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Original Research Paper

Application of Mathematical Models and Fuzzy Regression Analysis to Determine the Microbial Growth Kinetic Coefficients and Predicting Quality of Treated Wastewater

Mohammad Delnavaz*†, Hossein Zangooei* and Mohammad Zangooei**
*Kharazmi University, Faculty of Engineering, Civil Engineering Department, Tehran, Iran
**Razavi Khorasan Regional Water Company, Iran
†Corresponding author: Mohammad Delnavaz

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ABSTRACT

In this study, using aeration tank sludge of Ekbatan, Tehran wastewater treatment in pilot lab scale and observing the amount of aeration, temperature, pH and concentration of feed inlet to the treatment plant, system efficiencies and changes in microbial growth were evaluated, and with the use and application of mathematical methods and Monod equations and finally by modelling the process using fuzzy regression analysis, kinetic coefficient values and output quality effluent of the plant were determined and predicted. The results of the ASM1 model for kinetic coefficients of K_s were determined as 31.2 gCOD/m^3, μ_H as 3.9 day^{-1}, b_H as 0.077 day^{-1} and Y_H as 0.51gCOD X_H (gCOD S_S)$^{-1}$. Activated sludge biological treatment process modelling using fuzzy regression analysis showed that correlation coefficient between the actual data and model for VSS, COD and SCOD equals to 0.97 by power function, 0.95 by linear function and 0.86 by power function respectively.

INTRODUCTION

One of the most fundamental issues raised in the design and utilization of urban sewage treatment is the correct choice of constant values of kinetic growth and awareness of the values of quality parameters of the raw sewage and treated wastewater.

Given that the majority of municipal wastewater treatment plants (WWTP) using biological systems, tries to remove dissolved organic matter in the wastewater to maintain the growth conditions such as temperature, pH and environmental conditions have a significant impact on the choice of survival and growth of microorganisms. The efficiency of the biological processes used for wastewater treatment depends on the substrate utilization and microbial growth variables (Metcalf & Eddy 2008). Operation and design of such systems require understanding of the biological reactions and the basic principles governing the growth of microorganisms. Obviously, understanding all the environmental conditions affecting the substrate utilization and the rate of microbial growth may not be possible, but checking factors such as pH and nutrients is essential to provide effective treatment (Bitton 2005).

The rate of substrate utilization in biological systems could be modelled based on Monod equation for substrate solution (Chapra 2008). Monod equation can be the most important mathematical equation to study microbial growth and substrate utilization rate in a biological growth medium. On the other hand, the relations provided by the International Water Association (IWA) for activated sludge models (ASM) are also highly regarded by researchers and operators of wastewater treatment plants (Henze et al. 1987). Activated sludge models presented include ASM1, ASM2 and ASM3. Activated sludge models are based on phenomena that involves the oxidation of organic carbon, nitrification, denitrification and phosphorus removal in an activated sludge system. The main merit of these models is that, by identifying core processes, they state the most important reactions in the form of a matrix. The advantages of using a matrix form are allowing easy and quick identification and tracking all interaction results of each component in the system and following all the interactions of system components (Metcalf & Eddy 2008).

In the past, several studies have been conducted in the field of wastewater treatment processes to determine the kinetic coefficients, of which a small portion is devoted to using activated sludge model number 1. From among these studies, the study of major wastewater treatment plants in Switzerland by Siegristand Tschui (1992) and Nuhoglu et al. (2005), in the wastewater treatment of Arzinkan of Turkey can be noted. In a survey conducted in 2005 by Stricker & Racault (2005), applications of computer modelling of aerobic biological treatment systems for industrial wastewater were used to evaluate the new processes. ASM1 model showed good validation with treatment plant results.

Joseph & Malinain (1999) computed the kinetic coefficients for hydraulic retention time of 24 hours at a high rate of biological treatment plant. Pala & Bolukbas (2005), estimated kinetic coefficients for the biological removal of carbon, nitrogen and phosphorus from municipal wastewater. In a study in 2006, kinetic coefficients of an immersed membrane bioreactor for municipal wastewater treatment was calculated. It should be noted that the determination of these coefficients has been under different loading rates (Al-Malack 2006). Naghizadeh et al. (2008) determined the kinetic parameters in a municipal wastewater treatment with submerged membrane reactor using Monod equations. The results of their study showed that the coefficients of Y, k_d, K_s, and k were 0.6mgVSS/mgCOD, 0.51 day^{-1}, 65.5 mg/L and 1.86 day^{-1}, respectively. Baek et al. (2009) studied the application of activated sludge model for an aerobic membrane process for wastewater treatment. In their research, ASM3 model was used to examine the COD removal and nitrification in different operating conditions such as hydraulic retention time (HRT), solids retention time (SRT) and MLVSS concentrations. Bohlooli & Taebi (2010) studied the aerobic digestion process using the activated sludge models 1 and 3. The results showed that the activated sludge model 3, with respect to considering more parameters and internal storage of cell processes, had better results than the activated sludge model 1. Another study in 2013 was carried out on the kinetic constants of biological processes to evaluate the improvement of industrial wastewater treatment of the Amol city, with activated sludge process combined with fixed bed. In this study, the kinetic coefficient of Y was 0.419mgVSS/mgCOD, k_d was 0.062 day^{-1}, K was 2.6 day^{-1} and K_s was 54.7 mgCOD/L in MLSS concentration in the range of 1450 to 2000 mg/L. The results showed that the combined activated sludge system with fixed bed, due to characteristics such as simple design, low operational costs and high efficiency of COD removal, than conventional activated sludge system is a good idea for the treatment of various types of waste, particularly industrial waste (Azimi & Taheriyoun 2013). Liwarska et al. (2013) carried out a study with the purpose of calibration of a complex activated sludge model to ensure its ability to predict and to improve the effect of nutrients in full-scale plant in Poland. Modelling included a hybrid model of ASM1, ASM2 and ASM3 models where the results of the model were highly correlated with the actual results of temperature and sludge age.

Fuzzy regression was introduced first by Tanaka in 1987. Tanaka et al. (1987) offered a fuzzy linear regression model as a fuzzy regression system. They considered a model with certain inputs and outputs, but fuzzy parameters. In 1991, a modified form of a possible regression was proposed by Sakava & Yano (1991). Berdosi (1998) for the first time used fuzzy regression models in hydrological problems. Seshan et al. (2015) using a fuzzy linear regression model predicted different parameters affecting the sewage treatment plant at a treatment plant.

In this study, it was tried to evaluate the biological processes used in the wastewater treatment plant in West Tehran Ekbatan using ASM1 model and ASIM software and fuzzy regression analysis using FuReA software and comparing kinetic coefficients obtained from modelling and results of Monod model the information of operation of the plant. For this purpose, samples of biomass in the aeration tank of the plant at a pilot laboratory were grown in different substrate concentrations, and using three mathematical equations extracted from the original Monod relationship, kinetic coefficients of these biological processes were determined. Then, using the information contained in the plant, the amount of kinetic coefficients of experimental results was compared with the results of operating the plant, including the growth rate of output (Y), half-saturation constant (K_s), the maximum rate of substrate utilization (k) and its death coefficient (kd). Finally, using regression analysis and modelling of activated sludge, the amount of COD, VSS and SCOD of wastewater treatment plant were predicted and compared with actual values.

MATERIALS AND METHODS

Determining parameters of Monod model: In this study, after settling 20 L of recirculation of activated sludge of Ekbatan WWTP in the laboratory, the water was drained and using the thick sludge, a third of reactor volume (equivalent to the treatment plant aeration tank dimensional analysis plan dimensions 128×32 cm and height 10 cm) was filled and the remaining empty space was filled with raw sewage treatment plant with COD equivalent to 100 mg/L. Oxygen in the reactor was provided by three air pumps. The amount of substrate in the reactor was in the range of real conditions in WWTP and the differences of microorganisms concentration in this period was determined by measuring the sludge MLVSS continuously. To control the biological reactions under aerobic conditions and to provide an appropriate environment for microorganisms to use the input feed, pH, nutrients, dissolved oxygen and other parameters of the system were continuously controlled. For example, the pH in the range of 6.5-7.2 using acid (phosphoric acid) or caustic soda (sodium hydroxide) and dissolved oxygen in the range of 1.5-2.5 mg/L were controlled. The amount of filtered COD and efficiency of its removal was measured on a daily basis (due to the presence of solid particles, especially in the lower part of the reactor and the possibility of error SCOD was measured. Thus, at first the sample went through Whatman paper (No. 42) and the filtered sample was used for the analysis of COD. Therefore, in the results, COD means filtered COD in all cases. It is noteworthy that all the tests were based on the standard methods of testing water and sewage (APHA, AWWA, WEF 2005).

Activated sludge model (1): The process of removal of organic matter in wastewater treatment of Ekbatan is based on A_2O system, which is a combination of anaerobic processes, anoxic and aerobic. In this study, due to the limitations of the information contained in the plant, and to compare different modelling methods, only the aerobic treatment process using ASM1 with the help of information obtained during the period of one year (falling to March 2014) is modelled. According to the information received from the plant, the temperature of the implementation of the model was set at 20°C. ASM1 model includes 13 components and these values should be extracted based on the information from the plant. To simplify the model in this study, some parameters such as the growth of heterotrophic and autotrophic bacteria, which is negligible in the aeration tank, were removed. For this purpose, Table 1 information, which is the simplified form of the main table in ASM1, was used to build the model. Although the non-dissolved material analysis parameters (S_I) and non-degradable suspended solids (X_I) do not have the coefficients, their amount in the wastewater sample in the measurement of COD and VSS of output samples is important. There are three core processes in aeration tank such as heterotrophic aerobic growth, heterotrophic death and hydrolysis process, where the components of the model are determined by stoichiometric coefficients and the process track. In this table Y_H coefficient is the heterotrophic biomass production efficiency and f_P is the non-biodegradable biomass. For example, equation of quick biodegradable solution material in matrix form of ASM1 is according to Eq. 1.

$$S_S = -\frac{1}{Y_H}\mu_H\left(\frac{S_S}{K_S+S_S}\right)X_H + K_h\left(\frac{X_S/X_H}{K_X+(X_S/X_H)}\right)X_H \quad ...(1)$$

Where, μ_H is the maximum specific growth rate of heterotrophic biomass, K_s is the constant of half speed of heterotrophic biomass, k_h is the maximum rate of special hydrolysis and K_x is the half rate of organic slow biodegradable matter. All parameters of the model must be estimated to calibrate the results of modelling of aerobic process. In this study, to estimate model parameters, ASIM version 4 software is used. In this software different parameters are selected on a primary guess in a period of a year and the best parameters that have the lowest error are selected. The relationship between the components of the model and the measured values from the plant are according to Eq. 2 and 4.

$$VSS = X_H+X_S+X_I+X_P \quad ...(2)$$

$$COD = X_I+X_S+S_I+S_S \quad ...(3)$$

$$SCOD = S_I+S_S \quad ...(4)$$

Where, X_p is equivalent to the amount of suspended non-biodegradable COD obtained from cell damage. Regression analysis is a statistical tool to provide a model using a set of measured data, including the uncertainty of a population to provide an equation to predict for the entire population.

Fuzzy regression analysis: By this analysis one of the variables can be predicted from another variable. The purpose of regression analysis is to find a new formula to determine an appropriate and efficient model and determining the coefficient of the model with the best fit of the observed data (Yen & Ghoshray 1999). If, in the system checked by regression analysis, the data are not conclusive, but variables are random, probable and influenced by human errors or in the form of dialog, in general fuzzy regression analysis can be a more appropriate means of regression analysis. The basic concept of this method was proposed by Tanaka et al. (1982).

Table 1: ASM 1 parameters.

	Component → i Process↓ j	S_I	S_S	X_I	X_S	X_H	X_p	Process Rate, ρ ($ML^{-3}T^{-1}$)
1	Aerobic growth of heterotrophs		-1/Y_H			1		$-\frac{1}{Y_H}\mu_H\left(\frac{S_s}{K_s+S_s}\right)X_H$
2	Decay of heterotrophs				1-f_p	-1	f_p	$b_H X_H$
3	Hydrolysis		1		-1			$K_h\left(\frac{X_s/X_H}{K_X+(X_s/X_H)}\right)X_H$

In this study, regression analysis was done using FuReA software. This software allows user to simulate the dependent parameter using independent parameters by different linear and nonlinear functions.

In order to estimate error and assess the accuracy of the prediction COD, VSS and SCOD parameters with correlation of determination (Eq. 5) and root mean square of errors (RMSE) (Eq. 6) were used (Turkdogan & Yetilmezsoy 2010).

$$R^2 = \left(\frac{\sum_{i=1}^{n}(A-\bar{A})(F-\bar{F})}{\sqrt{\sum_{i=1}^{n}(A-\bar{A})^2(F-\bar{F})^2}}\right)^2 \qquad ...(5)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(F-A)^2} \qquad ...(6)$$

Where, A and F represent the actual values and predicted values using modelling methods and $\bar{A}$ and $\bar{F}$ represent the average of these values.

RESULTS

Determining parameters of Monod model: The substrate utilization rate in the aerobic biological process was determined using Monod equation (Eq. 7) (Metcalf & Eddy 2008). In this equation, coefficients can be calculated with the use of biomass to produce the organic substrate.

$$r_{su} = -\frac{k_0 XS}{K_s + S} \qquad ...(7)$$

Where, r_{su} is the rate of biomass concentration changes because of its use in (g/m^3.d), k_0 is the maximum specific substrate consumption rate in grams per gram substrate of microorganisms on a day, X is the biomass concentration (g/m^3), S is the concentration of substrate limiting growth in solution (g/m^3) and K_s is the constant of half speed, substrate at half the maximum speed of substrate utilization in terms of (g/m^3).

K_s and k_0 parameters of the main equation Monod line, and the slope and intercept the sum of the amounts are determined. In this study, three methods were used to make the original equation linear.

Lineweaver-Burk model: In this model, the original equation of Monod can be expressed as the Eq. 8 (Chapra 2008).

$$\frac{1}{k} = \frac{K_s}{k_0}\frac{1}{S} + \frac{1}{k_0} \qquad ...(8)$$

In this case, by drawing 1/k by 1/S, a straight line will be obtained whose slope is K_s/k_0 and its intercept will be $1/k_0$. Drawing Lineweaver-Burk plot based on the information of concentration of biomass and substrate input to the pilot is shown in Fig. 1a. As we can see, the values of k_0 and K_s are extractable as 3.8 and 32g/m^3 respectively.

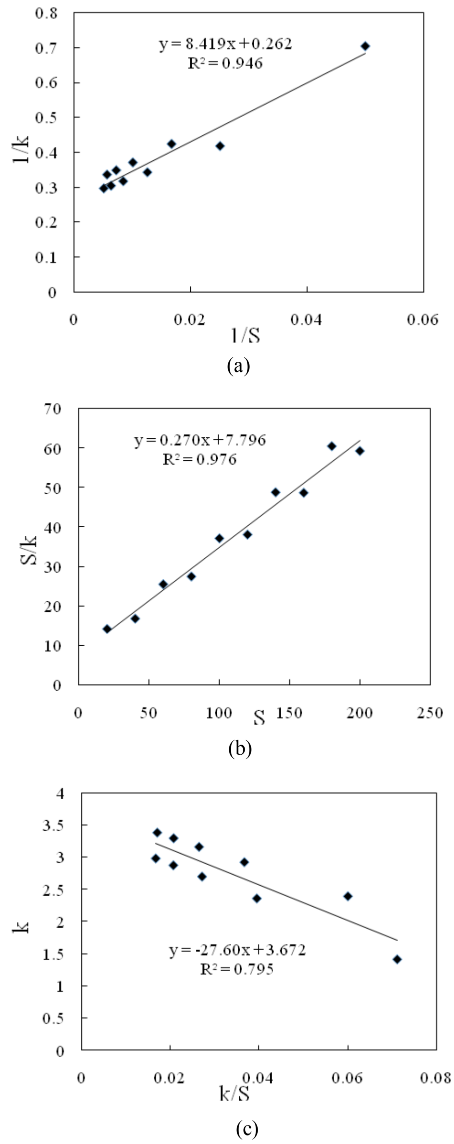

Fig. 1: Determination of synthetic growth microorganisms coefficients in Monod equation (a) Lineweaver-Burk model, (b) Hanes model, (c) Hofstee model.

Hanes model: This model has expressed main Monod as Eq. 9 (Chapra 2008).

$$\frac{S}{k} = \frac{S}{k_0} + \frac{K_s}{k_0} \qquad ...(9)$$

In this case, by drawing S/k based on S, a straight line

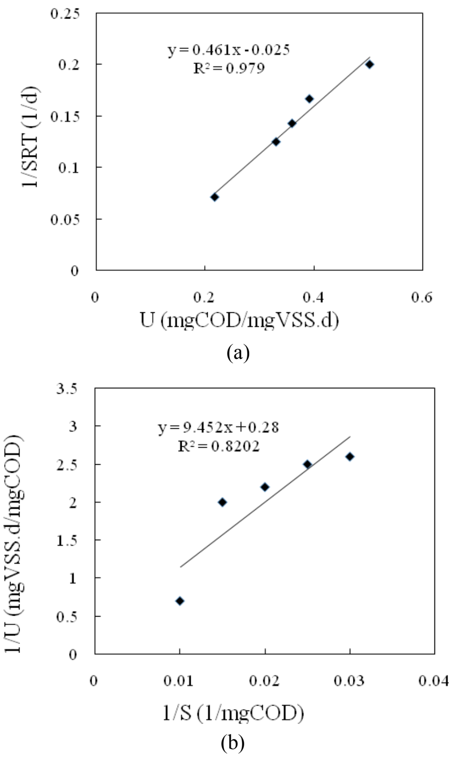

Fig. 2: Determination of synthetic growth microorganisms coefficients in operating treatment condition.

will be obtained whose slope is $1/k_0$ and its intercept is Ks/k0. Drawing Hanes plot based on the concentration of biomass and substrate input to the pilot is shown in Fig. 1b. The values of k_0 and K_s are obtained as 3.67 and 28.8 g/m^3 respectively.

Hofstee model: In this model, the original equation of Monod (KS + S)/S is multiplied and by simplifying, final Eq. 10 is obtained (Chapra 2008).

$$k = k_0 - k_s(\frac{k}{S}) \quad ...(10)$$

In this equation, by drawing k based on k/S, a straight line will be obtained whose slope is k_s and intercept is k_0. Drawing Hofstee plot based on the concentration of biomass and substrate input is shown in Fig. 1c. The values of k_0 and k_s are obtained as 3.67 and 27.6 g/m^3 respectively.

Mathematical equations to determine the kinetic coefficients using the operational information of the plant: Kinetic coefficients for activated sludge treatment were calculated using information obtained from the wastewater treatment plant of Tehran Ekbatan and using mathematical relations 11 and 12 that correspond to the conventional activated sludge system (Metcalf & Eddy 2008, Chapra 2008). Entering discharge to the aeration tank is 625 cubic meters per hour, the volume of the tank is 9830 cubic meter and hydraulic retention time is 15 hours.

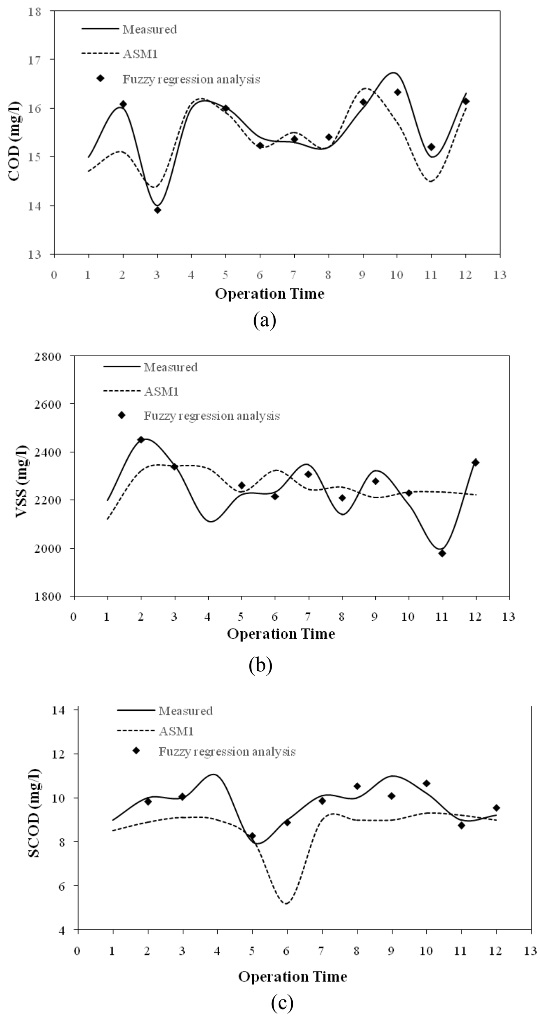

Fig. 3: The comparison between the best relationships extracted in Fuzzy regression method, ASM1 and actual values.

$$\frac{1}{SRT}YU - k_d = \frac{Y(S_0 - S)}{\theta X} - k_d \quad ...(11)$$

$$\frac{\theta X}{S_0 - S} = \frac{K_s}{k_0}\frac{1}{S} + \frac{1}{k_0} = \frac{1}{U} \quad ...(12)$$

Where, SRT is the cell retention time in days, S_0 is the input substrate concentration in milligrams per litre COD, S is the output substrate concentration in milligrams per liter COD, U is the substrate utilization rate in mgCOD/mgVSS, and θ is the hydraulic retention time per day. By drawing U-1/SRT and 1/S-1/U diagrams, kinetic coefficients were determined. By making above charts linear, intercept of figure U-1/SRT represents k_d and slope represents Y. For figure 1/S-1/U also,

Table 2: Operation condition of treatment plant.

Location		T (°C)	pH	TS	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	MLSS (mg/L)	MLVSS (mg/L)	SVI (mg/L)	DO
1. Input	average	24.2	8	646	191	194	323	-	-		
	range	22-29	7.6-8.2	473-760	191-253	100-264	160-453	-	-		
2. Aeration tank	average	23	7	-	-	-	-	2600	2243		
	range	19-28	7-7.1	-	-	-	-	1563-3335	1998-2450		
3. Output	average	24	7.3	19	11	6.4	19.8	-	-	134	2.6
	range	21-29	7-7.4	15-35	7-16	4-11	13-31	-	-	115-210	2.2-3.1

Table 3: Determination of kinetic coefficients by ASM1 and comparison with Monod model results.

Kinetccoe-ffcients	Unit	ASM1	Results of activated sludge formula	Monod equation			Typical parameters recommended by IWQA	Recommended values by Metcalf and Eddy [3]
				Lineweaver-Burk	Hanes	Hofste		
K_s	g $COD.m^{-3}$	31.2	33.75	32	28.8	27.6	20	5-40
$\mu_{H(k_0)}$	1/day	3.9	3.57	3.8	3.67	3.67	4	3-13.2
$b_{H(k_d)}$	1/day	0.077	0.085	-	-	-	0.062	0.06-0.2
Y_H	gCOD X_H (gCOD $S_S)^{-1}$	0.51	0.477	-	-	-	0.67	0.3-0.5
f_P	-	0.08	-	-	-	-	0.08	0.08-0.2
k_h	g cell COD. day^{-1}	2.23	-	-	-	-	3	-
K_x	g cell COD. day	0.022	-	-	-	-	0.03	-

intercept represents $1/k_0$ and the slope of this line also represents K_s/k_0.

As is clear from Fig. 2, Y value amount was determined as 0.447 mg, k_d as 0.085 day^{-1}, k_0 as 3.57 mgCOD/L, and K_s as 33.75 $gCOD.m^{-3}$.

Determination of synthetic coefficients of aerobic wastewater treatment process: To determine the kinetic coefficients of aerobic wastewater treatment process using ASM1 and modelling of biological processes using ASM, information was received for a period of one year from the wastewater treatment plant of Ekbatan.

It is worth noting that the sampling frequency is different in different months of the year and a total of 97 repeat samples have been taken. Changes in input and output parameters and corresponding information of the plant in a one year period is presented in Table 2. As can be seen in this table, average input COD to the refinery is 323 mg/L and its removal efficiency is more than 93 percent. MLVSS changes in the aeration tank are in 2450-1998 range, and in the entrance model to the software, weekly data model has been used.

To run the model considering COD, VSS and SCOD parameters, suitable range of kinetic coefficients were estimated in ASM1 model whose results are expressed in Table 3. As we can see, the difference between the results of the model in all cases is within the recommended range of International Water Association.

In this table, comparative results of Monod models with ASM model are also mentioned that show the good coefficient of kinetic processes for biological decimal between the results of the pilot study of the growth of microorganisms in the laboratory and the results of operation and ASM1 model. Kinetic coefficients were determined as K_s as 31.2 $gCOD.m^{-3}$, Hμ as 3.9day^{-1}, b_H as 0.077 day^{-1} and Y_H as 0.5 gCOD X_H (gCOD $S_S)^{-1}$ that disagree with the results of the kinetic coefficients using equations with the results of conventional activated sludge processes respectively as 7.6, 9.2, 9.4 and 6.9 percent. On the other hand, the kinetic coefficients of growth of microorganisms are in the recommended range of the authorities. In other words, leading refineries in terms of removal efficiency and biological conditions of the process are in a good condition.

Root mean square errors between the results of plant and ASM1 model of utilization in months was measured, which were obtained for COD, VSS and SCOD parameters respectively as 0.26, 102.2 and 1.07. As the results show, there is a good agreement between the results obtained from the model and plant.

Fuzzy regression analysis: The results of the use of three linear, power and exponential function to extract the relationship between measured parameters and the plant with COD, VSS and SCOD values are given in Table 4. As Table 4 shows, powered function with 0.97 correlation of determination and root mean square error of 0.175, linear function with correlation coefficient 0.95 and root mean square error of 38, and power function with 0.86 correlation, aver-

Table 4: Fuzzy regression analysis using linear and nonlinear functions.

Function	Obtained equation	R^2	RMSE
Linear	$Output\ COD = -60.44 + 0.4326 \times (Influent\ Temperature) + 7.545 \times (Influent\ pH) - 3.08E - 02 \times (Influent\ TSS) + 1.957E - 03 \times (Influent\ COD) + 2.6E - 03 \times (Influent\ Nitrate) - 7E - 04 \times (Influent\ Phosfat) + 5.636E - 02 \times (Aeration\ Tank\ Temperature) + 9.8E - 04 \times (Aeration\ Tank\ MLSS)$	0.946	0.792
	$Output\ VSS = -1.33E + 04 - 63.49 \times (Influent\ Temperature) + 1555 \times (Influent\ pH) - 9.006 \times (Influent\ TSS) + 2.639 \times (Influent\ COD) + 0.5123 \times (Influent\ Nitrate) - 0.1137 \times (Influent\ Phosfat) + 155.8 \times (Aeration\ Tank\ Temperature) + 0.6036 \times (Aeration\ Tank\ MLSS)$	0.954	38
	$Output\ SCOD = 5.34E + 04 - 0.9732 \times (Influent\ Temperature) - 1.805 \times (Influent\ pH) + 3.424E - 2 \times (Influent\ TSS) - 1.773E - 2 \times (Influent\ COD) - 1.233E - 2 \times (Influent\ Nitrate) + 7.52E - 3 \times (Influent\ Phosfat) + 3.609E - 2 \times (Aeration\ Tank\ Temperature) - 2.2E - 3 \times (Aeration\ Tank\ MLSS)$	0.854	0.636
Powered	$Output\ COD = -4.36E - 03 \times (Influent\ Temperature)^{0.6861} \times (Influent\ pH)^{2.823} \times (Influent\ TSS)^{(-0.2002)} \times (Influent\ COD)^{0.2714} \times (Influent\ Nitrate)^{(7.05E-02)} \times (Influent\ Phosfat)^{(9.156E-02)} \times (Aeration\ Tank\ Temperature)^{(-0.1663)} \times (Aeration\ Tank\ MLSS)^{(2.204E-02)}$	0.972	0.175
	$Output\ VSS = 8.719E - 02 \times (Influent\ Temperature)^{0.8596} \times (Influent\ pH)^{3.455} \times (Influent\ TSS)^{(-0.5374)} \times (Influent\ COD)^{0.1664} \times (Influent\ Nitrate)^{0.1025} \times (Influent\ Phosfat)^{(-6E-03)} \times (Aeration\ Tank\ Temperature)^{1.187} \times (Aeration\ Tank\ MLSS)^{0.4331}$	0.918	49.95
	$Output\ SCOD = 7.082E - 02 \times (Influent\ Temperature)^{-1.296} \times (Influent\ pH)^{2.893} \times (Influent\ TSS)^{(9.803E-02)} \times (Influent\ COD)^{(-6.9E-02)} \times (Influent\ Nitrate)^{-0.2754} \times (Influent\ Phosfat)^{0.169} \times (Aeration\ Tank\ Temperature)^{0.6942} \times (Aeration\ Tank\ MLSS)^{0.1861}$	0.86	0.413
Exponential	$Output\ COD = 0.1266 \times Exp(2.779E - 02 \times (Influent\ Temperature) + 0.4723 \times (Influent\ pH) - 2E - 04 \times (Influent\ TSS) + 1.25E - 03 \times (Influent\ COD) + 1.5E - 04 \times (Influent\ Nitrate) - 3.6E - 05 \times (Influent\ Phosfat) + 3.118E - 03 \times (Aeration\ Tank\ Temperature) + 5.68E - 05 \times (Aeration\ Tank\ MLSS))$	0.538	6.305
	$Output\ VSS = 1.859 \times Exp(-2.92E - 02 \times (Influent\ Temperature) + 0.7126 \times (Influent\ pH) - 4.1E - 03 \times (Influent\ TSS) + 1.21E - 03 \times (Influent\ COD) + 2.5E - 04 \times (Influent\ Nitrate) - 6.34E - 05 \times (Influent\ Phosfat) + 7.148E - 02 \times (Aeration\ Tank\ Temperature) + 2.749E - 04 \times (Aeration\ Tank\ MLSS))$	0.958	36.132
	$Output\ SCOD = 728.5 \times Exp(-0.1013 \times (Influent\ Temperature) - 0.171 \times (Influent\ pH) + 3.48E - 03 \times (Influent\ TSS) - 1.8E - 03 \times (Influent\ COD) - 1.2E - 03 \times (Influent\ Nitrate) + 7.54E - 04 \times (Influent\ Phosfat) + 5.497E - 03 \times (Aeration\ Tank\ Temperature) - 2.157E - 04 \times (Aeration\ Tank\ MLSS))$	0.842	0.668

age square error of 0.413 have had the best performance in predicting COD, VSS and SCOD parameters. Fig. 3 shows the comparison of the values of the best relationships extracted in this method, the results obtained from the ASM1 and actual values.

CONCLUSIONS

The most important results of this study are as follows:

- By making Monod equation linear using three different mathematical methods, the maximum growth rate and the constant of half speed were determined with a suitable accuracy. The results showed that there is a good correlation between biological kinetic coefficients in a lab environment with the same factors in operation.
- Parameters Y, kd, k0 and Ks in operation conditions in wastewater treatment of Ekbatan Tehran have indicated that these coefficients are in the standard range of authorities and thus the biological treatment of the plant is in suitable conditions.
- Estimating kinetic coefficients using ASM1 model were highly correlated with the results of Monod model and determine kinetic coefficients of operation of the plant. The results of the ASM1 model for kinetic coefficients were determined as Ks as 31.2 gCOD.m^{-3}, Hμ as 3.9 day^{-1}, b_H as 0.077 day^{-1} 077/0 and Y_H as 0.51 gCOD XH (gCOD $SS)^{-1}$ 51/0 which had a good correlation with the results of the kinetic coefficients using the equations of conventional activated sludge processes. Also, the root mean square of error between the results of plant and ASM1 model in a different operation month for the parameters COD, VSS and SCOD were respectively obtained as, 0.26, 102.2 and 1.07.
- The use of fuzzy regression analysis to predict the state of wastewater treatment in this study showed that by having information of treatment and pond aeration house, VSS, COD and SCOD values can be predicted with an acceptable precision. The percent of error of prediction of this method shows that its better function than ASM1 model.

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