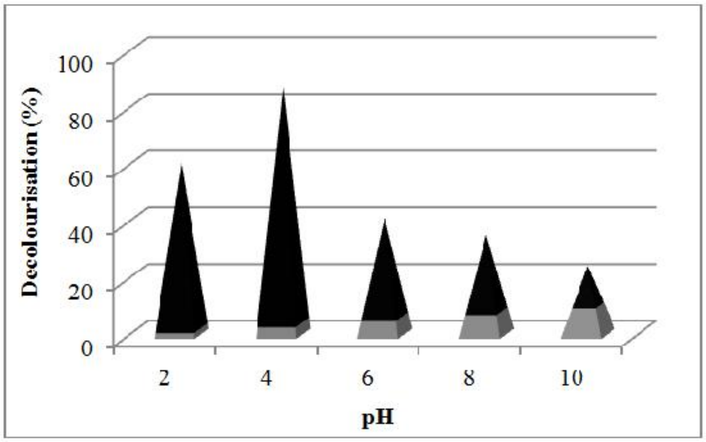


Fig. 3. Effect of Ph

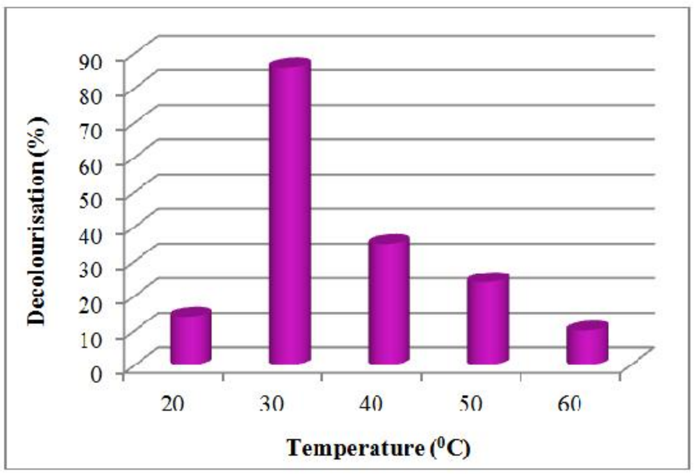


Fig. 4. Effect of temperature

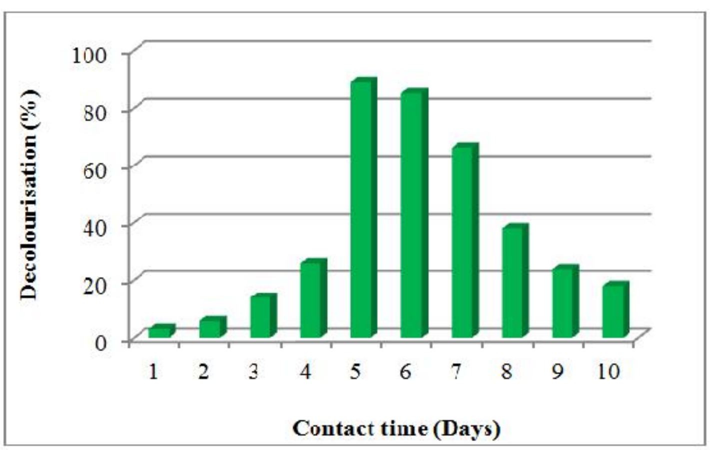


Fig. 5. Effect of contact time

concentration the available sites of adsorption become less and hence the percentage removal of dyes is dependent upon initial concentration. Said et al. [19] reported that 100% dye (methylene blue and orange II) removal was achieved in lower dye concentration (100 mg L^{-1}).

This confirms that the alkaline pH was unfavourable for dye decolourisation by sugarcane bagasse pith which was attributed to the anion exchange reaction between the dye and surface-active groups on the adsorbent [27]. Malik [28] and Mohamed [29] reported that at low pH, the active sites of the adsorbent will be largely protonated and the H^+ ion creates an electrostatic attraction between the adsorbent and the dye molecules which leads to maximum colour removal.

At pH above 4, the degree of protonation on the surface sites will be less which result in the decrease in diffusion and adsorption thereby due to electrostatic repulsion [30,31]. Furthermore, lower adsorption of the dyes in an alkaline medium can also be attributed to the competition from excess hydroxide ions (OH^-) with the anionic dye molecules for the adsorption sites. In this study, the adsorption was unfavorable in acidic pH. This is attributed to the increase in H^+ concentration leading to the formation of aqua complexes thereby retarding the dye sorption. A similar finding was reported by Abdullah et al. [22] who stated that the 82% of methylene red dye uptake was found at acidic pH (4) by

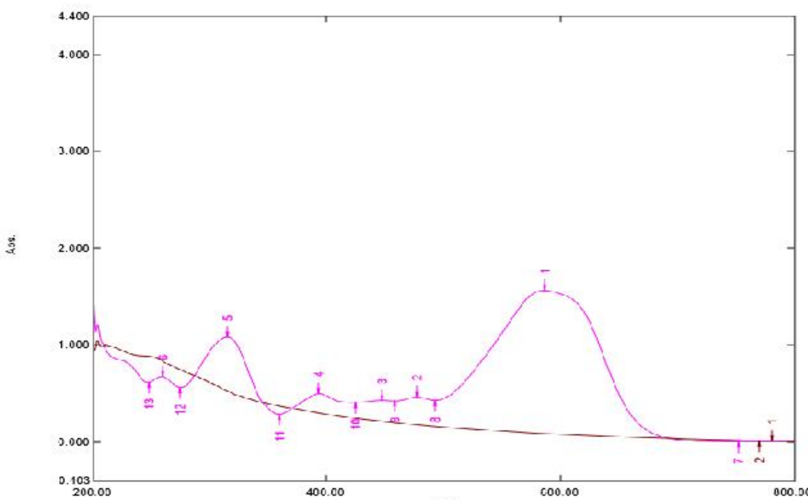
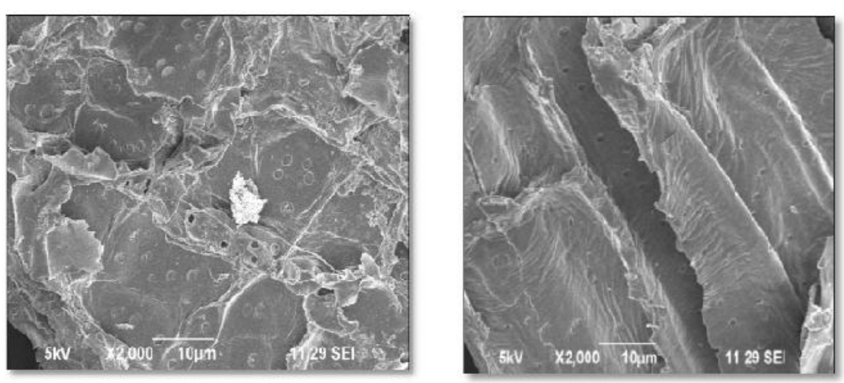


Fig. 6. UV-visible spectra of methyl red dye (before and after decolourisation)



Before decolourisation **After decolourisation**

Fig. 7. SEM image of sugarcane bagasse pith treated with methyl red

Table 1. Optimum conditions for maximum methyl red removal

S. No	Parameters	Adsorption condition	% Adsorption
1	Dye concentration	10g/L	85.62
2	Adsorbent dose	500g/L	87.41
3	pH	4	83.15
4	Temperature	30^0C	86.03
5	Contact time	5^{th} day	88.79

sugarcane bagasse. Adsorption is normally exothermic in nature and the extent and rate of adsorption decrease with increasing temperature of the system [32]. Similar such removal was observed in textile effluent [33] and Foron blue E-Bl [34] at 30°C using sugarcane bagasse.

5. CONCLUSION

Sugarcane bagasse is a farming waste material which is easily available at a low cost and also used as a successful adsorbent for the treatment of dyes in the effluent. The optimization study has been investigated under different experimental conditions for the elimination of dyes from the effluent. The decolourisation of methyl red was dependent relative on the solution pH, dye concentration, adsorbent dose, contact time and temperature. The maximum dye removal was achieved using sugarcane bagasse pith, hence it proves that, to be an outstanding low-cost material in the treatment of textile industrial effluent.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sharma P, Kaur H. Sugarcane bagasse for the removal of erythrosine B and Methylene blue from aqueous waste. Applied Water Science. 2011;3:135- 145.
2. Andleeb S, Atiq N, Ali MI, Razi-UL-Hussain R, Shafique M, Ahmed B, Ghumro PB, Hussain M, Hameed A, Ahmed S. Biological treatment of textile effluent in stirred tank bioreactor'. Int. J. Agric. Biol. 2010;12(2):256–260.
3. Jadhav JP, Phugare SS, Dhanve RS, Jadhav SB. Rapid biodegradation and decolorization of direct orange 39 (orange TGLL) by an isolated bacterium *Pseudomonas aeruginosa* strain BCH. Biodegradation. 2010;21:453–463.
4. Abioye OP, Iroegu VT, Aransiola SA. Biodegradation of methyl red by *Staphylococcus aureus* isolated from waste dump site. Journal of Environmental Science and Technology. 2015;8(3):131-138.
5. Chen H, Zhao J. Adsorption study for removal of congo red anionic dye using organo-attapulgite. Adsorption 2009;15: 381–389.
6. Adowei P, Horsfall M, Spiff AI. Adsorption of methyl red from aqueous solution by activated carbon produced from cassava peel waste. Innov. Sci. Eng. 2012;2:24-33.
7. Fatima N, Hany O, Alamgir A. Decolourization of textile effluent through indigenous microorganism, bulletin of environment. Pharmacology and Life Sciences. 2015;4(5):109-115.
8. Haq I, Bhatti HN, Asgher M. Removal of Solar red BA textile dye from aqueous solution by low cost barley husk: Equilibrium, kinetic and thermodynamic study. Can. J. Chem. Eng. 2011;89:593-600.
9. Asgher M, Bhatti HN. Evaluation of thermodynamics and effect of chemical treatments on sorption potential of citrus waste biomass for removal of anionic dyes from aqueous solutions. Ecol. Eng 2012;38:79-85.
10. Al-Qodah Z. Biosorption of heavy metal ions from aqueous solution of activated sludge. Desalination. 2006;196:164–176.
11. Ardejani FD, Badii K, Limaee NY, Mahmoodi NM, Arami M, Shafaei SZ, Mirhabibi AR. Numerical modeling and laboratory studies on the removal of Direct Red 23 and Direct Red 80 dyes from textile effluents using orange peel, a low cost adsorbent. Dyes Pigment. 2007;73: 178–185.
12. Hameed BH. Spent tea leaves, a new non-conventional and low-cost adsorbent for removal of basic dye from aqueous

solutions. Journal of Hazardous Materials. 2009;161:753–759.

13. Umesh K, Kaur MP, Garg VK, Sud D. Removal of Nickel (II) from aqueous solution by adsorption on agricultural waste biomass using response surface methodological approach. Bio resource Technology. 2008;99:1325–1331.
14. Said A, Aref AM, Mohamed AM, El-Wahab A, Soliman A, Soliman A, Helmey V, Goda N. Potential application of propionic acid modified sugarcane bagasse for removing of basic and acid dyes from industrial wastewater. Resources and Environment. 2012;2(3):93-99.
15. Gupta VK, Jain R, Varshney S, Saini VK. Removal of reactofix navy blue 2 GFN from aqueous solutions using adsorption techniques. J. Colloid Interface Sci 2006;307:326-332.
16. Alkan M, Dogan M. Adsorption kinetics of Victoria blue onto perlite. Fresenius Environ Bull. 2003;125:418-425.
17. Hameed BH, Mahmoud DK, Ahmad AL. Sorption equilibrium and kinetics of basic dye from aqueous solution using banana stalk waste. J. Hazard. Mater. 2008;158: 499-506.
18. Tripathi P, Srivastava VC, Arvind Kumar A. Optimization of an azo dye batch adsorption parameters using Box–Behnken design. Desalination. 2009;249: 1273–1279
19. Wong SY, Tan YP, Abdullah AH, Ong ST. The removal of basic and reactive dyes using quartenised sugarcane bagasse. Journal of Physical Science. 2009;20(1): 59-74.
20. Naveen prasad B S, Govindaraju K, Ganesh kumar V, Uma suganya KS, Vijai Anand K. Graphene from sugarcane extract and its application on organic dyes adsorption. Poll Res. 2015;34(4):803-808.
21. Pham TP, Cho CW, Yun YS. Environmental fate and toxicity of ionic liquids: A review. Water Res. 2015; 44(2):352–372.
22. Abdullah LAG, Mohd Salleh MA, Siti Mazlina MK, Megat Mohd Noor MJ, Osman MR, Wagiran R, Sobri S. Azo dye removal by adsorption using waste biomass: Sugarcane bagasse. International Journal of Engineering and Technology. 2005;2(1):8-13.
23. Subramanian R, Ponnusamy SK. Novel adsorbent from agricultural waste (cashew NUT shell) for methylene blue dye removal: Optimization by response surface methodology. Water Resources and Industry. 2015;11:64-70.
24. Ashoka HS, Inamdar SS. Adsorption removal of methyl red from aqueous solutions with treated sugarcane bagasse and activated carbon – a comparative study. Global Journal of Environmental Research. 2010;4(3):175-182.
25. Raymundo AS, Zanarotto R, Belisário M, Pereira MG, Ribeiro JN, Ribeiro AV. Evaluation of sugar-cane bagasse as bioadsorbent in the textile wastewater treatment contaminated with carcinogenic congo red dye. Brazilian Archives of Biology and Technology. 2010;53(4):931-938.
26. Natarajan ST, Jayaraj R, Thanaraj P, Prasath P. The removal of heavy metal chromium (VI) from aqueous solution by using marine algae *Graciliria edulis.* J. Chem. Pharm. Res. 2011;3(2):595-604.
27. Wu FC, Tseng RL, Juang RS. Comparative adsorption of metal and dyeonflake-and beads-types of chitosan prepared from fishery wastes. Journal of Hazardous Materials B. 2000;73:63–75.
28. Malik PK. Dye removal from wastewater using activated carbon developed from sawdust: Adsorption equilibrium and kinetics. J. Hazard. Mater. 2004;113:81-88.
29. Mohamed MM. Acid dye removal: Comparison of surfactant-modified mesoporous FSM-16 with activated carbon derived from rice husk. J. Colloid Interface Sci. 2004;272:28-34.
30. Khattri SD, Singh MK. Removal of malachite green from dye wastewater using neem sawdust by adsorption. J. Hazard. Mater. 2009;10:101.
31. Baztias FA, Sidiras DK. Dye adsorption by prehydrolysed beech sawdust in batch and fixed-bed systems. Bioresource Technology. 2007;98:1208-1217.
32. Kanawade SM, Gaikwad RW. Removal of dyes from dye effluent by using sugarcane bagasse ash as an adsorbent. International Journal of Chemical Engineering and Applications. 2011;2(3): 101-113.

33. Kadam AA, Lade HS, Patil SM, Govindwar SP. Low cost $CaCl_2$ pretreatment of sugarcane bagasse for enhancement of textile dyes adsorption and subsequent biodegradation of adsorbed dyes under soild state fermentation. Bio-resource Technology. 2013;132:276-284.

34. Zaheer S, Bhatti HN, Sadaf S, Safa Y, Rehman M. Biosorption characteristics of sugarcane bagasse for the removal of foron blue e-bl dye from aqueous solutions. J. Anim. Plant Sciences. 2014;24(1):272-279.

Peer-review history:
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