



STUDIES ON REMOVAL OF METANIL YELLOW DYE FROM WASTEWATER USING COCONUT SHELL POWDER AND OPTIMIZATION USING CENTRAL COMPOSITE DESIGN

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Abstract

The research investigated the removal of Metanil Yellow dye from wastewater using a low-cost, eco-friendly biosorbent-coconut shell powder. This biosorbent is widely available, economical, and effective. A dosage of 20 g/L with a 53 µm particle size removed 91% of the dye. The optimal contact time was 40 minutes for treating 20 mg/L dye in 50 mL solution. Biosorption efficiency decreased with larger particle sizes but increased with higher adsorbent doses. Removal was most efficient at pH 2, with efficiency decreasing as pH rose toward 8.

Keywords: *Biosorption, pH, time, RSM, Dosage and Temperature.*

1.0 Introduction

Water is the second most important natural resource after air, valued for its rarity and essential role despite covering most of the planet. Only a small portion is usable for human needs [1]. It must be carefully managed and maintained in quality for industrial, agricultural, and residential purposes [2]. Continuous monitoring of water sources is crucial to ensure cleanliness and environmental stability, as water body deterioration signals environmental stress and risks to life. Evaluating water quality is vital for public health, economic stability, and environmental protection. Wastewater from industries using pigments and dyes poses a treatment challenge because conventional biological methods are slow and ineffective at breaking down dyes. Chemical and physical treatments are commonly used but tend to be costly and inefficient for diverse dye wastes [3-4].

Adsorption is one of the best techniques for removing colors from wastewater, outperforming previous methods by effectively removing color even from diluted solutions and operating cleanly without producing sludge [5-6]. The

most effective adsorbent is activated carbon (granular or powdered) due to its high adsorption capacity for organic molecules. However, activated carbon is economically unaffordable, and its regeneration leads to a 10–15% loss of adsorbent and adsorption capacity when using refractory methods, while solution regeneration produces only a small amount of additional effluent [7-10]. Therefore, there is a need for novel adsorbents that are more affordable, accessible, and highly effective, as current adsorbents have limited adsorption capacities.

2.0 Experimental procedure

2.1 Reagents and materials

The compounds employed in this investigation were all analytical grade and did not undergo any additional purification. To achieve the appropriate pH, 0.1N HCL and 0.1N NaOH solutions were added to the dye solution.

2.2 Preparation of Biosorbent

To purify gathered coconut shells, any pulp or dirt that adheres to them is removed. Coconut shells are thoroughly cleaned with distilled water until the rinse water is clear

of pollutants such as dust and soluble contaminants. To remove moisture, the shells are dried in the sun or in a hot air oven between 60 and 80 degrees Celsius until their weight is stable enough to proceed to the next grinding step. The dry shells are ground in a mechanical grinder to produce a fine powder. The sieve, which was previously stored in a desiccator to prevent contamination, is used to get fractions of the required particle sizes (53, 75, 105, 125, and 152 μm for this experiment).

2.3 Preparation of the 1000mg/L of Metanil Yellow solution

All necessary solutions are made using analytical reagents and double-distilled water. In a 1 L volumetric flask, 1.0 g of Metanil Yellow is completely dissolved in distilled water to produce 1000 ppm (mg/L) of Metanil Yellow stock solution.

2.4 Studies on equilibrium biosorption:

A pre-weighed quantity of coconut shell powder was added to a specified volume of aqueous solution for a predefined duration of time in an orbital shaker to perform the biosorption in a batch operation. Below is an explanation of the methods used to assess the different parameters: temperature, pH, starting lead concentration in aqueous solution, biosorbent size, biosorbent dose, and agitation duration.

2.5 Experimental design for biosorption studies

Four independent criteria were chosen for the investigation in order to determine the ideal environment for the percentage elimination of MY dye. Preliminary tests are used to determine the pH (X1), concentration (X2), w, dose (X3), and temperature (X4) research ranges. The STATISTICA software's Response Surface Methodology (RSM) was used to ascertain the link between the parameters and response. The RSM was used for this investigation due of its robustness, flexibility, and efficiency. Thirty tests are carried out using the RSM design. The experimental design's response (Y) was calculated as the percentage of MY dye elimination. An ultraviolet spectrophotometer is used to examine samples collected after the specified time frame. Both graphical and regression analysis were performed.

3.0 Results and Discussion

3.1 Effect of agitation time: Plotting the percentage of Metanil Yellow dye biosorption versus agitation time, as seen in Figure 3.1, for interaction time intervals ranging from 3 to 180 minutes yields the equilibrium agitation time. A biosorbent size of 53 μm and a dose of 10 g/L (0.5 g mixed in 50 mL of aqueous solution) were used in the experiment. In the beginning, the rate of biosorption was quick. Up to 30 minutes, the percentage elimination rose quickly. The percentage of biosorption was nearly constant after 30 minutes, suggesting that equilibrium conditions had been reached. With a starting dye concentration (C0) of 20 ppm, the maximum biosorption clearance of around 65% was attained after 30 minutes of agitation. There are less accessible surface sites and

repulsive interactions between the adsorbed molecules and those in the bulk phase as more dye is adsorbed onto the surface over time [11-12].

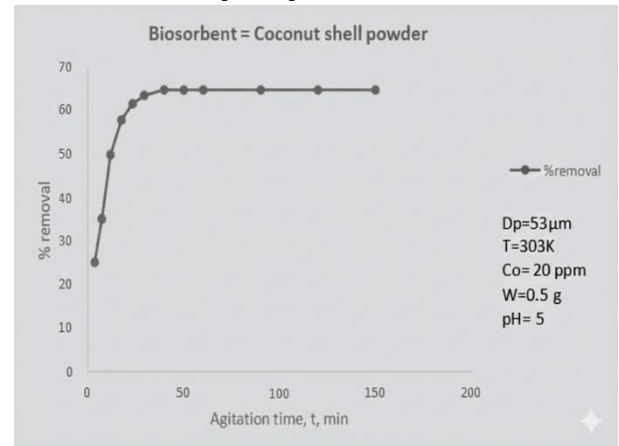


Figure 01: Effect of time on % removal of dye

3.2 Effect of biosorbent size:

The differences between the biosorbent size and the percentage biosorption of Metanil Yellow dye from the aqueous solution are obtained. Figure 3.2 shows the results, showing the proportion of Metanil Yellow dye biosorption as a function of biosorbent size. When the particle size was decreased from 150 μm to 53 μm , the removal effectiveness rose from around 45% to 65%. This result is predicted as the biosorbent's surface area rises as particle size decreases, increasing the number of active sites on the biosorbent [13-14].

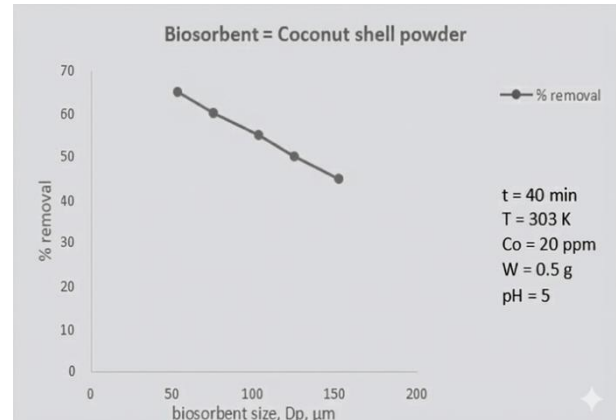


Figure 02: Effect of size on % removal of Metanil Yellow dye

3.3 Effect of pH

Figure 3.3 illustrates how the pH of an aqueous solution affects the percentage of Metanil Yellow dye biosorption. The graph illustrates how pH has a significant impact on the % biosorption of MY dye. At pH 2, the greatest biosorption was seen, removing around 80% of the dye. The percentage of biosorption dropped dramatically as the pH rose from 2 to 8, reaching a minimum of around 15% at pH 8. The biosorbent surface becomes less positive and finally negatively charged when the pH rises because the concentration of H⁺ ions falls and the surface functional groups get deprotonated [15-16].

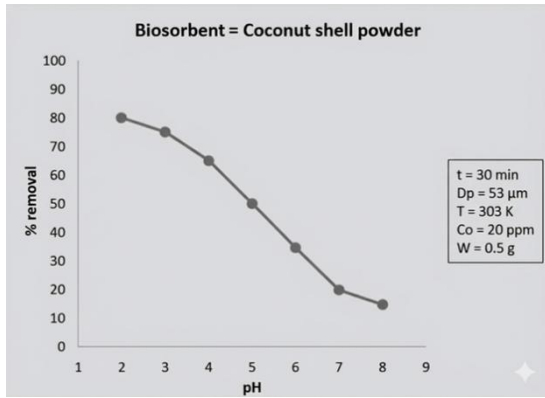


Figure 03: Effect of pH % removal of Metanil Yellow dye

3.4 Effect of initial concentration of Metanil Yellow dye:

Figure 3.4 illustrates how the initial concentration of Metanil Yellow dye in the aqueous solution affects the percentage of Metanil Yellow dye biosorption. With an increase in C_0 from 20 mg/L to 150 mg/L, the percentage biosorption of Metanil Yellow dye drops from 72.9% to 52.925%. The rise in biosorbate to the constant number of active sites on the biosorbent is responsible for this phenomenon [17-18].

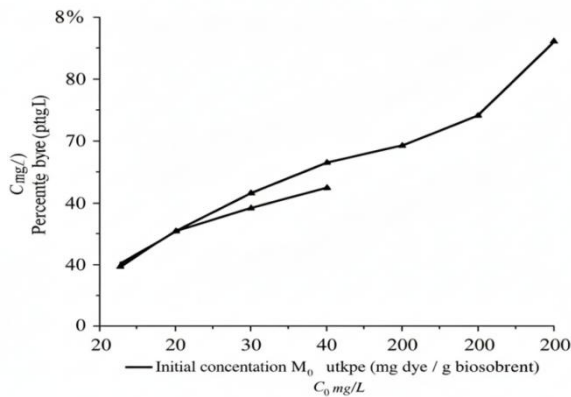


Figure 04: Effect of initial concentration on % removal of Metanil Yellow dye

3.5 Effect of biosorbent dosage

Figure 3.5 shows the proportion of Metanil Yellow dye biosorption against biosorbent dose for a 53 μm size biosorbent. When the biosorbent dose was raised from 10 to 40 g/L, the biosorption of Metanil Yellow dye rose from 73% to 84.4%. This tendency is evident because more active sites would be available for the biosorption of Metanil Yellow dye with an increase in biosorbent dose. When "w" is raised from 40 to 60 g/L, the percentage biosorption of Metanil Yellow dye changes little, from 84.4% to 86.9%. Therefore, the dose used in the subsequent tests is 40 g/L [19-20].

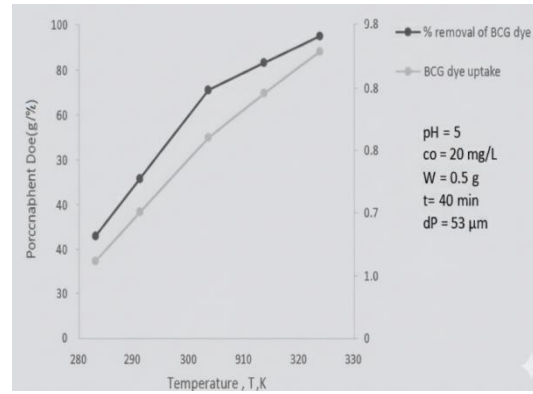


Figure 05: Effect of dosage on % removal of Metanil Yellow dye

3.6 Effect of Temperature

The equilibrium dye uptake was significantly impacted by temperature. Fig. 3.6 illustrates how temperature variations affect the absorption of the Metanil Yellow dye. Metanil Yellow dye absorption rose with temperature when the temperature was below 303 K, whereas the opposite was true when the temperature was above 303 K. This reaction suggested that the dye and the ligands on the cell wall interacted differently. Physical biosorption processes were often exothermic below 303 K, hence the amount of biosorption typically remained constant as the temperature increased [21-22].

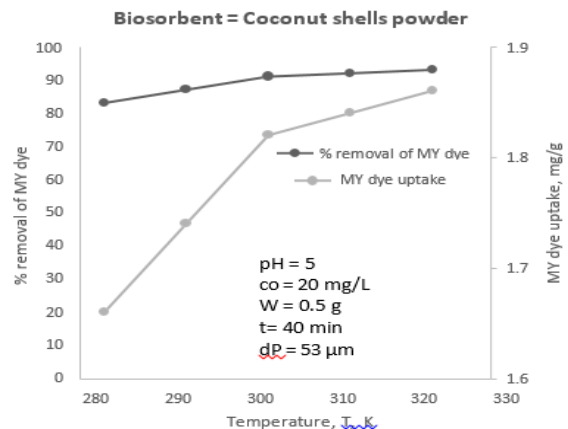


Figure 06: Effect of temperature on % removal of Metanil Yellow dye

3.7 Optimization using Response Surface Methodology (RSM):

3.7.1 Optimization using CCD

Finding the ideal conditions for the biosorption of Metanil Yellow dye requires identifying the characteristics that have the biggest impact on the reaction. In this study, the % biosorption of Metanil Yellow dye and four independent variables are related using the quadratic model. The regression equation for the percentage of Metanil Yellow dye (Y) biosorption depends on pH (X1), C_0 (X2), w (X3), and T (X4) [23-24]. Table 3.1 displays the differences in the corresponding coded values of four parameters and response.

Table-3.1 Levels of different process variables in coded and un-coded form for

Variable	Name	Range and levels				
		-2	-1	0	1	2
X ₁	pH of aqueous solution	3	4	5	6	7
X ₂	Initial concentration, C _o , mg/L	10	15	20	25	30
X ₃	Biosorbent dosage, w, g/L	20	30	40	50	60
X ₄	Temperature, T, K	283	293	303	313	323

% biosorption of Metanil Yellow dye using *Coconut shell*
 Multiple regression analysis of the experimental data for the biosorption of Metanil Yellow dye is represented by the following equation:

$$Y = -9004.47 + 32.06 X_1 + 4.51 X_2 + 2.30 X_3 + 58.73 X_4 - 3.17 X_1^2 - 0.12 X_2^2 - 0.03 X_3^2 - 0.10 X_4^2 + 0.05 X_1X_2 - 0.02 X_1X_3 - 0.00 X_1X_4 + 0.00 X_2X_3 - 0.00 X_2X_4 + 0.00 X_3X_4$$
 ----- (3.1)

Table 02: Results from CCD for Metanil Yellow dye biosorption by *Coconut shell*

Run no.	X ₁ , pH	X ₂ , C _o	X ₃ , W	X ₄ , T	% biosorption of Metanil Yellow dye	
					Experimental	Predicted
1	4	15	30	298	80.22	80.19
2	4	15	30	308	81.82	81.83
3	4	15	50	298	81.98	82.00
4	4	15	50	308	83.68	83.66
5	4	25	30	298	80.98	80.99
6	4	25	30	308	82.68	82.65
7	4	25	50	298	82.82	82.81
8	4	25	50	308	84.48	84.49
9	6	15	30	298	81.18	81.17
10	6	15	30	308	82.82	82.82
11	6	15	50	298	81.98	82.00

		5	0	8		
12	6	15	50	308	83.68	83.66
13	6	25	30	298	82.98	82.99
14	6	25	30	308	84.68	84.66
15	6	25	50	298	83.84	83.83
16	6	25	50	308	85.48	85.51
17	3	20	40	303	80.32	80.33
18	7	20	40	303	82.34	82.34
19	5	10	40	303	80.98	80.99
20	5	30	40	303	83.64	83.64
21	5	20	20	303	81.98	82.00
22	5	20	60	303	84.68	84.67
23	5	20	40	293	82.68	82.67
24	5	20	40	313	85.98	86.00
25	5	20	40	303	94.00	94.00
26	5	20	40	303	94.00	94.00
27	5	20	40	303	94.00	94.00
28	5	20	40	303	94.00	94.00
29	5	20	40	303	94.00	94.00
30	5	20	40	303	94.00	94.00

The response values of a central composite design with 24 factorial runs, 6 central points, and 8 axial points were observed under experimental settings [coded values]. The CCD findings are shown in Table 3.3, with the agitation period set at 20 minutes and the biosorbent size at 53 μm. The response derived from regression in equation 3.1 is displayed as an ANOVA.

Table 03: ANOVA of Metanil Yellow dye biosorption for entire quadratic model

Source of variation	SS	Df	Mean square(MS)	F-value	P > F
Model	654.7889	14	46.7706	106296	0.00000

Error	0.0066	15	0.00044		
Total	654.7889				

df- degree of freedom; SS- sum of squares; F- factor F; P- probability

R²=0.99999; R² (adj):0.99998:

Table 04: Estimated regression coefficients for the Metanil Yellow dye biosorption onto *Coconut shell*

Terms	Regression coefficient	Standard error of the coefficient	t-value	P-value
Mean/Intercept	-9004.47	14.97223	-601.412	0.0000
Dosage, w, g/L (L)	32.06	0.32251	99.406	0.0000
Dosage, w, g/L (Q)	-3.17	0.00402	-788.597	0.0000
Conc, Co, mg/L (L)	4.51	0.06440	69.979	0.0000
Conc, Co, mg/L (Q)	-0.12	0.00016	-727.581	0.0000
pH (L)	2.30	0.03220	71.418	0.0000
pH (Q)	-0.03	0.00004	-664.074	0.0000
Temperature, T, K (L)	58.73	0.09766	601.424	0.0000
Temperature, T, K (Q)	-0.10	0.00016	-601.812	0.0000
1L by 2L	0.05	0.00105	48.267	0.0000
1L by 3L	-0.02	0.00053	-46.840	0.0000
1L by 4L	0.00	0.00105	0.238	0.81528
2L by 3L	0.00	0.00011	0.238	0.81528
2L by 4L	0.00	0.00021	0.713	0.48661
3L by 4L	0.00	0.00011	0.713	0.48661

^ainsignificant ($P \geq 0.05$)

All of the interaction factors had no effect on the biosorption capacity ($P < 0.05$). The Pareto chart and normal probability plot (NPP) of residual values are displayed in Figures 3.7 and 3.8. The experimental points appear to be fairly aligned, indicating a normal distribution.

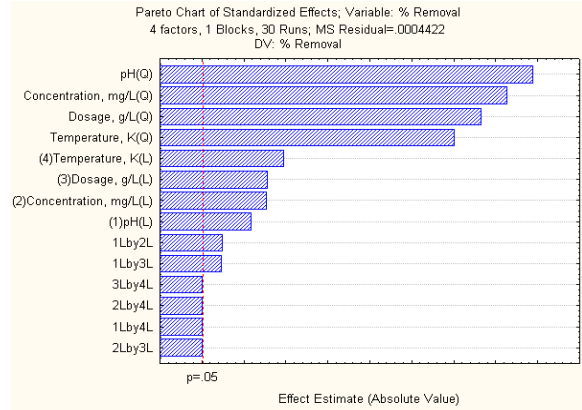


Figure 07: Pareto Chart

3.7.2 Interaction effects of biosorption variables

The percentage of biosorption as a function of for different combinations of independent variables is displayed in the three-dimensional perspective of response surface contour plots [Fig. 3.9 (a) to (f)]. Plots are shown as functions of two elements at a time, with all other components held constant at zero.

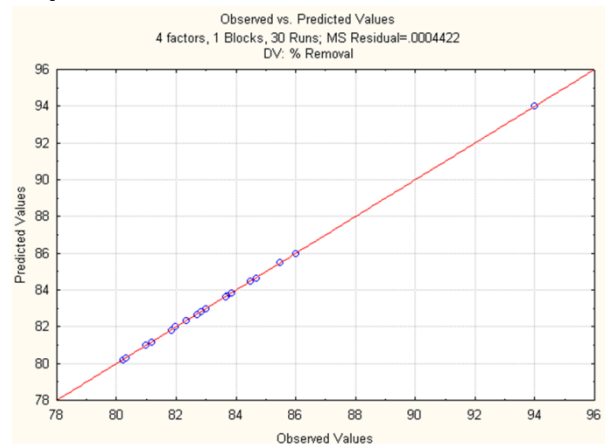


Figure 08: Normal probability plot for % biosorption of Metanil Yellow dye

The predicted optimal set of conditions for percentage biosorption of Metanil Yellow dye is

pH of aqueous solution

= 5.0791

Initial Metanil Yellow dye concentration =

20.5848 mg/L

Biosorbent dosage

= 41.2135 g/L

Temperature

= 303.8606 K

% biosorption of Metanil Yellow dye =

94.17045

Table 3.5 displays the experimental data as well as the ideal sets of circumstances that were achieved using CCD.

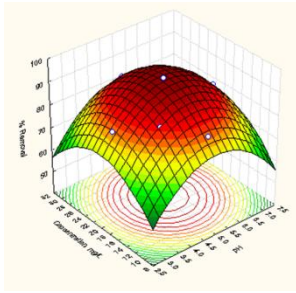


Figure 09(a): Surface contour plot for the effects of pH and initial Metanil Yellow dye concentration on % biosorption

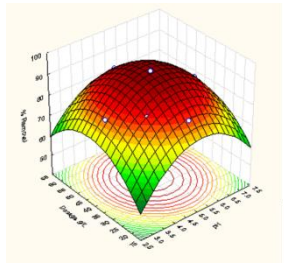


Figure 09(b): Surface contour plot for the effects of pH and dosage on % biosorption of Metanil Yellow dye

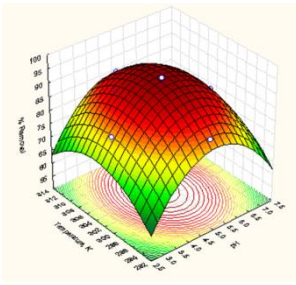


Figure 09(c): Surface contour plot for the effects of pH and Temperature on % biosorption of Metanil Yellow dye

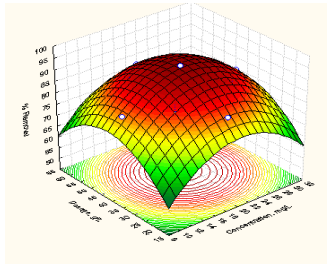


Figure 09 (d): Surface contour plot for the effects of initial concentration and dosage on % biosorption of Metanil Yellow dye

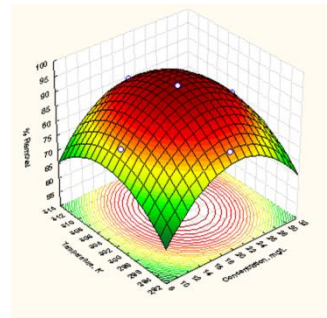


Figure 09(e): Surface contour plot for the effects of initial concentration and Temperature on % biosorption of Metanil Yellow dye

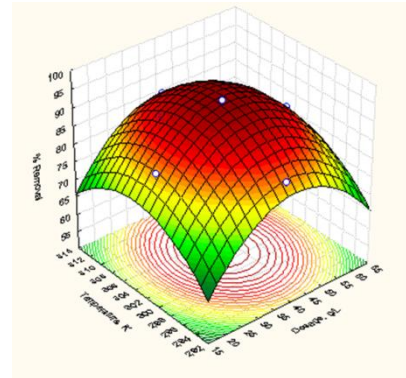


Figure 09(f): Surface contour plot for the effects of Dosage and Temperature on % biosorption of Metanil Yellow dye

Table 05: Comparison between optimum values from CCD and experimentation

Variable	CCD	Experimental value
pH of aqueous solution	5.0791	5
Initial Metanil Yellow dye concentration, mg/L	20.5848	20
Biosorption dosage, w, g/L	41.2135	40
Temperature, K	303.8606	303
% biosorption	94.17045	90

4. 0 Conclusion

This investigation aims to determine the suitability of coconut shells powder as a biosorbent for the removal of Metanil Yellow dye from aqueous solutions for biosorption of MY dye experimentally and theoretically, resulting in the following conclusions:

- The equilibrium agitation time for dye biosorption is 40 minutes.
- The percentage biosorption of MY dye decreased with the increase in biosorbent size from 53 μm (45 %) to 152 μm (65 %)
- Percentage biosorption of FG dye from the aqueous solution increases significantly with an increase in pH from 2 (80 %) to 8 (15 %).
- The optimum dosage for biosorption is 40 g/L.
- The maximum uptake capacity of 18.0831 mg/g is obtained at 303 K.
- The maximum sorption of MY dye (94.17045 %) onto coconut shells powder is observed when the processing parameters are set as: pH = 5.0791, w = 41.2135 g/L, Co = 20.5848 mg/L and T = 303.86 K using CCD.

As a result, the powdered coconut shells indicated above are a powerful biosorbent that may eliminate the dye Metanil Yellow.

5.0 Acknowledgements

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6.0 References

- Ahmad, A., Rafatullah, M., Sulaiman, O., Ibrahim, M. H., Hashim, R., & Ahmad, A. (2009). Removal of dyes from aqueous solutions using coconut shell-based activated carbon. *Chemical Engineering Journal*, 155(1-2), 191-198.
- Allen, S. J., & Koumanova, B. (2005). Decolorization of water and wastewater using adsorption techniques. *Journal of the University of Chemical Technology and Metallurgy*, 40(3), 175-192.
- APHA. (2017). *Standard Methods for the Examination of Water and Wastewater* (23rd ed.). American Public Health Association.
- Babel, S., & Kurniawan, T. A. (2003). Low-cost adsorbents for heavy metals uptake from contaminated water. *Journal of Hazardous Materials*, 97(1-3), 219-243.
- Bhattacharya, A. K., & Sharma, A. (2005). Kinetics and thermodynamics of methylene blue adsorption on neem leaf powder. *Journal of Chemical Technology & Biotechnology*, 80, 121-127.
- Brown, L., & Hart, K. (2018). Water pollution and global health: A review. *Environmental Science & Health Review*, 12(4), 255-272.
- Crini, G. (2006). Non-conventional low-cost adsorbents for dye removal. *Bioresource Technology*, 97(9), 1061-1085.
- Crini, G., & Lichtfouse, E. (2019). Advantages and disadvantages of techniques used for wastewater treatment. *Environmental Chemistry Letters*, 17, 145-155.
- Das, B., & Barma, R. (2014). Adsorption of acid dyes on agricultural waste materials. *Applied Water Science*, 4, 45-52.
- Jain, S. N., Tamboli, S. R., Sutar, D. S., Jadhav, S. R., Marathe, J. V., & Mawal, V. N. (2022). Kinetic, equilibrium, thermodynamic, and desorption studies for sequestration of acid dye using waste biomass as sustainable adsorbents. *Biomass Conversion and Biorefinery*, 12, 2597-2609.
- Kumar, P., & Prasad, A. (2015). Biosorption of heavy metals using tamarind fruit shell: Kinetic and equilibrium studies. *Environmental Science and Pollution Research*, 22(4), 2925-2934.
- Sintakindi and Ankanwar (2023) – Biosorption of Bromocresol Green from Aqueous Solution by *Earliella scabrosa* Fungal Biomass
- Onu et al. (2022) – Adsorptive Removal of Bromocresol Green Dye Using Activated Corn Cob
- Shokrollahi et al. (2011) – Removal of Bromocresol Green from Aqueous Solution via Adsorption of *Ziziphus nummularia* as a New, Natural, and Low-Cost Adsorbent: Kinetic and Thermodynamic Study
- Zhou et al. (2018) – Adsorption of Cu (II) and Cd (II) from Aqueous Solutions by Ferromanganese Binary Oxide–Biochar Composites
- Shokrollahi, A., Ghaedi, M., Rajabi, H. R., & Noshad, A. (2011). "Removal of Bromocresol Green from aqueous solution via adsorption of *Ziziphus nummularia* as a new, natural, and low-cost adsorbent: Kinetic and thermodynamic study", *Molecules*, 16(12), 10350-10360.
- Dawood, S., & Sen, T. K. (2014). "Review on dye removal from its aqueous solution into alternative cost-effective and non-conventional adsorbents", *Journal of Chemical and Process Engineering Research*, 1, 1-24.
- Kavitha, D., & Namasivayam, C. (2007). "Experimental and kinetic studies on methylene blue adsorption by coir pith carbon Bioresource Technology", 98(1), 14-21.
- Kumar, A., & Tripathi, R. (2019). "Use of tamarind seed powder as an efficient biosorbent for the removal of methylene blue dye from aqueous solution", *Environmental Technology & Innovation*, 14, 100334.
- Sgher, M., Bhatti, H. N., Bhatti, I. A., & Sheikh, M. A. (2010). Response Surface Methodology and Central Composite Design Analysis of Biosorption of Reactive Anthraquinone Dyes by *Citrus sinensis* Waste Biomass. *Asian Journal of Chemistry*, 22(10), 7817-7826.
- Demirel, M., & Kayan, B. (2012). Application of Response Surface Methodology and Central Composite Design for the Optimization of Textile Dye Degradation by Wet Air Oxidation. *International Journal of Industrial Chemistry*, 3, 24.
- Karthikeyan, K., Nanthakumar, K., Shanthi, K., & Lakshmanaperumalsamy, P. (2010).
- Response Surface Methodology for Optimization of Culture Conditions for Dye Detry, 3, 2colorization by a Fungus, *Aspergillus niger* HM11 Isolated from Dye Affected Soil. *Iranian Journal of Microbiology*, 2(4), 213-222.
- Kowsalya, P., Bharathi, S. U., Sivasankar, S., & Sundaram, S. (2023). Optimization of Photo-Active Carbon Dots for Reactive Dyes Degradation by Response Surface Methodology—An Industrial Approach. *Journal of the Iranian Chemical Society*, 20, 1545-1557.