REVIEW OF PROCESS EFFICIENCIES OF SEQUENTIAL BATCH REACTOR OF WASTE WATER TREATMENT PLANT

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Abstract

Reuse of waste water is an emerging field in developing countries. This is an area which is being explored in developed countries to manage water supplies. Reusing waste water has led much technological innovation still some restraining factors such as limitations of land, infrastructure, and implementation of policies are imposing as an obstacle. To ensure the quality criteria of reuse waste water, proper monitoring of process parameters are to be taken care. Waste water Treatment method such as Sequential batch Reactor is a promising technology which have been used worldwide. Reuse of waste water is categorized according to BOD, COD, TSS and bacterial presence. This paper deals with the work done on the water treatment on Sequential Batch Reactor (SBR) for the period 1986 to 2014.

Keywords: Sequential batch reactor, performance, process efficiency, influent and effluent

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Nomenclature/List of Symbols

Sr. No.	Abbreviation	Full Form
1	BOD	Biochemical Oxygen Demand
2	COD	Chemical Oxygen Demand
3	TSS	Total Suspended Solids
4	SBR	Sequential Batch Reactor
5	ASP	Activated Sludge Process
6	MBBR	Moving Bed Biofilm Reactor
7	RAS	Returned Activated Sludge
8	BCM	Billion Cubic Meters
9	CWC	Central Water Commision
10	MLD	Million Litre per day
11	LPCD	Litres per capita per day
12	UNESCO	United Nations Educational, Scientific and Cultural Organization
13	WWAP	World Water Assessment Program
14	TS	Total solids
15	TOC	Total Organic Carbon
16	TKN	Total kjeldahl Nitrogen
17	SVI	Sludge Vol. Index
18	MLVSS	Mixed Liquor Volatile Suspended Solids
19	MLSS	Mixed Liquor Suspended Solids
20	DO	Dissolved Oxygen
21	TN	Total Nitrogen
22	TP	Total Phosphorus
23	SS	Suspended Solids
24	mg/l	milligram per litre
25	MGD	million gallon per day
26	CPHEEO	Centre for Public Health and Environmental
27	CPCB	Central Pollution Control Board
28	STP	Sewage Treatment Plant
29	F/M	Food to Micro-organism Ratio
30	EPA	Environmental Protection Agency
31	VSS	Volatile Suspended Solids

1.0 Introduction

With an increase in urbanization and population water demand is increasing day by day. If there is a gap coming between demand and supply the possibilities to overcome this problem is either to create new water resources, less consumption of water or recycle waste water. The potential source which can be tapped to overcome this problem of water scarcity is to reuse waste water. Waste water is generated by domestic use, industrial use, and municipal use. Many treatment methods for recycling of waste water is in use and documented in various research papers. Technology has been upgraded from time to time depending on the increasing demand of such treatment plants. Sequential batch reactor installation consists of at least two identically equipped tanks with a common inlet, which can be switched between them. The tanks have a "flow through" system, with raw wastewater (*influent*) coming in at one end and treated water (*effluent*) flowing out the other. While one tank is in settle/decant mode the other is aerating and filling. At the inlet is a section of the tank known as the bio-selector. This consists of a series of walls or baffles which direct the flow either from side to side of the tank or under and over consecutive baffles. This helps to mix the incoming Influent and the *returned activated sludge* (RAS), beginning the biological digestion process before the liquor enters the main part of the tank. Sequencing batch reactors operate by a cycle of periods consisting of fill, react, settle, decant, and idle. The duration, oxygen concentration, and mixing in these periods could be altered according to the needs of the particular treatment plant. Appropriate aeration and decanting is essential for the correct operations of these plants. The aerator should make the oxygen readily available to the microorganisms. The decanter should avoid the intake of floating matter from the tank. The many advantages offered by the SBR process justify the recent increase in the implementation of this process in industrial and municipal wastewater treatment. A detailed study is being carried out in this research paper.

1.1 Water availability and uses

India accounts for 2.45% of land area and 4% of water resources of the world but represents 16% of the world population. Total utilizable water resource in the country has been estimated to be about 1123 BCM (690 BCM from surface and 433 BCM from ground), which is just 28% of the water derived from precipitation. About 85% (688 BCM) of water usage is being diverted for irrigation (Figure 1.1), which may increase to 1072 BCM by 2050. Major source for irrigation is groundwater. Annual groundwater recharge is about 433 BCM of which 212.5 BCM used for irrigation and 18.1 BCM for domestic and industrial use (CGWB, 2011). By 2025, demand for domestic and industrial water usage may increase to 29.2 BCM (Kaur et al., 2012). Thus water availability for irrigation is expected to reduce to 162.3 BCM. With the present population growth-rate (1.9% per year), the population is expected to cross the 1.5 billion mark by 2050. Due to increasing population and all round development in the country, the per capita average annual freshwater availability has been reducing since 1951 from 5177 m^3 to 1869 m^3, in 2001 and 1588 m3, in 2010. It is expected to further reduce to 1341 m^3 in 2025 and 1140 m^3 in 2050. Hence, there is an urgent need for efficient water resource management through enhanced water use efficiency and waste water recycling. Fig.1.1 shows the projected demand for different sectors.

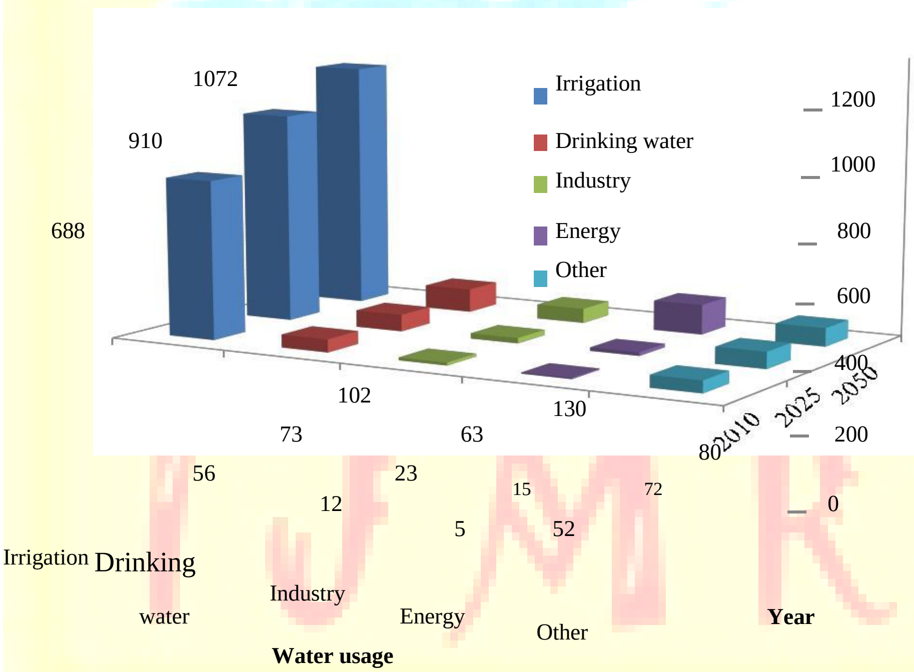
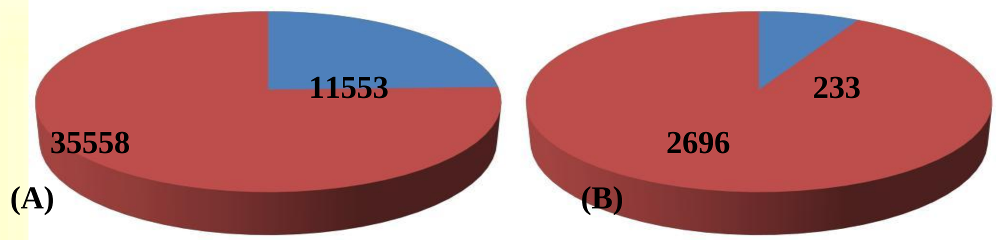


Fig. 1 Projected water demand by different sectors (CWC, 2010)

1.2 Waste water production and treatment

With rapid expansion of cities and domestic water supply, quantity of gray/waste water is increasing in the same proportion. As per CPHEEO estimates about 70-80% of total water supplied for domestic use gets generated as waste water. The per capita waste water generation by the class-I cities and class-II towns, representing 72% of urban population in India, has been estimated to be around 98 lpcd while that from the National Capital Territory-Delhi alone (discharging 3,663 mld of waste waters, 61% of which is treated) is over 220 lpcd (CPCB, 1999). As per CPCB estimates, the total waste water generation from Class I cities (498) and Class II (410) towns in the country is around 35,558 and 2,696 MLD respectively. While, the installed sewage treatment capacity is just 11,553 and 233 MLD, respectively (Figure 1.2) thereby leading to a gap of 26,468 MLD in sewage treatment capacity. Maharashtra, Delhi, Uttar Pradesh, West Bengal and Gujarat are the major contributors of waste water (63%; CPCB, 2007a). Further, as per the UNESCO and WWAP (2006) estimates (Van-Rooijen et al., 2008), the industrial water use productivity of India (IWP, in billion constant 1995 US$ per m3) is the lowest (i.e. just 3.42) and about 1/30th of that for Japan and Republic of Korea. It is projected that by 2050, about 48.2 BCM (132 billion litres per day) of waste waters (with a potential to meet 4.5% of the total irrigation water demand) would be generated thereby further widening this gap (Bhardwaj, 2005). Thus, overall analysis of water resources indicates that in coming years, there will be a twin edged problem to deal with reduced fresh water availability and increased waste water generation due to increased population and industrialization. Insufficient capacity of waste water treatment and increasing sewage generation pose big question of disposal of waste water. As a result, at present, significant portion of waste water being bypassed in STPs and sold to the nearby farmers on charge basis by the Water and Sewerage Board or most of the untreated waste water end up into river basins and indirectly used for irrigation. It has been reported that irrigation with sewage or sewage mixed with industrial effluents results in saving of 25 to 50 per cent of N and P fertilizer and leads to 15-27 % higher crop productivity, over the normal waters (Anonymous, 2004). In India, there are 234 Sewage Water Treatment plants (STPs). Most of these were developed under various river action plans (from 1978-79 onwards) and are located in (just 5% of) cities/ towns along the banks of major rivers (CPCB, 2005a). In class-I cities, oxidation pond or Activated sludge process is the most commonly employed technology, covering 59.5% of total installed capacity. This is followed by Up-flow Anaerobic Sludge

Blanket technology, covering 26% of total installed capacity. Series of Waste Stabilization Ponds technology is also employed in 28% of the plants, though its combined capacity is only 5.6%. Fig. 2 shows sewage generation and treatment capacity in 498 class I cities and 410 class II towns in India (CPCB, 2009).



Treatment capacity (MLD)
Sewage generation (MLD)
Planned treatment capacity (MLD)

Fig. 2 Sewage generation and treatment capacity in various cities and towns in India (CPCB, 2009)

2.2 LITERATURE REVIEW ON SEQUENTIAL BATCH REACTOR

Various authors worked on many aspects of water treatment on using sequencing batch reactors and their work from 1986 to 2014 have been summarized and presented in this section.

Tam et al. (1986) treated milking center waste using sequencing batch reactors with the help of three 5.0 litres, acrylic, plastic bench-scale sequencing batch reactors of 460 mm in height and 138 mm in diameter operated at 3.7, 10.5, 21.6 and 29.8°C for a 6-hours cycle. The removal efficiency for 5-days Biochemical Oxygen Demand (BOD5) and chemical oxygen demand (COD) over 90% and 70% were observed even at low temperatures 10.5 and 3.7°C.

NH3-N and total suspended solids removal efficiency was over 92% at 21.6 and 29.8°C and in the range 86 to 95%. Mohamed and Saed (1995) studied SBR efficiency in the treatment of waste water from a dairy plant. The SBR is utilized for 30-minutes aeration feed, 12-hours reaction with O2, 1-hour settling period without O2, 30-minutes draw without O2, and 15-minutes idle phase. The removal of 96.7% of NH3-N, 94% of COD, and 96% of SS were achieved. Samkutty et al. (1996) studied biological treatment of dairy plant waste water with SBR and concluded that SBR is a good system for the primary and secondary treatment of dairy waste waters. The study was carried for 2 months of operation in pH range 7 to 8. The viable biomass of the samples was determined by Adenosine Tri Phosphate (ATP), measured in Relative Light Units (RLU) and Heterotrophic Plate Count (HPC). BOD is highly correlated with COD, TS, TSS, HPC, and ATP in the effluent. A significant correlation was also observed between ATP and HPC. Results shows significant reduction of 97% BOD, 93% COD, 97% TSS, 76% TS. Abdullah et al. (2000) studied aerobic granular sludge formation for high strength agro-based waste water treatment in an open, cylindrical column type SBR having total volume of 3 liters, working volume of 1 litre, fed at loading rate of 2.5 kg COD/m^3/day, operated for successive cycles of 3 hours in pH range 6.5- 7.0, at initial MLSS concentration 3000 mg /l in the reactor. The removal efficiencies of 91.1%, 97.6% and 38% were obtained in COD, ammonia and colour removal. Stable granules were obtained with 2.0-4.0 mm diameter at COD loading rate of 2.5 kg COD/m^3/day and good biomass accumulation with good settling properties of granular sludge was obtained at sludge volume index (SVI) was 31.3 ml g/ss and biomass concentration of was 7600 mg /l. Bernet et al. (2000) studied combined anaerobic-aerobic SBR for the treatment of piggery waste water by utilizing an anaerobic reactor of liquid volume of 1.5 litres, seeded with 0.75 litre anaerobic sludge, operated at 350C temperature, magnetically stirred at a constant speed of 400 r.p.m. Aerobic reactors N1 had an active volume of 1.5 litres used when waste water flow rate was 0.1 l /d, N2 of 4 litres reactor containing 3 litres of mixed liquor used when the organic carbon load of the system was doubled, operated at temperature 20±2.20C, magnetically stirred at 700 r.p.m. For the 24 hours cycle TOC removal of 81-91% and TKN removal of 85 to 91% obtained.

Sirianuntapiboon (2002) studied application of Granular Activated Carbon- Sequencing Batch Reactor (GAC-SBR) system for treating pulp and paper industry waste water by utilizing six reactors of 10 litres capacity made up of 5 mm thick acrylic plastic with l8 cm in diameter and 40 cm in height, working volume was 7.5 litres, operated at 60 r.p.m. fed by paper and pulp industry waste water. GAC showed the COD and color adsorption under jar test conditions as 127.00 mg/g of GAC and 248'00 Pt-Co/g of GAC, respectively. For full aeration SBR conditions the COD and color removal efficiencies of GAC were increased by 3.l6% and 1.05%, after 30 days of operation of GAC-SBR, the COD adsorption ability of GAC was increased to 107.85 mg/g. The COD, BOD5 and colour removal efficiencies of SBR system were 73.26%, 95.10 % and 56.96% respectively under HRT 1 day and were up to 90.60%, 91.84% and 52.94% respectively under HRT of 10 days.

Goltara et al. (2003) studied carbon and nitrogen removal from tannery waste water with a membrane bioreactor by using a reactor of 3.5 litres equipped with a submerged hollow fibre membrane of 0.10 m2. surface area of 0.04 and 0.1 micrometers average and maximum pore sizes were operated for cycle time of 8 hours, with 20 minutes for feeding, 4 hours 45 minutes of aeration, 1 hour 15 minute anoxic stage, 30 minutes of re-aeration and 1 hour 10 minutes of permeation, at HRT of 24 hours and controlled with PLC. The maximum biomass concentration in the reactor 10 g/l. Low biomass yield was achieved due to the low food/microorganisms (F/M) ratio. Removal efficiency of 100% approximately in ammonium, 90% in COD and 60 to 90% in TN removal was achieved. Ganesh et al. (2003) studied biodegradation of tannery waste water using sequencing batch reactor - respirometric assessment by utilizing bench-scale reactor made up of Plexi glass, 8 litres working volume with respirometry combined. At a 12-hour SBR cycle with a loading rate of 1.9-2.1kg/m3.d, removal of 80-82% COD, 78–80% TKN and 83-99% NH3-N were achieved. About 66-70% of the influent COD was readily biodegradable, 10-14% was slowly degradable and 17-21% was non-biodegradable. Mahvi (2004) studied feasibility of continuous flow sequencing batch reactor in domestic waste water treatment by using pilot scale reactor with an operating volume 36 litres, operated at 10-30oC for Run 1: 6 - hour cycle (Q = 1.5 l/hr., HRT 16.7 hr), Run 2: 6 - hour cycle (Q = 2 l/hr., HRT 14 hr.), and Run 3: 6 - hour cycle (Q = 2.5 l/hr., HRT = 12.4 hr.).The removal efficiencies of 97.7%, 94.9%, 85.4%, 71.4 %, 55.9% and 99%were obtained in BOD, COD, TKN, TN, TP and TSS removal respectively.

Debsarkar et al. (2004) studied sequencing batch reactor treatment for simultaneous organic carbon and nitrogen removal in a laboratory study, by using a reactor made in 5 mm thick Perspex sheet, having effective volume 20.0 litres, operated at combination 1 - 4 hour aerobic react period and 4 hours anoxic react period, combination 2 - 5 hours aerobic react period and 3 hours anoxic react period, combination 3 - 3 hours aerobic react period and 5 hours anoxic react period in aerobic-anoxic sequence, fed by synthetic waste water having soluble chemical oxygen demand 1000±100 mg/l, ammonia nitrogen of 40-90 mg/l. The removal efficiency of 85-92% of COD removal was obtained for 8.0 hours cycle period, irrespective of aerobic react period. At combination 4+4 hours 88-100%, 73-75%, 91-94% removal efficiencies were obtained for nitrification, de-nitrification and organic carbon. Lefebvre et al. (2004) studied halophilic biological treatment of tannery soak liquor in a sequencing batch reactor by using lab-scale with peristaltic pumps, air compressor at 300C temperature operated for cycle 24 hours divided as 22 hours for reacting, 1 hour 30 minutes settling, 30 minutes withdrawal and filling . The reactor was fed at 2, 3 and 4 l/d, for hydraulic retention time (HRT) 5, 3.3 and 2.5 days. The removal efficiencies of 95%, 93%, 96% and 92% for COD, PO43-, TKN and SS respectively, were achieved for 5 days hydraulic retention time (HRT) and 0.6 kg COD/m3.d and 34 g NaCl /l organic loading.

Zinatizadeh et al. (2005) studied influence of process and operational factors on a sequencing batch reactor performance treating stimulated dairy waste water by using a lab-scale SBR, constructed from plexi glass with dimensions, 10 cm length, 10 cm width, 30 cm height with a working volume of 2 litres operated and controlled by pre-programmed timers under organic loadings 1000, 3000, 5000 mg/l in terms of COD, MLVSS 3000, 5000 and 7000 mg/l and aeration time 2, 10 and 18 hours. The experiments were carried out based on a Central Composite Design (CCD) and analyzed using Response Surface Methodology (RSM) giving COD removal efficiency of 96.5% for COD 3000 mg/l, MLVSS 5000 mg/l, and aeration time of 18 hours. Ozbas et al. (2006) studied aerobic and anaerobic treatment of fruit juice industry effluent operated at HRT of 24 hours, F/M ratio of 0.5, 12 hours of cycle time. The removal efficiency of 90-95 % was obtained for soluble COD. Aerobic SBR treatment gives no problem in sludge settling. Ahsan and Jafrudeen (2006) reviewed the technologies for treatment of hospital waste water and comparison of emerging and conventional technologies. The removal efficiency of SBR was 95-97% which produced effluent of quality having BOD5< 5 mg/l, COD < 50 mg/l, TSS < 10 mg/l, Total nitrogen as N < 10 mg/l, Total phosphorus < 10 mg/l, E-coli removal 99-99% MPN/100ml. SBR was found to be more effective in treatment of hospital waste water. Zhu et al. (2006) studied a laboratory scale sequencing batch reactor with the addition of acetate to remove nutrient and organic matter in pig slurry by using laboratory-scale column type reactor of transparent polyvinyl chloride (PVC), 190mm in diameter, total volume 11 litters, working volume 8 litters, operated at 21±2oC, hydraulic retention time (HRT) of 3.3 days, for 8 hours cycle, under anaerobic-anoxic-anaerobic-anoxic (An/Ax) 2 mode. The removal efficiencies of ammonium nitrogen, total Kjeldahl nitrogen, chemical oxygen demand, biochemical oxygen demand and total phosphorus are 100.0%, 98.7%, 97.4%, 100.0%, and 98.7%, respectively with acetate addition, without acetate addition the reductions are 100.0%, 100.0%, 97.7%, 100.0%, and 97.8%. Wei et al. (2007) studied process evaluation of an alternating aerobic-anoxic process applied in a sequencing batch reactor for nitrogen removal by using a lab-scale reactor of 38 litres operated at 30 - 32°C, MLSS concentration maintained at 3000 - 3100 mg/l fed by chemical industrial waste water operated under Alternating Aerobic-Anoxic process (AAA process)and One Aerobic-Anoxic (OAA). It concluded that the AAA process was an optimal strategy as under deficient influent alkalinity, the AAA process improved treatment efficiency and effluent quality with NH4+ N in the effluent below the detection limit and in the nitrification, the average stoichiometric ratio between alkalinity consumption and ammonia oxidation is 7.07 mg CaCO3/mg NH4+ N while in the de-nitrification, the average stoichiometric ratio between alkalinity production and NO3− N reduction is 3.57 mg CaCO3/mg NO3− N. Daumer et al. (2007) studied the effect of nitrification on phosphorus dissolving in a piggery effluent treated by a sequencing batch reactor by using modified 100 litters pilot reactor, fed by homogenized and separated with a 100 mm screen centrifuge of piggery waste water, operated in feeding, anoxic phase, anaerobic, aerobic phase and withdrawal phase. The dissolved phosphorus was increased with the increase in nitrified nitrogen, at regulated pH, dissolving of phosphorus was observed.

Iaconi et al. (2008) studied technological transfer to demonstrative scale of sequencing batch bio-filter granular reactor (SBBGR) technology for municipal and industrial waste water treatment by utilizing cylindrical steel reactor of volume of 2m3, completely automatic by using a programmable logic controller (PLC). For municipal waste water the removal efficiency of 80-90% was obtained for COD, total suspended solids and ammonia were independent of the hydraulic residence time (12 to 4 hours). For municipal waste water SBBGR technology removed 80-90% of the COD, suspended solids and ammonia content up to organic loading values of 3.5 kg COD/m3·d. In both cycles very high sludge age value < 150 days which led to a biomass concentration as high as 35 g TSS/l bed and a sludge production 5-6 times lower than conventional treatment plants. Mahvi (2008) studied the discharge of domestic and industrial waste water to surface or ground water The authors had conducted some investigations as a modification of sequencing batch reactor. Their studies resulted in very high percentage removal of biochemical oxygen demand, chemical oxygen demand, total kjeldahl nitrogen, total nitrogen, total phosphorus and total suspended solids respectively. Neczaj et al. (2008) studied sequencing batch reactor system for the co-treatment of landfill leachate and dairy waste water. Two laboratory scale-reactors of 5 litres were supplied with fine bubble air diffuser, magnetic stirrers and set of two peristaltic pumps. The reactors were operated at Dissolved Oxygen (DO) concentration above 3 mg/l and at the room temperature (18–20°C). The cycle time of the reactors was 24 hours, with leachate dilution of 25% by volume with a dairy waste water, 4 g/l sludge concentration. COD was varied between 6000 and 7500 mg/l and BOD concentration in the range of 4000–5000 mg/L of dairy waste water. The COD strength of the leachate was varied between 3800 and 4250 mg/l and BOD concentration less than 430 mg/l. Spagni et al. (2008) studied optimization of sanitary landfill leachate treatment in a sequencing batch reactor by using bench-scale reactor of working volume 24 litres, operated at 20 ±0.50C, for full cycle of 24 hours divided in 4 sub-cycles of 5.75 hours in series fed by municipal landfill leachate. The removal efficiencies of nitrification and N removal were usually higher than 98%, 90%, respectively, whereas COD (of the leachate) removal was approximately 30–40%. Chang and Cajucom (2008) studied feasibility of fish farm effluent treatment by sequencing batch membrane bioreactor of working volume of 6.0 litres, attached with membrane of pore size 0.4 um and surface area 0.108 m2, operated at initial biomass concentration of 2900 mg VSS/l, sludge retention time (SRT) of 20 days, dissolved oxygen concentration above 4 mg /l, at 25oC temperature, for 4 hours cycle duration fed by fish farm effluent. Two aerobic/anoxic durations aeration/stirring-settling, 100/45-45 minutes (as run 1) and 60/60-70 minutes (as run 2), were operated at MLSS concentration 1560 mg/l and 1890 mg/l for run 1 and run 2 respectively. The removal efficiencies of CODs and BODs were 81%, 90%, respectively of run 2. The average removal of nitrification and de-nitrification were significant during the same run and nitrite drawn to range 0.5-1.0 mg/l. Kaewsuk et al. (2010) studied kinetic development and evaluation of membrane sequencing batch reactor with mixed cultures photosynthetic bacteria for dairy waste water treatment. The kinetic coefficients half velocity coefficient (Ks), maximum rate of substrate degradation (k), bacteria decay rate (kd) , yield coefficient (Y) and biomass retention time (μm) were 174 mg-COD/L, 7.42 mg-COD/mg-VSS/d, 0.1383/d, 0.2281 mg-VSS/mg-COD and 1.69/d, and at controlled temperature of 25-400C, pH range 7.0-7.5 to get COD removal from concentration from 2500 mg/L to 149 mg/L. Hu et al. (2010) studied effect of aeration rate on the emission of N2O in anoxic-aerobic SBR (A/O SBR) by using three bench scale reactors of effective volume 24 litres operated at 23±20C, 3000 mg/l of MLSS, under anoxic-aerobic mode supplied by N2 and air for the cycle of 10 minutes feed, 2 hours anoxic, 4 hours aerobic, 40 minutes settling, 10 minutes decanting. The higher aeration rate causes smaller N2O emission, mild aeration rate led to best nitrogen removal efficiency. As most N2O was produced during aerobic phase, incomplete de-nitrification was responsible for higher N2O emission at low aeration rate and complete nitrification was the reason of N2O emission at higher aeration rate. Nitrogen removal efficiency was induced by reducing N2O emission and lowering energy consumption. Khan et al. (2010) studied degradation profile of phenol in sequential batch reactor of column type having 5 cm diameter 150 cm height made in transparent perfex glass with total volume of 1.5 litres operated at about 30±20°C fed with phenol as a sole carbon source at hydraulic retention time (HRT) of 8 hours. High concentration of phenol 400 mg /l, 650 mg/l took 240 minutes for complete removal and low phenol concentration of 50, 100,200 mg/l was not detected after for 170 minutes of the SBR cycle.

Luo et al. (2011) studied effect of trace amounts of polyacrylamide (PAM) on long-term performance of activated sludge by using four lab-scale identical reactors of an internal diameter 10 cm, height 40 cm, working volume of 3 litres, operated at pH 7.3 -6.8, dissolved oxygen (DO) within range 2.0 - 4.0 mg/l, mechanically stirred at 100 r.p.m. for 12 hours cycle of operation, fed by organic synthetic waste water with PAM concentrations of 0.0,0.01, 0.1, 1.0 mg/l. PAM addition dosage of PAM was 0.1 mg/L improved the best removal efficiencies of COD, ammonium and exhibited sludge performance in settling, flocculation and microbial activity. High level of PAM (1 mg/L) led to the formation of large amounts of loose-structure flocs, affecting dissolved oxygen transfer and caused the sludge disintegration, resulted in bad settle ability, lower microbial activity. Asadi and Ziantizadeh (2011) statistically analyzed and optimized of an aerobic SBR treating an industrial estate waste water using Response Surface Methodology (RSM), by using reactors of internal diameter 8.5 cm, total height 36 cm, working volume 2 litres, operated at dissolved oxygen (DO) concentration 7 mg/l, MLVSS concentration 2000-7000 mg/l. The maximum removal efficiency of 73.89% was obtained in total COD

(TCOD) removal under 24 hours aeration at 7000 mg/l of MLVSS and total nitrogen (TN) removal efficiency was 36.39.

Malakahmad A. et al. (2011) studied SBR for the removal of Hg2+ and Cd2+ from synthetic petrochemical factory waste water. The reactor of 24 litres capacity was fed by synthetic waste water prepared to match the characteristics of real waste water with addition of sugar, powdered milk and urea added as organic sources. Mercury and cadmium salts were then added at selected concentrations and pH was increased to 7.5 from 6.9. The reactor was connected to feed tank (120 litres), treated waste water tank (120 litres) and sludge tank (60 litres). Returned sludge brought from an activated sludge process was seeded and SBR was operated for 8 hours cycle consisting five distinct modes- fill, react, settle, draw and idle. At maximum concentrations of the heavy metals, the SBR removes 76-90% of Hg2+ and 96-98% of Cd2+.The removal efficiencies of COD and mixed liquor volatile suspended solids (MLVSS) show declination with addition of heavy metals. Average Hg2+ and Cd2+ removal efficiencies is found to be 88.3% and 97.4% for the concentrations of 9.03±0.02 mg/l Hg2+ and 15.52±0.02 mg/l Cd2+ respectively. Sombatsompop et al. (2011) studied sequencing batch reactor and moving bed sequencing batch reactor for piggery waste water treatment by using acrylic reactors of 0.5 cm thick, 16 cm diameter, 40 cm height, working volume of 6 litters, operated at pH 7.5±0.5, ambient temperature 27±2oC, volatile suspended solids /suspended solids ratio of the activated sludge was 0.89, mixed liquor suspended solids concentration of 3000 mg/l, sludge retention time (SRT) 10 days, hydraulic retention time (HRT) 0.75 day and dissolved oxygen concentration in maintained by an air flow rate of 1.0 l/min. Polyvinyl chloride sponge, cut in 1.5 cm cubes, was used as the floating medium in the moving-bed reactor circulated in the reactor by air, the moving medium of density of 0.0145 g/cm^3, specific surface area 400 m^2, was used at 20% fill fraction fed by varying the organic load from 0.59 to 2.36 kg COD/m3.d.

Rio et al. (2012) studied aerobic granular sequencing batch reactor systems applied to the treatment of industrial effluents by using four lab scale sequencing batch reactors each with height of 465 mm and inner diameter of 85 mm, height to the diameter ratio (H/D) being 5.5, total volume of 2.5 litres and a working volume of 1.5 litres, controlled by a Programmable Logic Controller (PLC). The reactors were operated at room temperature 15-20 °C and at oxygen concentrations 4 and 8 mg/l for 3-hours cycle fed by four different types waste water characterized by dairy products having a high concentration of suspended solids (R1), fish canning industry with 30 g NaCl/l (R2), marine products industry with previous physical-chemical treatment (R3) and a pig farm with high organic matter and nitrogen (R4) at organic loadings ranged between 0.7 - 5.0 g/l/d of COD and 0.15 - 0.65 g/l/d of nitrogen(NH4+-N) loading rates gave the removal efficiencies of 60-95% and 15% -76%. Adish kumar et al. (2012) studied coupled solar photofenton process with aerobic sequential batch reactor for treatment of pharmaceutical waste water by varying pH, ferrous ion concentration, H2O2 dosage, treatment time and BOD3/COD ratio from 0.015 to 0.54.

Main and Ingavale (2012) studied the sequencing batch reactor for grey-water treatment by using reactor made up of acrylic sheets with square cross sectional area 30.5 cm X 30.5 cm X 19.3 cm, total volume 23 litres, working volume 18 litres, outlet fixed at 13.5 cm height, volume of grey water to be treated was 5.4 litres, fed by 7 litres capacity feeding tank, operated at MLSS concentrations 2000- 4000 mg/l, HRT 4 to 8 hours, SRT of 10 days for one cycle per day. The SBR unit was operated for cycle time 5, 6, 7 and 8 hours and optimum BOD removal efficiency 94.69% was observed for 7 hour cycle. Then SBR unit was operated for four different fill : react ratios as per 7 hour cycle (105 minutes) and the react time is varied with ratios 1:1, 1:1.2, 1:1.4, 1:1.6 and 1:1.8. The optimum BOD removal efficiency 94.57% was observed for ratio 1: 1.2. The optimum cycle time was 399 minutes comprising - Fill time: 105 minutes, React time: 126 minutes, Settle time: 84 minutes, Draw time: 63 minutes and Idle time: 21 minutes. The average characteristics of treated effluent for ratio 1:1.2 were as pH -7.9, Total Suspended Solids - 30 mg/l, Total Solids - 178 mg/l, COD - 58.36 mg/l, BOD - 9.48 mg/l. Figueroa et al. (2012) studied the CANON reactor an alternative for nitrogen removal from pre-treated swine slurry by using a laboratory scale air pulsing sequencing batch reactor with a working volume of 1.5 litres, at pH 7.7±0.2, hydraulic retention time 0.5 days, feeding flow rate of 2.18 ml/min, at room temperature 18-240C, operational cycles of 360 minutes were distributed as: 345 minutes of feeding and aeration, 10 minutes of settling and 5 minutes of effluent withdrawal. The ammonium removal, under oxygen-limited conditions, in a system with anammox bacteria mainly in the form of granules and aerobic ammonium oxidizing bacteria mainly as dispersed biomass was researched in an air pulsing sequencing batch reactor operated at room temperature. The achieved nitrogen removal rate was of 0.46 kg N/m3d treating 300 mg NH4+-N/l with value of nitrogen removal efficiency around 75%. Kern and Boopathy (2012) studied use of sequencing batch reactor in the treatment of shrimp aquaculture waste water by using two pilot scales SBR with 5000 litres capacity, working volume 3000 litres, operated aerobically and an-aerobically alternated at regular intervals. The removal efficiencies of all nitrogen species were more than 95% and the treated waste water was successfully recycled to the shrimp and for complete the de-nitrification the C:N ratio should be maintained at 10:1.

Patil et al. (2013) studied in their paper that sequencing batch reactors had excellent performance and vast application in treating domestic as well as waste water from chemical, dairy, industrial estate waste water, landfill leachate, paper and pulp, petrochemical, petroleum, pharmaceutical, piggery, sewage, swine, synthetic waste water, tannery, textile, fish farming, food processing, fruit juice, hospital, palm oil mill, shrimp aquaculture, soybean curd, wood fiber industries etc. SBR manufacturer provided a process guarantee to produce an effluent of less than 10 mg/L BOD, 10 mg/L TSS, 5 - 8 mg/L TN, 1 - 2 mg/L TP (U.S. EPA Fact Sheet, 1983). Asadi et al. (2013) studied comparatively performance of two aerobic sequencing batch reactors with flocculated and granulated sludge treating an industrial estate waste water process analysis and modeling, by utilizing reactors of internal diameter 8.5 cm, total height 36 cm, working volume 2 litres, operated at dissolved oxygen (DO) concentration 7 mg/l, MLVSS / MLSS ratio at about 0.7 in average, one system operated with granulated sludge system (GSS) and another with flocculated sludge system (FSS) under varied aeration time of 6-24 hours. Shakerkhatibi et al. (2013) studied feasibility study on ethylene oxide/ethylene glycol (EO/EG) waste water treatment using pilot scale SBR by using four identical reactors of plexi glass with internal diameter 0.2 m, height 0.3 m, total volume 9 litres, effective volume 7 litres operated respectively in parallel, at pH 7.1±0.2, over dissolved oxygen concentration 2 mg/l, biomass concentration 3500-5000 mgVSS/l, at the room temperature 20°C, under organic loadings of 500, 1000, 1500 and 3000 g COD/m3.day, for sludge ages of 10, 20 and 30 days, fed by petrochemical waste water. The removal efficiencies of 79.5 and 83.5 % were obtained at SRT 20 days and 86% at SRT 30 days was observed for SBR 1 and 2 respectively in COD removal at the OLRs of 0.5 and 1 kg COD/ m3.day. COD removal efficiency of 86% at the SRT 20 days and 92% at the SRT 30 days was achieved at aeration time of 34.5 hours at the OLR of 1 kg-COD/m3.day for SBR 3. Faouzi et al. (2013) studied contribution to optimize the biological treatment of synthetic tannery effluent by the sequencing batch reactor fed by 500 and 1000 mg/l of total chromium to laboratory scale reactor. Both systems proved to be quite effective and the best one corresponds to total chromium concentration of 500 mg/l with one cycle per day, and an aeration time of 23 hours. The removal efficiencies of 100%, 100%, 95.6% and 100% for total chromium, COD, total nitrogen and suspended solids were obtained.

Bercoff and Morling (2014) studied a small SBR-plant (Sequencing Batch Reactor) operated at substantial load variations examined with respect to performance at changing load conditions. The analysis of the performance study demonstrated how flexible an intermittently operated biological reactor in treating varying loads, but also indicates possible operational strategies.

3.0 Conclusions

From the literature review, it is observed that sequencing batch reactors have excellent performance and vast application in treating domestic as well as waste water from chemical, dairy, industrial estate waste water, landfill leachate, paper and pulp, petrochemical, petroleum, pharmaceutical, piggery, sewage, swine, synthetic waste water, tannery, textile, fish farming, food processing, fruit juice, hospital, palm oil mill, shrimp aquaculture, soybean curd, wood fiber industries etc. Some researchers studied the biological treatment of dairy plant waste water with SBR and concluded that SBR is a good system for the primary and secondary treatment of dairy waste waters. Some of them studied the sequencing batch reactor and moving bed sequencing batch reactor for piggery waste water treatment by using acrylic reactors.

From the literature studied, it is also found that Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) are the main process efficiency parameters that have been used for reuse of waste water. It is concluded that the advanced treatment technologies are used by the developed countries there is a need to explore the technologies to reuse of waste water by the developing countries. The society may be convinced to reuse the wastewater for gardening purposes.

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