Sequential Batch Reactor- Application to Wastewater –A Review

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Abstract
The Sequential Batch Reactor (SBR) is one of the potential options for treatment of industrial wastewater. SBR is a fill-and draw system for aerobic and anaerobic wastewater treatment. In industrial wastewater wide variety of both, inorganic and organic pollutants are present in the effluents which include oil, greases, metallic wastes, suspended solids, phenols, toxins, acids, dyes, colors etc., many of which are not readily susceptible to degradation and thus causing problem during disposal. The SBR is one of the potential options for treatment of industrial wastewater. The general working of the SBR is in five steps, fill, react, settle, decant, and idle. The process modification is very easy due to flexible nature of the SBR. The cycles, hydraulic retention time (HRT), sludge retention time (SRT) can be changed and hence it provides wide scope for treatment that is too in a single reactor which is most advantageous factor. SBRs are also used as pre or post treatment options along with other treatment facilities successfully. As per the review taken in this paper for experimentation conducted by various authors removal efficiency of SBR for Chemical Oxygen Demand (COD), Biochemical Oxygen Demand(BOD), Total Nitrogen(TN), Total Phosphorus(TP), nutrients, total suspended solids(TSS) etc. is more satisfactory compared to conventional methods.

Keywords- Sequencing batch reactor, industrial wastewater, hydraulic retention time, sludge retention time

Introduction

The quality of the water is of vital concern to mankind, since it is directly linked with human welfare. Surface water and ground water pollution are of concern. The major sources of pollution include domestic wastewater, industrial wastewater and agricultural discharges. Indiscriminate disposal of domestic and industrial wastewater to surface and groundwater causes degradation of environment. Therefore treatment of any kind of wastewater to produce effluent with good disposable quality is necessary. However the choice of appropriate and effective treatment system is necessary. Industrial wastewater, in particular needs to be managed properly due to the specific nature of industrial wastewater.

In industrial wastewater wide variety of both, inorganic and organic pollutants are present in the effluents from breweries, tanneries, dying textiles, paper and pulp mill, steel industries, mining operations etc. The pollutants include oil, greases, metallic wastes, suspended solids, phenols, toxins, acids, dyes, colors etc., many of which are not readily susceptible to degradation and thus causing problem during disposal (Chauhan, 2008).

The SBR is one of the potential options for treatment of industrial wastewater. SBR is a fill-and draw system for aerobic and anaerobic wastewater treatment. In this system, wastewater is added to a single "batch" reactor, treated to remove undesirable components, and then discharged. Equalization, reaction/aeration, and clarification can all be achieved using a single batch reactor. SBR systems have been successfully used to treat both municipal and industrial wastewater (Mahvi, 2008). They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions (USEPA, 1999). The typical SBR operational cycle is shown in Fig.1.The general working of the SBR is in five steps, fill, react, settle, decant, and idle. The added advantage of the SBR system is its flexibility of adopting/eliminating various steps and adjusting the time of treatment as well.

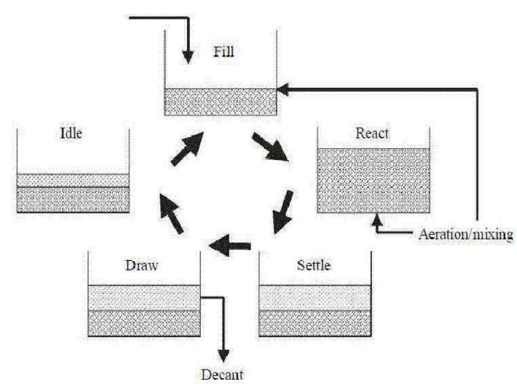

Fig.1: Typical cycles of SBR (Source: USEPA 1999)

Apart from eliminating various steps of treatment SBR allows modification which provides one more important option in the form of Anaerobic sequencing Batch Reactor (ASBR). ASBRs allow typical biological anaerobic metabolism from substrate consumption to methane and carbon dioxide production and operate according to the following cyclic steps: feed, reaction, settling and discharge (Dague *et al.*, 1992). The main advantages of this type of operation are its operational simplicity, efficient quality control of the effluent, possibility of eliminating the settling step for both the affluent and effluent wastewater and flexibility of use in the wide variety of wastewaters to be treated.(Rodrigues *et al.*, 2004). SBRs are capable to treat variety of wastewaters. As per the literature review taken in this paper, wastewaters like municipal sewage , leachates generated in a typical municipal solid waste , grey water, leachate added with dairy wastewater, landfill leachate, brewery wastewater , poultry slaughterhouse , Azo dye Orange II, dilute swine slurries , low strength swine wastewater, synthetically prepared wastewater, reactive dyes wastewater, synthetic wastewaters at different salt concentrations, swine manure, wastewater from an industrial milk factory, benzoic acid etc. are having the treatability aspect in SBR and ASBR.

Literature review

a) **Aerobic SBR application for treatment of wastewater**

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.

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.

Akýn and Ugurlu (2005) checked the treatment of synthetically prepared wastewater to observe the biological nutrient removal and to find out controlling factors on them in the form of oxidation reduction potential (ORP), dissolved oxygen (DO) and pH. The SBR system was tested for various SRT's i.e. 25, 15 and 10 days. The individual profiles of nitrogen removal, phosphorus removal, pH, ORP and DO were plotted verses cycle time. It was concluded that pH and ORP individually cannot be a control parameter for nitrogen and phosphorus removal but together they explain biological reactions in the system completely and can be referred for better control and monitoring of nutrient removal in SBR.

Uygur (2006) experimented with four step SBR (anaerobic/oxic/anoxic/oxic phases with HRT of (1 h/3 h/1 h /1 h) for investigation of nutrient removal from synthetic wastewater at different salt concentrations ranging from 0 to 6 % (w/v). Two different conditions were produced i.e. one is addition of halobacters to the system and other is halobacter free system. The addition of salt above 1% proved unfavorable for both systems as the nutrient removal efficiencies were decreased. It was concluded that the halobacters are advantageous for nutrient removal in presence of salt in SBR treatment system.

Zhang *et al.* (2006) studied the technical feasibility of simultaneously nitrogen and phosphorus removing from swine manure was investigated in SBR. The 8 hr. per cycle SBR with alternating anaerobic–anoxic–anoxic/anaerobic–anoxic/aerobic conditions realized the reductions of TN, TP, COD, BOD_5 and turbidity by about 98, 95, 96, 100, and 95%, respectively. The concentrations of $NH4^+$–N and soluble phosphorus (SP) were also reduced by about 100 and 97%.

Klimiuk and Kulikowska (2006) carried out the SBR study to treat the municipal landfill leachate. The SBR conditions were varied with HRT and SRT in two different series with four SBRs in each series. The SRT in series1 was approximately double that in series2. The study was devoted to nitrogen removal from leachate by activated sludge treatment in SBR. The influence of HRT and sludge age on nitrogen consumption on biosynthesis, effectiveness of dissimilative denitrification and ammonium losses in the aeration phase were analyzed. Following this, the rate of ammonium removal and nitrification rate in the SBR cycle were estimated. It has been shown that nitrogen removal was a result of biosynthesis and denitrification although a significant part of nitrogen was removed as a result of ammonium loss. The ammonium loss in series1 was two times higher than series2. The decrease in HRT resulted in consumption of nitrogen because of biomass synthesis. In reactors with 12, 6 and 3d HRT, the concentration of ammonium in the effluent did not exceed the value of 1 mgN_{NH4}/dm3 at sludge ages above 20d and the ammonium removal rate changed from 5.38 mg N_{NH4}/g VSS.h to 7.36 mg N_{NH4}/g VSS.h, while the nitrification rate changed from 0.75 mg N_{NO3}/g VSS.h to 0.99 mg N_{NO3}/g VSS.h.

Lamine (2007) carried out study of treatment of grey water by applying the SBR. The HRTs were 0.6 days and 2.5 days for load variation and effectively SBR can remove nutrients and carry out the biodegradation of organic matter with COD removal more than 90%. The SVI was 100 ml/g which is very satisfactory. The phosphorus removal performance was decreased and ammonium concentration was high in 0.6 days HRT system whereas it was less affected in 2.5 days HRT system. It is matter for study as optimization is necessary for HRT to be adopted by load variation.

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.

Kim et al. (2008) researched the treatment of low strength swine wastewater with municipal wastewater in enhanced SBR which involves eight steps of treatment i.e. fill, contact, settle, decant, nitrification, refill, react and idle. It was proved that independent nitrification can be achieved by incorporating the contact period within the system and nitrification in the external reactor. The COD, TN and TP removal were 87%, 81 % and 60 % respectively which can be considered far better than conventional treatments. As the ammonia nitrogen was nitrified 70% in the external reactor, this system does not require any externally added carbon for effective removal of nutrients and biodegradation of organic matter. Finally it was concluded that the system is best suited for regular as well as advanced wastewater treatment particularly for low strength wastewaters.

Moawada *et al.* (2009) investigated the treatability of the domestic sewage by an integrated system of anaerobic and aerobic treatment processes i.e. upflow anaerobic sludge blanket (UASB) followed by aerobic SBR produce wastewater suitable for irrigation. Three runs were experimented, which included 4 to 3 hrs variation of HRT of UASB and 6 to 12 hrs cycle variation of SBR in which the aeration period variation was from 2 to 9 hrs. The increase in HRT of SBR was beneficial for TN removal but it was not having any effect on TP as well as COD and BOD removal efficiencies. The removal efficiencies were 84 to 89%, 90 to 95.9 % and 85 to 93.9% of COD, BOD and TSS respectively which concluded that use of SBR as post treatment step after UASB is a promising technology.

El-Gohary and Tawfik (2009) aimed at removal of color and COD of reactive dyes wastewater. The use of SBR in this study was for increasing efficiency of COD removal. The feed to the SBR was chemically pretreated wastewater with alum and Cytec. The COD removal efficiency of SBR was 68% and 76% for BOD removal. Authors mentioned about the introduction of anaerobic process for dye removal instead of chemical treatment before SBR treatment which is not been experimented in this study.

Vaigan *et al*. (2009) checked the performance of SBR under various concentrations of dyes in the influent. The performance was checked based on dye removal, COD, Turbidity, Effluent TSS, mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS) and SVI. The dye removal efficiency was found to be 31 to 57 % and there was no significant effect on COD removal and sludge properties regarding variation in dye concentration. In the experimentation it is observed that only one HRT (1.83 days) kept for all conditions and there is a scope for additional experimentation regarding volumetric organic loading rate and specific organic loading rate like COD variation and also conditions can be varied like aerobic, anaerobic etc.

Freitas *et al*. (2009) proposed that short SBR cycles select and maintain a robust and active biomass, able to cope with typical disturbances occurring in wastewater treatment plants. In order to test this hypothesis, an SBR system was subjected to COD, N and P shock loads. It was shown that the sludge enriched in the SBR operated with short cycles was able to rapidly recover from the tested disturbances.COD and N removal recovered within 1–2 days for shock loads of 10 times the standard concentration. . It was concluded that SBR operated with short cycles led to a robust sludge that was able to respond well to shock loads.

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.

Ravichandran *et al.* (2011) treated textile effluent using SBR and pre and post treatments were done using sonochemical reactor. Kinetic modeling was performed to analyze the effect of individual parameters. These kinetic models were used for the quadratic approximation of the overall (cascaded) model for COD profile of wastewater during various treatment processes. The kinetic study was done and quadratic modeling through simulation and optimization was carried out. It was concluded that Shock load and abnormal load can be easily handled using proper controller for time allocation for chemical and biological SBR.

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.

b) ASBR application for treatment of wastewater-

Timur H. and Zturk I. OÈ (1999) used the six bench scale ASBR's to study the treatability of landfill leachate. It was concluded that raw leachate with high strength can be treated in ASBR. The COD removals of 64±85% are possible at volumetric and specific loading rates varying

0.4±9.4 g COD/ lit/ day and 0.17±1.85 g COD/ g VSS/ day respectively. Of all the COD removed 83% is converted to methane. With the assumption that the rest is converted to biomass, the calculated biomass yield is 0.12 g VSS/ g/ COD_{rem}. The relation between microbial growth and substrate utilization was formulated and results of biomass yield coefficient and specific biomass decay rate constant were calculated and also experimentally determined, the difference between the experimentally determined and calculated values is reasonable; and concluded that compared to conventional method, this method can be applied more easily.

Rodrigues *et al.* (2004) focused on enhancement of the performance of an ASBR, containing granulated biomass treating low-strength synthetic wastewater, through a study of the feasibility of implementing a variable stirring rate program. A simplified model of the biological process using apparent kinetic parameters, i.e., considering both kinetic and mass transfer effects, was proposed and validated with experimental results, assuming only two stages with first-order kinetic reactions in series, as a way to elucidate the improvement seen with the operational strategy adopted. The variable stirring program results in enhanced biological activity due to transfer of substrate into granulated biomass. This program also permitted maintenance and development of biomass with good settleability characteristic.

Ong *et al.* (2005) worked with aerobic as well as anaerobic SBR for removal of Azo dye Orange II. During this study the absorption, Specific Oxygen Uptake Rate (SOUR) and modeling of biosorption was done. The equilibrium of biosorption of Orange II was modeled using Freundlich and Langmuir isotherms. In order to examine the controlling mechanism of the adsorption process, pseudo-first order and -second order equations were used to test the experimental data. The SBR system performance with varying dye and organic loading rate was checked. It was observed that anaerobic SBR is more effective in degradation of dye and ineffective in COD removal and vice versa in aerobic SBR. Hence it was concluded to combine two systems for effective result.

Ndegwa *et al*. (2005) treated the dilute swine slurries in anaerobic sequential batch reactor. With due advantages of the anaerobic process the low strength swine slurry was treated with two different temperatures 20ºC and 35 ºC. The temperature difference does not have significant effect on quality of biogas. Although the performance of COD removal and solid settling was higher at lower temperature. The nutrient removal was almost nil as the equal amount of N and P was found in both influent and effluent. The fact of getting better performance at lower temperature has to be more rigorously tested as rightly pointed out by authors.

Sarti *et al.* (2007) dealt with ASBRs to find out the best possible mixing method by varying the conditions like the way of mixing and geometry. The mixing methods adopted were mechanical mixing and liquid circulation and geometry variation was done based on L-length/D-diameter ratio. The better performance was observed in the ASBR with mechanical stirrer as due to fragmentation of granular sludge and because of it loss of biological solids which affects the performance in negative way. It was also pointed out here that the variation in geometry is not affecting factor concerned to performance. Average removal efficiencies of 60% and 80% for COD and TSS respectively.

Cheong *et al.* (2008) determined the stability of the ASBR under varying organic loading conditions with variation of feed to cycle ratio. Two ASBR experimentation carried out, one is batch reactor and second fed batch reactor. The system that operated in the fed-batch mode attained stability and higher efficiency for treating organic wastewater in a higher organic loading condition. F: C ratios higher than or equal to 0.42, the fed-batch mode operation showed higher efficiency of the system in COD removal which reached 86–95%. Modifying the feed strategy is indicated as one of the beneficial parameters to solve the loading problem and tolerate relatively high organic loading that result in overloading conditions in batch mode systems.

Xiangwen *et al*. (2008) experimented with SBR by putting floating cover for brewery wastewater. For varying organic loading rates i.e. from 1 to 5 kg COD/m^3 d, the performance of COD removal was constant which was above 90 %. Also in this study the sludge granulations achieved was in 60 days which is much less than granulation time ever reported. The experiment also showed that ASBR has potential to produce energy by producing gas 2.4 L/L d. Authors concluded with the ASBR is a potential alternative for brewery wastewater. Authors mentioned that even during fluctuation of volatile fatty acids the COD removal was more than 90%, but the organic loading rate here was comparatively less. Hence there is more scope observing the performance of ASBR under higher OLR.

Discussion

As the treatment of industrial wastewater is a major and complicated issue regarding the environmental pollution, one can have the better solution in the form of SBR. The wide variety of wastewaters can be treated using SBR as can be concluded from the literature review. The process modification is very easy due to flexible nature of the SBR. The cycles, HRTs, SRTs can be changed and hence it provides wide scope for treatment that is too in a single reactor which is most advantageous factor. Some modifications are tried like addition of perforated baffle plates for creating the conditions of continuous flow in a batch reactor (Lin S.H. and Cheng K.W. 2001) which was not so much to the benefit from treatment aspect. There is also example of modification in cycle as the additional nitrification is provided and eight steps process was created (Kim *et al*., 2008) which proved very much effective as the treatment efficiency increased but with low strength wastewater. Additional study related to various strength of wastewater with SBR is part of further scope. The change in steps in terms of aerobic, anaerobic, oxic, anoxic also were tried (Kulikowska et al., 2007; Kargi and Uygur, 2003; Uygur and Kargi, 2004; Uygur, 2006; Zhang *et al.*, 2006) which also were on positive side as the treatment is concerned. The alteration of cycle duration along with variation in phases would be further scope of study.

SBRs are also used as pre or post treatment options along with other treatment facilities successfully. The chemical coagulation pretreatment followed by SBR for municipal wastewater (Lin S.H. and Cheng K.W. 2001) and also wastewater containing dyes (El-Gohary and Tawfik, 2009) provided satisfactory results, whereas the ultrasound treatment for leachate (Neczaj *et al*., 2005) also beneficial for COD removal. The treatment aspect of integration of aerobic and anaerobic process has been experimented in which UASB is followed by aerobic SBR to produce wastewater suitable for irrigation (Moawada *et al*., 2009). In another study the anaerobically treated poultry slaughterhouse wastewater was fed to SBR which is used as pretreatment followed by chemical-DAF and UV disinfection (Nardi *et al*., 2011) also resulted in satisfactory output in treatment efficiency.It can be seen from literature review that nutrient from wastewater can be removed effectively with SBR. (Neczaj *et al.*, 2008; Moawada *et al*., 2009; Nardi *et al*., 2011; Kim *et al*., 2008; Kargi and Uygur ,2003;Uygur,2006;Zhang *et al*. ,2006; Freitas *et al*., 2009; Li and Zang , 2002)

The ASBRs have also provided good solutions for variety of wastewaters. These are newly developed technology and have been extensively studied due to its advantages like no short circuit, high efficiency for both COD removal and gas production, no primary and secondary settles and flexible controls. This new technology has been successfully applied in laboratory and pilot scales for treatment of high strength wastewaters, such as landfill leachate, slaughterhouse wastewater, municipal sludge and dairy wastewaters, brewery wastewater etc. (Xiangwen *et al*., 2008) Different experimentations in ASBR were carried out to check the technological and efficient working. One of the studies was related to check the effect of geometry and method of mixing on working and efficiency of ASBR (Sarti *et al*., 2007) in which it was concluded that geometry does not have any effect on efficiency of reactor but method of mixing certainly has effect as it may have effect on formation of granulation, but there is scope to check the settlability of granules in various geometry. In case of stirring the mix, study was carried out by opting various stirring programs and its effect on granulation as well as efficiency of removal and results observed were beneficial biologically (Rodrigues *et al*., 2004) . Authors have worked on low strength synthetic wastewater and robustness of the system has to be proved with varying strength and shock loads. There are also attempts of kinetic parameter estimation and its experimental validation in SBR and ASBR (Timur H. and Zturk I. OÈ ,1999; Rodrigues *et al*., 2004;Ong *et al.*, 2005; Kargi and Uygur, 2003).

There are efforts in terms of experimentation taken for both SBR as well as ASBR. The suggestions are also been given by many authors regarding treatment in the form of combination of anaerobic and aerobic treatments. (Moawada *et al*., 2009; Nardi *et al*., 2011; Kim *et al*., 2008; El-Gohary and Tawfik, 2009; Ong *et al.*, 2005). The robustness of SBR for the shock loads and concentrated effluents has also been demonstrated through experimental studies and system was found to be capable of coping with the same (Freitas *et al*., 2009; Ravichandran *et al.*, 2011). From the review carried out it can be concluded that the SBR treatment system is efficient in treating various wastewater.

Scope for further work

The use of anaerobic and aerobic SBR for textile effluent has not been evaluated for its performance. In this context, exhaustive studies are essential to assess the performance of anaerobic and aerobic SBR. The design criteria/ data needs to be developed for such systems. The effect of varied organic loading, process times and solid retention time needs to be evaluated for various types of effluents, particularly medium and high strength effluents and also for shock loads. For less energy intensive and improved quality of effluent the coupling of aerobic and anaerobic SBR can be done. There is scope for optimal design of SBR systems with different process kinetics which is not been exhaustively addressed in the previous studies.

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