

# Modeling and kinetic evaluation of intermittent aeration bioreactor with continuous flow in hospital wastewater treatment

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## ABSTRACT

Modeling is powerful tool for optimization, design, operation and economic saving of biological treatment processes, too. The aim of this research is determination of model and kinetic of intermittent aeration bioreactor with continuous flow in hospital wastewater treatment. A 4-liter ICEAS bioreactor makes up for COD, BOD<sub>5</sub> and TSS parameters removal from hospital wastewater. The experiments were conducted based on central composite design (CCD). Used three variables of aeration time (2-4hr), mixing time (without aeration) (30-90 min) and MLSS concentration (2000-6000 mg/l) in 3 level and in 20 run in steady stable conditions. TSS, BOD<sub>5</sub> and COD removal efficiency maximum were obtained 98.6%, 96% and 95% respectively, in the aeration time 4 hr, mixing time (without aeration) 90 min and MLSS 6000 mg/l. Monod kinetic coefficients, K, K<sub>d</sub>, K<sub>s</sub>, Y and  $\mu_{max}$  were obtained 0.48-0.59 gbsCOD/gVSS.d, 0.06-0.09 d<sup>-1</sup>, 9.75-19.23 mg/LbsCOD, 0.44-0.72 mgVSS/mgBOD and 0.135-0.172 d<sup>-1</sup>, respectively. K<sub>1</sub>, K<sub>2</sub>, K<sub>B</sub> and U<sub>max</sub> were obtained 20.2-238.2, 1.13-1.49, 0.021-0.29 and 0.027-0.23, respectively. Basic models of first-order and Stover-Kin canon fitted with experimental data, well. By change of MLSS concentration can was changed reaction order to second-order.

**KEYWORDS:** Hospital wastewater, intermittent aeration, continuous flow, Kinetic, model.

## 1. INTRODUCTION

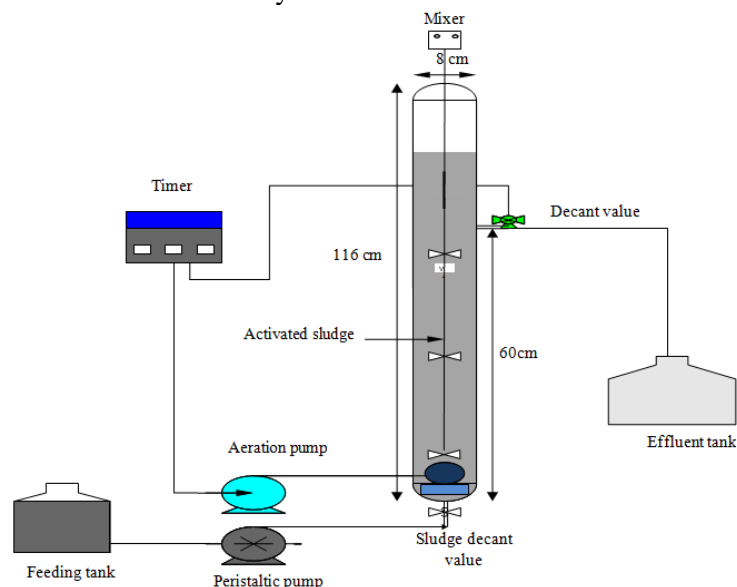
Hospital wastewater is one of the major pollution sources that containing of different type of toxic materials such as organic materials, pharmaceuticals residues and drugs metabolite, disinfectants, pathogenic microorganisms, solvents and radioactive elements (Davoodi, 2016; Almasi, 2014; Sorensen, 1998; Rodriguez, 2004). These materials aren't biodegradable if releases in environment without treatment. Discharge of these materials in environment especially in surface waters can have harmful impacts on environment and public health even at low concentrations (Chitnis, 2000; Chitnisa, 2004). Therefore, must be prevent from enter of untreated hospital wastewater in natural environment and discharge in receptive water that it's been caused to pollution and disease prevalence in healthy humans (Jolibois, 2006). On the basis of the above consideration, in this study, in order to wastewater treatment, an intermittent cycle extended aeration system (ICEAS) with mixing (without aeration), aeration, settle and decant stages was applied. ICEAS is a modified SBR system that is inclusive of three phases: react, settle, and decant (Crites, 1998). In this biological system, raw wastewater enters in all of treatment stages continuously; inflows not interrupts even during settle and decant stages and decant carry out intermittently (Mahvi, 2004; Metcalf, 2003). In noted reactor, hydraulic and organic loading is equal in all of phases. By time change any phase individually, change system performance, simply. The main advantages of ICEAS including flexibility with flow characteristic change, achieve of treatment aims in lower HRT (Hydraulic Retention Time) than conventional treatment and control over microbial population (BanaeiGhahfarokhi, 2010; Chang, 1999). In despite of relative similarity hospital wastewater to municipal wastewater, performance of biological treatment processes in those is different, properly.

Up to now, few studies have been carried out on ICEAS performance in hospital wastewater treatment; and carried out any study on kinetic coefficients of noted wastewater, approximately. Banaei (2010) was applied above system for hospital wastewater treatment and showed stabilized sludge volume and limiting the growth of filamentous bacteria in this system is low. Too, the results obtained from study indicated COD, BOD<sub>5</sub> removal efficiency were 92.97% and 95.54% respectively; influent average concentration COD 481.45 mg/l and BOD 275.2 mg/l (Banaei Ghahfarokhi, 2010).

Modeling is powerful tool for optimization, design, operation and economic saving of biological treatment processes (Miyata, 2004). Mathematical modeling results in survey of different design idea without give away of high time and money. Of course, is important that model fit with treatment process, properly. It results from the above; modeling is effective method for investigation of treatment process in pilot plant scale before use in full scale (Liu, 2009; Yetilmezsoy, 2010). Central in modeling is the use of kinetic coefficients. Kinetic coefficients vary in studies dependent on type of wastewater and different conditions operation. In the present study, the performance of ICEAS bioreactor in organic materials removing and too, Monod, Stover-Kin cannon, First-order and Second-order models were studied.

## 2. MATERIALS AND METHODS

**Experimental setup:** The schematic diagram of the ICEAS bioreactor is shown in Fig.1. Experiments were carried out in a Plexiglas cylinder column with total height, 116 cm; internal radial, 4cm and working volume, 4 L that discharge 1 liter in the end of each run by decant value in 60cm height. Raw wastewater in feeding tank, 10 L, introduced from the bottom of the reactor by a peristaltic pump, continuously. In order to provide sufficient air for microorganisms, was used an aeration pump with 80 watt power and 0.3 mega Pascal pressure, and 4 number diffusers that placed at the bottom of the reactor. In order to prevent from sludge settlement in without aeration phase, two number mixers (bottom of reactor and 50 cm heights) putted to use. It is to be noted that time of any phase and inflow level was set by an automatic time control system.



**Figure.1. Experimental setup.**

**Hospital wastewater composition:** Raw wastewater was collected from a hospital in north of Kermanshah city, Iran that including urgency, dialyzes, heart, radiography, urology, chemotherapy, endoscopy, blood, neurology, nephrology and so on. Samples stored at +2°C to +4°C. In this temperature, wastewater composition has stability. Composition of hospital raw wastewater used in this study including 481-654 mg COD, 233-351 mg/l BOD<sub>5</sub> and 259-520 mg/l TSS.

**Microorganism's adaption period:** At the first, Reactor was started up using return activated sludge to aeration pond of the industrial wastewater treatment plant and feed with hospital raw wastewater. Initial operating stages including feeding, aeration (24 hr) and decant. Due to using detergents and bactericide materials in hospital and entrance of those to its wastewater, microorganisms adapted with wastewater, difficulty. After passing of two month batch feeding, adaption period was continued for one month, continuously. Finally, experiments carried out according to Design Expert Software.

**Operation conditions:** The operation phases including mixing (without aeration), aeration, settling and decant, respectively. Experiments were performed in in 3 levels (-1, 0, +1) and 20 run involving: 1 center point, 7 axial points, 7 factorial points and 5 replications of the center according to table.1. MLSS concentration, 2000 – 6000 mg/l, aeration time, 2-4 hr and mixing time (without aeration), 30-90 min was surveyed. It must be noted that settling and discharge time was stable (30 and 5 min, respectively) in all runs. The system was operated at room temperature (25-27°C). After achieving steady state condition, were collected samples from influent, effluent and sludge. Dissolve oxygen concentration was maintaining in 5 mg/l. In the end of any cycle, 3L from treated wastewater (75% working volume) remain in reactor and 1 L was discharged.

**Table.1. Reactor performance for removing COD, BOD<sub>5</sub> and TSS according to Design Expert Software.**

Run	MLSS (mg/L)	Mixing time (hr)	Aeration time (hr)	COD removal (%)	BOD <sub>5</sub> removal (%)	TSS removal (%)
1	6000	1.5	4	95	96	98.6
2	6000	0.5	4	87.5	92	92
3	6000	1	3	82	89	91.3
4	6000	1.5	2	77.3	82	77
5	6000	0.5	2	70.3	76	74
6	4000	1	4	83	87	83.3
7	4000	1	3	70	75	70.3

8	4000	1.5	3	78	80	76.6
9	4000	0.5	3	63.6	68	63.2
10	4000	1	2	60.6	64	65
11	4000	1	3	69	74.1	69.5
12	4000	1	3	69	75.1	71
13	4000	1	3	72	76	72
14	4000	1	3	73	79	71.7
15	4000	1	3	71.8	76.2	72
16	2000	1.5	4	57.6	63	74.3
17	2000	0.5	4	51	57	61.3
18	2000	1	3	43.3	47	80
19	2000	1.5	2	35	40	41
20	2000	0.5	2	30	34	48.6

**Analytical method:** The following parameters were analyzed in accordance with Standard Methods (APHA, 2005): Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD<sub>5</sub>), Total Suspended Solids (TSS), Mix Liquid Volatile Suspended Solids (MLVSS) and pH. pH was almost inert, thus, no demand to adjust pH. Dissolved oxygen (DO) and pH were determined using a DO probe (B50, YSI Co., USA) and pH meter HANNApH211 model, respectively.

### Mathematical modeling

**Bio kinetic coefficients:** Bio kinetic coefficients were determined using Monod model (Najafpour, 2003). The following equation was used for substrate utilization rate in biological systems (Najafpour, 2007):

$$rsu = -\frac{kXS}{K_s + S} = -\frac{S_0 - S}{\theta} \quad (1)$$

By dividing above equation by the biomass concentration, X, equation (1) is defined as follows:

$$\frac{KS}{K_s + S} = \frac{S_0 - S}{X\theta} \quad (2)$$

Equation (3) was achieved by invert of equation (2):

$$\frac{X\theta}{S_0 - S} = \frac{K_s}{K} \frac{1}{S} + \frac{1}{K} \quad (3)$$

$K_s$  and  $\frac{1}{K}$  calculated by draw  $\frac{X\theta}{S_0 - S}$  versus  $\frac{1}{S}$ .  $Y$  and  $K_d$  was achieved by below equation:

$$\frac{1}{\theta c} = -Y \frac{rsu}{X} - K_d \quad (4)$$

With attention to  $rsu = -\frac{S_0 - S}{\theta}$  equation (4) is defined as follows:

$$\frac{1}{\theta} = Y \frac{S_0 - S}{X\theta} - K_d \quad (5)$$

Where:

$R_{su}$  is the rate of change in the substrate concentration due to utilization,  $g/m^3$ ,  $X$  is biomass concentration,  $g/m^3$ ,  $S_0$  and  $S$  is influent and effluent substrate concentration,  $g/m^3$ ,  $K_s$  is half-velocity constant,  $g/m^3$ ,  $K$  is maximum specific substrate utilization rate,  $g$  substrate/  $g$  microorganisms.  $d$ ,  $K_d$  is microbial decay rate,  $d^{-1}$ ,  $\theta$  is hydraulic retention time,  $d$ ,  $\theta_c$  is microbial retention time,  $d$ ,  $Y$  is maximum efficiency coefficient,  $g/g$ ,  $\mu_{max}$  is maximum specific growth rate,  $t^{-1}$ .

### Models:

**First- order:** Substrate change rate in mixed system as follows:

$$-\frac{ds}{dt} = \frac{QS_0}{V} - \frac{QS}{V} - K_1 S \quad (7)$$

In steady state condition, substrate change rate is ignorable and above equation could be corrected:

$$S_0 - \frac{S}{HRT} = K_1 S \quad (8)$$

Where,  $K_1$  is the rate constant,  $1/d$ ,  $Q$  is wastewater flow,  $l/d$ ,  $V$  is volume,  $K_1$  is obtained by gradient of  $(S_0 - S)/HRT$  in terms of  $S$ .

**Second – order:** The general equation of a second-order model is given below (Delnavaz, 2009):

$$-\frac{dS}{dt} = K_{2(s)} \cdot \left(\frac{S}{S_0}\right)^2 \quad (9)$$

If Eq. (9) is integrated and then linearizes to get the Eq. (10):

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$$\frac{S_0 \text{ HRT}}{S_0 - S} = \text{HRT} + \frac{S_0}{KX} \quad (10)$$

If the second term of the right part of this equation is accepted as a constant, equation will be modified as under:

$$\frac{S_0 \text{ HRT}}{S_0 - S} = a + b \text{ HRT} \quad (11)$$

Where:

$$a = S_0 / (kX),$$

X is the average biomass concentration in the reactor (g/L), and K is the second-order substrate removal rate constant (1/d) and b is a constant.

**Stover–Kincannon:** This model has been applied for expression and prediction of different bioreactors operation (Hosseiny, 2002; Hooshyari, 2009; Kavooosi2005). Equations of the Stover–Kin cannon model are as follows: where  $\frac{ds}{dt}$  is defined as follows:

$$\frac{ds}{dt} = \frac{Q}{V} (S_0 - S) \quad (12)$$

Where:

$\frac{ds}{dt}$ , substrate removal rate, g/l.d;  $U_{\max}$ , the maximum utilization rate constant, g/l.d and  $K_B$  is the saturation value constant, g/l.d. If  $(\frac{ds}{dt})^{-1}$  is taken as  $\frac{V}{Q(S_0 - S)}$ , which is the inverse of the loading removal rate and this is plotted against

the inverse of the total loading rate  $V/QS_0$ , a straight line portion of intercept  $\frac{1}{U_{\max}}$  and a slope of  $\frac{K_B}{U_{\max}}$  result.

$$\frac{dS}{dt} = \frac{U_{\max} \left( \frac{Q S_0}{V} \right)}{K_B + \left( \frac{Q S_0}{V} \right)} \quad (13)$$

$$\frac{1}{\left( \frac{ds}{dt} \right)} = \frac{V}{Q(S_0 - S)} = \frac{K_B V}{U_{\max} Q S_0} + \frac{1}{U_{\max}} \quad (14)$$

### 3. RESULTS AND DISCUSSION

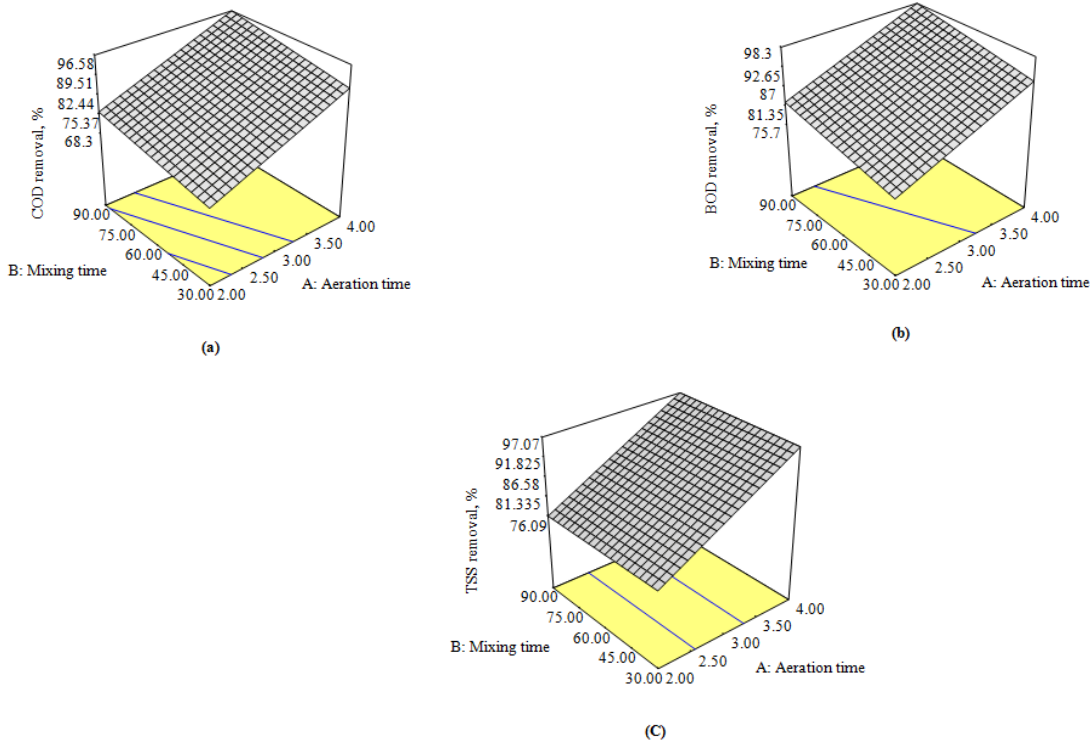
**Process analysis:** The predicted values were obtained from model fitting technique using the design expert software and were seen to be sufficiently correlated to the observed values. Central composite design (CCD) was applied for finding out the relationship between the variables (Aeration time, mixing time without aeration and MLSS concentration) and responses (COD, BOD<sub>5</sub> and TSS removal efficiency). Table.2 shows the reduced models and ANOVA results for responses. F-values: 350.44, 235.08 and 20.23 with very low probability values in model equations are indicative of significant corresponding of models and the individual coefficients. R<sup>2</sup>, adjusted R<sup>2</sup> and predicted R<sup>2</sup> coefficients in this study were close to 1 that indicating of goodness fit of the models. In experiment, adequate and precision values higher than 4 is suitable and reliable (Dincern, 2008). This value in now study was obtained 68.94, 56.6 and 21.73 that indicates adequate model discrimination. The proposed model could be used to predict treatment efficiency in this reactor and different operating conditions.

**Table.2. ANOVA results for the equations of the Design Expert for studied responses.**

Response	COD removal,%	BOD rem.%	TSS rem.%
<b>Modified Equations with significant terms</b>	+71.3+10.1A+4.04B+19.53C - 8.39C <sup>2</sup>	+75.84+9.90A+3.40B+19.40C-8.24C <sup>2</sup> -2.00AC	+71.4+10.49A+12.77C+2.41C <sup>2</sup>
<b>Type of model</b>	Quadratic	Quadratic	Quadratic
<b>R<sup>2</sup></b>	0.98	0.98	0.92
<b>Adj. R<sup>2</sup></b>	0.98	0.98	0.89
<b>Pred. R<sup>2</sup></b>	0.98	0.97	0.79
<b>Adeq. precision</b>	68.94	56.6	21.73
<b>S.D</b>	1.95	2.11	6.74
<b>CV</b>	2.91	2.94	9.29
<b>Press</b>	103.95	111.16	1221.13
<b>P-value</b>	<0.0001	<0.0001	<0.0001
<b>F-value</b>	350.44	235.08	20.23

**COD removal:** In this study, connection of variables and response was investigated and modeled. A reduced quadratic model was chosen to expression the variation of the removal efficiency as a result of changes in variables. COD concentration in treated wastewater was 31.4-395 mg/l, respectively. SbCOD in this study was obtained %68

TCOD. Maximum and minimum COD removal was achieved 95% in HRT, 6h and MLSS, 6000 mg/l and 30% in HRT, 3h and MLSS, 2000 mg/l, respectively. The aeration time and mixing time (without aeration) effect on COD removal shown in the figure 2. From figure 2, with increase in aeration time from 2 to 4h, as well as mixing time from 30 to 90 min, the response was increased, linearly. It might be noted that MLSS and mixing time (without aeration) have maximum and minimum effect on response, respectively (19.53, 4.04 as the coefficients in the model).



**Figure.2. surface plot and Perturbation plot for (a) COD removal, (b) BOD<sub>5</sub> removal and (c) TSS removal with respect to aeration time and mixing time at constant value of MLSS 6000 mg/l**

**BOD Removal:** In order to study of system performance on removing BOD, BOD/COD ratio in influent was measured and was achieved 0.41- 0.54 that is greater than 0.4. According to another researches, Wastewater is biodegradable if BOD/COD ratio be higher than 0.4 (Dincern, 2008). Therefore, can be biodegradation, simply. Proposed applicable model for BOD removal was reduced quadratic model (table.2). BOD concentration in treated wastewater was and 12.2- 165 mg/l. As is show in the fig.2, increase in MLSS and aeration time caused an increase in BOD removal. When was increased aeration time, environment condition is better for microorganisms, due to microorganisms be consumed more substrate. Additionally, in high MLSS, aeration time effect on response was low. As a result, with increase of MLSS concentration could decrease aeration time, therefore, where cost-effective is seen to be important, MLSS increasing in system seem a suitable solution.

**TSS removal:** Effluent TSS is a control parameter that indicating bioreactor performance. TSS removal efficiency was depicted in the fig. 2. Suggested model for this response was quadratic with 'prob F' <0.001 (table.2). In HRT, 6 hr and MLSS, 6000 mg/l, was achieved maximum removal efficiency (98.5%).

By SPSS software, Mean difference between TSS, COD and BOD efficiency removal with MLSS concentration was significant (P-value <0.05), but with another variables wasn't significant (P-value>0.05).

**Process optimization and verification:** Plot of overlay the contour graphs was applied for determination optimum point in bioreactor. The optimum region was determined based on below criteria: COD, BOD<sub>5</sub> and TSS removal more than 90%. Optimum region is yellow area in the overlay plots that meets optimum removal of responses. Fig.3 shows the graphical optimization as a function of aeration time and mixing time. The optimal region was determined in the mixing time, 30 to 90 min and aeration time 2 to 3.30 hr. In order to survey the accuracy of the models and compare actual responses with the predicted values, aeration time, 2 h and mixing time, 90 min, in the optimum region was chosen and system was operated based on. Result of obtained were close to the model prediction (table.3).

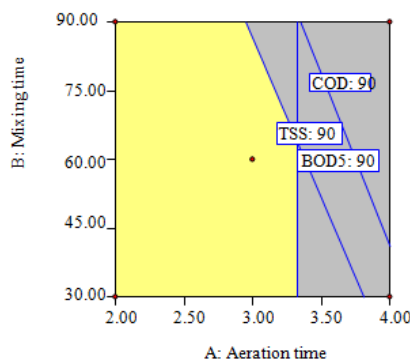


Figure.3. Overlay plots for the optimal region

Table.3. Verification experiments at optimum conditions.

Conditions	Run	Responses		
		COD removal (%)	BOD removal (%)	TSS removal (%)
Aeration time, 2h Mixing time, 90 min MLSS, 6000 mg/l	Experimental Values	77.3	82	77
	Model response with CI 95%Error	76.38	82.5	76.09
	Standard Error	1.24	1.53	3.69

Table.4. parameters level for calculating kinetic coefficient

MLVSS (mg/L)	MLSS (mg/L)	HRT (d)	SbCOD <sub>out</sub> (mg/L)	SbCOD <sub>in</sub> (mg/L)	BOD <sub>5out</sub> (mg/L)	BOD <sub>5in</sub> (mg/L)	Run
4744	6000	0.25	12.38	248.47	12.2	310	1
4646	6000	0.187	41.8	237.42	33.4	307	2
4564	6000	0.166	57.97	256.37	63.1	351	3
4675	6000	0.208	14.86	235.87	52.2	316	4
4542	6000	0.125	71.38	241.37	76.3	318	5
3082	4000	0.229	40.22	238.21	39	307	6
3025	4000	0.145	94.26	240.51	107	298	7
3000	4000	0.166	88.74	244.41	95	297	8
3015	4000	0.187	70.2	236.64	76.5	306	9
2798	4000	0.208	50.48	234.66	64.2	321	10
900	2000	0.208	107.27	198.7	124	235	11
920	2000	0.187	94.65	220.86	103	280	12
1050	2000	0.25	155.78	224.8	153	233	13
1000	2000	0.125	137.64	212.97	165	275	14
1200	2000	0.166	126.2	257.93	148	345	15

**Process kinetic and modeling:** Research in bio kinetic coefficient is connecting bridge of laboratory researches and industry. In present study, the kinetic coefficients were computed using the Monod equation. Using Data are available in table.4.  $K$ ,  $K_d$ ,  $K_S$ ,  $Y$  and  $\mu_{max}$  in MLSS concentration, 2000, 4000 and 6000 mg/l was achieved 0.48-0.59 gbsCOD/gVSS.d, 0.06-0.09 d<sup>-1</sup>, 9.75-19.23 mg/L bsCOD, 0.44-0.72 mgVSS/mg BOD and 0.135-0.172 d<sup>-1</sup>, respectively.  $R^2$  value was obtained 0.90, 0.80 and 0.59 for  $K$  and  $K_S$  in MLSS of 6000, 4000 and 2000 mg/l respectively.  $R^2$  value for  $Y$  and  $K_d$  was 0.95, 0.80 and 0.90 in MLSS of 6000, 4000 and 2000 mg/l respectively (fig. 4 and 5). Results show that in high MLSS, ability of organic compound for conversion to biomass is low. Concordant with increase biomass concentration, available substrate for microorganism was decreased, therefore, microorganisms endogenous and  $Y$  was decreased. Higher  $Y$  in now study can be related to high level of biodegradable compound that are synthesis into new cell.  $K$  is indicating of low speed treatment of hospital wastewater. In the other words, because of low biomass concentration, increased available substrate, microorganisms introduced into logarithm growth phase, therefore, increased rate substrate utilization and  $K$ .  $K$  and treatment level have inverse relation together, so much that, in MLSS 6000 mg/l was low. Regression coefficient was low in MLSS 2000 mg/l (0.59) that indicates in this condition; Monod model isn't explanatory of substrate utilization. Reduction of Cell mass is relative with microorganism's concentration, hence, in this research was studied  $K_d$  (biomass decay coefficient).  $K_d$  was lower than other coefficient. Whatever increase MLSS concentration, increase microorganisms endogenous and  $K_d$ . high  $K_d$  is following endogenous respiration. On the other hand, decay coefficient use for express of biomass decreasing due to death cell, oxidation of inter cellular accumulated product.  $\mu_{max}$  and MLSS concentration have reverse relation

together. Kinetic coefficient changing was shown  $\mu_{max}$ ,  $K_S$  and  $K_d$  have direct and inverse relation to outflow substrate concentration, respectively. By comparing above coefficient, it can be concluded that Monod model present suitable appraisal in low ratio of substrate to biomass concentration. It was because of the microorganism growth rate controlled by limiting substrate. Nevertheless, in higher substrate concentration, Monod model results can't be confidensable. Noted coefficient was plotted in the Figs.6 and 7. Above noted coefficient in studies is different regarding to type of rector, wastewater, microorganism, temperature and so on. For example,  $K_s$  and  $K_d$ , 85.5 and  $1.71 \text{ d}^{-1}$  was reported by Najafpour in activated sludge process for domestic wastewater treatment (Najafpour, 2007). Up the now, not existence study on kinetic of organic compound removal in hospital wastewater by activated sludge methods.

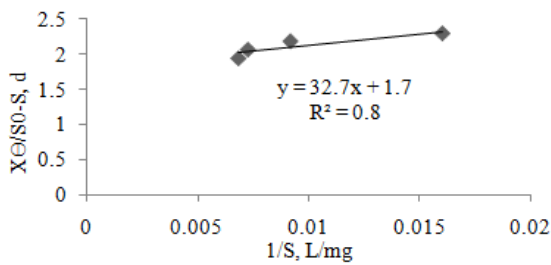


Figure.4.  $X\theta/S_0 - S$  versus effluent concentration for sbCOD removal at MLSS 4000 mg/l

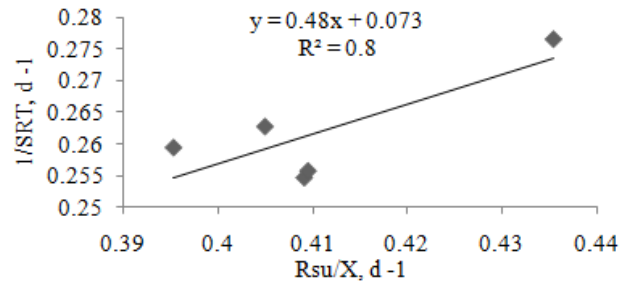


Figure.5. Specific microbial growth rate versus specific substrate utilization rate for BOD<sub>5</sub> removal at MLSS 4000 mg/l

Results of model survey were shown system behavior in present study follow First order model and MLSS concentration is not effective variable on noted model. But, in Second order model, by MLSS increasing can amplify intensity reaction. Actually, by increasing MLSS could varied system behavior to Second order.

Fig. 6 and 7 shows the correlation between the  $1/\text{COD}_{out}$  and HRT in First order model and  $\text{COD}_{in} \cdot \text{HRT}/(\text{COD} - \text{COD}_{out})$  and HRT in Second-order model that drawn based on Eq.7-11. Fig. 8 shows the correlation between the  $V/Q (\text{COD}_{in} - \text{COD}_{out})$  and  $(V/Q \cdot \text{COD}_{in})$  in Stover-kin canon model drawn based on Eq.12-14. Coefficient ( $R^2$ ) indicates that this model is very fit with experimental data ( $R^2 = 0.98$ ).  $K_1$ ,  $K_2$ ,  $K_B$  and  $U_{max}$  were obtained 20.2-238.2, 1.13-1.49, 0.019-0.29 and 0.015-0.23, respectively. Second order model in MLSS 2000 mg/l don't fit with data, well ( $R^2 = 0.49$ ).

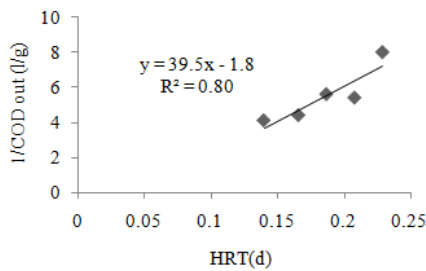


Figure.6. first- order model in MLSS 4000 mg/l

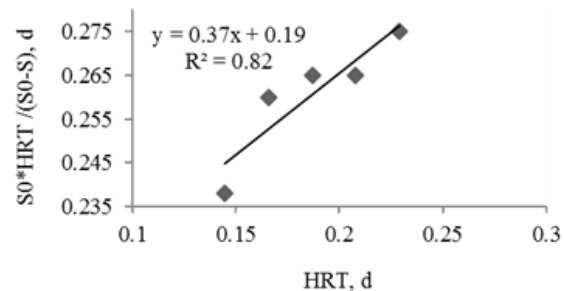


Figure.7. Second- order model in MLSS 4000 mg/l

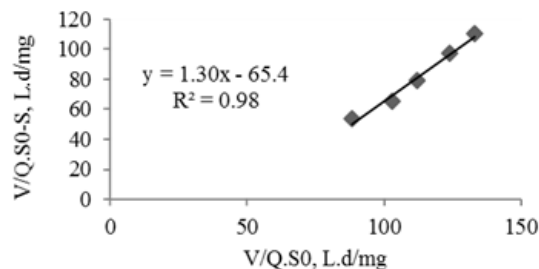


Figure.8. Stover kin canon model in MLSS 4000 mg/l

#### 4. CONCLUSIONS

As conclusion, the experiments indicated that intermittent cycle extended aeration system could remove organic pollutants from hospital wastewater, easily. Maximum of removal efficiency was obtained in HRT, 6 hr and MLSS 6000 mg/l. By increase microorganisms due to high MLSS could decrease aeration and mixing time that result in economic saving in operating system. The optimum value of the aeration time was in ranging 2 to 3.75 hr.

Experimental findings were in close agreement with the model prediction. Second order and Stover-kin canons describe treatment process, successfully.

## 5. ACKNOWLEDGEMENT

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## REFERENCES

Almasi A, Dargahi A, Amrane A, Fazlzade M, Mahmudi M, Hashemian AH, Effect of the retention time and the phenol concentration on the stabilization pond efficiency in the treatment of oil refinery wastewater. *Fresenius Environmental Bulletin*, 23(10a), 2014, 2541-2548.

APHA, Standard methods for the examination of water and wastewater, 21st edn. American Public Health Association, Washington, 2005.

BanaeiGhahfarokhi B, Ehrampoosh M.H, Nasiri P, Ghasemi A, javanmardi R, Survey of detergent and organic substance removal from hospital wastewater by advanced SBR, *Environmental sciences & technology*, 12, 2010, 62-70.

Borghei S.M, Sharbatmaleki M, Pourrezaei P, Borghei G, Kinetics of organic removal in fixed-bed aerobic biological reactor, *Bioresource Technology*, 99, 2008, 1118-1124.

Chang J.S, Chen A.C, Hung M.Y, Shih M, The operational strategy of intermittent cycle extended aeration system in treating sewage, *J Chem Technol Biotechnol*. 74, 1999, 688-692.

Chitnis V, Hospital Effluent, a Source of Multiple Drug Resistant Bacteria, *Curr.Sci*, 79, 2000, 989-991.

Chitnisa V, Bacterial population changes in hospital effluent treatment plant in central India, *Wat. Res*, 38, 2004, 441-447.

Crites R, Tchobanoglous G, Small and decentralized wastewater management systems, Mc-Graw Hill, New York, 1998.

Davoodi R, Almasi A, HoseiniAhagh MM, DargahiAbdollah, Karami A, A Mathematical Model For Organic Matter Removal In Constructed Wetlands Case Study, Wastewater Treatment Plant Of Qasr-E Shirin, Iran. *International Journal of Pharmacy & Technology*, 8(2), 2016, 13155-13167.

Delnavaz M, Ayati B and Ganjidoust H, Reaction kinetics of aniline synthetic wastewater treatment by moving bed biofilm reactor, *Health and Environment*, 2, 2009, 76-87.

Delnavaz M, Ayati B, Ganjidoust H, Treatment of wastewater containing Anilin using a moving bed biofilm reactor (MBBR), *Water and Wastewater*, 68, 2009, 9-18.

Dincern A.R, Removal of COD from oil recovery industry wastewater by the advanced oxidation processes (AOP) based on H<sub>2</sub>O<sub>2</sub>, *Global Nest*, 10, 2008, 31-38.

Hooshyari B, Azimi A, Mehrdadi N, Kinetic analysis of enhanced biological phosphorus removal in a hybrid integrated fixed film activated sludge process, *International Environmental Sciences and Technology*, 6, 2009, 149-158.

Hosseiny S.H, Borghei S.M, Modeling of organic removal in a moving bed biofilm reactor (MBBR), *ScientiaIranica*, 9, 2002, 53-58.

Jolibois B, Guerbet M, Hospital wastewater geno toxicity, *Ann OccupHyg*, 50, 2006, 189-196.

Kavoosi A, Borghee S.M, The use of light expanded clay aggregates as a biological support in wastewater treatment, *Water and Wastewater*, 53, 2005, 37-47.

Liu X.W, Yu H.Q, Ni B.J, Sheng G.P, Characterization, Modeling and Application of Aerobic Granular Sludge for Wastewater Treatment, *AdvBiochemEngin/Biotechnol*, 113, 2009, 275-303.

Mahvi A.H, Mesdaghinia A.R, Karakani F, Feasibility of Continuous Flow Sequencing Batch Reactor in Domestic Wastewater Treatment, *Applied Sciences*, 1, 2004, 348-353.

Metcalf and Eddy, Inc, Wastewater engineering, treatment and reuse. McGraw – Hill, New York, 2003.

Miyata J, Takao S, Toshiaki T, Wastewater treatment processing simulation technology using activated sludge model, *JFE Technical report*, 3, 2004, 27-34.

Najafpour G.H, Sadeghpour M, Zinatizadeh A, Determination of kinetic parameters in activated sludge process for domestic wastewater treatment plant, *CI&CEQ*, 13, 2007, 211-215.

Najafpour G.D, Shan C.P, Enzymatic hydrolysis of molasses, *Bioresour. Tech*, 86, 2003, 91-94.

Najafpour G.D, Younesi H, Bioconversion of synthesis gas to hydrogen using a light-dependent photosynthetic bacterium, *Rhodospirillum rubrum*, *World J. Microbiol Biotechnol*, 23, 2007, 275-284.

Rodriguez I, Gomez M, Ternes T, Behavior of pharmaceuticals, cosmetics and hormones in a sewage treatment plant, *Wat. Res.* 38, 2004, 2918–2926.

Sharbatmaleki M.A, Borghei S.M, Performance of pumice stone as a packing in fixed-bed aerobic bioreactor, *Water and Wastewater*, 56, 2006, 62-71.

Sorensen B.H, Nielsen N, Lanzky P.F, Ingerslev F, Lutzhoft H.CH, Jorgensen S.E, Occurrence, fate and effects of pharmaceutical substances in the environment—a review, *Chemosphere*. 36, 1998, 357–393.

US EPA, Sequencing Batch Reactor Systems, Onsite Wastewater Treatment Systems Technology Fact Sheet 3, EPA 625/R-00/008, US Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, 2000.

Yetilmezsoy K, Modeling studies for the determination of completely mixed activated sludge reactor volume, study-state, empirical and ANN applications, *Neural Network World*, 5, 2010, 559-589.