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Biological Treatment of Pb and Zn Using Sequencing Batch Reactor

(Rawatan Biologi Pb dan Zn Menggunakan Reaktor Sesekumpul Berjujukan)

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ABSTRACT

Effective wastewater treatment is essential to prevent water resources from being polluted. Usually, wastewater treatment can be divided into three distinct types; physical, chemical and biological treatment. This research aims to biologically treat Pb and Zn using the Sequencing Batch Reactor (SBR) system. There were four stages involved in the operation of SBR, which include; filled, react, settle and draw. The dissolved oxygen (DO) was controlled in the range of 2-5 mg/L, while the pH was maintained at the range of pH 6.5-7.5. Synthetic wastewater was used as influent with a C:N ratio of 200:40. In total, there were three HRT's tested, which were 8, 24 and 48 hrs respectively. Additionally, the water quality parameters analysed were (chemical oxygen demand) COD, ammonium, mixed liquor suspended solid (MLSS) and heavy metal Pb and Zn in the effluent. The average percentage of COD removals in this research was 66.0% while the average heavy metal removal for Pb and Zn were 97.1% and 94.7%, respectively. Therefore, based on the three hydraulic retention times, (HRT's), HRT 48 showed the highest performance in removing Pb and Zn.

Keywords: Sequencing Batch Reactor (SBR); Pb; Zn; Heavy metal wastewater; biological treatment

ABSTRAK

Rawatan air sisa logam berat yang berkesan dan praktikal adalah penting bagi mencegah pencemaran air yang kian meruncing. Rawatan air sisa boleh dibahagikan kepada tiga jenis iaitu rawatan secara fizikal, kimia dan biologi. Tujuan projek ilmiah ini adalah merawat Pb dan Zn secara biologi dengan menggunakan reaktor sesekumpul berjujukan (SBR). Dalam proses pengoperasian SBR terdapat empat proses yang terlibat iaitu pengisian, pengudaraan, pemendapan dan penyingkiran. Dalam kajian ini, oksigen terlarut berada dalam julat 2-5 mg/L manakala julat pH dikawal pada pH 6.5-7.5. Air sisa sintetik digunakan sebagai influen dengan nisbah C:N 200:40. Terdapat tiga HRT yang dikaji, iaitu HRT 8 jam, 24 jam dan 48 jam. Analisis terhadap keperluan oksigen kimia (COD), ammonium, MLSS dan kandungan logam dalam sampel dilakukan. Purata penyingkiran COD dalam kajian ini adalah 66.0%, purata penyingkiran logam plumbum dan zink masing-masing 97.1% dan 94.1%. Antara ketiga-tiga HRT, HRT 48 jam memberikan prestasi penyingkiran Pb dan Zn yang paling berkesan.

Kata kunci: Reaktor sesekumpul berjujukan (SBR); Pb; Zn; air sisa logam berat; rawatan biologi

INTRODUCTION

Heavy metals in wastewater produced from various types of industries show a great impact towards human health and living organism when being discharge to the environment. Heavy metals are elements having atomic weights between 63.5 and 200.6 and specific gravity greater 5.0 (Srivastava & Majumder 2008). Heavy metal is not biodegradable compare to organic compound and it tends to accumulate in living organism and most of heavy metals ions are known to be toxic or carcinogenic.

Lead (Pb) can cause serious health problem such as nervous system damage, damaging kidney, liver, reproductive system, basic cellular processes and brain functions. Other toxic systems are anaemia, insomnia, headache, dizziness, irritability weakness of muscle and renal damages. Zinc (Zn) elements are essential to human being. It benefits in terms of physiological functions of living tissue and regulates many biochemical processes. Too much of Zn in human body also could cause eminent health problem, such as stomach cramps, skin irritations, vomiting, nausea and anemia (Fu & Wang 2011).

Physiochemical methods such as chemical precipitation, solvent extraction and ion exchange processes have been used widely to treat heavy metal in wastewater. However, these methods have significant disadvantages, such as incomplete metal removal, high cost, high reagent or energy requirement or generation of toxic sludge or other waste pollutants and they are not selective to allow recovery of metals present in the effluent (Açikel & Alp 2009). Sequencing batch reactor (SBR) provides an alternative to conventional biological wastewater treatment system due to its simplicity and flexibility of operation. An SBR has five discrete periods of operation cycle: fill, react, settle, draw and idle. The reaction starts during fill stage and complete during react stage. After react the mixed liquor suspended solids (MLSSs) are allowed to separate by sedimentation during settle stage in a defined time period and treated effluent. The time period between the ends of draw process and beginning of the new fill is called idle (Herzbrun et al. 1985). Previous studies shows a good description and evaluation of SBR system has been published for various types of pollutants (Rarunroeng & Sirianuntapiboon 2012; Marques & Duque 2013; Muhamad et al. 2015).

The objective of this research was to investigate biological treatment of Pb and Zn using (SBR) system. The efficiency of SBR system with different hydraulic retention time (HRT) in reducing the toxic Pb and Zn was investigated. Pb and Zn were used because of their widespread industrial use and known toxicity to organisms.

METHODOLOGY

SETUP AND OPERATION OF SBR

SBR system was made from acrylic plastic with dimensions of 0.32 m height and 0.27 m diameter as shown in Figure 1. The total volume and working volume of the reactor were 7.5 and 5 L respectively. Air pump system was used for supplying air to the SBR reactor.

Once the concentration of biomass reached 1400 mg/L during acclimatization and growth, Pb and Zn was introduced into SBR system containing sludge. The SBR was operated through four main stages Filling, Reaction, Settle and Idle as depicted in Table 1. The performance of SBR system in removing Pb and Zn was investigated under HRT 8, 24 and 48 h. Effluent sample were taken and parameters such as pH, DO, Pb, Zn and COD were analyzed.

ACCLIMATIZATION OF SLUDGE FOR SBR SYSTEM

Activated sludge was collected from food industry. The activated sludge was acclimatized in SBR for 63 days until

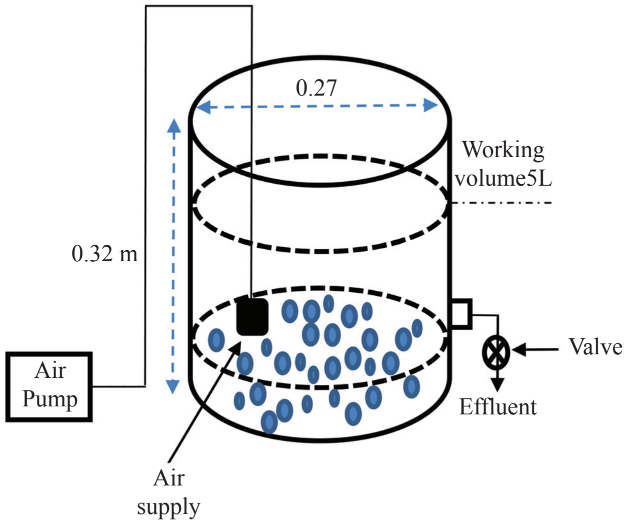

FIGURE 1. Schematic diagram of SBR system

TABLE 1. Operation of SBR system

Parameter	HRT 8	HRT 24	HRT 48
Fill (h)		0.5	
React (h)	6.5	22.5	46.5
Settle (h)		0.5	
Idle (h)		0.5	
Working volume (L)		5	

MLSS reached 1400 mg/L. During the acclimatization period, the sludge were supplied with nutrient for bacteria growth as summarized in Table 2. The pH and DO was monitored in the range of pH 6.5-7.5 and 2-5 mg/L.

SYNTHETIC PB AND ZN WASTEWATER

Wastewater samples used in this study were synthetic wastewater contain Pb and Zn with a concentration of 6 mg/L and 5 mg/L, respectively. Table 3 shows descriptions of metal used in this study.

TABLE 2. List of chemical for bacteria growth

Solution	Chemical list	Brand	Composition, mg/L
Glucose	$C_6H_{12}O_6$	Systerm (Malaysia)	200.0
Nutrient	NH_4SO_3	Fluka Chemie (Switzerland)	40.0
	$MgCl_2.6H_2O$	R&M Chemicals (Canada)	8.0
	$MnCl_2.4H_2O$	R&M Chemicals (Canada)	0.3
	$FeCl_3.6H_2O$	R&M Chemicals (Canada)	0.3
Buffer	KH_2PO_4	Merck (German)	2.5
	$NaHCO_3$	R&M Chemicals (Canada)	50.0

TABLE 3. Types of metal used

	Metal Pb	Metal Zn	COD
Chemical type	$Pb(NO_3)_2$	$ZnCl_2$	COD
Manufacturer	Riendeman Schmidt	Merck Germany	Hach, USA

ANALYTICAL METHODS

The COD were analysed, using spectrophotometer HACH DR/2010, Method 8000 in HACH DR/2010 Spectrophotometer Procedure Manual (USA). The Pb, Zn of wastewater (influent and effluent) were analyse using inductively coupled plasma (ICP) brand Perkin Elmer, model Optima 7300 DV. Meter pH Schott 672P (Great Lakes Instrument) was used to determine pH. Meter ORP Schott 672P (Great Lakes Instrument) was used to measure DO. Mixed liquor suspended solid (MLSS) of the system were determined by filtering a sample through a glass of fiber filter (Whatman grade GF/A, 1.6 µM) residue retain was dried in oven for 1 hour. COD, Pb, Zn, DO, pH, and MLSS were measured using standard methods of water and wastewater (APHA, AWWA, WPCF 1995).

RESULTS AND DISCUSSION

ACCLIMATIZATION OF BACTERIAL GROWTH

Based on Figure 2, throughout the SBR process, a steady rise from 350 to 1800 mg/L was demonstrated by the MLSS concentration. The rise of MLSS indicated that the bacteria were well growth. The bacteria consumed organic matter and multiplied to form a new cell. At early stage (day 0) of acclimatization phase, the concentration of bacteria was 360 mg/L. The biomass increased from 360 mg/L to 1400 mg/L at the end of acclimatization phase at day 60. Adequate biomass concentration was important to maintain the bacterial population sufficient enough for biological reaction during aerobic degradation (Vijayaraghavan et al. 2007). The Colony Forming Unit (CFU) at early stage was 2.00 × 105 CFU/ml increased to 1.20 × 106 CFU/ml at the end of acclimatization stage.

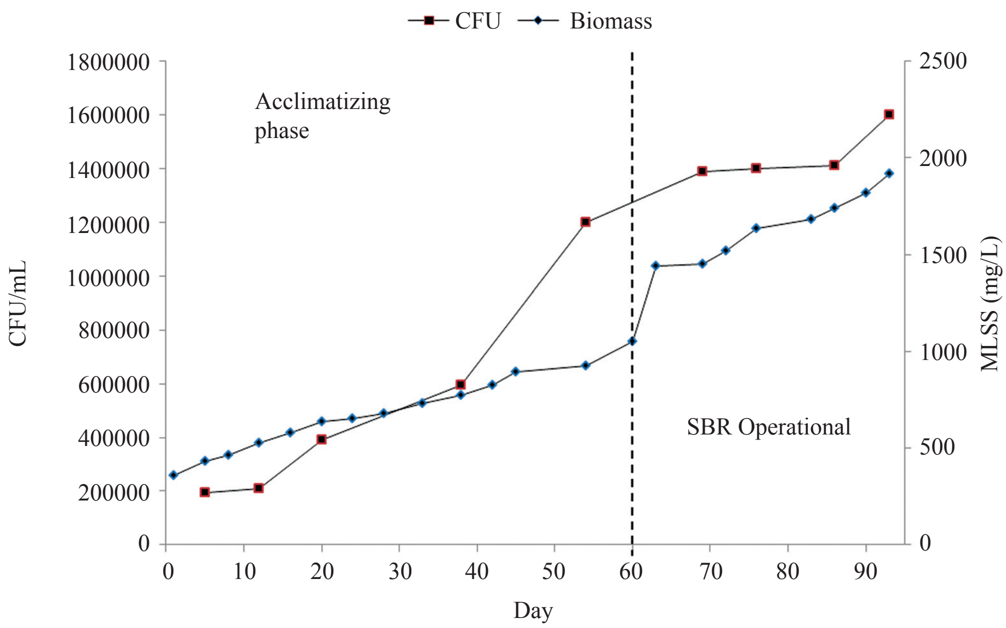

FIGURE 2. Bacterial growth

The COD removal during the acclimatization phase was illustrated in Figure 3. Once the reading of COD effluent was relatively constant, the acclimation process was considered done and was achieved after day 50. Minimum removal at early stage was 13% due to adaption of bacteria with the SBR reactor and environmental conditions, while maximum removal of COD achieved at day 63 with 80% removal. Although there were fluctuation in COD removal throughout the early stage process, COD removal showed 45% removal efficiencies on average. An adapted population can be indicated by the effluent COD concentration reaching constant values (Morgan-Sagastume & Allen 2003; Malakahmad et al. 2011).

PERFORMANCE EFFECTIVENESS OF THE PB AND ZN REMOVAL

During operational process synthetic wastewater consists of Pb and Zn were exposed in the SBR, where the biological process took place during reaction period of three different (HRT) 8, 24 and 48 hours. Effectiveness of this operations were determined by analyzing influent sample before and after treatment process. As illustrated in Figure 4 and 5, initially Pb and Zn were added in the concentration of 6 mg/L and 5 mg/L, respectively.

Figure 4, shows the performance removal of Zn. The average influent concentration of Zn for 3 different HRTs were 5.18, 5.19 and 5.16 mg/L respectively. The average

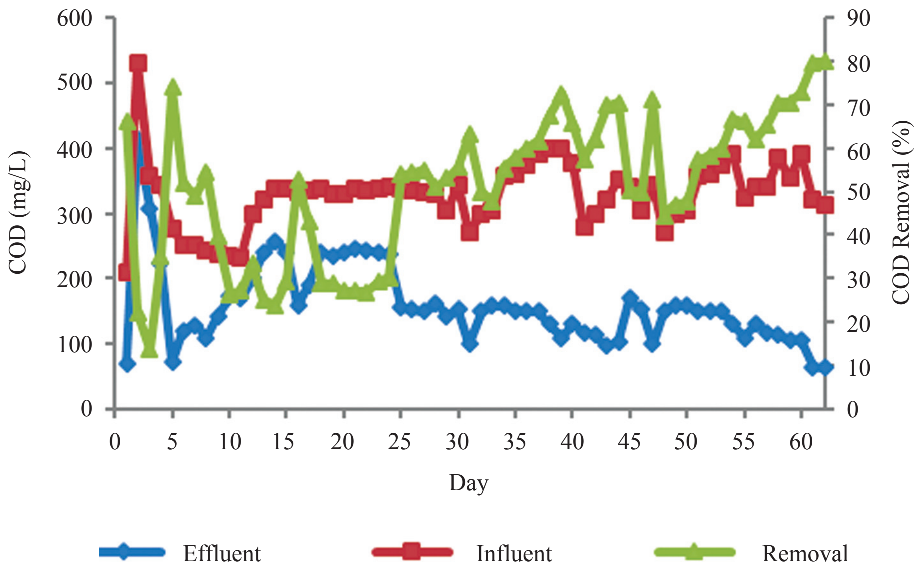

FIGURE 3. Percentage of COD removal during acclimatization process

removal of Zn at HRT 24 and 48 showed, were not so different from each other with removal of 92.5% and 94.7%, while average removal for HRT 8, was only 80.2%, this indicate that the length of time needed to get of rid Zn from wastewater (Ozbelge et al. 2007). It was found that, removal of Zn on day 89 at HRT 8 did not met the requirement of Department of Environment (DOE), for Zn which is below than 2.0 mg/L for Standard B.

Figure 5 shows the performance of Pb removal. The elimination of Pb for 8, 24 and 48 HRT were 97, 96.1 and 97.1%, respectively. From Figure 5, it was shown that the effluent of Pb complied the Standard B regulated by DOE which is 0.5 mg/L. Sirianuntapiboon and Boonchupleing (2009) reported that SBR system has the potential to remove 85.9% heavy metal Pb from synthetic industrial estate wastewater (SIEWW) at HRT 72.

Figure 6 shows the performance of COD for HRT 8, 24 and 48 h. As can be seen, the percentage of COD removals were fluctuating across the days. The average COD removal at HRT 8, 24 and 48 were 30.4 and 66%, respectively. The COD removal performance increased when HRT was increased. In this study, the COD removal the COD reading at 8 h HRT did not complied with the DOE standard, while at HRT 24 and 48 h show a good effluent and met the regulated limit below than 200 mg/L. Throughout this study, DO and pH were monitored in the range of 2.63-2.88 mg/L and pH 6.8-7.0, respectively (Marques & Duque 2013).

The results showed that the SBR system could be used to treat industrial heavy metal. Based on Figure 5 and 6, highest Pb and Zn removal were at HRT 48 with 97.1% and 94.7% with COD rejection 65.6% and lowest removal were at HRT 8 with removal of Pb, Zn and COD were 97.0, 80.2 and COD 30.1% respectively. This removal might be low due to the synthetic wastewater contained toxic substance and heavy metal that could suppress the growth and activity of sludge (Rarunroeng & Sirianuntapiboon 2012).

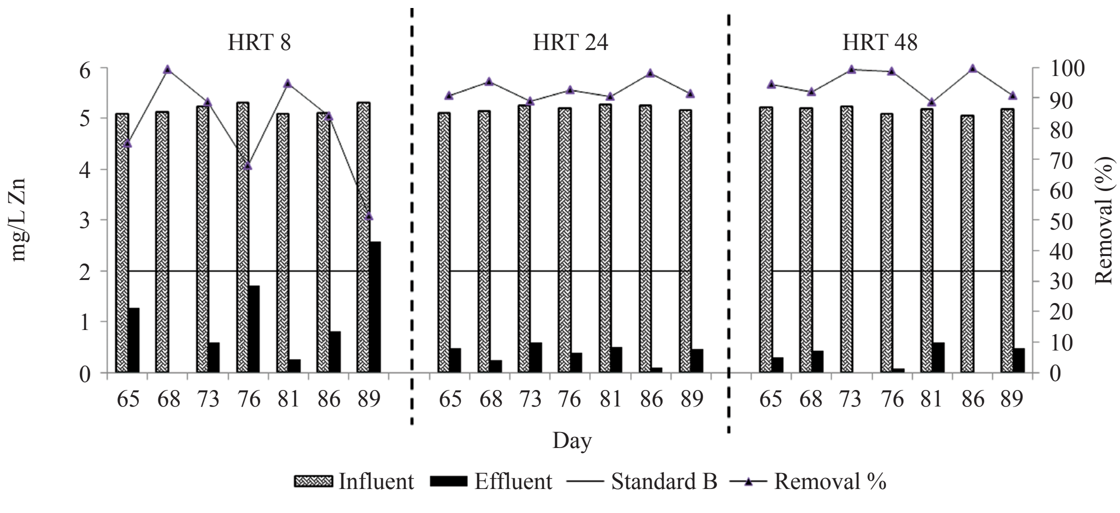

FIGURE 4. Percent removal of heavy metal Zn

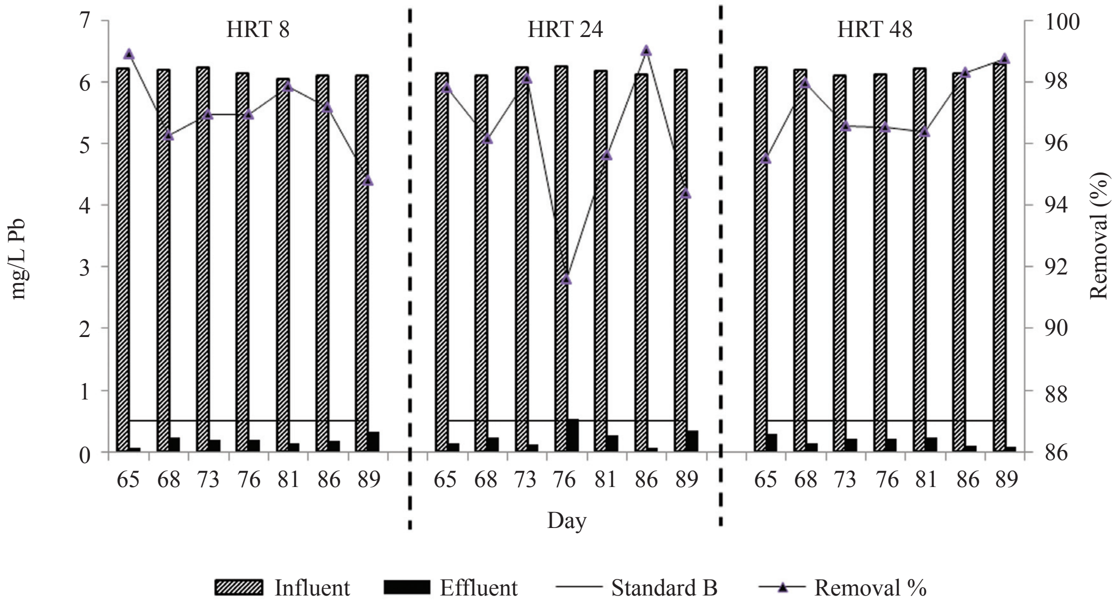

FIGURE 5. Percent removal of heavy metal Pb

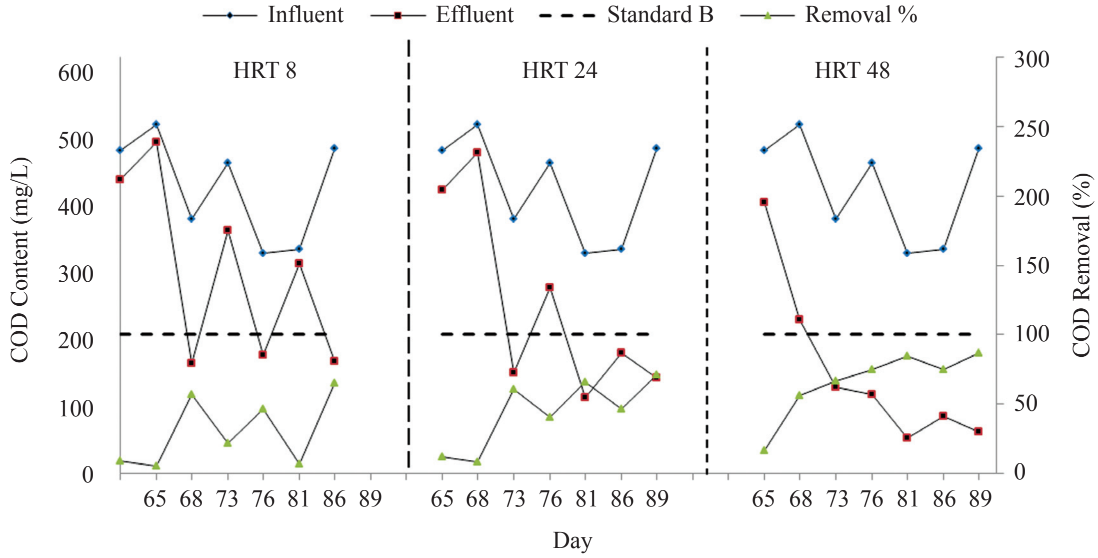

FIGURE 6. Performance of COD Removal

As shown in Table 4, Sirianuntapiboon and Hongsrisuwan (2007) had studied the removal of heavy metals Zn and Cu using SBR system which used synthetic industrial wastewater with SBR operating conditions for this study was HRT 72 h, heavy metal feed in reactor 10 mg/L Zn and Cu and percentage removal of 84.9% Zn and 87% Cu. They discovered that the Cu had more effect than Zn to repress the organic matter ability sludge. Molecular weight of Cu 63.55, atomic no 29 is smaller compared to Zn molecular weight 65.72, atomic no 30 resulting in occupation of more adsorption sites of sludge, and this had led to less free adsorption sites remain for free adsorption matter.

The effect of biosludge concentration on the efficiency of sequencing batch reactor (SBR) system to treat wastewater containing Pb and Zn had been studied by Sirianuntapiboon and Boonchupleing (2009). Under HRT of 72 h the system was able to eliminate 86% of COD and 85.6% of Pb. It was reported by Marques & Duque (2013) that by using aerobic granular sequencing batch reactor (AGS-SBR), it can reduce the COD as much as 91.5% and Zn 94% at HRT of 3 h.

In this study 3 different HRTs were tested and average percentage of COD removal was 66% and average heavy metals removals for Pb and Zn at HRT 48 were 97.1% and 94.7% respectively. Through this biological process even with shortage of microorganism it showed that SBR system able to remove heavy metal concentration from wastewater as a result of biosorption. This is an agreement with other researcher that have proven, biosorption play a big role in biological treatment of metal compound (Hasan et al. 2010; Marques & Duque 2013; Rarunroeng & Sirianuntapiboon 2012; Zainudin et al. 2016; Hasan et al. 2016).

TABLE 4. Comparison with previous studies

Wastewater type	Treatment system	COD (mg/L)	HRT (h)	Pb (mg/L)	Zn (mg/L)	Reference
Synthetic industrial estate wastewater (SIEWW)	SBR	92 ± 0	72	-	92.61	(Sirianuntapiboon & Hongsrisuwan 2007)
Synthetic industrial estate wastewater (SIEWW)	SBR	86 ± 0.5	72	85.63	-	(Sirianuntapiboon & Boonchupleing 2009)
Synthetic wastewater	AGS – SBR	91.5	3	-	94	(Marques & Duque 2013)

CONCLUSIONS

It is proven that SBR shows a good performance for treatment of synthetic wastewater contains Pb and Zn, which can be achieved considerable level of COD, Pb, Zn. The study indicate that the average COD removal was 45% and maximum COD removal was 80% at day 63 before addition of heavy metals due to acclimatization of sludge. Adequate biomass concentration was important to maintain the bacterial population sufficient enough for biological reaction during aerobic degradation. There were three HRT's being tested, which were 8, 24 and 48 hours. The average heavy metal removal for Pb and Zn were 97.1 and 94.7% respectively. Based on three HRT's, HRT 48 showed the highest performance in removing Pb and Zn.

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