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Investigation of Artificial Intelligence Approaches Capability in Predicting the Wastewater Treatment Plant Performance (Case Study: Tabriz Wastewater Treatment Plant)

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ABSTRACT: Due to the excessive concern about environmental issues, researchers had to come up with a better solution to control the Wastewater treatment plants (WWTPs). In this research, two approaches, including Artificial Neural Network (ANN) and Support Vector Machine (SVM) have been used for modeling the effluent quality of the Tabriz Wastewater Treatment Plant. Input data of models consist of BOD_{inf}, COD_{inf}, TSS_{inf}, and PH_{inf} of influent sewage related to Tabriz Treatment Plant which has been used to predict the corresponding value of BOD_{eff}, COD_{eff}, and TSS_{eff} concerning the treatment plant effluent. The daily, weekly, and monthly average data have been studied. According to the results, the two approaches mentioned, have the best performance in the prediction of the monthly average dataset of effluent parameters of Tabriz Wastewater Treatment Plant.

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1. Introduction

Rapid urban development in residential and urban areas has created a heavy burden on the environment, which is often of less importance for economic and industrial development, especially in developed countries [1]. Increasing concern over environmental issues has encouraged researchers to focus their attention on the proper performance and control of Wastewater treatment plants (WWTPs) [2], [3]. Considering the number of Wastewater treatment plants and their importance increased day by day, the prediction and the analysis of the pollutant parameters based on new methods are necessary [4]. Operation and safe control of a Wastewater treatment plant can be achieved by developing a modeling tool in predicting the Wastewater treatment plant performance based on past observations of key parameters of the quality. The Wastewater treatment plant contains several complex processes such as physical, biological, and chemical processes. Most of these processes exhibit nonlinear behaviors which are difficult to describe with linear mathematical models [3]. Therefore, artificial intelligence techniques have been developed as an alternative to these mathematical models [4]. Due to the complexity of estimating the quality parameters of the treatment process and their relation, in the present study, an artificial neural network and support vector machine has been used to model the behavior of the Tabriz Wastewater treatment plant. In recent years, many studies have been carried out to assess the behavior of Wastewater Treatment Plant by using Artificial Intelligence methods. Hamed et al. (2004) used Neural network models in predicting the daily concentration of BOD_{eff} and SS_{eff} parameters at Siro Wastewater Treatment Plant in Egypt [5]. Turkmenler and Pala (2017) developed Artificial Neural Network Techniques (ANN) to predict the BOD_{eff} of Wastewater Treatment Plant in Turkey [4]. Nourani et al. (2018) offered FFNN, ANFIS, SVM, MLR and Simple Averaging Ensemble (SAE), Weighted Averaging Ensemble (WAE), and Neural Network Ensemble (NNE) techniques to increase the performance of single models, to predict BOD_{eff}, COD_{eff}, and TN_{eff} of the Nicosia Wastewater Treatment Plant in Cyprus [6]. According to the high ability of Artificial Intelligence techniques, it is assumed that these methods can appropriately predict the effluent quality parameters by using influent quality parameters of the WWTP. According to the literature reviews, these approaches were mostly used in predicting daily average parameters and, there were no studies including all three types of daily, weekly, and monthly average. Therefore, in the present study, we compare the efficiency of ANN approach in simulating daily, weekly and monthly data on average of effluent quality parameters (BOD_5, COD and TSS) of Tabriz Wastewater Treatment Plant.

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2. Methodology

2.1. Case study (Tabriz Wastewater treatment plant)

The Tabriz Wastewater treatment process consists of two primary and secondary treatment stages. The first stage is a physical treatment, and the latter is biological treatment and finally disinfection. The datasets used in this research included BOD_5, COD, TSS, and PH parameters (daily, weekly and monthly) of influent of Wastewater treatment plant as independent parameters and BOD_5, COD, and TSS parameters (daily, weekly and monthly) of the effluent of Tabriz Wastewater treatment plant as dependent parameters. The data collected for daily and weekly average is assembled from March. 2009 till Nov. 2017 and the dataset for monthly average is gathered from 2002 up to Nov. 2017. 75% of the data were obtained for the training dataset while 25% of the data were classified for the testing dataset. The data is normalized with the mapminmax command in MATLAB-ready code.

2.2. Artificial Neural Network

One of the most common types of ANN is Multi-Layer Perceptron that consists of three typical layers: (I) input layer, (II) hidden layer, and (III) output layer [7]. To simulate the effluent quality parameters of Wastewater Treatment Plant, a Multi-Layered Perceptron (MLP) Neural Network model with one hidden layer, a different number of neurons and for mapping the information from the input layer to the hidden layer of the sigmoid tangent function and for mapping information from the hidden layer to the output layer, the linear simulator was used. The Levengburg-Markovart (LM) algorithm was used to train Multi-Layer Perceptron Network and the maximum number of repetitions in the network training process was considered 1000. The number of neurons in the hidden layer is determined by trial and error to find the model with the lowest error value from 1 to 20 neurons.

2.3. Support Vector Machine

The SVM algorithm can be used wherever it is necessary to identify patterns or classify objects into specific classes. Unlike most neural networks, SVM networks consider the operational risk as to the objective function and calculate its optimal value instead of reducing the modeling or classification error [8]. To model the effluent quality of the Tabriz Wastewater treatment plant, RBF kernel was used.

2.4. Multiple Linear Regression

The multiple linear regression is used to model the relationship between descriptive and response variables by placing a linear formula for the observed data. According to this feature, the MLR method has been used in various environmental studies [9].

2.5. Model Performance Criteria

In this study, the most common criteria consist of correlation coefficient (R), determination coefficient (DC) [10], root mean square error (RMSE) have been used.

$$R = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2 \sum_{i=1}^{N}(y_i - \bar{y})^2}} \quad (1)$$

$$DC = 1 - \frac{\sum_{i=1}^{N}(x_i - y_i)^2}{\sum_{i=1}^{N}(x_i - \bar{x})^2} \quad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(x_i - y_i)^2}{N}} \quad (3)$$

3. Results and discussion

3.1. Artificial neural network method

The modeling results for daily average data show that the ANN model in predicting BOD_{eff} performs better than COD_{eff} and TSS_{eff} according to R, RMSE, and DC values of testing datasets which is 0.82, 3.93, 0.676 for BOD_{eff}, 0.788, 6.206, 0.61 for COD_{eff} and 0.7, 3.03, 0.48 for $TSS_{eff,}$ respectively. The quality parameters obtained from the Neural Network are in good agreement with the observed values.

According to the values of R, RMSE, and DC of testing dataset of weekly average, Neural Network model in predicting BOD_{eff} parameter is 0.84, 3.127 and 0.703, 0.82, 4.8 and 0.68 in predicting COD_{eff} and 0.78, 2.69 and 0.622 in predicting TSS_{eff} parameter. Therefore, the performance of the Neural Network model in predicting BOD_{eff} is better than COD_{eff} and COD_{eff} is better than TSS_{eff}.

The performance of the Neural Network model in predicting monthly BOD_{eff}, COD_{eff}, and TSS_{eff} parameters, is acceptable due to R, RMSE, and DC of testing dataset of monthly average which is 0.87, 2.86, and 0.76 for $BOD_{eff,}$ 0.859, 4.51, and 0.715 for COD_{eff} and 0.8, 2 and 0.63 for TSS_{eff}, respectively. This model in BOD_{eff} predicting has better performance than COD_{eff} and in predicting COD_{eff} has better performance than TSS_{eff}. The quality parameters obtained from the neural network are in good agreement with the observed values.

3.2. Support Vector Machine method

According to the results of the Support Vector Machine model for daily average data, the model in predicting BOD_{eff} has better performance than COD_{eff} and in predicting COD_{eff} has better performance than TSS_{eff} due to R, RMSE, and DC values of the testing stage which are 0.82, 3.93 and 0.676 for BOD_{eff}, 0.79, 6.18 and 0.617 for COD_{eff} and 0.69, 3.06 and 0.476 for TSS_{eff}, respectively.

According to R, RMSE, and DC of testing dataset of weekly average, the support vector machine model in predicting BOD_{eff} has 0.817, 3.33, and 0.66 values, in predicting COD_{eff} has 0.8, 5.18, and 0.63 values and in the TSSeff parameter prediction has 0.78, 2.75 and 0.604 values, respectively. Therefore, the performance of the support vector machine model in predicting BOD_{eff} is better than COD_{eff} and in predicting COD_{eff} is better than TSS_{eff}. The quality parameters obtained from the support vector machine are in good agreement with the observed values.

The performance of the Support vector machine model in estimating the monthly BOD, COD, and TSS parameters of the effluent quality of the Wastewater treatment plant is acceptable according to R, RMSE, and DC values of the testing dataset which is 0.88, 2.8, and 0.77 for BOD_{eff}, 0.86, 4.38 and 0.73 for COD_{eff} and 0.79, 2.03 and 0.62 for TSSeff, respectively. The support vector machine model in predicting BOD_{eff} performs better performance than COD_{eff} and in predicting COD_{eff} performs better than TSS_{eff}.

According to the results, ANN and SVM methods have good performance in predicting the effluent quality parameters of the Tabriz Wastewater treatment plant on a daily, weekly, and monthly average. Both methods in modeling monthly datasets are better than weekly and daily.

3.3. Multiple Linear Regression

To investigate the results of ANN and SVM methods with other methods, the Multiple Linear Regression method was used, the results show that Artificial Intelligence methods are superior to the mentioned method.

4. Conclusions

Artificial Intelligence techniques are an alternative to linear methods. In this research, the capability of Support Vector Machine and Artificial Neural Network methods in simulation of BOD_{eff}, COD_{eff}, and TSS_{eff} parameters of daily, weekly and monthly data on average of Tabriz Wastewater treatment plant were evaluated. According to the results, both methods perform the best performance in modeling the effluent quality parameters of Tabriz Wastewater every month. The superiority of Support Vector Machine model in comparison with Artificial Neural Network model in simulation of BOD_{eff} and COD_{eff} parameters of daily and monthly average and the superiority of Artificial Neural Network model in comparison with Support Vector Machine model in simulation of BOD_{eff}, COD_{eff}, and TSS_{eff} parameters of weekly average and TSSeff parameter of daily and monthly average with the highest accuracy and least error in the testing. The MLR method was used to investigate the results of ANN and SVM methods with other methods, which shows the superiority of Artificial Intelligence methods over the mentioned method.

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