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"Analysis of Performance and Life Cycle Cost of Sequencing Batch Reactor A- Literature Review"

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Abstract: *Currently population is increasing and due to increment of population, wastewater also increasing So now treatment of wastewater is measure task. Nowadays Sequencing batch reactor is the most efficient method of treatment of wastewater. Sequencing batch reactor(SBR), due to its operational flexibility and excellent process control possibilities are extensively used for wastewater treatment which is including highly polluted water due to chemicals. This study investigates the performance analysis (Such as Bio Chemical Demand, Chemical oxygen Demand (COD) parameter, etc.) of SBR treatment plant waste water and the possible reuse for irrigation purpose. This study also provides knowledge about process of SBR and life cycle cost analysis of SBR treatment plant.*

Keywords: *SBR (sequencing batch reactor), BOD(bio-chemical oxygen demand), COD (Chemical oxygen Demand), anaerobic digester, Aeration, reactor)*

I. Introduction

Sequencing batch reactors (**SBR**) or **sequential batch reactors** are a type of activated sludge process for the treatment of wastewater. SBR reactors treat wastewater such as sewage or output from anaerobic digesters or mechanical biological treatment facilities in batches. Oxygen is bubbled through the mixture of wastewater and activated sludge to reduce the organic matter (measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD)). The treated effluent may be suitable for discharge to surface waters or possibly for use on land.

Sequencing batch reactors or SBRs use a separate pre-treatment section to mechanically hold back solids and a biological aeration and settling tank. Small SBR wastewater treatment systems clean incoming wastewater over a number of cycles. GRAF products achieve a cleaning performance of up to 98 %. In this respect the GRAF Klaro E Professional far surpasses legal minimum requirements.

Conventional activated sludge process (ASP) is not designed to remove nitrogen. Further, due to its short detention time, the sludge produced is not well digested warranting an additional sludge digestion treatment. Since the 1970s, a modification of the conventional activated sludge process has made the emergence of the sequencing batch reactor (SBR) process. Conventional ASP systems are space oriented. Wastewater flow moves from one tank into the next on a continuous basis and virtually all tanks have a predetermined liquid volume. The SBR, on the other hand, is a time-oriented system, with flow, energy input, and tank volume varying according to some predetermined, periodic operating strategy. Hence, SBR is best defined as a time-oriented, batch process, falling under the broad category of an unsteady-state activated sludge system.(**Vigneswaran, Sundaravadivel and Chaudhary, AUSTRAILA)**

1.1International status

TR-16 Guides for the Design of Wastewater Treatment Works is one of the most requested documents produced by the New England Interstate Water Pollution Control Commission. However, there is a need for supplemental information to address the design of sequencing batch reactor (SBR) wastewater treatment facilities. SBRs are becoming popular wastewater treatment options in New England and across the country due to their ability to treat varying flow rates and allow control flexibility. In addition, they have a small footprint and are potentially less expensive to construct and operate.(NEW ENGLAND INTERSTATE WATERPOLLUTION CONTROL COMMISSION, Poltak 2005)

SBR process is a widely used water treatment method in the developed countries from quite a long time. It has become popular in India, China, and other Asian countries in the recent years. When sewage is sent to the SBR Tank (also known as Reaction tank) one batch at a time, an activated sludge process gets activated. Timed sequence of operations occurs in the SBR tank and water gets purified. Here is the timed sequence if events:(Wikipedia)

Current interest in sequencing batch treatment of wastewater would appear to be a return to the original notion of the activated sludge process. The first notable, but shortlived, resurgence of interest in batch biological treatment occurred in the early 1950s when Porges (1955) and his co-workers first studied batch operation of ASP system for treating dairy wastewaters. The second resurgence occurred in the 1970s with the efforts of Irvine and his co-workers investigating the suitability of batch biological processes (Dennis et al., 1979; Irvine et al., 1977; Irvine and Richter, 1976). Around the same period, interest in the batch operated biological treatment systems surfaced also in Australia (Goronszy, 1979). The system developed in Australia was based on the original Passive oxidation ditch concept, where a single reaction vessel took the form of an endless loop of shallow ditch in which inflow, aeration, settlement and discharge followed a specific cycle.

II. Treatment process of SBR

Basically SBR is a type of Activated sludge Process. But SBR process undergo in single basin or a tank. All the treatment steps occurs in a single tank.

Steps of SBR process

- FILL
- REACT
- SETTLE
- DECANT
- IDLE

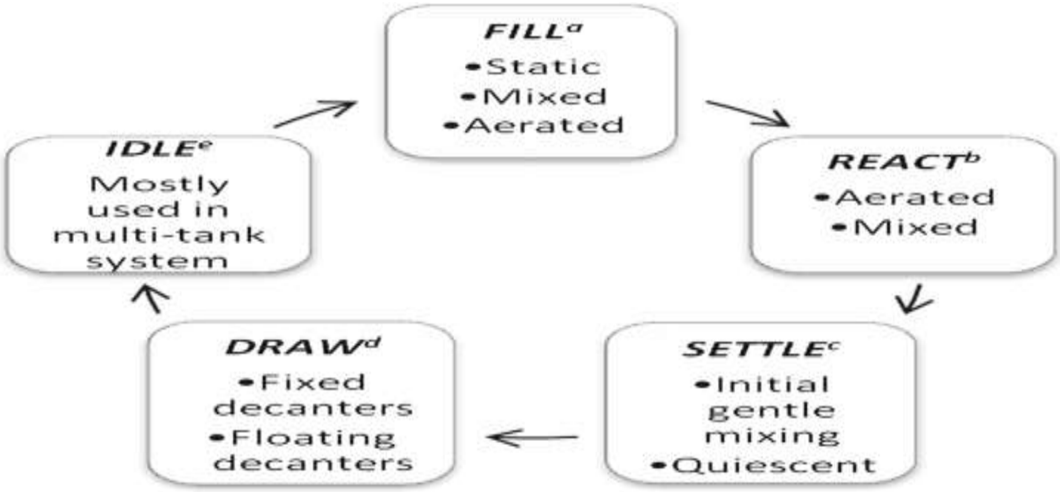

Fig.1 (NEW ENGLAND INTERSTATE WATERPOLLUTION CONTROL COMMISSION, Poltak 2005)

2.1 FILL

During the fill phase, the basin receives influent wastewater. The influent brings food to the microbes in the activated sludge, creating an environment for biochemical reactions to take place. Mixing and aeration can be varied during the fill phase to create the following three different scenarios:

Static Fill – Under a static-fill scenario, there is no mixing or aeration while the influent wastewater is entering the tank. Static fill is used during the initial start-up phase of a facility, at plants that do not need to nitrify or denitrify, and during low flow periods to save power. Because the mixers and aerators remain off, this scenario has an energy-savings component.

Mixed Fill – Under a mixed-fill scenario, mechanical mixers are active, but the aerators remain off. The mixing action produces a uniform blend of influent wastewater and biomass. Because there is no aeration, an anoxic condition is present, which promotes denitrification. Anaerobic conditions can also be achieved during the mixed-fill phase. Under anaerobic conditions the biomass undergoes a release of phosphorous. This release is reabsorbed by the biomass once aerobic conditions are re-established. This phosphorous release will not happen with anoxic conditions.

Aerated Fill – Under an aerated-fill scenario, both the aerators and the mechanical mixing unit are activated. The contents of the basin are aerated to convert the anoxic or anaerobic zone over to an aerobic zone. No adjustments to the aerated-fill cycle are needed to reduce organics and achieve nitrification. However, to achieve denitrification, it is necessary to switch the oxygen off to promote anoxic conditions for denitrification. By switching the oxygen on and off during this phase with the blowers, oxic and anoxic conditions are created, allowing for nitrification and denitrification. Dissolved oxygen (DO) should be monitored during this phase so it does not go over 0.2 mg/L. This ensures that an anoxic condition will occur during the idle phase.

2.2 REACT

This phase allows for further reduction or "polishing" of wastewater parameters. During this phase, no wastewater enters the basin and the mechanical mixing and aeration units are on. Because there are no additional volume and organic loadings, the rate of organic removal increases dramatically. Most of the carbonaceous BOD removal occurs in the react phase. Further nitrification occurs by allowing the mixing and aeration to continue—the majority of denitrification takes place in the mixed-fill phase. The phosphorus released during mixed fill, plus some additional phosphorus, is taken up during the react phase.

2.3 SETTLE

During this phase, activated sludge is allowed to settle under quiescent conditions—no flow enters the basin and no aeration and mixing takes place. The activated sludge tends to settle as a flocculent mass, forming a distinctive interface with the clear supernatant. The sludge mass is called the sludge blanket. This phase is a critical part of the cycle, because if the solids do not settle rapidly, some sludge can be drawn off during the subsequent decant phase and thereby degrade effluent quality.

2.4 DECANT

During this phase, a decanter is used to remove the clear supernatant effluent. Once the settle phase is complete, a signal is sent to the decanter to initiate the opening of an effluent-discharge valve. There are floating and fixed-arm decanters. Floating decanters maintain the inlet orifice slightly below the water surface to minimize the removal of solids in the effluent removed during the decant phase. Floating decanters offer the operator flexibility to vary fill and draw volumes. Fixed-arm decanters are less expensive and can be designed to allow the operator to lower or raise the level of the decanter. It is optimal that the decanted volume is the same as the volume that enters the basin during the fill phase. It is also important that no surface foam or scum is decanted. The vertical distance from the decanter to the bottom of the tank should be maximized to avoid disturbing the settled biomass.

2.5 IDLE

IDLE is the phase between discharging the treated effluent and before filling the reactor again. This time can be effectively used to waste sludge. The frequency of sludge wasting is determined by the net solids increase in the reactor for each cycle, and the mixing and aeration equipment capacity. After sludge wasting, aeration and/or mixing can be provided, depending upon the overall system objectives. Alternatively, IDLE can be eliminated altogether. In instances where operation of SBR does not include an IDLE period, as noted earlier, sludge wasting may be achieved by solid wasting from the mixed liquor during the REACT phase.

III. Physical parameters

Date	Sample	Parameters					
		pH	BOD (mg/l)	COD (mg/l)	TSS (mg/l)		Total Nitrogen (mg/l)
1	2	3	4	5	6		7
01.12.2013	1	6.8	137	415	139		7
	2	-	84	254	115		-
	3	7.1	6	16	11		1.3
06.12.2013	1	6.9	139	325	146		7.1
	2	-	82	244	124		-
	3	7.2	4	15	10		1.5
12.12.2013	1	7.2	146	440	144		7.4
	2	-	86	256	126		-
	3	7.4	5	18	9		1.7
19.12.2013	1	6.9	148	447	147		7.9
	2	-	88	264	128		-
	3	7.1	7	20	10		1.5
26.12.2013	1	6.9	151	450	152		7.6
	2	-	90	268	130		-
	3	7.2	5	17	8		1.7
02.01.2014	1	6.9	138	420	142		7.1
	2	-	85	250	119		-
	3	7.2	6	18	9		1.4
09.01.2014	1	7	119	363	127		5.9
	2	-	80	245	101		-
	3	7.1	5	15	10		1.5
16.01.2014	1	6.8	126	390	125		6
	2	-	83	240	98		-
	3	7.3	5	14	9		1.9
24.01.2014	1	6.9	130	400	130		6.1
	2	-	96	288	110		-
	3	7.2	6	17	10		1.8
28.01.2014	1	6.9	134	410	131		6.5
	2	-	110	320	100		-
	3	7	5	20	11		2.1
01.02.2014	1	6.7	113	335	109		6.0
	2	-	80	234	76		-
	3	7.4	5	15	10		1.5
02.02.2014	1	0.2	150	324	154		7.5
	2	-	126	256	98		-
	3	7.3	6	21	10		2.34

The effluent P_H is increasing with time. At 1.12.2013 P_H is 6.8 and at the date of 02.02.2013 P_H is 7.3.

Table 2 BOD Removal Efficiency

Date	Inlet (mg/l)	Outlet (mg/l)	Efficiency
01.12.2013	137	6	95.62 %
06.12.2013	139	4	97.12 %
12.12.2013	146	5	96.57 %
19.12.2013	148	7	95.27 %
26.12.2013	151	5	96.69 %
02.01.2014	138	6	95.65 %
09.01.2014	119	5	95.79 %
16.01.2014	126	5	96.03 %
24.01.2014	130	6	95.38 %
28.01.2014	134	5	96.26 %
01.02.2014	113	5	95.57 %
02.02.2014	150	6	96.00%

Table 3 TSS Removal efficiency

Date	Inlet	Outlet	Efficiency
01.12.2013	139	11	92.08 %
06.12.2013	146	10	93.15 %
12.12.2013	144	9	93.75 %
19.12.2013	147	10	93.19 %
26.12.2013	152	8	94.73 %
02.01.2014	142	9	93.66 %
09.01.2014	127	10	92.12 %
16.01.2014	125	9	92.8 %
24.01.2014	130	10	92.30 %
28.01.2014	131	11	91.60 %
01.02.2014	109	10	90.82 %
02.02.2014	154	10	93.51 %

Table 2: COD Removal efficiency

Date	Inlet	Outlet	Efficiency
01.12.2013	415	16	96.14 %
06.12.2013	325	15	95.38 %
12.12.2013	440	18	95.90 %
19.12.2013	447	20	95.52 %
26.12.2013	450	17	96.22 %
02.01.2014	420	18	95.71 %
09.01.2014	363	15	95.86 %
16.01.2014	390	14	96.41 %
24.01.2014	400	17	95.75%
28.01.2014	410	20	95.12 %
01.02.2014	335	15	95.52 %
02.02.2014	324	21	93.52 %

SOURCE; *American Journal of Engineering Research (AJER) 2014*

1. Average BOD at inlet is 134.63 mg/l with maximum of 151 mg/l and minimum of 113 mg/l respectively. After the advanced treatment, average BOD at outlet was observed to be 5.36 mg/l. Maximum BOD at effluent is 7 mg/l. Effluent BOD is within standard limits of discharging in the creek.
2. The overall BOD removal efficiency is 96 %.
3. The concentration of total suspended solids at inlet was observed to be 135.64 mg/l with the removal efficiency of 92.74% of which about 18.67 % of suspended solids were removed in degritor (primary treatment) itself.
4. The overall total suspended solids removal efficiency is 92.74%

IV. Life Cycle Cost Of SBR Treatment Process

Rate of interest is 10%

1.Effluent BOD,mg/l	<10
2.Average,Area,m^2per MLD	450
3.Capital Cost(in Lakh)	98.022±26.350
4.Eletricity Costs In 2011(in Lakh)	3.349±0.383
5.Eletricity Costs in 2031 (In Lakh)	136.018±15.593
6.Maintenance Costs in 2011(in Lakh)	1.383±1.924
7.Maintenance Costs in 2031)(in Lakh)	56.187±7.146
8.Manpower Costs In 2011(in Lakh)	0.356±0.00812
9.Manpower Costs In 2031 (in Lakh)	14.493±0.327
10.Chemical Costs In 2011(in Lakh)	2.390±0.1868
11.Chemical Costs In 2031(in Lakh)	144.746±7.623
12.Total LCC Cost/ MLD (in Lakh)	441.360±54.859

The LCC analysis of SBR was Calculated at 10% rate of interest and time period taken 20years from 2011to 2031. The cost is given in lacs per MLD.The chemical cost at 2031 is very high as compare to other cost. The maintenance cost at 2031 is too much in comparison of other cost**.**

V. Advantages

- Equalization, primary clarification (in most cases),biological treatment, and secondary clarification can be achieved in a single reactor vessel.
- Operating flexibility and control.
- Minimal footprint.

- Potential capital cost savings by eliminating clarifiers and other equipment.

VI. Disadvantages

- A higher level of sophistication is required (compared to conventional systems), especially for larger systems, of timing units and controls.
- Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches, and automated valves.
- Potential of discharging floating or settled sludge during the DRAW or decant phase with some SBR configurations.
- Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.
- Potential requirement for equalization after the SBR, depending on the downstream processes.

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