Application of Artificial Neural Networks in the Evaluation of Ekbatan Wastewater Treatment Plant

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Introduction

Performance of wastewater treatment plant is function of wastewater quality, management of treatment plant and environmental issues. The purpose of this research is to develop the efficiency of the artificial neural network model to evaluate the performance of Ekbatan treatment plant and to estimate quality parameters.

Materials and methods

In this study artificial neural network (ANN) was used for modeling wastewater treatment plant. Thus by measurement of quality parameters in wastewater treatment plant input, output parameters of the wastewater treatment plant was predicted. ANN input parameters includes temperature (T), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total solids (TS) and pH.

In this study the number of middle layer neurons according to the number of input and output layer neurons was suggested from equations of table 1.

Table 1: The proposed rules of the number of neurons in middle layer, according to the number of input and output neurons

Reference	Equations
Fletcher and Goss (1993), Patuwo et al. (1993)	$2 * n_i + 1$
Wang (1994)	$(2/3) * n_i$
Piramuthu et al. (1994)	$0.5 * (n_i + n_o)$
Lenard et al. (1995)	$0.75 * n_i$
Kanellopoulos and Wilkinson (1997, a)	$2 * n_i$
Kanellopoulos and Wilkinson (1997, b)	$3 * n_i$

n_i: Number of input data (6 neurons), n_o: Number of output data (6 neurons)

For each structure, the minimum normal root mean squared error (*NRMSE*) was calculated equation 1 and the maximum correlation coefficient (*r*) using equation 2. In suitable structure values of *NRMSE* and *r* will be close to 0 and 1, respectively.

$$NRMSE = \frac{\sqrt{\frac{\sum_{i=1}^{n}(T_i - Y_i)^2}{n}}}{\frac{\sum_{i=1}^{n} T_i}{n}} \quad (1)$$

$$r = \frac{\sum_{i=1}^{n}(T_i - \overline{T_i})(Y_i - \overline{Y})}{\sqrt{\sum_{i=1}^{n}(T_i - \overline{T_i})^2 (Y_i - \overline{Y})^2}} \quad (2)$$

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Where, T_i: The real (target), Y_i: The predicted, n: number of data, $\overline{Y}$: mean of The predicted by ANN and $\overline{T_i}$: mean of target.

Finally to evaluate wastewater treatment plants output and the results of ANN in isolation and loss of studied parameters, index of removal efficiency percentage, according to equation 3 was used. This index shows isolation percentage of each wastewater treatment quality parameter after treating.

$$RE_x = \frac{1}{n}\sum_{i=1}^{n}\frac{x_{in} - x_{out}}{x_{in}} \times 100 \qquad (3)$$

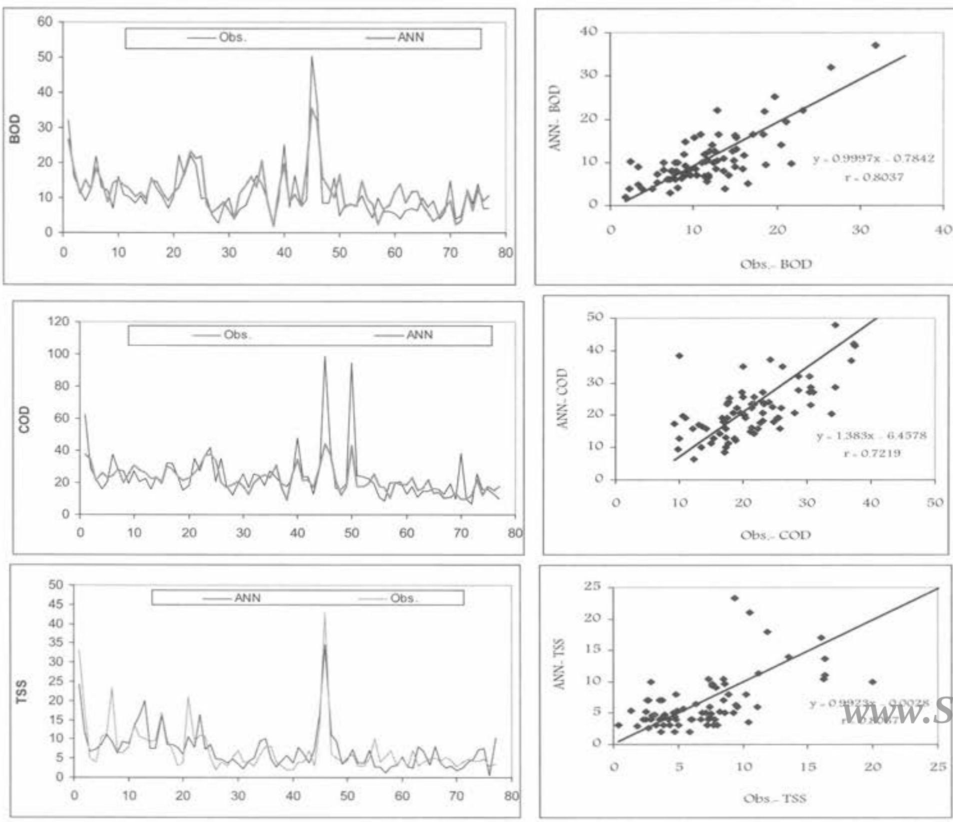
Where, RE_x: index of removal efficiency percentage of x parameter ($x=1\text{-}6$), x_{in}: amount of x parameter in input of treatment plant and ANN, $x_{out:}$ amount of x parameter in output of treatment plant and ANN and n: numer of data.

After determination of relationship between input and output treatment variables, different structures of ANN were implemented. Accuracy of ANN in estimation of monthly average concentrations of pollutants was calculated using statistics of r and NRMSE.

Discussion of Results

Different structures of ANN with different number of neurons in middle layer showed that structure of 6-12-6 with NRMSE= 0.26 and r= 0.82 as desired structure could be proposed. This structure has been successful in prediction of 72 to 97 percent of the effluent quality parameters changes in base of independent variables.

The comparison of the estimated parameters of ANN with 6-12-6 structure in contrast with the measured values are shown in figure 1.



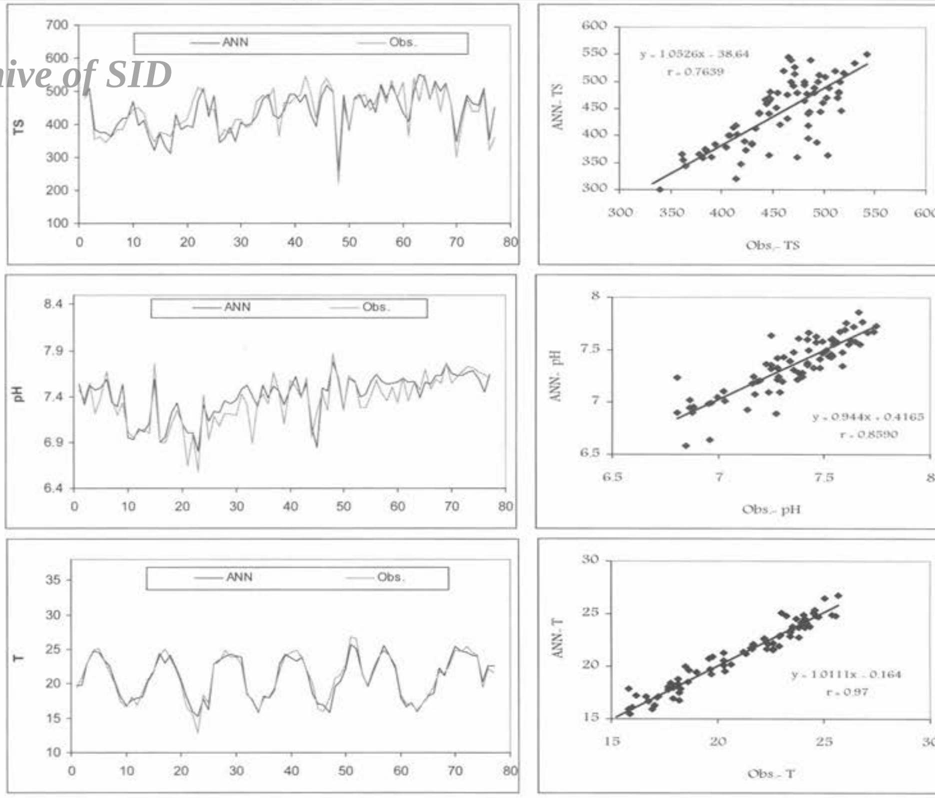


Fig. 1: Comparison of neural networks results in estimation of each of the studied parameters in constant with the values of observations

Figure 1 show that the estimated quality parameters of ANN in most cases have good agreement with observed values and even in some factors such as temperature, was the same as the estimated observed ones. Also, the high correlation coefficient can be confirmed. After comparing removal efficiency or reduction of the amount of pollutants in the treatment plant effluent obtained by equation 3, the values of observations and predictions of the neural network, separately, are given in table 3.

Table 3: Comparison of removal efficiency of each quality parameter in output of wastewater treatment plant and ANN

pH	TS	TSS	COD	BOD	T	Parameters	
--	mm/L				°C		
7.90	644.84	243.63	258.01	159.62	23.77	Input	treatment
7.35	439.48	7.29	24.06	11.19	21.00	Observed	
6.89	31.85	97.01	90.67	92.99	11.63	RE	
7.90	644.84	243.63	258.01	159.62	23.77	Input	ANN
7.35	454.22	7.35	22.07	11.98	20.94	Estimated	
6.95	29.57	96.99	91.45	92.50	11.92	RE	

By calculating the removal percentage of pollutants in the treatment plant effluent, the maximum and the minimum removal efficiency in the treatment plant were related to TSS, equal to 97 percent and TS, equal to 32 percent, respectively. Similarly, removal efficiency of cited pollutants by the estimated values of ANN is 97 and 30 percent, respectively, that shows the good performance of neural network because of being similar to observed amounts.

Conclusions

Overall, by comparing results of this study with other studies and with respect to the statistical indicators, one can be sure about the good performance of neural networks studied in this research.

Key words

Artificial Neural Network, Removal Efficiency, Ekbatan treatment plant, pollutants.