ARTIFICIAL NEURAL NETWORK FOR REMOVAL OF MANGANESE FROM AQUEOUS SOLUTION USING LOW COST ADSORBENT

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Abstract
The objective of the study is to optimize the percentage removal of manganese from waste water using limonia acidissima hull powder as adsorbent with applying artificial neural network (ANN). The effect of various parameters such as pH, adsorbent dosage and initial manganese concentration are investigated to optimize the process parameters and to achieve the maximum percentage removal of manganese ions. Out of total 56 experimental, 40 experimental data points for training and 16 data points for testing have been used by a single layer feed forward back propagation network with 12 neurons to obtain minimum mean square error (MSE) for the development of ANN model. The model was able to find out the percentage removal of manganese efficiently based on regression coefficient value (R^2 =0.995).
Keywords: Biosorption, Artificial Neural Network, Limonia acidissima hull powder, Manganese.

1. Introduction

Many industries like mining, chemical manufacture, rubber processing, metal plating, metal finishing, leather, fertilizers, and paint industry etc. discharging aqueous effluents containing heavy metals leads to severe problem to the environment [1]. Minimum 20 metals recognized as toxic and many of these metals if drained into the environment in bulk quantity cause risk to human health [2].

Manganese is one of the abundantly available and most significant metals for the enzyme activation as well as human life and also used in dry battery cells, electrical coils, ceramics and an alloying component. The other indirect sources of discharge of the manganese are burning of oil and coal [3]. Till this date, it is not reported any adverse effect on human beings if we consume the drinking water. However, manganese has severe effect in laundering operation, indicates remarkable stains to plumbing fixture and inducts trouble in distribution systems by supporting growths of iron bacteria. As per standards, domestic water supplies should not contain more than 0.05 mg/l of manganese according to the USEPA norms [4]. Therefore, the maximum standard limit of manganese in drinking water according to the World Health Organization (WHO) is 0.5 mg/L [5].

Reduction followed by chemical precipitation, electrochemical precipitation, membrane separation, evaporation, ion exchange, and foam separation etc. are considered as conventional techniques for the removal manganese from the industrial waste water. The above said are expensive at lower concentrations and may also lead to environmental problems. Hence, removal of manganese using natural adsorbents is one of the inexpensive techniques. A variety of natural adsorbents like tea waste, coffee and nut shells [6], rice husk [7], saw dusts, bark and bin [8], palm kerner husk [9], cactus leaves and charcoal [10] are cited in the literature for removal of heavy metals from waste water.

The conventional mathematical modeling is failed to simulate the mechanism of biosorption as it is highly non-linear and complicated and also due to the interaction of more number of adsorption parameters [11]. Application of Artificial Neural Network (ANN) has been successfully employed in environmental engineering as it is highly beneficial characteristics in tracking the non-linear relationships of variables in complex system [12]. It is very difficult to decide what architecture of ANN and training algorithm will solve a given problem. Based on trial and error, the best solution is obtained within acceptable limits of error [13]. To solve the non-linear problem, genetic algorithm (GA) is used by the fitter solutions in a population surviving and passing their traits to offspring which replace the poorer solutions [14]. A proportion of the population is selected to breed and produce new chromosomes. The Selection is according to fitness of individual solutions by roulette selection and deterministic sampling [15].

In the present investigation, batch experimental studies [16] have been carried out for the removal of manganese from aqueous solution using Limonia acidissima hull powder. The data point from the experiment has been used to train ANN model with 12 neurons in hidden layer with feed forward back propagation algorithm. Further the model has been tested for validation of the experimental data which was not used earlier for development of ANN technique. The input parameters for the percentage removal of manganese are initial manganese concentration, pH and adsorbent dosage. The process of optimization has been carried out using genetic algorithm to optimize the input parameters to the process for maximum manganese removal.

2 Materials and methods

2.1 Preparation of adsorbent and manganese solution

The adsorbents as *Limonia acidissima* hull collected from local market were washed, dried, and crushed by means of primary crusher and further air dried in sun for several days until its weight remains constant. After drying, it was crushed by means of roll crusher and hammer mills. The material obtained after crushing and grinding was screened by means of British Standard Screens. At the final stage, the products obtained were kept in glass bottles for the investigation for the removal of heavy metals from waste water. All the materials were used as such and no pretreatment was given to the materials. The average particle sizes were maintained in the range of 63 to 125 µm.

Preparation of Manganese solution

2.87 g of 99% $KMnO_4.5H_2O$ is dissolved in double distilled water in 1.0 L volumetric flask up to the mark to obtain 1000 ppm (mg/L) of manganese. Stock solutions of various concentrations of manganese are prepared with the appropriate dilutions to represent the manganese concentrations as 20, 40, 60, 80 and 100mg/L.

2.2 Experimental Studies

The influence of various parameters such as initial Mn(II) concentration, adsorbent dosage, and pH at the equilibrium time of 50 minutes and temperature of 303 K are found from the batch mode adsorption experiments[16]. The Solution containing Mn (II) and limonia acidissima hull powder were taken in 250 mL conical flasks and agitated at 180 rpm in a mechanical shaker at predetermined time intervals. The Mn (II) adsorbate was filterted and separated from the adsorbent powder using filter paper. Final residual metal concentration after adsorption was measured by atomic absorption spectrophotometer.

3 Results and Discussions

3.1 Artificial Neural Network

In the present work, single layer feed-forward ANN with one hidden layer was used as optimized structure (Figure 1). Sigmoid transfer function in the hidden layer and a linear transfer function in the output node have been used for all data set. The ANN has been trained using back propagation algorithm which carried out all calculations with *Matlab* software. Initial concentration of Manganese (20 to100 ppm), pH (1 to 7) and adsorbent dosage (4 to 6 g/L) were used as inputs for the development of ANN model. The percentage removal of manganese was output parameter. Total 56 experimental points were split randomly between training and test sets. 40 data points were used for training and 16 data points for testing.

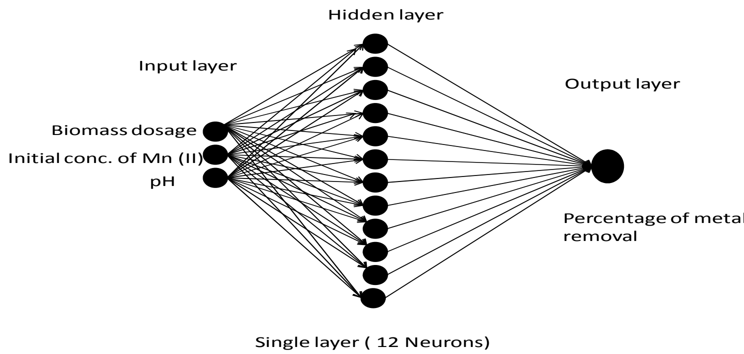

Figure 1. ANN optimized structure

The number of neurons (N) in the hidden layer has been determined with respect to the minimum prediction of mean squared error. For the determination of optimum number of neurons in the hidden layer, various topologies have been tested, in which the number of nodes have been varied from 2 to 22. Each topology has been repeated for consistency of the model. The mean square error (MSE) was used as the error function as measures of the performance of network which is given as under

$$MSE = \frac{1}{N}\sum_{i=1}^{i=N}(y_{i,pred} - y_{i,\exp})^2$$

N is the number of data points, $y_{i,pred}$ is prediction value $y_{i,\exp}$ is the experimental value and i is data point index.

Table 2. Weights and Biases of the artificial neural network.

W1 (12×3 matrix)			W2 (1×12 vector)	b1(12×1 vector)	b2(scalar)
-1.7127	-1.2173	-0.6589	[10.3559, 11.2957, 2.5482, -4.4691, -6.9578, 0.8075, -2.5, 4.3473, 4.0052, -10.2354, 5.9558, -13.8626]	6.0958	15.8997
-1.1550	-2.1748	-2.5861		4.5224	
0.2150	4.4508	6.9728		-3.5875	
1.5442	-1.0883	-0.0389		-4.9078	
0.8843	1.3964	0.6016		0.173	
-2.0644	-0.7901	-0.4097		6.167	
1.3382	-1.8655	1.0213		-0.5094	
-0.4567	1.3290	-1.1430		7.316	
-1.6183	-1.6706	3.6530		2.1594	
-0.8171	0.1835	-0.2139		-5.7611	
-0.1540	1.1061	-1.2354		6.1503	
0.0390	-3.5619	-0.0516		-2.2041	

Figure 2 illustrates the network error versus the number of neurons in the hidden layer. It has been observed that the network mean square error (MSE) was obtained the minimum at 12 neurons. So, the number of hidden neurons are equal to twelve and a single layer feed forward back propagation neural network was used for the ANN modeling. Table 2 shows the weights and bias values of the ANN model. The network was evaluated by comparing the predicted values with experimental values usin test data. The plot of experimental results versus the predicted output is shown in Figure 3. It was observed that the points have been well distributed around X=Y line in a narrow area. Experimental vs predicted data are in perfectly matched based on the regression correlation coefficient of R^2=0.995. The parity of experimental and estimated removal efficiency on testing data has been given in Table 3 and it is observed that the experimental removal efficiency and ANN model values are almost equal with low relative error and low relative percentage error. Therefore it is confirmed that the present ANN model is suited to optimize the removal of manganese from waste water using limonia acidissima hull powder with 3 input variables (pH, adsorbent dosage and initial manganese concentration).

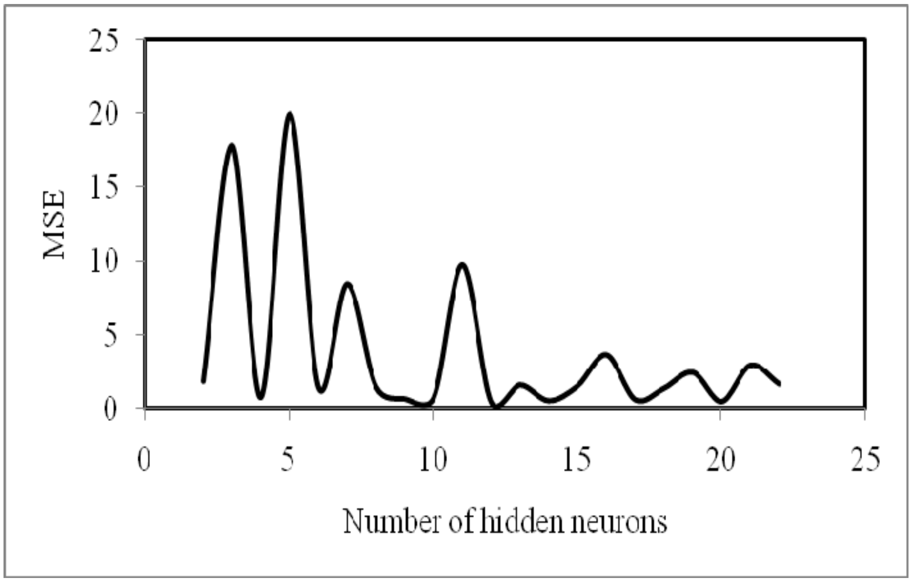

Figure 2. Variation of MSE versus number of neurons in hidden layer.

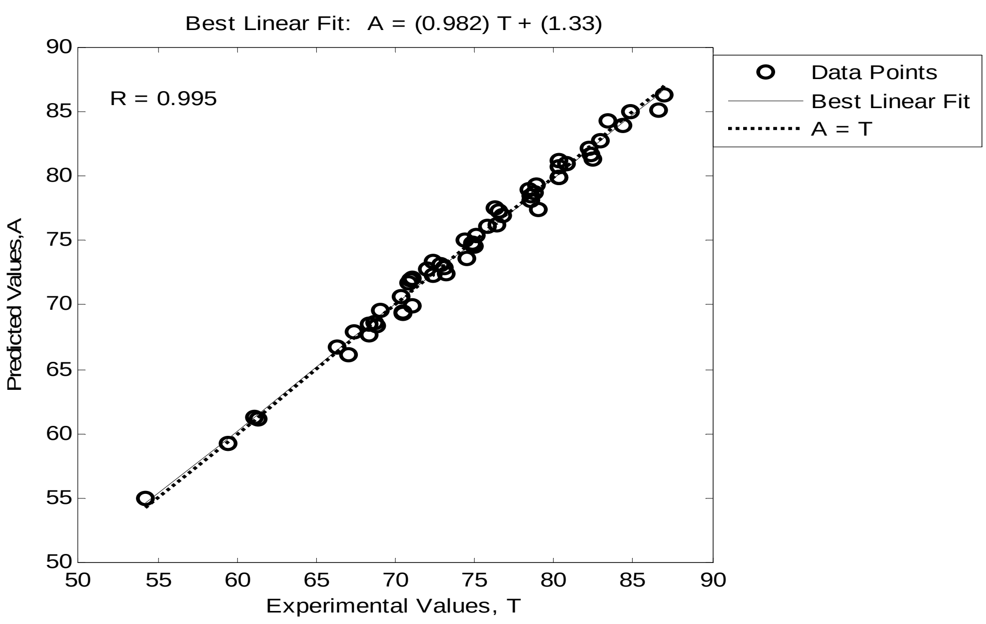

Figure 3. Experimental vs predicted removal percentage of manganese.

The ANN model was confirmed to be an adequate interpolation tool with good prediction for almost all experiments. ANN modeling technique was found to be with many favorable features such as its efficiency, generalization and simplicity, which make it an attractive choice for modeling of complex systems like waste water treatment processes.

Table 3. Comparison of experimental and predicted removal efficiency on testing data

Run No.	Initial manganese concentration, mg/l	pH	Biomass loading, g/l	Experimental efficiency, %	Simulated efficiency, %	Relative error
1	80	3	5	70.39	70.71	-0.3210
2	40	3	4	76.48	77.30	-0.8156
3	20	5	5	83.42	84.28	-0.8618
4	60	3	5	74.4	75.06	-0.6555
5	60	5	5	76.31	77.55	-1.2381
6	20	4	4	84.41	83.93	0.4767
7	20	4	6	87.03	86.32	0.7140
8	60	4	4	76.4	76.28	0.1197
9	60	5	4	74.91	74.72	0.1945
10	40	3	6	78.84	78.77	0.0728
11	40	5	4	78.52	78.18	0.3430
12	40	5	6	80.76	81.01	-0.2486
13	20	5	4	82.25	82.19	0.0569
14	80	4	4	72.42	72.37	0.0531
15	20	8	4	73.09	72.94	0.1490
16	100	3	5	66.35	66.71	-0.357

4 Conclusions

The ANN model has been developed for optimization of removal of manganese from waste water. A single layer feed forward neural network (FFNN-MLP) with one hidden layer (3:12:1:1) has been applied to predict the percentage removal of manganese from waste water with minimum MSE. The back propagation algorithm was used to train the ANN. The predicted and the test data are in perfect agreement with R^2 =0.995. The ANN model has been applied for the tracking of the non-linear behavior of removal percentage of manganese vs the initial concentration of manganese, pH and adsorbent dosage with low relative error. Hence, It can be recommended that the artificial neural network is a very promising tool for optimization of removal of manganese for waste water and similar system like waste water treatment processes.

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