SBR Technology and Role of Aerobic Granular Sludge in Biological Treatment of Wastewater

[1]Rajneesh Kumar Gautam*[1], Islamuddin[2], Nandkishor More[3]

[1,2]AssistantProfessor, Department of Civil Engineering, UIET;
[3] Associate Professor, Department of Environmental Sciences, Babasaheb Bhimrao Ambedkar Central University, Lucknow-226026, India

***Abstract**: Urban centers are unambiguously discharging wastewater in the natural streams, lakes, ponds and for irrigation in the agricultural fields. In the early stages of human civilization, wastewater discharges did not pose problem to water bodies as the nature had the capability for degradation and restoration of the quality of water to its normal condition.The key challenges towards better management of the water quality in India are spatial and temporal variation of rainfall, improper management of surface runoff , uneven geographic distribution of ground water resources, repeated droughts and floods, excessive use of groundwater, and contamination, drainage, and salinitization and water quality problems due to treated, partially treated, and untreated wastewater from urban, commercial settlements, industrial establishments, and run-off from the irrigation sector besides strapped management of municipal solid waste.SBRs are used all over the world and have been around since the 1930s. With their growing popularity in European countries, China as well as the United States, they are now being used profitably to treat both industrial and municipal wastewaters. They are now used in India and all over the world, particularly in areas characterized by low or varying flow profile. Municipalities, casinos resorts, and a number of industries, including tanneries, dairy, pulp, paperand textiles industries are using sequential batch reactors as practical wastewater treatment alternatives.*

Keywords: *Wastewater, Sequential Batch Reactor, Aerobic Granular Sludge, Municipal Solid Waste*

Introduction

The development of aerobic granules has recently been studied as a method of improving conventional activated sludge processes due to its applications in removing organic matter, nitrogen, and phosphorus compounds from wastewater (de Kreuk *et al*., 2005a).Activated sludge processes are aerobic suspended growth processes. Large amounts of oxygen are injected to maintain aerobic conditions and optimum mixing of the activated biomass is consequently done with the wastewater to be treated. Activated sludge systems are highly effective and efficient for removal of nutrient and organic matter, but pathogen removal is quite low as compared to other processes. In the view of reuse of the effluent for agricultural processes, it is not beneficial to remove all nutrients as nutrients as the nutrients provide ambient condition and vitalize the soil profile which is beneficial for good crop yield. The first sequential batch reactor plant was invented in late 1914's while the modifications started in early 1970's. SBR processes are time oriented process while as ASP process is space oriented.

Aerobic granular technology presents several advantages compared to activated sludge processes. These include good biomass retention, the ability to withstand shock and toxic loadings, and the presence of both aerobic and anoxic zones inside the granules which can simultaneously permit different biological processes (Beun *et al*., 1999).This technology offers great feasibility in terms of the control and implementation of different phases of the biological treatment processes e.g.anoxic elimination of nitrate (de-nitrification) and biological phosphorus removal, aerobic oxidation of nitrogen (nitrification) and Several studies demonstrated the effectiveness of SBR-technology and its application as an alternative to conventional flow system with respect to the treatment of municipal and industrial wastewater, especially for smaller flow (JANCZUKOWICZ *et al*., 2001; MACE & MATA-ALVAREZ, 2002).In such systems, the biomass grows as compact and dense microbial granules, which allows better biomass retention in the reactor, and, consequently, high biomass concentrations.

Therefore, these systems have lower space requirements than systems relying on activated sludge. The biotransformation of organic pollutants is carried out in the aeration tanks, where under the action of the existing biocenosis and in the presence of the required amount of dissolved oxygen in the water, the pollutants are converted into environmentally safe substances (TSACEV, 2001; Tchobanoglous *et al*., 2002; Raitchkov *et al*., 2004; Davis, 2010).

Granular sludge : Granular sludge is a special type of biofilm in which biomass grows in compact aggregates (granules) without any carrier material. Granular sludge technology started to be developed about 40 years ago at Wageningen University. At that time, granules were implemented for anaerobic treatment in up flow anaerobic sludge bed (UASB) reactors (Lettinga et al., 1983).

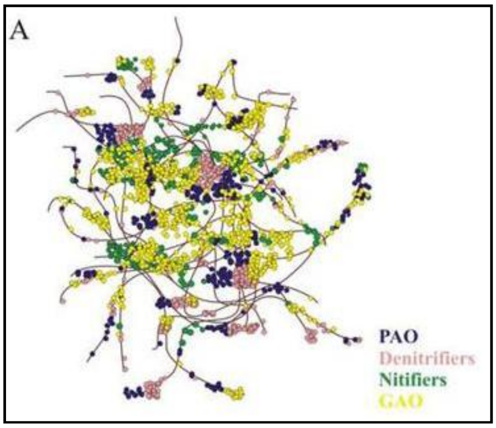

Figure 1: Microbial distribution in a sludge floc (winkler2012)

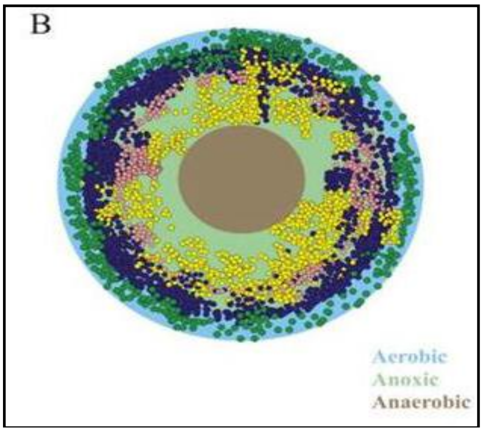

Figure 2: Microbial distribution a heterotrophic aerobic granule. (winkler 2012).

Disadvantages of anaerobic granulation include the long start-up time and the relative high operation temperature needed. Moreover, this technology only established for COD removal – no nutrient removal – and is not suitable for the treatment of low-strength organic wastewater and cannot remove nutrients. These drawbacks are overcome through aerobic granulation technology. Mishima and Nakamura (1991) established aerobic granules in an upflow sludge blanket reactor. The technology was further developed in sequencing batch reactors (SBRs) (van Loosdrecht and Heijnen, 1993; Morgenroth et al. 1997; Beun et al., 1999; Tay et al., 2002a).

SBR Process:

The sequencing batch reactor (SBR) is a fill-and draw activated sludge system for wastewater treatment. In this system, wastewater is added to asingle “batch” reactor, treated to remove undesirable components, and then discharged. Equalization, aeration, and clarification can all be achieved using a single batch reactor. To optimize the performance of the system, two or more batch reactors are used in a predetermined sequence of operations. SBR systems have been successfully used to treat both municipal and industrial wastewater. They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions. An SBR treatment cycle consists of a timed sequence which typically includes the following steps: FILL, REACT, SETTLE, DECANT, and IDLE. When biological nutrient removal (BNR) is desired, the steps in the cycle are adjusted to provide anoxic or anaerobic periods within the standard cycles (USEPA, 1992).In recent years, some modifications of SBR has been used by researchers, such as continuous flow SBR (Mahvi *et al*., 2004.a), sequencing batch bio-film reactor (SBBR) (Speitel and Leonard, 1992), anaerobic sequencing batch reactor (ASBR) (Dague *et al*., 1992) and anaerobic– aerobic sequencing batch reactor (Bernet *et al*., 2000). An anaerobic sequencing batch reactor (ASBR) is similar to aerobic SBR, except that ASBR is not aerated during reaction phase and has a cover to exclude air (Fu, *et al*., 2001).The technology is applicable for BOD and TSS removal, nitrification, de-nitrification and biological phosphorus removal. The technology is especially applicable for industrial pretreatment and for smaller flow (<1.0 MGD) applications as well as for applications where the waste is generated for less than 12 hours per day (USEPA, 1992).

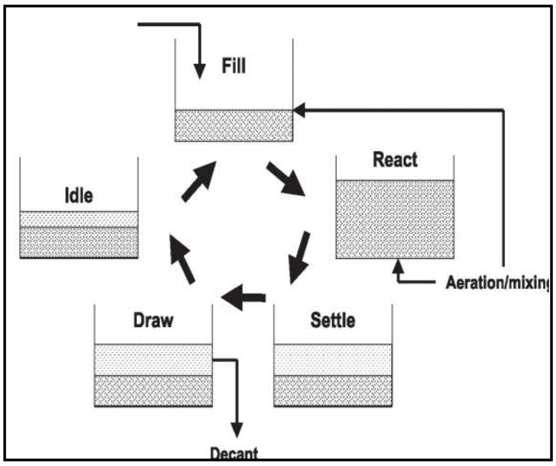

Figure3: Layout of Sequential batch reactor (U.S.EPA 1999)

Performance of SBR based on (USEPA 1992):
The performance of SBRs is typically comparable to conventional activated sludge systems and depends on system design and site specific criteria (USEPA, 1999). The average performance based on data from 19 plants is summarized below (USEPA, 1992)

- BOD Removal 89–98%
- TSS Removal 85–97%
- Nitrification 91–97%
- Total Nitrogen Removal >75 %

Table1: Key design parameters for a conventional load

Parameter	Municipal	Industrial
F/M ratio	0.5-0.4/day	0.15-0.6/day
Treatment cycle duration	4.0 Hours	4.0-24 hours
Typically low water mlss	2000-2500mg/l	2000-4000mg/l
Hydraulic Retention Time	6-14 hours	varies

Advantages
The primary advantages of the SBR process are (Washington Department of Ecology, 1998, USEPA, 1999):

- -Equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved in a single reactor vessel.
- -Small space requirements.
- -Common wall construction for rectangular tanks.
- -Easy expansion into modules.
- -Operating flexibility and control.

- Biological Phosphorus Removal 57–69%

SBR manufacturers will typically provide a process guarantee to produce an effluent of less than (USEPA, 1999):

- 10mg/L BOD
- 10mg/L TSS
- 5-8mg/L TN
- 1-2mg/L TP

Factors affecting SBR Process:
SBRs are considered to be a suitable system for wastewater treatment in small communities (Irvine *et al*., 1989), but are a relatively new technology for agricultural applications. Previous research on the SBR for animal waste was primarily concentrated on swine wastewater treatment (Li and Zhang, 2002). The major factors affecting SBR's performance include organic loading rate, HRT, SRT, dissolved oxygen, and influent characteristics such as COD, solids content, and C/N ratio. Depending controlling of these parameters, the SBR can be designed to have functions such as carbon oxidation, nitrification and denitrification, and phosphorus removal (Hisset *et al*., 1982; Hanaki *et al*., 1990).

Disadvantages
The primary disadvantages of the SBR process are (Washington Department of Ecology, 1998, USEPA, 1999):

- -A higher level of sophistication is required (compared to conventional systems), especially for larger systems, of timing units and controls.
- -Higher level of maintenance (compared to conventional systems) associated with more sophisticated controls, automated switches, and automated valves.
- -Potential of discharging floating or settled sludge during the DRAW or decant phase with some SBR configurations.
- -Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.

- -Potential requirement for equalization after the SBR, depending on the downstream processes.
- -Installed aeration power based on percent oxic of the treatment time.
- -Batch feeding from storage

Discussion:
BOD removal in SBR is more than 90%, while conventional modifications of activated sludge are capable to remove 60-95% of BOD (Metcalf and Eddy, 1991).Nitrogen content of process is low. The high nitrogen removals indicates that during settle and decant phases dissolved oxygen reached to zero and anoxic conditions become predominant, so that denitrification occurred (Mulbarger, 1971).
As mentioned, in SBRs P concentration in effluent arrives even to below 1mg/L (more than 90%). Maximum efficiency of conventional activated sludge systems in phosphorus removal is 10-20 percent (Bitton, 1999). Low TSS concentration in effluent indicates that settling of sludge is completely efficient. The high TSS removal is because of high sludge settleability velocity, as average sludge volume index is below 100 mL/g. This could be attributed to granular sludge formation, that prevent sludge washout and. Almost all aerobic granules can perform only in SBR (Mulbarger, 1971, Schwarzenbeck *et al*., 2005).Nitrogen content of process is low. The high nitrogen removals indicates that during settle and decant phases dissolved oxygen reached to zero and anoxic conditions become predominant, so that denitrification occurred (Mulbarger, 1971)

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