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ANFIS FOR PREDICTING REMOVAL EFFICIENCY OF METHYLENE BLUE ONTO CORDIA MIXA-A

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***Abstract**: In this study, Cordia myxa fruit (CM) was used as an adsorbent to remove methylene blue (MB) dye from industrial wastewater. Activated carbon was produced from (CM) by carbonization using a tubular furnace at temperatures of 400 °C and by passing nitrogen as inert gas for 2 hours. Appropriate tests were carried out for the biochar that was produced such as the effect of pH, adsorbent dose, adsorbate concentration and contact time on adsorption of MB on CM. The results also showed that the optimal pH was 7.5, the optimal dose of the adsorbent was 2 g/L, the optimal concentration of (MB) was 5 mg/L, and the contact time was 80 minutes. The removal efficiency of MB onto CM-A was modelled using Adaptive Neural Fuzzy Inference Systems (ANFIS). An MB-on-CM adsorption experiment was planned for ANFIS training. Using 40 experimental data sets, ANFIS was trained with gradient descent with momentum algorithm and averaged 0.52 per cent error. The testing accuracy was verified with 6 additional experimental data sets, and the average predicting error was 0.088%. The ANFIS model was used to discuss the effect of pH and contact time on MB removal from CM-B.*

Keywords: *Adsorption; biochar; Cordia myxa; Carbonization; ANFIS*

1. INTRODUCTION

Environmental pollution and the problems resulting from it are among the important issues that have occupied the world since the beginning of the twentieth century [1]. Industrial, agricultural and population growth has made the water used for utilitarian purposes free of various types of pollutants in a continuous decrease [2]. It is known that the various industrial wastes, whether the petrochemical industries or the agricultural pesticide industry and other industries contain slow decomposing organic compounds and dyes that cannot be removed by traditional methods [3]. Dyes are considered dangerous industrial pollutants due to their large quantities in industrial wastewater, the difficulty of decomposition, hazardous effect and carcinogenicity, so it has become necessary to find methods to remove these pollutants [4]. Methylene blue MB is a basic dye and one of the dyes resulting from industrial waste is dangerous and cannot be removed by traditional methods [5]. The molecular formula of (MB) is $C_{37}H_{27}N_3Na_2O_9S_3$ and the molecular mass is 779.8 g mol^{-1}. (MB) is used as a disinfector in pharmaceuticals, rubbers, varnishes, pesticides, dyestuff, colouring agents, and so on [6]. The discharging of (MB) into the water can significantly affect the food chain and aquatic life even in small concentrations [7]. (MB) shows adequate resistance to oxidation by photodegradation, biodegradation and traditional chemical oxidation because of its complex aromatic structure [6]. Therefore, efficient decolourization treatment of (MB) from aqueous solutions has been gaining notice in recent years. Some adsorbents have been considered for the efficient removal of (MB) from water, such as magnesium carbonate hydroxide [8], activated carbons [9], silicon–carbon–nitrogen hybrid materials [10] and manganese dioxide [11]. It is not possible to remove (MB) by traditional methods, so adsorption is the appropriate method to remove this dye from the aqueous body [12].

Adsorption is one of the traditional methods of controlling the release of organic compounds [13]. Adsorption is primarily used to reduce organic discharges, although metal removal has been demonstrated in some wastewater applications. Adsorption is a mass transfer process that can generally be defined as the accumulation of substances at the interface between two phases [14]. In general, chemicals in the liquid phase preferentially accumulate on an unsaturated solid surface causing the chemical to be removed from the liquid phase. The substance on which the chemical (such as carbon) is absorbed is known as an adsorbent. The substance that gets absorbed (usually the contaminant) is known as an adsorbate [15]. There are two types of adsorption, physical and chemical. Physical until the pH value became approximately 7 [29-31], then dried the product in an electric oven At a temperature of 105 °C for 2 hours and after taking it out of the oven, it is placed in a desiccator until its temperature becomes equal to the temperature of the laboratory. The resulting carbon from the Cordia myxa was activated with acid (CM-A), and then it is placed in a dark box for subsequent uses. The same procedure is repeated to produce activated carbon but at a temperature of 300 °C and 500 °C.

2.2. Tubular Furnace.

The tubular furnace of Chinese origin, is a Saftherm type, giving a temperature of from 30 to 3000 3000 °C. It contains a quartz cylinder with a length of 800 mm, an inner diameter of 50 mm and an outer diameter of 60 mm, through which nitrogen gas passes, and it also includes a ceramic crucible bearing a temperature of 3000 °C placed in this cylinder.

2.3. Batch adsorption experiments.

The adsorption experiments were conducted in a 100 mL conical flask on a shaking water bath. All experiments were conducted three times and the average values were reported. The optimum pH was calculated by taking 4 samples of variable pH with a fixed concentration of the adsorbate (MB) and a fixed dose of the adsorbent (activated carbon), where the adsorbent concentration was 2 g/L and the adsorbate concentration was 5 mg/L. pH values were varied from sample to sample 3, 5, 7, and 9. The alkaline and acidic pH of the solution was maintained by adding amounts of HCl or NaOH solutions at a concentration of 0.1 mol/L at a mixing speed of 150 rpm and by taking a test for each sample every 10 minutes using a UV-VIS spectrophotometer. The optimal dose of CM-A was calculated by fixing the pH and the concentration of adsorbate. Conversely, the dose of the adsorbent was changed and the values were 1, 2, 5, 10, 15, and 20 g/L at a mixing speed of 150 rpm for 80 minutes. The effect of the initial concentration of MB was performed by varying the initial MB concentrations from 1 to 40 mg /L. CM was added to a 100 mL volume of MB solution. After different interval times, results from the reaction mixture were analyzed for residual MB concentration using a UV-VIS spectrophotometer at 638 nm wavelength. The effect of contact time was investigated using 2 g of CM, and 5 mg/L MB solution. The adsorbent dose was investigated using a 5 mg/L initial MB concentration with sorbent masses by varying from 0.5 to 3 g. The removal efficiency and amount of dye adsorbed at equilibrium onto CM were calculated by the equations 1 and 2.

$$R\% = \frac{C_O - C_e}{C_O} \times 100 \quad (1)$$

Where R= Removal efficiency, C_o (mg/L) = Initial concentration, C_e (mg/L) = effluent equilibrium concentration of MB.

$$q_e = \frac{C_o - C_e}{M} \times V \quad (2)$$

Where q_e (mg/g) = adsorption capacity, M (g) =dosage of activated carbon, V (L) = Volume of solution.

2.4. ANFIS Basics

Adaptive Neural Fuzzy Inference Systems (ANFIS) are AI modelling techniques with a structure akin to human brain cells. ANFIS combines the best qualities of Fuzzy Logic (FL) Systems and Artificial Neural Networks (ANN), *i.e.* it is one of a special ANN family components, utilized to define the approach of parameter approximation of Fatigue Life modelling based on experimental data in this study.

ANFIS' 5 layers (Fuzzification, Rule, Normalization, Defuzzification, Output summation node). MATLAB uses fuzzy iteration to train and evaluate ANFIS. Figure 1 shows a dual-input ANFIS network[37].

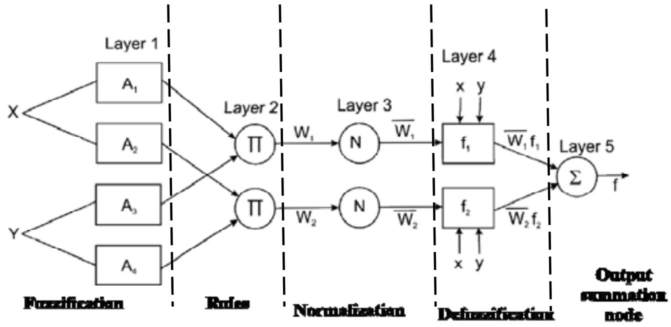


Figure.1. ANFIS structure.

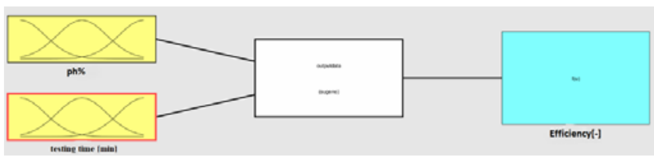
The model's performance was estimated using the RMSE statistical criterion, which is given in Equation 3: Root Mean Square Error:

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{(n_{ex} - n_{pr})^2}{N}} \quad (3)$$

Where nex is an Experimental number of the removal efficiency, npr is the Predicted number of the removal efficiency using the ANFIS model and N is the Data numbers This study used A Gaussian Membership function (GMFs.

2.5. ANFIS Model Design

Two neurons at the input layer (one for the testing time and one for pH on the adsorption of MB onto CM-A adsorbent), and one neuron at the output layer for calculating the removal efficiency in figure 2.



Figures 2..Fuzzy Inference System (FIS) modelling system

For fuzzy set input, the GMFs including pH and testing time variable is represented in Figure. 3a and b respectively.

3. RESULTS AND DISCUSSION

3.1. Effect of pH on the adsorption of MB onto CM-A adsorbent (Calculating the optimum pH).

The results showed that maximum removal efficiency calculated as in equations 1 was 65% at pH = 8 and contact time of 80 minutes as in Table 2 and Figure 5.

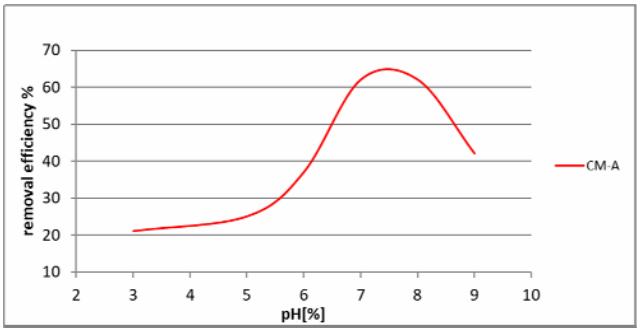


Figure 5. Effect of pH value on removal efficiency of MB onto CM-B

Table 2. The removal efficiency of MB by CM at various pH and times.

Time	Efficiency (%) (pH=3)	Efficiency (%) (pH=5)	Efficiency (%) (pH=7)	Efficiency (%) (pH=9)
0	0	0	0	0
10	10	14	33	31
20	16	25	44	35
30	21	27	47	39
40	22	29	49	44
50	23	30	50	46
60	23	31	52	48
70	24	33	53	50
80	25	33	54	51
90	25	33	54	51
100	25	33	54	51

3.2. Interchange effects of ANFIS

The results of the neural network were used to generate three-dimensional surface diagrams by taking into account the input parameters (test time and pH) as well as the output parameter (removal efficiency) as shown in Figure 6.

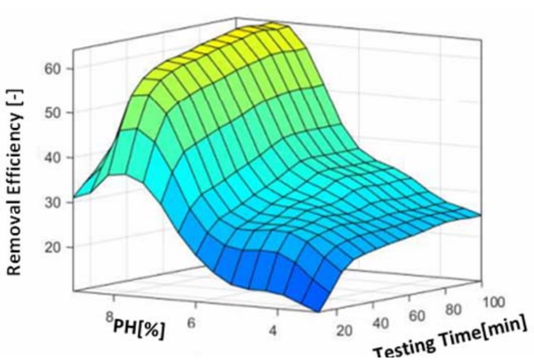


Figure 6. removal efficiency of MB onto CM-A are affected by the interchangeability of ph and testing time.

3.3. Essential effect curves of ANFIS

To investigate and analyze the effect of pH and testing time on the MB removal from CM-A by changing one parameter at a time, while keeping all other parameters constant at the centre level Figure 7.

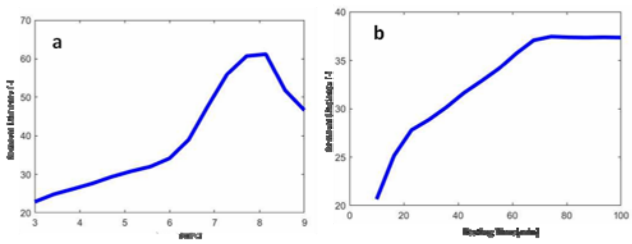


Figure 7. Affect MB removal from CM-A with a) pH, b) testing time

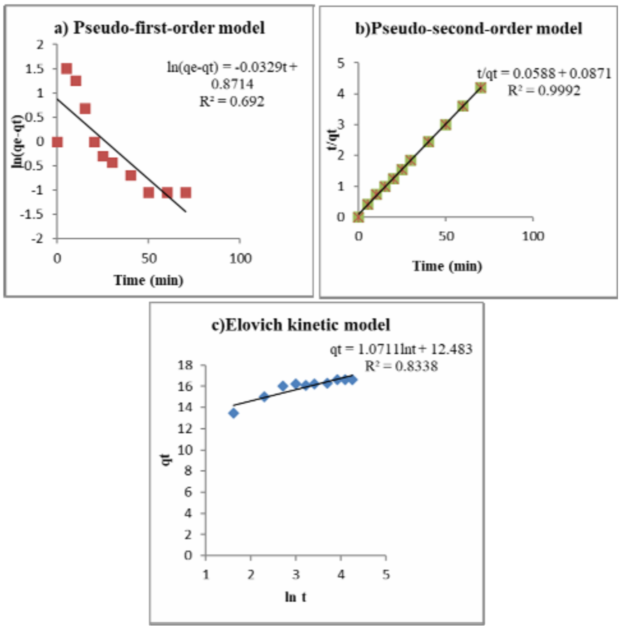


Figure 10. a) pseudo first order, b) pseudo-second order, c) Elovich, models to examine the adsorption behaviour of CM for MB.

and controlling mechanism for MB removal, the appropriate model is when the line of graph passes through all the points and the value of q_e (calculated by model) is close to q_e (experimental) and the value of R^2 is close to 1 [34]. The results showed that the pseudo-second-order is the best model to describe the experimental data Figure 10 a, b and c. Similar results have been previously reported in the kinds of literature for MB removal [21-23].

4. CONCLUSION

The study shows that CM-A is indeed a viable, cost-effective adsorbent material for the adsorptive removal of MB, where the process efficacyover 65% was achieved. The adsorption of MB dye onto CM-A was found to be highly dependent on pH, adsorbent dosage, initial dye concentration and contact time. The amount of dye adsorption was found to increase with the increase in its initial concentration. Percent MB dye removal was found to increase with the increase in dosage, adsorbent, and contact time. The rate of adsorption was found to conform to pseudo-second-order kinetics with a high correlation coefficient (R^2 = 0.999) for all studied concentrations.

Combining experimental results with the influencing modelling capabilities of ANFIS is a suitable approach to mathematical modelling and analysis of MB onto CM-A removal efficiency with practical applications in real manufacturing environments to define removal efficiency parameter settings to achieve desired performance.

The ANFIS model was trained with 40 basic experimental data sets and 6 additional experimental data sets. It was found that the mean prediction errors in the training and testing processes were 0.052% and 0.088%, respectively.

5. ACKNOWLEDGEMENT

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