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Research Article

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Determining the Kinetic's Coefficients in Treatment of Sugarcane Industry Using Aerobic Activated Sludge by Complete-Mix Regime

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ABSTRACT

Agro-industrial waste due to the high pollution potential among industrial wastewater can have significant impacts on the environment. Sugarcane industry wastewater requires applying biological methods such as activated sludge with complete-mix because of non-permanent drainage and high organic load. The purpose of this study is to review and determine the kinetic's coefficient of activated sludge of sugarcane industry wastewater treatment plant. This study was performed over a 6 -month period in 2012 and TSS, COD and BOD parameters in the input and output wastewater and the amounts of MLSS, F/M, MLVSS, SRT and HRT of the aeration basin were measured and kinetic values K_d, K_S, K, Y and μ_{max} were determined using the modified Monod equations as 0.05 d^{-1}, 36.6mg/l, 2.5 d^{-1}, 0.36gVSS/g COD and 1.02 d^{-1}. The results showed that the kinetic coefficients of activated sludge with complete mix of sugar cane industry was similar to other studies in this industry and system is functioning in reduced growth phase.

Keywords: Wastewater treatment, Culture and Sugarcane industry, kinetic coefficients, activated sludge - perfect mix-complete-mix

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INTRODUCTION

Agro-industry wastewaters are the swages created as a result of human activity in relation to the processing and production of raw materials that as sub-group of industrial waste can have significant impacts on the environment because their pollution potential is very high (6). Sources of pollution include: mill effluent which contains high levels of oil, grease and sugar and thus it has high levels of BOD, wastewater from washing sugarcane, including plentiful suspended particles and mud , wastewater from cleaning boilers which has dissolved solids and phosphates, cloth filter sewage including high dissolved solids and BOD, wastewater of the cooling system containing chemicals such as caustic soda, sodium carbonate and hydraulic acid used to remove germs (4) and wastewater resulting from infiltration ditch that has high BOD indicating the high sugar concentration (7).

One of the problems in the sugar industry is discontinuous nature of plant activities, the activity of this plant in the USA is 25-100 days per a year and 5-6 and 4 months a year in Iran and India respectively (6, 7).

Among the various methods for treating wastewater in the sugarcane industry, using biological methods is very important because of the discontinuity and high organic matter load. Therefore the bacteria in the selected treatment process should be resistant to change and they remain in the purification tanks when the sewage production stops and they should produce low levels of sludge so that it could be kept. Therefore an anaerobic biological treatment method followed by aerobic biological system should be devised. Upflow anaerobic sludge blanket (UASB) and activated sludge are among common biological methods used in this industry. At present, anaerobic reactors are widely used in treatment of organic waste, with medium and high concentrations. Biological treatment with activated sludge is the most common method for aerobic wastewater treatment. The process of growing aerobic bacteria is based on controlled conditions in terms of dissolved oxygen and biological suspended solids.

Almost all types of wastewaters can be biologically treated by environmental analysis and monitoring. Accordingly understanding biological processes' characteristics is essential to provide a suitable environment with and effective monitoring (13). Optimization, monitor and control of a biological process are among most important activities in the field of research and industry the importance of which is increasing day by day (see 11). Given the importance of this topic various studies have been done in this area. Kinetic coefficients of activated sludge system have been calculated and determined using the modified Monod equation for wastewater treatment of industries such as pulp and paper industry (1), oil (17,8) tanning and leather industry (9,14), poultry slaughterhouse(10), animals food production (12) and pre-refined palm oil industry(19)

For the design, operation and maintenance of aerobic- anaerobic wastewater treatment plants choosing kinetics coefficients Y, K_d, μ_{max}, Ks, and μ depending on the type of wastewater and climatic conditions of the region is necessary (3).

In this study Y, K_d, μ_{max}, Ks, and μ kinetics coefficients of the activated sludge of industrial wastewater treatment plant of Imam Khomeini sugar factories- Shushtar are determined and analyzed.

EXPERIMENTAL SECTION

The study was conducted during 6 months in 2012 on Khuzestan sugar factory using aerobic activated sludge treatment system with complete mix under an industrial scale. Due to the seasonality of factory activity, treatment plant is active only 6 months of the year (beginning of September with the sugarcane harvest to mid February). Production of wastewater in this industry due to climatic conditions, delay in harvesting sugarcane and interrupting the production is not permanent. In order to control discharge fluctuations and uniform quality of the input wastewater in terms of pollution load, raw wastewater is led to integration tank with 10 days of retention and then it is led to modification tank to set the parameters such as pH, COD/N/P and micro nutrients necessary for the growth of anaerobic bacteria. After the injection of chemicals required such as Caustic soda (NaOH) Hydrochloric acid (HCL), Urea and phosphoric acid (H_3 PO_4), the wastewater with a discharge of 50 m^3/h and temperature of 37℃ through the wastewater distribution pipes enters from the reactor surface with a distance of 1.20 cm enters the UASB anaerobic reactor with a length and width equal to 15.8m, height if 6m and approximate size of 1500m^3. Organic compounds in wastewater contact with the mass of microorganisms in the form of dense granular particles with and approximate size of 0.14-0.5mm and loose a high percentage of their pollution and the wastewater is ready to be sent to the aerobic treatment.

The system consists of three rectangular tanks that are connected to each at the bottom. Each tank has a mixer and a surface aerator with37kw power. In this system the treatment process is also based on the theory of the activated sludge and sedimentation. Two tanks of three tanks have spillways to exit treated wastewater.

The analysis of 7 samples was performed to determine the BOD, COD, TSS, pH and VSS parameters that resulted in a total of 21 samples for each parameter [18].

2-1 The parameters required to determine the kinetic coefficients
COD or (S_0): The concentration of raw wastewater entering the reactor in terms of mg/l
COD Or (S): The concentration of output wastewater from the reactor in terms of mg/l
MLVSS or (X): The concentration of microorganisms in the aeration basin in terms of mg/l
SRT or (θc): Cell retention time in terms of (day)
HRT or (θ_H): The hydraulic retention time in terms of (day)

2-2- Testing method

100 CC raw input and output wastewater was analyzed to determine the COD concentration using COD Spectrophotometer LOVIBOND brand Model ET 108 based on the test 5250B [18].

100 CC wastewater of aeration basin was analyzed to determine mixed liquor volatile suspended solids (MLVSS) and mixed liquor suspended solids (MLSS) using gravimetric method, a digital scale with precision 0.01 mg, stainless steel oven and furnace 550$\pm$50 degrees Celsius according to tests No. 2540E (18).

Using the results of testing input and output qualitative parameters of the activated sludge system SRT (θc) and HRT (θH) parameters were calculated monthly for the aerobic activated sludge system and using Minitab software and plotting kinetic coefficients K_{max}, Y, K_d, $\mu_{max}$and K_s were obtained based on Monod modified equation.

2-3- Method of determining the kinetic coefficients:

To determine the kinetic constants K and Ks equation (1) was used: (17)

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

Through dividing the above equation by X and reversing it equation (2) was obtained:

$$\frac{X_\theta}{S_0-S} = \frac{K_s}{k}\frac{1}{S} + \frac{1}{k} \quad (2)$$

The values of Ks and$\frac{1}{k}$can be obtained by drawing $\frac{X_\theta}{S_0-S}$versus$\frac{1}{S}$. The values of Y and $K_d$were obtained by equation 3 (5):

$$\frac{1}{\theta_c} = -Y\frac{r_{su}}{X} - K_d \quad (3)$$

According to $r_{su} = -\frac{S_0-S}{\theta}$ equation (3) was used as follows:

$$\frac{1}{\theta_c} = Y\frac{S_0-S}{X\theta} - k_d \quad (4)$$

By drawing$\frac{1}{\theta}$versus$\frac{S_0-S}{X\theta}$ the slope of the resulting line equals Y and intercept equals k_d

After determining Y and K through the above equations, fixed maximum specific growth μ_{max} can be calculated from the following equation:

$$\mu_{max} = K.Y \quad (5)$$

RESULTS

The results of the experiments in this study to determine the kinetic coefficients in November, December and January are shown in table (1). Using these information and other available tables the kinetics coefficients for November, December and January were calculated.

Table 1: Values obtained from tests to determine the kinetic coefficients in November, December and January

X (mg/l)			θ(d)			S (mg/l)			S_0 (mg/l)			Number sample
Jun	Dec	Nov	Jun	Dec	Nov	Jun	Dec	Nov	Jun	Dec	Nov	
2251	1423	3452	0.38	0.38	0.38	120	94	100	1500	1200	1700	**1**
2544	1656	1622	0.38	0.38	0.38	105	65	88	1640	1150	1400	**2**
2034	1974	2126	0.38	0.38	0.38	92	76	125	1300	1440	1650	**3**
1691	1614	7026	0.38	0.38	0.38	110	107	120	1370	1310	1900	**4**
2422	1970	562	0.38	0.38	0.38	115	87	200	1600	1500	1980	**5**
2613	2272	6665	0.38	0.38	0.38	118	101	117	1720	1700	1700	**6**
2582	1632	3331	0.38	0.38	0.38	98	108	145	1520	1400	1200	**7**

Using the information in Table 1the values of$\frac{1}{S}$,$\frac{X\theta}{S-S_0}$,$\frac{1}{\theta_c}$and $\frac{S-S_0}{X\theta}$ for November, December and January are presented in tables 2, 3 and 4.

Table 2: values of $\frac{1}{S}$, $\frac{X\theta}{S-S_0}$, $\frac{1}{\theta_c}$ and $\frac{S-S_0}{X\theta_c}$ in December

$\frac{S-S_0}{X\theta_c}$ (d^{-1})	$\frac{1}{\theta_c}$ (d^{-1})	$\frac{X\theta}{S-S_0}$	$\frac{1}{S}$	number
1.22	0.69	0.82	0.01	**1**
2.12	0.471	0.47	0.011	**2**
1.88	0.779	0.53	0.008	**3**
0.66	0.25	1.5	0.083	**4**
8.34	3.564	0.12	0.005	**5**
0.62	0.23	1.6	0.085	**6**
0.83	0.32	1.2	0.068	**7**

Table 3: values of $\frac{1}{S}$, $\frac{X\theta}{S-S_0}$, $\frac{1}{\theta_c}$ and $\frac{S-S_0}{X\theta_c}$ in November

$\frac{S-S_0}{X\theta_c}$ (d^{-1})	$\frac{1}{\theta_c}$ (d^{-1})	$\frac{X\theta}{S-S_0}$	$\frac{1}{S}$	number
2	0.731	0.489	0.01	**1**
1.71	0.610	0.584	0.015	**2**
1.78	0.615	0.559	0.013	**3**
1.94	0.675	0.513	0.0093	**4**
1.88	0.642	0.53	0.011	**5**
1.82	0.627	0.547	0.0099	**6**
2.1	0.737	0.483	0.0092	**7**

Table 4: values of $\frac{1}{S}$, $\frac{X\theta}{S-S_0}$, $\frac{1}{\theta_c}$ and $\frac{S-S_0}{X\theta_c}$ in January

$\frac{S-S_0}{X\theta_c}$ (d^{-1})	$\frac{1}{\theta_c}$ (d^{-1})	$\frac{X\theta}{S-S_0}$	$\frac{1}{S}$	number
1.59	0.691	0.626	0.0083	**1**
1.57	0.681	0.635	0.0095	**2**
1.55	0.630	0.644	0.01	**3**
1.94	0.845	0.514	0.0009	**4**
1.61	0.721	0.620	0.0086	**5**
1.59	0.691	0.627	0.0084	**6**
1.44	0.619	0.690	0.01	**7**

Fig. 1, 3 and 5 present linear regression curve between $\frac{1}{S}$ and $\frac{X\theta}{S-S_0}$ for November, December and January. Also the linear regression curves between $\frac{1}{\theta_c}$ and $\frac{S-S_0}{X\theta}$ for indicated months are provided in Fig. 2, 4 and 6.

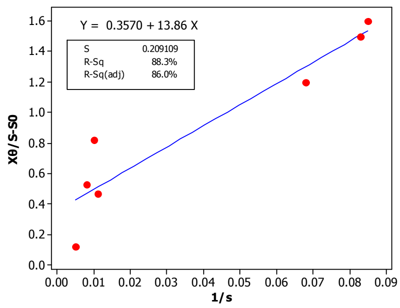

Fig (1) regression between $\frac{1}{S}$ and $\frac{X\theta}{S-S_0}$ in November

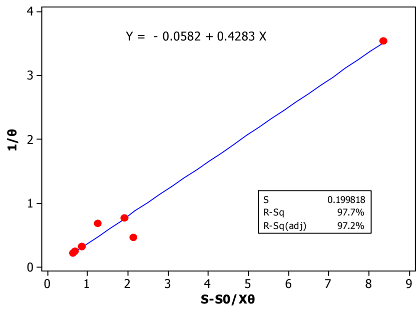

Fig (2) linear regression between $\frac{1}{\theta_c}$ and $\frac{S-S_0}{X\theta}$ in November

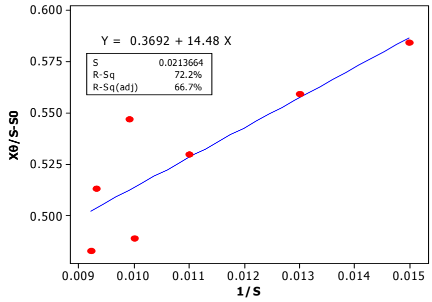

Fig (3) regression between $\frac{1}{S}$ and $\frac{X\theta}{S-S_0}$ in December

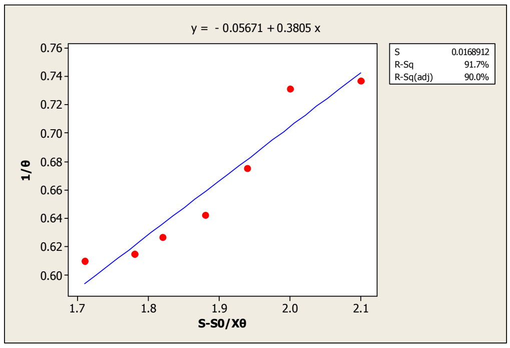

Fig (4) linear regression between $\frac{1}{\theta_c}$ and $\frac{S-S_0}{X\theta}$ in December

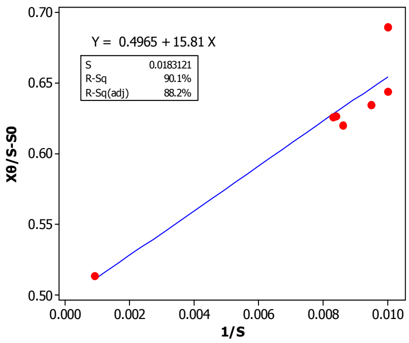

Fig (5) regression between $\frac{1}{S}$ and $\frac{X\theta}{S-S_0}$ in January

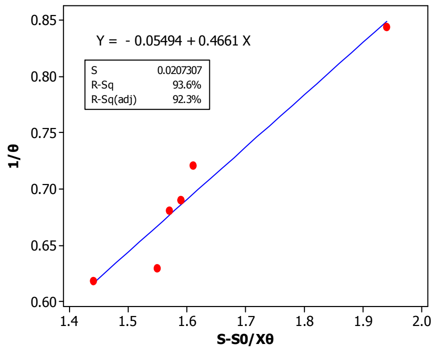

Fig (6) linear regression between $\frac{1}{\theta_c}$ and $\frac{S-S_0}{X\theta}$ in January

According to figures 1 and 2 the kinetic coefficients Y, K_d, K_s, μ_{max} and K_{max} of November equal 0.4 g vss /g COD, 0.05 d^{-1}, 38.8 mg/l, 1.12 d^{-1} and 2.8 d^{-1}.

According to Figures 3 and 4 the kinetic coefficients of December equal 0.3 g vss /g COD, 0.05 d^{-1}, 39.2 mg/l, 1.02 d^{-1} and 2.7 d^{-1}; also these values for January equal 0.4 g vss /g COD, 0.05 d^{-1}, 31.8 mg/l, 0.93 d^{-1} and 2.01 d^{-1}. Kinetic coefficients obtained in November, December and January of activated sludge system in wastewater treatment plant of Imam Khomeini sugarcane industry are Provided in Table 5:

Table 5: kinetic coefficients of activated sludge systems with complete mixing

Kinetic coefficients	Coefficients		Research findings		
	Range	Usual	November	December	January
$K(d^{-1})$	(2-10)	5	2.8	2.7	2.01
K_s (mg/l)	(10-60)	40	38.8	39.2	31.8
$K_d(d^{-1})$	(0.03-0.08)	0.05	0.05	0.05	0.05
Y (kgvss/kgCOD)	(0.3-0.6)	0.4	0.4	0.3	0.4
$\mu_{max}(d^{-1})$	(0.3-0.3)	1	1.12	1.02	0.93

Kinetic studies are very important to extend the possibility of using the results of research on an industrial scale. Environmental conditions can be controlled by setting pH, temperature, adding nutrients or trace elements, adding or reducing dissolved oxygen and proper mixing. Environmental conditions help to make sure about presence of the excellent medium for microbial growth (5). Table (7) presents the sample kinetic coefficients related to urban wastewater (17).

Table 6: Summery of the results of parameters obtained from activated sludge system

month			parameter
Jun	**Dec**	**Nov**	
Wastewater Influent Quality parameters			
45.3 ± 582.8	60.2 ± 464.2	70 ± 510	**BOD_5(mg/l)**
148.6±1521.4	187.4±1385	271.2±1647.1	**COD(mg/l)**
159.9±751.4	178.5±825.7	189.8±766	**TSS(mg/l)**
0.3±1.34	0.1±1.18	0.2±1.44	**(Kg/m^3.d)**
0.03±0.38	0.04±0.33	0.03±0.31	**BOD/COD**
0.2±7.4	0.1±7	0.2±7.4	**pH**
2.6±36.1	2.5±33.3	2.1±32.2	**θ**
Wastewater outlet Quality parameters			
3±31.7	4±23.2	4.3±30.4	**BOD_5(mg/l)**
10±108.1	16±91.1	36±127.8	**COD(mg/l)**
4.4±51.4	2.9±52.5	4.8 ± 45.4	**TSS(mg/l)**
0.03±0.29	0.04±0.3	0.02±0.24	**BOD/COD**
0.1±8.3	0.1±8.3	0.1±8.3	**pH**
0.1±6.3	0.1±5.8	0.1±6.3	**DO(mg/l)**
1.2 ± 19.35	1.3 ± 20.7	1.9±22.8	**θ (ºC)**
Pollution removal efficiency			
0.5±94.5	0.95±95	1.2±94	**BOD_5(mg/l)**
1.7±92.8	1.6±93.4	2.3±92.2	**COD(mg/l)**
1.4±93.7	2.4±97.7	1.4±94	**TSS(mg/l)**

Table 7: Bio- kinetic coefficients for activated sludge process in domestic sewage treatment (17)

Coefficients		**Research Results**	
Usual	Range	Single	Coefficients
5	2 - 10	day $^{-1}$	**K**
60	25 - 100	Mg / l BOD_5	**K_s**
40	10 - 60	Mg / l COD	
0.1	0.4 - 0.8	Day $^{-1}$	**K_d**
0.6	0.025 - 0.075	VSS mg / BOD_5 mg	**Y(Kgvss / kgCOD)**

These values have been reported for 20 ° C.

Table (7) presents the sample kinetic coefficients related to urban wastewater (17). The average kinetic coefficients calculated in this study are within the range of values related to urban sewage in activated sludge system.

Average K coefficient or the overall rate of the reaction within the month under study was 2.5 d^{-1}. This figure indicates the nature and biodegradable property of the wastewater and presents the decomposition rate of organic matter.

Sajad Heydar *et al* (2008) in their study on the leather industry wastewater treatment by means of aerobic activated sludge system obtained the reaction rate coefficient equal to 3.1 d^{-1}. Other kinetic coefficients K_s, K_d and Y in this study were equal with 488 mg/l, 0.035 d^{-1} and 0.64 kgvss/kg COD (14).

Ting Hues et al. (2012) in their study to determine kinetic coefficients of activated sludge by (ASR) reactor in poultry slaughterhouse, obtained K or the overall rate of the reaction as 3.2 d^{-1}. Other kinetic coefficients K_s, K_d and Y in this study were equal with 78 mg/l, 0.08 d^{-1} and 0.34-0.36 kgvss/kg COD(10). Also in the study conducted by Ahmad Kamarolenajio *et al*., (2007) on the treated wastewater of palm oil the kinetic coefficients K, K_s, K_d and Y were obtained as 1-1.57 d^{-1}, 272-348 mg/l, 0.07-0.092 d^{-1} and 0.34-0.75 kgvss/kg COD (19).

In this study the mean value for the growth rate is equal to 1.02 that comply with the proposed limit values and show high removal efficiency of organic materials.

Heydar and Aziz (2009) in their study on the leather industry wastewater obtained the specific growth rate of 1.46 d^{-1}. Other obtained kinetic coefficients K, K_s, K_d and Y in this study are 3.125 d^{-1}, 1.25 mg/l, 0.041 $d^{-1}$and 0.44 kgvss/kg COD (10).

Gilbert et al (2004) in their studies on the oil industry wastewater obtained specific growth rate coefficient μ_{max} as 0.25. The value of kinetic coefficients K_s, K_d and Y were obtained as 2 d^{-1}, 0.01 d^{-1} and 0.69kgvss/kgCOD (12).

Compared with kinetic coefficients obtained from industrial wastewater coefficient Y of the present study which is equal to 0.36 kgvss/kg COD is similar to coefficient Y of pretreatment wastewater of palm oil in the study of Ahmad Kamarolenajio and coefficient Y of poultry slaughterhouse in the study of Ting Hues that were 0.34 and 0.34-0.36 kgvss/kg COD. Kinetic coefficient K in this study equals 2.5 d^{-1} which is correlated with K coefficient in leather, slaughterhouse and oil industry wastewater that were 3.125, 3.2 and 3.28 d^{-1}. The coefficient K_d of this study is 0.05 and complies with the K_d coefficient of oil industry wastewater in Tellez study, wastewater pretreatment of palm oil, poultry slaughterhouse, leather and petrochemical wastewater that were 0.04, 0.07-0.09, 0.08-0.01, 0.03 and 0.06 d^{-1}.

CONCLUSION

The average kinetic coefficients K_s, Y, K_d,μ_{max} and k_{max} of aerobic process with complete-mix of wastewater treatment of Shoushtar sugarcane equal: 36.6mg/l, .36gVSS/g COD, 0.05 d^{-1}, 1.02 d^{-1} and 2.5 d^{-1}, the average organic load equals 1.32 kgCOD/m^3.d and COD removal efficiency equals 92.8%. Kinetic coefficients $\mu_{max,}k_{d,}$ Y, k_s and k_{max} values of this study comply with other studies and they are within the range of urban wastewater in activated sludge system and the system is functioning in reduced growth phase. The kinetic coefficients obtained in this study can be used in navigation, operation and similar treatment plants of sugar cane industry.

Indicates the proper functioning of the UASB anaerobic system as suitable pre-treatment for aerobic activated sludge system.

Appendix (2)
S_0 (COD): Input substrate concentration in terms of mg/l
S (COD): Output substrate concentration in terms of mg/l
X: The concentration of microorganisms in terms of mg/l
θ_c or SRT : Cell retention time in terms of (day)
HRT or (θ_H): The hydraulic retention time in terms of (day)
K_d: cell death coefficient
K_s: Half reaction rate constant
μ_{max}: maximum specific growth rate
Y: maximum return coefficient
K_{max} Maximum speed of decomposition of organic matter

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