Environment Protection Engineering

Vol. 33 2007 No. 1

MICHAŁ MAŃCZAK*

MUNICIPAL SEWAGE TREATMENT IN SBR-COMPACT SYSTEMS

Although there is a significant potential for the application of the SBR (Sequencing Batch Reactor) concept, most of the SBR systems so far have been successfully used for the treatment of municipal and industrial wastewater. A major requisite for an effective operation of the SBR is the inflow of raw wastewater into the system. Single SBR plants need the application of retention tanks. It is comparatively easy to combine the SBR with a retention tank placed on the top of the reactor. Such a system is referred to in this contribution as a SBR-compact. The advantages of the upper retention tank over the lower one have been listed elsewhere. This contribution presents the results of a case study. Our study has shown that the removal efficiencies in SBR-compact for municipal wastewater were high, despite a high influent concentration of COD, total nitrogen and total phosphorus.

1. INTRODUCTION

Recent developments in periodic process technology as well as various applications of periodically operating systems have been reported for several decades. Nowadays, the use of the SBR concept for wastewater treatment is becoming a frequent practice, especially when the volume of the wastewater to be treated is small [1], [2].

SBR systems are easy to operate and far more flexible than continuous flow activated sludge systems. The duration of the cycle, and consequently the hydraulic retention time, can be easily varied so as to adjust both the parameters to the volume and composition of the incoming wastewater. Another major advantage of SBR processes is that the equalization of flow and organic loading can be established and the SBR system itself may be controlled in a way which allows a low substrate concentration to be maintained by changing the operating strategy in the filling phase.

In the past few years, a number of municipal wastewater treatment plants involving systems of SBR-compact type have been established in Poland in the Lower Silesian Region (Rudna, Niemcza, Żórawina – Wrocław District; Proszków – Opole District). The SBR-compact systems are fed batchwise with wastewater after mechanical treatment (screens, grit

* Wrocław University of Technology, Poland. E-mail: michal.manczak@pwr.wroc.pl

trap) from the upper retention tank, combined with the top of the SBR. Figure 1 shows the scheme of the SBR system operated in Proszków. The technological train includes a separate mechanical treatment and biological activated sludge treatment in the SBR. Mechanical treatment is carried out using the Ro-5 system (made by HUBER, Germany).

The SBR-compact treatment plant of Proszków operates a fecal matter receiving tank, from which fecal matter is pumped (continuously) to the inflowing raw wastewater before it reaches the screens (figure 1). After passing through the screens and grit trap, the wastewater flows to the pumping station, from there it is pumped to the upper retention tank. The tank is equipped with a submersible mixer and electric valve.

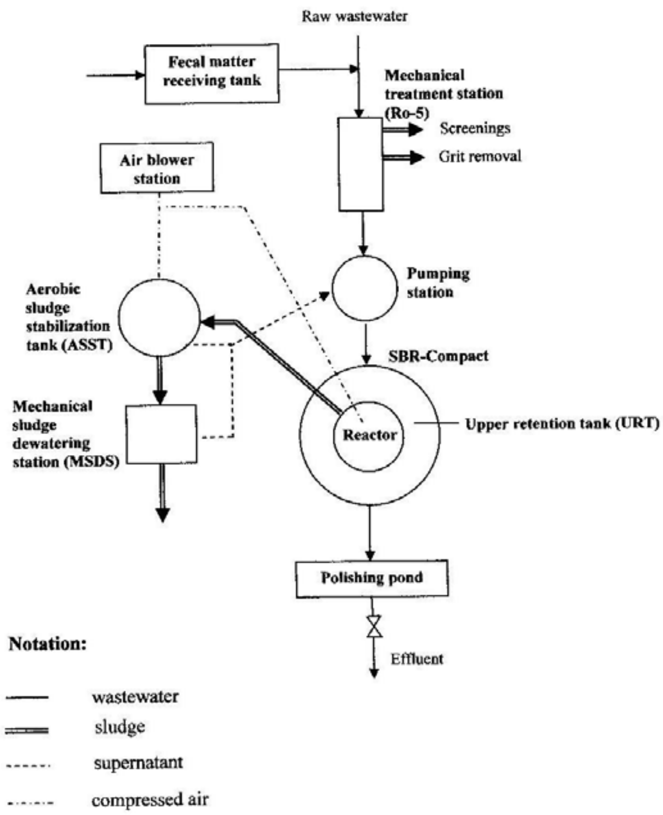


Fig. 1. Scheme of the SBR-compact treatment plant

The equipment of the SBR-compact includes the following items (figure 2):

Upper retention tank:
- submersible mixer (M-1),
- electric valve (V-1).

Reactor:

• fine-bubble aeration systems involving membrane-type diffusers (V-2 is to cut off air flow),

• submersible mixer (M-2) providing mixing of the liquid volume in the SBR during anaerobic or anoxic fill and aeration phase with switched-off compressed air supply (dissolved oxygen concentration > 2.0 g O_2/m^3),

• floating weir (decanter) for withdrawal of the treated effluent (V-3, cut-off valve in the withdrawing system),

• system for excess sludge withdrawal (V-4).

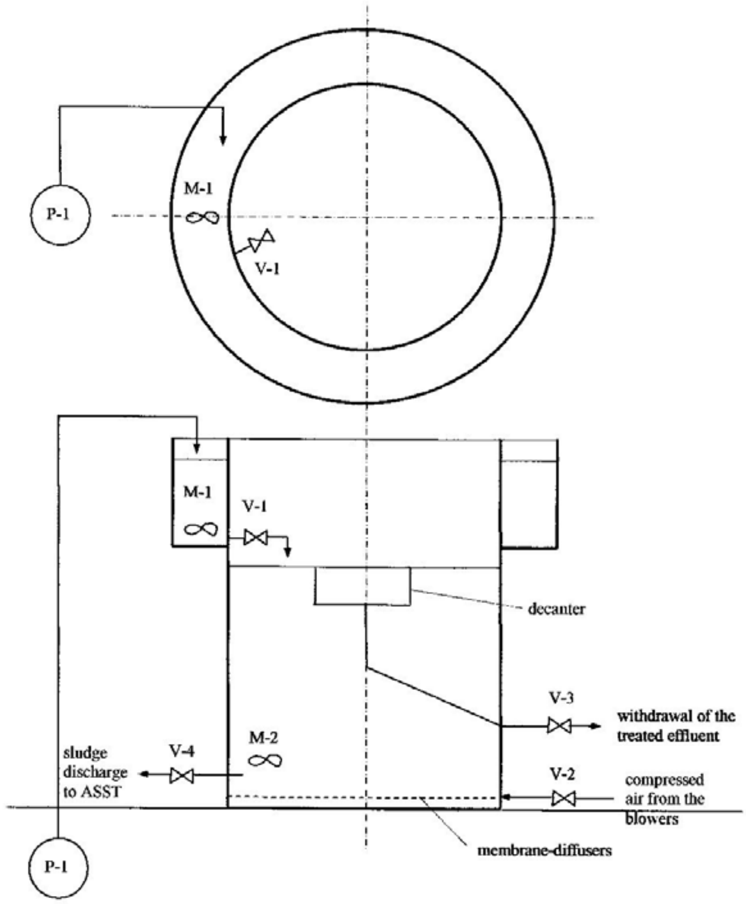


Fig. 2. A cross-section of the SBR-compact. P – pumps, M – mixing devices, V – valves

The biological treatment facility includes a multifuncional SBR and a polishing pond (not aerated) for final or post-treatment. The wastewater collected in the retention tank flows to the SBR-compact by gravity according to a defined operating strategy. The feeding of the SBR should be accomplished in the shortest possible period. Prior to the adopted time of wastewater discharge into the SBR, the mixers (M-1) in the upper retention tank are set in motion to allow the layer of suspended solids, which have settled on the tank bottom, to enter the SBR. A scheme of the SBR-compact is shown in figure 2.

After treatment in the SBR, the wastewater flows by gravity to the polishing ponds of an average depth from 0.7 to 0.8 m and a retention time of approximately 24 h. At the outflow from the ponds, a floating overflow is now under construction. For sludge treatment a separate ASST (aerobic sludge stabilization tank) is installed. The tank in question can also serve as a gravitational thickener of the stabilized sludge. The diagram is shown in figure 3.

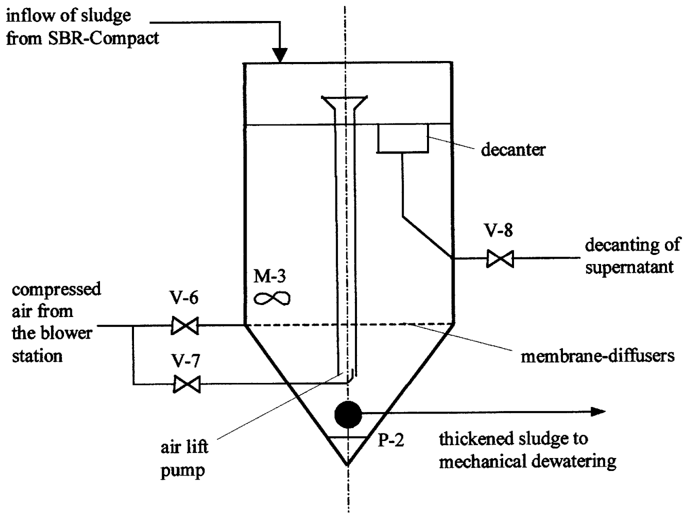


Fig. 3. Scheme of the ASST.
P – pumps, M – mixing devices, V – valves

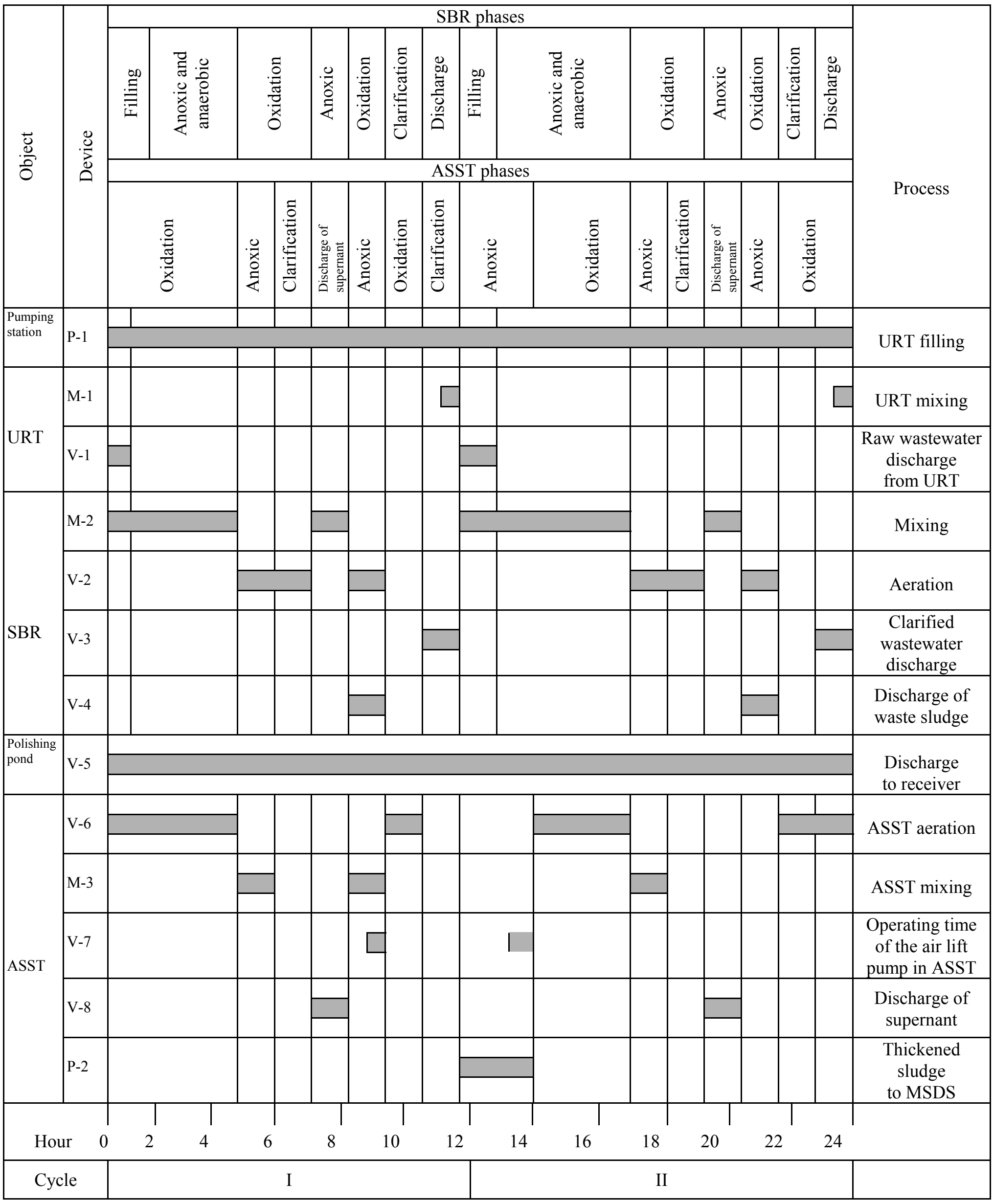
The ASST is equipped with the following devices:

- a fine-bubble aeration system with membrane-type diffusers (V-6),
- a submersible mixer (M-3),
- a floating weir for decanting the supernatant (V-8),
- pumps providing sludge transport to the mechanical sludge dewatering station (P-2),
- an air-lift pump (V-7).

The stabilized sludge (sludge age over 35 days) is pumped (P-2) to the mechanical dewatering plant (DRAIMAD) provided with a system for polyelectrolytes solubilization and dosage.

T a b l e 1

Operating strategy for the SBR-compact and the ASST (12-hour cycle).
URT – upper retention tank, SBR – sequencing batch reactor,
ASST – aerobic sludge stabilization tank, MSDS – mechanical sludge dewatering station,
P – pumps, M – mixing devices, V – valves



The SBR-compact wastewater treatment plant works without excessive operator attention. The responsibilities of the operating staff have been reduced to the following:

- controlling whether the facilities and devices are properly driven and work without breakdown,
- removing screenings and grit from the Ro-5 unit,
- attending the DRAIMAD sludge dewatering.

The SBR-compact can be operated in 8-hour, 12-hour or 24-hour cycles, depending on the volume of the inflowing wastewater. The operating strategy for the SBR-compact working in 12-hour cycle and performing a multiphase activated sludge process (at the Proszków SBR-type wastewater treatment plant) is illustrated in table 1, which also presents the operating strategy for the ASST.

2. FULL-SCALE TREATMENT EFFICIENCIES OBTAINED WITH THE SBR-COMPACT (AT THE WWTP OF PROSZKÓW)

In the period investigated – which covered the time span from January 2002 to May 2003 – the daily volume of incoming wastewater approached 450 m^3. The treated effluent supplies via a rivulet a water reservoir.

Table 2

Composition of the wastewater entering the WWTP of Proszków

Constituent	Unit	Raw wastewater					
		2002			2003		
		Minimum	Maximum	Average	Minimum	Maximum	Average
BOD_5	g O_2/m^3	216	420	325	280	720	540
COD	g O_2/m^3	476	836	614	598	1273	882
Suspended solids	g /m^3	167	275	202	128	511	248
Total nitrogen	g N/m^3	42	107.3	71.8	92.7	130.1	110.9
Organic nitrogen	g N/m^3	2.8	48.8	27.6	–	–	–
Ammonia nitrogen	g N/m^3	29.3	55	38.3	44	90	72
Nitrate nitrogen	g N/m^3	3.3	5.3	4.1	3.9	17.5	8.6
Total phosphorus	g P/m^3	7.38	12.2	9.96	3.8	64.5	40.7

The efficiency of wastewater treatment was evaluated on the basis of analyses (both for raw and treated sewage samples) performed at the laboratory of the Environmental Engineering Institute, Wrocław University of Technology [3]. Table 2 and table 3 present the composition of raw and treated wastewater, respectively. Table 4 gathers the major technological parameters of the SBR operating at the WWTP of Proszków, and table 5 summarized the treatment efficiencies obtained with the SBR-compact in 2003.

As shown in table 2, wastewater entering the WWTP of Proszków in 2003 had high content of nutrients. Average total nitrogen, ammonia nitrogen and total phosphorus concentrations of raw wastewater were 110.9 g N/m^3, 72 g N/m^3 and 40.7 g P/m^3, respectively. The COD and BOD_5 concentrations in raw wastewater were also high.

Table 3

Composition of the treated effluent at the WWTP of Proszków

Constituent	Unit	Treated effluent					
		2002			2003		
		Minimum	Maximum	Average	Minimum	Maximum	Average
BOD_5	g O_2/m^3	4	30	15	2	46	13
COD	g O_2/m^3	49	85	61	25	116	58
Suspended solids	g /m^3	3.25	17	8.6	2.4	34.8	11
Total nitrogen	g N/m^3	6.2	10.2	8.4	5	39.5	12.7
Organic nitrogen	g N/m^3	–	–	–	–	–	–
Ammonia nitrogen	g N/m^3	0.3	3.4	1.8	0.25	32.2	4.35
Nitrate nitrogen	g N/m^3	0.4	4.9	3.2	1.96	12.5	6.1
Total phosphorus	g P/m^3	0.23	2.31	0.92	0.8	5.25	2.18

Despite so high influent concentrations of COD, total nitrogen and total phosphorus, the removal efficiencies in the SBR-compact system were high (table 3). With 12-hour cycle and technological parameters not deviating from the design values the average total nitrogen, ammonia nitrogen and total phosphorus concentrations in the treated effluent were 12.7 g N/m^3, 4.35 g N/m^3 and 2.18 g P/m^3, respectively. The BOD_5 concentration in treated wastewater was 13 g O_2/m^3, COD – 58 g O_2/m^3, and the total suspended solids concentration did not exceed 35 g/m^3. The composition of the treated effluent at the WWPT of Proszków was consistent with the Polish regulations for the wastewater treatment plants of this capacity.

As shown in table 2, the usage of polishing pond after biological treatment in the SBR reactor did not contribute to the lowering of pollutants concentrations in the effluent discharged into the water reservoir. The reason for so low efficiency of the effluent post-treatment in the pond may have been maintenance negligence, which considering low concentrations of pollutants in wastewater entering the pond may have had a significant impact.

From the data of tables 4 and 5 it may be inferred that if the technological parameters do not deviate from the design values, the treatment efficiency is sufficiently high.

Table 4

Technological parameters of the SBR operating at the WWTP of Proszków

Parameter		Unit	Design value	Real value
Sludge age		day	17	24
Sludge concentration		kg/m^3	3	2.8
Flow rate		m^3/d	600	450
Hydraulic detention time		day	2.5	3
Sludge loading	BOD_5	$kg\ O_2/kg\ d$	0.066	0.056
	COD	$kg\ O_2/kg\ d$	0.092	0.092
	Total nitrogen	kg N/kg d	0.020	0.011
	Phosphorus	kg P/kg d	0.0019	0.0042
	Suspended solids	kg/kg d	0.033	0.025
Phases	Filling time	h/cycle	0.8	0.8
	Denitrification time	h/cycle	4.0	4.0
	Aeration time	h/cycle	4.0	4.0
	Clarification time	h/cycle	1.2	1.2
	Discharge time	h/cycle	1.0	1.0
	Number of cycles per 24 h		2 cycles/24 h	2 cycles/24 h

Table 5

Efficiency of WWT at the Proszków WWTP [3]

Constituent	Unit	Raw wastewater	After mechanical treatment	After biological treatment	Effluent from the polishing ponds
BOD_5	$g\ O_2/m^3$	601	510	5.9	5.0
COD	$g\ O_2/m^3$	1264	1147	19.6	39.2
Suspended solids	g/m^3	882	1024	18	20
Total nitrogen	$g\ N/m^3$	93.8	110.6	4.2	4.74
Organic nitrogen	$g\ N/m^3$	30.8	33.6	2.0	1.6
Ammonia nitrogen	$g\ N/m^3$	63.0	77.0	1.4	2.8
Nitrate nitrogen	$g\ N/m^3$	–	–	0.7	0.2
Total phosphorus	$g\ P/m^3$	16.3	14.3	1.7	1.8

3. CONCLUSIONS

1. In the investigated application of the SBR system, it is advisable to use a retention tank. As the pumps in the system differ greatly in size, the SBR design of Proszków involves the upper retention tank.

2. The effluent entering the polishing pond, which belongs to the final stage of the treatment process (post-treatment procedure), should contain the smallest possible amount of suspended solids, since the environment of the pond supports further biological processes and thus raises the value of this parameter (table 5).

3. The SBR-compact concept with a 12-hour cycle was found to be best suited for application at the WWTP of Proszków. The removal efficiencies were high, despite the high influent concentrations of COD, total nitrogen and total phosphorus.

4. The wastewater treatment technology involving the SBR-compact system is becoming popular also in Poland. It should, however, be emphasized that effective SBR facilities require well educated designers and well trained operators.

REFERENCES

[1] OLESZKIEWICZ J.J., BERQUIST S.A., *Low temperature nitrogen removal in sequencing batch reactors*. Wat. Res., 1988, 22(9), 1163–1171.

[2] WILDERER P.A., IRVINE R.L., GORONSZY M.C., *Sequencing Batch Reactor Technhology*, IWA Publishing, 2001, Scientific and Technical Report No. 10.

[3] MAŃCZAK M., BALBIERZ M., SZETELA M., *Records of wastewater analyses of the Proszków WWTP*, Institute of Environmental Engineering, 2003, Wrocław University of Technology (Scientific and Technical Report – in Polish).

OCZYSZCZANIE ŚCIEKÓW KOMUNALNYCH W REAKTORACH SBR-KOMPAKT

Reaktory SBR są jednym z urządzeń stosowanych do biologicznego oczyszczania ścieków. Istotnym warunkiem ich prawidłowej pracy jest sposób zasilania ściekami surowymi. W przypadku pojedynczego reaktora SBR niezbędne jest stosowanie zbiorników retencyjnych. Stosunkowo łatwo można powiązać konstrukcyjnie reaktor SBR ze zbiornikiem retencyjnym usytuowanym na jego koronie. Układ taki jest nazywany reaktorem SBR-kompakt. Przewagę górnego zbiornika nad zbiornikiem dolnym wykazano wcześniej. Przedstawiono wyniki badania skuteczności oczyszczania ścieków komunalnych na przykładzie kilku dolnośląskich oczyszczalni SBR. Badania wykazały bardzo dobrą skuteczność usuwania zanieczyszczeń ze ścieków, które charakteryzowały się wysokim ChZT oraz wysokimi stężeniami azotu ogólnego i fosforu.