ADSORPTIVE REMOVAL OF CONGO RED DYE FROM AQUEOUS SOLUTION USING ALOE VERA AS A BIOSORBENT

Sidharth Santhoshkumar Vishnu
Department of Chemical Engineering
Amal Jyothi College of Engineering
Kanjirappally, India
sidvishnu9@gmail.com

Aleena Manoj
Department of Chemical Engineering
Amal Jyothi College of Engineering
Kanjirappally, India
aleenamanoj2023@ch.ajce.in

Gokul Krishnan
Department of Chemical Engineering
Amal Jyothi College of Engineering
Kanjirappally, India
gokulkrishnan93001@gmail.com

Dr. Jerin Jose
Department of Chemical Engineering
Amal Jyothi College of Engineering
Kanjirappally, India
jerin.jose@amaljyothi.ac.in

***Abstract*— Effluent generated from textile and paper industries contains a lot of toxic, carcinogenic, and teratogenic pigments. Azo dyes are one major category among them, which degrade and liberate aromatic amines, a class of chemical that raises the risk of cancer. Congo red (CR) is a commonly used diazo dye in various industries, but it is known to cause cancer, mutagenesis, and other toxicities to flora, wildlife, and humans and hence it is necessary to remove CR from industrial wastewater. Green adsorbents based on agricultural waste products provides a double advantage of eliminating the pollutants and management of agricultural residues. This project aims to create a green adsorbent from Aloe Vera (AV) waste to remove CR from samples of polluted water easily, affordably, and effectively as well as optimizing the adsorption process and improving the removal capability of AV leaves. In this work we use AR rind powder as the biosorbent to remove an azo dye Congo red from aqueous solutions using batch experiment procedures. Adsorption parameters such as contact time, CR concentration, AV dosage and pH were studied to determine the efficiency of CR dye removal. The time required for contact time equilibrium was 60 minutes. An AV dosage of 1.5g/L could remove almost 43ppm of CR dye from its 50 ppm solution giving an utmost efficiency of 85.30% for untreated leaves.**

Keywords—Congo Red, Aloe Vera, Adsorption, biosorbents, industrial waste.

I. INTRODUCTION

The rapid industrialisation leads to the generation of various complex effluents which have harmful impacts on the environment. Emergence of industries such as paper and pulp, pharmacy, textile industries lead to the release of various dyes and many of them are non-biodegradable organic compounds These dyes up on breaking down release by-products that are carcinogenic and mutagenic to living beings. Congo Red (CR) [1-naphthalenesulfonic acid, bis (4-amino-) disodium salt, 3, 3 - (4, 4 -biphenyl bis (azo)] is an anionic diazo dye and it is a benzidine-based compound. Congo red is widely used in Textile, printing, dyeing, paper, and plastic industries. This anionic dye has the potential to be metabolised into benzidine, a recognized human carcinogen. Due to this dye's complex aromatic structure, which provides physicochemical, thermal, and optical stability, as well as resistance to biodegradation and photodegradation, the treatment of CR polluted wastewater can be problematic. Adsorption, coagulation/flocculation, advanced oxidation processes, ozonation, membrane filtration, and biological treatment are some of the methods that have been developed and utilised to remove dye pollutants from wastewater. Adsorption has been identified as the most common treatment procedure for the elimination of dyes in aqueous solution due to its high efficiency, simple operation, and ease of adsorbent recovery and reuse. Activated carbon adsorption is highly efficient in removing organic and inorganic pollutants such as dyes and pigments. However, it has limitations of high cost and difficulties in regeneration. Compared to AC, biosorbents have the advantages of bulk availability, inexpensiveness, and easy regeneration, and hence, they are intensively researched. The aim of this study is to assess the ability of locally accessible Aloe Vera (AV) rind powder to remove CR from water. Aloe Vera is easily available and its rind is considered as a bio-waste, hence it makes a cheaper biosorbent for dye removal. The study sought to determine how process operating factors such as initial dye concentration, adsorbent dose, pH, and contact time impact the adsorption capacity of Aloe Vera based biosorbent.

II. MATERIALS & METHODS

A. Adsorbent

Fresh Aloe Vera leaves were obtained from local markets as well as from surrounding fields. The freshly cut Aloe Vera leaves were first cleaned with fresh water and the inner sap was removed. The rind was cut into small pieces and then cleaned with distilled water. It was then dried under sunlight for 12h and then dried in a hot air oven at 80ºC for 2hrs. The dried Aloe Vera rind was ground to powder from and then sieved to obtain an average particle size of 90µm. The powder was kept in an airtight container for future use

B. Chemicals

Congo Red (CR) (Direct Red 28, C.I. 22120, azo dye, $C_{32}H_{22}N_6Na_2O_6S_2$, molecular weight 696.7g) was selected as anionic dye. The pH was adjusted with 0.1N NaOH or 0.1N HCl solutions. All chemicals were of analytical grade. The dye solutions were prepared by diluting a stock CR solution (100mgL^{-1}) with distilled water.

C. Batch Adsorption Experiment

Batch adsorption experiments were conducted in a 250 mL conical flask using an orbital shaker. Working concentration solutions of CR were prepared by appropriate dilution. All adsorption experiments were conducted at room temperature of 300 K and stirring rate of 120 rpm. The flask was constantly agitated using a shaker at 120 rpm with initial dye concentrations of 5, 10, 20, 30 and 50mgL−1 to study the effect of initial dye concentration. The effect of contact time on the sorption was investigated at a dye concentration (50 mg/L) and biosorbent dosage of (1.5 g/L) from 30 min to 90 min. The effect of CR on solution pH was investigated at different initial pH values (2-6). Each flask was filled with 100 mL (50 mg/L) CR solution and the amount of AV added was 0.1 g. The pH of the CR solution was adjusted by adding 0.1N HCl or 0.1N NaOH solution. Effect of AV dosage was performed by varying the weight of AV (0.05-0.25 g) in 100 mL CR solutions, while the pH and concentration of MB were kept constant at 5 and 50 mg/L, respectively. After predetermined time intervals, samples collected were centrifuged at 2000 rpm for 3min. The supernatant was analysed for residual dye concentration using a UV-Visible spectrophotometer (UV 1800, Shimadzu, Japan) at a wavelength, λmax = 498 nm. The total concentration of the dye adsorbed per adsorbent mass was calculated using the following equation:

$$q_t = \frac{(C_o - C_t)V}{W}$$

where, q_t is the amount of the dye adsorbed (mg g^{-1}) at time t (min). C_o and C_t represent the dye concentrations (mg L^{-1}) at zero time and at any time t in the solution respectively. V is the volume of the solution (L) and W is the mass of the adsorbent (g). Efficiency is calculated using the following equation:

$$Efficiency(\%) = \frac{C_o - C_t}{C_o} \times 100$$

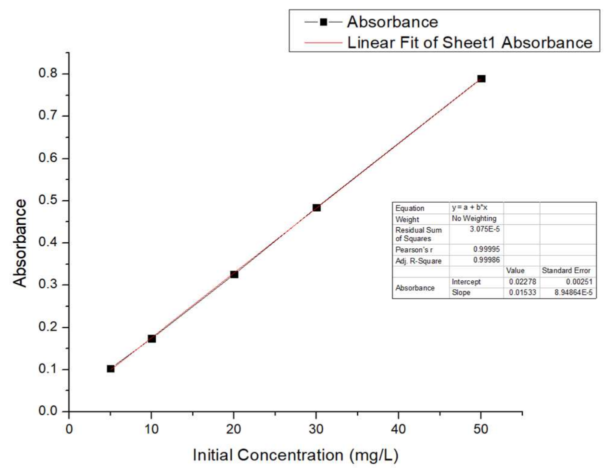

Fig. 1. Calibration Curve

III. RESULTS & DISCUSSION

The calibration curve is plotted using 5, 10, 20, 30 and 50 mg/L of concentration of Congo red dye with absorbance as shown in Fig 1. The absorbance is determined using a UV visible spectrometer and is a crucial factor in determination of the efficiency of the process. The linear plot is obtained for the curve with R^2 (goodness to fit) value of 0.9999 and equation,

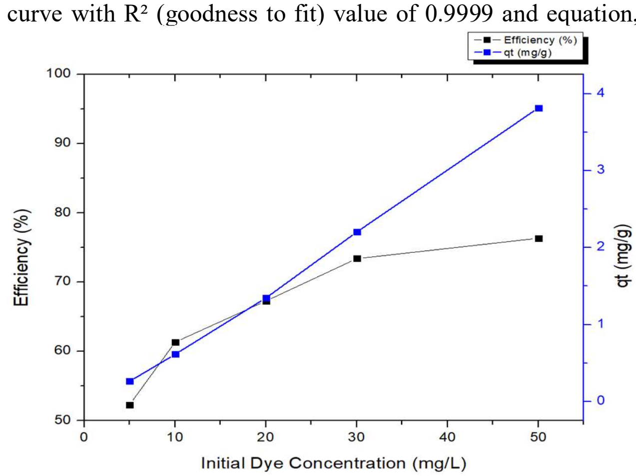

Fig. 2. Effect of Initial Dye Concentration

y=0.0153x + 0.0228. This calibration curve is used to determine other efficiencies by the same procedure by interpolating the graph to determine the respective concentration through the given absorbance value.

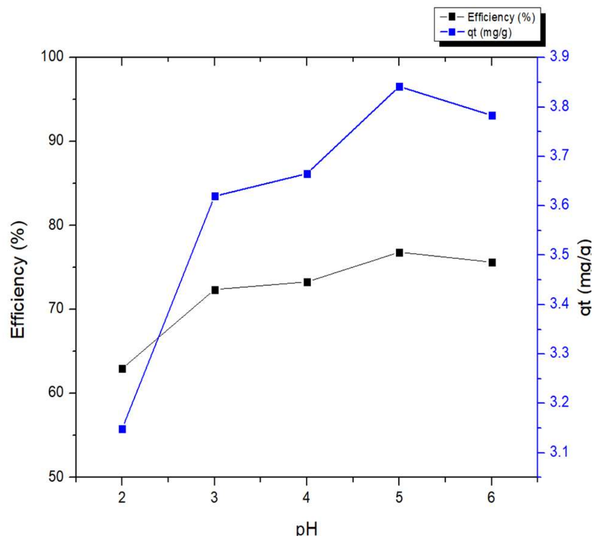

Fig. 3. Effect of pH on CR dye removal

A. Effect of Initial Dye Concentration

Initial dye concentration has played a significant role in the sorption process. The effect of dye concentration (5–50mg/L) on the sorption process was studied. It was revealed that the removal efficiency declined from 90.11% to 87.13% with increased in concentration from 5 to 50mg/L as shown in Fig 2. With the study of concentration, we chose 50 mg/L as our optimum dye concentration for the study so as to increase the efficiency of AV rind powder.

B. Effect of pH

Looking into the pH studies, CR is an anionic diazo dye. Optimum pH at which maximum adsorption takes place will be at acidic pH.

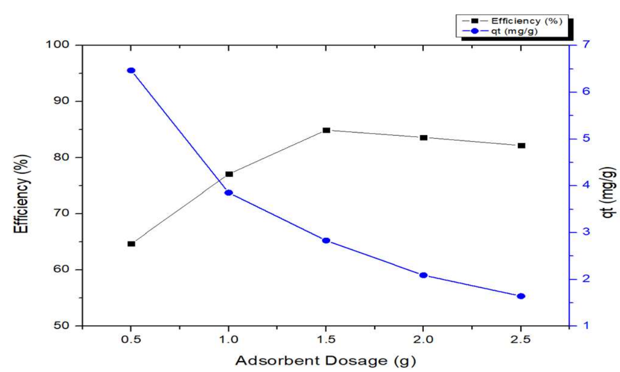

Fig. 4. Effect of Adsorbent Dosage

For acidic solutions the surface of adsorbent is positively charged and is beneficial for the adsorption due to the increase in electrostatic interactions of anionic dyes with it. By studying the variation of efficiency at various pH levels, this was confirmed as we obtained maximum adsorption at a pH of 5 as shown in Fig. 3. Further studies were conducted at an optimum pH of 5 to obtain the maximum efficiency.

C. Effect of Adsorbent Dosage

On studying the effect of adsorbent dosage as shown in Fig. 4 on CR dye removal, we see a rise and then a fall in the curve which shows adsorption efficiency decreases as the adsorbent dosage increases is that the solute concentration on the surface of the adsorbent is higher than the solute concentration in the solution. Therefore, as the mass of the adsorbent grows, the number of adsorbate absorbed per unit weight of adsorbent drops, this results in a decrease in q_e value as the concentration of the adsorbent mass increases.

D. Effect of Contact Time

The effect of contact time on the sorption was investigated at optimized condition of dye concentration (50 mg/L) and amount of biosorbent dosage (1.5 g/L) from 15 to 90 min. The adsorption efficiency increased from 78.52% to 85.73%, as the contact time varied from 15 to 60min as shown in Fig. 5. After 60mins, a small decrease in efficiency was observed. As adsorption takes place, adsorbates attach to adsorbent active sites, number of active sites decreases, and probability of adsorption decreases. It happens when adsorbate molecules and adsorbent active sites are of comparable population, unlike the case of dilute adsorbate concentration. Initial increase in the efficiency occurs due to the rapid adsorption of CR by the surface of biosorbent followed by slow diffusion of ions from the surface to the adsorption sites in the micropores which are less accessible, due to which an equilibrium will probably be attained with further increase in contact time.

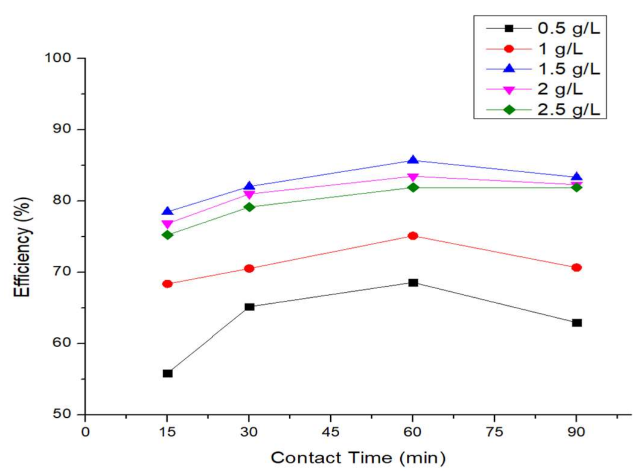

Fig. 5. Effect of Contact Time

IV. CONCLUSION

Biosorption has shown to be cost effective and potential technology for removing a variety of pollutants from water and wastewater. Compared to other technologies, biosorption seems as a potential process because of its advantages such as low-cost of operation, ease of handling, non-generation of secondary pollutants like toxic sludge, and high efficiency over a variety of pollutants. Choosing AV rind as the biosorbent we create a sustainable solution for the removal of various pollutants from the environment. The current study demonstrated the feasibility of employing AV rind powder as an adsorbent for Congo red dye removal from water. The concentration was determined with the use of a UV visible spectrometer. Adsorbent dosage, contact duration, pH, and starting CR dye concentration were all investigated. The results showed that raising the CR starting concentration, pH, and contact duration enhanced the CR dye adsorption capability. Otherwise, when the adsorbent dosage increased, the adsorption capacity decreased. The Congo red dye was maximally adsorbed at an adsorbent concentration of 1.5 g/L at a pH of 5, with an efficiency of 85.73%. As a result of its bulk availability and low cost of production, we may conclude that untreated AV is a promising bio adsorbent for Congo Red removal. A kinetic study and adsorption isotherm investigations are being conducted to choose the best one to follow the results. Expecting a good result in the column adsorption can make this process to be used widely in industries as a low cost, non- toxic and high uptake capacity biosorbent. Industry level utilization of this biosorbent can be really effective as the waste product of one industry is applied to be a useful material for the other.

References

[1] Mohammad Malakootian, Hossein Jafari Mansoorian, Ahmadreza Yari (June 2014),Removal of reactive dyes from aqueous solutions by a non-conventional and low cost agricultural waste: adsorption on ash of Aloe Vera plant, Iranian Journal of Health, Safety & Environment, Vol.1, No.3, pp.117-125.

[2] Thet Thet Wai, Ei Mon Aung, Nyein Chan Kyaw (August 2019)"Potential of Neem Leaf Powder as Bio-Adsorbents for Dye Colour Removal", International Journal of Trend in Scientific Research and

[3] Development(ijtsrd), ISSN: 2456-6470, Volume-3 Issue-5, pp.2502-2505, https://doi.org/10.31142/ijtsrd27987

[4] Mustafa T. Yagub, Tushar Kanti Sen, Sharmeen Afroze, and H.M. Ang (April 2014), Dye and its removal from aqueous solution by adsorption: A review, Advances in Colloid and Interface Science.

[5] Reena Malik, Suman Lata and Sushila Singha (2015), Removal of heavy metal from wastewater by the use of modified Aloe vera leaf powder, International Journal of Basic and Applied Chemical Sciences ISSN: 2277-2073

[6] K. C. Rani, Aduja Naik, Ram Saran Chaurasiya and K. S. M. S. Raghavarao,(2017), Removal of toxic Congo red dye from water employing low-cost coconut residual fiber.

[7] Omidi Khaniabadi Y, Mohammadi MJ, Shegerd M, Sadeghi S, Saeedi S and Basiri H. (2017), Removal of Congo red dye from aqueous solutions by a low-cost adsorbent: activated carbon prepared from Aloe vera leaves shell. Environmental Health Engineering and Management Journal 2017; 4(1): 29–35. doi: 10.15171/ EHEM.2017.05.

[8] Megat Ahmad Kamal Megat Hanafiah, Siti Zubaidah Mohd Jamaludin, Khadijah Khalid and Shariff Ibrahim, (February 2018) Methylene Blue Adsorption on Aloe vera Rind Powder: Kinetics, Isotherm and Mechanism, Nature Environment and Pollution Technology, Vol.17 No. 4.

[9] Malakootian, M., Jafari Mansoorian, H., & Yari, A. (2014). Removal of reactive dyes from aqueous solutions by a non conventional and low cost agricultural waste: adsorption on ash of Aloe Vera plant. Iranian Journal of Health, Safety and Environment, 1(3), 117-125. http://www.ijhse.ir/index.php/IJHSE/article/view/52.

[10] Al Hamadi, A., Uraz, G., Katırcıoğlu, H. & Osmanağaoğlu, Ö. (2017). Adsorption of Azo Dyes from Textile Wastewater by Spirulina Platensis. Eurasian Journal of Environmental Research, 1 (1), 19-27. Retrieved from https://dergipark.org.tr/en/pub/ejere/issue/31884/334653

[11] Deepak Pathania, Arush Sharma, Zia-Mahmood Siddiqi (2016), Removal of Congo Red Dye from Aqueous System Using Phoenix Dactylifera Seeds, Journal of Molecular Liquids, Volume 219, 2016, Pages 359-367, ISSN 0167-7322, https://doi.org/10.1016/j.molliq.2016.03.020.

[12] Malik, Reena & Lata, Suman & Singhal, Sushila. (2015). Removal of Heavy Metal from Waste Water by the Use of Modified Aloe Vera Leaf Powder. 5. 2277-20736.

[13] Rajeev Jain & Shalini Sikarwar (2010), Adsorptive and Desorption Studies on Toxic Dye Erioglaucine Over Deoiled Mustard, Journal of Dispersion Science and Technology, 31:7, 883-893, DOI: 10.1080/01932690903223872

[14] Rakesh Kumar Vij, V. Aruna Janani, Deepalakshmi Subramanian, Chintan R. Mistry, Gokul Devara and Sivakumar Pandian (2021), Equilibrium, kinetic and thermodynamic studies for the removal of Reactive Red dye 120 using Hydrilla verticillata biomass: A batch and column study, Environmental Technology & Innovation, Volume 24, 102009, ISSN 2352-1864, https://doi.org/10.1016/j.eti.2021.102009