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Influence of cycle time on sewage treatment using Sequencing Batch Reactor

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ABSTRACT A Sequencing Batch Reactor (SBR) was tested for performance under two different cycle times – 8 hours per cycle and 6 hours per cycle. The effluent quality after treatment was compared against specified effluent quality limits to determine the plant's performance in terms of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS), ammonia-nitrogen, nitrate-nitrogen, and phosphorus. The reduction of BOD, COD, SS and nitrate-nitrogen content in the SBR was not significantly affected by the cycle time – the levels under both time cycles complied with the effluent limits imposed. In fact, the SBR plant provides excellent treatment performance for conventional parameters of BOD, COD and SS, as well as nitrate-nitrogen at both 6-hour and 8-hour cycles. However, the study showed that removal efficiency of ammonia-nitrogen and phosphorus was better using the 8-hour cycle, compared to the 6-hour cycle. Nevertheless, it is has been established that the SBR would require a stabilisation period of at least three months for optimum phosphorus removal. Data obtained from this study is expected to be useful in the selection of the optimal cycling times in SBR for tropical conditions.

ABSTRAK Reaktor peringkat rentetan (Sequence batch Reactor-SBR) telah diuji keberkesanannya di bawah dua kitar masa yang berbeza- 8 jam per kitar dan 6 jam per kitar. Kualiti effluen selepas rawatan dibandingkan dengan had kualiti effluen yang tertentu bagi menentukan keupayaan logi dalam bentuk keperluan oksigen biokimia (BOD), keperluan oksigen kimia (COD), pepejal terampai (SS), ammonia-nitrogen, nitrat-nitrogen dan fosforus. Pengurangan dalam BOD, COD, SS, ammonia-nitrogen, nitrat-nitrogen dalam SBR adalah tidak berkaitan secara signifikan dengan kitar masa- tahap bagi kedua-dua kitar masa mematuhi had effluen yang telah ditetapkan. Bahkan logi SBR menawarkan keupayaan rawatan yang baik untuk parameter-parameter konvensional bagi BOD, COD dan SS, begitu juga dengan nitrat-nitrogen bagi kedua-dua kitar 6- jam dan kitar 8- jam. Walau bagaimanapun, kajian tersebut menunjukkan bahawa keberkesanan penyingkiran ammonia-nitrogen dan fosforus adalah lebih baik dengan menggunakan kitar 8-jam berbanding dengan kitar 6-jam. Namun begitu, telah diketahui bahawa SBR memerlukan tempoh penstabilan sekurang-kurangnya 3 bulan bagi menyediakan kondisi penyingkiran fosforus yang optima. Data yang diperolehi dari kajian ini dijangka bermanfaat dalam pemilihan kitar masa yang optima bagi SBR untuk iklim tropika.

(Sequenccing Batch Reactor (SBR), cycle time, sewage, treatment)

INTRODUCTION

The sequencing batch reactor (SBR) is a fill-and-draw activated sludge treatment system. The SBR process involves a single, complete-mix reactor in which all steps of treatment occur. Discrete cycles are used during prescribed time intervals. Mixed liquor suspended solids (MLSS) remain in the reactor during all cycles, thereby eliminating the need for a separate clarifier (USEPA, 1986a).

Studies in other parts of the world have shown that the SBR is a good system for biological nutrient removal (Irvine and Ketchum, 1989; Ketchum, 1997; USEPA, 1992). In Malaysia, a few SBR plants have been designed, usually with either an 8-hour cycle or 6-hour cycle. However, there is a dearth of data comparing the performance of the plants operating under these two cycle times. It was therefore proposed that the SBR plant investigated in the communication concerned be operated under these two commonly used cycle times. All other design parameters, facilities, equipment, operating procedures and instrumentation remained the same. The performance of the plant operating under these two cycle times could then be compared.

The objective of this research was to determine the influence of the 8-hour cycle time against the 6-hour cycle time on the performance of the SBR plant with respect to the reduction in BOD, COD, SS, ammonia-nitrogen, nitrate and phosphorus.

The BOD, COD and SS are the basic parameters tested for performance, and effluent quality limits are specified in the Environmental Quality Act (EQA) 1974. Ammonia-nitrogen, nitrate and phosphorus concentrations give an indication of the level of nutrients in the wastewater effluent. Nitrogen and phosphorus promote the growth of algae, (and where both nitrogen and phosphorus are plentiful, algal blooms occur) which may produce a variety of nuisance conditions (Sawyer *et al.*, 1994).

The effluent quality of the plant was compared against Standard B effluent quality limits for wastewater discharged downstream of water intake, as specified in the Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 of the Environmental Quality Act 1974 (Act 127 of the Laws of Malaysia). The Standard B parameter limits for SS, BOD and COD are 100 mg/l, 50 mg/l and 100 mg/l, respectively.

There are currently no Malaysian regulations for limiting concentration of nitrogen and phosphorus in effluent from sewage treatment plants. The limits for these selected parameters were therefore based on those recommended by the Urban Waste Water Directive 1991 (ammonia-nitrogen and phosphorus) and by the USEPA (nitrate-nitrogen), as follows:

- Ammonia-nitrogen – 5.00 mg/l (UWWD, 1991)
- Nitrate-nitrogen – 10.0 mg/l (USEPA, 1986b)
- Phosphorus – 2.00 mg/l (UWWD, 1991)

METHODOLOGY

Description of the SBR Plant

The SBR plant used for this study is located at the Kuala Lumpur International Airport, Sepang, Selangor. The plant was designed to serve a population equivalent (PE) of about 76,700 or 17,250 m^3/day. It was commissioned on 15 February 1998, and, during the study period, served a PE of about 15,000 to 20,000. Inflow to the SBR plant ranged from 3,000 - 4,700 m^3/day during the study period. The SBR plant was designed to treat domestic wastewater so that the treated effluent discharged will achieve at least the Standard B effluent limit. The performance of the SBR plant was investigated from 23rd June 1999 to 22nd December 1999, a total of six months. During the duration of the study, only two of the four SBR tanks were operated at any one time, as the low flows did not warrant the use of more tanks. Each SBR tank had a volumetric capacity of 2,220 m^3. About 1,480 m^3 to 1,665 m^3 of the total volume was retained in the tank as activated sludge buffer, while inflow and outflow from each tank during one cycle was about 555 m^3 to 740 m^3. No idle time was allocated in the process design for the SBR. The total fill time was not half of the total cycle time as would have been expected in a 2-tank SBR plant. This is because an equalization tank was provided to hold incoming sewage prior to biological treatment. When necessary, sludge was wasted during the idle sequence.

The schematic flow-chart for the plant is given in (Figure 1). The overall plant comprised the following components: inlet works (screening, grit chamber), SBR tanks (aeration tanks, settling), disinfection of effluent, and sludge treatment and disposal. Wastewater was conveyed to the plant via underground sewers to the inlet works where the raw wastewater underwent pre-treatment. Coarse solids were removed from the raw wastewater with the help of mechanical bar screens. Grit and grease were also removed in the grit and grease removal tank. The wastewater was then held in an equalization tank (capacity 1,750 m^3) before being pumped into the SBR tank. In the 6-hour cycle mode, each SBR tank operated four cycles a day, while in the 8-hour cycle mode, each SBR tank operated three cycles a day. In the SBR tank the wastewater underwent biological treatment, settling and clarification, as shown in the sequence in (Table 1).

The wasted sludge was thickened at the sludge treatment facility, using rotary drum thickener, and dewatered using filter press to 20%-30% solids (w/w). The sludge cake was disposed at the designated sanitary landfill.

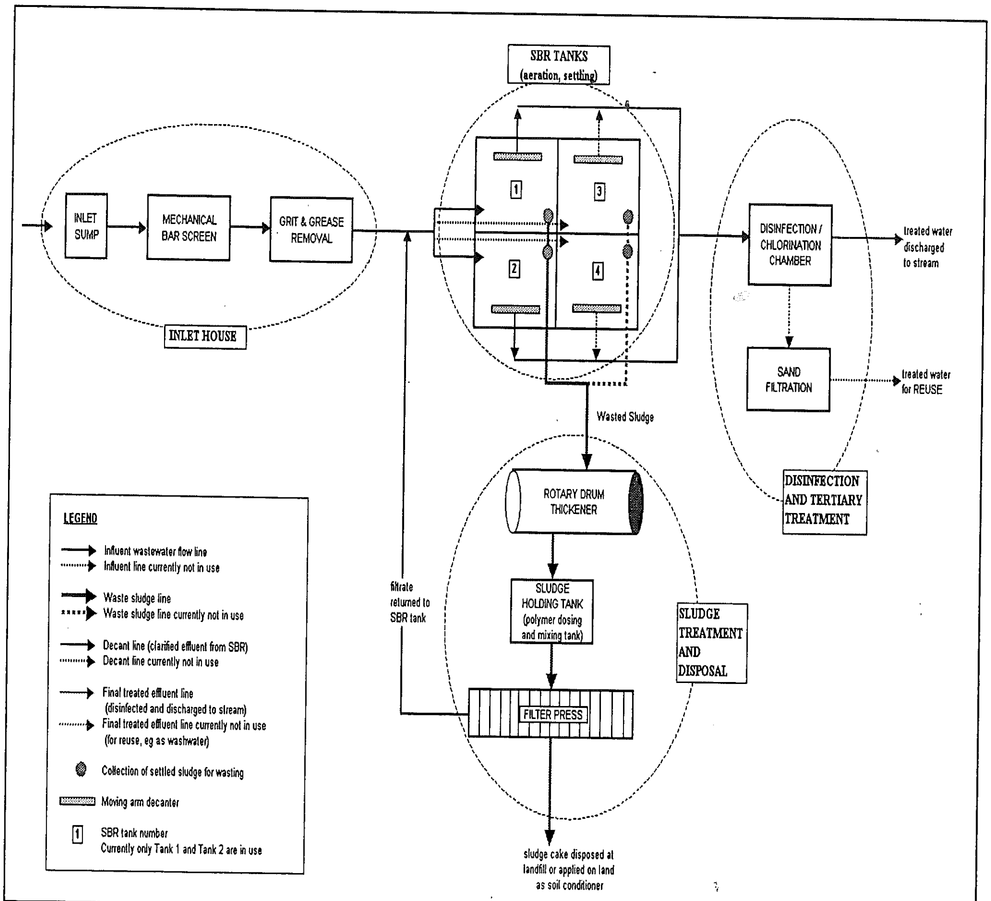

Figure 1: Schematic Flow Diagram for SBR Plant at Kuala Lumpur International Airport (KLIA)

Table 1. Sequence for 8-Hour Cycle and 6-Hour Cycle

Process	8-hour cycle	6-hour cycle
Fill & Anoxic-Anaerobic Mix	2.0 hours	1.0 hour
Fill & Aerate	0 hours	1.0 hour
Aerate	3.5 hours	2.0 hours
Settle	1.5 hour	1.0 hour
Decant & Sludge Wasting	1.0 hour	1.0 hour

8-Hour Cycle Mode

In the 8-hour cycle mode, the cycle started with the Fill sequence which lasted 2.0 hours. During Fill, the contents of the SBR tank were slowly mixed in anoxic-anaerobic conditions, resulting in denitrification and a subsequent reduction of oxygen demand and energy input. This gave rise to the anoxic or anaerobic conditions required for phosphorus removal. Mixing enhanced the dispersion of the feed substrate throughout the activated sludge content which was rich in micro-organisms. Some of the carbonaceous BOD and COD were removed due to consumption by anaerobic micro-organisms in the activated sludge. Phosphorus release occurred. During the anoxic-anaerobic mix, nitrate and nitrite were converted to nitrogen gas which was released to the atmosphere, in a process known as anoxic denitrification or anaerobic denitrification. After Mixed Fill, the SBR went into the Aerate phase, lasting 3.5 hours. No Filling was carried out during this phase. The contents of the SBR, also known as mixed liquor suspended solids (MLSS), were aerated using fine-bubble diffusers. Under aerobic conditions, the aerobic micro-organisms in the MLSS consumed the carbonaceous feed substrate, thus reducing the concentration of BOD and COD in the wastewater significantly. During the aerobic phase of the treatment, reduction of biological nutrients was expected to occur. The wastewater underwent nitrification whereby ammonia-nitrogen was oxidised to nitrite and nitrate by nitrifiers in the wastewater. Phosphorus was expected to be consumed during the aerobic phase.

The Settle sequence was next, set to last 1.5 hours. During this time, the sludge blanket settled in the SBR tank under truly quiescent conditions (i.e. no mixing, no filling, no aeration, no decanting, and no sludge wasting), leaving a clear supernatant. Observations at the plant indicated that sludge settled to about half the volume of the tank within the first half-hour of the Settle sequence, after which settling proceeded more slowly due to filamentous growth and sludge bulking hindering the settling process. The Decant sequence which followed was set to proceed for 1.0 hour. Once the Decant sequence was activated, the stainless steel moving arm decanter, comprising a weir and effluent pipes, was slowly lowered onto the surface of the supernatant at a specified rate to ensure minimal turbulence at the weir. The clear supernatant above the sludge blanket flowed over the weir into the effluent pipes and was conveyed to the disinfection chamber before final discharge. The decanter was lowered at a very low speed, so that effluent flow rates were low and turbulence at the point of draw-off was minimised. Draw-off rates ranged from 62.5 to 83.3 l/lin.m/min (liters per linear meter per minute). The linear meter here refers to the length of the decanter. This draw-off was equivalent to about 90 to 120 m^3/m.day. Sludge wasting was carried out simultaneously with Decant. The base of the SBR tank sloped slightly down towards the inlet portion of the tank. Sludge was collected in the sludge trough along the inlet wall of the SBR tank. Sludge pumps located in the sludge trough conveyed the wasted sludge to the waste sludge treatment facility.

6-Hour Cycle Mode

In the 6-hour cycle mode, the sequence was slightly modified to include a Fill-Aerate phase after the Fill-Anoxic Mix phase. The cycle began with Fill and Anoxic-Anaerobic Mix sequence which proceeded for 1 hour, at which time the aerators were activated, and filling was continued for another 1 hour. Thus, filling and aeration occurred simultaneously during this phase. After the two hours of filling, the feed valve was closed so that filling stopped. Aeration was continued for another two hours after filling was stopped. Thus, aeration proceeded for a total of three hours during the 6-hour mode. The aerobic phase was followed by the Settle sequence which lasted one hour during the 6-hour cycle mode. The Decant sequence then proceeded for one hour. Sludge wasting was carried out simultaneously with Decant.

Sampling and Analysis

In order to determine the performance of the SBR plant, sampling and monitoring instruments were located at the inlet sump to monitor influent quality, and at the effluent discharge point to monitor effluent quality. Daily composite samples comprising of six one-hourly samples mixed on the basis of flow rate, were collected and analyzed for eight parameters: temperature, pH, SS, BOD, COD, ammonia-nitrogen, nitrate-nitrogen and phosphorus.

RESULTS AND DISCUSSION

The summary of influent and effluent wastewater quality for the SBR operating under the 8-hour cycle mode is provided in (Table 2), while the influent and effluent quality for SBR operating under the 6-hour cycle mode is provided in (Table 3).

The quality of the influent wastewater is comparable with typical composition of untreated domestic wastewater, with the nutrients on the high side (Tchobanoglous and Burton, 1991).

Table 2. Summary of Influent and Effluent Wastewater Quality (8-hour mode)

Parameter	Unit	Limit Design Influent Standard	Influent Maximum Value	Influent Minimum Value	Influent Average ± Std. Dev.	Limit Effluent Standard	Effluent Maximum Value	Effluent Minimum Value	Effluent Average ± Std. Dev.
23 June – 22 July 1999									
Temperature	^oC	-	28.8	27.6	28.4±0.2		29.8	27.1	28.4±0.4
pH		-	7.3	6.6	7.1±0.2	5-5 – 9.0	7.5	6.4	7.0±0.2
TSS	mg/L	300	300	120	173±42	100	18.0	4.3	10.4±2.8
BOD_5 at 20^oC	mg/L	245	205.6	110.3	170.6±27.7	50	42.8	22.6	34.4±3.9
COD	mg/L	-	820	210	449±169	100	42	24	35.2±5.1
Phosphorous	mg/L	10	16.2	9.0	12.3±1.8	2	5.2	0.6	1.5±0.7
Ammonia-Nitrogen	mg/L	30	42.4	28.4	33.1±3.5	5	5.0	0.1	2.5±1.2
Nitrate-Nitrogen	mg/L	-	31.6	15.1	25.8±4.3	20	21.2	4.4	7.5±3.5
23 November – 22 December 1999									
Temperature	^oC	-	29.0	23.1	28.0±0.2		29.4	27.6	28.3±0.3
pH		-	7.2	6.6	6.8±0.1	5-5 – 9.0	8.2	7.0	7.2±0.2
TSS	mg/L	300	320	180	232±32	100	38	6	14.6±6.5
BOD_5 at 20^oC	mg/L	245	248.1	135.4	208.8±25.8	50	48.1	21.5	36.0±5.5
COD	mg/L	-	730	210	373±122	100	322	24	53.2±8.6
Phosphorous	mg/L	10	22.2	11.6	14.5±2.6	2	7.9	0.7	5.0±2.2
Ammonia-Nitrogen	mg/L	30	41.6	30.6	35.5±2.7	5	0.9	0.0	0.4±0.1
Nitrate-Nitrogen	mg/L	-	32.2	20.8	24.3±3.3	20	7.6	4.0	5.2±0.7

Table 3. Summary of Influent and Effluent Wastewater Quality (6-hour mode)

Parameter	Unit	Limit Design Influent Standard	Influent Maximum Value	Influent Minimum Value	Influent Average ± Std. Dev.	Limit Effluent Standard	Effluent Maximum Value	Effluent Minimum Value	Effluent Average ± Std. Dev.
23 August – 22 September 1999									
Temperature	^oC	-	29.8	28.0	28.4±0.4		29.6	25.1	28.2±0.6
pH		-	7.6	6.9	7.2±0.2	5-5 – 9.0	8.21	6.7	7.4±0.4
TSS	mg/L	300	240	120	163±26	100	18	6	11.7±2.2
BOD_5 at 20^oC	mg/L	245	241.6	129.6	182.4±35.9	50	42.1	22.8	34.0±4.0
COD	mg/L	-	960	180	427±202	100	47.0	21.0	34.1±6.8
Phosphorous	mg/L	10	18.2	7.6	13.0±2.7	2	9.3	0.4	4.3±2.3
Ammonia-Nitrogen	mg/L	30	45.2	20.8	34.4±5.2	5	15.2	0.8	7.3±3.0
Nitrate-Nitrogen	mg/L	-	39.8	9.6	21.7±6.7	20	11.1	1.5	4.6±1.8
23 September - 22 October 1999									
Temperature	^oC	-	29.2	26.2	28.3±0.6		30.1	27.6	28.5±0.6
pH		-	8.6	6.8	7.3±0.4	5-5 - 9.0	8.4	6.9	7.5±0.5
TSS	mg/L	300	700	120	189±110	100	18.0	6.0	10.4±2.6
BOD_5 at 20^oC	mg/L	245	225.4	114.2	172.4±34.9	50	46.2	18.2	34.9±6.0
COD	mg/L	-	1,200	120	556±276	100	73	7	27±12
Phosphorus	mg/L	10	18.2	2.0	12.0±3.5	2	12.1	0.1	4.1±2.7
Ammonia-Nitrogen	mg/L	30	42.1	18.0	34.2±5.3	5	23.7	1.4	8.4±4.4
Nitrate-Nitrogen	mg/L	-	42.8	12.8	24.5±6.2	20	21.4	2.4	6.6±4.8

Table 4. Treatment Efficiency for BOD, COD and SS

Cycle Mode	Period of run	BOD Efficiency	BOD Compliance	COD Efficiency	COD Compliance	SS Efficiency	SS Compliance
8-hour	23/6/99 - 22/7/99	79.8%	100%	92.2%	100%	93.9%	100%
6-hour	23/8/99 - 22/9/99	81.4%	100%	92.0%	100%	92.8%	100%
6-hour	23/9/99 - 22/10/99	79.8%	100%	95.1%	100%	94.5%	100%
8-hour	23/11/99 - 22/12/99	82.8%	100%	87.1%	100%	93.7%	100%

Note: BOD Compliance level: 50mg/l (Standard B, regulatory limit)
COD Compliance level: 100mg/l (Standard B, regulatory limit)
SS Compliance level: 100mg/l (Standard B, regulatory limit)

Performance In Terms of BOD, COD and SS reduction

Levels in the effluent wastewater from the SBR plant were consistently below the DOE limit, complying with Standard B. Carbonaceous BOD removal and consumption of COD occur during both the anaerobic and aerobic phases of the SBR process, resulting in effluent quality with low BOD and COD concentrations. Since effluent was decanted from the clear supernatant of the reactor contents after settling under quiescent conditions, the SS level in the effluent was low as expected.

The treatment efficiency of the plant for BOD, COD and SS based on average values under the two cycle conditions, are given in (Table 4). In every case, the BOD concentration of the effluent discharged from the plant complied with the Standard B regulatory level of 50 mg/l (see Figure 2a). The treatment efficiency of the plant, ranging from 79.8% to 82.8%, was satisfactory. The t-test was applied to compare effluent concentrations of different runs, and showed that there was no significant difference at the P=5% level in the effluent BOD concentrations, between the 8-hour mode and the 6-hour mode.

Similarly, the COD concentration of the effluent discharged from the plant complied with the regulatory Standard B compliance level of 100 mg/l in every case (see Figure 2b). The treatment efficiency of the plant, ranging from 87.1% to 95.1%, was satisfactory. However, the results of a t-test showed that generally, there was a significant difference at the P=5% level in the COD concentrations between different runs. Also the effluent COD concentrations from the 8-hour mode runs was significantly lower than the 6-hour mode runs at the P=5% level.

The SS concentration of the effluent discharged from the plant complied with the Standard B regulatory level of 100 mg/l (see Figure 2c). The treatment efficiency of the plant ranged from 92.8% to 94.5%. However, the results of the t-test showed that generally, there was a significant difference at the P=5% level in the SS concentrations between different runs. Also the effluent SS concentrations from the 8-hour mode runs differed significantly from the 6-hour mode runs at the P=5% level.

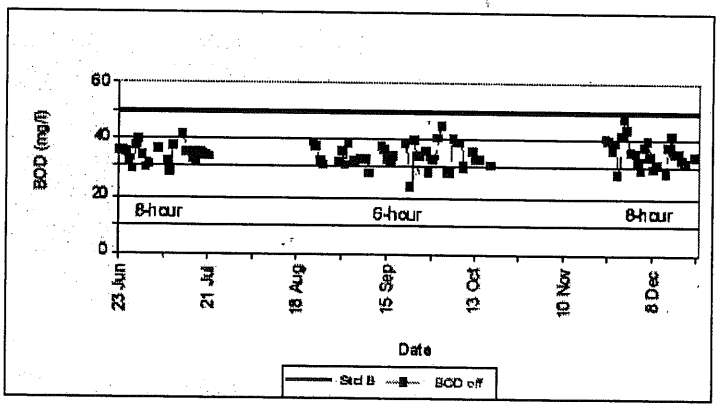

Figure 2a

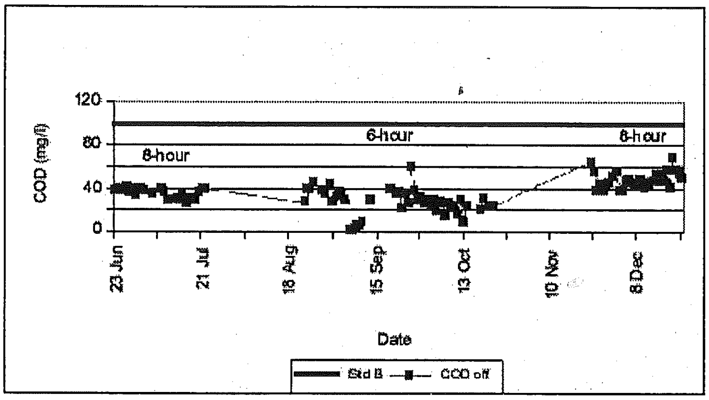

Figure 2b

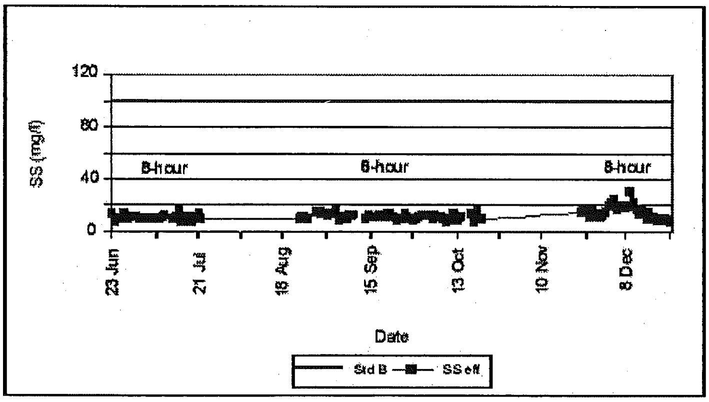

Figure 2c

Figure 2. BOD, COD and SS of effluent discharged after treatment

Performance in terms of Biological Nutrient Removal

Removal of nutrients was indicated by NH_3-N, NO_3-N and phosphorus (as phosphate PO_4-P). The compliance level of nutrients (NH_3-N, NO_3-N and phosphorus) in the effluent varied from 10% to 100%. The fluctuation in nutrient levels have some correlation with the cycle time.

The treatment efficiency for NH_3-N, NO_3-N and phosphorus based on average values under the two cycle conditions, are given in (Table 5).

Table 5. Treatment Efficiency for Ammonia-Nitrogen, Nitrate-Nitrogen and Phosphorus

Cycle Mode	Period of run	Ammonia-Nitrogen		Nitrate Nitrogen		Phosphorus	
		Efficiency	Compliance	Efficiency	Compliance	Efficiency	Compliance
8-hour	23/6/99 - 22/7/99	**92.4%**	100%	70.9%	89.6%	88.0%	95.8%
6-hour	23/8/99 - 22/9/99	**78.8%**	20.0%	78.8%	98.0%	67.0%	18.0%
6-hour	23/9/99 - 22/10/99	**75.3%**	18.5%	73.1%	87.0%	65.9%	22.2%
8-hour	23/11/99 - 22/12/99	**98.8%**	100 %	78.6%	100 %	65.6%	10.0%

Note: Ammonia-Nitrogen proposed compliance level: 5mg/l (UWWD, 1991)
Nitrate-Nitrogen proposed compliance level: 10mg/l (USEPA, 1986a)
Phosphorus proposed compliance level: 2mg/l (UWWD, 1991)

The NH_3-N concentration in the effluent was low, below 5.0 mg/l, during the 8-hour cycle (June-July and November-December 1999), but somewhat higher (up to 20 mg/l) during the 6-hour cycle (August-September and September-October 1999). In fact, while the plant was operated on the 8-hour cycle mode, the effluent complied 100% with the prescribed limit of 5.0 mg/l with treatment efficiencies over 90% (see Figure 3a). Compliance levels during the 6-hour cycle mode fell to 20% or less, with treatment efficiencies between 75% and 79%. The results of the t-test comparing effluent NH_3-N concentrations of different runs showed that there was a significant difference at the P=5% level in the effluent NH_3-N concentrations between different runs. Also the effluent NH_3-N concentrations from the 8-hour mode runs differed significantly from the 6-hour mode runs at the P=5% level. Since NH_3-N is known to be consumed during the aerobic phase and increased during anaerobic period (Sasaki *et al.*, 1996), the lower compliance level for the 6-hour cycle mode indicated that the time allowed for aeration was not sufficient for adequate denitrification of the NH_3-N. The fluctuation of the NH_3-N concentration in the effluent from day to day was pronounced, more so during the 6-hour cycle mode of operation.

The NO_3-N concentration in the effluent was low, generally below 10.0 mg/l (see Figure 3b). The results obtained for NO_3-N concentration in the effluent had a compliance level of more than 95% at any time. Treatment efficiency of the system varied between 70% and 79%. The overall comparison between the 8-hour mode effluent concentrations and the 6-hour mode effluent concentrations showed that at the P=5% level, there were no significant differences between the two types of runs. Since the NO_3-N concentration in the effluent was below 10.00 mg/l most of the time and regardless of cycle mode used, it is concluded that the SBR is able to perform satisfactorily in terms of nitrate-nitrogen removal operating on either the 6-hour cycle mode or the 8-hour cycle mode. The compliance level achieved was more than 95% at any time (limit of compliance 10 mg/l).

The level of phosphorus in the effluent was low and generally within the compliance limit of 2.0 mg/l during the June-July run on 8-hour mode. The level of phosphorus in the effluent then increased significantly during the August-October run on 6-hour mode. Again, the November-December run on 8-hour mode the effluent phosphorus level remained high (see Figure 3c). The results obtained showed that the effluent quality in terms of phosphorous content was good (about 98% compliance and 88% efficiency) for the 8-hour cycle mode studied in June-July 1999. However, when the plant was switched to 6-hour cycle mode, the compliance level for phosphate dropped drastically to about 20%, with treatment efficiency of about 66%. Then, when the plant was reverted to 8-hour cycle mode the compliance level dropped even further to 10%, with a treatment efficiency of about 65%. The overall comparison between the 8-hour mode effluent concentrations and the 6-hour mode effluent concentrations showed that there was significant difference at the P=5% level between the two types of runs. However, statistical comparisons (t-test, arithmetic mean, standard deviation and 95% confidence level around the arithmetic mean) indicated that there was little difference between the 6-hour cycle mode and the November-December run (8-hour cycle mode).

Under fluctuating anaerobic-aerobic process conditions, certain phosphorus assimilating bacteria can flourish and dominate the population, resulting in an increased phosphorus content in the waste sludge, while reducing the phosphorus content in the wastewater (Eckenfelder, 1989). From literature (Cuevas-Rodriguez *et al.*, 1998; Garzón-Zúñiga, M. A. and González-Martínez, S., 1996), it was expected that longer aerobic phase would result in lower phosphate levels in the effluent. In the case of this study, changing from 8-hour mode to 6-hour mode reduced the anaerobic period from 2 hours to 1 hour, while slightly reducing the aeration period from 3.5 hours to 3 hours during each cycle. Thus the time available in each cycle for the bacteria to accumulate the phosphates in its cells was reduced, and the amount of phosphorus removed was correspondingly reduced.

The difference in plant performance under the 8-hour cycle mode observed between the June-July operation period and the November-December operation period could be attributed to insufficient time for the phosphorus removing characteristics of the plant to stabilise. The SBR plant in November-December was reverted from 6-hour mode to 8-hour mode in November and had not had sufficient time to stabilise (only two months). From literature (Cuevas-Rodreguez *et al.*, 1998; Wang and Park, 1998), the phosphorus removal system required a long stabilisation period, and between 100 and 150 days have usually been sufficient. The SBR plant in June-July was well stabilised, having operated under the 8-hour mode for more than 3 months previously (about 90 days). This compares favourably with other studies where more than 100 days were required to allow the plant to stabilise.

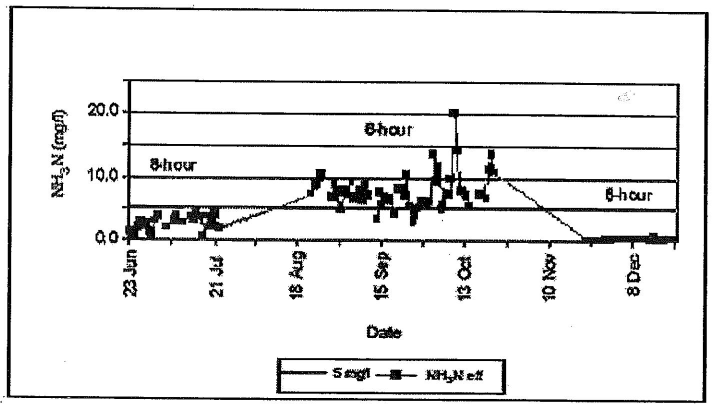

Figure 3a

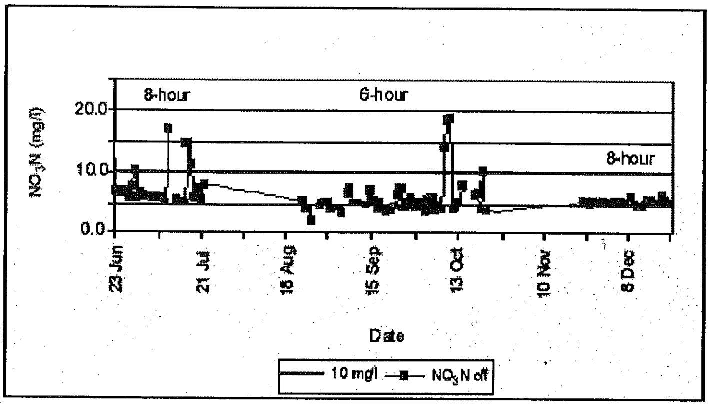

Figure 3b

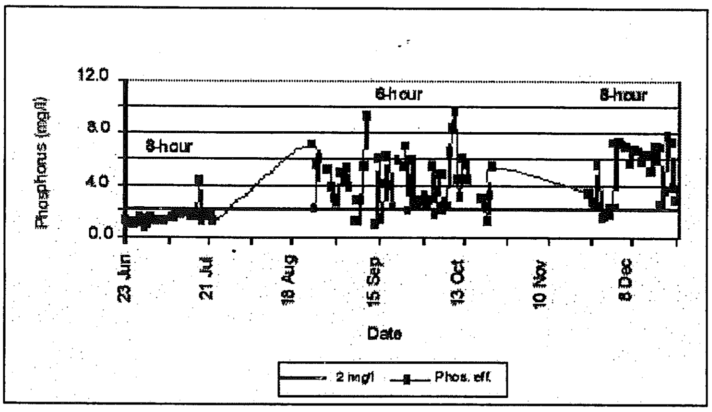

Figure 3c

Figure 3. Amm.-N, Nitrate-N and P in the effluent discharged after treatment

CONCLUSIONS

The results show that the SBR reduced BOD, COD and SS to meet the specified limits under both 8-hour cycle and 6-hour cycle operating conditions. BOD, COD and SS levels in the effluent wastewater from the SBR plant complied with Standard B levels at all times. (BOD, COD and SS are the common and accepted parameters by which sewage treatment plants in Malaysia are judged in terms of performance). Thus, this study has shown that the SBR system performs equally well under both 6-hour cycle mode and 8-hour cycle mode.

With regard to NO_3-N, the study concluded that effluent quality within the stipulated levels can be obtained under both operating conditions. However, for the removal of NH_3-N, a treatment efficiency of over 90% and compliance rate of 100% was recorded using the 8-hour cycle, compared to a treatment efficiency from 75% to 80% with only 20% compliance level using a 6-hour cycle. The study showed that removal of phosphorous was better using the 8-hour cycle (about 98% compliance and 88% removal efficiency) compared with the 6-hour cycle (20% compliance and 66% efficiency). Thus the 8-hour cycle achieved a higher removal of NH_3-N and phosphorus.

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