Efficiency Assessment of Wastewater Treatment Plant of Tabriz Using Artificial Intelligence Models

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Expanded Abstract

Introduction

Because of shortage of water resources in the world, it seems necessary to refine wastewater, particularly in arid and semi-arid areas such as Iran. Correct treatment, management and the control of refining process needs to investigate about effective parameters in this process. Therefore, because of the uncertainty and complexity in finding qualitative parameters and their relationship, artificial intelligence such as a fuzzy model (FL) and Artificial Neural Networks (ANNs) were used in this study for modeling the behavior of Tabriz wastewater treatment plant.

Tabriz city as the capital of the East Azarbaijan Province is the most industrialized and urbanized city in Northwest Iran (Fig. 1). The sewage of Tabriz city, including industrial and domestic wastewaters, collects gravitationally the wastewaters and conveys them into the wastewater treatment plant. It is located in Qaramalek District, four kilometers away in west of downtown on the southern side of the Ajichay river and on the lowest part of the city in an elevation of at 1334 meters above sea level. The wastewater treatment plant is designed in

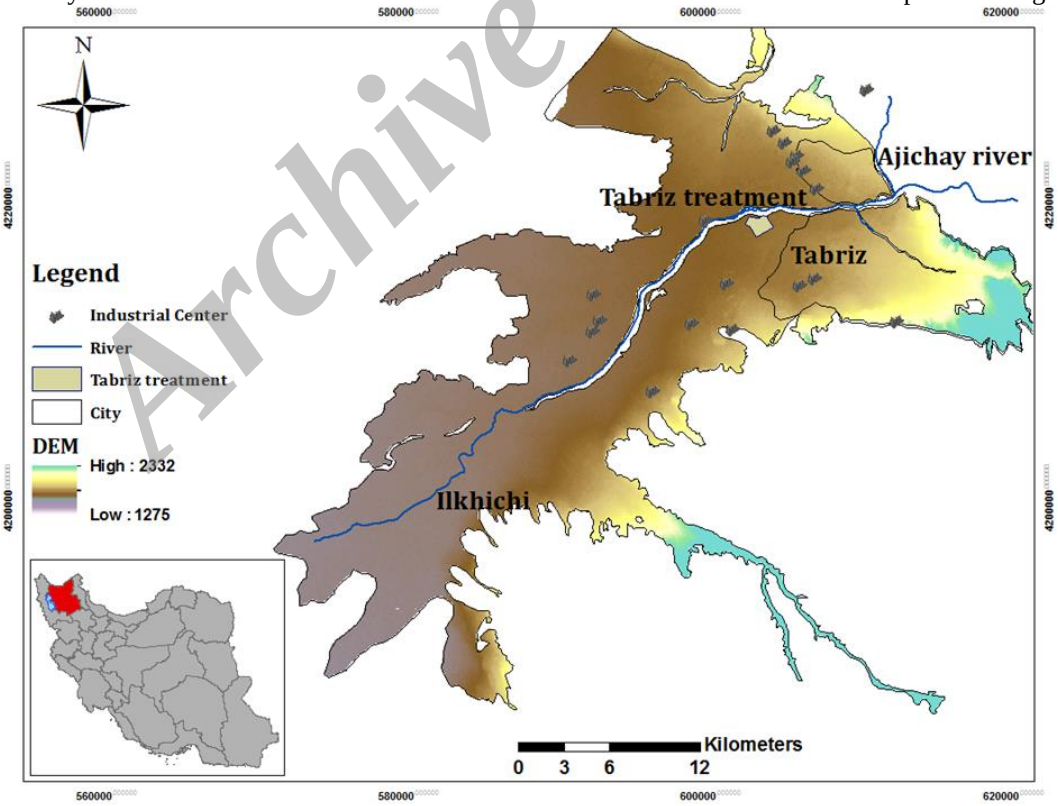

Fig. 1. Location of wastewater treatment plant of Tabriz city in Tabriz plain

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three stages. The first phase of Tabriz wastewater treatment plant was established in July of 2001. Currently, due to incomplete sewerage network in Tabriz city, only the first phase of this plant is exploited with about 30% of total capacity. The second and third phases are under study. Tabriz wastewater refinery has an average annual rate 1.5 cubic meters per second and a peak flow rates in the rainy and non-rainy days of 3.8 and 2.5 cubic meters per second, respectively. Refinery process is including both primary and secondary treatment stages. The physical refining is done in the first step and biological treatment and finally disinfection are carried out subsequently.

Materials and Methods

Influent and effluent data of refinery system were used in this study to develop an artificial neural network and two fuzzy logic model and Mamdani and Sugeno FL models for evaluating the performance of wastewater treatment plant of Tabriz city. In this study, the system influent applied as input model to estimate the qualitative factors of effluent. For quality assessment in wastewater and sewage treatment plant, the parameters that are usually measured and recorded are the Temperature (T), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and pH compared in the input and output of wastewater treatment. In Hence, the monthly values of BOD, COD, TSS, T, and pH of effluent raw wastewater and effluent treated water of treatment plant were analyzed for the 11 years from 2002 to 2012.

At first, the data set containing 660 data from Tabriz refinery were divided into two parts of testing (130 data) and training (530 data). A FL method consists of three main parts, fuzzification, inference engine (fuzzy rule base), and defuzzification. In the fuzzification step, the four crisp inputs are transformed into fuzzy set for constructing the inference engine. The inference engine is composed of rules. Each rule, in turn, is formed from multiple inputs and a single output. When the antecedents of fuzzy rules include more than one rule, then fuzzy operators are used to connect them. The most common fuzzy operators are AND which supported min (minimum) and prod (product), OR (maximum) and NOT. The consequences of a fuzzy rule assign an entire fuzzy set to the output through the process which is called implication. The input to the implication process is a single number given by the antecedent, and the output is a fuzzy set. Since decisions are based on the testing of all of the rules in an FIS, the rules must be combined via aggregation processes in order to make a decision. The process of transforming the aggregation result into a crisp output is termed defuzzification. The most common defuzzification methods are centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum.

Results and Discussion

The Sugeno fuzzy logic model is constructed by subtractive clustering method. The optimal cluster radius is assigned based on the minimum Root Mean Square Errors (RMSE) and MAPE of 2.71 and 8.08, respectively. Based on the optimal clustering radius, five clusters and five If-Then rules were determined using Gaussian membership functions. The average correlation coefficient of this model is 0.82.

For constructing Mamdani fuzzy model, FCM clustering method is also applied. By using minimum RMSE and MAPE that are 2.83 and 8.88, respectively, the optimal numbers of input and output clusters are assigned. The Membership functions are Gaussian membership functions and the average correlation coefficient of this model is 0.8.

The perceptron network and three layers of artificial neural networks are including input, hidden and output layers. Data division in train and test steps is same as the FL models. Input layer have 5 nodes including BOD, COD, TSS, T and pH that is used as input data for predicting 3 output parameters (i.e., BOD, COD and TSS). To select the appropriate number of neurons in the hidden layer the various methods such as trial and error and also mathematical rules were proposed. In this study, 3 neurons are determined in the hidden layer by the trial and error method. At the first step, the network must be trained. The purpose of the learning network is achieving Minimum Absolute Percentage Errors and optimal weights of the network. Due to the high R^2, thelowest RMSE in the optimal structure is 5-3-3. The obtained results for test step (average RMSE= 3.63) confirm high ability of artificial neural network in estimating parameters of wastewater treatment plant.

Finally, to evaluate the output of wastewater treatment plant and the results of artificial intelligence models in removing and reducing studying parameters, percentage of removal efficiency was used according to equation 1.

$$RE_x = \frac{1}{n}\sum_{i=1}^{n}\frac{x_{in} - x_{out}}{x_{in}} \times 100 \quad (1)$$

This index indicates the isolation of each of the quality parameters of the wastewater after treatment. In this equation, RE_X is the index of removal efficiency percent of x, X_{in} is the amount of input mass of parameters x to treatment plant and artificial intelligence, X_{out} is amount of output mass of the parameters x from the treatment plant which was estimated by artificial intelligence, and n is the number of data for each pollutant. This equation

was performed in two cases, one based on the measured data in the input and output of treatment plant and the other based on the measured data in the input and the estimates of the artificial intelligence. At the end, the efficiency of reducing emissions calculated and compared separately for each pollutant for both cases.

The removal efficiency of each three contaminants is close together and the TSS pollutant has maximum removal efficiency (93.74%) for three artificial intelligence models. The results represent a good performance of applied models. Consequently, the neural network and Mamdani and Sugeno fuzzy models have good accuracy in evaluating the performance of treatment.

Conclusions

Although three artificial intelligence models have acceptable results, but based on the correlation coefficient and RMSE for each of the parameters in the models, the Sugeno fuzzy model is more prefered than other models. The superiority of the Sugeno fuzzy model over an artificial neural network is due to high uncertainty of wastewater treatment plant parameters.Calculation of the percentage of contaminant removal efficiency was also determined in the output treatment. The maximum removal efficiency was related to TSS pollutant that is equal to 93%. TSS values were also very close to other pollutants. Similarly, the removal efficiency of pollutants from the estimated values by fuzzy model and neural network is the same and close to the observed values due to the good performance of used models.

Keywords: Artificial Neural Networks (ANNs), Mamdani and Sugeno fuzzy model, removal efficiency, wastewater treatment plant of Tabriz.