Evaluation the turbidity removal efficiency in Al-Wahda water treatment plant using statistical indicators

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Abstract. Most of drinking water consuming all over the world has been treated at the water treatment plant (WTP) where raw water is abstracted from reservoirs and rivers. The turbidity removal efficiency is very important to supply safe drinking water. This study is focusing on the use of multiple linear regression (MLR) and artificial neural network (ANN) models to predict the turbidity removal efficiency of Al-Wahda WTP in Baghdad city. The measured physico-chemical parameters were used to determine their effect on turbidity removal efficiency in various processes. The suitable formulation of the ANN model is examined throughout many preparations, trials, and steps of evaluation. The prediction models of the turbidity removal are presented. Results found that the estimating of the turbidity removal efficiency by ANN and MLR model could be successful. Moreover, results showed that influent and effluent turbidity concentration have more effect on removal efficiency predicting from the other parameters. Finally, the ANN model could be more accurate than the MLR model according to the coefficient of correlation (0.925).

Key Word: Water Treatment Plant, Removal Efficiency, Turbidity, Artificial Neural Network (ANN), Multiple Linear Regression (MLR).

1. Introduction

Drinking water is consumed from the treatment plants (WTP) where the raw water collects from water bodies and enters multiple stages of treatment to supply it to the humans. The quality and source of water are the main parameters that affecting on the type of water treatment. Generally, raw water of low quality is treated under various stages with more operations and expensive work. The various processes of most WTP can be applied globally using conventional stages from coagulation then sedimentation and filtration to the last stage of disinfection. The removal efficiency of each process is different as mentioned in WHO. [1,2]. The probable variation in the operations and maintenance of the conventional treatment process has an effects on the removal efficiency, so there is a high degree of confidence in the removal of suspended and dissolved particles, bacteria by conventional treatment processes [3].

In the policy of environmental protection, the monitoring of water quality has the highest priority to control pollution problems and provide appropriate water quality to serve different purposes like drinking, irrigation etc. [4]
There are many studies in the field of WTP assessment to evaluate the WTP efficiency, the simplest method is the operation and removal efficiency in which their works at different times of the year can be compared for giving priority for the required treatment of a site [5]. Another important tool is the statistical analysis which can be used to process data of large quantities by explaining the relationship between two or more variables. Thus, helped to minimize the number of variables that may not affect the dependent variable without losing essential information [6]. Empirical multilayers artificial neural network model is presented to predict water quality index (WQI) of DO and BOD in Iran (Marad Big River) using various physico-chemical parameters then find the model of BOD of 93.7 % $R^2$ and 97.2 % $R^2$ for the DO model [7].

The objectives of the present study are evaluating Al-Wahda turbidity removal efficiency for drinking purposes, predicting the most significant parameters that affect turbidity removal efficiency using the Multiple Linear Regression (MLR) and artificial neural network (ANN) technique with the results displaying by SPSS program.

2. Material and Methods

2.1 Case study description

One of the most important water treatment plants in Baghdad city is Al-Wahda WTP on the Tigris River were selected to study which is located in the Mesopotamian alluvial plain between latitudes 33°14'-33°25' N and longitudes 44°31'-44°17' E, 30.5-34.85 m above mean sea level (MSL) [8] as shown in Figure 1. Al-Wahda WTP is located in the Al-Wahda neighborhood, opposite the General Company for Vegetables Oil at Al-Masbah Street entrance. As for the surrounding, the second project feeding the Riyadh neighborhood i.e. (Camp Sarah), University of Technology, Al-Sina'a Street, 52nd Street and the adjacent areas. These areas are characterized by high consumption of water, especially during the day, due to the high population density of this area [9].

Al-Wahda is considered one of the oldest water treatment plant in Iraq, as it was completed during the royal era and has not been witnessed any attempts to develop it to keep pace with the great industrial, commercial and residential development that the region has witnessed since the establishment of Al-Wahda WTP and to this day. The design capacity of Al-Wahda WTP is (75,000 m$^3$/day) and the available capacity is about 73,000 m$^3$/day, but it is not known the actual capacity of the plant due to the lack of measurements of inflow and outflow. A set of raw water parameters have been selected based on both availabilities of data from the WTP and importance during the period from 2015 to 2020. These fourteen parameters are: Alkalinity, Calcium (Ca), Total Hardness (TH), Total Dissolved Solids (TDS), Magnesium (Mg), Chloride (Cl$^-$), pH value, Sulphate (SO$_4^{2-}$), Electrical Conductivity (EC), Nitrate (NO$_3^-$), and Orthophosphate (PO$_4^{3-}$), Nitrogen dioxide (NO$_2^-$), Ammonia (NH$_3$) and Turbidity.
2.2 Data collection

In this research, monthly data (54 measured value) were collected for six years from 2015 to 2020 for the concentrations of physical and chemical properties of water i.e. (Alk., Ca, TH, TDS, Mg, Cl-, pH value, SO_4^{2-}, EC, NO_3^{-}, PO_4^{3-}, NO_2, NH_3, Turbidity, and the turbidity removal efficiency) of Al-Wahda WTP. Data were taken for the raw water entered into the WTP and the treated water. Excel 2013 software was used for data analysis [11,12]. The multilayer prediction artificial neural network analysis and the regression analysis were performed by IBM SPSS 20 software.

3. Mathematical Modeling

3.1 Artificial neural network (ANN)

The ANN is a mathematical modeling tool that is biologically inspired specifically by studies made on human's nervous system. This method is particularly useful in prediction and forecasting for purposes where the underlying phenomenon is complex. The ANN was a nonlinear design that able for handling big number from independent variables to define the dependent variable [13].

A neural network is a processor consist of several parameters to process the inputs with their interconnections. It contains many building blocks, while the most important ones are: Input layer, hidden layer, and output layer as shown in Figure 2. These three layers are linked in a feed forward...
way where each square represents input data. The following Equation 1 could be used to normalize the input and output data [13, 14]:

$$x_{\text{norm}} = \frac{x_i - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}}$$

(1)

Where: $x_{\text{norm}}$ is the normalize rate, $x_i$ is the original information, $x_{\text{max}}$ and $x_{\text{min}}$ is the maximum and minimum values respectively.

![Simple feed-forward neural network](image)

**Figure 2.** Simple feed-forward neural network [15].

The major aspect of neural network is the selection of input parameters. Hence, great consideration of input variable should be taken into account when the ANN structure has been used in order to provide effective results and better understanding of the problems. The input variables used in this research are influent- effluent Turbidity, Alk., T.H, Ca, Cl, Mg, pH, EC, SO$_4$, TDS, NO$_2$, NO$_3$, NH$_3$ and turbidity removal efficiency as shown in Figure 3. Those parameters have an important effect on the presentation of an ANN, and to make the network work effectively [16].

To expect the outcome information from input data, the neural networks could be used depending on simulates operation of human nervous time. In order to obtain convergence, the output and input information must normalize.
3.2 Multiple Linear Regression (MLR)

The MLR methods are used to approximate the linear relation between single definite dependent variable of turbidity removal efficiency with the group of quantitative independent variables of raw water specifications. The raw water parameters are used as independents variables in MLR linear equation to calculate the functions of classification [13, 17] as follow:
\[ Y_i = A + a_1 x_1 + a_2 x_2 + \cdots + a_n x_n \]  (2)

Where \( Y_i \) : Represents the function of classification when \( i = 1 \) to \( j \) (number of condition classes), \( X \): Represents the independent variables (1 to \( n \)), \( a_i \): Represent the coefficients of classification and \( A \): represent the offset.

4. Results and Discussion

4.1 Neural network formulation

The neural network consists of 54 measured values in the raw water characteristics as a set of data. To find a set of model parameters that enables the model with given function form with efficient presentation, many training in ANN has been prepared with desired input and output relation. In one set, the 54 readings are combined to examine the possibility of developing a neural network model for predicting the turbidity removal efficiency. The ANN function model in Equation 3 and the correlation coefficient \( R^2 \) was 92.5 %. Results showed that influent, effluent Turbidity and TH have more effect on the turbidity removal efficiency predicting model to other parameters as shown in Figure 4.

\[ Y = 15.14 + 0.81 x \]  (3)

Where \( Y \) is the turbidity removal efficiency and \( x \) is the water parameters. Equation (3) reflects the fitting line of the model so it can use for any point to know the predicted value of the turbidity removal efficiency (RE) depending on the other parameters.

![Figure 4. Independent Variable Importance.](image-url)
To expect the outcome information from input data, the neural networks could be used depending upon simulates operation of human nervous time. The detailed parameters of the proposed model were illustrated in Table 1 for the estimation of hidden and output layers of ANN.

**Table 1.** Prediction parameters of output and hidden layers.

| Predictor | Hidden Layer 1 | Output Layer | Removal |
|-----------|---------------|--------------|---------|
| (Bias)    | -1.225-       | -0.09-       |         |
| Tur.in    | -0.719-       | 0.386        |         |
| Tur.out   | 0.468         | 0.949        |         |
| Alkalinity| -0.085-       | 0.461        |         |
| TH        | -0.182-       | -0.422-      |         |
| Ca        | -0.065-       | 0.455        |         |
| Cl        | 0.062         | 0.049        |         |
| Mg        | 0.102         | 0.278        |         |
| pH        | -0.032-       | 0.053        |         |
| EC        | 0.294         | -0.365-      |         |
| SO4       | -0.120-       | 0.695        |         |
| TDS       | -0.183-       | 0.380        |         |
| NO2       | 0.124         | 0.375        |         |
| NO3       | 0.034         | 0.146        |         |
| NH3       | -0.243-       | -0.157-      |         |
| PO4       | 0.021         | 0.031        |         |

Where: Bias is the constant element, H (1:1) is the first hidden layer and H (1:2) is the second hidden layer.

To reduce the complexity the neural network was used to compose the synthetic neurons which joined and variety in the diverse layer [18]. The weights of connection are resolute by minimizing the mistake among the values of expected output and the definite output under experiential information. The processing of the model was selected as the inputs varies to 63% for the training, 25.9% for the testing and around 11.1% for the holdout as shown in Table 2.
Table 2. Case Processing Summary

|        | N   | Percent |
|--------|-----|---------|
| Training | 34  | 63.0%   |
| Sample  | Testing | 14     | 25.9%   |
| Holdout | 6    | 11.1%   |
| Valid   | 54   | 100.0%  |
| Excluded| 0    |         |
| Total   | 54   |         |

4.1.1 Verification of the ANN Model

In order to verify the accuracy of the ANN model for predicting the Turbidity removal efficiency at Al-Wahda WPT the recorded data (observed) for years 2015 to 2020 were plotted against the predicted values (from the AAN model) [19] as shown in Figure 5. The model gave good accuracy with a coefficient of determination $R^2 = 0.9127$.

\[
y = 1.0441x - 6.292 \\
R^2 = 0.9127
\]

Figure 5. Verification of the ANN model for predicting Turbidity removal efficiency at Wahda WTP for years 2015-2020

4.2 Multiple Linear Regression (MLR) formulation models

The data set available for 54 measured values in the water characteristics as a set of data. SPSS regression tool is used adopting the stepwise procedure in the variable selection progression; this resulted in Table 3. Results showed the maximum coefficient of determination ($R^2$) of 88.7 illustrated in the last model.
Table 3. MLR model results

| Model | R   | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-----|----------|-------------------|---------------------------|
| 1     | .550| .302     | .289              | 12.55560                 |
| 2     | .917| .841     | .834              | 6.06032                  |
| 3     | .936| .876     | .869              | 5.39374                  |
| 4     | .942| .887     | .878              | 5.20974                  |

5. Conclusion and Recommendations

This research work is an attempt to:

- Identify and assess the turbidity removal efficiency of Al-Wahda WTP conditions. The physico-chemical analysis reveals the present status of the water treatment plant and their effect on the works of AL-Wahda WTP emphasizes the need for a high degree of reliability in the operation of the individual unit operations.
- Identify a number of raw water parameters with the ANN model that are used to provide a solution that has contributed to improvements in the overall performance of Al-Wahda WTP.
- Analysis of Al-Wahda turbidity removal efficiency during the study period (2015-2020) revealed that the removal rate during this time was good and notice removal rates are very high due to the high quantities of sediment coming from the river, thus reducing the velocity of flow and increase the amount of alum added and large amounts of sediments were removed by the sedimentation tank.
- Application of Artificial Neural Network (ANN) showed the effective role of turbidity on turbidity removal efficiency. Thus, the outcomes acquired during this study, provided an accurate view of Al-Wahda WTP showed the problem of its work efficiency. Finally, the paper strategy can be applied to different processes of the water treatment plants.

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