



INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Biological Treatment of Wastewater Using Activated Sludge Process and Sequential Batch Reactor Process - A Review

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Abstract

This paper intends to provide an overall information about Biological Treatment of Sewage using Activated Sludge process(ASP) and Sequential Batch Process(SBR). There are various processes for treating municipal domestic sewage but amongst all of them it has been observed that Activated sludge process(ASP) and Sequential Batch Process(SBR) was adopted at most of the places. The overall efficiency of SBR is higher than ASP at low cost in less space for continuous flow and even for intermittent flow provides preference to SBR in selection of technology for biological treatment of wastewater.

Keywords: Activated Sludge Process(ASP), Sequencing Batch Reactor(SBR), Operational parameters, Biological process, aeration, removal efficiency.

Introduction

Sewage is 99 % water carrying domestic wastes originating in kitchen, bathing, laundry, urine and night soil. Besides sewage also contains water borne pathogenic organisms of cholera, jaundice, typhoid, dysentery and gastroenteritis which originate from the night soil of already infected persons.

The objective of sewage treatment is to meet the relevant discharge standards laid down by the CPCB. Sewage Treatment is normally by either the aerobic bacteria or anaerobic bacteria whereby these metabolise the organic matter and multiply themselves and which are settled out and disposed as sludge. Treated sewage as effluent is discharged into nearby waterbody or it can be reuse as an attractive strategy which can significantly contribute to water conservation in areas suffering from water scarcity or overconsumption. Specific purposes to reuse of treated sewage as effluent which depends upon the application, and treatment given to domestic sewage and characteristics of effluent. Direct discharge of sewage or discharge of effluents from STP's into nearby natural water body may be one of the reason of pollution of natural water body if STP's performance is not upto the mark or as expected.

To prevent/reduce pollution of the natural water resources, treatment of sewage becomes compulsory. And Treatment of sewage is possible by using various processes like Oxidation Ponds, Trickling Filter, Rotating Biological contactors, Up-flow

Anaerobic Sludge Blanket (UASB) Process, Activated Sludge Process (ASP), Fluidized Bed Reactor, Sequential Batch Reactor (SB), Advanced method of Waste Water Treatment, Membrane Reactor, Combi-treat Technology, Nitrogen Control, Biological Phosphorus Control, Coagulation sedimentation and Carbon adsorption . Out of these process Activated Sludge Process (ASP) and Sequential Batch Reactor (SB) process are commonly used at most of the places.

Activated Sludge process and Sequencing Batch Reactor History

Activated Sludge process has become the most extensively employed secondary unit process for the treatment of wastewater. Arden & Lockett's original investigations in 1913 involved aerating sewage for several weeks before the treated liquor was permitted to settle & the supernatant water was decanted. Thus, the very original activated sludge process was operated as a batch reactor & became identified as the fill & draw method. SBR's treatment process is characterized by a repeated treatment cycle consisting of a series of sequential process phases; filling, reaction, settling, & decanting . (Mahvi et al., 2008; Aziz et al., 2011)

Activated Sludge process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process. The process flow diagram is as

shown in Fig(a). The municipal wastewater treatment is the Biochemical Oxygen Demand (BOD) removal. The removal of BOD is done by a biological process, such as the suspended growth treatment process. This biological process is an aerobic process and takes place in the aeration tank, in which the wastewater is aerated with oxygen. By creating good conditions, bacteria will grow fast. The growth of bacteria creates flocks and gases. These flocks are removed by a secondary clarifier. In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension. Commonly used aeration devices include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD wastewaters. Sewage containing waste organic matter is aerated in an aeration basin in which micro-organisms metabolize the soluble and suspended organic matter. Part of the organic matter is synthesized into new cells and part is oxidized to carbon dioxide and water to derive energy. In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluents. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solid (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variations of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principal is similar. (Metcalf and Eddy 2003 & CPHEEO manual 2010)

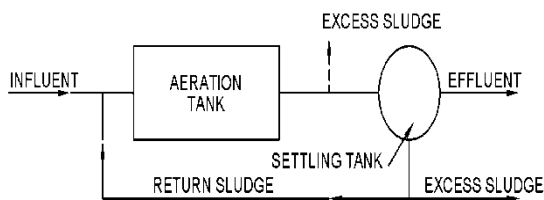


Fig (a) Activated Sludge Process

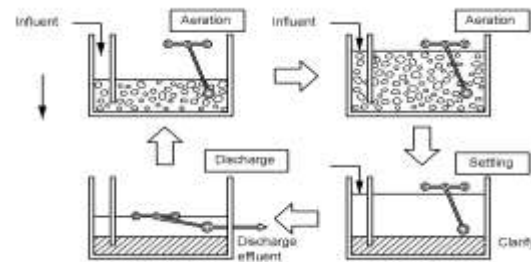


Fig (b) Sequential Batch Process

Sequencing Batch Reactor process

Sequential Batch Reactor treatment process itself indicates that it is intermittent treatment process. In this process Five stages are employed to treat sewage viz, Filling, Reaction, Settling, Decanting and Idle etc. In this process, the raw sewage, free from debris and grit, is taken up for biological treatment to remove organic matter, nitrogen, and phosphorus. The activated sludge bio-system is designed using the Advanced Cyclic Activated Sludge Technology which operates on extended aeration activated sludge principle for the reduction of carbonaceous BOD, nitrification, denitrification as well as phosphorus removal using energy-efficient, fine bubble diffused aeration system with automatic control of air supply based on oxygen uptake rate. This conventional SBR configuration uses sequences described as Fill, React, Settle, Decant, and Idle as shown in Figure (b) The complete biological operation is divided into: 1) Fill-Aeration , 2) Settling, and 3) Decanting. These phases in a sequence constitute a cycle. During the period of a cycle, the liquid volume inside the reactor increases from a set operating bottom water level. During the fill-aeration sequence, the mixed liquor from the aeration zone is recycled into the selector. Aeration ends at a predetermined period of the cycle to allow the biomass to flocculate and settle under quiescent conditions. After a specific settling period, the treated supernatant is decanted, using a moving weir decanter. The liquid level in the reactor is so returned to bottom water level after which the cycle is repeated. Solids are separated from the reactor during the decanting phase or in some cases in idle condition. (CPHEEO manual 2010)

Modified Ludzck Ettinger(MLE) process

For denitrification of wastewater Modified Ludzack Ettinger process is used which comprises anoxic and aerobic tank alongwith secondary clarifier, return activated sludge from secondary clarifier and return nitrified liquor from aerobic tank. In this

process by using readily biodegradable substrate, nitrate associated with return activated sludge is removed and to achieve higher levels of nitrate removal from wastewater nitrified liquor from aerobic tank is bring back to anoxic tank for nitrification is known as Modified Ludzack Ettinger (MLE) process. (CPHEEO manual 2010)

Operational parameters

The performance of ASP & SBR treatment units

depends upon various operational parameters selected to design hydraulic process of biological units given in Table 1 and Table 2 (CPHEEO manual 2010) for ASP & SBR.

Activated Sludge process

Design Parameters for activated sludge systems for sewage reported in CPHEEO manual 2010 are given in Table 1.

Table 1 Design Parameters for activated sludge systems for sewage (CPHEEO manual 2010)

Sr.no	Parameters	Units	Conventional	Complete mix	Extended aeration
1	Flow Regime		Plug Flow	Complete mix	Complete mix
2	F/M ratio	d-1	0.3 – 0.4	0.3 – 0.5	0.1 – 0.18
3	Θ_c	D	5 – 8	5 – 8	10 – 25
4	KgO ₂ /kg BOD removed	Ratio	0.8 – 1.0	0.8 – 1.0	1.0 – 1.2
5	MLSS	mg/l	1500 – 3000	3000 - 4000	3000 – 5000
6	MLVSS/MLSS	Ratio	0.8	0.8	0.6
7	HRT	Hrs	4 – 6	4 – 5	12 – 24
8	Q _R /Q	Ratio	0.25 – 0.5	0.25 – 0.8	0.5 – 1.0
9	BOD Removal	%	85 – 92	85 – 92	95 – 98

Sequencing Batch Reactor

Design Parameters for SBR systems for sewage reported in CPHEEO manual 2010 are given in Table 2.

Table 2 Design Parameters for SBR systems for sewage (CPHEEO manual 2010)

S.no	Parameters	Units	Continuous Flow & Intermittent Decant	Intermittent Flow & Intermittent Decant
1	F/M ratio	d-1	0.05-0.08	0.05-0.3
2	Sludge age	D	15-20	4-20
3	Sludge yield	Kg dry solids/kg BOD	0.75-0.85	0.75-1
4	MLSS	mg/l	3000-4000	3500-5000
5	Cycle Time	H	4-8	2.5-6
6	Settling Time	H	>0.5	>0.5
7	Decant Depth	M	1.5	2.5
8	Fill volume Base	-	Peak flow	Peak flow
9	Process oxygen			
	- BOD	Kg O ₂ /kg BOD	1.1	1.1
	- TKN	Kg O ₂ /kg TN	4.6	4.6

Nitrogen(N) removal adjustment was achieved by adjustment of the operating parameters of SBR. The coefficients for heterotrophic and autotrophic maximum growth rate, endogenous decay, yield coefficient and Anoxic correction factor for growth and hydrolysis for tannery wastewater needs to be determined for each plant individually. (S. Murat et.al, 2002)

For denitrification and biological phosphorus removal, pH and Oxidation Reduction Potential(ORP) values can be used as control parameters. In the the oxic phase pH provided much information while in the anoxic phase ORP was informative. (Akm, B.S et al., 2005)

For efficient decolorization of Remazol Rot RR and COD removal minimum 15 days sludge retention time(SRT) is required in SBR system. (Ilgı Karapınar Kapdan et al., 2005)

Anaerobic Sequencing Batch Reactor(ASBR) showed that as temperature and HRT decreases, the COD removal and methane production decreases. For lower operational temperatures (>15 °C) and lower reactor VSS content Longer hydraulic retention time and cycle time were required in the ASBR process. (Kayranlı Birol et al., 2011)

With an aeration rate of 6 L/min, the effective reduction of influent parameters were achieved within 6 hr of total cycle time, at 33°C temperature and at 7.50 pH in the Biological Treatment of Domestic Wastewater using SBR. (R. Lognathan et al., 2012)

In the performance of SBR method, cycle time, aeration rate, volume of reactor, HRT etc. were ruling parameters. (Shuokr Qarani Aziz et al., 2013)

In SBR system treatment with Mixed Culture for nitrification and denitrification of Slaughterhouse Wastewater optimum react period for aerobic and anoxic reaction found to be 4 hour each as combination. (Pradyut Kundu et al., 2014).

To achieve higher degree of nitrification in SBR system five hour period of aeration has been found to be effective. (Pradyut Kundu et al., 2014)

Suitability to treat different types of wastewater

ASP

Domestic wastewater of all types is treated with the help of activated sludge process but only for removal of COD, BOD, TSS, Fecal coliforms and upgradation of pH and DO recovery and TKN and phosphate upto some extent by using some tertiary treatment additionally.(Anne-Emmanuelle Stricker et al., 2006, Amr M. Abdel Kader et al., 2009, K. Sundara Kumar et al., 2010, N. Banadda et al., 2011et al., Silvia C. Oliveira et al., 2011, Fu. E. Tang et al., 2011, Vaishali Sahu et al., 2013, E. C. Ukpong et al., 2013, Prachi N. Wakode et al., 2014)

SBR

SBR is well suited to tannery wastewater for effective COD and N removal. (S. Murat et al., 2002) It is possible to treat poultry wastewater using adapted sludge in a SBR, despite the low phosphorus concentration. (Mauro P. Moreira et al., 2002) Animal wastewater concentrated on swine wastewater treatment is possible in SBR. (Li and Zhang et al., 2002) Biological nutrient removal from simulated wastewater containing glucose as carbon source using SBR is possible. (B. Manoj Kumar et al., 2003) The conventional SBR produced better nitrification performance than that of the hybrid MLE process. (H.L.S. Tam et al., 2004) Biological nutrient removal by a sequencing batch reactor (SBR) using an internal organic carbon source in digested piggery wastewater is achieved. (D. Obaja et al., 2004) An SBR operated with anaerobic and aerobic cycle stages could be considered a suitable technology for organic load removal from wool dyeing effluents. (Isolina Cabral Goncalves et al., 2005) Remazol Red RR a vinylsulphonyl (VS) and monochlorotriazine (MCT), reactive azo dye was used in the study and treated in SBR and found that decolourization is achieved. (Ilgı Karapınar Kapdan et al., 2005) Carbon can be removed from dairy wastewater by using sequential batch reactor (SBR). (Soledad Gutierrez et al., 2007) The SBR process could be applied for nutrients removal, high biochemical oxygen demand containing industrial wastewater, wastewater containing toxic materials such as cyanide, copper, chromium, lead and nickel, food industries effluents, leachates and tannery wastewater. (Mahvi A. H. 2008) Domestic sewage can be effectively treated by using SBBR which was controlled by an ICS. (Dahu Ding et al., 2010) The ASBR process can be used for treatment of low strength wastewaters at low temperatures. Anaerobic sequential batch reactor is a promising treatment

alternative for domestic wastewater, and can be operated effectively under low temperatures. (Kayranli Birol et al., 2011) Biological Treatment of Domestic Wastewater Using Sequential Batch Reactor(SBR) is possible. (R. Lognathan et al., 2012) SBR can be used for Landfill leachate treatment. (Shuokr Qarani Aziz et al., 2013) Biological Treatment of Slaughterhouse Wastewater Using Mixed Culture in sequencing Batch Reactor can be done. (Pradyut Kundu et al., 2014) Biological process at bhilai steel plant sewage treatment plant activated sludge process can be changed by using sequential

batch reactor (Devendra Dohare, Miss Nupur Kesharwani et al., 2014).

Performance of ASP and SBR

The performance of STP’s typically comparable with each other but depends on system design & site specific criteria. The avg. performance data values reported in CPHEEO manual 2010 is given in Table 3.

Table 3 The avg. performance data values(CPHEEO manual 2010)

Parameters	% removal efficiency	
	Sequential Batch Reactor	Activated Sludge Process
BOD	89-98%	85-95%
TSS	85-97%	85-90%
Total Nitrogen Removal	>75%	No treatment
Biological Phosphorus removal	57-69%	No treatment
Total Coliforms	99%	90-96%

The SBR system has a higher ability to remove the total nitrogen TKN concentration than the AS system under all cases of operation. The average of TKN removal for the SBR and AS systems is equal to 85.0 % and 80.0 % respectively. Also, the SBR system has a higher ability to remove the total ammonia NH₃ + concentration than the AS system under all cases of operation. The average NH₃ + removal for the SBR and AS system is equal to 98.0 % and 90.0 % respectively. (Amr m. Abdel_kader et al., 2009)

Specific Performance of ASP

The removal efficiency of BOD was found to be 94.56% and that of TSS was 93.72%. BOD and TSS removal efficiencies of the activated sludge plant(Aeration tank + Secondary clarifier) are 91.27% and 86.76% respectively.(K. Sundara kumar et al., 2010)

The performance showed by the activated sludge (AS) plants considering organic matter removal, was the highest among all these systems of septic tank, anaerobic filter, facultative pond, anaerobic pond facultative pond, activated sludge, UASB reactors alone, UASB reactors followed by post-treatment

but it was below the expected performance. (Sílvia C. Oliveira et al., 2011)

At normal temperature and equilibrium pH value of 7 wastewater was treated such that effluent from treatment plant was without smell and with clear colour . The BOD, COD, TSS, TDS, & total alkalinity reduction values were 32.79% , 49.54%, 4.68, 8.61 and 0% respectively. 17 to 21% removal efficiency for total Coliform was achieved . Wastewater was treated to achieve high quality effluent on a continuous bases and the wastewater treatment plant, has good potential for the same . (E. C. Ukpong et al., 2013)

The order of removal efficiency was found to be VSS < COD < BOD < TSS and COD < TSS < BOD < VSS respectively in UASB and ASP STP’s. (Vaishali Sahu et al., 2013)

The air driven RBC process and the mechanically driven RBC process was found to be an approximately 30% and 50% more energy efficient process than AS. (Steven E. Williams et al., 2006)

Specific Performance of SBR

In SBBR with PUF media and suspended biomass, phosphorus and nitrogen was removed biologically which were comparable with SBR containing only suspended biomass. (B. Manoj Kumar et al., 2003)

Nitrification performance of conventional SBR was better than that of the hybrid MLE process. (H.L.S. Tam et al., 2004)

From digested piggery wastewater, nitrogen and phosphorus was removed 100% and 98%, respectively. With the C/N ratio equal to or higher than 1.7, complete denitrification was obtained. (D. Obaja et al., 2004)

An SBR operated with anaerobic and aerobic cycle stages could be considered a suitable technology for organic load removal from wool dyeing effluents. Soluble COD and BOD₅ degradation efficiencies was found to be 85 ± 6% and 95 ± 4%, respectively. Colour removal was achieved (Isolina Cabral Goncalves et al., 2005)

COD removal performance slightly decreases with increasing initial dyestuff concentration. If dyestuff concentration after anaerobic operation is high, aerobic phase helps to remove colour. The aeration is necessary as long as remaining dyestuff concentration is high after anaerobic biodegradation. (Ilgı Karapınar Kapdan et al., 2005)

Irrespective of the aerobic react period SCOD could be removed between 85 to 92% in overall reaction period of 8 hour. The performance of the reactor with operating cycle as 4+4 hour considered as optimum in which nitrification, denitrification and organic carbon removal was found to be 88-100%, 73-75% and 91-94% respectively. (Debaskar Anupam et al., 2007)

In SBR process Very high percentage of removal of biochemical oxygen demand, chemical oxygen demand, total kjeldahl nitrogen, total nitrogen, total phosphorus and total suspended solids is possible. (Mahvi A. H. et al., 2008)

The SBBR controlled by the ICS promises for the effective treatment of domestic sewage. Advanced performance of the SBBR controlled by the ICS could be obtained with a shortened aeration time. Efficiency of 98% was achieved for which the optimum COD/N ratio for the SND in the SBBR was found to be 12.5 at which the removal efficiencies of

NH₃-N, TN and COD at an HRT of 7 h were 90%, 87% and 95%, respectively. (Dahu Ding et al., 2010)

Under low temperatures for domestic wastewater treatment Anaerobic sequential batch reactor(ASBR) is promising technology. COD removal efficiency > 93% was achieved at 9.6±0.4 gVSS/L, But, at 5.3±0.2 g VSS/L, the system performance decreased to 33%. (Kayranli Birol et al., 2011)

In SBR process the removal efficiency of carbonaceous constituents (BOD, COD and TSS) was achieved more than 90 % . (R. Lognathan et al., 2012)

In the Biological Treatment of Slaughterhouse Wastewater Using Mixed Culture in sequencing Batch Reactor nitrification and denitrification was achieved efficiently alongwith oxidation of organic carbon. (Pradyut Kundu et al., 2014).

SBR showed the performance such that BOD of effluent was within standard limits of discharging in the creek. The overall removal efficiency of BOD, Total suspended solids, total nitrogen and phosphates was found to be 96 %, 92.74%, 75.67 % and 71.79 % respectively and about 18.67 % of suspended solids were removed in degritor (primary treatment) itself. (Prachi N. Wakode et al., 2014)

Critiques in ASP & SBR

The coefficients for heterotrophic and autotrophic maximum growth rate, endogenous decay, yield coefficient and Anoxic correction factor for growth and hydrolysis for tannery wastewater should be evaluated individually for each plant. (S. Murat et al., 2002)

The total nitrogen and COD removal efficiencies should be calculated from the difference between the final and initial masses. (Mauro P. Moreira et al., 2002)

Initial concentration of nitrogen compounds inside the reactor , aeration rate, biological floc size, amount and characteristics of available organic materials were effective parameters for nitrification and denitrification processes and aeration rate has a complicated effect on these processes. (Ali Akbar Azimi et al., 2005)

Effect of increasing aeration ratios beyond stoichiometric values not affected significantly on

organic material removal efficiency. (Ali Akbar Azimi et al., 2005)

Oxygen requirement should be calculated based on removal of organic materials and nitrification both. (Ali Akbar Azimi et al., 2005)

Increase in sludge age do not have significant effect on performance of anaerobic phase and aerobic phases for the dyestuff removal. (Ilgi Karapinar Kapdan et al., 2005)

The decanting of floating matter from the tank should be avoided. Proper aeration and decanting is essential for the correct functioning of the plants. (Wisaam S. Al-Rekabis et al., 2007)

All the carbon removal mechanisms are still unclear for SBR process, they seem to be influenced by non-respirometric ways (storage, biosorption, accumulation, etc.). (Soledad Gutierrez et al., 2007)

No consistent relationship between loading rates and effluent quality was found. (Silvia C. Oliveira et al., 2011)

Longer period of aeration (five hour) affected the percent removal of nitrate due to prevalence of shorter anoxic period essential for denitrification. (Pradyut Kundu et al., 2014)

Additional Advantages of ASP & SBR

ASP

By decreasing the number of operating cycles in Intermittently Decanted Extended Aeration (IDEA) treatment system the operational costs can be reduced by 3%. The operational costs can be minimized by 12 % by using a smaller capacity air blower in the conventional activated sludge wastewater treatment system. (Fu E. Tang et al., 2011)

SBR

The hybrid MLE configuration is a suitable process for upgradation of existing conventional works for Nitrogen(N) removal and for increasing hydraulic capacity of existing Nitrogen(N) removal works, without major civil works modifications. (H.L.S. Tam et al., 2004)

Use of an internal carbon source has a very positive effect on the plant's operating costs. (D. Obaja et al., 2004)

The SBR process has some superior features in terms of operation control and data collection since it offers: 1)Simplified pilot plant setup (less tanks, pumps, and tubings) 2) Greater operational flexibility. 3) Easier and more accurate flow and SRT control. 4)Easier and more accurate sampling and determination of mass balances. 5)The possibility of measuring reaction kinetics and settling characteristics directly in-situ, as opposed to a side bench reactor. 6) The information rich and easier to interpret on-line data (Stricker Anne- Emmanuelle et al., 2006)

The process advantages includes single tank configuration, easily expandable, simple operation and low costs. Primary and secondary settling tanks not required because wastewater aeration and settling are occurring in same tank. Lesser land area requirement reported because of absence of primary and secondary settling tanks, return pumps and also operation and maintenance costs for the same. (Mahvi A. H. et al., 2008) (Wisaam S. Al-Rekabis et al., 2007)

Conclusion

The treatment of sewage has been a challenge throughout the years due to varying raw water characteristics & strict effluent regulations . SBR system has oxygen dissolving capacity higher than ASP and provides Higher Fecal coliform removal efficiencies with less cost and space. Future expansion is one of the critical task in case of ASP but SBR system provides flexibility for the same. As the effluent quality is better in case of SBR system than in ASP system, hence helps in maintaining satisfactory quality of water body in which effluent is being discharged. Higher overall efficiencies with lesser cost and space requirement of SBR process provides itself the maximum probability in selection of technology for biological treatment of wastewater treatment.

Acknowledgements

It is my pleasure to acknowledge my guide, Er. Devendra Dohare, Assistant Professor, CE-AMD, SGSITS, Indore, M.P, INDIA for his guidance and support at every step.

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