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Synthesis & Effectiveness Study Of Banana Peel Adsorbent & Artificial Neural Network Modeling In Removal Of Cu (II) Ions From Aqueous Solution

Shekhar Pandharipande *, Rucha Deshpande**
*(Associate Professor, Department of Chemical Engineering , RTM Nagpur University, Nagpur-33)
** (B.Tech (Chemical Engineering) , RTM Nagpur University, Nagpur)

ABSTRACT
Release of poisonous and harmful gases in the open air and of untreated polluted water to fresh water bodies has made the environmental conditions severe. Presence of excessive heavy metals like copper is found to damage not only fishes but humans also through the food cycle. The present work aims to synthesize an effective adsorbent from Banana peels, a material readily available by chemical treatment. The adsorbent synthesized is employed in removal of copper ions from waste water & is observed to be effective in removal of 12% to 89.47% of copper for adsorbent dosage varied between 0.5gm to 2 gm. Conventional adsorption isotherms have been estimated to describe the adsorption process & efforts have been made to develop Artificial Neural Network models for the same. It can be concluded that there is a lot of potential in Banana peel adsorbent that need to be tapped.
Keywords – Artificial Neural Network, Banana Peel Adsorbent, Copper Sulphate, Wastewater treatment, Percent adsorption

I. INTRODUCTION

Today, the environment is mainly affected by air and water pollution. Release of poisonous and harmful gases in the open air and of untreated polluted water to fresh water bodies has made the environmental conditions severe. In order to sustain the healthy surroundings, it is essential for all the industries contributing to the pollution to treat the generated wastes before discharging the effluent streams. This includes discharge of pollutant gases even from low ppm level to elevated heights. Discharge of treated water to water bodies is essential to ensure the safety of the marine life.

Presence of excessive heavy metals like copper is found to damage the marine life since it affects the gills, liver, nervous system of the fishes & the problems are transferred to the humans through the food cycle. Existence of copper in drinking water may cause mucosal irritation, hepatic and renal damage, capillary damage, gastrointestinal irritation and central nervous problem in humans. Several research articles have highlighted about the utilization of activated carbon for the removal of the heavy metals from wastewater [1]. The overall cost of the treatment process increases as the adsorbent cost goes on increasing. There is a need for development of efficient, low cost, economical alternative to activated carbon and other costly adsorbents.

The present work addresses to exploring the possibility of synthesizing an effective adsorbent from Banana peels, a material readily available [2]. The peel is characterized by a heterogeneous, rough and porous surface with crater like pores that helps to its possible use as an adsorbent. The effectiveness of the adsorbent synthesized is determined in removal of copper ions from waste water. Conventional adsorption isotherms have been employed to describe the adsorption process[3] & efforts have been made to develop Artificial Neural Network models for the same.

Artificial neural network is a paradigm in itself that is inspired by the functioning of biological neural networks. ANN is viewed as a black box modeling tool & has been applied by researchers in several chemical processes for various purposes such as prediction of parameters, modeling of complex nonlinear multivariable relationships, in fault detection & diagnostics & in control, as among others. There are several types of artificial neural network & error back propagation (EBP) is common for modeling applications. Each layer has a number of processing elements called as neurons or nodes and it is decided by the number of input & output parameters that are to be correlated. The output from each neuron in the input layer is altered by a multiplication factor or weight and every node in the next layer receives the summation of the product of the outputs of all the nodes from the preceding layer. The resulting signal received by the node is transformed further by using functions like sigmoid & the resulting signal acts as an input for the nodes in the next layer. Training of EBP is essential & the algorithm suggested by Rummelhart is popular for this purpose.

II. MATERIALS AND METHODS

2.1 Banana peel as an adsorbent

In the present work chemically treated and dried banana peel adsorbent has been synthesized and is employed in the adsorption studies experimentations.

The banana peels are oven dried at 100^0C and screened to determine the particle size. The particulate matter is treated with Sodium hydroxide pellets in hot distilled water. Similar procedure is adopted with oxalic acid. The treated peels are washed with hot distilled water for the removal of the adhered chemicals on the surface [4]. Dried banana peel adsorbent samples are stored in air tight container for further adsorption studies [5]. The details of consolidated observation in the Banana peel adsorbent synthesis are given in TABLE 1.

Table 1. Observations in the synthesis of Banana peel adsorbent

Sr. no	Initial weight of banana peels (gm)	Final weight of peels (gm)	Water removed (gm)	Drying temperature (O C)	Percent yield
1	180.3	6.8	153.5	100	14.86

2.2 Methodology

The first part of the present work deals with the standardization of the digital colorimeter by correlating the optical density of the samples of aqueous solution and the known concentration of copper sulphate. The ANN model is developed on the data generated by conducting experiments in determination of optical densities of the aqueous solutions samples for known Cu(II) concentration. The second part is related to the adsorption studies, using the synthesized Banana peel adsorbent in removal of Cu(II) from aqueous solution. This is carried out by dosing a known volume and concentration of copper sulphate solution with a known quantity of banana peel adsorbent [6]. The solution is filtered after ensuring that the equilibrium is reached the optical density of the filtered solution is determined using a digital colorimeter The optical density determined is used for estimation of the concentration of the solution by applying the ANN model developed. The adsorption parameters like percent adsorption, amount of adsorbate adsorbed per unit amount of adsorbent are calculated with the help of equilibrium concentrations of the Cu(II) estimated using the ANN model.

The adsorption studies data generated is used in developing ANN models to correlate the percentage adsorption of Cu(II), equilibrium concentration of adsorbate on adsorbent & amount of adsorbate adsorbed per unit amount of adsorbent with the initial concentration of Cu(II) in feed solution and adsorbent dosing. In this study, elite-ANN© is used in developing all ANN models [7].

III. RESULT AND DISCUSSION

3.1 Developing ANN model for standardization of Digital colorimeter

The objective of this part of the present work is to develop a ANN model for the standardization of the digital colorimeter for the estimation of remaining Cu(II) in aqueous solution after adsorption. The data sets of input copper concentrations and the corresponding optical densities obtained using digital colorimeter is used to train the ANN model. Based on the training the model predicts the concentration of the solution after adsorption. There is one input parameter as optical density and one output parameter as concentration of Cu (II) ions (gm/ml).

Three different ANN models BS-30, BM-30, BC-30 having different topologies are developed for standardization of colorimeter with 22 data points.

The details of the topology of ANN models developed for the standardization of digital colorimeter is given in TABLE 2. All the models developed have good accuracy levels.

Table 2. Neural Network topology for standardization of colorimeter

Model	Number of Neurons					RMSE training data Set
	Input Layer	1^{st} Hidden layer	2^{nd} hidden layer	3^{rd} hidden layer	Output Layer	
BS-30	1	00	05	05	1	0.01766
BM-30	1	00	05	05	1	0.01744
BC-30	1	00	05	05	1	0.0162
Number of Iterations= 30000;Input parameter: Optical density of aqueous solution Output parameter: Concentration of Cu(II) ions in aqueous solution						

Fig.1 shows a schematic for the typical neural network architecture used in developing model BC-30.

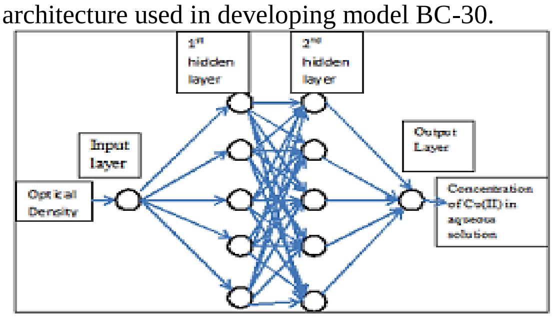

Figure 1: Neural Network Architecture for ANN model BC-30

Based on the values of RMSE, model BC-30 has been selected for the standardization of the colorimeter for estimation of Cu(II) ions in aqueous solution with the corresponding values of its optical density.

Fig.2 & Fig. 3 show the graphs plotted between the predicted values as obtained using ANN model BC-30 and the actual values of copper concentration in aqueous solution samples for training and test data set respectively.

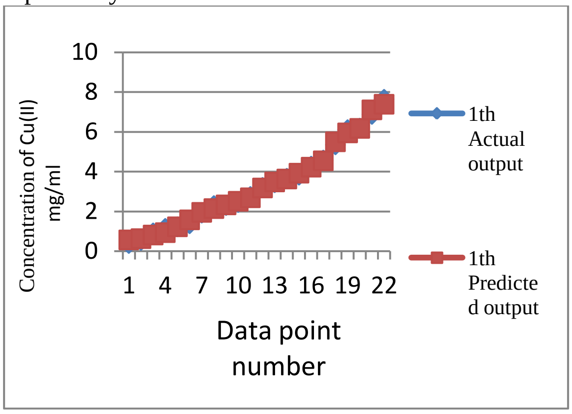

Figure 2 : Comparison of actual and predicted values of Copper concentration for training data set using model BC-30

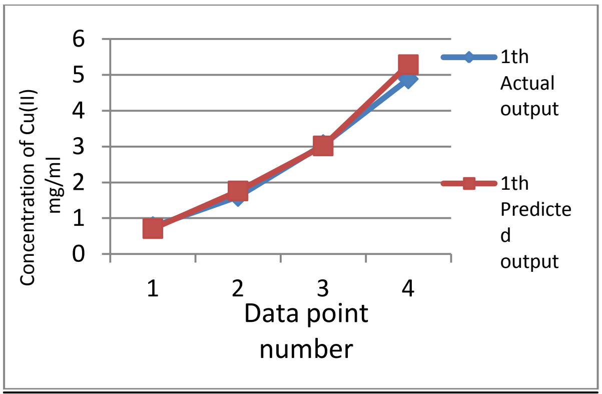

Figure 3: Comparison of actual and predicted value of copper concentration for test data set using model BC-30

From these graphs it can be seen that the actual & predicted values are very close to each other. ANN model BC-30 developed has higher accuracy of prediction & is used for estimation of the equilibrium concentration of Cu(II) ions in the solution samples that are obtained during the adsorption studies. The estimated values are further used for determining the effectiveness of the synthesized adsorbent by calculating adsorption terms such as percentage adsorption and amount adsorbed per unit amount of adsorbent.

Percentage adsorption of Cu(II) ions is evaluated as:

Percentage adsorption = (Initial concentration- Equilibrium concentration)/ Initial concentration x 100 [8]

Amount of adsorbate adsorbed per unit amount of adsorbent = ((Initial concentration- Equilibrium concentration) x Volume of solution)/ Amount of adsorbent

TABLE 3 shows the details of the observations & corresponding calculated values of percentage adsorption of Cu (II) & amount of adsorbate adsorbed per unit amount of adsorbent.

Table 3: Adsorption terms calculated from equilibrium Cu (II) concentration

Sr, No.	*Initial copper ion concentration (mg/ml)*	*Adsorbent Dosage (gm)*	*Copper ion concentration after adsorption C_e (mg/ml)*	*Percent adsorption*	*Amount of adsorbate adsorbed per amount of adsorbent (mg/gm)*
1	*3.8175*	*0.5*	*3.328*	*12.81*	*24.45*
2	*3.8175*	*1*	*3.328*	*12.81*	*12.22*
3	*3.8175*	*2*	*0.401*	*89.47*	*42.69*
4	*4.581*	*0.5*	*3.174*	*30.70*	*70.32*
5	*4.581*	*1*	*1.572*	*65.66*	*75.20*
6	*4.581*	*2*	*0.564*	*87.68*	*50.21*
7	*6.108*	*0.5*	*4.219*	*30.91*	*94.40*
8	*6.108*	*1*	*3.919*	*35.82*	*54.70*
9	*6.108*	*1.2*	*2.852*	*53.30*	*67.83*

3.2 Developing ANN models for adsorption studies

The objective of this part of present work is to develop ANN model for adsorption studies correlating the percentage adsorption of Cu (II) and equilibrium concentrations of adsorbate, on adsorbent & in aqueous solution for the known input parameters such as initial concentration of Cu (II) & adsorbent dosing. The data generated in adsorption studies of the present work as given in TABLE 3 is used for this purpose.

Three ANN models AS, AM and AC having different topology as given in TABLE 4 are developed. Fig. 4 shows a typical architecture of one of the models AS developed.

All the ANN models developed in the present work are using elite-ANN©. The snapshot of elite-ANN© in run mode and the variation of error versus iteration during training mode for developing "AM model" are shown in Fig. 5 & Fig.6 respectively.

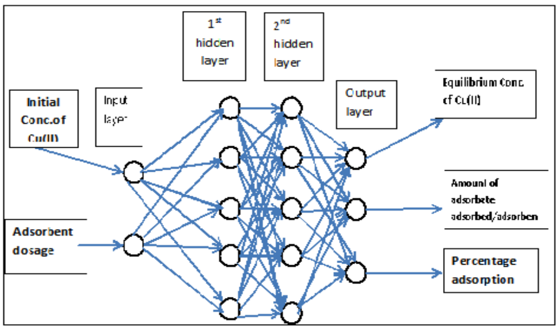

Figure 4: Neural Network architecture for ANN model AM-50

ANN model AM-50 is selected because of its lower RMSE value among the three models that are developed & employed for estimating the equilibrium concentration of the copper sulphate solution, percentage adsorption and the amount of adsorbent adsorbed per unit amount of the adsorbent.

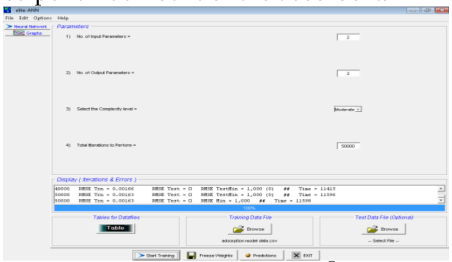

Figure 5: Snapshot of elite-ANN© in run mode

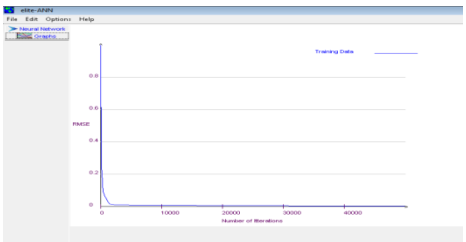

Figure 6: RMSE variation with iterations for training data set for AM-50 model

Fig. 7, Fig. 8 & Fig. 9 show the graphs plotted for the comparison of actual and predicted values of equilibrium Cu(II) concentration, percent adsorption, amount of adsorbate adsorbed per amount of adsorbent respectively.

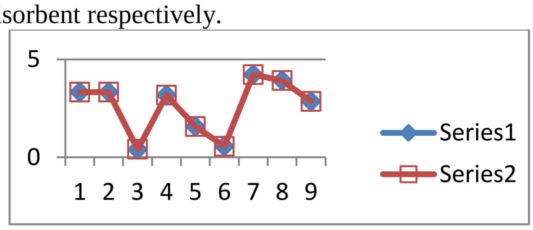

Figure 7: Comparison of actual and predicted values of copper concentration after adsorption using model AM-50

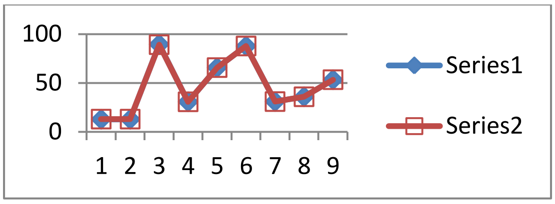

Figure 8: Comparison of actual and predicted values of percentage adsorption

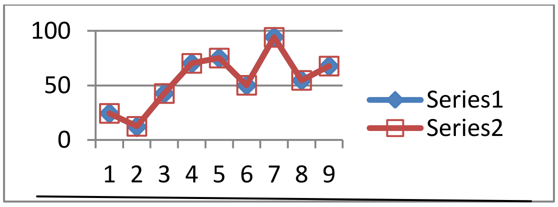

Figure 9 : Comparison of actual and predicted values of amount of adsorbent adsorbed per amount of adsorbent adsorbed

The claim of accuracy is further substantiated by calculation of the % relative error for each data point for all the output parameters as given below:
% relative error = (actual value- predicted value)* 100/ (actual value)

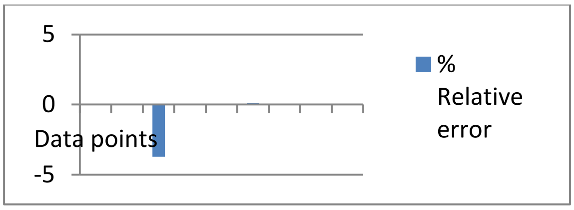

Figure 10 :% Relative error for equilibrium concentration of Cu(II) between training data set and that obtained by model AM-50

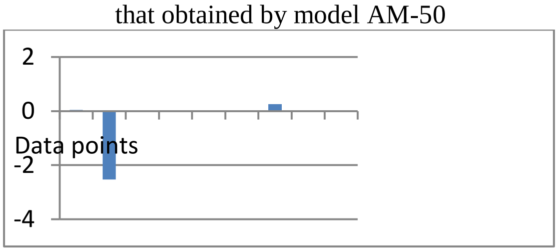

Figure 11: % Relative error for percent adsorbed of Cu(II) between training data set and that obtained by model AM-50

Table 4: Neural Network topology

Model	**Number of Neurons**					**RMSE training data Set**
	Input Layer	**1st hidden layer**	**2nd hidden layer**	**3rd hidden layer**	**Output layer**	
AS-50	2	00	05	05	3	0.0034
AM-50	2	00	10	10	3	0.0016
AC-50	2	00	10	10	3	0.00216
Number of Iterations= 50000 Input parameters: Initial Concentration Cu(II) ions, adsorbent dosage Output parameters: Equilibrium Conc. Of Cu(II) ions, amount of adsorbate adsorbed per unit amount of adsorbate adsorbed per unit amount of adsorbent, % adsorption						

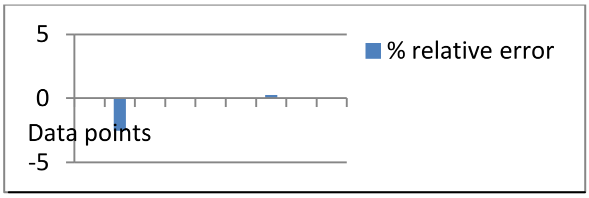

Figure 12: % Relative error for amount of Cu (II) adsorbed er unit amount of adsorbent between training data set and that obtained by model AM-50

As can be seen from Fig.10, Fig.11& Fig. 12; the percent relative error for AM-50 ranges between 0 to 4%, 0 to 1.4%, 0 to 2.5% in estimation of equilibrium concentration of Cu(II) ions, percent adsorption and amount of adsorbate adsorbed per amount of adsorbent respectively. Thus it can be said that the ANN model AM-50 has high accuracy of predictions & is acceptable.

IV. Conclusion and Future Scope

The objective of the present work was to explore the utilization of Banana peel adsorbent for the removal of Copper (II) metal ions from aqueous solution. Based on the adsorption studies it is observed that the adsorbent was effective in removal of 12% to 89.47% of copper for the adsorbent dosage varying between 0.5gm to 2 gm [9]. The novel feature of the present work is to develop ANN models in adsorption studies having high accuracy levels.

There is a need for extending the laboratory scale work to pilot plant scale so that activated carbon and other costly adsorbents can be replaced with this low cost effective adsorbent which is developed from waste material. Further research can also be carried out to study the effectiveness of Banana peel adsorbent in removal of other metallic compounds that are present in industrial waste water.

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