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Adsorption of Basic Dye from A Synthetic Wastewater -Analysis with Batch, Column and IoT Studies

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Abstract: *the most vital component for all earthly life is water. In addition to being necessary for human consumption, it is also necessary for a variety of productive endeavors, including industry, agriculture, tourism, and cattle rearing. More sophisticated equipment is needed to maintain water quality as cities grow.. Widespread water shortages in developed nations are brought on by non-point sources of pollution, such as agricultural chemicals and industrial effluents, which contaminate surface and ground water. When wastewater with significant quantities of organic and inorganic materials is released into the environment, it causes a number of issues. Therefore, eliminating dyes from wastewater is crucial to lessening the damage they cause to the environment and ecosystem The goal of the current work was to elucidate the potential of parthenium weed-derived activated carbon in dye adsorption. Changes in pH, concentration, adsorbent dosage, and contact duration were taken into account while evaluating the removal efficiency in our experimental-laboratory work.*

Keywords: Dyes, Adsorption, Parthenium, Sustainability

I. INTRODUCTION

Natural and synthetic dyes are the two primary categories of colors used in industry. Natural dyes are made from plants, such as madder root, whereas synthetic dyes are made from animals, such as sea snails.Azo dyes and non-azo dyes are the two primary categories of synthetic dyes. Azo dyes are divided into acidic, basic, reactive, dispersion, sulfur, and vat dyes [1]. Natural dyes are used less frequently in the printing, cosmetics, and food processing sectors due to population growth and the fashion industry's expansion [2]. Synthetic colors react with water and cause health issues, thus it is crucial to clean wastewater that contains dyes. Paper, food coloring, cosmetics, leather, pharmaceuticals, printing, carpeting, and other industrial processes all discharge dyes into wastewater. More dyes are used in the textile production and dyeing sectors, which discharge these dye pollutants into the environment as wastewater effluents [3]. Since these colors are extremely harmful and can even cause cancer in both mammalian animals and microbial populations, they must be eliminated from water effluents before they are discharged into bodies of water. Dyes represent one of the most challenging categories to remove from industrial wastewater because they are resistant to aerobic digestion, resilient to light, and not biologically degradable. Natural and synthetic dyes are both often used in the textile industry to color raw materials and final products. Natural dyes are made from a mix of minerals and plants and starch. Petroleum and coal tar were used to make synthetic dyes. Once waste water is discharged into a body of water, it affects the water's aquatic and aesthetic qualities and decreases light penetration, which has a negative impact on the process of photosynthesis [4]. According to current studies, biosorbents are the most advantageous applications.

It produces the least amount of chemical and biological sludge because to its great efficiency. One of the most promising methods for treating wastewater is adsorption. Since adsorbent cost is a major consideration when using it to remove colors, parthenium hysteroporous, an undesired weed with year-round high biomass and strong adsorption capability, is used as an adsorbent [5].

Sustainable Development goals: Research mapped with 3,6,9,13,14,15

1.1 Types of Dyes

The two primary categories of dyes used in industry are natural dyes and synthetic dyes. Natural dyes are made from plants, such as madder root, whereas synthetic dyes are made from animals, such as sea snails. Azo dyes and non-azo dyes are the two primary categories into which synthetic dyes fall. Azo dyes are divided into acidic, basic, reactive, dispersion, sulfur, vat dyes, and direct dyes. Natural dyes are used less frequently as a result of population growth and the expansion of the fashion industry. The printing, cosmetics, and food processing sectors solely use synthetic colors, which react with water and cause health issues. For this reason, it is crucial to treat wastewater that contains dyes [6].

II. MATERIALS & METHOD

2.1 Adsorbent

Parthenium is a highly toxic herb that is found all over the world. a poisonous plant that is well-known for harming human health as well as agriculture, crop production, and biodiversity. It is a herbaceous annual weed that has little commercial significance. It is one of the world's seven intolerance weeds. It is a member of the genus Parthenium, species Parthenium hysterophorus, and kingdom Plantae of the family Asteraceae. Known by a variety of names, including Santa Maria, Santa Maria feverfew, and white top weed, it is also known as Congress grass and carrot grass in our country.

2.2 Adsorbate

The stock solution of Crystal violet dye was prepared with adding 1.5g powdered dye in 1 liter of water concentration of 1500 PPM was prepared. And different concentration was prepared by series of dilution using RO water, synthetic sample was prepared and 25/50 ml of working solution is taken for analysis [14].

2. 3 Methodology

The preparation of synthetic dyes from different categories and used in the process of adsorption [15].

In this study, a healthy entire parthenium weed is gathered, washed to eliminate dirt and soil, and sun-dried for 72 hours. Parthenium hysteroporous is utilized as an adsorbent. The powdered dried parthenium was ground into a powder and sieved through a 300 micron screen. The activation procedure is then carried out using the powder. In order to create the stock solution for each dye, powder dyes with the appropriate concentration were added. 50 ml of the working solution was obtained for analysis, a synthetic sample was made, and various concentrations were created by dilution using RO water. The N1*V1=N2*V2 formula is used to create the adsorbate for varying concentrations.

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Chemical Activation Process

The process of activation, known as the chemical activation process, involves adding concentrated sulfuric acid to powdered parthenium in a ratio of 1:1.5 (W:V) and then keeping it in a hot air oven at 120 C for 12 hours. After washing until the acid is gone and its pH reaches about 6.0, it is soaked in 1% sodium bicarbonate solution overnight to eliminate free acids. and repeatedly cleaned, stored in a zip-lock cover, then baked at 105 degrees Celsius for 24 hours [7].

2.4 Sorption Studies

Adsorption was carried out in a batch using a 250 ml conical flask for the batch adsorption process study. The adsorbent dose was combined with the adsorbate by adjusting various parameters such as pH and contact time. The adsorbate and adsorbent dosage were then placed in an orbital shaker, and additional research was conducted under the appropriate wavelength.

SEM analysis was used to see how the carbon's shape changed. The interaction between the adsorbent and the adsorbate can be linked to the porosity in the biosorbent structure. SEM analysis was performed both for dye loaded and unloaded carbon [8].

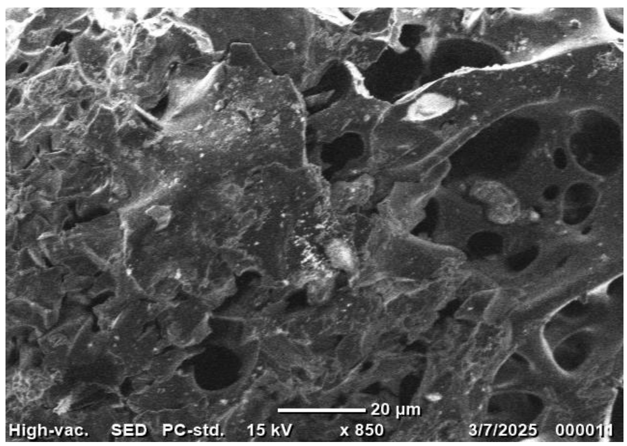

Fig 1. Shows SEM Analysis of Chemically treated Activated carbon before Adsorption

Fig 2. Shows SEM Analysis of Chemically treated Activated carbon after Adsorption

2.5 IOT in Adsorption

In order to ensure the safe water the quality needs to be monitor in real time. design and development of a low cost system for real time monitoring of the water quality in IOT(internet of things).The system consist of several sensors is

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used to measuring physical and chemical parameters of the water. The parameters such as temperature, PH, turbidity, flow sensor of the water can be measured. The measured values from the sensors can be processed by the core controller. The Arduino model can be used as a core controller. Finally, the sensor data can be viewed on internet using WI-FI system.

YOLOv8 is the newest state-of-the-art, YOLO model that can be used for object detection, image classification, and instance segmentation tasks. Colour detection using image processing" refers to the technique of identifying specific colours within an image by analyzing the pixel values,.

2.6 Column Studies

Continuous-flow of fixed-bed adsorption experiments were performed in a glass column of A rubber cork of 2 cm was provided was provided at the top and bottom of the column to support the inlet and outlet pipes [3]. The column was packed with 5 cm of pebbles both at the top and bottom the column was packed with 1.8 cm of glass wool followed by glass beads and mesh was provided to avoid floating of carbon along with adsorbent and was packed separately in the column to Obtain a bed height of 15 cm [9].

A column, 5.5 cm diameter and 38 cm height, filled with adsorbent (15cm) were employed for this study [6]. The column was charged with synthetic dye solution of initial 1000 mg/l concentration the column was run with an average flow rate of 100 ml/min [11]. Samples were collected at specific interval hours and residual dye concentration was measured using double-beam UV/visible spectrophotometer [12]. The column was operated in up-flow mode.

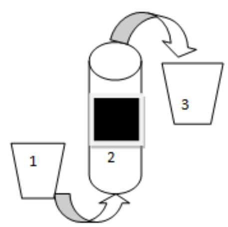

Fig.3 Fixed Bed Column, Representing 1. Dye Inlet, 2. Carbon, 3. Dye Outlet

SEM analysis was used to see how the carbon's shape changed. The interaction between the adsorbent and the adsorbate can be linked to the porosity in the biosorbent structure. SEM analysis was performed both for dye loaded and unloaded carbon [13].

III. RESULTS & DISCUSSION

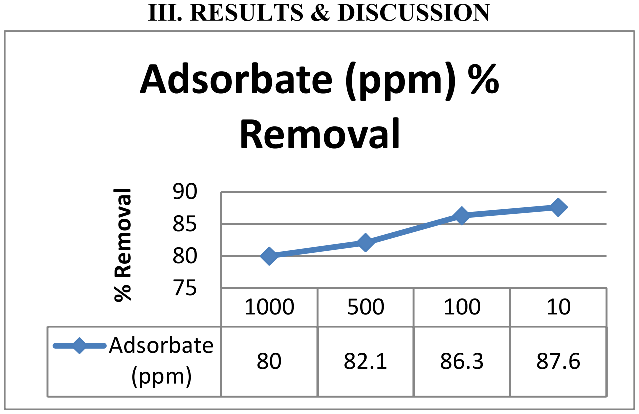

Fig.4 Effect of Asdsorbate vs % Removal

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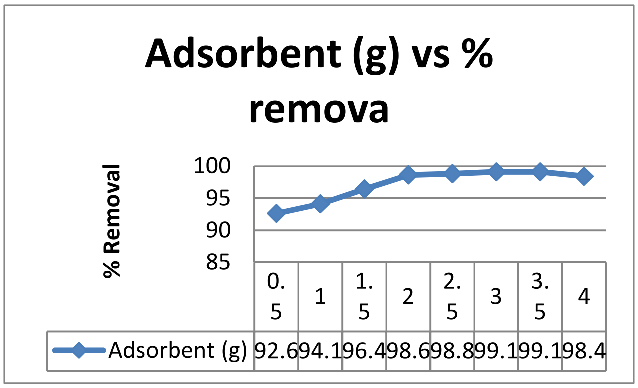

Fig.5 Effect of Asdsorbent vs % Removal

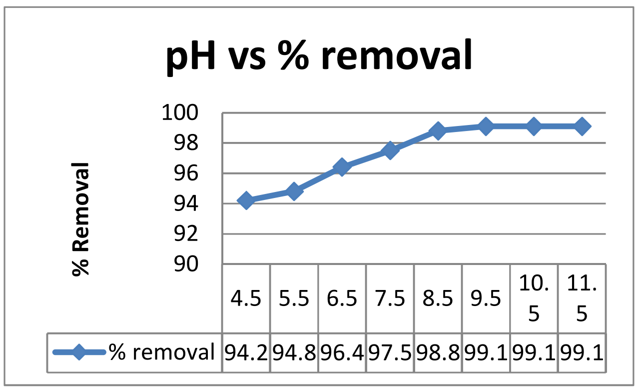

Fig . 6 Effect of pH vs % Removal

A stock solution of 1000 mg L–1 of different categories of dyes was prepared by dissolving 1 g of dye powder in 1000 mL of deionized water [5]. Experimental solutions of required initial dye concentrations were made by further diluting the stock solution After adsorption, the unknown residual dye concentration was determined by measuring the absorbance at respective nm using a double-beam UV/visible spectrophotometer.

Table 1. Results of Column studies with variation in pH

Sl.No	pH	Adsorbate (PPM)	fLow rate	Bed Depth (cm)	% removal
1.	4.5	1000	100 ml/min	15 cm	85.2
2.	6.5	1000			87.4
3.	**8.5**	**1000**			**91.1**
4	10.5	1000			91.1
5	4.5	100	100 ml/min		89.4
6	6.5	100			90.2
7	**8.5**	**100**			**92.8**
8	10.5	100			92.8

Table: 2. Results of Column studies with constant pH

Sl.No	pH	Adsorbate (PPM)	fLow rate	Bed Depth (cm)	% removal
1.	8.5	1000	50 ml/ min	15 cm	91.1
2.	8.5	500			91.8
3.	8.5	100			92.8
4	8.5	10			95.6

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5	8.5	1000	**100 ml/min**		**91.0**
6	8.5	500			**91.6**
7	8.5	100			**92.6**
8	8.5	10			**95.2**
9	8.5	1000	150 ml/min		90.3
10	8.5	500			89.2
11	8.5	100			90.8
12	8.5	10			91.4

According to Coloumn Studies which Conducted for Congo red Dye. the results shows that 8.5 is the optimum pH and the flow rate of 100 ml/min is more effective in Adsorption process [10], also Table 2 shows Decrease in the concentration of dye Increases the removal percentage. And also increase in the Flow rate Decreases the removal percentage i.e 100ml/min Shows optimum.

Table 3: Results obtained from IOT with RGB values

Date	Time	Initial Conc. In PPM	Final Conc. In PPM	RGB values
24/7/25	06:23 PM	10	0.0233	(26.0, 21.69, 17.18)
24/7/25	06:27 PM	100	0.0064	(16.0, 31.49, 19.16)
24/7/25	06:27 PM	500	0.02865	(21.0, 18.69, 30.32)
24/7/25	06:27 PM	1000	0.07958	(23.1, 26.49, 19.18)
24/7/25	06:29 PM	1500	0.04880	(22.0, 26.69, 15.18)

IV. CONCLUSION

Considering the findings of research The most effective technique for removing dyes is adsorption. Adsorbents that are inexpensive will remove dyes effectively. Because parthenium is widely available compared to other adsorbents and has an expected removal effectiveness of 95 to 99 percent, it will be the best low-cost adsorbent. It has potential advantages for industrial use and supports industrial ecology for sustainability. Although the activated carbon derived from P. hysterophorus is generally regarded as a promising adsorbent, more research into the precursor material is strongly advised prior to its commercial use in the treatment of water and wastewater.

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