DIJBAR
www.daagu.org
Volume-3 Issue-1

STUDY ON CHARACTERISATION FOR THE REMOVAL OF CRYSTAL VIOLET DYE FROM INDUSTRIAL WASTEWATER USING SPATHODEA CAMPANULATA LEAVES--SEM, FTIR, XRD ANALYSES.

Ravi Kumar M[1*], King P[2], Zinabu Wolde[3], Melkamu Mulu[4], Anwar Fole[5]

ABSTRACT

The objective of the present study is to remove crystal violet (CV) dye from their industrial waste water using *Spathodea campanulata* leaves powder as low cost biosorbent in a batch study. The effects of parameters were contact time, solution pH, initial CV dye concentration, biosorbent dosage, average particle size of the biosorbent and temperature. Scanning electron microscope (SEM) analysis is used to investigate the surface morphology of the biosorbent. The morphological characterization of the *Spathodea Campanulata* leaves biosorbent before and after biosorption of crystal violet was studied. The Fourier transform infrared spectroscopy (FTIR) provides structural and compositional information on the functional groups present in the biosorbent. The functional groups present in the *Spathodea Campanulata* leaves biosorbent before and after biosorption of crystal violet was investigated within the range of 400 – 4000cm^{-1} wave number. The analysis of Fourier transform infrared spectrum shows the presence of large number of functional groups present on the surface of the *Spathodea Campanulata* leaves biosorbent. XRD patterns for crystal violet treated powder exhibit more amorphous nature and increase in surface area and porosity. The maximum removal efficiency was predicted to be 89% for crystal violet, which was obtained at a temperature of 303.28 K, solution pH of 6.06, initial dye concentration of 20.09 mg/L and biosorbent dosage of 1.50g, on to *spathodea campanulata* leaves.

Keywords: Crystal violet, *Spathodea Campanulata*, SEM, FTIR, XRD.

Citation: Ravi Kumar M, King P, Zinabu Wolde, Melkamu Mulu, Anwar Fole (2021). STUDY ON CHARACTERISATION FOR THE REMOVAL OF CRYSTAL VIOLET DYE FROM INDUSTRIAL WASTEWATER USING SPATHODEA CAMPANULATA LEAVES--SEM, FTIR, XRD ANALYSES. Daagu International Journal of Basic & Applied Research-DIJBAR. Volume3, Issue-1, pp (38-51)

Corresponding Author: Ravi Kumar M

Email: kumar4611@gmail.com

Received: 26/03/2021

Accepted: 07/06/2021

Published: 28/06/2021

OPEN ACCESS

[1]Department of Chemical Engineering, College of Engineering and Technology, Samara University, Afar, Ethiopia.
[2]Environmental Pollution Control Engineering Laboratory, Department of Chemical Engineering, Andhra University College of Engineering, Visakhapatnam - 530003, Andhra Pradesh, INDIA.
[3,4,5]Department of Chemical Engineering, College of Engineering and Technology, Wachemo University, Hosanna, Ethiopia

1. INTRODUCTION

Water is an irreplaceable natural resource on this earth on which all life depends. As a valuable natural resource, it comprises marine, estuarine, fresh water (river and lake) and ground water environments, across costal and inlands areas. Even though there is a huge water resource in this world, about 97% of water is salt water (marine) and only 3% is fresh water, and in this small fraction of fresh water most of it is locked up in polar ice caps and just 0.003% is readily available to us in the form of ground water and surface water. Fresh water is a limited resource in many parts of the world. And this will become more dearths due to increasing in population, urbanization and climate change. The major fact for this paucity of fresh water is not only due to demand for water but also due to pollution in fresh water ecosystem. Dyes are also used in industries such as rubber, paper and pulp dye and dye intermediate industries, pharmaceutical, tannery, food technology, hair colouring, plastic, cosmetic, etc. There are more than 10,000 commercially available dyes with over 7 lakh times of dyestuff being produced annually across the world **[1]**. The textile industry consumes more than 107 kg of die per year of which 90% ending upon fabrics **[2]**. Of this total usage 10 to 15% of the die is lost during the dying process and released with effluent. Colour is contributed by phenolic compounds such as tannins, lignans (two to three percent) and organic colorants (three to four percent) and with a maximum contributions from dye and dye intermediates which could be sulphur or mordant / reactive / cationic / disperse / acid / azo vat die **[3]**. Crystal violet has antibacterial, antifungal, and anthelmintic properties and was formerly important as a topical antiseptic. The medical use of the dye has been largely superseded by more modern drugs, although it is still listed by the World Health Organization. Crystal violet when dissolved in water has a blue-violet colour with an absorbance maximum at 590 nm. The functional groups on the surface of the biosorbents that contribute to the biosorption are characterized using Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD) analyses.

2. MATERIALS AND METHODS

2.1. Preparation of dye solution

Stock of crystal violet concentration 1000 mg/L was prepared by dissolving 1 g of 100% crystal violet in 1000 ml of distilled water. The solution was prepared using standard flasks. The range of concentration of the prepared dye solutions varied between 20 and 200 mg/L was prepared using the stock solution of individual dye.

2.2. Preparation of bio sorbent

The green colored *Spathodea campanulata* leaves used in the present study were collected from the college of Engineering, Andhra University, Visakhapatnam, India.

The collected leaves were washed with deionised water several times to remove dirt particles. The washing process was continued till the wash water contains no dirt. The washed leaves were then completely dried in sunlight for 20 days. The dried leaves were then cut into small pieces and powdered using domestic mixie. In the present study the powdered materials in the range of 53–152 μm particle size were directly used as biosorbents without any pretreatment.

3. RESULTS AND DISCUSSION

3.1. Effect of contact time

The percentage of biosorption was determined at different contact times and the results are shown in Fig1. The figure reveals that the percentage of biosorption of crystal violet was steeply increased with an increase in contact time from 5 to 30 min and there after reached plateau after attaining equilibrium 30 min for crystal violet. Therefore, contact time of 30 min is sufficient for the removal of crystal violet under the experimental conditions used in this study. The percentage of biosorption of *Spathodea campanulata* leaves as biosorbent for crystal violet dye removal was increased from 12 to 66%, with an increase in contact time from 5 to 30 min for an initial dye concentration of 20 mg/L. For 200 mg/L, the percentage of biosorption increased from 7.5 to 59 %, respectively with an increase in contact time from 5 to 30 min**.**

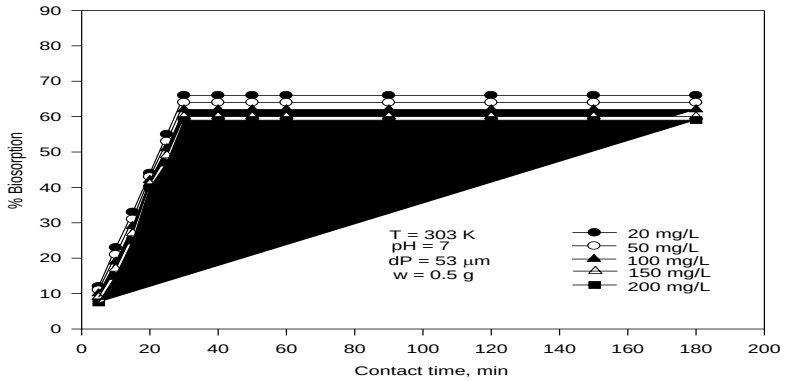


Figure.1. Effect of contact time on % biosorption of Crystal violet using *Spathodea Campanulata* leaves as biosorbent.

3.2. Effect of solution pH

The solution pH is one of the important controlling parameters of the biosorption process. The effect of solution pH on % biosorption for the removal of crystal violet dye was shown in the Fig.2. It was observed that the increase in solution pH from 2 to 6 for Crystal violet resulted in an increase in percentage of biosorption from 39 to 75% for Crystal violet for an initial concentration of 20 mg/L. For an initial concentration of 200 mg/L, the percentage of biosorption was increased from 33 to 68 % for Crystal violet with an increase in solution pH from 2 to 6**.**

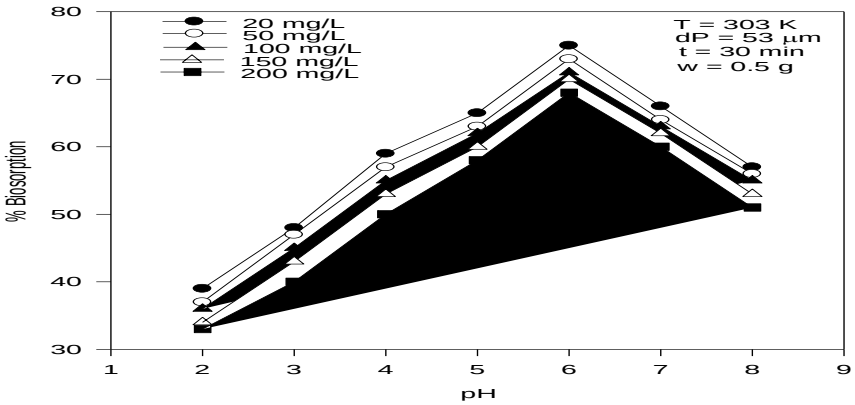


Figure.2. Effect of solution pH on % biosorption of Crystal violet using *Spathodea Campanulata* leaves as biosorbent

3.3. Effect of initial concentration of dye

The effect of initial dye concentration on the percentage of biosorption is shown in Fig.3. It is evident from the figure that the percentage of biosorption decreased with an increase in initial concentration of dye from 20 to 200 mg/L at all temperatures. The percentage of biosorption of Crystal violet decreased from 71 to 42 % and 76 to 47 for Crystal violet with an increase in initial concentration of Crystal violet from 20 to 200 mg/L at the temperature of 283 K and 323 K, respectively**.**

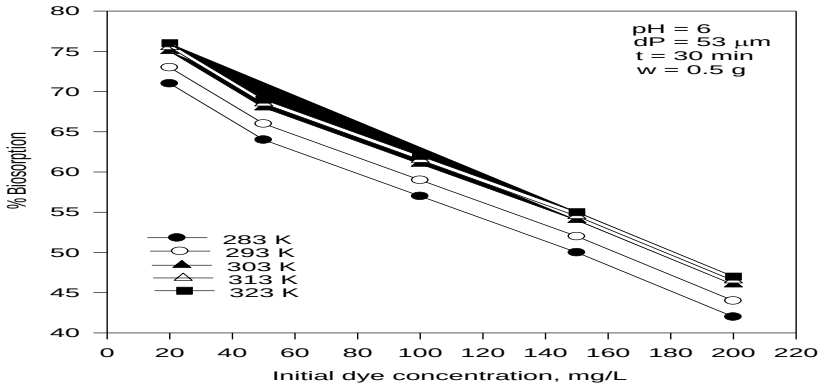


Figure.3. Effect of initial concentration of dye on % biosorption of Crystal violet using *Spathodea Campanulata* leaves as biosorbent.

3.4. Effect of biosorbent dosage

The result obtained is shown in Fig.4, illustrate that the percentage of biosorption was increased with an increase in biosorbent dosage. The percentage of biosorption

increased from 75 to 86 % from biosorbent dosage 0.5 to 4 g for an initial concentration of crystal violet 20 mg/L. For an initial concentration of crystal violet 200 mg/L, the percentage of biosorption increased from 67 to 79% from biosorbent dosage 0.5 to 4g**.**

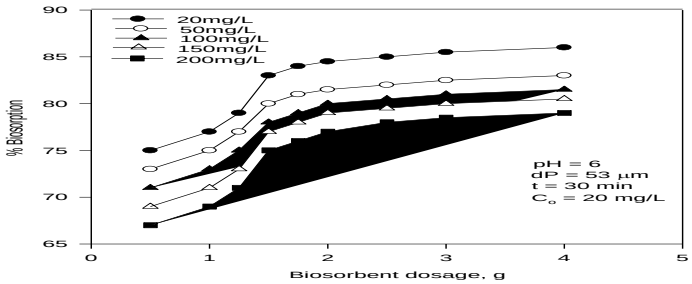


Figure.4. Effect of biosorbent dosage on % biosorption of Crystal violet using *Spathodea Campanulata* leaves as biosorbent.

3.5. Effect of particle size of biosorbent

The result obtained is shown in Fig.5. The result indicated that the percentage of biosorption was decreased with an increase in average particle size of biosorbent. The percentage of biosorption decreased from 83 to 60 % and 75 to 52% with an increase in average particle size of biosorbent from 53 to 152 μm for an initial concentration of crystal violet 20 mg /L and 200 mg/L, respectively**.**

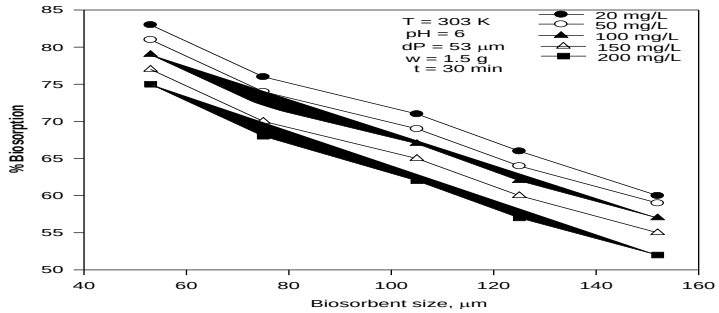


Figure.5. Effect of average particle size on % biosorption of Crystal violet onto *Spathodea Campanulata* leaves biosorbent.

3.6. Effect of Temperature

The result obtained is shown in Fig.6: The figure indicated that the percentage of biosorption was increased with an increase in temperature of the solution. This suggests the endothermic nature of the biosorption process. The percentage of biosorption increased from 80 to 85% and 72 to 77% with an increase in solution temperature from 283 K to 323 K for an initial concentration of Crystal violet 20 mg /L and 200 mg/L, respectively**.**

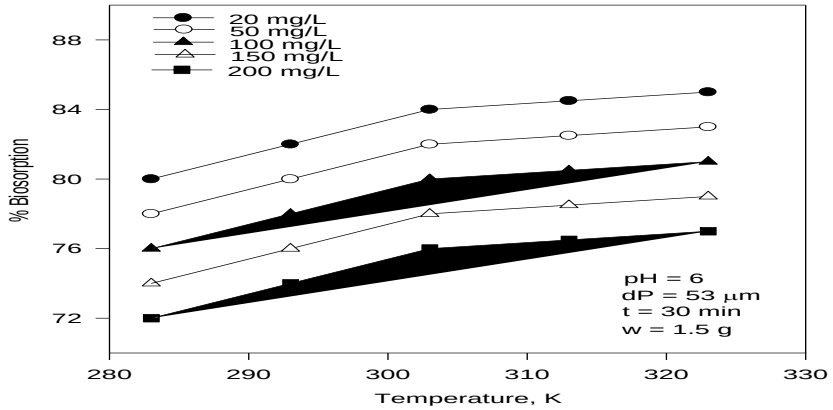


Figure.6. Effect of temperature on % biosorption of Crystal violet onto *Spathodea Campanulata* leaves biosorbent

3.7. Characterization of Spathodea Campanulata leaves biosorbent using SEM, FTIR and XRD analyses

3.7.1. Scanning Electron Microscopy (SEM)

Scanning electron microscopy (SEM) analysis is used to investigate the surface morphology of a biosorbent. The morphological characterization of the *Spathodea Campanulata* leaves biosorbent before and after biosorption of crystal violet was studied by SEM and micrographs are shown in Figs. 7 - 8. Raw biosorbent i.e before biosorption of dye shown in Fig.7. represents a highly porous and heterogeneous morphology, which indicates that the *Spathodea Campanulata* leaves biosorbent has good biosorption capacity of dye molecules on the surface of the biosorbent. It is evident from this figure that the surface of the biosorbent is rough. SEM micrographs of the biosorbent after biosorption of crystal violet dye is shown in Fig.8. These figures showed a significant difference with that of micrograph of raw biosorbent. It is evident from these figures that the surface texture of Spathodea Campanulata leaves biosorbent is completely changed before and after biosorption of dyes. It is clear from these figures that the pores of the biosorbent were completely filled with dye molecules. Therefore, the surface of the *Spathodea Campanulata* leaves biosorbent after biosorption of crystal violet is appeared to be smooth**.**

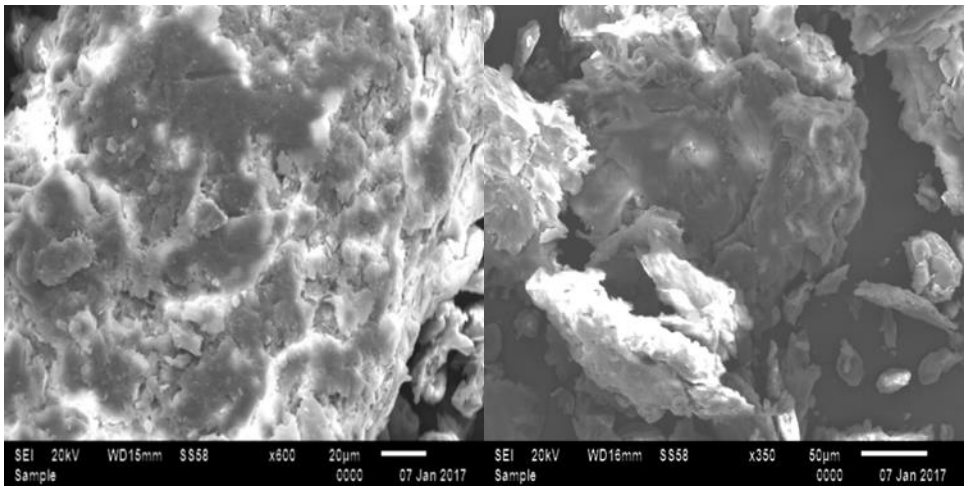


Figure.7. SEM micrographs of *Spathodea Campanulata* leaves biosorbent before biosorption.

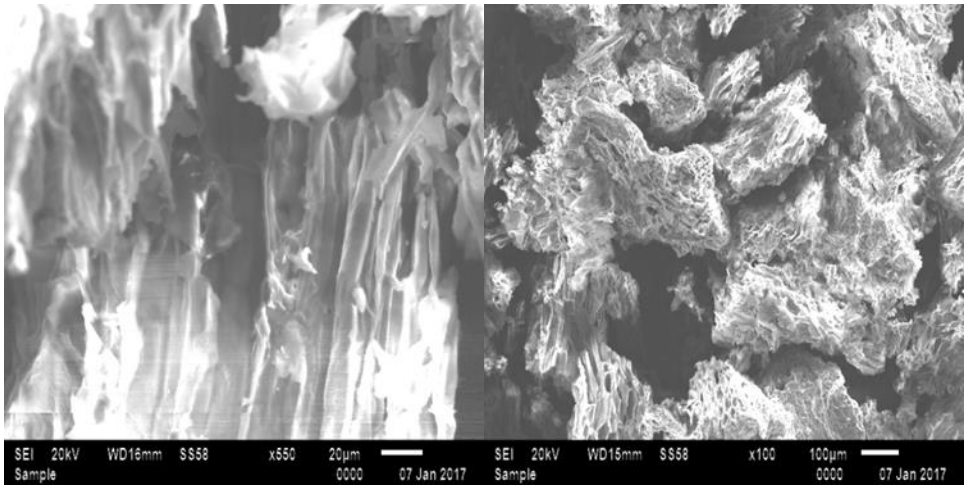


Figure.8. SEM micrographs of *Spathodea Campanulata* leaves biosorbent after biosorption.

3.7.2. Fourier Transform Infrared Spectroscopy (FTIR)

The Fourier transform infrared spectroscopy (FTIR) provides structural and compositional information on the functional groups presented in the biosorbent. The functional groups present in the *Spathodea Campanulata* leaves biosorbent before and after biosorption of crystal violet was investigated by FTIR spectra within the range of 400 – 4000cm^{-1} wave number and shown in Fig. 9 and 10. The adsorption spectra of raw biosorbent (Fig.9.) shows the broad band at 664 cm^{-1} is due to C-Br stretch bands from alkyl halides. The bands at 818.82cm^{-1} denote the presence of C–Cl stretching band. The band at 904.65 cm^{-1} suggests the presence of C–H aromatics. A number of

absorption peaks, indicating the complex nature of the biosorbent and it was composed of various functional groups which are responsible for the binding of crystal violet dye. Fig.10. shows some of the absorption peaks that are shifted or disappeared and new peaks are formed. This could be due to the biosorption of crystal violet dye on surface of the biosorbent. The broad band at 560.35 cm^{-1}represents C–Br stretch bands from alkyl halides. The band at 818.82 cm^{-1} is due to the presence of C–Cl stretching band. The band at 904.65 cm^{-1} indicates the presence of C–H Aromatics mode. The band positions in the FTIR spectra of the *Spathodea Campanulata* leaves biosorbent before and after biosorption of crystal violet is presented in Table.1**.** It shows that biosorption bands shifted to higher values. These shifts may be attributed to the changes in counter ions associated with carboxylate and hydroxylate anions. This indicates that the main contributors in dye uptake may be acidic groups, carboxyl and hydroxyl group.

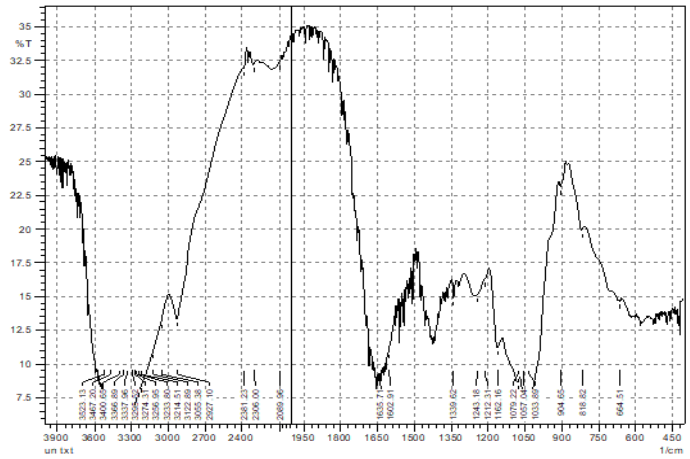


Figure.9. Untreated Crystal violet.

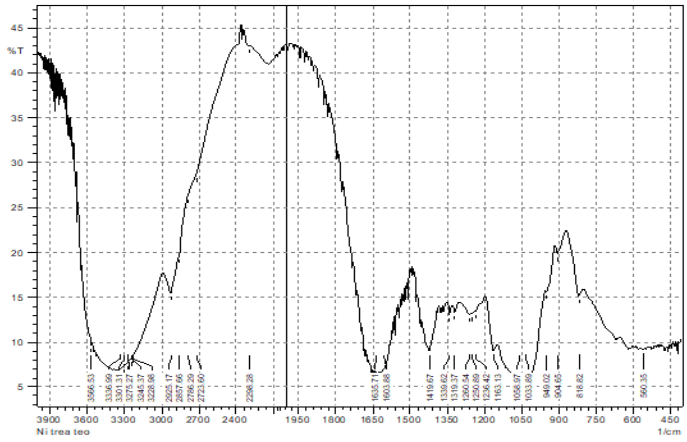


Figure.10. Treated Crystal violet.

TABLE.1. FTIR spectra of *Spathodea Campanulata* leaves biosorbent for Crystal violet.

Sl No	Peaks in untreated powder, cm^{-1}	Peaks in biosorbent Treated Crystal violet powder	Bond and Functional group Description
1	-----	560.35	C–Br stretch bands from alkyl halides
2	664	-----	C–Br stretch bands from alkyl halides
3	818.82	818.82	C–Cl stretching band
4	904.65	904.65	C–H Aromatics
5	-----	949.02	The bands observed at 949 (in IR) and at 928 cm-1(in Raman) respectively are assigned CN to be due to stretch
6	1033.89	1033.89	Si-O stretching band
7	1057.04	-----	C=S stretching modes
8	-----	1058.97	C=S stretching modes
9	1079.89	-----	C=S stretching modes
10	1162.16	-----	Aromatic C–H bending mode
11	-----	1163.12	Aromatic C–H bending mode
12	1212.31	-----	=C–H bend alkenes mode
13	-----	1236.42	
14	1243.18	-----	
15	-----	1250.89	
16	-----	1260.54	
17	-----	1319.37	
18	1339.62	1339.62	
19	-----	1419.67	C=C stretch mode
20	1602.91	-----	Alkyl C–H stretch mode
21	-----	1603.88	Alkyl C–H stretch mode
22	1635.71	1635.71	OH bending mode of vibration
23	2089.96	-----	C≡C bands of the alkynyl ligand
24	-----	2298.28	Amine N–H stretch mode
25	2306.00	-----	
26	2381.23	-----	
27	-----	2723.60	
28	-----	2786.29	
29	-----	2857.66	Asymmetric –CH2–, symmetric –CH3 and –CH2– stretching vibrations
30	-----	2925.17	Asymmetric –CH2–, symmetric –CH3 and –CH2– stretching vibrations
31	2927.10	-----	Amine N–H stretch mode
32	3055.38	-----	aromatic C–H stretching mode
33	3122.89	-----	
34	3214.51	-----	
35	-----	3228.98	

36	3233.80	-----	Amine N–H stretch mode
37	-----	3245.37	
38	3256.95	-----	
39	3274.31	-----	
40	-----	3275.17	
41	3295.52	-----	–CH stretch mode
42	-----	3301.31	
43	-----	3336.99	
44	3337.96	-----	
45	3400.65	-----	
46	3467.20	-----	OH stretch mode
47	3523.13	-----	
48	-----	3566.53	

3.7.3. X-RAY DIFFRACTION

The X-ray diffraction (XRD) is used to investigate the existence of crystallinity in biosorbent material. The X-ray diffraction diffractograms of Spathodea Campanulata leaves biosorbent before and after biosorption of Crystal violet dye is shown as plots of Fig 11, and 12. The diffracted X-ray intensities are recorded as a function of 2θ by using copper target (Cu-Kα radiation with wave length λ= 1.5492 A^0) at a scan speed of 2^0/min. XRD patterns are recorded from 3 to 90^0.

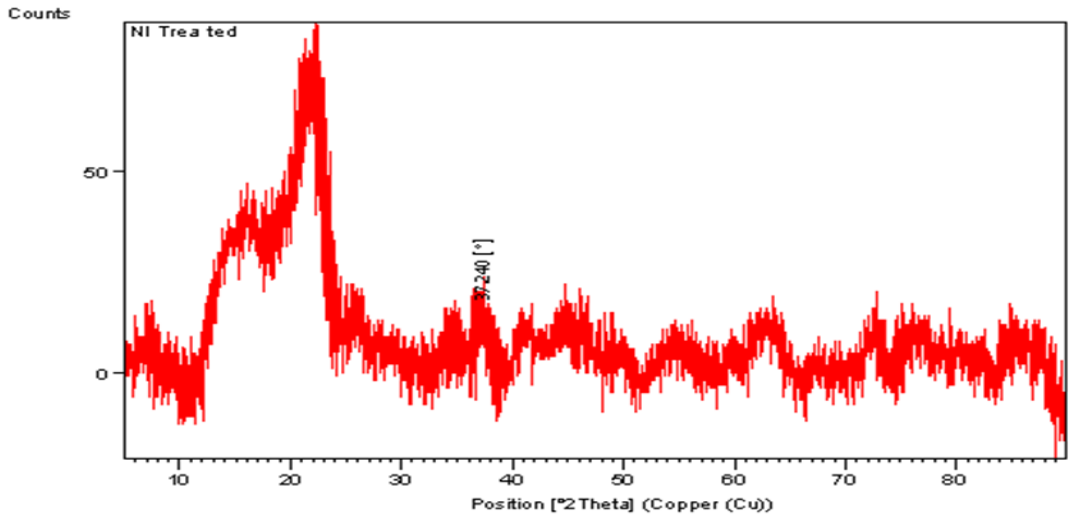


Figure.11. XRD pattern of Crystal violet treated *Spathodea Campanulata.*

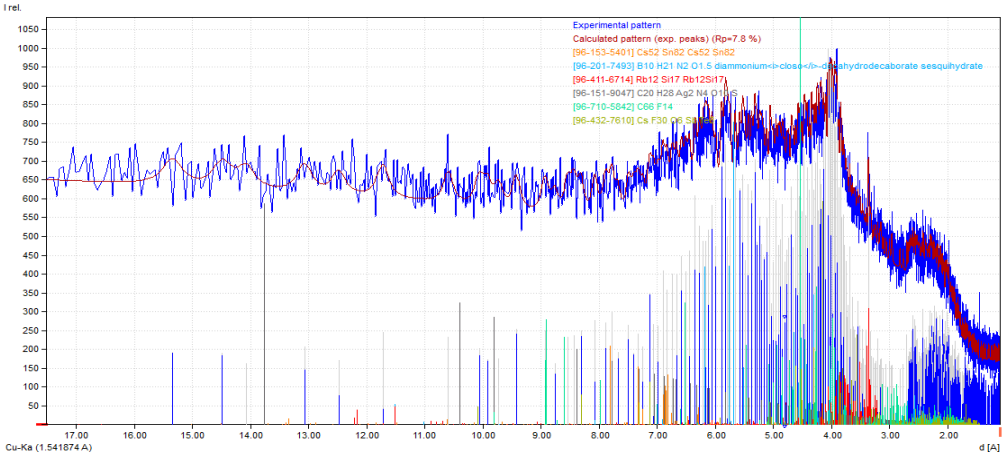


Figure.12. XRD pattern of Crystal violet treated *Spathodea Campanulata* with matching compounds.

XRD patterns for Crystal violet treated powder [Figs.11 & 12] exhibit more amorphous nature and increase in surface area and porosity. The peaks at 2θ values of 0.7400, 0.7104, 0.5667, 0.6598 and 0.6134 reflect the presence of $Rb_{12}Si_{17}$, $C_{66}F_{14}$, $Cs_{52}Sn_{82}$, $B_{10}H_{21}N_2O_{1.5}$ and $C_{20}H_{28}Ag_2N_4O_{10}S$, their corresponding d-values are 4.8072, 4.9561, 4.6587, 4.5135 and 4.2819.

4. CONCLUSION

The contact time of 30 min was sufficient for the maximum removal of crystal violet dye onto Spathodea Campanulata biosorbent. The maximum removal efficiency was predicted to be 89% for crystal violet, which was obtained at a temperature of 303.28 K, solution pH of 6.06, initial dye concentration of 20.09 mg/L and biosorbent dosage of 1.50 g. Characterization of Spathodea Campanulata biosorbent was analysed with SEM, FTIR and XRD with effectively.

REFERENCES

1. Robinson, T., McMullan, G., Marchant, R., Nigam, P., Remediation of dyes in textile effluent: a critical review on current treatment technologies with a proposed alternative, Bioresource Technology, 77 (2005) 247-255.
2. Kassim, T.L.S.M.J.N.M. Acidic and Basic Dyes Removal by Adsorption on Chemically Treated Mangrove Barks, International Journal of Applied Science and Technology, 2(3) (2012) 270-276.
3. Raghavacharya, C. Colour Removal from Industrial effluents - A comparative review of available technologies, Chem. Eng. World, 32(7) (1997) 53-54.
4. Namasivayam, C., N. Muniasamy, K. Gayatri, M. Rani, and K. Ranganathan. "Removal of dyes from aqueous solutions by cellulosic waste orange peel." Bioresource Technology, 57 (1) (1996) 37-43.
5. Sivaraj, Rajeshwari, C. Namasivayam, and K. Kadirvelu. "Orange peel as an adsorbent in the removal of acid violet 17 (acid dye) from aqueous solutions." Waste management, 21 (1) (2001) 105-110.

6. El-Geundi, Mohammad S. "Colour removal from textile effluents by adsorption techniques." Water Research, 25 (3) (1991) 271-273.
7. Namasivayam, C., and N. Kanchana. "Waste banana pith as adsorbent for color removal from wastewaters." Chemosphere, 25 (11) (1992) 1691-1705.
8. Al-Ghouti, M., M. A. M. Khraisheh, M. N. M. Ahmad, and S. Allen. "Thermodynamic behaviour and the effect of temperature on the removal of dyes from aqueous solution using modified diatomite: a kinetic study." Journal of Colloid and Interface Science, 287(1) (2005) 6-13.\
9. Namasivayam, C., and R. T. Yamuna. "Removal of congo red from aqueous solutions by biogas waste slurry." Journal of Chemical Technology and Biotechnology, 53(2) (1992) 153-157.
10. Namasivayam, C., R. Jeyakumar, and R. T. Yamuna. "Dye removal from wastewater by adsorption on 'waste'Fe (III)/Cr (III) hydroxide." Waste management, 14 (7) (1994) 643-648.
11. Wang, Shaobin, Y. Boyjoo, A. Choueib, and Z. H. Zhu. "Removal of dyes from aqueous solution using fly ash and red mud." Water research, 39 (1) (2005) 129-138.
12. Arami, Mokhtar, Nargess Yousefi Limaee, Niyaz Mohammad Mahmoodi, and Nooshin Salman Tabrizi. "Removal of dyes from colored textile wastewater by orange peel adsorbent: equilibrium and kinetic studies." Journal of Colloid and interface Science, 288(2) (2005) 371-376.
13. Kannan, Nagarethinam, and Mariappan Meenakshi Sundaram. "Kinetics and mechanism of removal of methylene blue by adsorption on various carbons—a comparative study." Dyes and pigments, 51 (1) (2001) 25-40.
14. Al-Degs, Y., M. A. M. Khraisheh, S. J. Allen, and M. N. Ahmad. "Effect of carbon surface chemistry on the removal of reactive dyes from textile effluent." Water Research, 34(3) (2000) 927-935.
15. Martin, Maria J., Adriana Artola, M. Dolors Balaguer, and Miquel Rigola. "Activated carbons developed from surplus sewage sludge for the removal of dyes from dilute aqueous solutions." Chemical Engineering Journal, 94 (3) (2003) 231-239.
16. Demirbas, Ayhan. "Agricultural based activated carbons for the removal of dyes from aqueous solutions: a review." Journal of hazardous materials, 167 (1-3) (2009) 1-9.
17. Sivaraj, Rajeshwari, C. Namasivayam, and K. Kadirvelu. "Orange peel as an adsorbent in the removal of acid violet 17 (acid dye) from aqueous solutions." Waste management, 21(1) (2001) 105-110.
18. Kannan, Nagarethinam, and Mariappan Meenakshi Sundaram. "Kinetics and mechanism of removal of methylene blue by adsorption on various carbons—a comparative study." Dyes and pigments, 51 (1) (2001) 25-40.
19. Arami, Mokhtar, Nargess Yousefi Limaee, Niyaz Mohammad Mahmoodi, and Nooshin Salman Tabrizi. "Removal of dyes from colored textile wastewater by orange peel adsorbent: equilibrium and kinetic studies." Journal of Colloid and interface Science, 288 (2) (2005) 371-376
20. Namasivayam, C., and Dyes Kavitha. "Removal of Congo Red from water by adsorption onto activated carbon prepared from coir pith, an agricultural solid waste." Dyes and pigments 54, (1) (2002) 47-58.

21. Robinson, T., B. Chandran, and P. Nigam. "Removal of dyes from an artificial textile dye effluent by two agricultural waste residues, corncob and barley husk." Environment International, 28 (1-2) (2002) 29-33.
22. Yagub, Mustafa T., Tushar Kanti Sen, Sharmeen Afroze, and Ha Ming Ang. "Dye and its removal from aqueous solution by adsorption: a review." Advances in colloid and interface science, 209 (2014) 172-184.
23. Namasivayam, C., R. Radhika, and S. Suba. "Uptake of dyes by a promising locally available agricultural solid waste: coir pith." Waste management, 21 (4) (2001) 381-387.
24. Sivaraj, Rajeshwari, C. Namasivayam, and K. Kadirvelu. "Orange peel as an adsorbent in the removal of acid violet 17 (acid dye) from aqueous solutions." Waste management, 21 (1) (2001) 105-110.
25. Mall, Indra D., Vimal C. Srivastava, and Nitin K. Agarwal. "Removal of Orange-G and Methyl Violet dyes by adsorption onto bagasse fly ash—kinetic study and equilibrium isotherm analyses." Dyes and pigments, 69 (3) (2006) 210-223.
26. Gong, Renmin, Mei Li, Chao Yang, Yingzhi Sun, and Jian Chen. "Removal of cationic dyes from aqueous solution by adsorption on peanut hull." Journal of Hazardous Materials,121 (1-3) (2005) 247-250.
27. Ho, Yuh-Shan, Tzu-Hsuan Chiang, and Yu-Mei Hsueh. "Removal of basic dye from aqueous solution using tree fern as a biosorbent." Process Biochemistry, 40 (1) (2005) 119-124.
28. Ozacar, Mahmut, and İ. Ayhan Şengil. "Adsorption of metal complex dyes from aqueous solutions by pine sawdust."Bioresource technology, 96 (7) (2005) 791-795.
29. Poots, V. J. P., G. McKay, and J. J. Healy. "Removal of basic dye from effluent using wood as an adsorbent." Journal (Water Pollution Control Federation) (1978) 926-935.
30. Khattri, S. D., and M. K. Singh. "Colour removal from synthetic dye wastewater using a bioadsorbent." Water, Air, and Soil Pollution, 120 (3-4) (2000) 283-294.
31. Jain, A. K., V. K. Gupta, Amit Bhatnagar, and Suhas. "A comparative study of adsorbents prepared from industrial wastes for removal of dyes." Separation Science and Technology, 38 (2) (2003) 463-481.
32. Gong, Renmin, Mei Li, Chao Yang, Yingzhi Sun, and Jian Chen. "Removal of cationic dyes from aqueous solution by adsorption on peanut hull." Journal of Hazardous Materials,121 (1-3) (2005) 247-250.
33. Al-Ghouti, M., M. A. M. Khraisheh, M. N. M. Ahmad, and S. Allen. "Thermodynamic behaviour and the effect of temperature on the removal of dyes from aqueous solution using modified diatomite: a kinetic study." Journal of Colloid and Interface Science, 287 (1) (2005) 6-13.
34. Namasivayam, C., and Dyes Kavitha. "Removal of Congo Red from water by adsorption onto activated carbon prepared from coir pith, an agricultural solid waste." Dyes and pigments, 54 (1) (2002) 47-58.
35. Wang, Shaobin, Y. Boyjoo, A. Choueib, and Z. H. Zhu. "Removal of dyes from aqueous solution using fly ash and red mud." Water research, 39 (1) (2005) 129-138.
36. Khattri, S. D., and M. K. Singh. "Colour removal from synthetic dye wastewater using a bioadsorbent." Water, Air, and Soil Pollution, 120 (3-4) (2000) 283-294.
37. Gupta, G. S., G. Prasad, and V. N. Singh. "Removal of chrome dye from aqueous solutions by mixed adsorbents: fly ash and coal." Water Research, 21(1) (1990) 45-50.

38. Bhatnagar, Amit, and A. K. Jain. "A comparative adsorption study with different industrial wastes as adsorbents for the removal of cationic dyes from water." Journal of Colloid and Interface Science, 281 (1) (2005) 49-55.
39. Mohan, Dinesh, Kunwar P. Singh, Gurdeep Singh, and Kundan Kumar. "Removal of dyes from wastewater using flyash, a low-cost adsorbent." Industrial & engineering chemistry research, 41(15) (2002) 3688-3695.
40. Kuo, W. G. "Decolorizing dye wastewater with Fenton's reagent." Water Research, 26 (7) (1992) 881-886.
41. Al-Ghouti, M., M. A. M. Khraisheh, M. N. M. Ahmad, and S. Allen. "Thermodynamic behaviour and the effect of temperature on the removal of dyes from aqueous solution using modified diatomite: a kinetic study." Journal of Colloid and Interface Science, 287 (1) (2005) 6-13.
42. Bulut, Yasemin, and Haluk Aydın. "A kinetics and thermodynamics study of methylene blue adsorption on wheat shells." Desalination, 194 (1-3) (2006) 259-267.
43. Wang, Li, Jian Zhang, Ran Zhao, Cong Li, Ye Li, and Chenglu Zhang. "Adsorption of basic dyes on activated carbon prepared from Polygonum orientale Linn: equilibrium, kinetic and thermodynamic studies." Desalination, 254 (1-3) (2010) 68-74.
44. Mahmoodi, Niyaz Mohammad, Bagher Hayati, Mokhtar Arami, and Christopher Lan. "Adsorption of textile dyes on pine cone from colored wastewater: kinetic, equilibrium and thermodynamic studies." Desalination, 268 (1-3) (2011) 117-125.
45. Asgher, Mahwish, and Haq Nawaz Bhatti. "Evaluation of thermodynamics and effect of chemical treatments on sorption potential of Citrus waste biomass for removal of anionic dyes from aqueous solutions." Ecological Engineering, 38 (1) (2012) 79-85.
46. Juan Rafael García , Ulises Sedran , Muhammad Abbas Ahmad Zaini , Zainul Akmar Zakaria "Preparation, characterization, and dye removal study of activated carbon prepared from palm kernel shell." Environ Sci Pollut Res Int 25(6) (2018) 5076-5085.
47. Edu J. Inam, John B. Edet, Patrick E. Akpan, Kufre E. Ite "Characterization and equilibrium studies for the removal of methyleneblue from aqueous solution using activated bone char" J. Mater. Environ. Sci., 11(10) (2020) 1667-1675.
48. Radouane Laib, Samira Amokrane, Nibou, Djamel Nibou and Mohamed Trari "Recovery of recycled paper in the removalofthetextiledyebasicyellow28: characterization and adsorption studies" Nordic Pulp & Paper Research Journal, 34 (2) (2019) 218–227.
49. M. Rafiqul Islam and M. G. Mostafa, "Characterization of textile dyeing effluent and its treatment using polyaluminum chloride" Applied Water Science, 10 (119) (2020) 1-10.
50. Xinxia Yue, Jiwei Huang, Fang Jiang, "Synthesis and characterization of cellulose-based adsorbent for removal of anionic and cationic dyes" Journal of Engineered Fibers and Fabrics, 14(25) (2019) 1-10.