Treatment of Textile Industry Wastewater by Sequencing Batch Reactor (SBR), Modelling and Simulation of Biokinetic Parameters

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Abstract

In this study; variation of effluent BOD_5's (S_e) with reaction time (t_r) in Sequencing Batch Reactor (SBR) unit for textile industry wastewater treatment plant and effective parameters on this variation have been researched. Determination of appropriate reaction time (t_r) is an important value for design and operation of activated sludge unit. An appropriate kinetic equation for Sequencing Batch Reactor (SBR) unit has been researched and simulation studies were made according to parameters' minimum, average and maximum values. In simulation studies, it has been observed that effect of parameters (S_o, Q, k, V_b, V_a, V_{ab}) on Sequencing Batch Reactor (SBR) effluent concentration (S_e) variation with reaction time (t_r). In addition, theoretical variation of effect parameters on effluent BOD_5's (S_e) and interaction of these parameters were researched. Ten different values with determined ranges were chosen for each parameter. Calculations have been done using our computer program. In the result of calculations were obtained theoretical values. Calculated values have been plotted and fitted graphics by Grapher program. Also, regression coefficient were determined and given suitable equations. This method of Sequencing Batch Reactor offers a significant improvement for the treatment of textile wastewater and this theory can be used to help define Sequencing Batch Reactor (SBR) kinetics with the optimum operational characteristics.

Key Words: Parameter; Simulation; Sequencing batch reactor (SBR); Textile industry; Wastewater treatment

1. Introduction

Textile industries use large amounts of water and chemicals for finishing and dying processes. Dyestuff is a type of refractory organic matter, and thus microorganisms find it difficult to use it as a carbon or energy source. However, many researchers are still interested in biological treatment processes for the treatment of textile wastewater due to the low cost and the absence of chemical waste production (Santhy and Selvapathy, 2006; Sirianuntapiboon *et al.,* 2007). Aerobic granular sludge sequencing batch reactors (SBR) are a promising technology for treating wastewater (Liu *et al.*, 2005).

A Sequencing Batch Reactor (SBR) is an activated sludge biological treatment process. This type of process is usually used in small systems. Sequencing Batch Reactor (SBR) systems are hybrid systems with some characteristics of continuous flow PF (plug flow) and CM (complete mixed) systems but they have other characteristics that are truly unique. One complete cycle is composed of the fill, react, settle, draw and idle, respectively. A Sequencing Batch Reactor (SBR) differs from the conventional flow true activated sludge process in that SBRs do not require separate tanks for aeration and sedimentation. There is no return activated sludge system in the SBR system (Droste, 1997; İleri and Damar, 2005; Teichgraber *et al.,* 2001; Tchobanoglous, 1991; EPA, 2000; Lin, 2001).

An SBR system is a modified AS system used in solving the low-density bio-sludge and bulking sludge problems due to the large volume of the clarifier (Metcalf & Eddy, 1991). Biological processes will only achieve near-optimal performance if they are modeled and monitored using reliable techniques. An adequate model of a biological process enhances the understanding of the process and can form the basis for better process design, control, and operation. In addition, efficient process monitoring and early fault detection methods allow corrective action to be taken well before a dangerous situation occurs. In biological wastewater treatment plants, most changes are slow when theprocess is recovering from a 'bad' state to a 'normal' state (Chang Kyoo Yoo, Kris Villez, In-Beum Lee, Christian Rose´n, Peter A. Vanrolleghem, 2007).

When a problem occurs in such a process, it may give rise to subtle changes that gradually grow until they become a serious operational problem. In recently developed industrial biological plants, many variables are measured in various operating units and an abundance of data is recorded. However, such data sets are highly correlated and are subject to considerable noise. In the absence of an appropriate processing method, only limited information can be extracted. In such situations, the operator may not understand the process sufficiently to maintain stable operation. If properly treated, however, this process data can provide a wealth of information that can assist plant operators in understanding the process status and enable them to take appropriate action when an abnormality is detected (Chang Kyoo Yoo, Kris Villez, In-Beum Lee, Christian Rose´n, Peter A. Vanrolleghem, 2007).

Sequencing batch reactor (SBR) processes have demonstrated their efficiency and flexibility in the treatment of wastewaters with high concentrations of nutrients (nitrogen, phosphorous) and toxic compounds from domestic and industrial sources. A SBR has a unique cyclic batch operation, usually with five well-defined phases: fill, react, settle, draw, and idle. Most of the advantages of SBR processes can be attributed to their single-tank design and their ability to adjust the durations of the different phases, which endows these processes with a flexibility that allows them to meet many different treatment objectives. However, SBR processes are highly nonlinear, time-varying, and subject to significant disturbances such as hydraulic changes, composition variations, and equipment failures. Small changes in concentrations or flows may have large effects on the biological reaction kinetics, leading to batch-to-batch variations in effluent quality and microorganism growth. Such influent variations cause SBR processes to evolve over time as the microorganisms adapt to the changing operating conditions. These factors lead to changes in the microbial community and multiple operation modes within a bioreactor.

Moreover, compared to data from continuous wastewater treatment processes, SBR operation data have the added dimension of Batch number, which, when combined with the measured variables and sample times, gives a three-way matrix (batches_ variables_time). Batch processes generally exhibit some batch-to-batch variation in the trajectories of the process variables. However, treatment performance, the key indicator of process performance, is often only examined off-line in a laboratory. This lack of real-time on-line monitoring of treatment performance means that situations can arise where operators are aware of problems in the treatment performance, but cannot determine the underlying causes of the problems or predict when they will occur.

Therefore, the monitoring and supervision of SBR processes are crucial to the detection and timely correction of faults. Prompt fault identification and correction is particularly necessary in biological processes because such processes may take days, weeks, or even months to recover from an abnormal state (Lennox et al., 2001; Nomikos and MacGregor, 1994). SBR is convenient for organics and nutrient removal. Sequencing batch reactor (SBR) that is enforced in the world for municipal and industrial wastewater treatment in the recent years was developed (Droste, 1997; Lin, 2001; Lee and Lin, 2000). The Sequencing Batch Reactor technology is applied in about 1.3% of the wastewater treatment plants in Germany (Teichgraber *et al.,* 2001). In Turkey, the textile industry comprises nearly 35% of total export and textile factories are known to vary in their treatment performance and efficiency. Also studies on these issues are still lacking (Aktan and Salih, 2006). Stable N removal via nitrite could be obtained through the control of the aeration time in a sequencing batch reactor (SBR) treating domestic wastewater. Aeration was stopped as soon as nitritation finished (i.e., complete oxidation of NH_4), as indicated by a bending point on the pH profile. An external carbon source (glucose) was added to enable denitrification in the following anoxic period. Clearly, the use of an external carbon source rather than the COD contained in wastewater for denitrification considerably undermines the overall benefits of the nitrite pathway (Romain L., Marcos M., Zhiguo Y., 2008).

Mathematical modeling has proven very useful to study complex processes, such as the aerobic granular sludge systems. Biological processes in the granules are determined by concentration gradients of oxygen and diverse substrates. The computational model used in this study is based on previously developed models. The SBR and granular sludge descriptions are principally which described heterotrophic organisms storing acetate (without phosphate accumulation) in a feast-famine regime in combination with autotrophic organisms for nitrogen removal (M.K. de Kreuk, C. Picioreanu, M. Hosseini, J.B. Xavier, M.C.M. van Loosdrecht, 2007). Conventional biological wastewater treatment plants do not easily degrade the dyes and polyvinyl alcohols (PVOH) in textile effluents. Results are reported on the possible advantages of anaerobic/aerobic cometabolism in sequenced redox reactors.

A six phase anaerobic/aerobic sequencing laboratory scale batch reactor was developed to treat a synthetic textile effluent (Shaw *et al.,* 2002). The SBR system could also be used to treat high nitrogen containing wastewater because such systems facilitate nitrogen removal by nitrification–denitrification. However, the operation with aerobic-SBR still has some problems such as the low settleability of bio-sludge, high excess sludge production under high organic loading or hydraulic loading and less increase in the removal efficiency due to the limitation of the increasing of bio-sludge (Lee and Lin, 2000). Sequencing batch reactor (SBR) systems have been proven to offer substantial benefits to alternative conventional flow systems for the biological treatment of both domestic and industrial wastewater. The SBR is a wastewater treatment system anomaly, because operationally it is extremely flexible in its ability to meet many different treatment objectives while physically it is very simple (Sheng-Bing *et al.,* 2007).

A sequencing batch reactor (SBR) has certain advantages over conventional activated sludge processes (ASP) for the treatment of complex wastewater. The SBR showed relatively more efficient performance over conventional suspended growth systems (Mohan *et al.,* 2005). The major elements of design that accomplish population dynamics control to prevent filamentous sludge bulking, cycle time, oxygen supply, biological nitrification, denitrification, phosphorous removal and solids-liquid separation need to be set in such away that sufficiently, optimal conditions are provided to permit the reactions and processes to take place (Novak *et al.,* 1997). SBR operation is divided in two major phases: aerobic and anoxic, to achieve total pollutants removal within minimum time. The nitrogen removal efficiency decreased gradually with increasing ammonium-loading rates at constant COD loading. Therefore, appropriate control of the carbon source concentration can stimulate the SND (simultaneous nitrification–denitrification) in a traditional SBR to optimize biological nutrient removal (Chiua *et al.,* 2007). The substrate removal kinetic of aerobic granules would be size-dependent. Smaller aerobic granules exhibited higher metabolic activity in terms of the substrate removal rate in SBR (Li and Liu, 2005).

The sequencing batch reactor (SBR) system can be applied for treatment of TWW containing vat dyes with high efficiency. The dye adsorption ability of bio-sludge was about the same, whether it acclimatized with the STWW with or without direct dyes. This may be because the direct dyes did not induce the dye adsorption ability of the bio-sludge. On successive dye adsorptions, the dye adsorption ability of bio-sludge gradually decreased with each subsequent replacement, but the deteriorated bio-sludge recovered adsorption ability when washed with surfactants, such as SDS, Tween 80 and Triton X-100 solutions. This is similar to the results from a previous study on heavy metal adsorption on biosludge, where the adsorption ability of bio-sludge was increased with an increase in sludge age (solids retention time (SRT). Biosludge from domestic wastewater treatment systems can be used as an adsorbent of direct dyes, as well as organic matter, due to the high adsorption ability of bio-sludge (Sirianuntapiboon *et al.,* 2007). Our objective is to look at the treatment of textile industry wastewater by sequencing batch reactor (SBR), kinetics theory and simulation of parameters.

2. Materials and methods

2.1. Laboratory Scaled Plant

A laboratory scaled plant was built in order to treat textile industry wastewater in a Sequencing Batch Bioreactor (SBR). The laboratory scaled plant was built by minimizing a Sequencing Batch Bioreactor unit which is a part of treatment plant where textile industry wastewater is treated. Active sludge (8.586 L) was taken from real scaled plant and a raw wastewater example (0.954 L) was used in the attempts. The flow scheme of the laboratory scaled plant is given in Fig. 1.

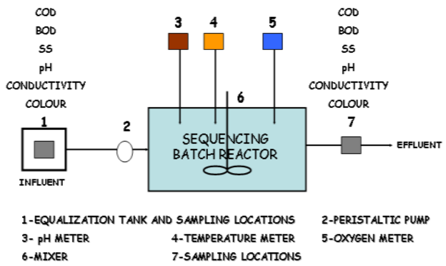


Fig. 1. Flow scheme of laboratory scaled plant

In this laboratory scaled plant experiment studies, treatment plant influent wastewater and active treatment sludge were used. These were taken from a treatment plant where synthetic textile industry wastewater was treated. Measurements of influent and effluent wastewater were carried out according to standard methods (APHA, 1995).

2.2. Study area

Also in this study, one packaged biological treatment plant such as sequencing batch reactor (SBR), has been used for treatment of textile wastewater. Flow rates of industrial and domestic wastewater are 940-2000 m^3d^{-1} and 40-100 m^3d^{-1}, respectively. There are three parallel bioreactors. Total and active volumes of each bioreactor are 1000 m^3 and 160 m^3, respectively. Flow chart of textile wastewater treatment plant has been shown in Fig. 2. Raw textile wastewater characteristics are such as BOD_5=300-3000 mgL^{-1}, COD=500-5000 mgL^{-1}, SS=10-50 mgL^{-1}, Sulphur=2 mgL^{-1}, pH=4-12, T=40 ^{0}C.

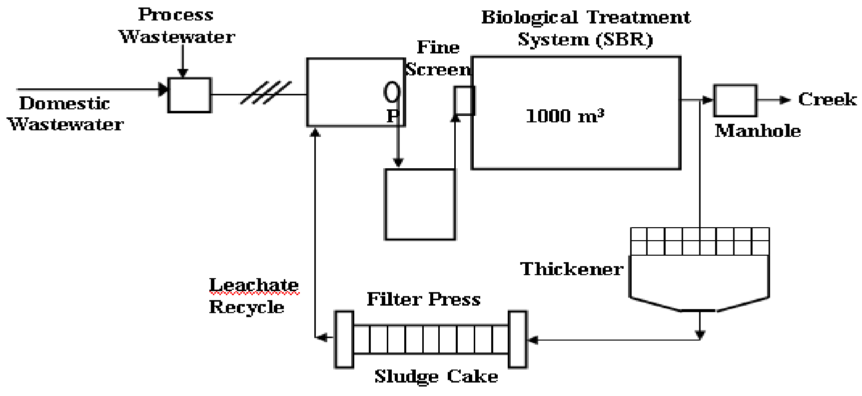


Fig. 2. Flow chart of wastewater treatment plant for textile

2.2. Theory

The substrate concentration remaining at the end of the period is a variable function of the volume and the kinetic expression for substrate removal that applies during the fill-period. The mass balance during the fill period is (Droste, 1997).

In – Out + Generation = Accumulation

$$Q\,S_o - 0 + r_{sf}\,V = \frac{d}{dt}(V\,S) \quad (1)$$

$$r_{sf} = -k\,S \quad (2)$$

Using Eq. (2) for r_{sf} , Eq. (1) becomes.

$$Q\,S_o \text{ - } k\,S\,V = S\,\frac{dV}{dt} + V\,\frac{dS}{dt}$$

The equation can be further simplified by recognizing that $dV / \mathrm{dt} = \mathrm{Q}$. Using this diving by V and rearranging the equation,

$$\frac{dS}{dt} + \frac{Q}{V}S + \mathrm{k}\,S = \frac{Q}{V}S_o \quad (3)$$

Q / V is $1 / t$. At the beginning of the fill period the reactor contains a volume V_a and $t = V_a / Q$; at the end of the fill period $t = V_b / Q$. The differential equation to be solved is.

$$\frac{dS}{dt} + \frac{S}{t} + k\,S = \frac{S_o}{t} \quad (4)$$

The equation is solved using an integrating factor. The solution of the equation is.

$$S = e^{-\int\left(\frac{1}{t}+k\right)dt} \int \frac{S_o}{t}\; e^{-\int\left(\frac{1}{t}+k\right)dt} dt + \mathrm{C}\,e^{-\int\left(\frac{1}{t}+k\right)dt}$$

where C is integrating constant.

$$S = \frac{S_o}{t} e^{-kt} \int e^{\mathrm{kt}}\, dt + \frac{C}{t} e^{-kt}$$

Performing the integration,

$$S = \frac{\mathrm{S_o}}{k\,t} + \frac{C}{t} e^{-k\,t}$$

(5)

Using the initial condition $t = V_a / Q$ and $S = S_e$.

$$S_e = \frac{S_o\,Q}{k\,V_a} + \frac{C\,Q}{V_a} e^{-k\left(\frac{V_a}{Q}\right)}$$

$$C = \left(\frac{V_a}{Q} S_e - \frac{S_o}{k}\right) e^{-k\left(\frac{V_a}{Q}\right)}$$

Making the substitution for C the final equation becomes.

$$S = \frac{S_o}{k\,t} + \left(\frac{\mathrm{V_a}}{\mathrm{Q}} S_e - \frac{\mathrm{S_o}}{k}\right)\frac{1}{t} e^{-k\left(\frac{Va}{Q} - t\right)} \qquad (6)$$

The substrate concentration at the end of the fill period can be found by using,

$$t_f = \frac{V_b}{Q} \quad \text{ve} \quad S = S_f$$

$$S_f = \frac{\mathrm{S_o}\,Q}{k\,V_b} + \left(\frac{V_a}{Q} S_e - \frac{S_o}{k}\right)\frac{Q}{V_b} e^{k\left(\frac{V_a}{Q} - \frac{V_b}{Q}\right)} \quad \text{or}$$

$$S_f = \frac{S_o\,Q}{k\,V_b} + \left(\frac{V_a}{V_b} S_e - \frac{Q\,S_o}{V_b\,k}\right) e^{k\left(\frac{-V_{ab}}{Q}\right)} \qquad (7)$$

For most of the substrate removal expression a numerical solution is required to solve the differential equation describing substrate removal during the fill period (Droste, 1997). Calculating the amount of removal during the react period is straightforward. The equation for substrate removal is integrated directly as in the case for PF. Using Eq. (2),

$$\frac{dS}{dt} = -k\,S$$

$$\int_{S_f}^{S_e} \frac{dS}{S} = -k \int_0^{t_r} dt \quad \text{or}$$

$$S_e = S_f\, e^{-k\,t_r} \qquad (8)$$

where, S_f is the substrate concentration at the end of the fill period.

S_e is the substrate concentration at the end of react period.

$$E_{EXPERIMENTAL} = \frac{S_0 - S_e}{S_0} \qquad (9)$$

If (7) and (8) numbered equations is put into the (9) numbered equation, the new equation for efficiency (E) of the treatment is obtained according to this study.

$$E_{MODEL} = 1 - \left[\frac{Q}{k.V_B}\left(1 - e^{-k.(\frac{V_{AB}}{Q})}\right).e^{-k.t_R} + \frac{V_A}{V_B.S_0}.S_e.(e^{-k(\frac{V_{AB}}{Q})}).(e^{-k.t_R})\right] \qquad (10)$$

Furthermore, in order to make comparison, by using the equation at the bottom, $E_{EXPERIMENTAL}$ values are obtained. As in the (10) numbered equation the parameters which effects E_{MODEL} are like that E=f (Q, k, V_A, V_B, V_{AB}, t_R, S_o, S_e).

One complete cycle is composed of the fill, react, settle, draw and idle periods (Droste, 1997; Irvine and Ketchum, 1988).

$$t_c = t_f + t_r + t_s + t_d + t_i \qquad (11)$$

where, the subscripts *c, f, r, s, d* and *i* indicate cycle, fill, react, settle, draw and idle, respectively.

In a sequencing batch reactor (SBR) system the fill time (t_f) for an individual reactor depends on the available volume in the reactor. The available volume is the total volume of the reactor less the portion occupied but the settled sludge remaining in the reactor after the previous cycle. In equation form (Droste, 1997):

$$V_{ab} = \alpha \mathrm{V_b}$$

(12)

$$t_f = \frac{V_{ab}}{Q} = \frac{\alpha V_b}{Q}$$

(13)

where, Q is the influent flow rate during the fill period.

α is the unoccupied fraction of the total volume of the batch reactor at the beginning of the fill period.

V_b is the volume of a batch reactor when t is empty.

V_{ab} is the available volume at the beginning of the fill period.

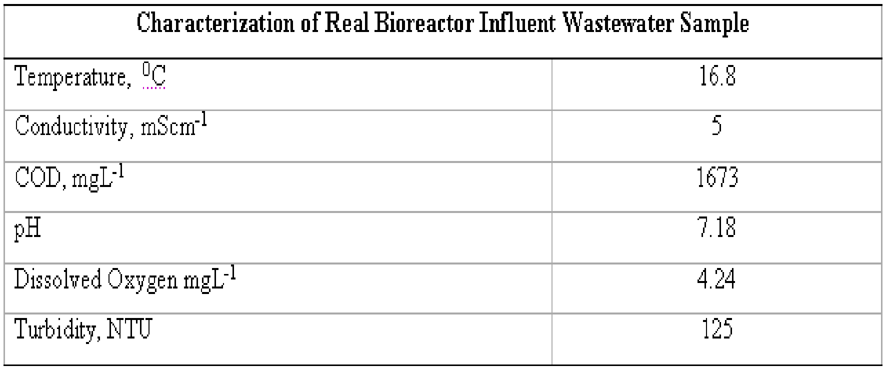
3. Results and discussion

3.1. Experimental results

3.1.1. Laboratory Scaled Plant

Reaction period (t_R)= 1.5 h and settlement period (t_S)=1.5 h are found from laboratory scaled plant studies and the studies continued working in laboratory scaled and real scaled plants on these values. In samples taken from real scaled plant at different times (S_{01}=1950 mgCODL^{-1} and S_{02}=958 mgCODL^{-1}) COD, turbidity and color parameters and removal efficiencies were examined (Damar, 2009). Characteristic of the wastewater used in laboratory scaled pilot plant is given in Table 1.

Table 1. Characteristics of wastewater used in laboratory scaled plant



Characterization of Real Bioreactor Influent Wastewater Sample	
Temperature, ^{0}C	16.8
Conductivity, mScm^{-1}	5
COD, mgL^{-1}	1673
pH	7.18
Dissolved Oxygen mgL^{-1}	4.24
Turbidity, NTU	125

In wastewater with 1950 mgCODL^{-1} influent concentration (I. Attempt), comparison of COD removal and treatment efficiency during reaction period (t_R) is given in Fig. 3. COD value measured in the system at t=0 moment is 1950 mgL^{-1} and t_F=0.5 h. As reaction began during filling time (t_F), t_R=1.5 h and t_F=0.5 h and at the end of 2 h period 80% removal was realized in the system.

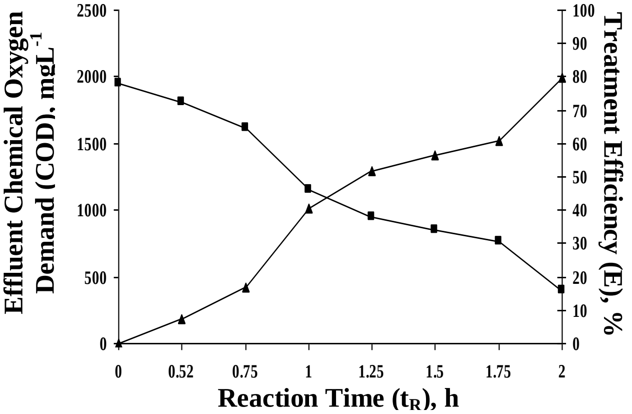


Fig. 3. In wastewater with 1950 mgCODL^{-1} influent concentration (I. Attempt), comparison of COD removal and treatment efficiency during reaction period (t_R)

In wastewater with 958 mgCODL^{-1} influent concentration (II. Attempt), comparison of COD removal and treatment efficiency during reaction period (t_R) is given in Fig. 4. COD value measured in the system at t=0 moment is 958 mgL^{-1} and t_F=0.5 h. As reaction began during filling time (t_F), t_R=1.5 h and t_F=0.5 h and at the end of 2 h period 70% removal was realized in the system.

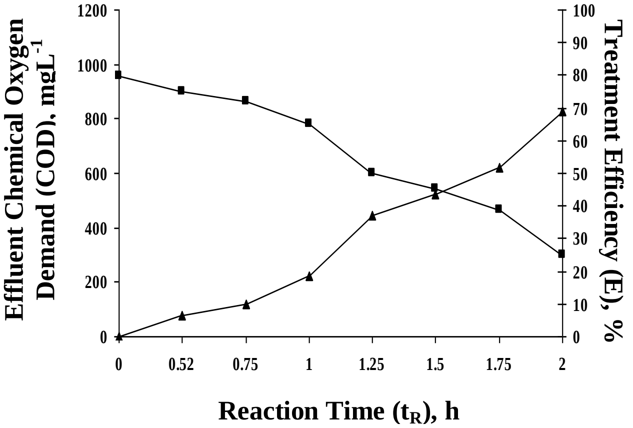


Fig. 4. In wastewater with 958 mgCODL^{-1} influent concentration (II. Attempt), comparison of COD removal and treatment efficiency during reaction period (t_R)

3.1.2. Study Area

Raw textile wastewater characteristics are such as BOD_5=300-3000 mgL^{-1}, COD=500-5000 mgL^{-1}, SS=10-50 mgL^{-1}, Sulphur=0.04-2 mgL^{-1}, pH=4-12, T=40 ^{0}C. Effluent concentrations from sequencing batch reactor (SBR) are determined BOD_5= 25-55 mgL^{-1}, COD=151-230 mgL^{-1}, SS= 4 mgL^{-1}, Sulphur= 0.021 mgL^{-1}, pH=7.5.

3.2. Simulation of parameters

An appropriate kinetic equation for Sequencing Batch Reactor (SBR) unit has been researched and simulation studies were made according to parameters' minimum, average and maximum values. In simulation studies, it has been observed that effect of parameters (S_o, Q, k, V_b, V_a, V_{ab}) on Sequencing Batch Reactor (SBR) effluent concentration (S_e) variation with reaction time (t_r). Effluent concentrations (S_e) have been determined using variable aeration times (t_r) applying equations (7) and (8) with choosing different values. Obtained values have been plotted. Average S_o, Q, k, V_b, V_a and V_{ab} parameters have been chosen from real treatment system and literature. Values of simulation parameters have been taken such as avarage when using one of the parameters' minimum, average and maximum values in equation (7).

For example, simulation values were formed for $S_{o\ min}$=300 mgL^{-1}, $S_{o\ ave}$=1650 mgL^{-1}, $S_{o\ max}$=3000 mgL^{-1}, whereas constant values where formed Q_{ave}=55 m^{3}h^{-1}, k_{ave}=0,275 h^{-1}, $V_{b\ ave}$=900 m^3, $V_{a\ ave}$=450 m^3, $V_{ab\ ave}$ =125 m^3. Calculations have been done using our computer program. In the result of calculations were obtained theoretical values.

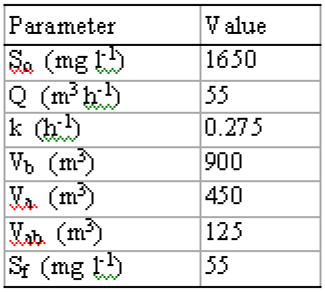
The combination of anaerobic and aerobic periods in the operation cycle of a Sequencing Batch Reactor (SBR) was chosen to study biological colour removal from simulated textile effluents containing reactive. 90% colour removal was obtained for the violet dye in a 24-h cycle with a Sludge Retention Time (SRT) of 15 days and an aerated reaction phase of 10 h (Lourenço et al., 2001).

An anaerobic–aerobic sequencing batch reactor with a sludge age of 8 days and anaerobic+aerobic+settling times of 18+5+1h, was used to decolorize an azo-reactive dye wastewater (Panswad et al., 2001).

3.2.1. Effect of influent substrate concentration (S_o)

S_o values such as $S_{o\ min}$=300 mgL^{-1}, $S_{o\ ave}$=1650 mgL^{-1} and $S_{o\ max}$=3000 mgL^{-1} were chosen. The values of parameter used in the model for textile industry has been given in Table 2. Effect of influent concentration (S_o) on variation of react time (t_r) with effluent concentration (S_e) has been shown in Fig. 5. When influent concentration (S_o) decreased the effluent concentration (S_e) decreased.

Table 2. The values of parameter used in the model for textile industry



Parameter	Value
S_o (mg l^{-1})	1650
Q (m^3 h^{-1})	55
k (h^{-1})	0.275
V_b (m^3)	900
V_a (m^3)	450
V_{ab} (m^3)	125
S_f (mg l^{-1})	55

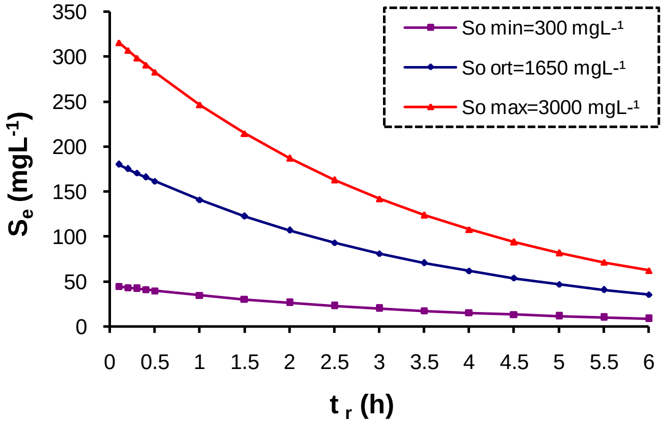


Fig. 5. Effect of influent concentration (S_o) on variation of react time (t_r) with effluent concentration (S_e)

3.2.2 Effect of influent flow rate during the fill period (Q)

Q values such as Q_{min}=10 m^{3}h^{-1}, Q_{ave}=55 m^{3}h^{-1} and Q_{max}=100 m^{3}h^{-1} were chosen. Effect of flow rate (Q) on variation of react time (t_r) with effluent concentration (S_e) has been shown in Fig. 6. When flow rate (Q) decreased the effluent concentration (S_e) decreased.

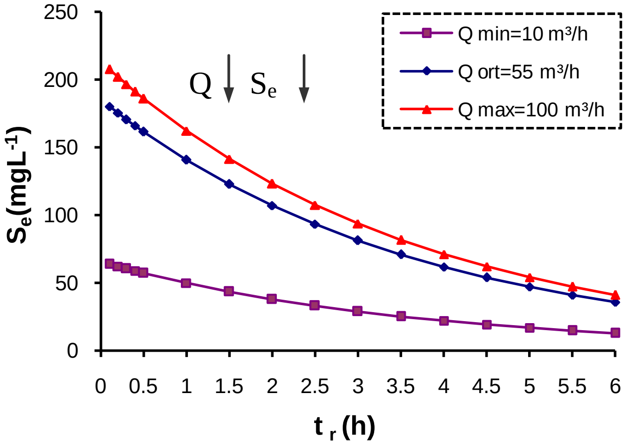


Fig. 6. Effect of flow rate (Q) on variation of react time (t_r) with effluent concentration (S_e)

3.2.3. Effect of reaction constant (k)

k values such as k_{min}=0,05 h^{-1}, k_{ave}=0,275 $h^{-1}$and k_{max}=0,5 h^{-1} were chosen. Effect of reaction constant (k) on variation of react time (t_r) with effluent concentration (S_e) has been shown in Fig. 7. When reaction constant (k) increased the effluent concentration (S_e) decreased.

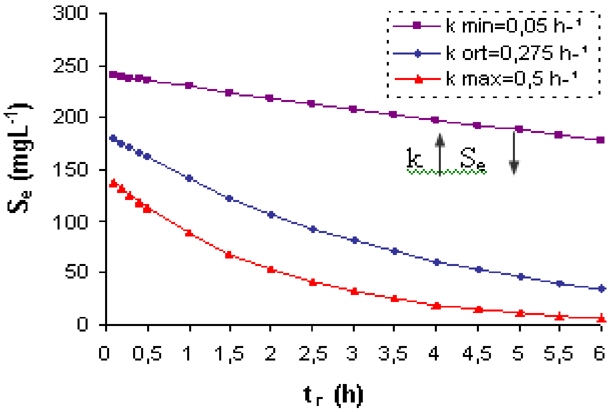


Fig. 7. Effect of reaction constant (k) on variation of react time (t_r) with effluent concentration (S_e)

3.2.4. Effect of volume of a batch reactor when is empty (V_b)

V_b values such as $V_{b\,min}$=800 m^3, $V_{b\,ave}$=900 m^3, $V_{b\,max}$=1000 m^3 were chosen. Effect of volume of a batch reactor when is empty (V_b) on variation of react time (t_r) with effluent concentration (S_e) has been shown in Fig. 8. When volume of a batch reactor when is empty (V_b) increased the effluent concentration (S_e) a few decreased.

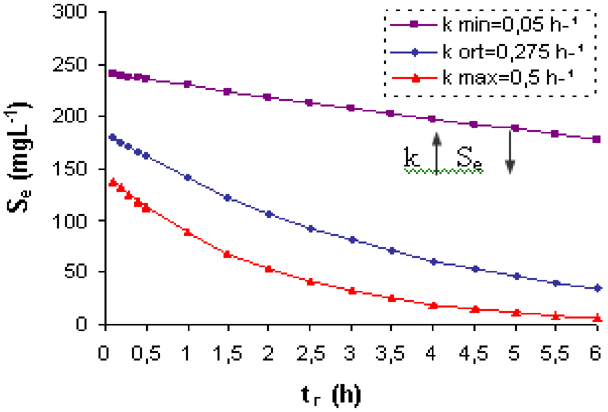


Fig. 8. Effect of volume of a batch reactor when is empty (V_b) on variation of react time (t_r) with effluent concentration (S_e)

3.2.5. Effect of volume of a batch reactor when is initially (V_a)

V_a values such as $V_{a\ min}$=300 m^3, $V_{a\ ave}$=450 m^3, $V_{a\ max}$=600 m^3 were chosen. Effect of volume of a batch reactor when is initially (V_a) on variation of react time (t_r) with effluent concentration (S_e) has been shown in Fig. 9. When volume of a batch reactor when is initially (V_a) decreased the effluent concentration (S_e) a few decreased.

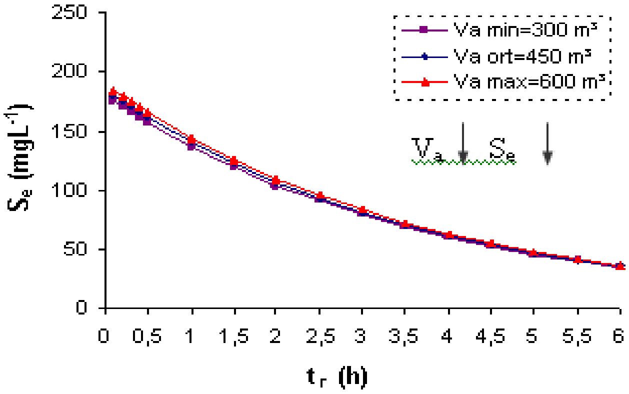


Fig. 9. Effect of volume of a batch reactor when is initially (V_a) on variation of react time (t_r) with effluent concentration (S_e)

effluent concentration (S_e)

3.2.6. Effect of available volume at the beginning of the fill period (V_{ab})

V_{ab} values such as $V_{ab\ min}$=50 m^3, $V_{ab\ ave}$=125 m^3, $V_{ab\ max}$=200 m^3 were chosen. Effect of available volume at the beginning of the fill period (V_{ab}) on variation of react time (t_r) with effluent concentration (S_e) has been shown in Fig. 10. When available volume at the beginning of the fill period (V_{ab}) decreased the effluent concentration (S_e) decreased.

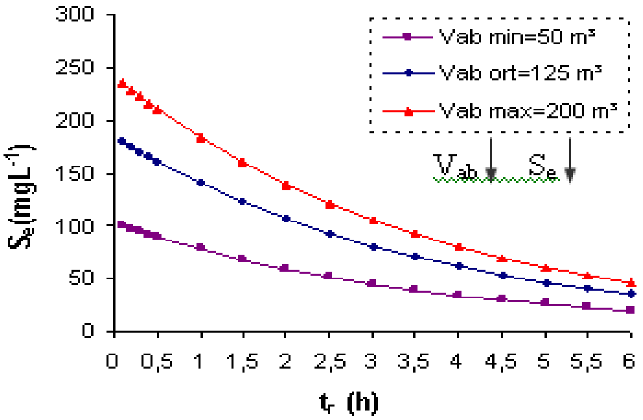


Fig. 10. Effect of available volume at the beginning of the fill period (V_{ab}) on variation of react time (t_r) with effluent concentration (S_e)

3.3. Relationship of parameters

Theoretical variation of effect parameters (S_o, Q, k, V_b, V_a, V_{ab}) on effluent BOD_5's (S_e) and interaction of these parameters were researched using equations (7) and (8). Ten different values with determined ranges were chosen for each parameter. Calculations have been done using our computer program. In the result of calculations were obtained theoretical values. Calculated values have been plotted and fitted graphics by Grapher program. Also, regression coefficient were determined and given suitable equations.

3.3.1. Relationship of influent concentration (S_o) and effluent concentration (S_e)

Relationship of influent concentration (S_o) and effluent concentration (S_e) has been shown in Fig. 11. Relationship of influent concentration (S_o) and effluent concentration (S_e) was increased-linear.

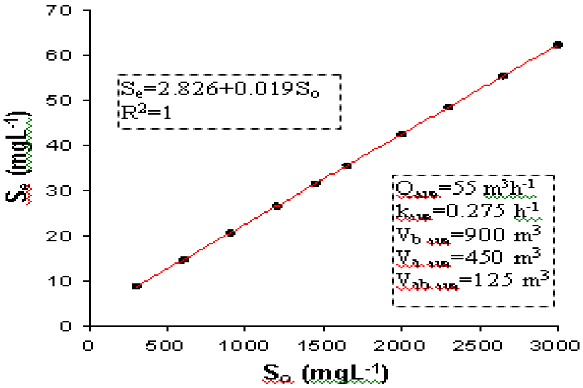


Fig. 11. Relationship of influent concentration (S_o) and effluent concentration (S_e)

3.3.2. Relationship of influent flow rate during the fill period (Q) and effluent concentration (S_e)

Relationship of influent flow rate during the fill period (Q) and effluent concentration (S_e) has been shown in Fig. 12. Relationship of influent flow rate during the fill period (Q) and effluent concentration (S_e) was increased-nonlinear.

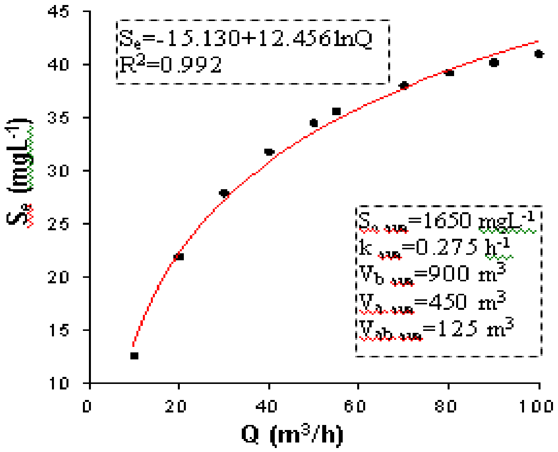


Fig. 12. Relationship of influent flow rate during the fill period (Q) and effluent concentration (S_e)

3.3.3. Relationship of reaction constant (k) and effluent concentration (S_e)

Relationship of reaction constant (k) and effluent concentration (S_e) has been shown in Fig. 13. Relationship of reaction constant (k) and effluent concentration (S_e) was decreased-nonlinear.

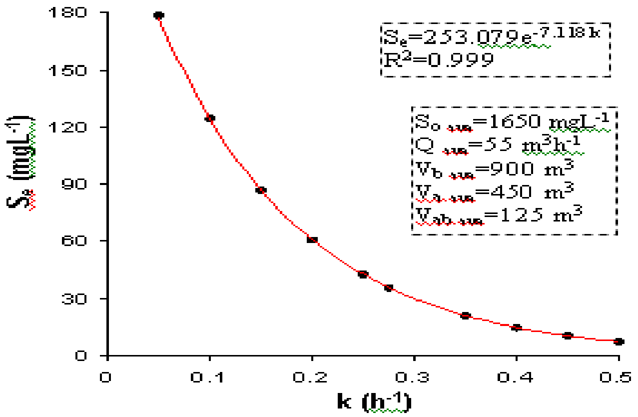


Fig. 13. Relationship of reaction constant (k) and effluent concentration (S_e)

3.3.4. Relationship of volume of a batch reactor when is empty (V_b) and effluent concentration (S_e)

Relationship of volume of a batch reactor when is empty (V_b) and effluent concentration (S_e) has been shown in Fig. 14. Relationship of volume of a batch reactor when is empty (V_b) and effluent concentration (S_e) was decreased-linear.

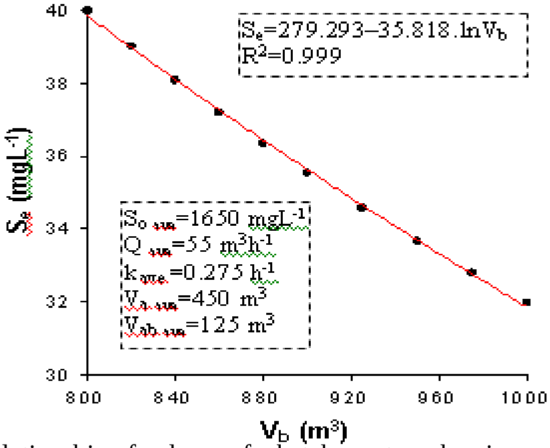


Fig. 14. Relationship of volume of a batch reactor when is empty (V_b) and effluent concentration (S_e)

3.3.5. Relationship of volume of a batch reactor when is initially (V_a) and effluent concentration (S_e)

Relationship of volume of a batch reactor when is initially (V_a) and effluent concentration (S_e) has been shown in Fig. 15. Relationship of volume of a batch reactor when is initially (V_a) and effluent concentration (S_e) was increased-linear.

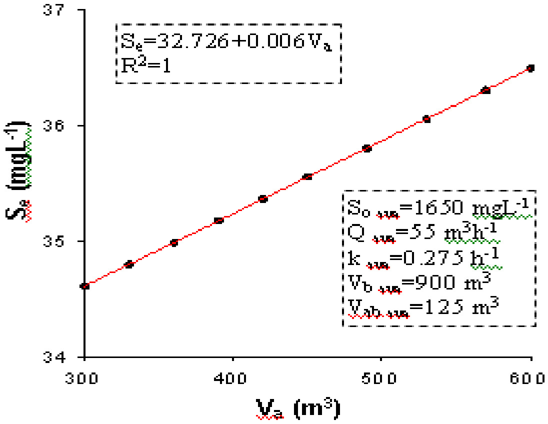


Fig. 15. Relationship of volume of a batch reactor when is initially (V_a) and effluent concentration (S_e)

3.3.6. Relationship of available volume at the beginning of the fill period (V_{ab}) and effluent concentration (S_e)

Relationship of available volume at the beginning of the fill period (V_{ab}) and effluent concentration (S_e) has been shown in Fig. 16. Relationship of available volume at the beginning of the fill period (V_{ab}) and effluent concentration (S_e) was increased-linear.

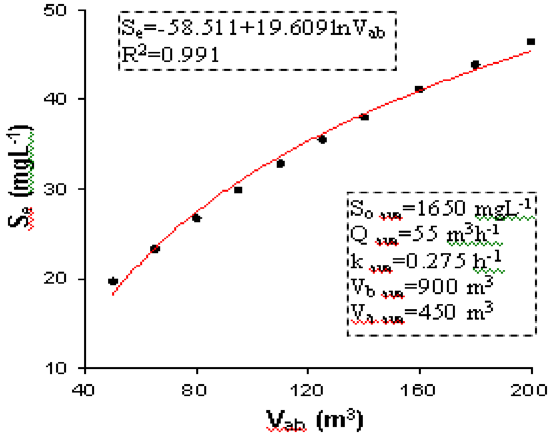


Fig. 16. Relationship of available volume at the beginning of the fill period (V_{ab}) and effluent concentration (S_e)

3.4. Comparison of the theory with experimental results

Comparison of experimental with theoretical effluent concentration according to different aeration times for textile industry has been given Table 3. As seen as in Table 2, average effluent concentration (S_e) has been obtained 43 mg BOD_5/l during 1.5 hours of aeration time and of 1.5 hours of sedimentation time for sequencing batch reactor (SBR). Kinetics of treatment for sequencing batch reactor (SBR) are a quick event most of which takes places within the first one hour. Kinetics are as slow event after one hour. These results have been obtained from both experimental with theoretical studies. Comparison of experimental with theoretical effluent concentration according to different aeration times for textile industry has been shown in Fig. 17. In addition, results of experimental and theoretical studies are close to each other.

Table 3. Comparison of experimental with theoretical effluent concentration according to different aeration times for textile industry

t_k (h)	**Theoretical S_e (mgl^{-1})**	**Experimental 1 S_e (mgl^{-1})**	**Experimental 2 S_e (mgl^{-1})**
0	350	350	350
0.5	51.2	121	79
1	46.1	79	45
1.5	41.5	55	30
2	37.4	44	29
2.5	33.6	-	28
3	30.3	36	27
3.5	27.2	-	-
4	24.6	32	26
4.5	22.1	-	-
5	19.9	30	25
5.5	17.9	-	-
6	16.1	23	20

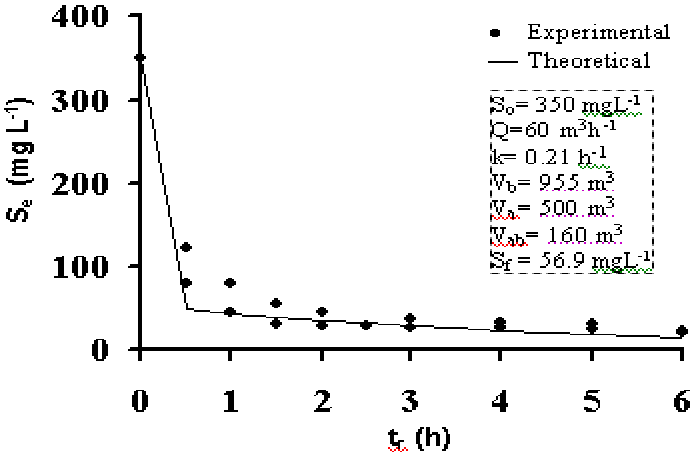


Fig. 17. Comparison of experimental with theoretical effluent concentration according to different aeration times for textile industry

4. Conclusions

The fraction of aerobic granules in the reactors seems to be related to the settling time the settling time of SBR may represent the magnitude of hydraulic selection pressure exerted on microbial community (Qin *et al.,* 2004). For aerobic granules with a size smaller than 0.4 mm, no diffusion limitation of substrate and dissolved oxygen occurred. However, when aerobic granules grew to a size larger than 0.5 mm, dissolved oxygen became a major limiting factor of metabolic activity of aerobic granule over substrate. These imply that the optimal size of aerobic granule would be less than 0.5 mm in the sense of mass transfer. It was revealed that the substrate removal rate was inversely related to the size of aerobic granules, the substrate removal rate by aerobic granules with a size of 0.5 mm was almost three times of that by aerobic granules with a size of 1 mm (Li and Liu, 2005).

In this study; variation of effluent BOD_5's (S_e) with reaction time (t_r) in Sequencing Batch Reactor (SBR) unit for textile industry wastewater treatment plant and effective parameters on this variation have been researched. According to obtained graphics from the results of simulation studies for chosen equation parameters, S_o, Q, k and V_{ab} were effective but V_b and V_a were a few effective.

In addition, theoretical variation of effect parameters (S_o, Q, k, V_b, V_a, V_{ab}) on effluent BOD_5's (S_e) and interaction of these parameters were determined. Relationship of influent concentration (S_o) and effluent concentration (S_e) was increased-linear. Relationship of influent flow rate during the fill period (Q) and effluent concentration (S_e) was increased-nonlinear. Relationship of reaction constant (k) and effluent concentration (S_e) was decreased-nonlinear. Relationship of volume of a batch reactor when is empty (V_b) and effluent concentration (S_e) was decreased-linear. Relationship of volume of a batch reactor when is initially (V_a) and effluent concentration (S_e) was increased-linear. Relationship of available volume at the beginning of the fill period (V_{ab}) and effluent concentration (S_e) was increased-linear.

As a conclusion, the optimum treatment efficiency has been taken under 1.5 hours of aeration time and of 1.5 hours of sedimentation time. Fill, draw and idle times have been taken such as 1 hour. Total time for one cycle is 4 hours. The treatment system has been operated 6 cycles per day. Volume of wastewater 160 m^3 has been treated in an each cycle. Treated wastewater is totally 960 m^3d^{-1} for each tank. Average effluent concentration (S_e) has been experimentally determined 43 mg BOD_5/L during 1.5 hours of aeration time and of 1.5 hours of sedimentation time for sequencing batch reactor. Average effluent concentration (S_e) has been theoretically determined 41.5 mg BOD_5/L at the same conditions for sequencing batch reactor. It has been observed that results of experimental and theoretical studies are close to each other.

This method of Sequencing Batch Reactor offers a significant improvement for the treatment of textile wastewater and this theory can be used to help define Sequencing Batch Reactor (SBR) kinetics with the optimum operational characteristics.

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Notation

C	Integrating constant
Q	The influent flow rate during the fill period (m^3 h^{-1})
V	Volume (m^3)
V_a	The volume of a batch reactor when is initially (m^3)
V_b	The volume of a batch reactor when is empty (m^3)
V_{ab}	The available volume at the beginning of the fill period (m^3)
S	The substrate concentration (mg L^{-1})
S_f	The substrate concentration at the end of the fill period (mg L^{-1})
S_e	The substrate concentration at the end of react period (mg L^{-1})
S_o	The substrate concentration at the beginning of cycle period (mg L^{-1})
t	Time (h)
t_c	In a sequencing batch reactor system the cycle time (h)
t_d	In a sequencing batch reactor system the draw time (h)
t_f	In a sequencing batch reactor system the fill time (h)
t_i	In a sequencing batch reactor system the idle time (h)
t_r	In a sequencing batch reactor system the react time (h)
t_s	In a sequencing batch reactor system the settle time (h)
α	The unoccupied fraction of the total volume of the batch reactor at the beginning of the fill period
r_{Sf}	The rate of substrate removal during the fill period (mg $L^{-1}h^{-1}$)
k	reaction constant (h^{-1})