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THE ARTIFICIAL NEURON NETWORK FOR PHOTOCATALYTIC DEGRADATION OF ACID ORANGE 7 USING CERIUM OXIDE (CeO₂)

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ABSTRACT

The presence of dyes in water resources contributes to the accumulation of dyes in fish and other aquatic life. Azo dye toxic compounds mix with bodies and penetrate fish and other aquatic species that are taken up by humans with prolonged health effects. In order to overcome this problem, scientists discovered the photocatalytic process, which is one of the most effective solutions for eliminating organic compounds in wastewater. However, developing an automated dye wastewater treatment plant is very difficult because the condition (e.g. concentration, pH, etc) of dye waste changes severely, depending on the type of the dye. Hence in this research an artificial neural network was developed to predict the adsorption efficacy of CeO₂ photocatalysts. A network was trained by using the experimental data reaction time and pH as the input while the degradation of AO7 as output. The reflective input-response correlation is predicted *via* a feed forward neural network with hidden layers trained by Lavenberg-Marquardt method. The optimum number of neurons was decided by using trial and error methods. The simulation performance of ANN models was evaluated by using the Root Mean Square Error (RSME) and the coefficient of determination (R²). ANN predicted high accuracy in which R² is 0.99835 while MSE is around 0.35014.

Keywords: Artificial Neural Network (ANN), photocatalytic degradation, cerium oxide, Azo dye.

INTRODUCTION

Synthetic dyes are widely used in many industrial fields commonly in textile, paper and plastics industries (J Perera, 2019) due to their versatility and cost efficient in synthetic solidness, high light resistance, temperature, detergent and microbial attack and colour variety of natural dyes (Rodríguez Couto, 2009). However, the effluent from these industries normally contains large

amounts of unused dyes. They are toxic for both humans and aquatic life. Hence, it is crucial to treat the effluent with proper treatment methods before discharging it into water resources. On the other hand, cerium oxide (CeO_2) has been widely used as an adsorbent in wastewater treatment, from heavy metal wastewater to organic wastewater including dye effluent (Kurian, 2020). Hence, in this study CeO_2 has been used as adsorbent synthetic dye, Acid Orange 7(AO7).

The photocatalytic degradation is generally depending on a number of parameters such as temperature, contact time, pH and dosage of absorbent (Sun et al., 2018). Consequently, developing an automated dye wastewater treatment plant is very difficult because the condition of dye waste changes severely, depending on the type of the dye. Therefore, in this research an artificial neural network was developed to predict the adsorption efficacy of CeO_2 photocatalysts. Two important parameters were selected as the input, namely time and pH.

ANN is a method developed based on the biological nervous processing and due to its simplicity, this method is popular among engineers. Moreover, this model can be trained and learned from experimental data and solve complex linear and non-linear function without any assumptions (Ghaedi et al., 2017).

METHODOLOGY

This research used the real time dye adsorption data obtained from experimental work. The ANN has been developed with the MATLAB R2021a software. The complex non-linear relationship between inputs and outputs was modelled by a multilayer feed-forward-back propagation network to present outputs as three-dimensional graphs, rather than as statistical models because of their strong non-linear mapping capability. A few stages will be applied in this modelling. Two inputs for this model are time and pH, respectively. The target variable to produce output for this modelling is the degradation of acid orange 7 (AO7). In this analysis, the reflective input-response correlation is predicted *via* a feed forward neural network with hidden layers trained by Lavenberg-Marquardt method. The optimum number of neurons is decided by using trial and error methods.

The sample data are distributed into three types of sets which are 70 percent training set, 15 percent validation set, and 15 percent test set, respectively. The validation was used to warn the ANN when the training is to be completed. The test set provides a completely independent approach for the precision testing of ANN. The test set is a set of data samples used for ANN model evaluation (Alaloul & Qureshi, 1993). The simulation performance of ANN models was evaluated by using the Root Mean Square Error(RSME) and the coefficient of determination (R^2). RMSE values equal to zero represent a perfect fit while for R^2 , the value one is the optimal value(Kourgialas et al., 2015).

RESULTS AND DISCUSSIONS

A two-layer feed-forward back propagation neural network (2:12:1) was used to study the effect of pH on photocatalytic degradation in presence of cerium oxide as a catalyst. In the feed-forward back propagation, numerous training runs were used to find the best potential weight, and the final network design was then trained for 15 epochs. Evaluation of the performance of the neural network based on mean square error (MSE) and coefficient of determination (R^2) was also carried out. Figure 1 shows ANN topology design for AO7 dye adsorption. Figure 2 and Figure 3 show that the R^2 is approximately 0.99948 while MSE is

around 0.35014. The finding verified that the selected algorithm and topology were able to predict well the effect of pH and contact time on degradation of acid orange 7. Figure 3 demonstrates that the R value for validation, testing, and training was approximately 1, indicating that the network model had a good regression. The result also demonstrates the model's accuracy, as the expected data is almost close to the regression experimental data. Table 1 summarizes the findings of models that were successfully generated, as well as their setup. The setup division data refers to the portioning of the input data into 70% training, 15% testing, and another 15% validation.

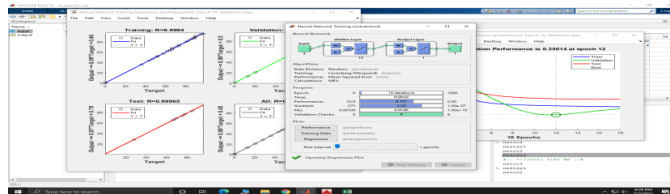


Figure 1: ANN Modelling for AO7 dye adsorption.

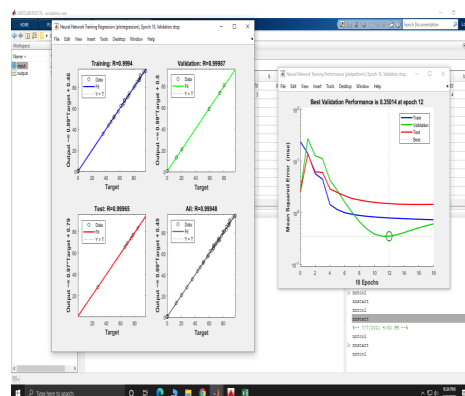


Figure 2: Validation performance for ANN modelling for AO7 adsorption.

Table 1: Mean square error (MSE) and regression for network design

Fitting Network Sequence	Setup Division of Data	MSE	Regression		
			Training	Validation	Testing
2-12-1	70-15-15	0.35014	0.9994	0.99987	0.99965

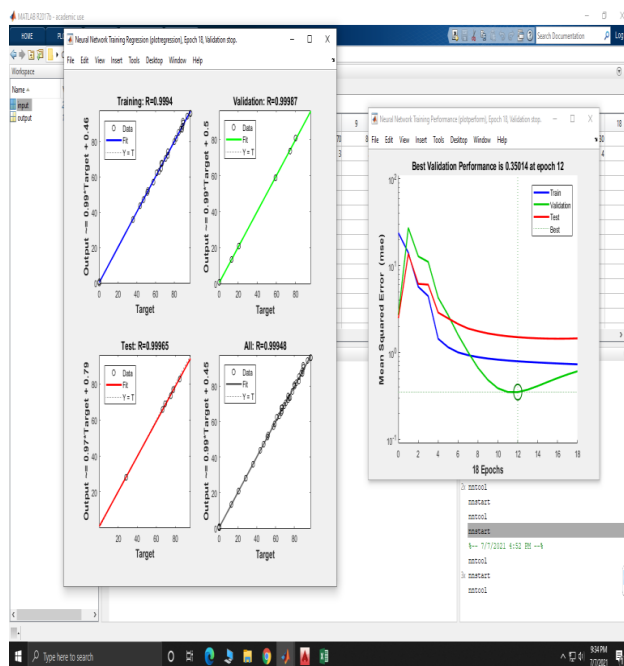


Figure 3: Regression Training of Developed ANN Modelling for AO7 adsorption.

CONCLUSIONS

In this research, the main goal is to develop Artificial Neural Network (ANN) modelling for the degradation of Acid Orange 7 using cerium oxide (CeO_2) by employing two important parameters, namely pH and contact time. By using a feed-forward backpropagation network with Levenberg-Marquardt Algorithms and topology (2:12:1) were established. The $R^2 = 0.99948$ and $\text{MSE} = 0.35014$, indicate that the developed ANN modelling is able to the adsorption of AO7 at different pH and contact time.

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