Removal of crystal violet dye using sugarcane fiber

Siti Kartina ABDUL KARIM, Rabuyah NI, Millaa-Armilla ASLI & Siti Hajijah ISMAIL*

Faculty of Applied Science, Universiti Teknologi MARA, Samarahan 2 Campus, 94300 Kota Samarahan, Sarawak, MALAYSIA.
*Corresponding author: sitik094@sarawak.uitm.edu.my; Tel: +6082678434; Fax: +6082678300

Received: *5 September 2015*
Revised: *22 September 2015*
Accepted: *29 September 2015*
Online: *22 December 2015*

Keywords:
Crystal violet dye, sugarcane fiber.

Abstract

The occurrence of dye in water is a visual nuisance and greatly affects the appearance of water. Use of natural based sorbent, such as sugarcane, can reduce the amount of dye in water without changing it into more toxic substance. In this paper, the effect of sorbent dose, pH and initial concentration was studied towards the percent removal of crystal violet dye in water. A high sorbent dose, up to 50 mg/mL can remove about 95% of this dye in water. Further increase in sorbent dose will only increase the removal slightly, moreover it will also increase the cost of the sorbent. The dye can be removed efficiently even at concentration as low as 200 ppm, where the removal was about 75%. At higher initial concentration, the percent removal increased accordingly. However, the pH did not greatly affect the percent removal. Varying the pH from 3 to 11, the percent removal was changed from about 90% to 95% only.

Introduction

Dye is used in large quantities especially in textile, paint and food industries. Appearance of color increases the esthetic values in any medium it is in. However, the occurrence of color in water is the first visual indicator that the water is polluted.

The conventional methods of removing dye in water are by using photocatalytic degradation (Abramovic *et al*., 2013) and Fenton oxidation (Ersoz, 2014). Photocatalytic degradation and Fenton oxidation are chemical based method that produces toxic byproducts. Thus, adsorption is currently investigated as an alternative as it only involves physical process. Adsorption can be done using commercial activated carbon (Cardoso *et al*., 2012) and natural based adsorbents such as orange waste (Irem *et al*., 2013). Natural based adsorbents are usually selected from plants or animals that are native to the country or region due to cost and avalability factors.

Sugarcane is found easily in Malaysia as it is grown for use directly as drinks or for sugar production. The sugarcane bagasse is thrown as waste and this creates an opportunity to use it as sorbents. It has shown potential as dye sorbents (Noreen & Bhatti, 2014), where it was used to treat Novacron Orange dye.

Therefore, it is the intention of this paper to study the removal of crystal violet dye in water using sugarcane fiber. The effects of sorbent dose, initial concentration and pH were studied to determine the percent removal of this dye in water.

Methodology

Materials

Sugarcane was collected from a roadside stall in Kota Samarahan, Sarawak. The chemicals used were crystal violet dye (Sigma, US), sodium hydroxide (Systerm, Malaysia), and nitric acid (J.T. Baker, Thailand). Crystal violet dye was prepared as 1000 ppm stock solution and diluted as needed. Sodium hydroxide and nitric acid was prepared as 0.1M solution to adjust the pH of solution.

Preparation of Sugarcane Fiber

Sugarcane bagasse collected was dried under the sun for two days, before drying in the oven at 60°C for another two days. Then the sugarcane was washed several times with distilled water before final drying in the oven at 60°C for 24 hours. The sugarcane was then cut into manageable size before grinding. Then it was grinded using analytical mill and sieved to 250 µm. The fiber was then kept in a container before use.

Adsorption Study

The adsorption study was done in conical flask using batch method. In all experiments, 100 mL of dye solution was used at room temperature of 25 ± 2°C using stirring speed of 150 rpm. For study with different sorbent dose, the dye solution was kept constant at 1000 ppm and pH was adjusted at 7. The sorbent dose was varied at 100 mg, 500 mg, 1000 mg, 2000 mg and 5000 mg. For study with initial concentration, the mass of sorbent used was 5000 mg and pH was adjusted at 7. The initial concentration was changed from 200 to 1000 ppm. The last study was done at different pH. The initial concentration was 1000 ppm and mass of sorbent was 5000 mg. The pH was varied from 3, 5, 7, 9 and 11. The percent removal of dye was given using this formula:

$$\text{Percent removal} = \frac{(C_0 - C_e)}{C_0} \, x100 \qquad (1)$$

where C_0 is the initial concentration and C_e is the final concentration.

Result and Discussion

Effect of Sorbent Dose

The sorbent dose used was varied from 100 mg to 5000 mg. A more appropriate representation of this data was given in mass of sorbent/volume of solution. Therefore, the sorbent dosage used was 1 mg/mL, 5 mg/mL, 10 mg/mL, 20 mg/mL and 50 mg/mL. The effect of sorbent dose in crystal violet dye removal is given in Fig 1.

The increase in sorbent dose increased the percent removal of dye in solution. At lower sorbent dose, the increase was not significant. However, as the dose increased to 10 mg/mL, the removal inclined to more than 60 percent. At 50 mg/mL, the removal percentage was found to be ~95%. In batch experiments, it was acceptable as increasing the sorbent dose was not feasible in a small conical flask.

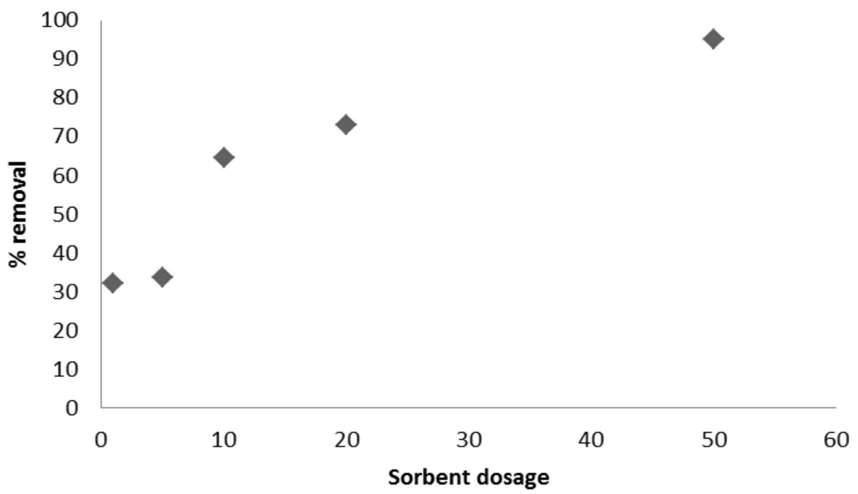

Figure 1: Effect of sorbent dose to percent removal of crystal violet dye

The increase in adsorbent dose have a positive effect to percent removal of dye until its saturation point or critical point, after which the percent removal either stays constant or decreased (Ghaedi *et al*., 2013). From the result, it can be seen that at 50 mg/mL, the removal was already near maximum at ~95%. Increasing the sorbent dose at this point will only increase the removal slightly.

Effect of Initial Concentration

To study this effect, the initial concentration of dye solution was changed between 200 to 1000 ppm. The effect of different initial concentration is illustrated in Fig 2.

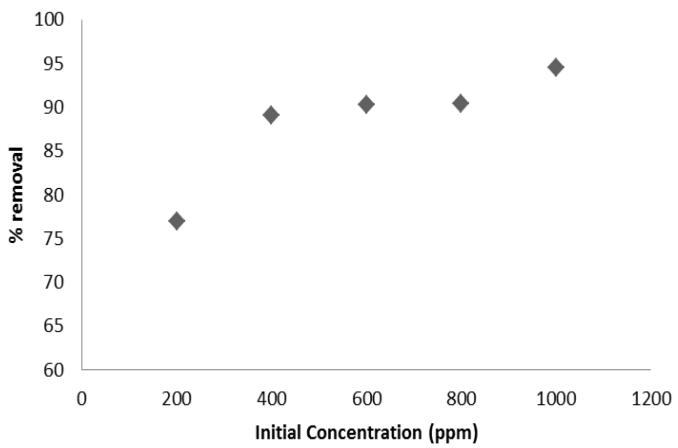

Figure 2: Effect of initial concentration to percent removal of crystal violet dye

At initial concentration of 200 ppm, the percent removal of crystal violet dye was quite high, at approximately 75 percent. At higher initial concentration, the dye removal was consistently about 90 percent, until 800 ppm. At 1000 ppm, the removal of dye reached about 95%.

The higher initial concentration provides a larger driving force needed for adsorption process (Ozer *et al*., 2006). Thus, it can be seen that higher percent removal of dye was achieved at higher initial concentration. Nonetheless, the removal of this dye at lower initial concentration (200 ppm) shows potential use as removal of lower dye concentration in water.

Effect of pH

The effect of pH was studied by varying the pH from 3 to 11. The results are shown in Fig 3. From Fig 3, it can be seen that at very low or very high pH, the percent removal of dye declined to about 90%. The removal of crystal violet dye was best achieved at neutral or slightly basic medium, where the removal was between 93 to 95%. That said, it seems that pH does not affect the percent removal greatly, as the difference between the highest removal to the lowest was less than 10 percent.

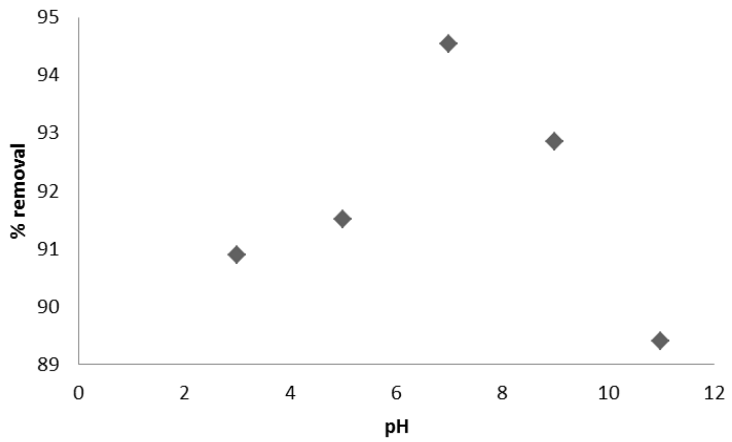

Figure 3 : Effect of pH to percent removal of crystal violet dye

Cationic dye such as crystal violet will favour the higher pH as the surface of sorbent is negatively charged (Khataee *et al*., 2013). This will attract the positive functional group in crystal violet dye.

Conclusion

The effect of three different variables towards removal of crystal violet dye in water was studied using sugarcane fiber. High sorbent dosage, high initial concentration and slightly basic pH favors the removal of dye using this fiber. Sugarcane fiber shows great potential to be used as sorbent, due to high removal of dye at favorable condition.

Acknowledgements

Authors are highly thankful to the Faculty of Applied Science, Universiti Teknologi MARA, Sarawak Branch for the facility specially instrument usage.

References

Abramovic, B.F., Despotovic, V.N., Sojic, D.V.,Orcic, D.Z., Csanadi, J.J. & Cetojevic-Simin, D.D. 2013. Photocatalytic degradation of the herbicide clomazone in natural water using TiO_2:Kinetics, mechanism, and toxicity of degradation products. *Chemosphere*. **93**(1):166-171.

Cardoso, N.F., Lima, E.C., Royer, B., Bach, M.V., Dotto, G. I., Pinto L. A. & Calvete, T. 2012. Comparison of spirulina platensis microalgae and commercial activated carbon as adsorbents for the removal of reactive red 120 dye from aqueous effluents. *Journal of Hazardous Materials.* **241-242**:146-153.

Ersoz, G. 2014. Fenton-like oxidation of reactive black 5 using rice husk ash based catalyst. *Applied Catalysis B:Environmental.* **147**:353-358.

Ghaedi, A. M., Abdi, F., Roosta, M., Vafaei, A. & Afghari, A. 2013. Principal component analysis-adaptive neuro-fuzzy inference system modeling and genetic algorithm optimization of adsorption optimization of adsorption of methylene blue by activated carbon derived from pistacia khinjuk. *Ecotoxicology and Environmental Safety.* **96**:110-117.

Irem, S., Mahmood Khan, Q., Islam, E., Jamal Hashmat, A., Anwarul Haq, M., Afzal, M. & Mustafa, T. 2013. Enhanced removal of reactive navy blue dye using powdered orange waste. *Ecological Engineering.* **58**:399-405.

Khataee, A. R., Vafaei, F. & Jannatkhah, M. 2013. Biosorption of three textile dyes from contaminated water by filamentous spirogyra sp:Kinetic, isotherm and thermodynamic studies. *International Biodeterioration and Biodegradation.* **83**:33-40.

Noreen, S. & Bhatti, H.N. 2014. Fitting of equilibrium and kinetic data for the removal of novacron orange p-2r by sugarcane bagasse. *Journal of Industrial and Engineering Chemistry.* **20**(4):1684-1692.

Ozer, A., Akkaya, G. & Turabik, M. 2006. The removal of acid red 274 from wastewater:Combined biosorption and biocoagulation with spirogyra rhizopus. *Dyes and Pigments.* **71**(2):83-89.