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ACTIVATED CARBON-BASED ADSORPTION OF PHENOL RED : A STUDY ON DYE REMOVAL

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ABSTRACT

Activated carbon is widely recognized as an effective adsorbent for removing various pollutants from water. In this study, the adsorption behaviour of Phenol Red dye on activated carbon was examined. Different operational factors were evaluated, including the influence of pH, initial dye concentration, the amount of activated carbon used, and the contact time required for adsorption. The removal of Phenol Red was measured using a UV–Vis spectrophotometer at its maximum absorbance wavelength of 558 nm. Results showed that the adsorption efficiency increased when the initial dye concentration and adsorbent dosage were raised. An equilibrium state was reached after approximately 60 minutes of contact. To understand the adsorption mechanism, the obtained data were fitted to both Langmuir and Freundlich isotherm models, and their respective constants were calculated.

Key words: Activated carbon, phenol red, adsorption, isotherm equilibrium

INTRODUCTION

Rapid industrial growth has resulted in serious water pollution, especially from industries that release large quantities of dye-containing wastewater. A significant portion of dyes produced worldwide is discharged into the environment by textile industries because colouring materials do not get fully absorbed during processing and washing. Wastewater with strong colour usually originates from dye manufacturing units, textile mills, paper and pulp industries, and research laboratories. Even when present in very small amounts, such coloured effluents are easily visible. When these pollutants enter natural water bodies, they not only harm the environment but also block sunlight penetration, disrupting the food chain of aquatic life. The dyes released into water are often toxic and can even cause cancer in animals and humans. Their complex aromatic chemical structures make them highly stable and resistant to degradation by light, heat, water, microorganisms, and many chemicals.

The use of adsorption techniques to remove phenol red from wastewater has been studied. This is because phenol red is a highly water-soluble dye. It can be used as a pH indicator in water testing and cell biology laboratories. In addition, toxicity data show that this dye can prevent the development of epithelia cells. The effects of phenol red on the skin, eyes, and respiratory system are reported to be severe. It is also reported that this dye can cause mutagenic effects. To remove phenol red from wastewater, we used activated carbon from Ipomoea Carnea. This method is very cost-effective and efficient. Ipomoea carne is a member of the Convolvulaceae family. It is a morning glory plant. In this study, activated carbon was utilized as an adsorbent.

LITERATURE REVIEW

Baylor S.M. and S. Hollingworth (1990) investigated the absorbance signals produced in resting frog skeletal muscle fibers in their study “Absorbance signals from resting frog skeletal fibres.” Using sensitive optical measurement techniques, they analyzed how endogenous pigments and intracellular chromophores absorb light at different wavelengths when the muscle is in a non-contracting state. The study showed that variations in absorbance mainly arise from components such as myoglobin, mitochondrial pigments, and other protein-associated molecules inside the fiber. Their findings are important because the optical properties of resting fibers provide a stable reference point for understanding later changes that occur during muscle activation, especially shifts associated with calcium movements and structural transitions. This work offered a strong methodological foundation for future studies in skeletal muscle physiology and helped validate optical monitoring as a reliable tool for exploring excitation–contraction mechanisms.

Chung, Fulk, and Andrews (1981), in their study “Mutagenicity Testing of Some Commonly Used Dyes,” evaluated the mutagenic potential of a range of industrial dyes that are widely used in textiles, food, and other commercial applications. Using standard microbial assays, including Ames tests with multiple Salmonella strains, the researchers found that several dyes showed significant mutagenic activity, particularly after metabolic activation. Their results highlighted that certain azo dyes and related synthetic colorants can undergo metabolic transformation to form harmful intermediates capable of inducing genetic mutations. This study provided early and important evidence that some commonly used dyes pose potential genetic and health risks, emphasizing the need for stricter safety evaluation, regulated usage, and improved wastewater treatment to minimize environmental and human exposure.

Mishra and Tripathy (1993), in their article “A critical review of the treatment for decolourization of textile effluent,” provided an early and comprehensive overview of the major technologies used for removing color from textile wastewater. They examined physical, chemical, and biological treatment methods such as coagulation–flocculation, oxidation, adsorption, and microbial degradation. The authors emphasized that synthetic dyes are highly resistant to conventional treatment processes because of their complex aromatic structures. Their review highlighted that adsorption and advanced oxidation processes showed comparatively better efficiency, although cost and sludge generation remained major concerns. This work played an important role in identifying gaps in existing treatment technologies and encouraged the search for economical, high-efficiency methods for dye removal from industrial effluents.

Mittal *et al.* (2009), in the study “Adsorption Studies on the Removal of Coloring Agent Phenol Red from Wastewater Using Waste Materials as Adsorbents,” investigated the potential of low-cost agricultural and industrial waste materials for removing Phenol Red dye through adsorption. Their experiments demonstrated that several waste-derived adsorbents exhibited high uptake capacity, making them attractive alternatives to commercial activated carbon. Kinetic analysis showed that the adsorption process followed pseudo-second-order kinetics, while equilibrium data fitted well to Langmuir and Freundlich isotherms. The authors concluded that waste materials can serve as efficient, economical, and environmentally friendly adsorbents for color removal from wastewater. This study significantly contributed to the growing body of research promoting sustainable and low-cost treatment options for dye-contaminated effluents.

Sharma *et al.* (2009), in their study “Fast removal of malachite green by adsorption on rice husk activated carbon,” examined the efficiency of low-cost activated carbon prepared from rice husk for removing the toxic dye malachite green from aqueous solutions. Their results showed that rice husk activated carbon possessed a high adsorption capacity and removed the dye rapidly, reaching equilibrium within a short contact time. The study reported that adsorption efficiency increased with higher adsorbent dose and suitable pH conditions, while kinetic data closely followed the pseudo-second-order model, indicating chemisorption as the dominant mechanism. The authors concluded that rice husk, an abundant agricultural waste, can be converted into an effective, economical, and environmentally friendly adsorbent for dye removal. This work supported the growing trend of using agro-waste–based activated carbons for sustainable wastewater treatment.

MATERIAL AND METHOD

Preparation of activated carbon-

The Ipomoea Carnea stem , used as adsorbent for removal of phenol red were

cut and dried in sunlight until then oven dried at 110^0C over night. Dried material was treated with HCL for a period of 24 hours. Then the material was placed in the muffle furnace and carbonized at 400-800°C, for a period of 60 minutes[9]. Chemical activation promotes the high adsorption capability due to its high internal surface area and porosity formed during carbonization.

Adsorbent-

The dye used in the study was phenol red, 4'- (3H- 2, 1-benzoxathiol-3-ylidene) bis-phenol, S,S-dioxide having molecular formula $C_{19}H_{14}O_5S$ and molecular weight 354.38 its chemical structure shown in Figure 1. Phenol red is also commonly known as phenol sulfonephthalein. An intense colour is due to the extended conjugation systems of the alternate double and single bond in the dye structure. Phenol red dye stock solution is prepared by 0.1 gram of the phenol red dye was accurately weighed and made up to 1000 ml of distilled water. The stock solution was further diluted with distilled water to desired concentration for obtaining the test solutions.

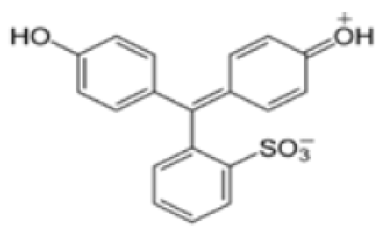

Fig. – 1 : Chemical structure of phenol Red

Batch Adsorption Studies-

Batch adsorption experiments were carried out at ambient temperature. In order to investigate the nature of activated carbon and phenol red interaction, initially the effect of pH on % adsorption was carried out and then further experiments on the effect of contact time, initial concentration, adsorbent dose and contact time were conducted on optimized pH. Only one parameter was changed at a time while others were maintained constant. The quantity adsorbed by a unit mass of an adsorbent at equilibrium and the adsorption percentage were calculated using the following relations.

$$\% R = \frac{C_o - C_e}{C_o} \times 100$$

$$Q_e = \frac{(C_o - C_e)}{m} \times V$$

Where is the concentration of adsorbate at equilibrium (mg.L-1); is the initial concentration of adsorbate (mg.L-1);

RESULTS AND DISCUSSION

Adsorption studies

Effect of pH - The effect of pH on the percentage of the phenol red dye removed was studied over the pH range of 2 to 10. It was observed that with the increase of the pH of the solution, the extent of the dye removal increased. The maximum removal of phenol red dye was recorded at pH of 8, decreases as the pH was increased up to pH 10 Figure- 2.

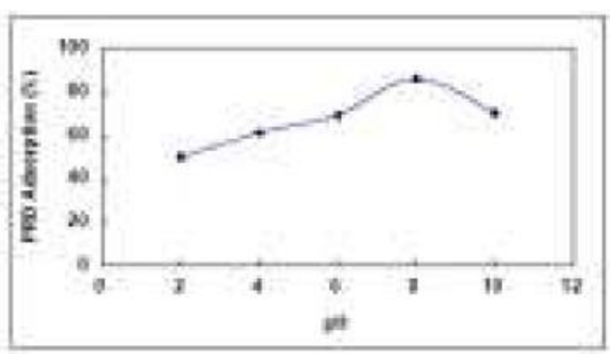

Figure -2. Effect of pH on adsorption of phenol red dye

Effect of Adsorbent Dose-

The effect of dosage was studied for adsorbent dosages in the range of 0.2 g to 0.6 g. It can be seen that the rate of dye removal increases with increase in amount of adsorbent (Fig. - 3). The result shows that the adsorbent was efficient for maximum removal of dyes at the level

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of adsorbent dosage. The increase in the percentage removal of dyes with the increase in adsorbent dosage was due to the increased surface area with more active functional groups which also gave rise to availability of more adsorption sites.

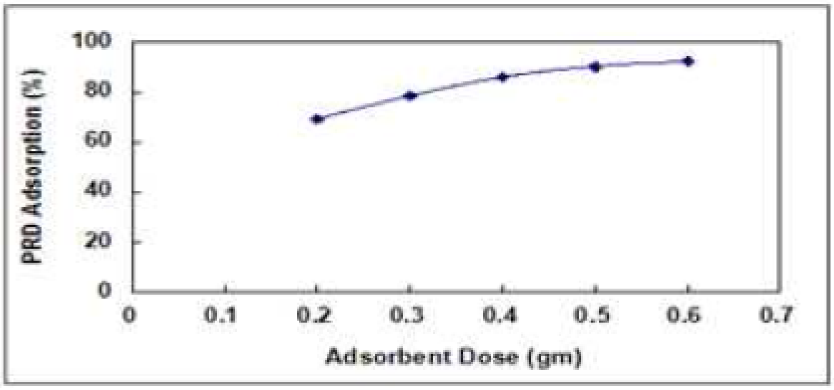

Figure - 3. Effect of Adsorbent Dose on adsorption of phenol red

Effect of Contact Time-

The results showed that as the time increased, the percentage adsorbed increased, until equilibrium was reached at about 60 minute, as shown in Figure-4. The initial rapid adsorption was due to the availability of positively charged surface of the adsorbents for the adsorption of phenol red.

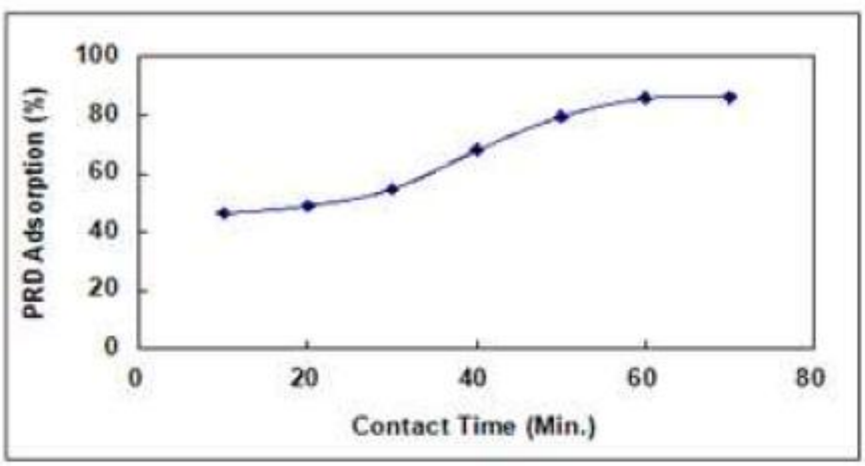

Figure -4. Effect of Contact Time on adsorption phenol red

Effect of phenol red ions concentration

The effect of initial ion concentration shows a decrease in percentage adsorbed, with the increase of the initial ion concentration of dyes, as seen in Fig. - 5. This is because at lower concentration, the ratio of the initial number of the dye molecules to the available surface area was low.

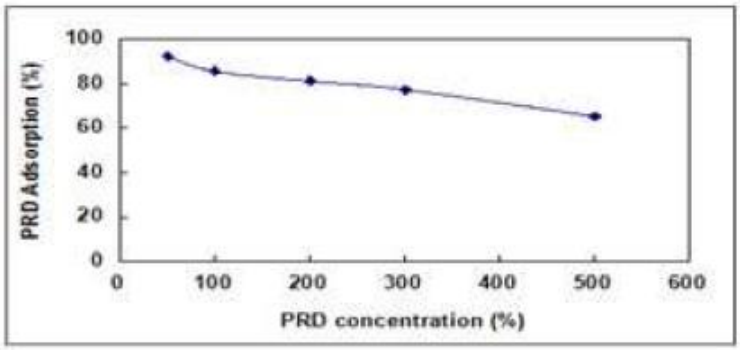

Figure - 5. Effect of phenol red concentration on adsorption

Adsorption isotherm Data Analysis

The relation between the amount of a substance adsorbed at constant temperature and its concentration in the equilibrium solution is called the adsorption isotherm. The results obtained from the Langmuir and Freundlich isotherm model for the removal of phenol red dye onto activated carbon are shown in Table-1.

Table – 1 : Comparison of the coefficients isotherm parameters

for phenol red adsorption

Isotherm Model	Coefficients Parameters		Isotherm
Langmuir	Q_m (mg/g) 54.64	b (L/mg) 0.0169	R^2 0.9987
Freundlich	1/n 0.6119	K_f (mg/g) 1.999	R^2 0.9783

The correlation coefficients reported in Table-1 showed strong positive evidence on the adsorption of phenol red onto activated carbon, following the Langmuir and Freundlich isotherm. (Fig 6 & 7) The applicability of the linear form of both the models to activated carbon was proven by the high correlation coefficients, R2 grater then 0.98. This suggest that the both the models provides a good model of the sorption system. It will be noted that the value of 1/n was between 0 and 1 indicating the adsorbent prepared are favourable for adsorption of the phenol red. The maximum monolayer capacity Qm obtained from the Langmuir is 50.25 mg/g.

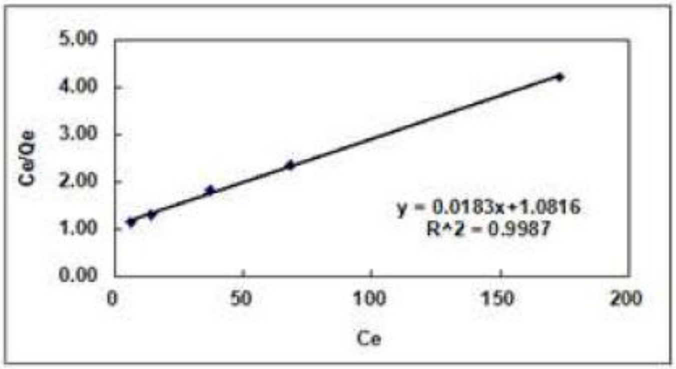

Figure-6 Linear plot of Langmuir isotherm for phenol red adsorption

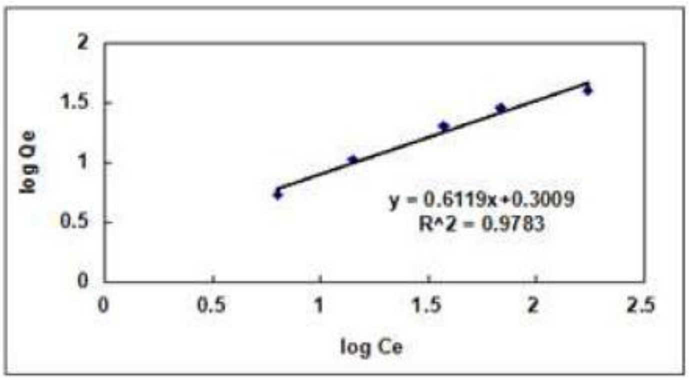

Figure-7 Linear plot of Freundlich isotherm for phenol red adsorption

Conclusions

The present study reports batch studies for the removal of phenol from activated carbon derived from Ipomoea Carnea stem waste Due to the presence of high surface area, porosity, and the activated carbon prepared from the agricultural waste it can be used for a variety of environmental application, dye removal, wastewater treatment and adsorption process too. Adsorption of phenol was dependent on initial pH, adsorbent dosage, contact time and initial phenol concentration. It can be concluded that some low cost material can be used as effective and alternative adsorbents for the sorption of organics such as phenol from aqueous solution, because of they are readily available, hence reducing pollution

REFERENCES

Arockiaraj I and Renuga V "Sorption kinetics and dynamic studies of basic dye by lowcost nanoporous activated carbon derived from Ipomoea Carnea stem waste by sulphate process" Frontiers in Nanoscience and Nanotechnology 2016.

Baylor S.M. and S. Hollingworth, "Absorbance signals from resting frog skeletal fibres" The Journal of General Physiology.96: 449-471, 1990.

Chung K., G.E. Fulk and A.W. Andrews, "Mutagenicity Testing of Some Commonly Used Dyes",Applied Environmental Microbiology 42: 641- 648. 1981.

G. Mishra, M. Tripathy, "A critical review of the treatment for decolourization of textile effluent" Colourage 40, 35–38, 1993.

Lekene Ngouateu R. B., Kouoh Sone P M. A., Ndi Nsami J., Kouotou D., Belibi Belibi P. D., Ketcha Mbadcam J. "Kinetics and equilibrium studies of the adsorption of phenol and methylene blue onto cola nut shell based activated carbon" Int J Cur Res Rev | Vol 7 Issue 9 M ay 2015rocess" Frontiers in Nanoscience and Nanotechnology 2016

Mittal A., D. Kaur, A. Malviya, J. Mittal and V.K. Gupta, "Adsorption Studies on the Removal of Coloring Agent Phenol Red from Wastewater Using Waste Materials as Adsorbents" Journal of Colloid and Interface Science. 337: 345-354, 2009.

N.A. Oladoja, I.O. Asia, "Studies on the sorption of basic dye by rubber (Hevea brasiliensis) seed Shell". Turkish J. Eng. Env. Sci., 32, 143-152, 2008.

Pagga U.M. and K. Taeger, "Development of a Method for Adsorption of Dyestuffs on Activated Sludge". Water Resource Research. 28: 1051-1057, 1994.

Robinson T., G. Mullan, R. Marchant and P. Nigam, "Remediation of Dyes in Textiles Effluent: A Critical Review on Current Treatment Technologies with a Proposed Alternative". Journal of Bio resource Technology. 77: 247-255, 2001.

S.Karthikeyan , P.Sivakumar and P.N.Palanisamy Department of Chemistry, "Activated Carbons from Agricultural Wastes and their Characterization '' net Vol. 5, No., pp. 409-426, April 2008

S. Pirillo, M.L. Ferreira, E.H. Rueda, "Adsorption of alizarin, eriochrome blue black R, and fluorescein using different iron oxides as adsorbents" Ind. Eng. Chem. Res. 46 ,8255–8263,2007.

Walsh-Reitz M.M. and F.G. Toback, Phenol Red Inhibits Growth of Renal Epithelial Cells. American Journal of Physiology Renal Physiology. 262: F687-F691,1992.

Y.C. Sharma, B. Singh, Uma, "Fast removal of malachite green by adsorption on rice husk activated carbon", The Open Environment Pollution and Toxicology Journal, 1, 74-78, 2009.