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Determination of a Statistical Model to Predict COD and TKN from the BOD_5 and NH_4^+ Results

Parvaneh Talebi Hematabadi [1], *Hadi Zarei Mahmoud Abadi* [2*], *Hadi Eslami* [3]

[1] *Department of Natural Recourses Engineering, Branch of Environmental Pollution, School of Agriculture and Natural Resources, Islamic Azad University of Meybod, Yazd, Iran.*

[2] *Department of Environment, College of Agriculture and Natural Resources, Islamic Azad University of Meybod, Yazd, Iran.*

[3] *Environmental Science and Technology Research Center, Department of Environmental Health Engineering, School of Public Health, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.*

A R T I C L E I N F O

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****Corresponding Author:***
Hadi Zarei Mahmoud Abadi

Email:
hadyzarei@yahoo.com

Tel:
+983527770163

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ABSTRACT

Introduction: The development of an appropriate model for the quality control of an industrial wastewater treatment system can save the time as well as the cost. This study was performed to determine an appropriate model in order to predict the COD and TKN parameters by BOD_5 and NH_4^+ in the Meybod industrial estate wastewater treatment plant (WWTP).

Materials and Methods: This descriptive – analytical study was performed on 120 samples of the influent and effluent of the industrial estate wastewater treatment plant in Jahan Abad, Meybod, Yazd in 2015. The studied parameters were BOD_5, TKN, COD, and NH_4^+. After measuring, they were imported to SPSS and Excel software to determine the relationship between them and then the linear regression model of the statistical method was used.

Results: The predictive results of COD values on the basis of BOD_5 in the regression model showed that the coefficient of determination was 0.88 and the correlation coefficient was 0.93 (p = 0.00) for this relationship. The prediction of TKN values on the basis of NH_4^+ in the regression model showed that for this relationship the determination coefficient of TKN and NH_4^+ influent parameters was 0.87 and the correlation coefficient was 0.93 (p = 0.00).

Conclusion: This study represented that using the linear regression model for predicting COD and TKN values through BOD_5 and NH_4^+ was in close accordance with the laboratory data and can thus be applied when the Meybod industrial estate WWTP faces time limitations or sampling problems.

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Introduction

Nowadays, rise of concern about the environment has made experts pay more attention to correct and appropriate operations and more exact control of the wastewater treatment plants ($WWTP_s$)[1]. The main goals of wastewater treatment system's establishment include preservation of community health, protection of the environment, prevention of water resources' contamination, reuse of the treated wastewater in agriculture and environment [2, 3]. The improper performance of industrial and municipal WWTPs and discharge of polluted effluent into the water resources can make the environment polluted and endanger human beings, animals, and plants' health [4-7].

The industrial estate WWTP in Jahan Abad, Meybod, located in 30 Km of Yazd city, has two zones of aerobic and anaerobic. The operating units of JahanAbad industrial estate WWTP consist of the raw wastewater pump station with manually screens, grit chamber channel, equalization unit, anaerobic unit of UABR, aerobic process of IFAS, settling basin, and chlorination unit. The treatment system of Up-flow Anaerobic Biological Reactor (UABR) is an anaerobic system which removes organic matter and produces biogas. In this system, the reactor is operated during a short hydraulic retention time because of high VSS level. The conditions of the influent wastewater flow and the produced biogas result in wastewater mixing with the produced granule [8-10]. The integrated fixed-film activated sludge (IFAS), with a fixed media, is a type of activated sludge system in which the media increases the microbial population. This system makes use of both the suspended and attached growths. The use of this activated sludge system causes a decrease in WWTP volume and dimension [11, 12].

The more appropriate and safer control and operation of the WWTP can be performed by a suitable model to predict the WWTP efficiency on the basis of observations and the past data of the key parameters of the wastewater quality [13]. The various parameters such as BOD_5, COD, TKN, ammonia, etc have a main role in determining the efficiency of the wastewater treatment system and controlling the quality of the effluent. These parameters are usually measured and experimented in the environmental chemistry laboratory, but a long time is generally required for measuring these parameters [14]. To deal with these problems, the development of a suitable model for controlling the quality of the effluent in a wastewater treatment system on the basis of some simple parameters can save time and cost [15]. Various studies have shed light on modeling with respect to different objectives for example; the study performed by Akratos et al, on the removal efficiency prediction of COD and BOD_5 for the treatment of wastewater [16] and the study carried out by Gikas et al. (2011), on the efficiency and modeling of the wetland system [17]. The results of these researches suggested that higher efficiency can be attained through this model. Also, the results of modeling studies were in close accordance with the laboratory data [18]. As a result, the objective of the present study was the determination of the statistical method to predict the TKN and COD parameters by the BOD_5 and NH_4^+ results in the Meybod industrial estate waste water treatment plant.

Materials and Methods

This descriptive–analytical study was performed on influent and effluent samples of the industrial estate wastewater treatment plant in JahanAbad, Meybod. The samples were collected during a six-month period (from June to November) in 2015 and about 10 liters was sampled in each stages. To do the experiments, 5 samples were considered for each parameter in every month regarding the studied chemical and biochemical parameters (BOD_5, TKN, COD, and NH_4^+) which made the total number of 120 sample cases. The mentioned samples were collected in plastic containers for chemical and biochemical experiments and were then transferred to laboratory in particular conditions of sampling for further investigations. In this study, the measurement of the surveyed parameters was conducted based on the standard method applied [19], in which the 5-day instrumental method (2510 D) for BOD_5, the open reflux digestive method (5220 B) for COD, Nesalization (4500 NH_4-C) for NH_4^+, and the instrumental Kjeldahl for TKN were used. Finally, the results achieved through the experiments were transformed to SPSS and Excel software. The statistical methods of the linear regression model and correlation coefficient then were applied for predicting COD and TKN values by BOD_5 and NH_4^+, respectively.

Results

In this study, the chemical and biochemical parameters consist of BOD_5, COD, TKN, and ammonia in the influent and effluent of the Meybod industrial estate wastewater treatment plant (WWTP) were studied.

The results show that the mean ± standard deviation of the input and output of BOD_5 were 450.76 ± 28.21 and 86.36 ± 9.63 mg/l, respectively. Also, the mean removal efficiency of BOD_5 was 80.84 ± 1.57% (Figure 1).

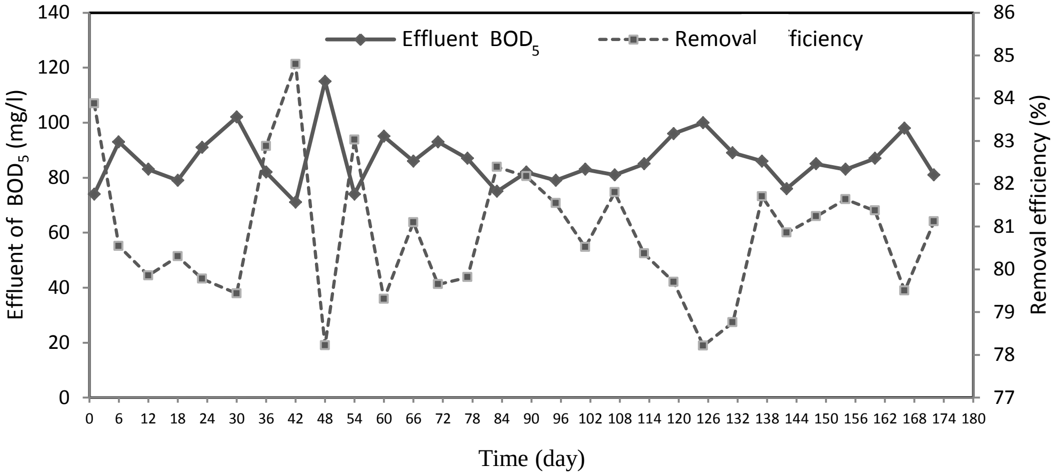

Figure 1: Changes' trend and the removal efficiency of the effluent BOD_5 in Meybod industrial estate WWTP

The results show that the mean ± standard deviation of the influent and effluent of COD were 1467.5 ± 115.99 and 299.13 ± 29.02 mg/l. Also, the mean removal efficiency of COD was 79.62 ± 0.91% (Figure 2).

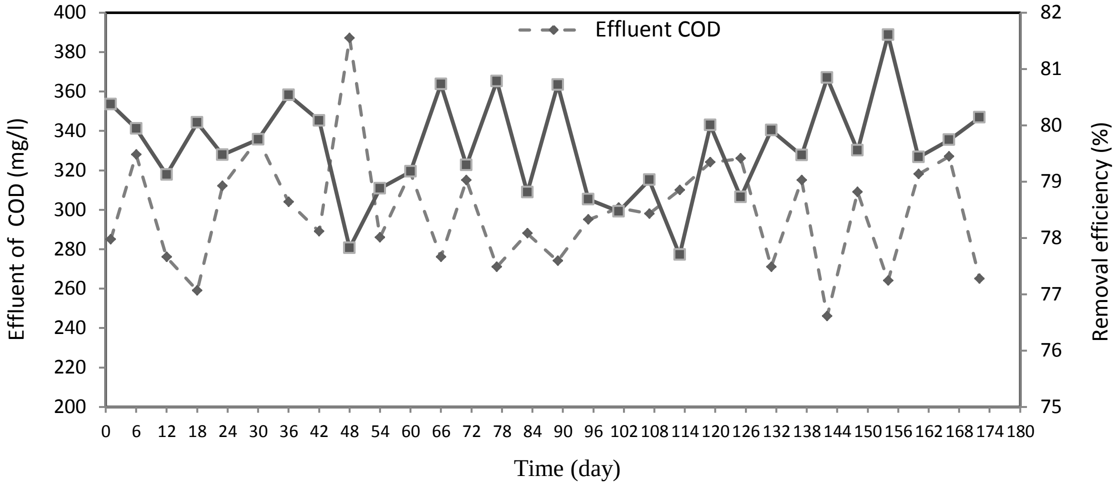

Figure 2: Changes' trend and removal efficiency of the effluent COD in Meybod industrial estate WWTP

The coefficient of determination was 0.88 and the correlation coefficient was 0.93 which show that this relationship can predict the effluent COD with a power of 88%. Moreover, this relationship was statistically significant on the basis of Pearson's correlation test (p = 0.00) (Figure 3).

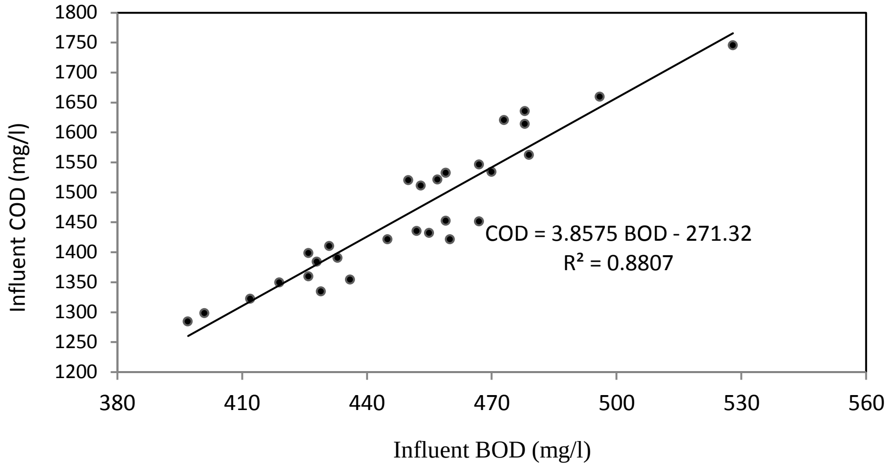

Figure 3: Relationship between the influent COD with the influent BOD_5 entering the Meybod industrial estate WWTP using linear regression model

The coefficient of determination was 0.62 and the correlation coefficient was 0.79 which show that this relationship can predict the effluent COD with a power of 66%. This relationship was statistically significant on the basis of Pearson's correlation test (p = 0.00) (Figure 4). So, this model is more efficient for predicting the relationship between the influent COD and BOD_5.

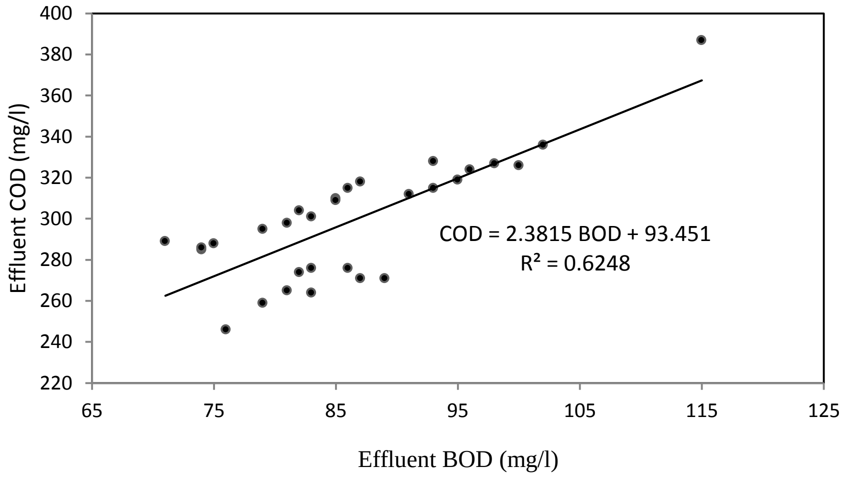

Figure 4: Relationship between the effluent COD with the effluent BOD_5 discharging from Meybod industrial estate WWTP using linear regression model

The results show that the mean ± standard deviation of the influent and effluent of TKN were 80.33 ± 5.27 and 57.3 ± 4.69 mg/l. Further, the mean removal efficiency of TKN was 28.72 ± 2.18% (Figure 5).

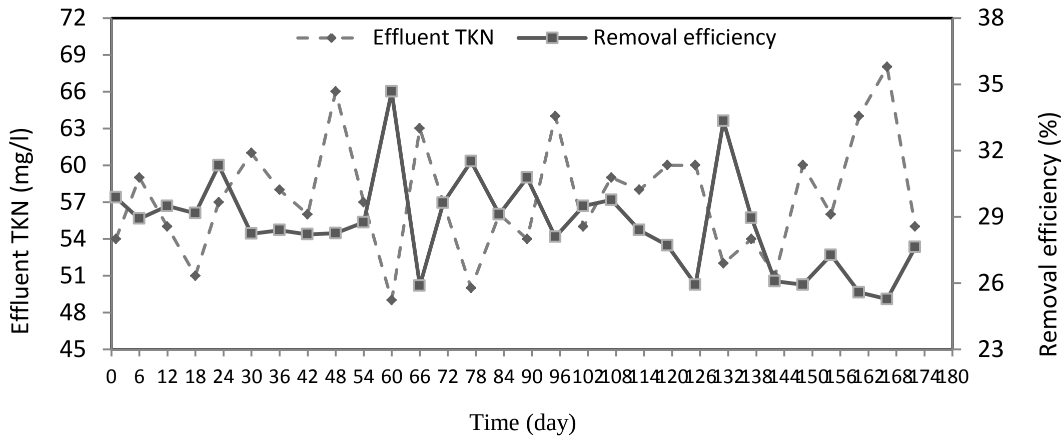

Figure 5: Changes' trend and removal efficiency of effluent TKN in Meybod industrial estate WWTP

The results show that the mean ± standard deviation of the influent and effluent of TKN were 50.7 ± 3.79 and 36.2 ± 3.23 mg/l. More, the mean removal efficiency of TKN was 28.64 ± 2.39% (Figure 6).

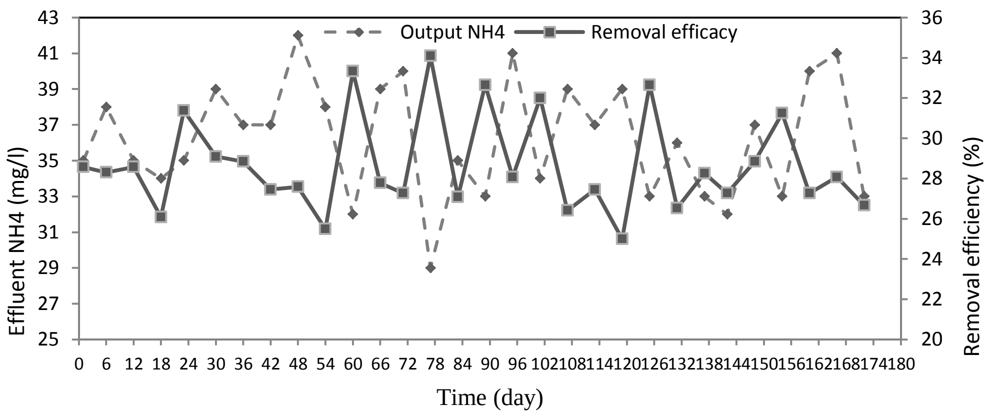

Figure 6: Changes' trend and removal efficiency of effluent NH_4^+ in Meybod industrial estate WWTP

The coefficient of determination was 0.87 and the correlation coefficient was 0.93 which show that this relationship can predict the effluent TKN with a power of 87.7% and this relationship was statistically significant on the basis of Pearson's correlation test (p = 0.00) (Figure 7).

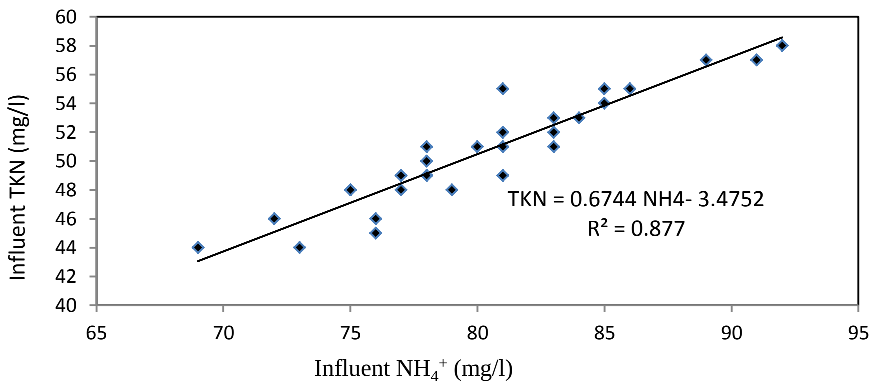

Figure 7: Relationship between the influent TKN with the influent NH_4^+ entering to Meybod industrial estate WWTP using linear regression model

The coefficient of determination was 0.701 and the correlation coefficient was 0.83 which show that this relationship can predict the effluent TKN with a power of 83.8%. This relationship was statistically significant based on Pearson's correlation test (p = 0.00) (Figure 8).

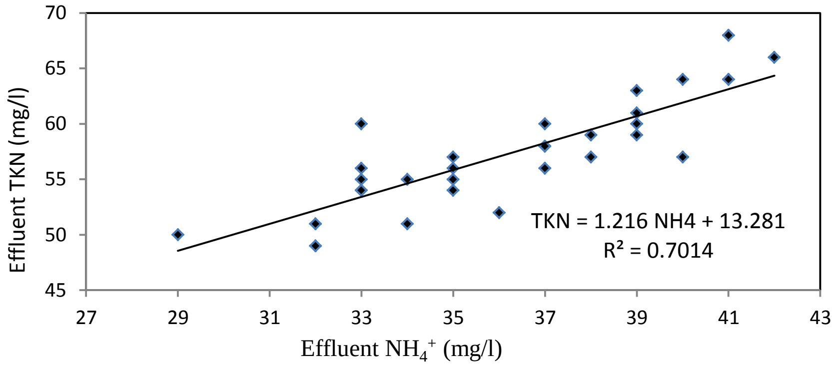

Figure 8: Relationship between the effluent TKN with the effluent NH_4^+ discharging from Meybod industrial estate WWTP using linear regression model

Discussion

The Application of the model for BOD_5 and COD

The results of this study showed that the mean removal efficiency of BOD_5 and COD in Meybod industrial estate WWTP were 80.84 ± 1.57 and 79.62 ± 0.91%, respectively. While, the study conducted by Baraee et al, on application of wastewater treatment of Abadan industrial estate for stabilizing ponds, showed that the removal efficiencies of COD and BOD_5 were 89 and 87 percent, respectively [20]. However, another study performed by Naddafi et al, on industrial Bou-ali zone in Hamedan demonstrated that the mean removal efficiencies of COD and BOD_5 were 89 and 91 percent, respectively [21].The comparison of this study with the similar studies shows that the combination of the UABR anaerobic process and IFAS aerobic process has a fairly suitable efficiency in relation to the other idustrial wastewater treatment processes.

The linear regression model was used to determine the relationship value between the two variables of the influent COD and BOD_5 and also to predict the COD value on the basis of BOD_5. It was reported that the coefficient of determination for this relationship was 0.88 and the Pearson's correlation coefficient was 0.93. It means that the attained relationship predicts the influent COD as strong as 88 percent. Also, this relationship between the two variables of the influent COD and BOD_5 represented that the coefficient of determination (R^2) for this relationship was 0.62 and the Pearson's correlation coefficient was 0.79. In other words, the attained relationship predicts the output COD with a strength of 66 percent and as a result, the efficiency of this model for predicting the relationship between the effluent COD and BOD_5 is more than that of influent. In various studies, the regression model can be used for predicting the different parameters especially when the measurement of the pollutant amounts is difficult in the different time periods [22]. The study carried out by Oliveira-Esquerre et al, on the application of the linear regression model for predicting the input and output of the BOD_5 values of an aerated lagoon of wastewater treatment system at a pulp and paper mill, showed that the R^2 value was 0.57 for predicting the influent BOD_5 value and 0.67 for that of the effluent BOD_5 [23]. Yet, Mjalli et al, who investigated the determination of wastewater treatment system efficiency by using artificial neural net (ANN) model, reported that the value of the model coefficient of determination for predicting COD was 0.63 on the basis of BOD_5 [13]. Further, Akratos et al, studied the predicting COD values on the basis of BOD_5 in the artificial wetland processes by using the artificial neural net and reported that the value of the model coefficient of determination was 0.69 [16]. Therefore, it can be seen that the coefficient of determination (R^2) in the used linear regression model in this study was higher than that of the similar studies. This can be due to differences in the measuring precision and the standard deviation value of the measured parameters. The more is the changing value of the measured parameters in a period of time, the less is the precision value of the linear relationship between these parameters, and consequently the value of that R^2 will be less. On the other hand, the high value of R^2 can be an indicator of the high linear relationship between the two surveyed parameters. In conclusion, it can be entrenched that the linear regression model has a good efficiency in predicting COD value from that of BOD_5 and this model can be used in the case of having problems for the sampling and performing the experiments.

The Application of the model for NH4+ and TKN

The mean removal efficiencies of TKN and NH_4^+ in the Meybod industrial estate WWTP were 28.72 ± 2.18 and 28.64 ± 2.39%, respectively. Also, the linear regression model was used for predicting the TKN values on the basis of NH_4^+. Its results showed that the coefficient of determination for this relationship between the input TKN and NH_4^+ parameters was 0.87 while the correlation coefficient was 0.93 which indicates that the gained relationship can predict the output TKN with a power of 87.7 percent. Furthermore, the coefficient of determination for this relationship between the output TKN and NH_4^+ parameters was 0.701 and the correlation coefficient was 0.83 which indicates that the gained relationship can predict the output TKN with a power of 83.8 percent.

In a study carried out by Akratos et al, on predicting NH_4^+ values by using artificial neural net in the wetland wastewater treatment system, the results showed that the value of R^2 was 0.42 [24]. The high value of R^2 in the linear regression model of the current study in relation to the similar studies can be due to difference in the input wastewater quality and the changes in the surveyed parameters. In other words, with higher value of these changes, there will be no appropriate linear relationship between these parameters. In conclusion, the high value of the coefficient of determination in the linear regression model indicates that there is a suitable linear relationship between the TKN and NH_4^+ parameters and the model has a good efficiency for predicting TKN values on the basis of NH_4^+.

Conclusion

With respect to the results achieved from the surveyed parameters, it can be concluded that modeling through the linear regression model for predicting the COD and TKN values on the basis of BOD_5 and NH_4^+ was in close accordance with the laboratory data. Thus, this model is recommended to be used while operating experts are faced with time limitations or sampling problems in different time periods in the Meybod industrial estate WWTP.

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Conflict of interest

We have no competing interests.

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