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Comparative Study between Conventional Activated Sludge System & Sequential Batch Reactor

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***Abstract*— Our Earth is the only Planet in our Milky Way galaxy which is a perfect blend of each ingredient essential for existence of life. It has approximately an area of 510 million Sq Km. Ninety-seven percent of the water on the earth is salt water. Salt water is filled with salt and other minerals, and humans cannot drink this water. Although the salt can be removed, it is a difficult and expensive process.**

Two percent of the water on earth is glacier ice at the North and South Poles. This ice is fresh water and could be melted; however, it is too far away from where people live to be usable.

Less than 1% of all the water on earth is fresh water that we can actually use. We use this small amount of water for drinking, transportation, heating and cooling, industry, and many other purposes.

The fresh water used by per capita per day is 20 percent and rest 80 percent gets wasted. This waste water must be treated so as to reuse of waste water. Thus Sewage Treatment Plants are constructed to get clean water out of the waste water. Sewage Treatment can be done by different several technologies. But the latest technology nowadays used is Sequential Batch Reactor (SBR).

The object of this project is to represent the information regarding Sewage Treatment Plant integrated with latest treatment technology named as Sequential Batch Reactor (SBR). We will discuss about Planning, Designing, Construction, Management as well as Result of SBR Technology.

***Index Terms*— Conventional Sewage Treatment Plant; Sequential Batch Reactor, Construction, Management**

INTRODUCTION

Lin S.H. and Cheng K.W., (2001) carried out the study in which the treatment of municipal sewage is done with coagulation as a first process followed by SBR treatment. A different design for the SBR reactor was attempted in this study which allows continuous inflow of sewage wastewater while the other batch-wise operating steps of the SBR process are retained. The SBR cycle is 12 hrs. Two perforated baffle plates containing a large number of 2-mm holes that occupied a total surface area about 20% of the plate, divided the SBR tank into three equal compartments. The perforated baffle plates served to minimize the influence of the continuously in-flowing sewage wastewater on the “settle” and “draw” operations of the SBR process. The results of the modified SBR were compared with conventional SBR and concluded that modified SBR gives the same results with added advantage of continuous flow. The COD and BOD removal was 93.6% and 91.8 % respectively. Author also concluded that chemical coagulation is good option for wastewater pretreatment for SBR input. As modified SBR does not provide any significant change in result, also may increase the maintenance, the modifications carried out have certain scope for improvement.

Li and Zang (2002) studied the SBR performance for treating dairy wastewaters with various organic loads and HRTs. At 1 day HRT and 10000mg/l COD, the removal efficiency of COD, Total solids, Volatile solids, Total Kjeldal Nitrogen (TKN) and nitrogen was reported to be 80.2,63.4,66.3,75 and 38.3% respectively. Kargi and Uygur (2003) optimized the nutrient removal efficiency by generating results with experimental data by treating the synthetic wastewater in SBR and using them with Box-Wilson statistical experiment design. The independent variables were COD/Nitrogen ratio and COD/ Phosphorus ratio and objective functions were COD, Nitrogen and Phosphorus removal efficiencies. Experimental results were correlated with a Box-Wilson response function and the coefficients were determined by regression analysis. A computer program was used to determine the optimal nutrient ratios maximizing the nutrient removal efficiencies. COD/NH4-N/PO4-P ratio of 100/2/0.54 was found to maximize the removal efficiencies in SBR.

Uygur and Kargi (2004) experimented with four step SBR (anaerobic, oxic, anoxic, and oxic phases with HRT of (1 h/3 h/1 h /1 h) for investigation of nutrient removal from synthetic wastewater at different phenol concentrations ranging from 0 to 600 mg/l. It was observed that the nutrient removal efficiency was almost 90% and 65% for nitrogen and phosphorus respectively and above 95% for COD removal for phenol concentration up to 400 mg/l. The performance of SBR was drastically affected above 400 mg/l concentration of phenol. There was similar observation in case of SVI as there was drastic increase from 45 ml/g to 90 ml/g.

Mohseni-Bandpi and Bazari (2004) investigated the bench scale aerobic SBR to treat the wastewater from an industrial milk factory. The SBR system was exposed to different working conditions in three phases in which the variation of organic loading, aeration period and cycle period were tested. The results obtained were very much satisfactory i.e. the COD removal was more than 90% in all conditions. The flexibility and treatability of the dairy waste was proved in this study.

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Neczaj et al. (2005) aimed to study the effectiveness of applying ultrasound field for enhancement of biological treatability of leachates generated in a typical municipal solid waste sanitary landfill. The dilution of leachate in SBR was varied in volume with synthetic wastewater from 5% to 40 %. Upper limit was found to be 10% of leachate dilution for organic compound removal above 85%. The sonification was carried out with disintegrator of frequency 20 KHz and applied at different amplitudes varying from 8 to 16 µm. satisfactory results were obtained with 12 µm amplitude when the organic compound removal with SBR was more than 90%. The ultrasound treatment can be a costly pretreatment for SBR and also the optimization of the process would be a future scope in the studied paper.

Kulikowska et al. (2007) aimed to estimate the BOD5 and COD removal efficiency and biomass yield coefficient in SBR treating landfill leachate. The SBRs were operated at various HRTs with aerobic-anaerobic condition and aerobic condition i.e. with and without anoxic phase. It was observed that there is no change in BOD removal efficiency due to change in HRT but COD removal efficiency was affected by about 4 to 5 % in both conditions. The observed yield was increased in condition without anoxic phase. Also there is significant increase in biomass decay rate, as it was observed fivefold increase in aerobic condition as compared to aerobic-anaerobic phase (0.006 d -1 to 0.032 d-1). Due to lower biomass aerobic system was considered to be optimal for municipal leachate.

Neczaj et al. (2008) carried out the study of SBR for co-treatment of leachate and dairy wastewater. Two SBR setups were used, among which one was exclusively treating dairy wastewater while other was in 25% dilution of landfill leachate. Authors experimented for variation in aeration period. The most suitable aeration period for landfill leachate co-treatment was 19 hrs with anoxic phase of 2 hrs. The COD, BOD and TKN removal efficiencies were 98.4%, 97.3% and 79.2% respectively which shows satisfactory treatment ability of SBR. Authors also experimented with variation in HRT along with varied organic loading rate (OLR). The results showed there is significant effect on removal efficiency i.e. efficiency was reduced due to less HRT and more OLR. The best effluent quality was observed under OLR of 0.8 kg BOD5/m3 d and HRT of 10 days for co-treatment process of landfill leachate. During the experimentation there was scope for authors to find the optimum amount of co-treating leachate with dairy wastewater since only 25% dilution is experimented.

SCHEME OF EXPERIMENTATION

Conventional activated sludge systems require separate tanks for the unit processes of biological reactions (aeration of mixed liquor) and solids-liquid separation (clarification) and also require process mixed liquor solids (return activated sludge) to be returned from the final clarification stage to the aeration tanks. In contrast, SBR technology is a method of wastewater treatment in which all phases of the treatment process occur sequentially within the same tank. Hence, the main benefits of the SBR system are less civil structures, inter-connecting pipe work, and process equipment and the consequent savings in capital and operating costs. The sequencing batch reactor utilizes the Mix Air system by providing separate mixing with the direct drive mixer (DDM) and an aeration source such as jet surface aerator or Aerobic diffused-aeration. This system has the capability to cyclically operate the aeration and mixing to promote anoxic/aerobic and anaerobic environments with low energy consumption. In addition, the Mix Air system can achieve and recover alkalinity through denitrification, prevent nitrogen gas disruption in the settle phase, promote biological phosphorus removal. The Aerobic floating decanter follows the liquid level, maximizing the distance between the effluent withdrawal and sludge blanket. It is an integral component to the SBR system and provides reliable, dual barrier subsurface withdrawal with low entrance velocities to ensure surface materials will not be drawn into the treated effluent. The decanter option is easily accessible from the side of the basin and requires minimal maintenance.

Conventional Activated Sludge Process (ASP) System:

This is the most common and oldest biotreatment process used to treat municipal and industrial wastewater. Typically wastewater after primary treatment i.e. suspended impurities removal is treated in an activated sludge process based biological treatment system comprising aeration tank followed by secondary clarifier. The aeration tank is a completely mixed or a plug flow (in some cases) bioreactor where specific concentration of biomass (measured as mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS)) is maintained along with sufficient dissolved oxygen (DO) concentration (typically 2 mg/l) to effect biodegradation of soluble organic impurities measured as biochemical oxygen demand (BOD5) or chemical oxygen demand (COD).

The aeration tank is provided with fine bubble diffused aeration pipework at the bottom to transfer required oxygen to the biomass and also ensure completely mixed reactor. Roots type air blower is used to supply air to the diffuser pipework. In several older installations, mechanical surface aerators have been used to meet the aeration requirement. The aerated mixed liquor from the aeration tank overflows by gravity to the secondary clarifier unit to separate out the biomass and allow clarified, treated water to the downstream filtration system for finer removal of suspended solids. The separated biomass is returned to the aeration tank by means of return activated sludge (RAS) pump. Excess biomass (produced during the biodegradation process) is wasted to the sludge handling and dewatering facility.

Sequential Batch Reactor (SBR)

The sequencing batch reactor system features time-managed operation and control of aerobic, anoxic and anaerobic processes within each reactor. Equalization and clarification takes place within a reactor itself. The SBR system utilizes five basic phases of operation to meet advanced wastewater treatment objectives. The duration of any particular phase may be based upon specific waste characteristics and/or effluent objectives:

Fill
React
Settle
Decant
Idle

Parameters to be monitored manually by an Operator specifically dedicated for the operation of CASP.

Oxidation reduction potential (ORP), dissolved oxygen (DO), pH, and alkalinity are parameters that should be monitored by the operator. Though these operating parameters are widely used, the details of the operating procedure will vary at different activated sludge plants, depending on the type of facilities available, strength and character of the wastewater, temperatures, requirements of the receiving waters, etc. The best operating procedure for each plant must be determined by experience. There must be sufficient aeration to maintain a dissolved oxygen concentration of at least 2 mg/L at all times throughout the aeration tanks. Dissolved oxygen should be present at all times in the treated wastewater in the final settling tanks. Activated sludge must be returned continuously from the final settling tanks to the aeration tanks. Optimum rate of returning activated sludge will vary with each installation and with different load factors. In general, it will range from 20 to 40 percent of the influent wastewater flow for diffused air and 10 to 40 percent for mechanical aeration units. The optimum mix liquor suspended solids concentration in the aeration tanks may vary considerably, but usually is in the range of 600 to 3000 mg/L. Optimum MLSS concentrations should be determined experimentally for each plant. A sludge volume index of about 100 and a sludge age of three to fifteen days are normal for most plants. When the optimum sludge volume index is established for a plant, it should be maintained within a reasonably narrow range. A substantial increase in SVI is a warning of trouble ahead. The suspended solids content in the aeration tanks may partially be controlled by the amount of sludge returned to them. All sludge in excess of that needed in the aeration tanks must be removed from the system. It should be removed in small amounts continuously or at frequent intervals rather than in large amounts at any one time. Sludge held too long in the final settling tank will become septic, lose its activity and deplete the necessary dissolved oxygen content in the the tank. Septic conditions in the primary sedimentation tanks will adversely affect the functioning of the activated sludge process. Pre-chlorination or pre-aeration may be used to forestall septic conditions in the wastewater entering the aeration tanks. Septic primaries have been shown to cause filamentous bulking. Periodic or sudden organic overloads that may result from large amounts of sludge digester overflow to the primary tanks or from doses of industrial wastes having an excessive BOD or containing toxic chemicals will usually cause operating difficulties. Whenever possible, overloading should be minimized by controlling the discharge or by pretreatment of such deleterious wastes. The basic indicator of normal plant operation is the quality of the plant effluent. Failure of plant efficiency may be due to either of the two most common problems encountered in the operation of an activated sludge plant, namely, rising sludge and bulking sludge.

Parameters to Be Monitored by the Supervisory Control and Data Acquisition (SCADA) System.

Oxidation reduction potential (ORP), dissolved oxygen (DO), pH, and alkalinity are parameters that should be monitored by the Supervisory Control and Data Acquisition (SCADA) system. Manufacturers determine what parameters can be monitored and controlled by the SCADA system. Monitoring of certain parameters is important, and the ability to adjust these parameters from a remote location is ideal. The operator needs to be able to add chemicals to raise the alkalinity and subsequently the pH. The set point should be an alkalinity value rather than pHbased. The operator should have the ability to fully control (i.e., modify) the plant-operating parameters, such as (but not limited to) cycle times, volumes, and set points.

Alkalinity monitoring and addition ensures that a pH of less than 7.0 does not occur. Nitrification consumes alkalinity, and with a drop in alkalinity, pH also drops. If a plant has adequate alkalinity, pH does not change, so it does not need to be raised. Chemicals that raise alkalinity, such as sodium bicarbonate and soda ash, are recommended over sodium hydroxide. Sodium hydroxide does not raise alkalinity; it does raise pH. See section 2.1.3.1 for a discussion of the pros and cons of various chemicals used to increase alkalinity

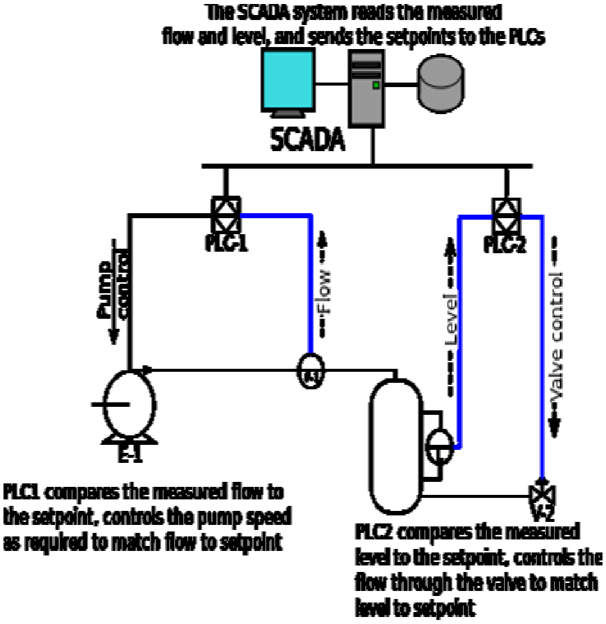
For plants that nitrify and denitrify, ORP monitoring is desirable. ORP is the measure of the oxidizing or reducing capacity of a liquid. DO varies with depth and location within the basin. ORP can be used to determine if a chemical reaction is complete and to monitor or control a process.

Operators need the ability to make changes that will modify these readings to achieve appropriate nutrient removal. ORP readings have a range and are site specific for each facility. General ranges are: carbonaceous BOD (+50 to +250), nitrification (+100 to +300), and denitrification (+50 to -50).

On-line dissolved oxygen meters are very useful in SBR operation. They allow operators to adjust blower times to address the variable organic loads that enter the plant. Lack of organic strength reduces the react time during which aeration is needed to stabilize the wastewater. DO probes can be used to control the aeration-blower run time during the cycle, which in turn reduces the energy cost of aeration.

It is desirable to locate DO, pH, and/or ORP probes in a place that can be reached easily by operators. These probes often clog or foul and need cleaning and calibration. If they are not easily accessible, proper maintenance may not occur.

The plant operator should have the knowledge and the ability to program the SCADA system to increase or decrease blower speed. Allowing the operator to adjust the blower speed, through the SCADA system, gives the operator much more control over the DO in the SBR



<u>SCADA's schematic overview</u>

Both AS and SBR plant models run by using three cases of operations. First case of operation (case 1) was run with influent BOD concentration equal to 200 mg/l. Second case of operation (case 2) was run with influent BOD concentration equal to 300 mg/l. Whereas, the third case of operation (case 3) was run with influent BOD concentration equal to 400 mg/l. The influent flow rate for all cases for both AS and SBR plant models were constant along the running time. All cases run for 8 days of operation. Influent wastewater characteristics for both AS and SBR plant showed on Table 1.

Table :Influent wastewater characteristics for both AS and SBR plant model

Parameter	**Concentration (mg/l)**
BOD_5 for case 1, case 2, case3	200, 300, 400 respectively
Total SS	250
Volatile SS	150
TKN	34
NH_3^- for AS and SBR plant	27.2, 32.0 respectively

RESULTS AND DISCUSSIONS

Case 1 of Operation

Both the AS and SBR plant models for the case 1 of operation run for 8 days of operation with average influent BOD5 equal to 200 mg/l. The operation conditions for both AS and SBR system is similar. The start up period for both AS and SBR plants is about one day. Table 2 shows the treatment efficiency of AS and SBR plants at case 1 of operation. Figure 3 shows the relation between effluent BOD5 concentrations with time of operation for the SBR plant. Figure 4 shows the relation between the effluent TKN with time of operation for the SBR plant.

The BOD removal efficiency for both AS and SBR plants is approximately the same (BOD removal for both AS and SBR systems equal to 97.5 %, 97.4 % respectively). The suspended solids removal for the AS plant is higher than the SBR plant. Whereas, the efficiency of the TKN and ammonia nitrogen NH3+ removal for the SBR plant is higher than the AS plant. The TKN removal efficiency for the AS and SBR are 83.8 % and 88.2 % respectively. The efficiency of ammonia NH3+ removal for the AS and SBR are 90.4 % and 99.0 % respectively. It can be concluded form these results that, the efficiency of nitrogen and ammonia removal for SBR system is higher than the AS system under the same operation conditions

Table :Treatment Efficiency of AS and SBR Plants at Case 1 of operation.

Parameter	**AS Plant**			**SBR Plant**		
	Influent	Effluent	Removal Efficiency	Influent	Effluent	Removal Efficiency
	mg/l	mg/l	%	Mg/l	mg/l	%
BOD	200	5.0	97.5 %	200	5.2	97.4 %
TSS	250	8.7	96.5 %	250	16.0	93.6 %
TKN	34.0	5.5	83.8 %	34.0	4.0	88.2 %
NH_3^+	27.2	2.6	90.4 %	32.0	0.3	99.0 %

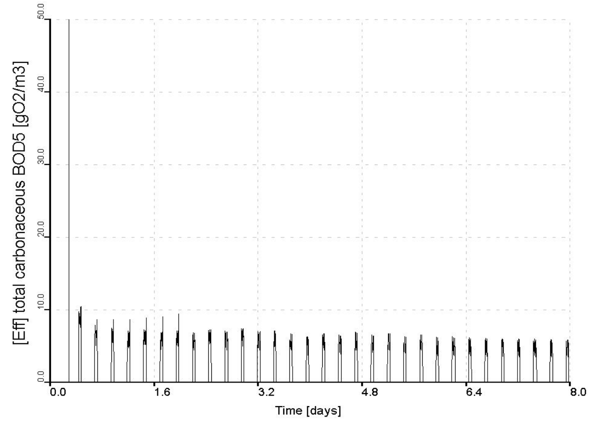


Figure :Relation Between Effluent BOD with Time for SBR Plant at Case 1.

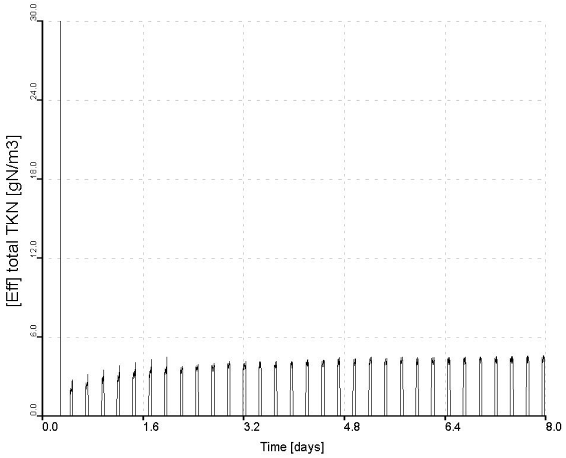


Figure : Relation Between Effluent TKN with Time for SBR Plant at Case 1.

Case 2 of Operation

Both the AS and SBR plant models for the case 2 of operation run for 8 days of operation with average influent BOD5 equal to 300 mg/l. The startup period for both AS and SBR plants is about one day. Table 3 shows the treatment efficiency of AS and SBR plants at case 2 of operation. Figure 5 shows the relation between effluent BOD5 concentrations with time of operation for the SBR plant. Figure 6 shows the relation between the effluent TKN with time of operation for the SBR plant

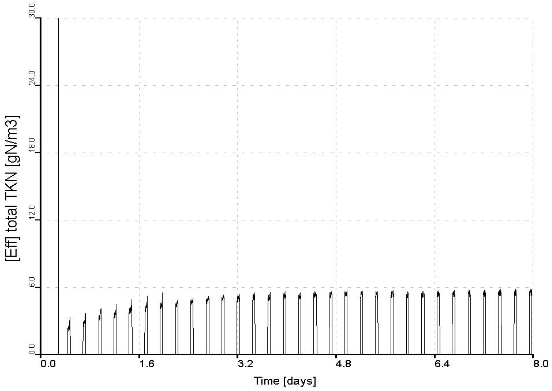


Figure :Relation Between Effluent TKN with Time for SBR Plant at Case 2.

The BOD removal efficiency for both AS and SBR plants is approximately the same. The suspended solids removal for the AS plant is higher than the SBR plant. Whereas, the efficiency of the TKN and ammonia nitrogen NH3+ removal for the SBR plant is higher than the AS plant. The TKN removal efficiency for the AS and SBR are 79.7 % and 84.1 % respectively. The efficiency of NH3+ removal for the AS and SBR are 89.7% and 98.1 % respectively. It can be concluded form these results that, the efficiencyof nitrogen and ammonia removal for SBR system is higher than the AS system under the same operation conditions.

Table shows the summary of results for both AS and SBR systems for all cases of operation. It can be concluded form these results that, under all cases of operation, the efficiency of nitrogen and ammonia removal for SBR system is higher than the AS system under the same operation conditions. Also, the efficiency of BOD removal for both AS and SBR system is similar. But the efficiency of suspended solid removal for the AS system is higher than the SBR system.

Parameter	**Case 1**		**Case 2**		**Case 3**	
	AS	**SBR**	**AS**	**SBR**	**AS**	**SBR**
BOD removal	97.5 %	97.4 %	97.8 %	97.8 %	98.1 %	97.9 %
TSS removal	96.5 %	93.6 %	96.6 %	93.6 %	96.5 %	93.6 %
TKN removal	83.8 %	88.2 %	79.7 %	84.1 %	77.1 %	82.4 %
NH_3^+ removal	90.4 %	99.0 %	89.7 %	98.1 %	89.6 %	96.3 %

CONCLUSION

Main Conclusion of the Study

Based on the observation and results obtained from this study, the following points are concluded:

The treatment efficiency of the AS and SBR systems based on BOD removal is similar during the all cases of operation (the BOD removal ranged between 97.4 % and 98.1 % for both systems).

The AS system has a higher ability to remove the suspended solids than the SBR system during all cases of operation (the TSS removal for AS and SBR systems 96.5 % and 93.6 % respectively).

The SBR system has a higher ability to remove the total nitrogen TKN concentration than the AS system under all cases of operation (the TKN removal for SBR system ranged from 82.4 % to 88.2 %, and for AS system manged from 77.1 % to 83.8 %).

The SBR system has a higher ability to remove the total ammonia NH3+ concentration than the AS system under all cases of operation (the NH3+removal for SBR system ranged from 96.3 % to 99.0 %, and for AS system ranged from 89.6 % to 90.4 %).

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