Significance of Conventional Activated Sludge System & Sequential Batch Reactor

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Abstract— 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.

Key Words : Wastewater , Batch Reactor, Construction, Management.
Sub Area : Construction Technology & Management
Broad Area : Civil Engineering

Aim of Wastewater Treatment

The traditional aim of wastewater treatment is to enable wastewater to be disposed safely, without being a danger to public health and without polluting watercourses or causing other nuisance. Increasing another important aim is to recover energy, nutrients, water and other valuable resources from wastewater.

Conventional Treatment Plants

Waste water influent from Houses, Schools, Colleges, Hospitals, Hotels, Industries like Paper, Pulp, Pharmaceuticals, Sugar, Slaughter houses, Dyeing, Powder coating consists of various parameters which are harmful for Public Health and Watercourses. Wastewater Treatment are widely used for its treatment, but they all are based on conventional space sequence of continuous-flow systems. Conventional Treatment Plants is a continuous flow, an aerobic biological process that employs suspended growth microorganisms to biodegrade organic contaminants. The influent is introduced in aeration basin and is allow to mixing with the contents by mechanical mixing or by turbulence induced by diffused aerators. A series of biochemical reactions takes place in basin were the organics are degraded and new biomass are generated. After a specific period the mixture is passed to a settling tank or a clarifier where microorganisms are separated from treated water. Major portion of settled sludge is recycled back to aeration tank to maintain a desired concentration of microorganisms in the reactor and remainder of the settled solids are sent to Sludge drying bed.

Sequential Batch Reactor

The major differences between SBR and conventional continuous-flow, activated sludge system is that the SBR tank carries out the functions of equalization aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems. In addition, the SBR system can be designed with the ability to treat a wide range of influent volumes whereas the continuous system is based upon a fixed influent flow rate. Thus, there is a degree of flexibility associated with working in a time rather than in a space sequence.

SBRs produce sludges with good settling properties providing the influent wastewater is admitted into the aeration in a controlled manner. Controls range from a simplified float and timer based system with a PLC to a PC based SCADA system with color graphics using either flow proportional aeration or dissolved oxygen controlled aeration to reduce aeration to reduce energy consumption and enhance the selective pressures for BOD, nutrient removal, and control of filaments. An appropriately designed SBR process is a unique combination of equipment and software. Working with automated control reduces the number of operator skill and attention requirement.

The majority of the aeration equipment of sequencing batch reactors consists of jet, fine bubble, and coarse bubble aeration systems. The main focus of this report is a jet aerated sequencing batch reactor activated sludge system with a PLC to a PC based SCADA system.

LITERATURE REVIEW

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

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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.

Nardi et al. (2011) carried the research work for advanced wastewater treatment of poultry slaughterhouse for its reclamation. The advanced treatment consisted of use of SBR, chemical-DAF and UV disinfection. The wastewater was given anaerobic pretreatment in the form UASB. The use of SBR was aimed denitrification. The total denitrification efficiency was more than 90%, also the TCOD removal was 54±24% and TP 43%. The sludge also presented good settling characteristic with SVI 118 ± 35 mL g-1 . Authors concluded that the SBR system along with chemical-DAF and UV disinfection is appropriate for anaerobically pretreated poultry wastewater.

Catalina et al. (2011) carried evaluation of nitrogen removal in wastewater from a meat products processing company, using a SBR at pilot scale. The complete cycle of the SBR (filling, reaction, settling and draw) was 8 h, with three cycles performed per day. It was concluded that the SBR was an appropriate treatment system to perform the joint removal of organic matter and ammonia nitrogen in wastewater from a meat processing company products, demonstrating the SBR system to operate with discharges that present strong variations in composition.

Subbaramaiah and Mall (2012) have worked on treatability of benzoic acid (BA) with SBR system. For the design of SBR various experimental optimizations for parameters were carried out i.e. MLSS, OLR, aeration rate during fill phase and temperature. Also kinetic model at different temperature was carried out in SBR. Two sets of SBR's were operated with 12 hrs. cycle, 6-12 hrs. HRT and 72-120 hrs. SRT. It was concluded that optimum MLSS concentration is 5000 mg/l. Treatability of benzoic acid above 200 mg/l is good, optimum operating temperature is 30ºC and optimum value of aeration is 3hrs. There is scope for finding optimum values for treatability of BA above 200mg/l as the concentration above this is not tried and the same is the case with aeration time

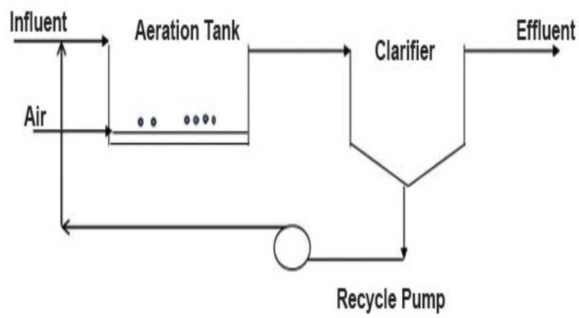
EXPERIMENTATION

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.

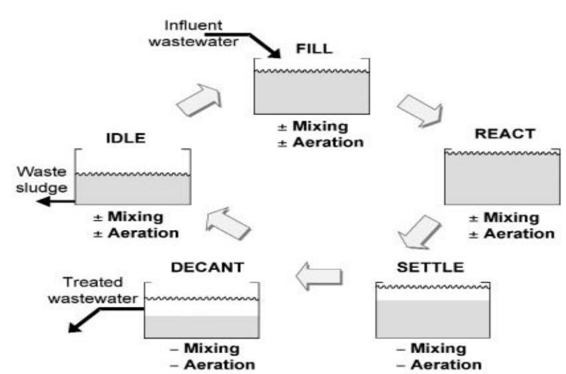


Conventional *ASP System*

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:

A. Fill
B. React
C. Settle
D. Decant
E. Idle



Major Phases of the SBR operational cycle

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 reestablished. 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.

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.

Settle

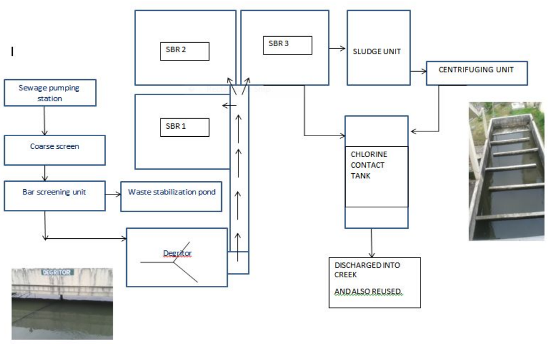
During this phase, activated sludge is allowed to settle under quiescent conditions—no flow enters the basin and no aeration and mixing takes place. The activated sludge tends to settle as a flocculent mass, forming a distinctive interface with the clear supernatant. The sludge mass is called the sludge 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.

Decant

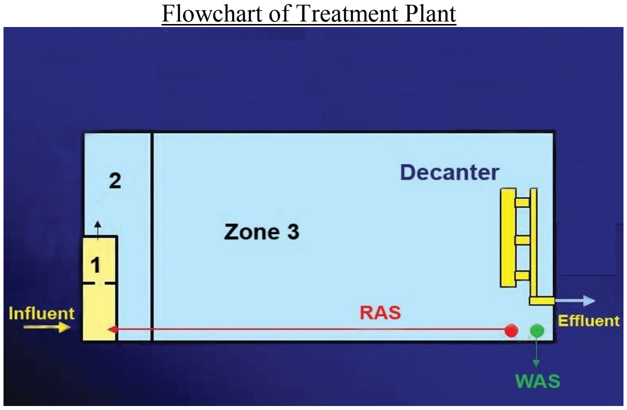
During this phase, a decanter is used to remove the clear supernatant effluent. Once the settle phase is complete, a signal is sent to the decanter to initiate the opening of an effluent-discharge valve. There are floating and fixed-arm decanters. Floating decanters maintain the inlet orifice slightly 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.

Idle

This step occurs between the decant and the fill phases. The time varies, based on the influent flow rate and the operating strategy. During this phase, a small amount of activated sludge at the bottom of the SBR basin is pumped out—a process called wasting.



Flowchart of Treatment Plant



Typical Rectangular SBR basin layout

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.

Table 5.1 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 %

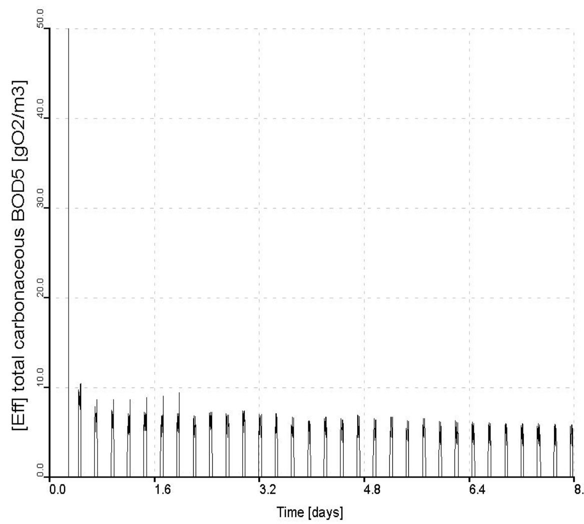


Figure 5.1 Relation Between Effluent BOD with Time for SBR Plant at Case 1.

CONCLUSION

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).

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