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Improvement of MSBR Process for Treatment of Sand-laden Sewage

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Abstract: The influent of a sewage treatment plant was mainly composed of domestic sewage. Modified Sequencing Batch Reactor (MSBR) process was adopted, in order for the design effluent quality to meet the first level B criteria specified in the Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB18918 - 2002). High Sand content in the influent caused operational problems such as poor aeration in sequencing batch tank, high sediment content and siphon effect in the effluent of MSBR. The problems were solved by analyzing the reasons and taking improvement measures, thus ensuring the effluent quality to meet the discharge standard.

Keywords: MSBR, High Sand Content, Rectification Measures

1. General Situation of Engineering

A municipal sewage treatment plant, whose total capacity is 8.0×104m3/d, was built in a county-level city in 2010. The 2nd phase project adopts MSBR process, developed by C.O. Yang et al [1, 5], and treats 4.0×104m3 of sewage per day. MSBR process is composed of A2/O and SBR process in series, incorporating the characteristics of SBR and the traditional activated sludge process, which requires less land and shows a good treatment result. The municipal sewage treatment plant has been running for nearly five years. Its pipe network mainly receives tidal river, and faces an influx of tidewater when water level in the tidal reach is high. High sand content in the influent caused difficulty in MSBR sludge discharge. Through rectification, the municipal sewage treatment plant is now stable in operation, and the effluent quality can reach the first level B criteria specified in the Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB18918 - 2002).

2. Engineering Design

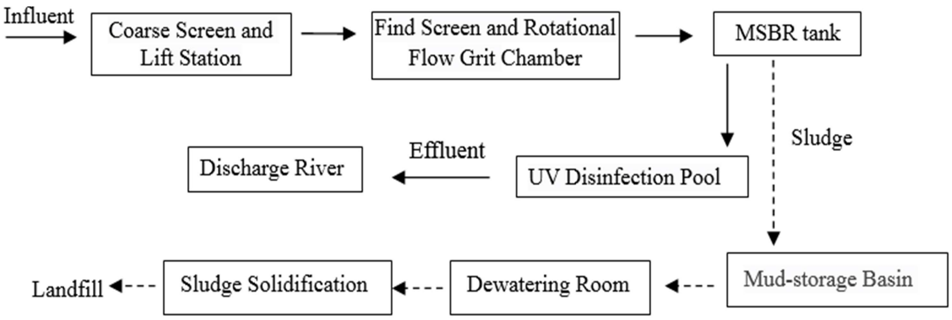
2.1. Water Quality of the Design

The design influent water quality in 2nd phase project is determined according to the actual water quality of 1st phase project and monitored values. The quality of effluent meets the first level B criteria of the Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB18918 - 2002). The main index of influent and effluent are shown in Table 1.

Table 1. *Design influent and effluent quality*

index	pH (mg/L)	COD_{cr} (mg/L)	BOD_5 (mg/L)	SS (mg/L)	NH_3-N (mg/L)	TN (mg/L)	TP (mg/L)
incoming	6~9	≤400	≤160	≤250	≤30	≤40	≤4
outgoing	6~9	≤60	≤20	≤20	≤8(15)	≤20	≤1.0

2.2. The Treatment Proess



The treatment process is shown in figure 1.

Figure 1. *Flow chart of waste water treatment process.*

2.3. Process Design

(1) Coarse screen and lift station

Coarse screen and lift station were built together. The size of the master inlet valve well is 2.4m×2.4m×5.97m. The coarse screen well takes up 7.20m×10.8m×5.97m, and the sump pump pit occupies 13.6m×6.30m×7.72m. Coarse screen and sump pump pit are divided into 2 panels individually.

A mechanically cleaned bar screen is added to the coarse screen well. The size of the screen is B=1.4m,b=20mm, and the install inclination is 70°.

There were 3 submersible pumps in the pump pit, 2 in use and 1 for backup. In 2nd phase project, three additional pumps (Q=1167m^3 /h, H=155kPa, N=75kW) have been added totaling 4 in use, 2 for backup.

(2) Fine screen and rotational flow grit chamber

Fine screen and grit chamber were built together. The construction plan was made for 40,000m3/d scale, and equipment was installed at the same scale.

This project uses rotational find bar screen, the size of which is 6.0m×3.1m×2.0m, each has two grid canals. Design parameter is B=1.2m, b= 5mm, and install inclination is 75°. The water depth in front of the gate is 1.5m. The velocity of flow is 0.85 m / s.

There are two rotational grit chambers, Φ3 650 mm each, which adopts air-lift sand sedimentation. The rotational grit chambers deployed two sets of adjustable-blade grit chamber agitators, design parameters of D=1000mm, N=0.75kW; two sets of roots blowers (1 for use, 1 for backup), design parameters of Q=2m3/min, P=34.3kPa, N=2.2kW; one set of spiral sand water separator , processing capacity of 10 to 30m^3/h, N=0.37kW, less than water content of sand is less than 60% , the install inclination is 25° .

(3) MSBR tank

There are two sets of the MSBR tanks. Each MSBR tank consists of 7 units , its size is 71.9m×55.7m×5.8m . It is composed of sludge thickener, pre-hypoxia pool, anaerobic tank, anoxic tank, aerobic tank, and two SBR tanks. The specific dimensions of each unit are as follows:

The size of sludge thickener is 15.2m×8.0×5.8 m, and the water depth is 5.3 m. There are 1.5m wide reflux sludge flume at the front end of the tank and 0.8m wide supernatant outlet flume at the back end. The sludge enrichment tank is connected to the pre-anoxic tank at the bottom so as to allow the sludge concentration gravity to flow into unit 3. A 1.5m-wide return sludge flume is equipped at the front of the tank, and a 0.8-wide supernatant effluent flume at the back end. The sludge thickener is connected to the bottom of the pre-hypoxia pool, which ensures gravity thickened sludge flowing into pre-hypoxia pool.

The size of the pre-anoxic tank is 15.2m×10.3m×5.8m, and the water depth is 5.3m. It is equipped with a mixer with slag removal buoy (N=5.5kW) and 2 sludge lift pumps (Q=1020m3/h, H=6.5kPa, N=4.0kW).

The size of the anaerobic tank is 15.2m×13.7m×5.8m, and the water depth is 5.3m, equipped with one slag removal buoy type agitator (N=7.5kW).

The size of anoxic tank is 15.2m×19.2m×5.8m, and the water depth is 5.3m , equipped with a slag removal buoy type agitator (N=7.5kW).

The size of aerobic tank is 15.2m×86.4m×5.8m, and the water depth is 5.3m. There are 660 sets of tube membrane aerators, and two sets of nitrifying liquid reflux pumps (Q=1800m3/h, H=7.5 kPa, N=7.5kW).

The size of SBR tank 1 and SBR tank 2 are 15.2m × 32.6m × 5.8m, and the water depth is 5.3m. 240 tube membrane aerators and one mixing liquid reflux pumps (Q=1020m3/h, H=6.5 kPa, N=4.0kW) were installed in a single tank.

The design parameters of the MSBR tank are shown in Table 2.

Table 2. *Design parameters of the modified MSBR.*

parameter	numerical value
BOD_5 load	0.095kg BOD_5/(kgMLSS·d)
TN load	0.018 kg TN/(kgMLSS·d)
TP load	0.001 kgTP/(kgMLSS·d)
MLSS	3000 mg/L

The MSBR tank construction diagram is shown in Figure 2:

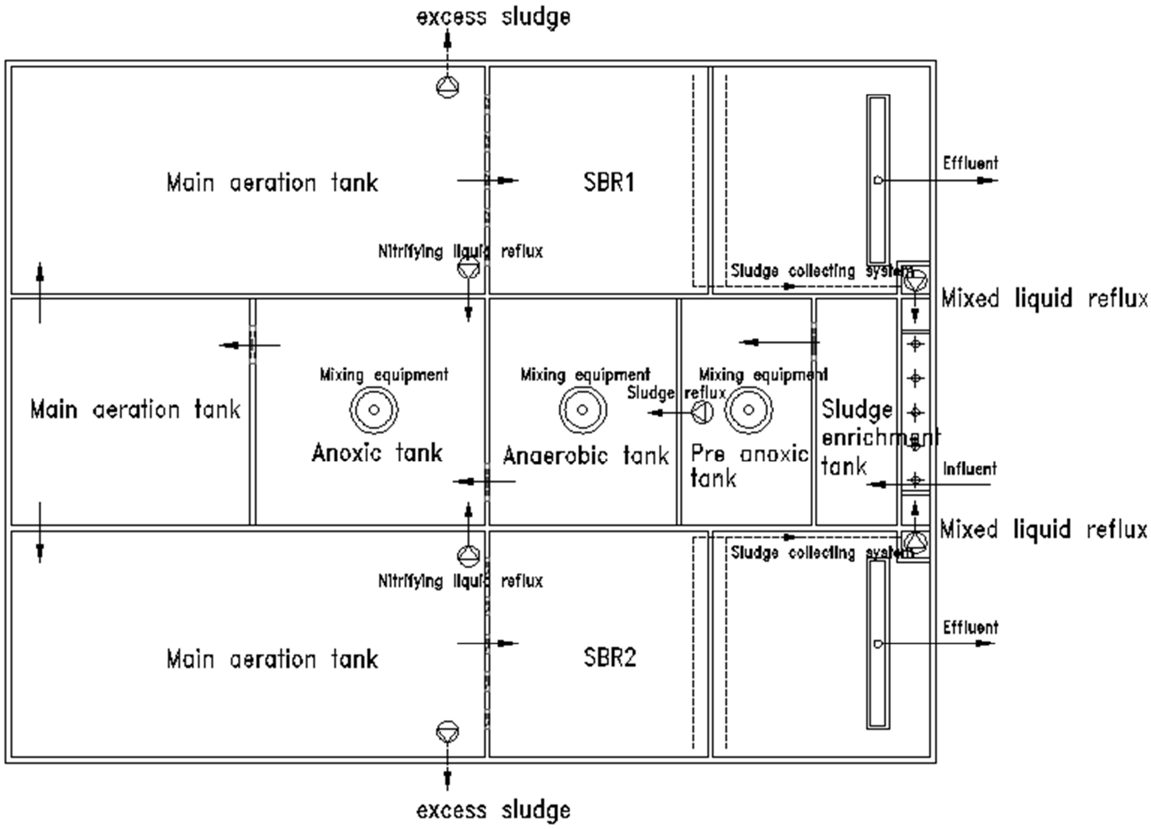


Figure 2. *Structure of the modified MSBR.*

The status of each unit in the MSBR tank is shown in Table 3.

Table 3. *Operational status of response units for each running period.*

time interval	SBR 1	Sludge enrichment tank	Pre anoxic tank	Anaerobic tank	Anoxic tank	Main aeration tank	SBR 2
1	stir	stir	stir	stir	stir	aeration	Sedimentation and effluent
2	aeration	stir	stir	stir	stir	aeration	Sedimentation and effluent
3	preliminary sedimentation	stir	stir	stir	stir	aeration	Sedimentation and effluent
4	Sedimentation and effluent	stir	stir	stir	stir	aeration	stir
5	Sedimentation and effluent	stir	stir	stir	stir	aeration	aeration
6	Sedimentation and effluent	stir	stir	stir	stir	aeration	preliminary sedimentation

The duration of each period is30 min in period 1 and period 4, 60 min in period 2 and period 5, and 30 min in period 3 and period 6.

If influent quality is bad and removal of CODCr and NH3-N is ineffective, the mode needs to be adjusted accordingly: 90-min aeration, 30-min preliminary sedimentation, and 120-min sedimentation and effluent [8, 9].

If the effluent efficiency is low and the concentration of SS is high, the mode needs to be adjusted accordingly: 60-min aeration, 60-min preliminary sedimentation, and 120-min sedimentation and effluent.

If the removal of CODCr and NH3-N is still ineffective, the operation period can be adjusted to 6 hours, and the mode adjusted as: 150-min aeration, 30-min preliminary sedimentation, and 180-min sedimentation and effluent. Alternatively, the mode can be adjusted to intermittent operation, shortening effluent time properly: 120-min aeration, 30-min preliminary sedimentation, and 90-min sedimentation and effluent.

(4) UV Disinfection Pool

The size of UV Disinfection Pool is 17.50m×3.20m×1.80m, the water depth is 1.2m and the residence time is 3min. Equipped with 1 set of low voltage and high strength ultraviolet lamp, the power of the equipment is 27. 5kW.

(5) Pasteurian flow flume

The size of the pasteurian flow flume is 9.20m×1.70m×1.40m and the water depth is 0.8m. Equipped with an ultrasonic open channel flowmeter, the power of the equipment is 15W.

(6) Reservoir

Some of the effluent from the disinfection canal enters the reservoir, which can be used as backwash water and cooling water for blower to reduce the consumption of tap water.

The size of the reservoir is 5.0m × 5.0m × 4.3m, the depth of water is 3.8m. It is equipped with two sets of self-priming pumps (1for use, 1 for backup). The design parameters are Q=10m3/ h, H=180kPa, N = 1.5kW.

(7) Blower room

According to the long-term design scale, the civil construction of blower room is one-time completed project, while installation of equipment is by stages. The plane size of blower room is 24.0m×12.0m and the height of the layer is 7.0m. Six roots blowers (Q=53m3/min, H=60kPa, N=90kW) were installed in the 2nd phase. The adjustment range is 45% -100%.

(8) Sludge storage pond

The sludge storage pond is conducive to the intermittent operation of the mechanical thickening dehydrator and reduces the amount of sludge dewatering. The dry weight of sludge is 6.15 t/d, the water content of sludge is 99.2%, the design size is 20×10×5.0m, and the effective water depth is 4. 5m.

(9) Dewatering room

The dewatering room was one-time completed according to the long-term design scale, the equipment has been installed by stages, and the plane size is 30.0m×15.0m×8.0m. The design of dry mud capacity in the2nd phase is 6.15 t DS / d. The moisture content of influent and effluent sludge is 99.0% and 80% respectively. In the 2nd phase, an integrated condensing and dehydrating machine (Bandwidth =2 m, Q=35m^3/h, N=3.75kW) is added, which is mutually reserved with the original two concentrated dehydrators in the 1st phase.

(10) Sludge drying system

The design scale of sludge drying system is 70 t /d (the water content is 80%). The process adopts "sludge modified + plate-frame pressure filtration" , which is equipped with one sludge modification machine (Φ 1800 × 2200mm, N=11kW),one plate and frame filter press (treatment capacity of 50 t/d ,N=18 kW), and an agitator mixer(N=11kW),belt conveyer, medicament conveying pump and other equipment.

2.4. Design Features

(1) In view of the difficulty of biological denitrification in this project, when the residence time of anaerobic tank is shortened, and the residence time of aerobic and anoxic pool is increased appropriately, and the effect of aerobic decarbonization, nitrification and denitrification would be strengthened.

(2) The sludge reflux and excess sludge discharge from the MSBR tank are effectively connected through the eight-claw perforated sludge collecting pipe, which increases the sludge reflux and excess sludge discharge concentration, and the perforated sludge discharge system is used. The combination of mixing well and reflux pump can effectively reduce energy consumption and cost.

(3) In the MSBR tank, the low head internal reflux pump and the slide valve are used together, and the slide valve and the opening / closing device are arranged at the outlet of inner return pump. Through electric hoist to prevent flow reversal and promote flow regulation.

3. Operation Effect and Reaching Standard

The practical operation result of the sewage treatment plant is shown in Table 4. It can be seen from the above table that the water quality of the influent is close to the design water quality after the operation of the sewage treatment plant. In this case, the concentration of CODCr, BOD5, NH3-N, TN, TP in effluent and other indexes of the sewage treatment plant can fully reach the discharge standard, and CODCr, NH3-N and other indexes have reached the first level B criteria specified in the "Discharge standard of pollutants for municipal wastewater treatment plant"(GB18918-2002) for most of the time. MSBR process performs well for the municipal sewage treatment plant. Under proper control of the quality of sewage flowing into sewers, the effluent can meet the first level B criteria specified in the "Discharge standard of pollutants for municipal wastewater treatment plant"(GB18918-2002).

4. Analysis of Existing Problems and Rectification Measures

(1) The MSBR tank adopts eight claw perforated mud collecting pipe to improve the sludge discharge effect, however incomplete sludge discharge situation persists. . The surrounding area of the perforated sludge collection pipe has good sludge discharge effect, but still has a bad sludge discharge effect at the far end, and the sludge rising phenomenon existed in the effluent area of the terminal of the sequencing batch tank. On one hand, it is difficult to discharge the sludge after pushing the sludge into this area because there is no collecting pipe. On the other hand, although the effluent load of the air weir is lower than that of the decanter, but it still has the high load problem.

To solve the problem of rising sludge, the layout of the perforated sludge pipe can be added, especially the arrangement of the sludge system under the air weir to avoid adverse impact of the sludge accumulation on water quality. The load of the air weir should be set as low as possible, which is beneficial to avoiding running sludge and improving the water quality.

(2) Siphonage arises in the effluent of MSBR tank. When the air weir starts to discharge, water flux is high and water flow is turbulent. Siphonage arises due to negative pressure brought by the air entering the outlet pipe, then the discharge flow increases greatly, which leads to obvious decrease of liquid level in the MSBR tank, which is not conducive to the stability of effluent quality. Syphonage of outlet pipe can be avoided by adopting P-shaped pipe structure in design. Air weir air intake can be used in operation to replenish air entrained in water, balance the pressure and avoid the influence of siphonage.

Table 4. *The actual influent and effluent quality.*

Index	COD_{Cr}		BOD_5		NH_3-N		TN		TP	
date	influent	effluent	influent	effluent	influent	effluent	influent	effluent	influent	effluent
Jan	165~480	12~45	56~210	3~11	15.9~31.4	4.8~12.5	18.6~42	5.8~16.2	2~4.5	0.1~0.8
Feb	180~427	18~33	72~185	2~12	17.7~33.8	3.8~9.0	19.2~40.4	6.4~12.5	1.8~4	0.2~0.6
Mar.	170~380	16~38	45~142	4~14	14.0~34.4	3.5~13.0	18.6~35.5	5.8~15.7	2.2~3.5	0.1~0.9
Apr.	137~342	17~50	56~157	5~15	12.4~30.4	2.4~8.1	15.4~38.3	5.7~18.6	1.5~3.8	0.2~1.0
May	172~368	25~48	58~165	3~14	18.6~34.1	3.1~8.3	22.6~39.7	5.8~13.5	2.2~4.5	0.1~0.7
June	184~448	20~48	52~190	5~16	15.6~28.8	1.0~6.1	18.6~32.6	8.5~13.0	1.3~3.8	0.3~0.9
Jul	140~376	18~41	45~155	2~12	9.4~23.8	1.7~5.7	11.7~25.1	4.5~14.3	0.8~3.2	0.3~0.5
Aug	128~330	20~54	38~164	3~17	9.3~23.6	1.4~5.8	12.2~29.0	3.6~12.4	1.3~3.5	0.3~1.0
Sep	108~358	15~43	32~178	3~15	12.3~32.7	1.5~6.2	15.8~35.4	6.8~17.2	1.8~3.7	0.2~0.7
Oct	157~442	27~52	51~197	3~16	15.3~38.4	2.3~8.8	15.4~40.3	6.6~18.2	1.5~3.8	0.2~0.6
Nov	154~388	18~48	53~194	4~9	12.6~28.2	1.6~6.1	14.5~32.3	5.5~16.9	1.3~3.5	0.1~0.4
Dec	138~428	14~38	42~159	2~9	12.6~33.4	1.2~5.3	16.8~37.0	5.5~19.4	2.1~4.8	0.1~0.5

(3) The sewage treatment plant mainly accepts the polluted water body from tidal river, when the tidal reach is high, the pipe network would face an influx of tidewater, resulting in high sand content and high concentration of SS in the influent. Because of the limited land and investment consideration, no primary sedimentation tank was built, because the removal effect of rotational sedimentation sand is actually modest , which a large amount of inorganic mud sand enters MSBR tank and gradually deposits in the sequence batch pond. After a period of time, the concentration of mud sand the sequence batch pool is much higher than that in the main aeration tank, which leads to high back pressure of initial aeration and poor aeration effect in aeration stage [10]. To solve this problem, the following thoughts are adopted:

a. Under the premise of ensuring the effluent quality, the concentration of sludge in the whole tank can be controlled below 2500mg/L to reduce the aeration resistance of the sequencing batch tank;

b. Extended sludge releasing time of MSBR: the original sludge discharge time of the sequencing batch tank was controlled according to the time sequence, and the sludge discharge time was 30 minutes per cycle. In order to strengthen the sludge discharge, the sludge discharge time should be extended to more than 40 minutes when sludge treatment system capacity permits, and the sludge condensing section of the excess sludge pump should be kept open for sludge discharge. The reflux time from sequencing batch tank to sludge thickening tank was prolonged from 1 hour to 1 hour and 20 minutes respectively.

c. When the sequence batch tank is being aerated, the electric valve of the main aeration section is closed. On the one hand, the aeration rate is increased, and the other side plays the role of holding back the pressure of the blower, increasing the aeration pressure, and strengthening the aeration capacity. After entering normal aeration, open the electric valve of aeration section and run normally. When the sequencing batch tank is being aerated, the electric valve of the main aeration section should to be closed at first. Then, aeration rate need to be raised. At the same time, the pressure of blower need to be hold back so that aeration pressure is increased and aeration capacity is strengthened. After aeration becomes normal, the electric valve of aeration section can be turned on.

d. An independent blast system is installed in the sequencing batch tank to separate the air supply for sequencing batch tank and aeration section, which can balance unsatisfactory aeration caused by the difference of required air pressure between the two tanks. A new set of Roots blower is added for aeration of the batch tank during revamping. The model parameters are Q=22.54m3/min, P=68.6kPa, N=45kW.

It is proved by practice that the above 4 measures solves the aeration problem of sequencing batch thoroughly.

5. Conclusion

The MSBR process has the advantages of lowland occupancy and good treatment effect. However, in treatment of high sand-containing municipal sewage, drawbacks might stand out, such as low flow of sludge, siphon drawing mud from air weir and bad aeration effect of sequencing batch pool. Ineffective sludge discharge can be resolved by increasing perforation and reducing the air weir load. Siphonage drawing mud from air weir can be avoided by adopting P-shaped pipe and air weir to replenish gas during operation. The best solution is to set up independent aeration system for the poor aeration effect of sequencing batch pool. By taking the above measures, the effluent can be stabilized to the first level B criteria of the discharge standard.

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