Municipal wastewater treatment and recycle by an electrocoagulation process and a submerged membrane bioreactor system

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Abstract. To remove phosphates and nitrates from municipal wastewater, an electrocoagulation process with membrane bioreactor process (EC-MBR) was used. Experiments were carried out incrementally to evaluate the new design. In a lab-scale (EC-MBR) treatment of municipal wastewater, the structure and distribution of the organic matter removal utilizing the membrane are being examined. The study's objectives were to evaluate the efficiency of the Al-Hawraa wastewater's organic matter removal process for nitrate (NO_{-3}) and phosphate (PO_4^{-3}) as well as how it related to machine learning indicators. It was chosen to use an EC-MBR with operational parameters of 25 Co, pH 7 and DO (4-6 mg/L), initial and final concentrations of NO_{-3} (4.4-0.6 mg/L), and (PO_4^{-3}) (6.0-0.1 mg/L) to collect and analyze effluent from municipal wastewater treated using biological and chemical methods. According to the results, it may be possible to measure the effectiveness of organic matter removal using a neural network method. The results also showed that an overall reactor had agreeable maximum NO_{-3} and (PO_4^{-3}) removal efficiencies of (87.6% and 98.1%), respectively. The accuracy model by its (98.1 and 85.7) for both NO_{-3} and (PO_4^{-3}) was effective, according to the models' accuracy results.

1 INTRODUCTION

Over the past three decades, industrialization and tremendous economic growth have considerably worsened the environment in certain developing nations, and the demand for water has increased as a result of people using vast amounts of it for both household and industrial purposes on a daily basis. Water utilized by the community and containing all items added to it during the consumption period is known as domestic wastewater. In addition to making the already severe freshwater deficit worse, untreated wastewater has a significant detrimental impact on the environment and human health. Treated sewage may be utilized for a number of purposes, such as irrigation and industrial uses. Researchers have therefore concentrated their efforts on finding solutions to these issues, particularly when conventional treatments have proven ineffective or insufficient. Membrane separation has recently gained

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popularity as a promising solution technology for the treatment and reuse of municipal wastewater. Since recovered water is available close to urban areas where water supplier dependability is crucial and water is more expensive, wastewater reuse has emerged as a key option for the environment and economic water management because it conserves freshwater, is ecologically benign, and is cost-effective [1]. When biological activity and physical or physio-chemical processes are coupled, wastewater treatment has shown passable results. This is where the electrocoagulation process EC with membrane bioreactor MBR has shown its ability to offer an excellent waste water recycling option [2]. A number of studies employ the electrochemical water treatment procedure known as electrocoagulation (EC). Contaminating particles, ions, such as heavy metals, and colloids get destabilized and collected during the process, which uses an electrical charge to keep them in solution[3]. Usually the process stimulates an anode and a cathode with a DC power source to destabilize the charges. Through this procedure, flocculated particles are removed from the water, resulting in the production of pure water [4]. Membrane bioreactors are used to treat wastewater. MBR combine membrane filtration technology, for the treatment of wastewater, such as low-pressure microfiltration (MF) systems or ultrafiltration, or UF, membranes with a suspended growth biological treatment technology, such as activated sludge. The membranes' basic role is to separate between liquids and solids [5]. To accomplish this in activated sludge plants, secondary, tertiary, and tertiary filters have historically been used. Vacuum (or gravity-driven) systems and pressure-driven systems are the two most common forms of MBR systems [6]. With hollow fiber or flat sheet membranes implanted in the bioreactors or a subsequent membrane tank, immersed vacuum or gravity systems are frequently employed. Pressure-driven systems are in-pipe cartridge systems and are located outside the bioreactor [7]. MMBR has carried out numerous studies in the area of treating municipal wastewater. In order to assess the microbial populations in a bio-electrochemical reactor under various operating conditions [8]. conducted research on the utilization of electro-technologies in biological treatment techniques currently employed in the United Arab Emirates. At lower current concentrations, both continuous and intermittent electric field supply considerably boosted the observed bacterial populations, growth rates, and COD clearance. Using the EC system as a pre-treatment step before the MBR system is another strategy to reduce direct microbial community contact with the applied DC field. The two reactor systems were connected in series and operated in continuous flow mode to treat municipal waste water utilizing an electrocoagulation unit as a pre-treatment for an MBR in this work (i.e., EC-MBR process) [9]. The principal goals of the study are to analyze the organic matter removal efficiency for the purpose of reuses, predict the most important parameters that determine the organic matter removal efficiency, and assess how well the MBR process for municipal wastewater treatment performs when combined with the EC process. The EC technique generally offers additional benefits, such as the lack of a need for chemical addition and the preservation of alkalinity.

2 Methodology

2.1 Case Study Description

On the fringes of the city, in the Wasit Governorate, Iraq, is the Al-Hawraa Residential Area (HRA), which has over 5000 housing units, eight schools, one sports city, one health center, one rain station, and one wastewater plant. Al-Hawraa cost a total of (41) billion dinars to construct and took up (67) acres. The current study is focused on the municipal wastewater from HRA. It is assumed that there is an average of (5) family members and that every family generates wastewater from the water needed for everyday demands, with an estimated 80% of all wastewater generated from daily needs.

2.2 Data Collection

The production of an electrocoagulation with membrane bioreactor and testing of its effectiveness in removing (NO-3) and (PO4-3) over time, as well as other environmental factors, such as BOD (mg/L), COD (mg/L), and TSS (mg/L) of Al-Hawraa Residential Area, were the laboratory experiments used in this study. Information gathered from the residential unit's municipal wastewater discharge. Graphs were made and data was analyzed using Microsoft Excel 2019. Data analysis was carried out with SPSS Modeler 18 software.

2.3 Experimental Set-up

In the current study, a pilot-scale of the EC-MBR with an effective capacity of 8 Liter was used. As shown in Figure 1, a hollow fiber membrane module composed of polyvinylidene fluoride (PVDF) from Mitsubishi Rayon Co. Ltd. in the Republic of Korea was dropped into the bioreactor's riser with a preset pore size of (0.01) micron and filtering area of (0.8) m^2. The EC (with 3 Liter in volume) is operated twice daily for hydraulic retention time (HRT 12 hr.) and once daily for (HRT 24 hr.). Additionally, electrodes are operated for five minutes while bacteria activity is at its greatest. Five minutes of water placement in the EC is followed by a pump transfer to the feeding tank and membrane (which works continuously). The variation in flow rate of (15–20%) as a sign of membrane fouling development Two (2.5) L per minute pumps are put beneath the membrane module to provide aeration. These pumps are connected to a distributor in the feeding tank and another in the membrane. One of the advantages of the reactor connected to EC is the efficiency of the reactor relative to the average economic cost, which must be taken into account. High energy expenditures and greater capital and operating costs associated with membrane cleaning and replacement are the disadvantage of this reactor compared to bioreactors. Additionally, to speed up a waste sludge's settling rate in the system, extra chemicals can be needed. High-quality effluent, greater volumetric loading rates, lower hydraulic retention times (HRT), less sludge generation, and the possibility of concurrent nitrification and denitrification in lengthy solid retention times are some of its benefits.

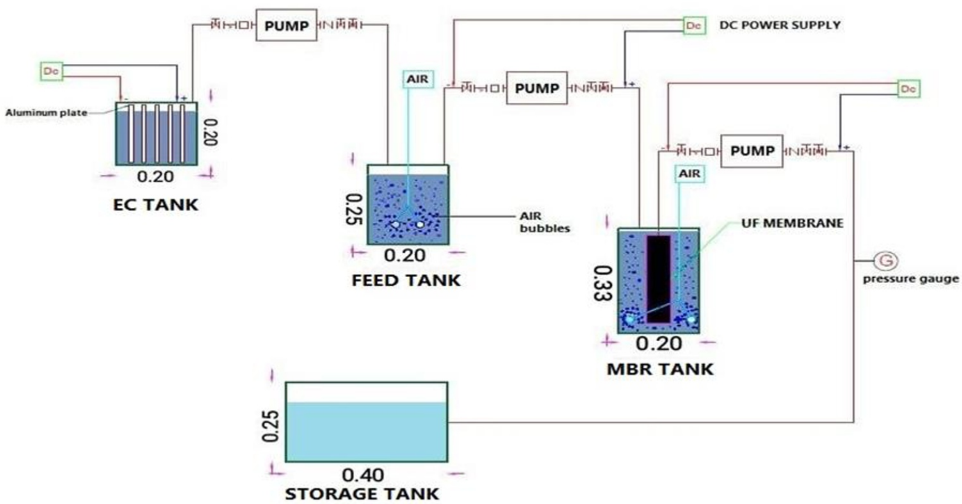

Fig. 1. A pilot-scale of EC-MBR system.

2.4 Data Analysis

SPSS Modeler is a very popular program that describes variables and parameters. SPSS also can be a statistical application which has a variety of tools and lists that can be obtained from entered data. Then, the data is analyzed and generalized. Neural networks (NN) are one of the SPSS classes of machine learning (ML). Neural Network uses multiple layers of neurons which the data is inserted in the network, then passes to a hidden layer, and outputs prediction. Figure shows the NN frames process from input through hidden layer to outputs. In this technique, the gradient descent is used as a training algorithm. The error is calculated based on the difference between the target and prediction values [10]. clarifies the NN algorithm's neuron weighting procedure. A neuron inserts a collection of weight inputs. The inputs are then used to train a set of data and variables using a function of gradient descent. The neuron will then deliver the results of its comparison of the prediction and target values to the outputs as shown in Figure 2 [11].

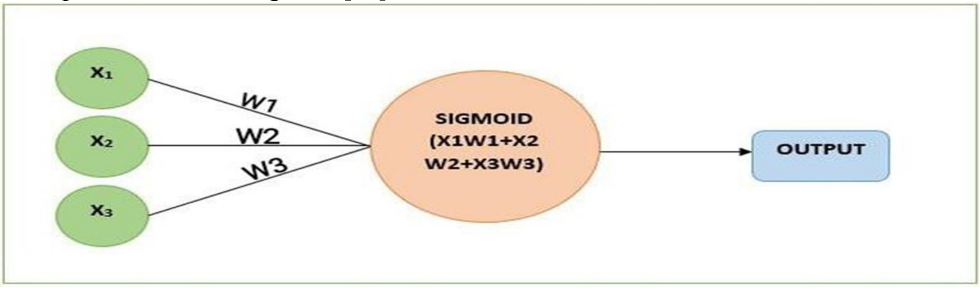

Fig. 2. The Neuron process.

3 Results Discussion

The system's overall removal of (NO_{-3} and PO_4^{-3}) was achieved in the present study's two removals (R1 and R2), which were carried out in an electric tank and a membrane bioreactor, respectively. This study examined municipal wastewater treatment under two different HRT (12 and 24 hours). As a result of a free anodic appearing in the EC reactor and interfering with charged double layers after a period of adaption, the removal in mixed liquor improved. In Figure 3 for 12 hours and Figure 4 for 24 hours, the (NO_{-3}) and (PO_4^{-3}) concentrations (influent and effluent) temporal patterns and their total removal efficiency are shown in Figure 3 and Figure 4.

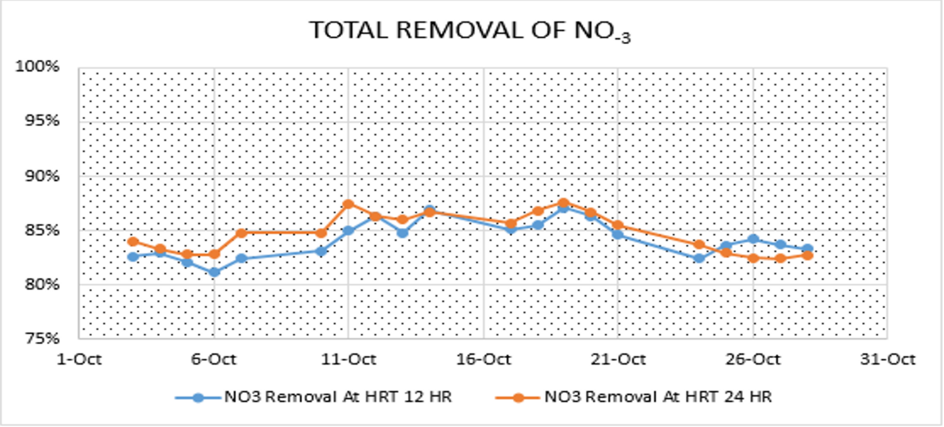

Fig. 3. NO_{-3} total removal at R1 and R2.

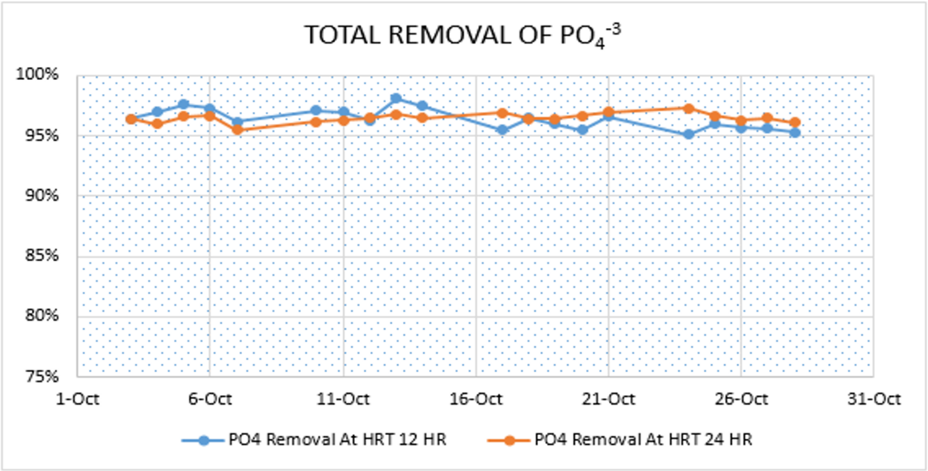

Fig. 4. PO_4^{-3} total removal at R1 and R2.

15.2% of (NO_{-3}) was removed during electrolysis using the EC technique which is a significant variation in removal rates over the period of electrolysis. The elimination efficiency is unquestionably higher when the electrolysis period is longer. The effectiveness of EC treatment was impacted by EC time. Additionally, the membrane bioreactor's average (NO_{-3}) removal efficiency for various HRT is 83.9%. This represented a minor variation in the clearance rates of HRT administered for 12 and 24 hours. The membrane can remove nitro-bacteria at a fast rate of removal, which extends the age of the sludge. At the same time, the high removal rates show that nitrate nitrogen was successfully converted to nitrogen gas. As a result of the treatment throughout the entire system, the overall elimination, as shown in the figure 3 is 87.6%. This finding agreed with [12] and [13]. The overall removal of (PO_4^{-3}), as shown in the figure 4, is 98.1% as a result of treatment across the entire system [EC-MBR]. The previous studies [14] were reported that the EC method has a high removal efficiency rate of PO_4 of over 93%, [15, 16, 17, 18, 19]. There could be two main causes for this. The first is that as current density and electrolysis time rise, so does the metal dissolution. This causes PO_4^{-3} ions to be absorbed. The second explanation is that $AlPO_4$ precipitates out as a result of the interaction between Al^{+3} and PO^{-3}. PO_4^{-3} has a low removal efficiency rate, in contrast. In a membrane bioreactor system, the average removal efficiency for various HRT was 33.2%. This is due the absence of an anaerobic chamber limits the MBR system's functionality and capacity. Additionally, the conversion of dissolved phosphorus to biomass was caused by the high phosphorus removal that was maintained in the MBR unit.

3.1 Result of Data Analysis

The accuracy and prediction of data were evaluated using the SPSS modeler by neural network algorithm. All removal efficiencies were predicted using the concentrations of all parameters treated using the EC and MBR processes, as well as the experimental HRT work times of 12 and 24 hours. For R1 (HRT 24 HR) of (NO_{-3}) and (PO_4^{-3}) the accuracy and prediction of all data were evaluated as shown in Figure 5, Figure 6, Figure 7 and Figure 8.

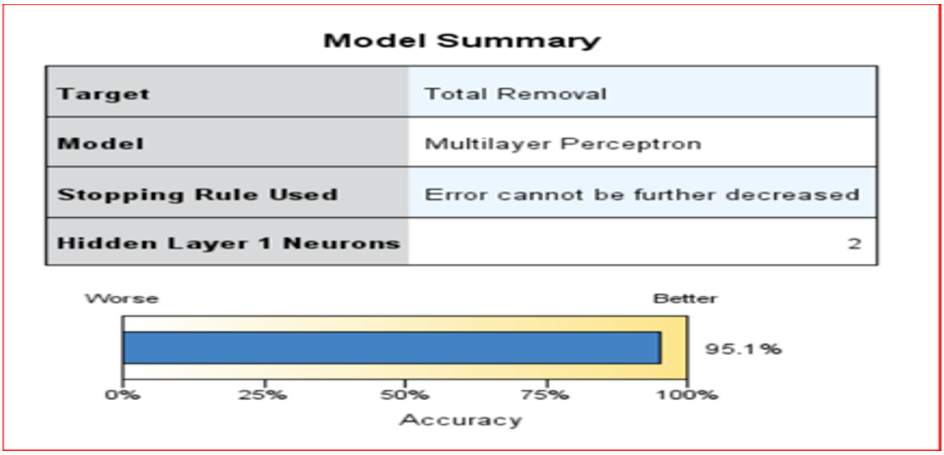

Fig. 5. Accuracy of NO_{-3} removal data at HRT 24 hr.

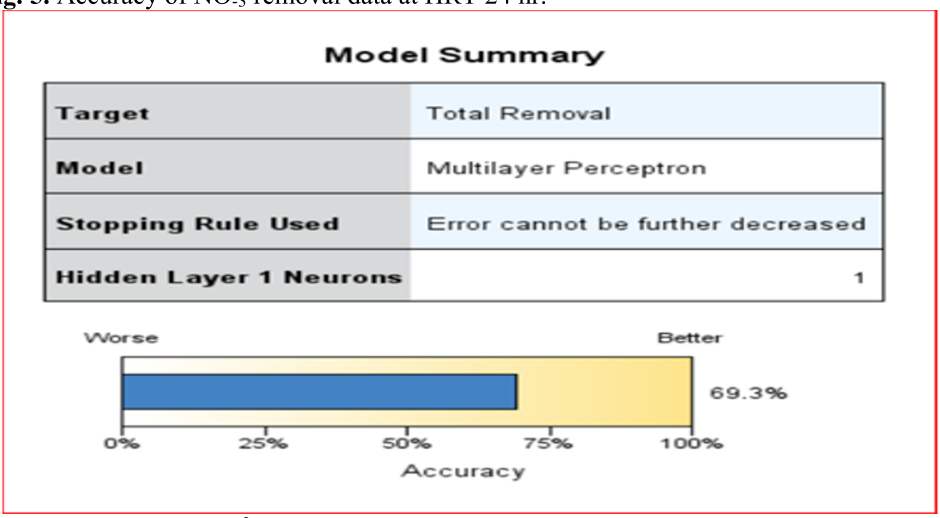

Fig. 6. Accuracy of PO_4^{-3} removal data at HRT 24 hr.

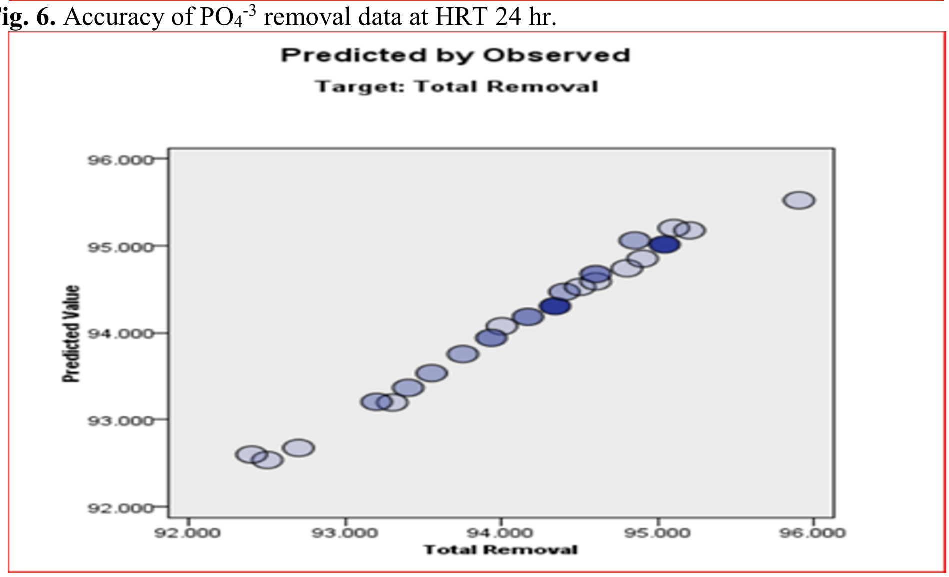

Fig. 7. Prediction of (NO_{-3}) removal data at HRT 24 hr.

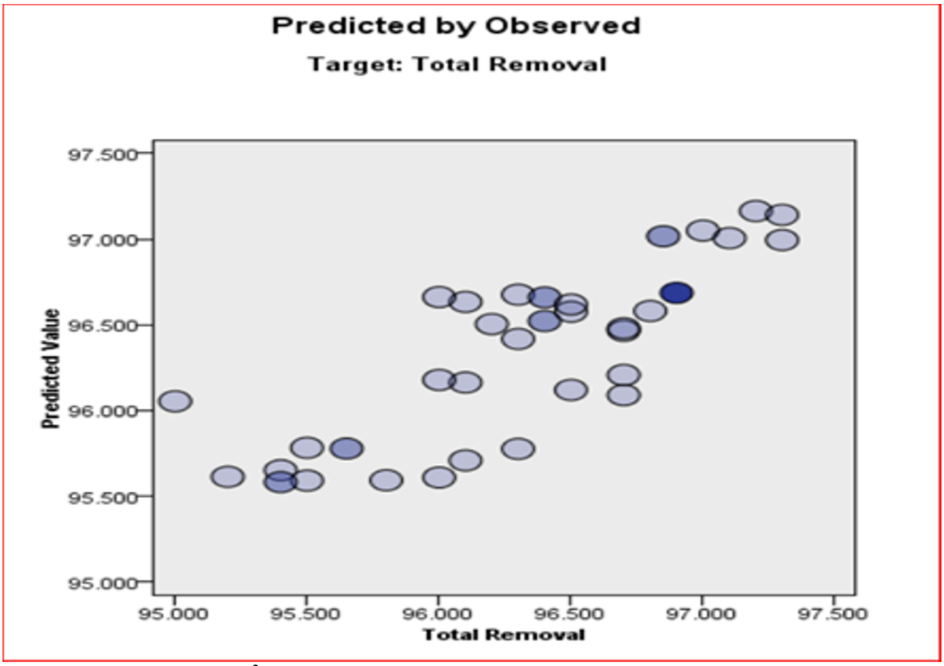

Fig. 8. Prediction of PO_4^{-3} removal data at HRT 24 hr.

In this study, it was compared input and output data from the processing process throughout the entire system, the accuracy readings were showed that the correlation was strong in each model. The analysis of enormous amounts of data in order to discover fresh patterns and connections that might be utilized to forecast future behavior or events is known as predictive analytics. Numerous approaches were used in it, such as statistics, data mining, machine learning. The precision and predictability of all data for R2 (HRT 12 HR) of NO_{-3} and PO_4^{-3} were assessed as follows in Figure 9, Figure 10, Figure 11 and Figure 12.

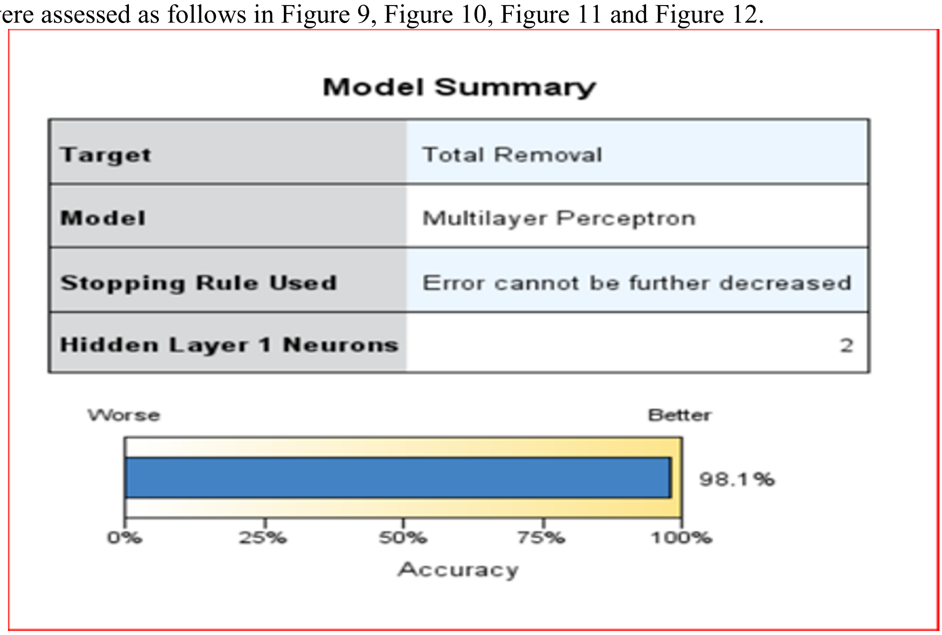

Fig. 9. Accuracy of NO_{-3} removal data at HRT 12 hr.

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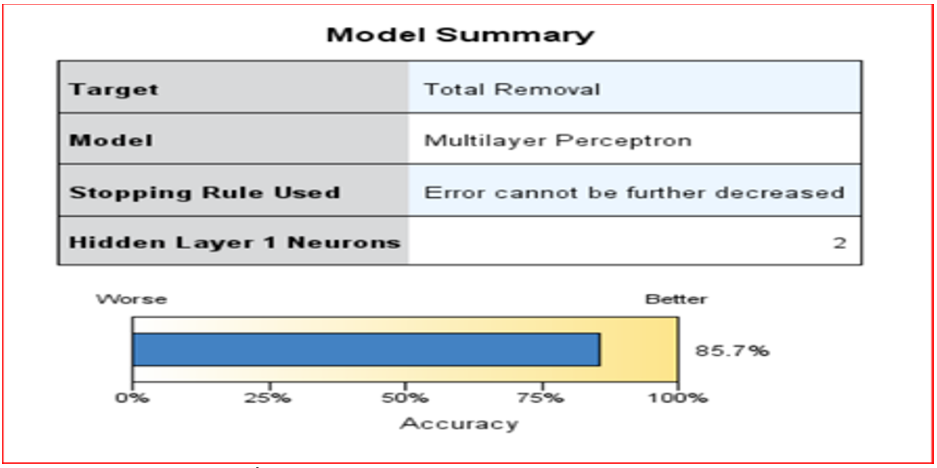

Fig. 10. Accuracy of PO_4^{-3} removal data at HRT 12 hr.

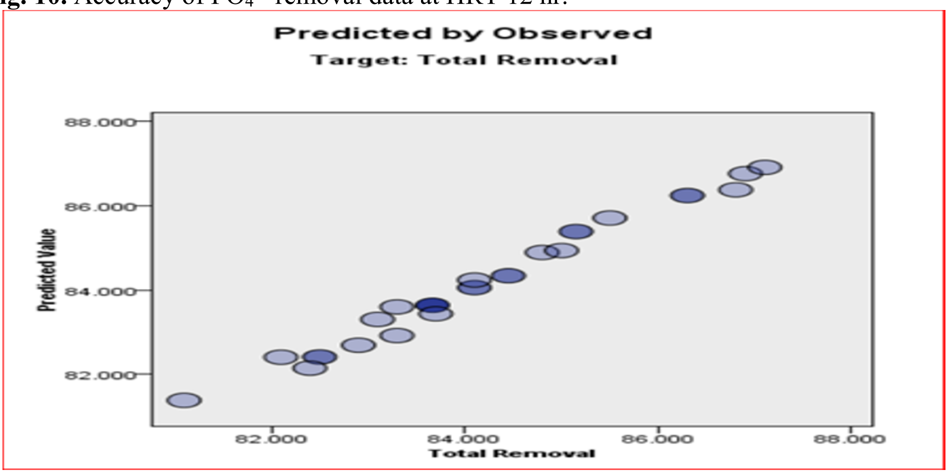

Fig. 11. Prediction of NO_{-3} removal data at HRT 12 hr.

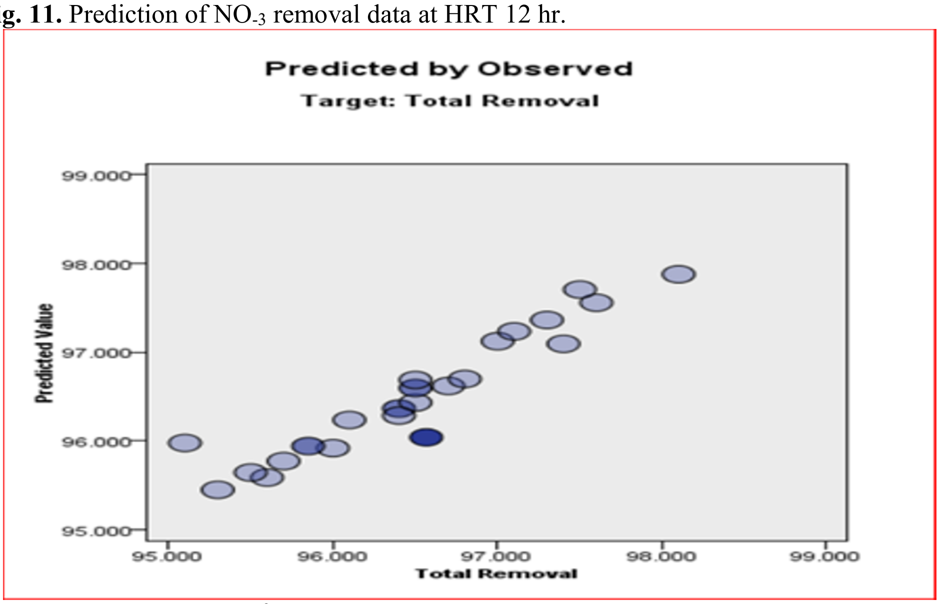

Fig. 12. Prediction of PO_4^{-3} removal data at HRT 12 hr.

Same as above the result of data analysis showed that the accuracy of both (NO_{-3}) and PO_4 had an acceptable strong correlation of the model. By looking at the results of the prediction analysis, it can be noticed that the prediction scheme is well-represented, which shows that the model is efficient.

4 Conclusions

The purpose of this study is to evaluate the effectiveness of an EC system when combined with an MBR system to treat municipal wastewater at various hydraulic retention times, and the following conclusions were made:
The results showed that the Hydraulic Retention Time, which was used in the MBR process, it was caused an improvement in removal efficiency when HRT is increased to 24 hours. HRT was showed the average amount of time wastewater spends inside the biological reactor, indicating the amount of time the pollutant and microorganisms actually come into touch. Using the EC-MBR system under certain operating conditions, high removal results for NO_{-3} and PO_4^{-3} were achieved. The maximum removal percentage for NO_{-3} was attained, which was 87.6 percent, as well as for PO_4^{-3}, which reached 98.1 percent. According to the findings, the EC-MBR system has a high removal effectiveness of more than 95% when it comes to removing contaminants without the use of chemicals. Some contaminants, however, were resistant to being eliminated by the EC or MBR processes alone. When the removal efficiency falls to under 20%. All data were analyzed for accuracy and predictability using the SPSS modeler via neural network algorithm. The concentrations of all parameters treated with the EC and MBR processes, as well as the experimental work times of 12 and 24 hours (HRT), were used to model each removal efficiency for NO_{-3} and PO_4^{-3}, the result of data analysis showed that the accuracy of removal NO_{-3} and PO_4^{-3} was a passable and the correlation was strong in the model.

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