Advances in Environmental Technology 4 (2018) 211-221

Advances in Environmental Technology

journal homepage: http://aet.irost.ir

Effect of operating parameters on the performance of wastewater treatment plant (Case study: The southern Tehran wastewater treatment)

Mina Rafati[a], Mohammad Pazouki[a *], Hossein Ghadamian[a], Azarmidokht Hosseinnia[a], Ali Jalilzadeh[b]

[a] *Materials and Energy Research Center, Karaj, Iran*

[b] *Arman Tadbir Palayesh Consulting Engineer Company, Tehran, Iran*

ARTICLE INFO

Article history:
Received 21 December 2018
Received in revised form
12 June 2019
Accepted 15 June 2019

Keywords:
Simulation
Activated Sludge Model No.1
Return Activated Sludge
Internal Recycle Flow
Dissolved Oxygen
Concentration

ABSTRACT

Despite the fact that there are wastewater treatment plants (WWTPs) currently operational across Iran and great advances have been made in this area, there are still problems in the design, construction and operation of WWTPs with large nonlinear systems, varying flow rates, and pollution charges. The objective of this study was to investigate the effect of operating parameters including the return activated sludge (RAS) ratio, internal recycle (IR) ratio and dissolved oxygen (DO) concentration in an activated sludge system for the Modules 5&6 of the Southern Tehran WWTP. This study designed and simulated a plant based on the activated sludge model No.1 (ASM1) to determine the factors affecting wastewater treatment systems; then, the kinetic parameters were measured. The kinetic parameters such as the yield coefficient (Y), decay coefficient (k_d), maximum specific growth rate (K), and saturation constant (Ks) were in the range of 0.303-0.331g/g, 0.030-0.033d^{-1}, 1.65-1.93d^{-1} and 37.6-44.92mg/l, respectively. The RAS ratios, IR ratios, and DO concentration varied from 0.2 to 2, 1 to 3.5, and 0.27 to 3.54 mg/l, respectively. The amount of the RAS had the greatest impact on the effluent. The amounts of IR and DO concentration had no significant effect on the concentration of the five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and total suspended solids (TSS) in the effluent. After the RAS, the amount of IR had the most direct effect on reducing the effluent total nitrogen (TN) concentration. As a result, the overall removal efficiency increased up to 75% when the IR rate was 200% of the influent flow rate, the RAS rate was 90% of the influent flow rate, and the DO concentration in the first aeration unit was 2 mg/l considering the aeration cost. Therefore, proper operating parameters can provide the best quality of effluent that meet environmental standards.

1. Introduction

Water shortages around the world have become more severe and more attention is being afforded to the reuse of wastewater from municipal and industrial plants; an activated sludge process [1] often treats their wastewaters aerobically. The activated sludge process is widely used in wastewater treatment, as it is reliable, efficient, and capable of producing high quality effluent; it is also comprised of a biological reactor along with a secondary clarifier [2]. This process is considered as a secondary wastewater treatment. The activated sludge processes have a high removal efficiency for ammonia, TSS, COD, and BOD_5 as well as producing quality effluents for the final disposal that are in accordance with the discharge standard [3]. The performance of the activated sludge process is influenced by the RAS, IR flow, and the amount of DO, so the principal purpose of this work is to evaluate the effect of these three operational parameters, in an activated sludge system for the modules 5 and 6 of the Southern Tehran Wastewater Treatment Plant. Therefore, the simulation of this wastewater treatment plant is based on the active sludge model number one (ASM1), introduced by the IWA International Water Association [4].

*Corresponding author. Tel: +98-26-36280040-7
E-mail address: mpazouki@merc.ac.ir
DOI: 10.22104/aet.2019.3010.1167

The type of the activated sludge process in this plant is the oxidation ditch. This process has been developed as an advanced process due to its advantages: less construction cost compared with the other processes, minimum mechanical equipment requirements, minimal attention to operate, relatively stable sludge production, and minimum odor production as an advanced process [5]. The carousel process, in accordance with the developmental model of the International Water Association, has been simulated in the Golbey-Epinal wastewater treatment plant in France, and the results have been used to design the control system and process optimization [6]. Three modified activated sludge processes have been used extensively in 60% of China's wastewater treatment plants, and 51% of their wastewater has been treated with this method [7]. In a previous study, the performance of three active sludge processes (Oxidation Ditch / A/O, A_2/O) in eight municipal wastewater treatment plants with the aim of removing organic pollutants and reducing pollutants were investigated. The efficiency of all three processes in removing major pollutants in the wastewater, including BOD_5, COD, TP, and TN, was high; the efficiency of the oxidation ditch process in removing toxic substances in wastewater, such as tyrosine and tryptophan, was higher than the other two processes [8]. An activated sludge system was used to treat the Amole's industrial park. The COD removal, SVI, and DO were determined, and the optimal values were obtained. It was observed that at an HRT of 16 h and sludge recycle ratio of 0.85, the COD removal and SVI were 95 and 85 %, respectively. Sludge recycle ratio greater than 0.85 had no significant effect on the COD removal [9].This research was conducted in order to enhance the efficiency of the plant by providing optimum RAS, IR, and DO concentration. Therefore, a good performance with maximum efficiency could be achieved.

2. Materials and methods

2.1. The southern Tehran wastewater treatment plant

The city of Tehran has a population of 12 million and is one of the most populous cities in the world. According to Tehran's demand for water for various uses, refined wastewater has been used in the irrigation of green spaces and to fill the groundwater, especially in areas where the level has decreased [10]. The Southern Tehran Wastewater Treatment Plant has an area of about 110 hectares and is located south of Shahre-e-Ray and between the Tehran-Varamin road and Tehran-Garmsar railway; it is located approximately 1035 meters above ocean level. The plant was designed for eight modules of wastewater treatment with a capacity of 4.2 million people. The initial design of this plant (1-4 modules) employed the completely mixed activated sludge process (CMAS). The second phase (5-6 modules) was designed by the oxidation ditch method. This method is ordinarily used for achieving biological nitrogen removal in the full-scale plant, but it currently employs the completely mixed activated sludge process (CMAS). The third phase (7-8 modules) will be constructed in the future. The average influent flow in the 5&6 modules is about 2700 l/s, and the maximum influence flow is about the 3600 l/s. The input wastewater after passing the screening and grit chamber units divided into the four primary sedimentation tanks in which each volume is 4784 cubic meters and has a diameter of 46 beats. Therefore, the wastewater enters into eight biological tanks. The volume of each reaction tank is 15560 cubic meters. The activated sludge reactor is followed by eight secondary settlers with a diameter of 54 meters. The volume of each settler is 8830 cubic meters. The effluent, after passing the disinfection units, will be transferred to the Varamin channels in order to irrigate the Varamin plain [11]. Figure 1 shows a view of the Southern Tehran WWTP.

Fig. 1. A view of the Southern Tehran Wastewater Treatment Plant

2.2. Analytical method

In this study, 80 liquid samples were taken from the influent, biological reactors, and effluent of the plant. Analyses were performed in the laboratory of the Southern Tehran WWTP. The BOD_5, COD, TN, DO, pH, alkalinity, temperature, TSS, MLSS, and MLVSS were measured daily in warm and cold seasons. These parameters were measured according to the methods described in sections 5210, 5220, 4500-N, 4500-O, 4500-H+, 2320, 2550, 2540D and 2540E in the standard method for the examination of water and wastewater [12]. A summary of the analysis method is shown in Table1.

Table 1. Summary of the analysis method

Parameter	Method of test	Device model
BOD_5	Respirometric BOD	Spectrophotometer AL800-Aqualitic /Germany
COD	Vario Tube Test Photometry	Spectrophotometer AL800-Aqualitic /Germany
TN	Vario Tube Test Photometry	Spectrophotometer AL800-Aqualitic /Germany
DO	Winkler Test-DO meter	DO Meter HQD Hach/USA
pH	pH meter	pH Meter AL p20 Aqualitic / Germany
Alkalinity	Titration	AL p20 Aqualitic / Germany
Temperature	Thermometer	AL p20 Aqualitic / Germany
TSS	Gravimetric	Oven- Fater Electronic Rizpardaz Co. /Iran ADAM Scale/England
MLSS	Gravimetric	Oven- Fater Electronic Rizpardaz Co. /Iran ADAM Scale/England
MLVSS	Gravimetric	Oven- Fater Electronic Rizpardaz Co. /Iran ADAM Scale/England

The inlet wastewater characteristics differed during the day operating period. However, the average parameters were measured for the evaluation of the plant's efficiency and for treating the wastewater. The average characteristics of the inlet wastewater are demonstrated in Table 2.

Table 2. Raw wastewater characteristics of the Southern Tehran WWTP

Variable	Unit	Value
Flow rate	m^3/d	125667
BOD_5	mg/l	185
COD	mg/l	355
TSS	mg/l	248
TN	mg/l	61

2.3. Modeling and simulating of the activated sludge process

Dynamic modeling has proven to be very useful in process design, operation, and optimization. A recent trend in WWTP modeling is to include the different subunits in the so-called plant-wide models rather than focusing on parts of the complete process [1,2]. The purpose of the simulation is to create a tool that analyzes the effects of the system changes on system performance, thereby optimizing the performance of existing systems. In this study, activated sludge model number 1 was programmed in the Simulink environment in Matlab software with regard to the environmental standards. The simulation method consisted of solving a series of equations at each step for each of the compounds in the wastewater. To simulate Modules 5&6 of the southern Tehran WWTP, the Activated Sludge Model no. 1 (ASM1) has been selected to describe the biological phenomena-taking place in the biological reactor, and the Generic model, which was presented by Takacs et al, has been selected to describe the dynamic sedimentation model in the secondary sedimentation tanks [13-15].

The following steps were performed for simulation:

1- The methodology of the work includes studying the concepts of process modeling, the types of activated sludge models and their comparison, model selection, and implementation of the model.
2- The determination of the kinetic and stoichiometric coefficients of the activated sludge model number one including 5 stoichiometric parameters and 14 kinetic parameters [16].
3- The determination of the general characteristics of the system, including the identification of the type of activated sludge process, the characteristics of the process units, and the capacity coefficients of the projection equipment.
4- The determination of the results of the existing wastewater treatment tests.
5- Computational transformation of input variables into the ASM1 model [17].
6- The calculation of mass balance equations.
7- The input of the ASM1 model data into the Simulink simulation environment in MATLAB software; these data include 8 biological processes and 13 process parameters.
8- Running the simulation program, model calibration, simulation program validation, and sensitivity analysis of the system.
9- Analyzing the simulation results.
A simplified scheme of the plant was entered in the software and is visible in Figure 2.

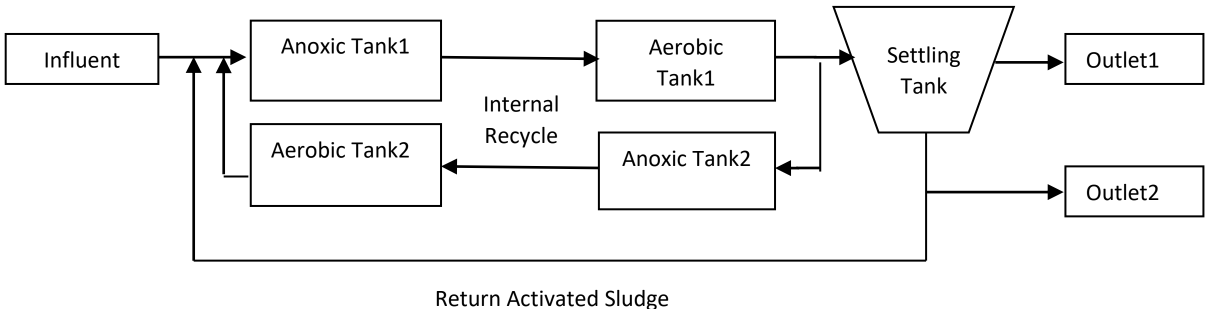

Fig. 2. Oxidation ditch block diagram in the Southern Tehran WWTP

2.4. Performance evaluation and bio kinetic coefficients determination of the oxidation-ditch process

In the past, the designs of biological wastewater treatment processes were based on the empirical parameters developed by experience, which included hydraulic loading, organic loading, and retention time. Nowadays, the design utilizes empirical as well as rational parameters based on biological kinetic equations. Theses equations describe the growth of biological solids, substrate utilization rates, food-to-microorganisms ratio, and the mean cell residence time. The reactor volume, substrate utilization, biomass growth, and the effluent quality can be calculated from those equations. The biokinetic coefficients used in the design of activated sludge processes include specific growth rate (μ), maximum rate of substrate utilization per unit mass of microorganisms (k), half velocity constant (Ks), maximum cell yield (Y), and endogenous decay coefficient (kd). In the different wastewater treatment processes, several investigators have evaluated biokinetic coefficients [22-27]. The main objective of this section was the evaluation of the performance and determination of kinetic parameters for activated sludge processes [18]. The performance of the activated sludge system was evaluated by the following process parameters [19]:

$$\text{Removal efficiency}(\%) = \frac{100(S0 - Se)}{S0} \quad (1)$$

The S_0 is the initial substrate (mg/l) in an aeration tank and Se is the final substrate (mg/l). The specific substrate utilization rate (mg COD/mg.d) is expressed in the following equation [20-21].

$$U = \frac{(S_0 - S_e)}{X \times \theta_H} \quad (2)$$

Where the variable Θ_H stands for the sludge residence time (d) and X is the mixed liquor volatile suspended solids (MLVSS, mg/l). In order to fit the data with the linear equation, the double reciprocal form of the specific growth is written by the following equation.

$$\frac{1}{U} = \frac{K_s}{KS_e} + \frac{1}{K} \quad (3)$$

Where the S_e is the effluent concentration of the pollutant (mg/l), Ks is the saturation constant for COD removal (mg/l), and K is the maximum specific rate constant for COD removal (d^{-1}). The sludge retention time is expressed as a function of the process yield, as shown in Equation 4.

$$\frac{1}{SRT} = YU - K_d = \frac{Y(S_0 - S)}{\theta X} - K_d \quad (4)$$

Where Y is the maximum growth yield coefficient (mgVSS /mg sCOD) and K_d is the decay rate constant (d^{-1}).

2.5. Control Factors Overview

The proper operation of an activated sludge plant will require knowledge of biological and physical factors that influence the efficiency of the process. In this study, we investigated three factors: dissolved oxygen (DO) concentration in the aeration tank, return activated sludge (RAS) ratio, and internal recycle (IR) ratio. Note: Where Q_f is the feed flow rate, Q_{RAS} is the return activated sludge flow, Q_{IR} is the internal recycle flow, and the DO is dissolved oxygen concentration in an activated sludge system, RAS ratio= (Q_{RAS}/Q_f) and IR ratio= (Q_{IR}/Q_f). In this research, the sludge return ratios, internal recycle ratios, and the DO varied from 0.2 to 2, 1 to 3.5, and 0.27 to 3.54 mg/l, respectively. By applying these changes, we could determine which of the parameters change the process results, or whether the change in the parameters had an indirect, reverse, major, or minor effect on the effluent. It was also possible to determine the quality of the wastewater, according to the expected quality and its compliance with environmental standards. In the following section, these results are described in detail.

3. Results and discussions

The activated sludge process is a biological process that can be used for removing the organic pollutants from wastewater treatment plants. The wastewater used in this research was obtained from the plant's inlet wastewater.

The kinetic parameters for the activated sludge process as well as the RAS ratio, IR ratio and DO concentration were obtained. The COD, BOD_5, TSS and TN were tested for the designed experimental aeration basin. A linear model was fitted to the experimental data obtained by the activated sludge system implemented for the Tehran WWTP (Figure 3). The double reciprocal plot for the specific growth and organic pollutants were perfectly fitted according to the expression stated in Eq. (3). The rate constant and the Monod constant were found from the slope and the intercept of the best-fitted line. Similarly, the experimental data obtained with the variable SRT were plotted in the form of 1/θc versus U according to Eq. (4), and the following constants were determined from the slope and the intercept of the best-fitted line (Figure 3). The results showed that the yield coefficient (Y), decay coefficient (k_d), maximum specific growth rate, and saturation constant (Ks) for the oxidation-ditch activated sludge process were in the range of 0.303-0.331mgVSS /mg sCOD, 0.030-0.033 1/day, 1.65-1.93 1/day and 37.6-44.92 mg sCOD/l, respectively. The results also showed a mean of COD, BOD_5, TSS and TN removal was obtained at 94.8 ± 0.4, 97.3 ± 0.65, 94.7 ± 1.5 and 56 ± 7.46, respectively.

Other researches were determined kinetic parameters of the Monod model on the wastewater of Iran and a summary of the results are shown in Table 3.

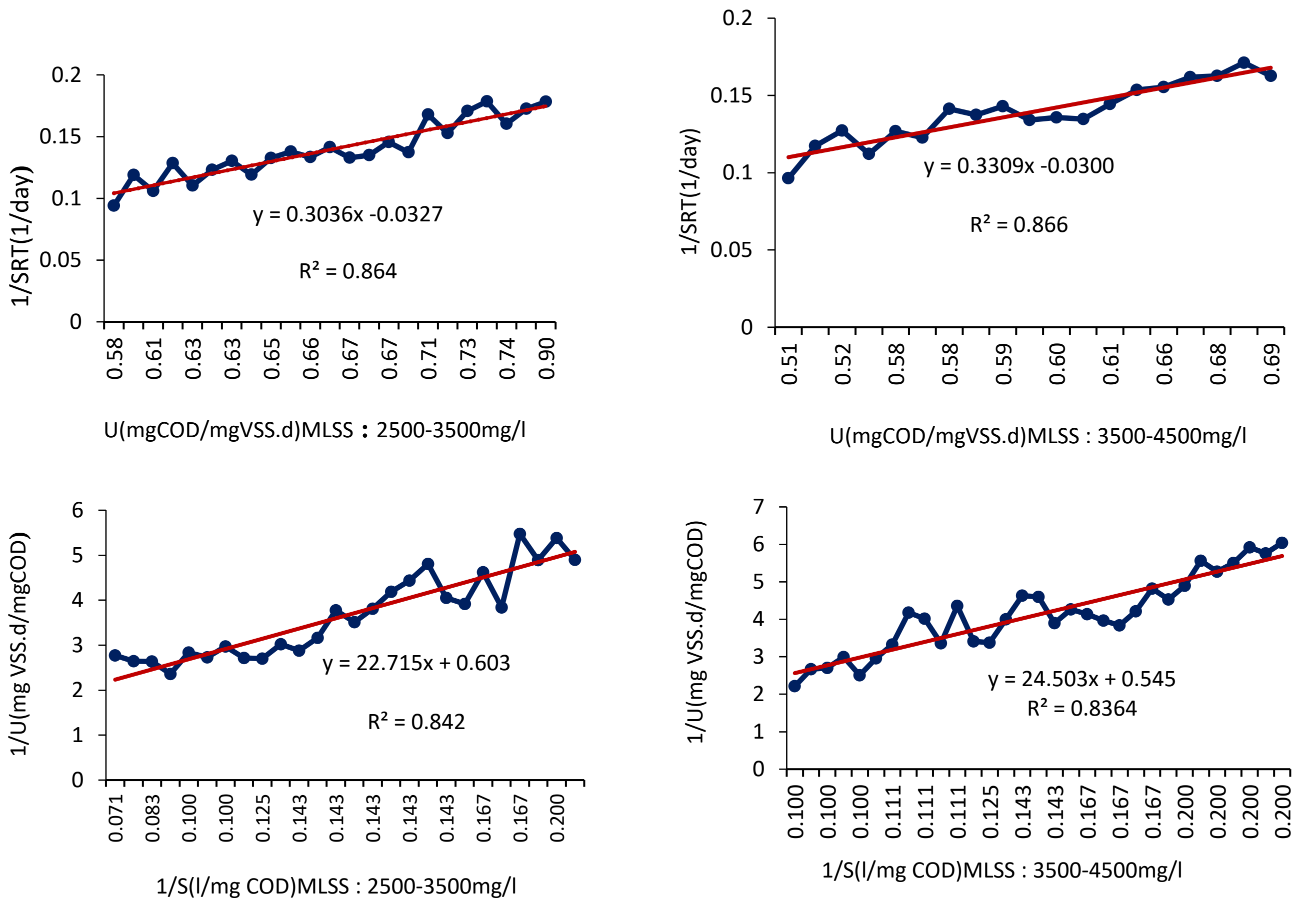

Fig. 3. Fitting the Monod model to the experimental data at different values of MLSS

Table 3. Summary of kinetic parameters of Monod model

Research	K_S (mg/l)	K (1/day)	K_d (1/day)	Y (mg/mg)
A: [22]	55.7	3.57	0.3	0.69
B: [23]	65.5	2.77	0.5	0.67
C: [18]	52-71.1	0.95-0.98	0.019-0.026	0.49-0.8
D: [1]	85.5	-	0.06	0.52
E: [24]	4.25	2.5	0.027	0.013
F: [25]	179-251	0.72-1.09	0.002-0.015	0.14-0.49
G: [26]	33.75	3.9	0.077	0.51
H: [27]	305.25	3.34	0.126	0.657

The standard values for effluent pollutant concentrations permitted by the Environmental Protection Agency [28] for compounds such as BOD_5, COD, TSS, NO_3^-, NH_4-N, and TN are as follows and are the maximum allowable value for entry of the effluent in the surface waters. In order to achieve acceptable effluent quality while consuming the lowest amount of energy, the operation of the wastewater treatment plant should be such that the quality of the effluent is within the limits of the environmental standards.

BOD_5e = 30 mg/l

CODe = 60 mg/l

TSS= 40 mg/l
TKN=15.5 mg/l as N
NO_3^- = 50 mg/l as NO_3
NO_2^{-} = 10 mg/l as NO_3
NH_4-N = 2.5mg/l as NO_3

3.1. The effect of increasing of the return activated sludge (RAS) ratio on BOD₅, COD, TSS and TN removal

Return activated sludge (RAS) refers to the biological solids (mixed liquor solids) that settle in the secondary clarifier and are continuously returned back to the aeration tank. Return activated sludge brings active, hungry microorganism back into the aeration tank where they can again feed on incoming wastes. The Mahram Asia plant was designed according to the domestic wastewater source, and the effect of increasing of MLSS concentration on the removal of COD concentration was evaluated. The results found that a larger quantity of sludge was required to remove the pollutants in the wastewater. However, an excessive increase of sludge led to a decrease in the efficiency of the process. This decrease was attributed to the rise of the ratio of TSS and Nocardia foam in the effluent. Therefore, it was shown that the best removal for a COD concentration of 95% was at 3500 mg/l MLSS, and the returning quantity was about 75%. Also, considerable quantities of phosphorus could be removed by increasing the MLSS concentration [29]. The effect of the sludge recycle ratio in an activated sludge system for the treatment of the Amol industrial park wastewater was investigated. The results showed that as the recycle ratio increased gradually, the percentage of the COD removal increased; at the recycle ratio of 0.75, the DO was 3 mg/l, which was suitable for the activated sludge process [30].

In this section, the changes in effluent quality due to the changes in the amount of return activated sludge (RAS) ratio from the secondary sedimentation unit for the first anoxic unit varied from 0.2 to 2; the obtained results are shown in Figure 4.

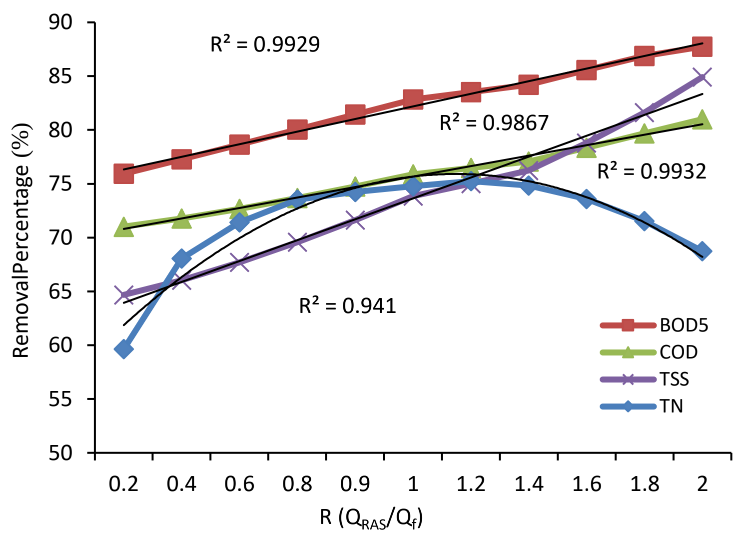

Fig. 4. The effect of the RAS ratio on BOD_5, COD, TSS and TN removal

Figure 4 shows that the BOD_5, COD, TSS and TN removal was based on the RAS ratio. As the return activated sludge ratio increased gradually, the percentage of the BOD_5, COD, TSS and TN removal increased. As a result, the nitrogen removal efficiency decreased when the return activated sludge ratio was up to 100% of the influent flow rate; so, an RAS rate equal to 90-100% was recommended.

3.2. The effect of increasing of internal recycle (IR) ratio on BOD₅, COD, TSS and TN removal

The internal recycle rate is one of the most important operational factors that affect the overall removal efficiency in the wastewater treatment plant (WWTP). The effect of the internal recycle on the nitrogen removal efficiency of an anaerobic/anoxic/oxic (A2/O) wastewater treatment plant was evaluated in a pilot plant, and the experimental results obtained show how increasing the internal recycle ratio from 0 to 5 produced a 12% increase in nitrogen removal. In order to obtain high removal efficiencies, high recycle ratios should be maintained, although this implies a higher economic cost. A general recommendation would be to maintain a mean recycle ratio of 2 under normal conditions. This ratio should be decreased, but not totally eliminated, in the case of lower load conditions (for example using a ratio of 1). Finally, when higher loads of nitrogen are detected, a higher ratio should be used in order to meet regulations [31]. In an article, the effect of the internal recycle ratio of nitrogen and phosphorus removal characteristics in a lab-scaled anaerobic/anoxic/oxic-biological aerated filter (A2/O-BAF) combined system was investigated during the treatment of real domestic wastewater with the temperature at 15 degrees C, the C/N ratio of 4.9, and internal recycle ratio of

100%, 200%, 300% and 400%. The experimental results clearly showed that the COD, N, and P could be simultaneously deeply removed from this combined system. In addition, there was no distinct relationship between the internal recycle ratio and the removal efficiencies of COD, TP and ammonia nitrogen. However, the removal efficiencies of TN increased with the increasing of the internal recycle ratio, the rising rate was descending [32]. Also, in another study, an anaerobic/aerobic system combining an anaerobic up flow-sludge bed filter (UBF) and an aerobic membrane bioreactor (MBR) was operated to enhance organic and nitrogen removal efficiency. The internal recycle rate was varied from 100% to 300% of the influent flow. Under these conditions, the overall removal efficiencies of organic matter and nitrogen were studied. As a result, nitrogen removal efficiency was increased to 67% when the internal recycle rate was 300% of the influent flow rate [33]. In another study, a combined up flow anaerobic sludge bed (UASB) -activated sludge (AS) reactor system was undertaken to explore the effect of the recycle-to-influent ratio (R (e) =1, 2, and 3) on the activities of nitrifies and denitrifies. At the R (e) of 1-3, the combined reactor system achieved an efficient removal of COD (96-97%), TKN (100%), and total nitrogen TN (54-77%). A higher R(e) resulted in a larger amount of high-activity denitrifies and, thereby, achieved a higher TN removal efficiency [34]. In this section, the changes in effluent quality due to changes in the amount of internal recycle (IR) ratio from the first aeration unit to the second anoxic unit varied from 1 to 3.5, and the simulation results are presented in Figure 5.

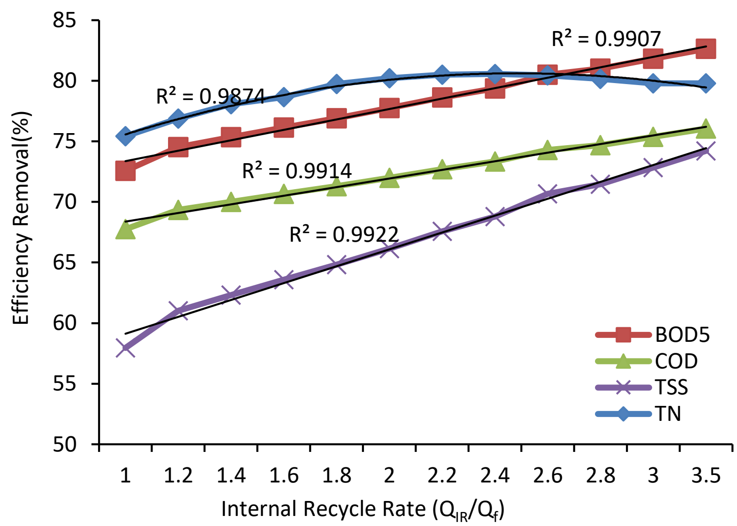

Fig. 5. The effect of the IR rate on BOD_5, COD, TSS and TN removal

Figure 5 shows that the BOD_5, COD, TSS and TN removal was based on the IR ratio. As the internal recycle (IR) ratio increased gradually, the percentage of the BOD_5, COD, TSS and TN removal increased. As a result, the overall removal efficiency increased up to 75% when the internal recycle rate was 300% of influent flow rate; therefore, an IR rate equal to 200-300% was recommended considering the pumping cost.

3.3. The effect of increasing of dissolved oxygen (DO) concentration on BOD_5, COD, TSS and TN removal

The concentration of dissolved oxygen in the aeration tank(s) of an activated sludge system is one of the most important process control parameters. It has a great effect on the treatment efficiency, operating cost, and system stability. As the DO drops, the quantity of these filamentous microorganisms increases, adversely affecting the settle-ability of the activated sludge. If dissolved oxygen is 5.0 or higher, then there could be problems in the settling of sludge due to shearing of the flocs and re-suspension of inert materials. A high DO concentration also makes the denitrification less efficient. Both of the above-mentioned factors will lead to a waste of energy. On the other hand, a low DO level cannot supply enough oxygen to the microorganisms in the sludge, so the efficiency of organic matter degradation is reduced. Therefore, the concentration of DO must be maintained within a reasonable range [35].

In an article, the effect of dissolved oxygen concentration on photosynthetic bacteria (PSB) wastewater treatment was investigated. This study set different DO levels and detected the pollutant removal. The results showed that DO significantly influenced the performances of the PSB wastewater treatment process. The highest COD (93%) and NH3-N removal (83%) was achieved under a DO of 4–8mg/l, but a DO of 2–4mg/l was recommended considering the aeration cost [36]. In this section, the concentration of dissolved oxygen (DO) in the first aeration unit was increased from 0.27 to 3.54mg/l. The efficient removal of the BOD_5, COD, TSS and TN with respect to the DO concentration and the relationship between the DO concentration and NH_4, NO_3 and TN concentration are shown in Figures 6 and 7. The other conditions such as the RAS ratio and IR ratio are 0.9 and 2, respectively. The efficient removal of BOD_5, COD, TSS and TN is higher than 70%. So in this condition, the DO concentration in the aeration unit had no significant effect on the BOD_5, COD, TSS and TN removal; but while the DO concentration increased, the NH_4 concentration decreased, and the NO_3 concentration increased until it stabilized to a DO equal to 3mg/l. Therefore, DO concentration of 2–3mg/l is more suitable considering the aeration cost.

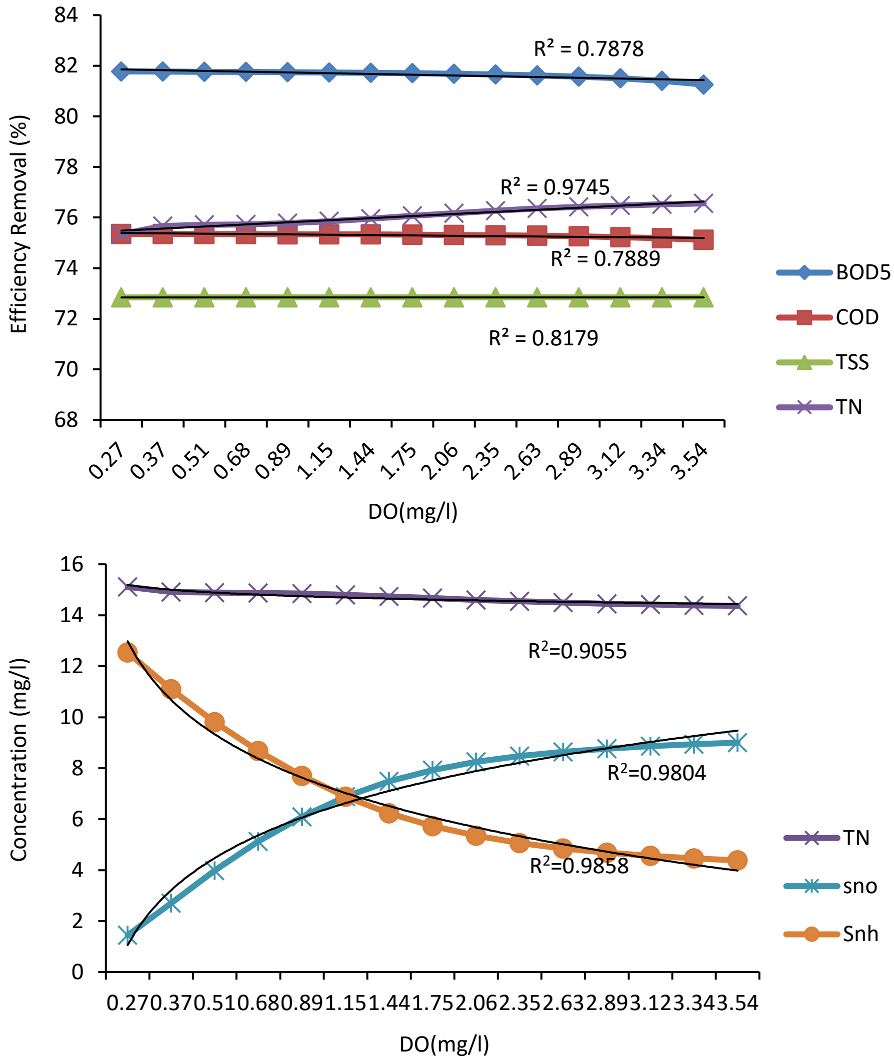

Fig. 7. The effect of the DO concentration on NO_3, NH_4&TN concentration

3.4. Investigating the effective level of process control parameters

After drawing the diagrams regarding the quality change of the effluent based on the changes in every process control parameter and considering the graph-related equations obtained, the effectiveness of each parameter on the effluent quality has been investigated and presented in Table 4.

In Table 4, the TSS, COD, and BOD_5 changes' gradient and total amount of the output nitrogen in the effluent compared to the RAS are higher than the effluent qualitative changes' gradient compared to the IR and the aeration level. And, the effluent's qualitative changes gradient compared to the dissolved oxygen level is almost equal to zero.

Table 4. The effluent quality variation equations in RAS, IR & DO

The effluent quality variation equation in RAS	The effluent quality variation equation in IR	The effluent quality variation equation in DO
F (RAS, BOD_5) = 1.17RAS+ 75.16	F (IR, BOD_5) = 0.86RAS+ 72.5	F (DO, BOD_5) = -0.13DO+ 27.4
F (RAS, COD) = 0.97RAS+ 69.83	F (IR, COD) = 0.71RAS+ 67.66	F (DO, COD) = -0.12DO+ 71.5
F (RAS, TSS) = 1.94RAS+ 61.99	F (IR, TSS) = 1.39RAS+ 57.73	F (DO, TSS) = 7E-05DO+ 40.5
F (RAS, TN) = 0.42(RAS)^2+5.74RAS+ 56.54	F (IR, TN) = 0.09(RAS)^2+1.54RAS+ 74.12	F (DO, TN) = 0.06DO+ 15.1
Slope of the effluent quality variation equation in RAS	Slope of the effluent quality variation equation in IR	Slope of the effluent quality variation equation in DO
m_{BOD5} =1.17	m_{BOD5} =0.86	m_{BOD5} =-0.13
m_{COD} = 0.97	m_{COD} =0.71	m_{COD} =-0.12
m_{TSS} = 1.94	m_{TSS} =1.36	m_{TSS} =7E-05
m_{TN} = 0.84RAS+5.74	m_{TN} =0.18IR+1.54	m_{TN} =0.06

4. Conclusions

The changes made in the quantity and quality of wastewater are one of the many problems in the operation of wastewater treatment plants; the qualitative and quantitative change of input waste water changes the loading and types of the materials in the aeration tanks and the user cannot easily control these changes. Therefore, the use of a simulation helps the operator to predict the optimum conditions for the organic matter and the nutrient removal. The effect of RAS, IR and DO concentration were studied as parameters that affected the removal efficiency of the COD, BOD_5, TSS and TN value in an aerobic activated sludge system. The changes in effluent quality due to changes in the amount of the return activated sludge (RAS) ratio from the secondary sedimentation unit for the first anoxic unit varied from 0.2 to 2; a RAS of 90% provided the best quality of effluent. Also, where the return activated sludge ratio increased gradually, the percentage of the BOD_5, COD, TSS and TN removal increased. The changes in effluent quality due to changes in the amount of the internal recycle (IR) ratio from the first aeration unit to the second anoxic unit varied from 1 to 3.5, and at an IR of 200%, the best quality of effluent was obtained. In addition, where the internal recycle (IR) ratio increased gradually, the percentage of the BOD_5, COD, TSS and TN removal increased. The changes in effluent quality due to changes in the amount of concentration of dissolved oxygen (DO) in the first aeration unit in the range of 0.25-3.5 mg/l were investigated, and the simulation results showed that the DO concentration in the aeration unit had no significant effect on the BOD5, COD, TSS and TN removal. DO concentration depletion may cause a problem during the increase of the sludge recycling. However, at the recycle ratio of 0.90, the DO was 2 mg/l, which was suitable for the activated sludge process. Based on the results obtained from the designed simulator, it could be found that excess levels of RAS had the highest effect on the concentration of the qualitative parameters of the effluent; the IR levels, as well as the aeration level, did not have a considerable effect on the TSS, COD, and BOD_5 concentrations of the outlet effluent. After the return activated sludge, the IR had the highest direct effect in the reduction of TN concentration in the outlet effluent.

Abbreviation

Feed flow rate	Q_f (m^3/d)
Return activated sludge flow	Q_{RAS} (m^3/d)
Return activated sludge ratio	RAS
Internal recycle flow	Q_{IR} (m^3/d)
Internal recycle ratio	IR
Dissolved oxygen concentration	DO
Removal efficiency	R (%)
Initial substrate concentration	S_i (mg/l)
Final substrate concentration	S_e (mg/l)
Volume reactor	V (m^3)
Specific substrate utilization rate	U (mg COD/mg.d)
Mixed liquor volatile suspended solids	X (mg/l)
Sludge residence time (SRT)	Θ_H (d)
Maximum growth yield coefficient	Y (g/g)
Decay rate constant	K_d (d^{-1})
Maximum specific rate constant	K (d^{-1})
Saturation constant	K_S (mg/l)
Active sludge model number one	ASM1
Biochemical oxygen demand	BOD_5 (mg/l)
Chemical oxygen demand	COD (mg/l)
Total suspended solids	TSS (mg/l)
Total nitrogen	TN (mg/l)
Sludge Volume Index	SVI (ml/g)

Acknowledgements

We sincerely appreciate the Materials and Energy Research Center in Karaj and the Tehran Sewage Company for their cooperation and participation in this project.

References

[1] Najafpour, G., Sadeghpour, M., Lorestani, Z. A. (2007). Determination of kinetic parameters in activated sludge process for domestic wastewater treatment plant. *Chemical industry and chemical engineering quarterly/CICEQ*, *13*(4), 211-215.

[2] Ekama, G. A., Sötemann, S. W., Wentzel, M. C. (2007). Biodegradability of activated sludge organics under anaerobic conditions. *Water research*, *41*(1), 244-252.

[3] Emamjomeh, M. M., Tari, K., Jamali, H. A., Karyab, H., Hosseinkhani, M. (2017). Quality assessment of wastewater treatment plant effluents for discharge into the environment and reuse. *Journal of Mazandaran university of medical sciences*, *26*(145), 283-292.

[4] Henze, M., Gujer, W., Mino, T., van Loosdrecht, M. C. (2000). *Activated sludge models ASM1, ASM2, ASM2d and ASM3*. IWA publishing.

[5] Mirbagheri, S., Saberi, S., Kalhor, K., Vakilian, R. (2014). Efficiency assessment of conventional and innovative wastewater treatment methods – case study: ekbatan wastewater treatment plant. The 7th Conference and Exhibition on Environmental Engineering (p. Verbally). Tehran: University of Tehran.

[6] Pons, M. N., Mourot, G., Ragot, J. (2011). Modeling and simulation of a carrousel for long-term operation. *IFAC Proceedings Volumes*, *44*(1), 3806-3811.

[7] Zhang, Q. H., Yang, W. N., Ngo, H. H., Guo, W. S., Jin, P. K., Dzakpasu, M., Ao, D. (2016). Current status of urban wastewater treatment plants in China. *Environment international*, *92*, 11-22

[8] Han, X., Zuo, Y. T., Hu, Y., Zhang, J., Zhou, M. X., Chen, M., Liu, A. L. (2018). Investigating the performance of three modified activated sludge processes treating municipal wastewater in organic pollutants removal and toxicity reduction. *Ecotoxicology and environmental safety*, *148*, 729-737.

[9] Hosseini, B., Darzi, N. G., Sadeghpour, M., Asadi, M. (2008). The effect of the sludge recycle ratio in an activated sludge system for the treatment of Amol's industrial park wastewater. *Chemical industry and chemical engineering quarterly/CICEQ*, 96 *14*(3), 173-180.

[10] Noori, Z. (2018). Investigation of effluent quality of ekbatan wastewater treatment plant for farm and green space irrigation. *Journal of land management* 6(1) 95-102.

[11] Sewage Company, (2019). https://ts.tpww.ir/p18. Retrieved from https://ts.tpww.ir.

[12] APHA. (2005). Standard methods for the examination of water wastewater, Volume 21. Washington, DC: American public health association.

[13] Takács, I., Patry, G. G., Nolasco, D. (1991). A dynamic model of the clarification-thickening process. *Water research*, *25*(10), 1263-1271.

[14] Derakhshan, Z., Mahvi, A. H., Ghaneian, M. T., Mazloomi, S. M., Faramarzian, M., Dehghani, M., Bahrami, S. (2018). Simultaneous removal of atrazine and organic matter from wastewater using anaerobic moving bed biofilm reactor: A performance analysis. *Journal of environmental management*, *209*, 515-524.

[15] Faridnasr, M., Ghanbari, B., Sassani, A. (2016). Optimization of the moving-bed biofilm sequencing batch reactor (MBSBR) to control aeration time by kinetic computational modeling: simulated sugar-industry wastewater treatment. *Bioresource technology*, *208*, 149-160.

[16] Du, X. J., Hao, X. H., Li, H. J., Ma, Y. W. (2011). Study on modelling and simulation of wastewater biochemical treatment activated sludge process. *Asian journal of chemistry*, *23*(10), 4457.

[17] Alex, J., Benedetti, L., Copp, J., Gernaey, K. V., Jeppsson, U., Nopens, I., Vanrolleghem, P. (2008). Benchmark simulation model no. 1 (BSM1). *Report by the IWA Taskgroup on benchmarking of control strategies for WWTPs*, 19-20.

[18] Mardani, S., Mirbagheri, A., Amin, M., Ghasemian, M. (2011). Determination of biokinetic coefficients for activated sludge processes on municipal wastewater. *Journal of environmental health Science Engineering*, *8*(1), 25-34.

[19] Metcalf, L., Eddy, H. (2003). Wastewater engineering: treatment, disposal, and reuse. New York: McGraw-Hill.

[20] Abyar, H., Younesi, H., Bahramifar, N., Zinatizadeh, A. A., Amini, M. (2017). Kinetic evaluation and process analysis of COD and nitrogen removal in UAASB bioreactor. *Journal of the Taiwan institute of chemical engineers*, *78*, 272-281.

[21] Noroozi, A., Farhadian, M., Solaimanynazar, A. (2016). Kinetic coefficients for the domestic wastewater treatment using hybrid activated sludge process. *Desalination and water treatment*, *57*(10), 4439-4446.

[22] Kordkandi, S. A., Khoshfetrat, A. B., Faramarzi, A. (2018). Performance modelling of a partially-aerated submerged fixed-film bioreactor: Mechanistic analysis versus semi data-driven method. *Journal of industrial and engineering chemistry*, *61*, 398-406.

[23] Naghizadeh, A., Mahvi, A. H., Mesdaghinia, A. R., Sarkhosh, M. (2008, October). Bio-kinetic paramters in municipal wastewater treatment with a submerged membrane Reactor (SMBR). In p*roceeding of 12th national congress of environmental health*.

[24] Mohammadi, P., Khashij, M., Takhtshahi, A., Mousavi, S. A. (2016). Performance Evaluation and Biokinetic Coefficients Determination of Activated Sludge Process of Sanandaj Wastewater Treatment Plant. *Safety promotion and injury prevention*, *4*(2), 109-116.

[25] Sadeghi, M., Fadaei, A., Kheiri, S., Najafi-Chaleshtori, A., Shakeri, K. (2014). Investigation on bio kinetic coefficients for making biological treatment of wastewater treatment plants in cold region. *Journal of Shahrekord uuniversity of medical sciences*, *15*. 41-52

[26] Delnavaz, M. (2017). Application of mathematical models for determination of microorganisms growth rate Kinetic coefficients for wastewater treatment plant evaluation. *Journal of environmental health engineering*, *4*(3), 268-257.

[27] Noshadi, M., Ahadi, A. (2017). Determination of Kinetic coefficient of Shiraz municipal of wastewater treatment plant by batch reactor. *Journal of civil and environmental engineering*, *47*, 63-73.

[28] "Environmental criteria for Reuse of recycle waters and treated wastewaters" (2011) related to participation "Iran Water Resources Management Company" (IWRMC) and" Country Management and Planning Organization" (CMAPO). Publication No. 535, Chapter 6, 85-110 (in Farsi).

[29] Basim, K., Ahmed, M. (2018). The Effect of MLSS values on removal of COD and phosphorus using control method of return activated sludge concentration. *Journal of engineering and applied sciences, 13*(22), 9730-9734.

[30] Hosseini, B., Darzi, N. G., Sadeghpour, M., Asadi, M. (2008). The effect of the sludge recycle ratio in an activated sludge system for the treatment of Amol's industrial park wastewater. *Chemical industry and chemical engineering quarterly/CICEQ*, *14*(3), 173-180.

[31] Baeza, J. A., Gabriel, D., Lafuente, J. (2004). Effect of internal recycle on the nitrogen removal efficiency of an anaerobic/anoxic/oxic (A_2/O) wastewater treatment plant (WWTP) *Process biochemistry*, *39*(11), 1615-1624.

[32] Chen, Y. Z., Peng, Y. Z., Wang, J. H., Zhang, L. C. (2011). Effect of internal recycle ratio on nitrogen and phosphorus removal characteristics in A_2/O-BAF process. *Huan jing ke xue= Huanjing kexue*, *32*(1), 193-198.

[33] Ahn, Y. T., Kang, S. T., Chae, S. R., Lim, J. L., Lee, S. H., Shin, H. S. (2005). Effect of internal recycle rate on the high-strength nitrogen wastewater treatment in the combined UBF/MBR system. *Water science and technology*, *51*(10), 241-247.

[34] Huang, J. S., Chou, H. H., Chen, C. M., Chiang, C. M. (2007). Effect of recycle-to-influent ratio on activities of nitrifiers and denitrifiers in a combined UASB–activated sludge reactor system. *Chemosphere*, *68*(2), 382-388.

[35] Du, X., Wang, J., Jegatheesan, V., Shi, G. (2018). Dissolved oxygen control in activated sludge process using a neural network-based adaptive pid algorithm. *Applied sciences*, *8*(2), 261.

[36] Meng, F., Yang, A., Zhang, G., Wang, H. (2017). Effects of dissolved oxygen concentration on photosynthetic bacteria wastewater treatment: Pollutants removal, cell growth and pigments production. *Bioresource technology*, *241*, 993-997.