International Journal of Civil Engineering Research and Development (IJCERD)

ISSN 2248 – 9428(Print)
ISSN 2248 – 9436(Online)
Volume 4, Number 2, April - June (2014), pp. 51-58
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IJCERD

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DETERMINATION OF BIO-KINETIC PARAMETERS FOR SEQUENCING BATCH REACTOR TYPE SEWAGE TREATMENT PLANT

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ABSTRACT

The SBR is basically a single tank that serves both as a biological reactor and settler in a temporal sequence; whereas aeration and settling are simultaneous but in a spatial sequence in the continuous-flow activated sludge, they are carried out in the same reactor but in a temporal sequence in the SBR systems. SBR inherently involves a cyclic operation, each cycle incorporating the same pattern of successive selected phases. The objective of the study is determination of Bio-kinetic parameters for SBR type Sewage Treatment Plant. The system was operated under 5 different biomass retention time. The samples from the influent wastewater, mixed liquor and effluent were collected periodically and experimented by the Standard Methods. The data were analyzed and the investigation showed that the the kinetic parameters, yield coefficient (Y), organism decay rate (K_d), BOD removal rate (k), half-velocity constant i.e., substrate concentration at one half the maximum growth rate (k_s) and maximum specific growth rate (μ_m) which governs the treatment process were found to be 0.67, 0.021 d^{-1}, 0.219 d^{-1}, 80.88 mg/l and 0.147 d^{-1} respectively. These values are near to the normal range of bio-kinetic values for activated sludge. The higher value of sludge yield (Y) and lower value of organism decay (K_d) shows that there is extremely higher production of excess sludge in the plants. Optimum sludge removal at frequent intervals has to be designed and sludge disposal mechanism has to be developed. A major finding determined from this study is that biomass retention time can be considered for operation control instead of adjusting the MLSS. The biomass retention time can be computed from the sludge wasting. As the computed wasting rate increases, more solids are removed from the system. Selection of optimum of biomass retention time will make system self stabilizing.

Index Terms: Wastewater treatment; Bio-kinetic coefficient; Sequencing Batch Reactor; Solid / Biomass retention time.

I. INTRODUCTION

According to the United Nations report on world water developments (UNO, 2006), lots of cities suffer from water scarcity, depletion or pollution already, however the urban water demand still increases rapidly. Water can be easily stocked, but is more difficult to transport. Consequently, local water availability must be enhanced. In developed countries water is use is in a range of 100 to 150 lpcd and wastewater represents 60-70 % of this amount (Friedler et al., 2005). Wastewater reuse plays an important role in the sustainable water management approach and is significant.

Sewage Treatment Plants (STPs) are supposed to make the municipal sewage compatible for disposal into the environment (surface and underground water bodies or land), to minimize the environmental and health impacts of the sewage, and to make the sewage fit for recycling and reuse (agricultural and aqua-cultural uses and municipal and industrial uses).Various types of sewage treatment technologies are available for the treatment of sewage. One of the advanced technologies available is Sequencing Batch Reactor type.

This technology is suitable for the city corporations and metropolitan cities since it occupies less space.

The sequencing batch reactor (SBR) is a fill-and draw activated sludge system for wastewater treatment. In this system, wastewater is added to a single “batch” reactor, treated to remove undesirable components, and then discharged. Equalization, aeration, and clarification can all be achieved using a single batch reactor. To optimize the performance of the system, two or more batch reactors are used in a predetermined sequence of operations. A number of process modifications have been made in the times associated with each step to achieve specific treatment objectives (USEPA, 1986).

Being a very popular technology SBR was not frequently used for the treatment of wastewater like activated sludge process (ASP). In Indian School of Mines, Centre of Mining Environment Danbad, a study has been carried out where SBR was used for capacity expansion of existing ASP plant and was converted to SBR. As per USEPA (1985) cost for SBR is same as oxidation ditch and 20 % less than ASP. In terms of energy use, SBR is 13.5 % more efficient than oxidation ditch. There is not a single pilot scale SBR study reported in India. So far only few case studies are presently available to use SBR efficiently for capacity expansion of existing overloaded wastewater treatment plants (Maithi, 2007).

The SBR is basically a single tank that serves both as a biological reactor and settler in a temporal sequence; whereas aeration and settling are simultaneous but in a spatial sequence in the continuous-flow activated sludge, they are carried out in the same reactor but in a temporal sequence in the SBR systems SBR inherently involves a cyclic operation, each cycle incorporating the same pattern of successive selected phases. As contrasted to continuous-flow systems, wastewater feeding is provided during the desired portions of the cycle which then secures a batch wise, fill-and-draw type of an operation.

The fill-and-draw scheme, constituting the basic principle of the SBR system was the essential instrument that initiated the development of the original activated sludge, an excellent review of the historical evolution of the activated sludge process was recently presented by Wilderer et al (2001).

Performance of SBR is typically comparable to conventional, activated sludge systems and depends on system design and sight specific criteria. Depending on their mode of operation, SBRs can achieve good BOD and nutrient removal. SBR will produce an effluent of less than 10 mg/l of BOD (USEPA, 1999). The design F/M ratio and MLSS concentrations for SBRs should be similar to other conventional and extended aeration processes (Terry et al, 2000). Regardless this trend an intensive literature survey showed the lack of information for bio-kinetic parameters in wastewater treatment, which is needed for proper plant design (R.Scheumann et al, 2008).

Sludge wasting is important step in the SBR operation that greatly affects performance. In SBR operation, sludge wasting usually occurs during the settle phase. If Bio-kinetic parameters are known, the SBR plant can be sized, controlled and operated properly (Metcalf & Eddy., 1995). Studies of Bio-kinetic parameters of aerobic biological treatment yields the rate at which microorganisms, degrade a specific waste and therefore provides the basic information required for sizing biological aerobic reactors. (Moises et al, 2001)

The objective of the study is determination of Bio-kinetic parameters for SBR type Sewage Treatment Plant.

II. METHODOLOGY

The methodology described by HenrykMelcer et al, 2003 was adopted for operating bench scale SBR. A single cycle SBR operation consists of five operating modes or periods. The periods are fill, react, waste, settle and draw (decant), in sequence. The SBR is operated on the basis of a 24 hr cycle, with a selected maximum volume. The volume of supernatant (effluent) withdrawn after the settle period is equal to the volume of wastewater added at each cycle, less that wasted. At start up, the system should was seeded with a mass of microorganisms from an activated sludge system. Quasi-steady state conditions are achieved by repeating the following 24-hour cycle of actions over a period of time:

1. At the start of each cycle, a fixed volume of wastewater of a specified COD concentration is added to the reactor (FILL).
2. After the “instantaneous” fill, the contents of the reactor were aerated for a period of 23 and 1/2 hours (REACT).
3. At the end of react period, a fixed volume of mixed liquor was wasted from the reactor for maintaining a constant sludge age, fixed reactor volume is wasted directly from the reactor. The mixed liquor wastage provides samples volume for analysis.
4. After wastage, the air supply was turned off and the sludge was allowed to settle for a period of approximately 30 minutes (SETTLE).
5. At the end of the settle period, the treated effluent (supernatant) was withdrawn from the reactor (DRAW), leaving the settled sludge at the bottom of the reactor.

Five bench-scale sequencing batch reactors with a working volume of 5 liters each were used. The reactors operated with a hydraulic retention time (HRT) of 24 h. Each bench-scale reactor was operated at different solid (biomass) retention time i.e., 10 days, 8 days, 6 days, 4 days and 2 days. At the end of the aerobic period, definite volume of sludge, as necessary in each case, was removed from the reactors. Aerobic conditions were achieved by compressed air supply at the rate of 1.5 lts / min.

The reactor performance was monitored throughout the experimental period every day through the determination of BOD, COD, solids, nitrogen and phosphorus. The samples were obtained from the synthetic wastewater storage tank, mixed liquor during sludge waste and at the end of the cycle from the withdrawn wastewater. The SBRs were operated for a period of 20 days.

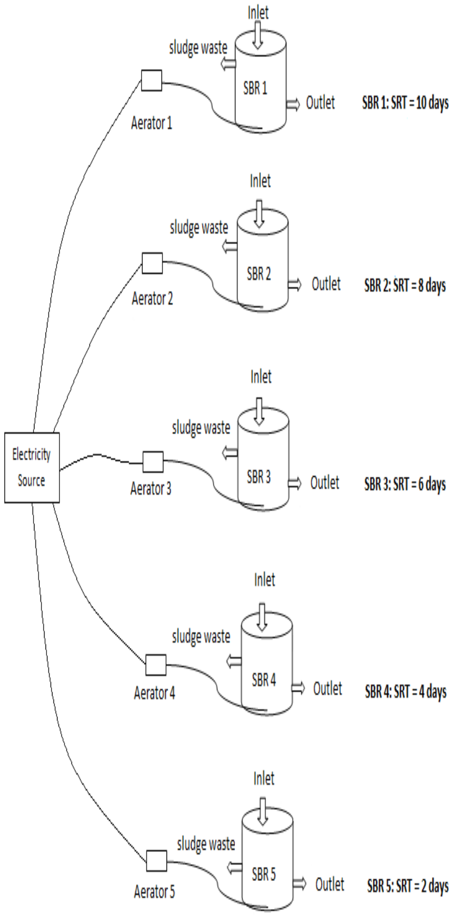

Figure 1: Experimental set-up for bench scale Sequencing Batch Reactor

To determine the parameters 'Y', the yield coefficient, 'K' BOD removal rate coefficient, 'K_d', the organism decay coefficient 'K_s'', half velocity constant i.e., substrate concentration at one-half the maximum growth rate and 'μ_m', maximum specific growth rate, the basic mathematical relationship proposed by Monad was used. The rate of substrate utilization was derived as below:

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

Dividing the above equation by x yields

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

The linearized form of this equation was obtained by taking its inverse:

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

The values of K_s and K was determined by plotting the term ($X\Theta/S_0$-S) versus (1/s)

Similarly, in order to determine the values of ‘Y’ and K_d following pseudo-first order equation was used:

$$\frac{1}{\theta_c} = Y\frac{r_{su}}{X} - K_d$$

Substituting the expression for r_{su} given above, the resultant expression is given as:

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

By plotting $1/\Theta_c$ versus $(S_0-S)/X\Theta$, slope of the line passes through the plotted experimental datum point gives “Y” and intercept equals to K_d.

To determine μ_m, equation $K = \frac{\mu_m}{Y}$ was adopted and the maximum specific growth rate (μ_m) was determined by multiplication of K and Y.

III. RESULTS

The average values from the results obtained during the experiments and date required for determining the bio-kinetic coefficients are provided in the following tables:

Table 1: Average values of the results of reactor performance to determine bio-kinetic coefficients

Biomass Retention Time Θc (day)	Hydraulic Retention Time Θ (day)	MLSS X (mg/l)	BOD S_0 (mg/l)	BOD S (mg/l)	Removal efficiency
10	1	3899	302.60	32.2	89%
8	1	3489	302.60	58.9	81%
6	1	2745	302.60	72.6	76%
4	1	1902	302.60	98.6	67%
2	1	608.5	302.60	102.4	66%

Table 2: Computation of Data for determining Bio-kinetic Coefficients

Reactor	$X\Theta$ (mg/l d)	$\frac{X\Theta}{(S_0 - S)}$ (d)	$\frac{1}{S}$ [(mg/l)$^{-1}$]	$\frac{(S_0 - S)}{X\Theta}$ (d^{-1})	$\frac{1}{\Theta_c}$ (d^{-1})
SBR1	3899	14.42	0.031	0.069	0.1
SBR2	3489	14.32	0.017	0.07	0.125
SBR3	2745	11.93	0.014	0.084	0.167
SBR4	1902	9.324	0.01	0.107	0.25
SBR5	608.5	3.039	0.01	0.329	0.5

The data presented above were fitted in the linear equations arrived at for determination of bio-kinetic coefficients. Graphical representation is given below:

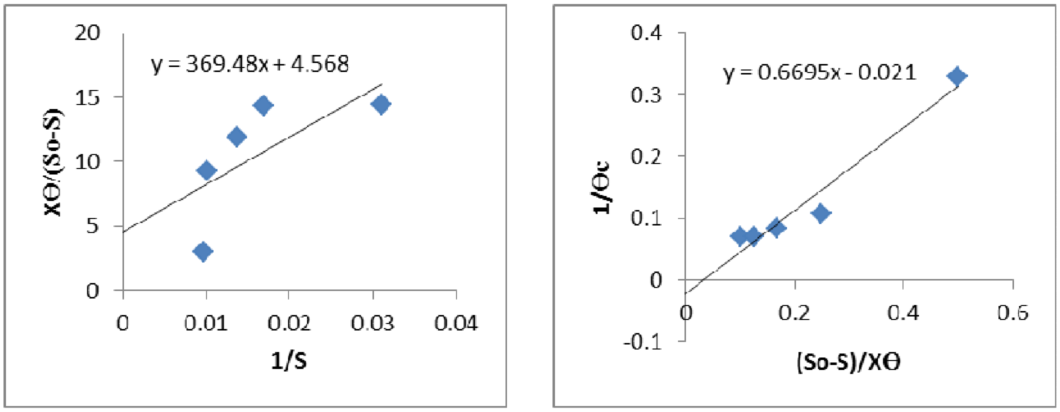

Figure 2 & 3: Plots for determination of Bio-kinetic coefficients

The bio-kinetic coefficients determined from the study are given in the table below:

Table 3: Bio-kinetic coefficients determined from the study

Coefficient	Basis	Value
K	/day	0.219
K_s	mg/l BOD	80.88
Y	mg VSS/mg BOD	0.67
K_d	/day	0.021
μ_m	/day	0.147

The influence of change in Biomass Retention Time on removal of COD, nitrate, phosphates and suspended solids in the bench scale Sequencing Batch Reactor were also analyzed. It was observed that with increase in the biomass retention time, the removal efficiency of these parameter increases and their concentration reduces.

IV. CONCLUSION

The kinetic parameters, yield coefficient (Y), organism decay rate (K_d), BOD removal rate (k), half-velocity constant i.e., substrate concentration at one half the maximum growth rate (k_s) and maximum specific growth rate (μ_m) which governs the treatment process were found to be 0.67, 0.021 d^{-1}, 0.219 d^{-1},80.88 mg/l and 0.147 d^{-1} respectively. These values are near to the normal range of bio-kinetic values for activated sludge. The higher value of sludge yield (Y) and lower value of organism decay (K_d) shows that there is extremely higher production of excess sludge in the plants. Optimum sludge removal at frequent intervals has to be designed and sludge disposal mechanism has to be developed.

With the increase in biomass retention time, improvement in BOD removal was observed. Hence, higher biomass retention time of the order of 8 days and 10 days can be considered as optimum for requisite BOD removal efficiency.

The values of the bio-kinetic coefficients vary significantly on daily basis. This variability does not follow a definite pattern. This could be attributed to nature of the process itself, as it could be a selective one and the bio-kinetic coefficients obtained may represent different species. Same has been concluded by Sh. Mardani et al, 2010 while determining bio-kinetic coefficients for activated sludge process.

From the study it is evident that the K_d and K_s are directly proportional to the effluent substrate concentration, while μ_m is inversely proportional to the effluent substrate concentration, which is also documented by Rahman and Al-Malack, 2012.

A major finding determined from this study is that biomass retention time can be considered for operation control instead of adjusting the MLSS. The biomass retention time can be computed from the sludge wasting. As the computed wasting rate increases, more solids are removed from the system. Selection of optimum of biomass retention time will make system self stabilizing.

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