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MICHAŁ MAŃCZAK*

CLASSIFICATION OF SEQUENCING BATCH REACTORS

The principles of fill-and-draw systems and sequencing batch reactor (SBR) operations are described and SBRs are classified according to the treatment train, the feeding method and the sludge stabilization technique applied.

The following generalizations can be made. Batchwise fed SBRs should be operated in combination with storage tanks for economical reasons (energy demand is much lower). The settleability of activated sludge can be upgraded by sending the effluent from mechanical treatment into the internal selectors. A thorough analysis of the costs of activated sludge management must be made at the stage of design, and such analysis should include the potential for transporting non-stabilized sludge to the nearest wastewater treatment plant for processing.

1. INTRODUCTION

In wastewater engineering, sequencing batch reactor (SBR) systems have been known since the early 1960s. Currently, the interest in fill-and-draw systems is reviving and the use of SBR operations in wastewater treatment has become increasingly frequent.

In the SBR method, use is made of a fill-and-draw activated-sludge treatment system. Although the unit processes involved in the SBR and in the conventional activated-sludge systems are the same, there is one major difference between them. In a conventional (throughflow) system, anaerobic, anoxic and aerobic processes as well as biomass separation are carried out in separate tanks at the same time, while in the SBR system, they are performed sequentially in the same tank. In the throughflow reactor, wastewater is fed and discharged in a continuous flow mode, whereas in the SBR wastewater is supplied either continuously or batchwise and discharged batchwise only [1], [2].

Prior to SBR operations, it is necessary to remove floating bodies and granular suspended solids, and the best way to achieve this is to use dense screens, fine sieves or sand traps.

* Institute of Environmental Protection Engineering, Wrocław University of Technology, pl. Grunwaldzki 9, 50-377 Wrocław, Poland.

As already mentioned, in the SBR system, the processes involved are carried out in the same tank. This means that secondary settling tanks are not included, though primary settling tanks or anaerobic, anoxic and aerobic selectors can be found. According to the removal efficiencies required for particular pollutants (RER) the SBR system can be used to remove organic suspended solids (carbon compounds and nitrogen compounds) as well as phosphorus via biological and chemical methods.

An SBR system has five steps: filling, reaction (aeration), stirring, settling (sedimentation/clarification) and drawing (decanting, removing effluent) [3]. Some investigators include the so-called idle step [2], which covers the period between the final phase of the decanting step and the initial phase of the sequential filling step. When nutrients are to be removed from wastewater (denitrification and enhanced biological nitrogen removal), there is a need to maintain anaerobic, anoxic and aerobic conditions during the reaction step in a clearly defined technological regime.

The duration of particular steps for the SBR system must be precisely determined at the stage of the wastewater treatment plant design and thereafter verified during start up.

2. DESCRIPTION OF SBRS

2.1. WASTEWATER TREATMENT IN THE SBR SYSTEM

The SBRs can be classified according to (a) the treatment train, (b) the feeding method, and (c) the sludge technique applied, and the processes involved can be itemized as follows:

- mineralization of organic compounds,
- mineralization of organic compounds and nitrogen removal by nitrification,
- mineralization of organic compounds and nitrogen removal by nitrification–denitrification,
- mineralization of organic compounds, nitrification–denitrification and enhanced biological removal of phosphorus in the presence of phosphorus–accumulating organisms (PAO).

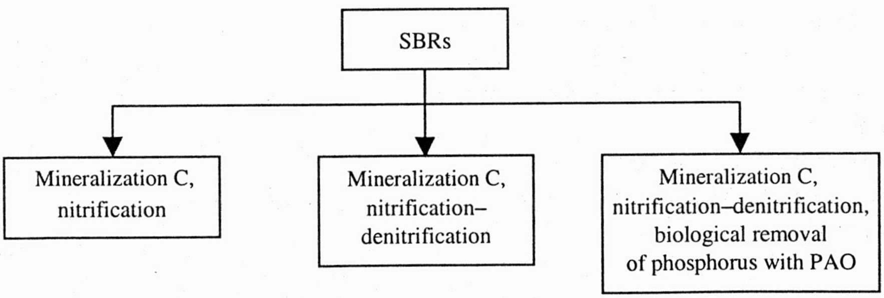


Fig. 1. Classification of SBRs according to RER

The type of the process involved affects the effective volume and the equipment of the SBR.

Figure 1 classifies the SBRs according to the unit processes involved, whereas figure 2 relates the SBR operation steps to the desired treatment efficiency (RER).

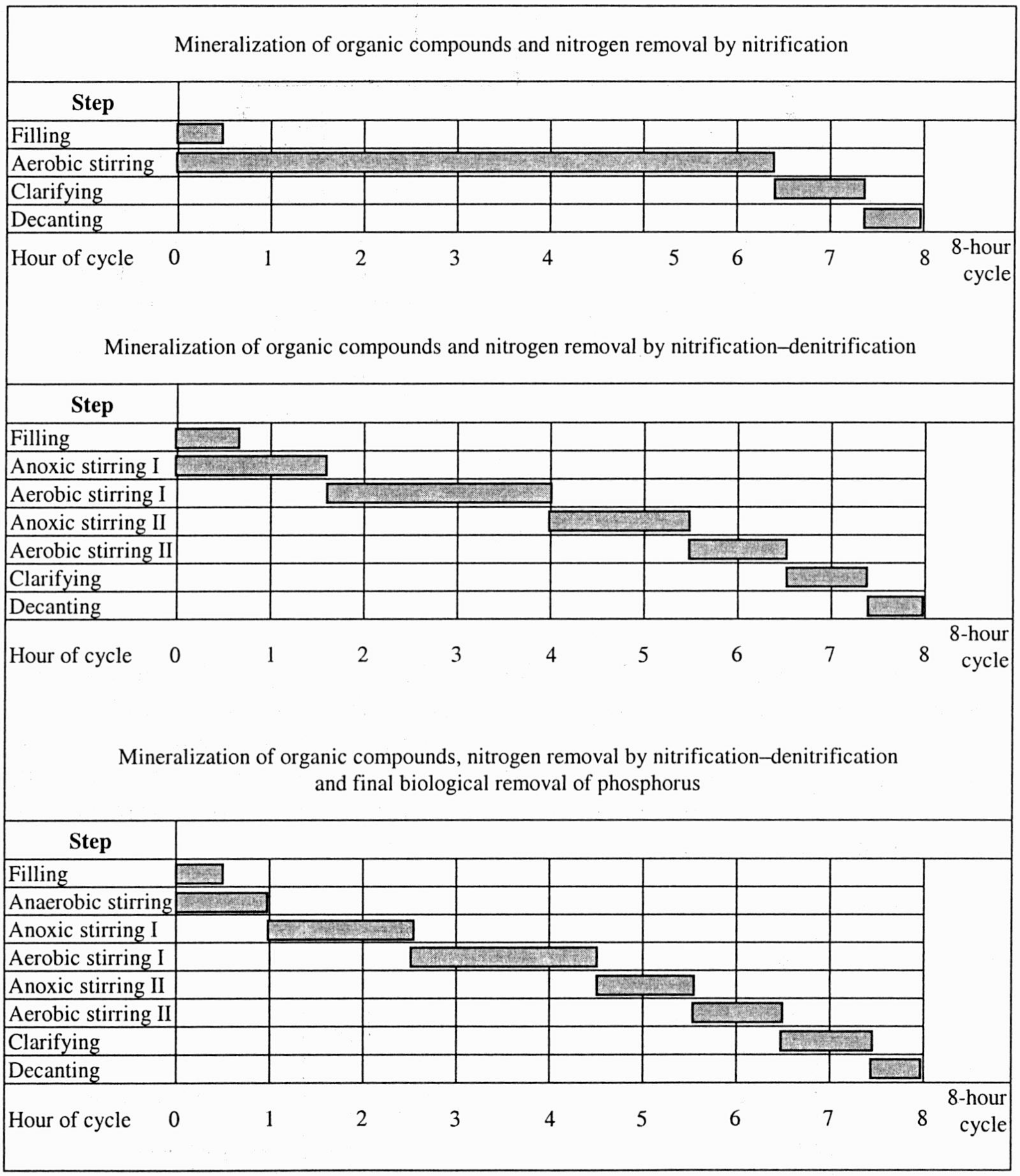


Fig. 2. SBR operating strategies related to RER (8-hour cycles)

2.2. FEEDING METHOD

The SBRs are fed either in the continuous flow mode or batchwise. In figure 3, the SBRs are grouped according to the method of wastewater supply.

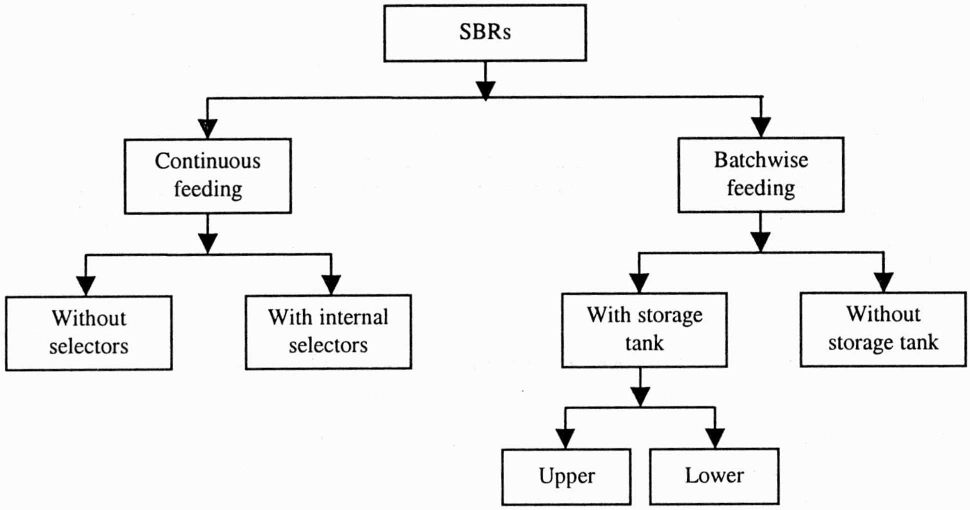


Fig. 3. Classification of SBRs according to the feeding method

2.2.1. CONTINUOUS FEEDING

Continuous feeding includes 24-hour inflow of wastewater per day and batchwise removal of the effluent. The schematic of a continuously fed SBR is shown in figure 4.

A continuously fed multi-reactor system supplies a Q/n daily volume of wastewater to n reactors. This means that the SBR feeding unit provides n reactors with wastewater in a uniform, continuous manner. Figure 5 depicts the operating strategy for an SBR fed in a continuous flow mode, with a 24-h cycle.

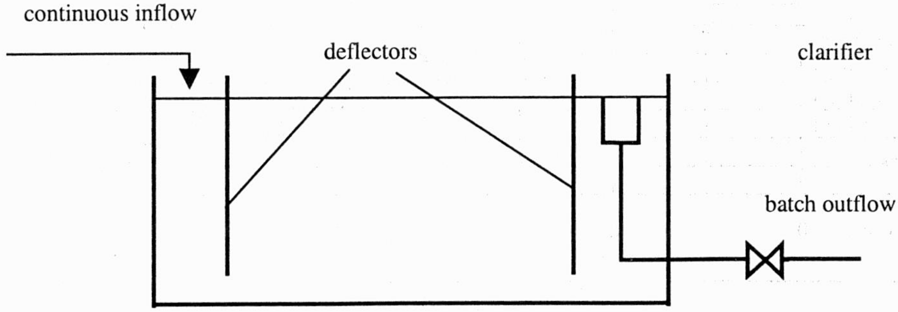


Fig. 4. Schematic of SBR fed in a continuous flow mode

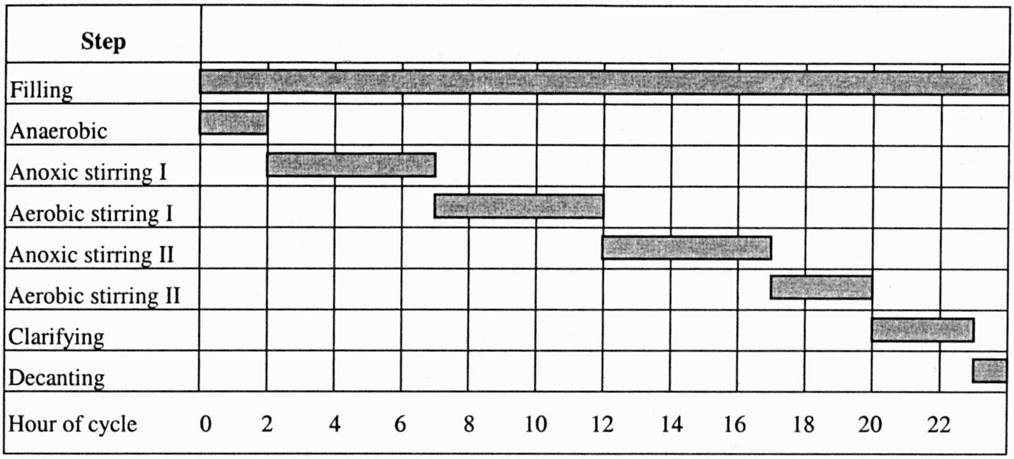


Fig. 5. Operating strategy for continuously fed SBR (24-hour cycle)

In order to improve the settling properties of activated sludge, TCHOBANOGLOUS [2] has recommended the application of a selector at the inflow to the technological zone. With the selector arranged in this way it is possible to maintain a high sludge load and to limit the growth of filiform microorganisms. Figure 6 shows the schematic of an SBR with an anaerobic selector and a continuous flow mode of feeding. The introduction of an internal selector, where the wastewater supplied to the SBR combines with a mixture of wastewater and activated sludge from the reactor, calls for a recirculation pump.

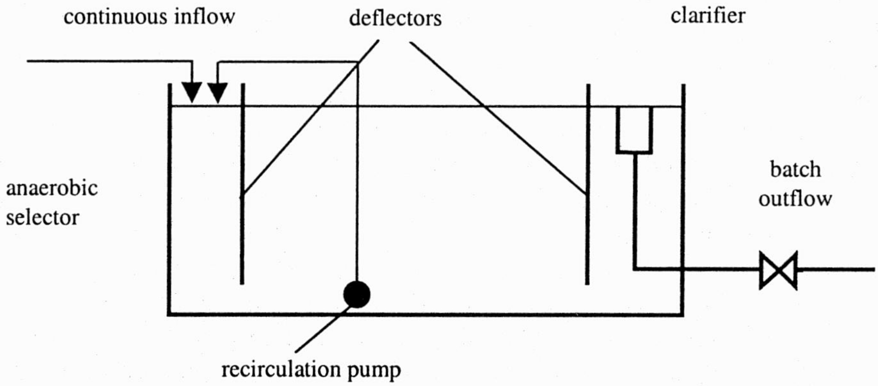


Fig. 6. Schematic of a continuously fed SBR with an anaerobic selector

Figure 7 illustrates the operating strategy for a continuously fed SBR with an internal selector.

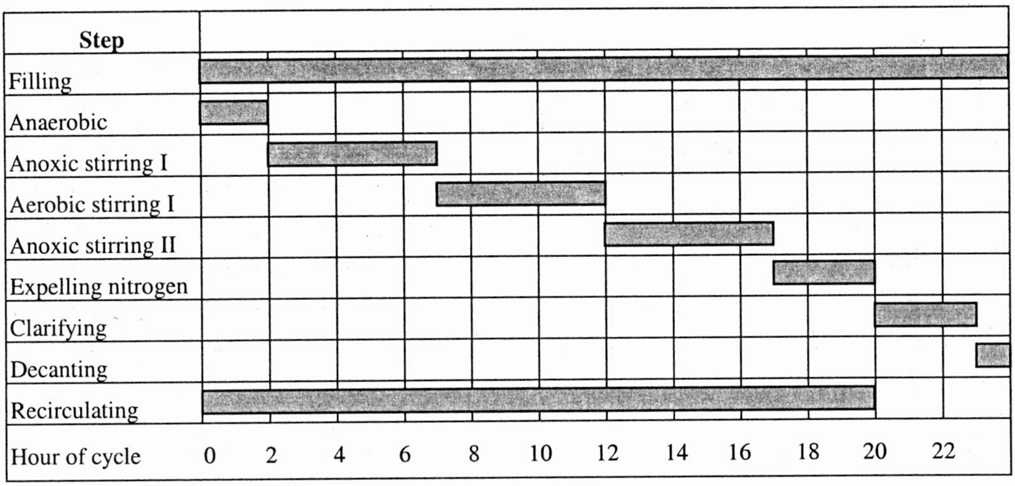


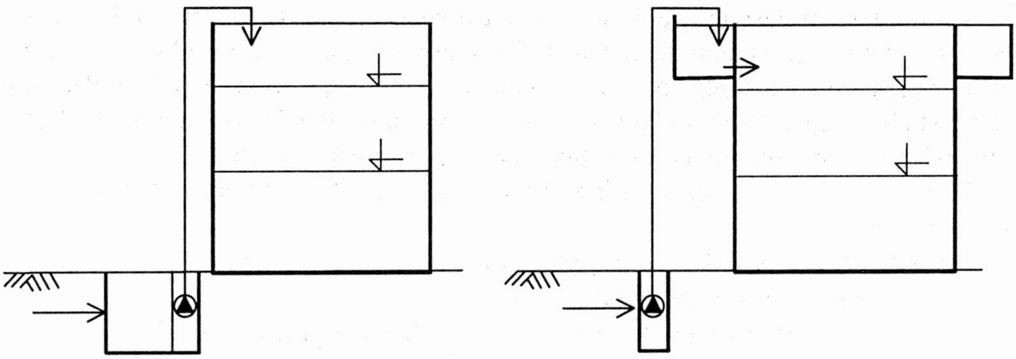
Fig. 7. Operating strategy for continuously fed SBR with an internal selector (24-hour cycle)

2.2.2. SBRs COMBINED WITH STORAGE TANKS

An SBR system with batchwise feed must include a storage tank for the effluent from mechanical treatment. Such a tank can be located as a separate unit either before the SBR ("lower" storage tanks) or in the top part of the SBR ("upper" storage tank).

For wastewater treatment plants with rated capacities of up to 1000 m^3/d, a single SBR in combination with a storage tank is recommended. Economic considerations have shown that the costs involved in the design and construction of one 1500 m^3 volume tank, which enables treatment of a daily wastewater volume of 1000 m^3 (Q = 1000 m^3/d), are by about 23% lower than those needed for the construction of two 750 m^3 capacity tanks. Thus, to achieve an optimal use of the effective SBR volume it is advisable to feed the system with raw wastewater within the shortest possible time. What can act as a storage tank for raw wastewater is the wet well of the wastewater pumping station (variant A, lower tank). The capacity of the well depends on the nonuniformity of the raw wastewater inflow and on the number of the reactor cycles (with nitrogen compound removal, three 8-hour cycles daily at the most). An alternative concept is the location of the storage tank for the effluent from mechanical treatment on the top of the SBR (variant B, upper tank).

With variant A (lower tank), at a 30-minute duration of the fill step, three 8-hour cycles and a rated capacity of 1000 m^3/d (330 m^3/cycle), the required delivery of the pump amounts to 660 m^3/h. With variant B (upper tank), the duration of pumping for a wastewater treatment plant of the same capacity (Q = 1000 m^3/d) and the same number of cycles (three 8-hour cycles) totals 8 h. Thus, the calculated value of the required delivery of the pumps amounts to 41 m^3/h, which means that the power demand with variant B is one-sixteenth that with variant A [4], [5]. Figure 8 shows the diagrams of the SBR with a lower (a) and an upper (b) storage tanks.



(a) lower storage tank (b) upper storage tank

Fig. 8. SBR with lower (a) and upper (b) storage tanks

2.3. STABILIZATION OF SLUDGES

The processing method recommended for sludges from wastewater treatment plants of a rated capacity of up to 200 m^3/d is aerobic stabilization. In wastewater treatment plants, where SBRs are operated, either simultaneous stabilization is carried out, or the sludges are sent to separate aerobic stabilization tanks. For wastewater treatment plants of 200 m^3/d or lower capacity, simultaneous stabilization is recommended. In wastewater plants of a capacity higher than 200 m^3/d, it is advantageous to send the sludge to the aerobic stabilization tanks.

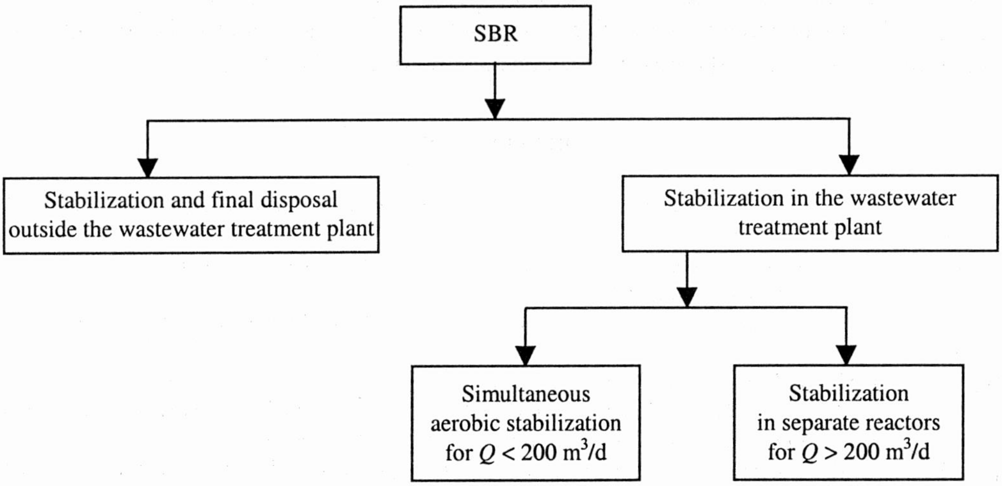


Fig. 9. Classification of SBRs according to sludge stabilization methods

At the stage of designing a wastewater treatment plant with an SBR mode it is advisable to take into account the potential for transporting non-stabilized sludges to the nearest plant where a sludge processing system is under operation. Any final decision about sludge disposal should be made after thorough economic considerations. Helpful advice can be found in the case study reported by MAŃCZAK [6].

Figure 9 provides a classification of the SBRs according to the method of sludge stabilization.

Final disposal of stabilized sludge includes:

- agricultural and non-agricultural uses,
- storage on landfills after dewatering (e.g. in sludge drying beds).

4. SUMMARY

1. Sequencing batch reactors have been classified according to
- the unit processes involved,
- the method of feeding reactors with raw wastewater,
- the method of sludge processing and disposal.

2. It has been shown that the reactor with batchwise feed should be combined with a storage tank located in its top part (upper storage tank). In such a system, energy demand is lower than in the one where the reactor is combined with a storage tank placed in the bottom part (lower storage tank).

3. The settleability of activated sludge can be increased by sending the effluent from mechanical treatment to the internal selectors.

4. At the stage of design, it is necessary to analyze thoroughly the costs of activated sludge management and to take into consideration the potential for transporting nonstabilized sludge to the nearest wastewater treatment plant for processing.

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KLASYFIKACJA REAKTORÓW OKRESOWEGO DZIAŁANIA – SBR

Scharakteryzowano technologię SBR i zaproponowano kryteria podziału reaktorów w zależności od realizowanych procesów jednostkowych oczyszczania, sposobu zasilania ściekami oraz metod stabilizacji osadów.

Wykazano, że reaktory SBR zasilane porcjowo powinny współpracować z „górnymi” zbiornikami retencyjnymi z uwagi na niższą energochłonność takiego układu w stosunku do układów ze zbiornikami „dolnymi”. Wskazano na możliwość poprawienia zdolności sedymentacyjnych osadu czynnego przez kierowanie ścieków mechanicznie oczyszczonych do selektorów wewnętrznych. Zwrócono uwagę, że na etapie projektowania należy zanalizować koszty gospodarki osadowej, uwzględniając transport osadów do innej oczyszczalni.