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Spectrophotometric Determination of Dye Removal Using UV/H_2O_2 Process

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Abstract: Dyes are complex organic compounds that are used by various industries to color their products. The textile industry is important in most countries and consumes about 45-60 liters of water for every kilogram of fabric. The generated wastewater from the various industries restrains the effect on photosynthesis and causes several effects on aquatic and humans. The objective of the study is to remove the dye from the aqueous solution using the UV/H_2O_2 process. The removal efficiency of the dye is determined by using the UV spectrophotometer. The effect of different parameters such as pH, H_2O_2 concentration, dye concentration, and time on the removal rate. In addition, the optimum conditions of the removal rate also investigate. The removal efficiency of dye will be noted and reported in the study.

Keywords: Adsorption, Brilliant Blue FCF Dye, Hydrogen Peroxide(H_2O_2), UV Spectrophotometer.

1.Introduction:

A important cause of water contamination is dye wastewater. The textile, paper, printing, carpet, plastic, culinary, and cosmetic sectors all utilize dyes. The three primary categories of dyes are cationic, anionic, and non-ionic dyes. Given that anionic dyes are water soluble and generate vivid colors in water with acidic qualities, their removal should be regarded as the most difficult undertaking. Many companies utilize dyes, which are sophisticated chemical molecules, to color their products. The majority of nations have a significant textile sector, which uses 45 to 60 liters of water for every kilogram of cloth produced. Large volumes of water are required by the textile sector, which also generates a sizable amount of effluent. This effluent is produced by a number of different processes while treating fabrics wet. More than 10,000 tons of dye are reportedly consumed annually by the textile sector, and during the dying process, 10 to 15 percent of these colors are discharged as effluents. Potential toxins from these effluents can harm aquatic life and humans. Even at low quantities, colors in water are highly detectable. This is not only unsightly, but the water's coloring could prevent aquatic ecosystems from photosynthesis. Dyes may also be difficult to break down anaerobically in sediment because incomplete breakdown frequently results in the production of hazardous amines. Dye degradation byproducts are poisonous and mutagenic. Because of this, industrial facilities' effluent has been cleaned up. Improvements to the water's properties and administrative requirements for environmental protection must be made before discharge.

2. Methodology:

Initially we take a closed box and that box is completely covered with aluminum foil internally. Now fix the 11W UV lamp inside the box exactly placed near to the sample beaker and the UV lamp is connected to the UV adaptor choke to supply power to the lamp. The purpose of aluminum foil is to avoid the loss of intensity of UV from inside the box. The entire process of dye removal happening inside the closed box only.

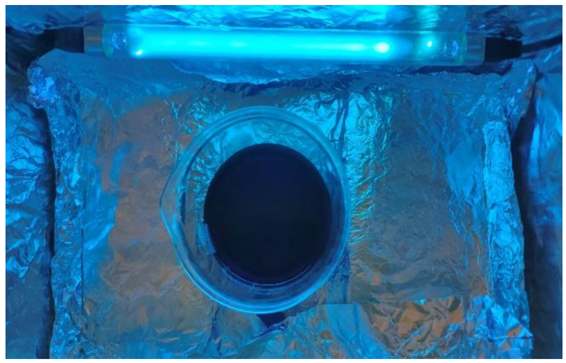

Figure 1: Reactor Setup

- Initially we prepare the solution with a concentration of 1g/l and from that we prepare required samples using formulae

$$N_1V_1=N_2V_2$$

N_1= Concentration of initial sample (1000 mg/l).

V_1= Volume of dye sample required for preparing sample solution.

N_2= Concentration of required sample (10,15,25,50,75,100 and 150 mg/l).

V_2= Volume of sample solution (250 ml).

- We prepare NaOH and H_2S0_4 samples of different (0.1, 0.5 and 1N) concentration for balancing pH.
- We prepare $Na_2S_2O_3$ sample (10% of solution) for stopping the reaction of dye and H_2O_2 after every 30 minutes.
- In this study in order to remove dye from solution some parameters are required (pH, H_2O_2 and dye concentrations).
- In order to identify optimal pH we maintain initially other two parameters are constant (H_2O_2(50 mg/l) and Dye Concentration (50 mg/l)) and varying the pH between 2 to 11.
- After finding the optimal pH we need to fix that pH as constant and Dye Concentration (50 mg/l) for finding optimal H_2O_2.
- After finding the optimal H_2O_2 we need to maintain pH and H_2O_2 at optimal conditions for finding optimal dye concentration
- In above all for every 30 minutes we need to identify absorbance of sample using spectrophotometer and every 15 minutes we need blend the solution using stirrer.

After identifying the absorbance of values of samples before and after reactions using spectrophotometer we need to analyze and interpretate those values to understanding better and identify the removal efficiency.

$$\text{Removal Efficiency \%} = \frac{(C1-C2)}{C1} \text{ X } 100$$

C1 = Initial concentration of dye mg/l (before treatment).

C2 = Final concentration of dye mg/l (after treatment).

3. Analysis:

A UV-vis spectrophotometer was used in the laboratory at Aditya Engineering College of Environmental Engineering to analyses the dye concentrations in the water samples.

Following is a list of the analysis steps:

The precise amount of Brilliant Blue FCF dye (5 to 150 mg/L) that was required was created. As shown in figure 2, a spectrophotometer was used to measure the maximum wavelength (nm) for each dye using a survey scan between 300 and 900 nm.

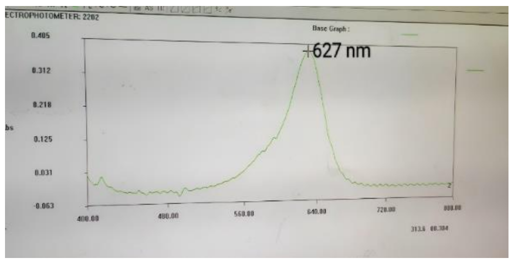

Figure 2: Maximum Wavelength for Brilliant Blue FCF Dye

The Brilliant Blue FCF dye was produced in seven solutions at concentrations of 5, 10, 25, 50, 75, 100, and 150 mg/l. Spectrophotometer measurements of absorbance at the maximum wave length (627 nm) were made. In order to determine the link between absorbance (at the maximum wavelength of the dye) and each dye concentration, in order to estimate unknown concentrations of dye, as seen in below table 1 and figure 3.

Table 1- Absorbance Values of Different Dye Concentration

S.no	Dye Concentration (mg/l)	Absorbance
1	0	0
2	5	0.0701
3	10	0.1612
4	25	0.4136
5	50	0.7850
6	75	1.2477
7	100	1.6822
8	150	2.5093

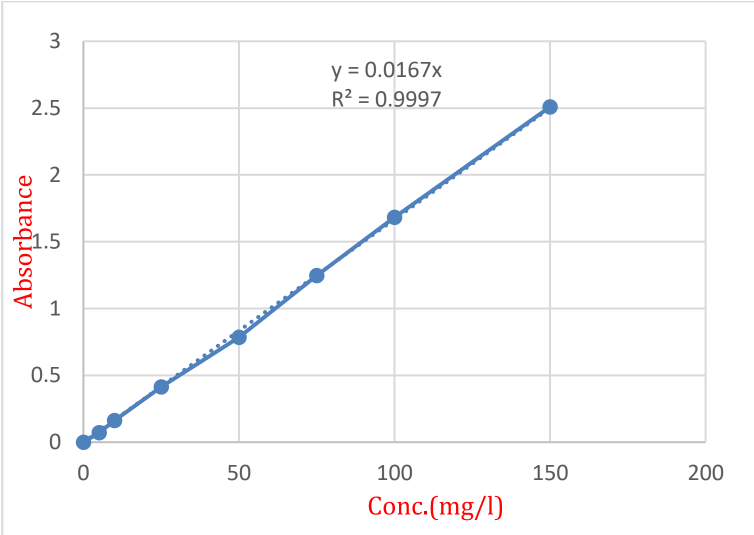

Figure 3- Calibration curve for Brilliant Blue FCF Dye

4. Result and Discussion:

4.1 Effect of pH:

In order to determine the pH needed to destroy the dye most efficiently, the effects of pH on the UV/H_2O_2 process were investigated. In this series of tests, the H_2O_2 concentration (50 mg/L) and dye concentration (50 mg/L) were fixed in order to achieve the ideal pH at various intervals. The study's ideal pH for dye removal is 3. Each result is listed in the tables below and plotted in figure 4.

Table 2- Effect of pH=2 on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, H_2O_2 con= 50mg/l.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.4986	31.76	36.48
2	60	0.3434	21.88	56.25
3	90	0.2172	13.84	72.33
4	120	0.1203	7.67	84.67

Table 3- Effect of pH=3 on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, H_2O_2 con= 50mg/l.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.4723	30.09	39.83
2	60	0.2508	15.98	68.05
3	90	0.1145	7.3	85.41
4	120	0.0427	2.72	94.56

Table 4- Effect of pH=5 on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, H_2O_2 con= 50mg/l.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.5224	33.28	33.45
2	60	0.4091	26.06	47.89
3	90	0.2751	17.52	64.96
4	120	0.1621	10.33	79.35

Table 5- Effect of pH=7 on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, H_2O_2 con= 50mg/l.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.5121	32.62	34.76
2	60	0.3512	22.37	55.26
3	90	0.2351	14.98	70.05
4	120	0.1367	8.71	82.59

Table 6- Effect of pH=11 on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, H_2O_2 con= 50mg/l.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.6140	39.11	21.78
2	60	0.4790	30.01	39.98
3	90	0.3703	23.59	52.83
4	120	0.2604	18.06	66.83

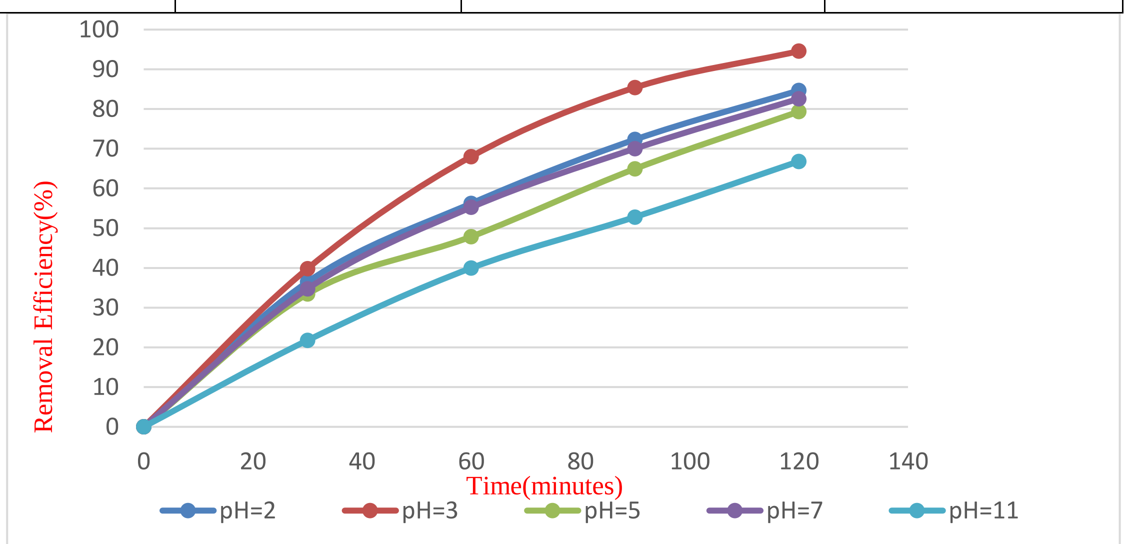

Figure 4- Effect of pH on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, H_2O_2 con= 50mg/l

4.2 Effect of H_2O_2 Concentration:

By conducting studies with a range of H_2O_2 concentrations (10, 15, 25, 40, and 50 mg/L), the impact of the starting concentration of H_2O_2 on the UV/H_2O_2 process was investigated. In these experiments, the ideal pH value of 3 from the earlier inquiry stage was used. For the elimination of dye, 25 mg/l of H_2O_2 is ideal. Figure 5 shows a visualization of all the results, which are listed in the tables below.

Table 7- Effect of H_2O_2 con= 10mg/l on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.7080	45.09	9.81
2	60	0.6261	39.88	20.24
3	90	0.5632	35.88	28.25
4	120	0.5021	31.98	36.04

Table 8- Effect of H_2O_2 con= 15mg/l on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.5814	37.03	25.94
2	60	0.4703	29.96	40.09
3	90	0.3470	22.10	55.80
4	120	0.2693	17.16	65.69

Table 9- Effect of H_2O_2 con= 25mg/l on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.3637	23.17	53.67
2	60	0.1201	7.65	84.70
3	90	0.0343	2.19	95.63
4	120	0.0118	0.75	98.50

Table 10- Effect of H_2O_2 con= 40mg/l on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.3915	24.94	50.13
2	60	0.2101	13.38	73.24
3	90	0.0895	5.7	88.60

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4	120	0.0382	2.44	95.13

Table 11- Effect of H_2O_2 con= 50mg/l on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.4982	31.73	36.54
2	60	0.2976	18.96	62.09
3	90	0.1359	8.66	82.69
4	120	0.0878	5.59	88.82

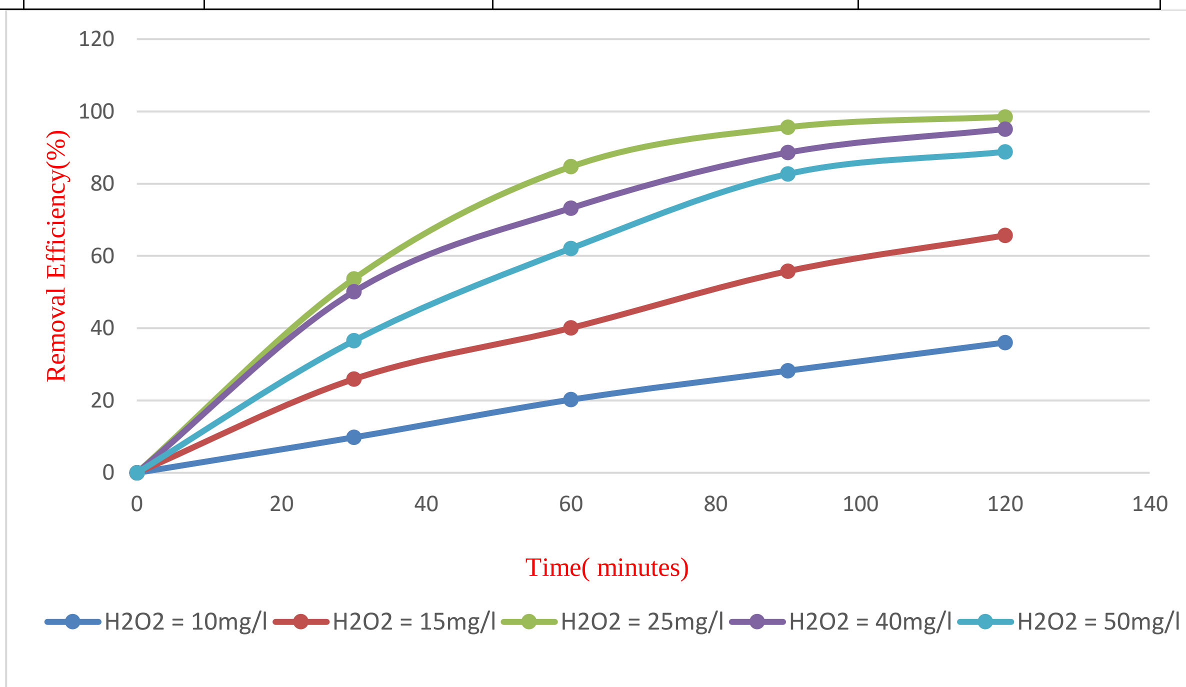

Figure 5- Effect of H_2O_2 concentrations on the degradation of dye by UV/H_2O_2 process at dye con= 50mg/l, pH=3.

4.3 Effect of Dye Concentration:

At an H_2O_2 concentration of 25 mg/L and a pH of 3, various dye concentrations (10, 25, 50, 75, and 100 mg/L) were utilized. In a 10mg/L solution, the reaction happens more quickly. Therefore, those values are not appropriate for ideal circumstances. 50 mg/L is the ideal dye concentration value. Figure 7 shows a visualization of all the results, which are listed in the tables below.

Table 12- Effect of dye con= 10mg/l on the degradation of dye by UV/H_2O_2 process at H_2O_2 con= 25mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.0048	0.30	97.02
2	60	0.0022	0.14	98.63

Table 13- Effect of dye con= 25mg/l on the degradation of dye by UV/H_2O_2 process at H_2O_2 con= 25mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.0744	4.47	82.01
2	60	0.0425	2.57	89.72
3	90	0.0293	1.77	92.91
4	120	0.0121	0.73	97.07

Table 14- Effect of dye con= 50mg/l on the degradation of dye by UV/H_2O_2 process at H_2O_2 con= 25mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.3594	22.89	54.21
2	60	0.1476	9.4	81.20
3	90	0.0256	1.63	96.74
4	120	0.0042	0.27	99.46

Table 15- Effect of dye con= 75mg/l on the degradation of dye by UV/H_2O_2 process at H_2O_2 con= 25mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	0.9535	57.31	23.58
2	60	0.7573	45.52	39.30
3	90	0.5815	34.96	53.39
4	120	0.4565	27.44	63.41

Table 16- Effect of dye con= 100mg/l on the degradation of dye by UV/H_2O_2 process at H_2O_2 con= 25mg/l, pH=3.

S.no	Time (minutes)	Absorbance	Final Concentration (mg/l)	Removal Efficiency (%)
1	30	1.4719	87.5	12.5
2	60	1.2342	73.37	26.63
3	90	1.0652	63.32	36.68
4	120	0.9233	54.89	45.11

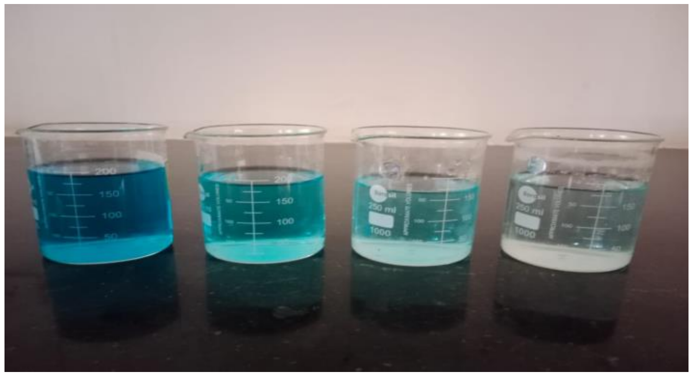

Figure 6- Degradation of dye by UV/H_2O_2 Process at H_2O_2 con= 25mg/l, pH=3, Dye con= 50 mg/l.

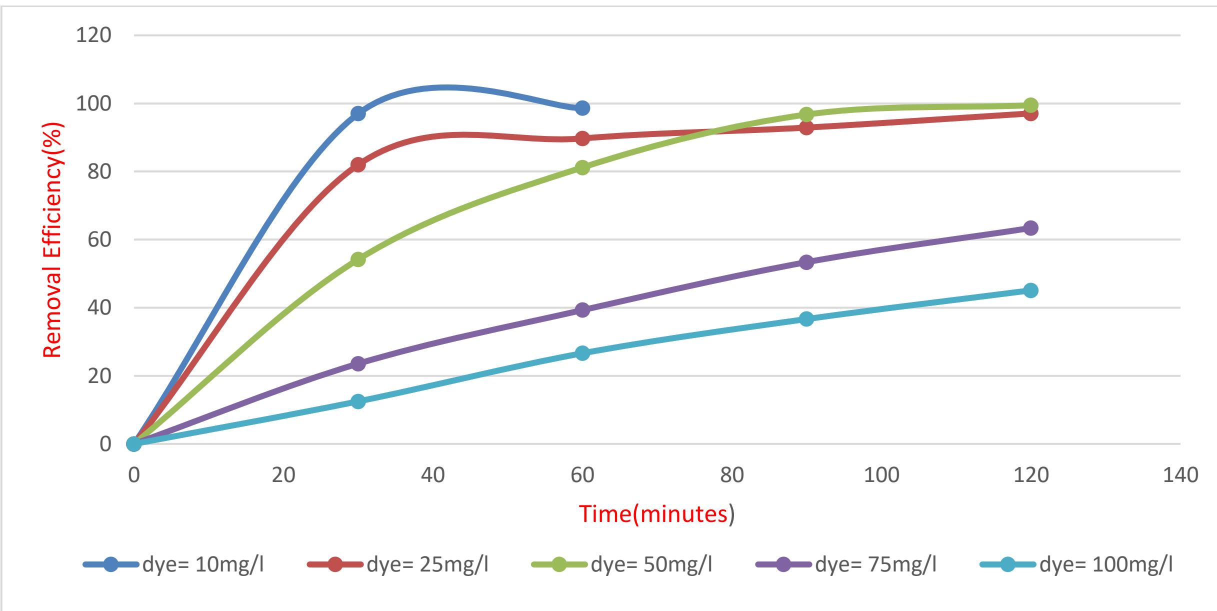

Figure 7- Effect of dye concentrations on the degradation of dye by UV/H_2O_2 process at H_2O_2 con= 25mg/l, pH=3.

5. Conclusion and Future Scope:

In this work, a UV/H_2O_2 process was used to cleanse water that had been tainted with the Brilliant Blue FCF dye. The input hydrogen peroxide (H_2O_2) concentration, pH, temperature, and dye content in the wastewater all had an impact on the process. The removal effectiveness of the UV/H_2O_2 process was found to be 54.21%, 81.20%, 96.74%, and 99.46% at 30 min, 60 min, 90 min, and 120 min, respectively, under ideal circumstances and dosage (H_2O_2 = 25 mg/L, pH=3, for 50 mg/L dye concentration).

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Although the primary goal of this study is to remove dye from aqueous solutions using the UV/H_2O_2 Process, there are other chemicals and metals in the sample as well. In the future, we should concentrate on the removal of various heavy metals, and we still need to make progress in the direction of creating materials that are more stable and capable of simultaneously removing a number of contaminants, including toxic metal ions, organic dyes, and bacterial pathogens. In order to satisfy the requirement of rising environmental contamination, a variety of treatment methods should be created for the purification of water.

6. References:

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