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Landfill Leachate Treatment Using PAC Supplemented SBR Technique-Influence of Input Air

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Abstract. In this study, sequencing batch reactors (SBR) was used for treatment of raw landfill leachate from Kulim landfill site. To show the effect of adsorbent on SBR performance, two types of SBRs (namely non–powdered activated carbon–SBR (NPAC–SBR) and powdered activated carbon–SBR (PAC–SBR)) were used for treatment of landfill leachate. Results showed that the average removal efficiencies of phenols, total iron, zinc, ammonia (NH_3–N), colour, suspended solids, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), and total dissolved salts (TDS) parameters inside NPAC–SBR were 25%, 33.33%, 63.48%, 89.40%, 10.2%, –98.08%, –42.90%, 98.5%, and 36.47%, respectively; whereas those inside PAC–SBR were 55%, 83.33%, 65.22%, 89.90%, 65.40%, 13.46%, 27.30%, 99.40%, and 37.32%, respectively. Additionally, saving quantities of supplied air in NPAC–and PAC–SBR were 0% and 50.54 %, respectively. It can be conclude that PAC as adsorbent in the PAC–SBRs was enhanced the removal efficiencies of the mentioned pollutants from leachate, increased dissolved oxygen (DO) and saving quantity of supplied air in the reactor.

Keywords: Landfill Leachate, Sequencing Batch Reactor, Powdered Activated Carbon, Aeration, Pollutant

1. Introduction

Landfill leachate is a very complex liquid that may contain high concentrations of phenols, ammonia nitrogen (NH_3-N), biodegradable and non-biodegradable organic matter, heavy metals, phosphate, sulfide, hardness, acidity, and alkalinity, among others. When raw leachate is directly disposed to a natural environment, it severely contaminates the surface and groundwater sources. To prevent the contamination of water resources and avoid both severe and continual toxicity, the treatment of the hazardous components of leachate prior to discharge is required by law (Aziz et al., 2010). In literature, to reduce the negative impact of discharged leachate on the environment, several methods of water and wastewater treatment have been used (Aziz et al., 2011a; Bashir et al., 2011; Mohajeri et al., 2011; Bashir et al., 2010).

Because landfill leachate has a high degree of variation in quality and quantity, the sequencing batch reactor (SBR), which has greater process flexibility among biological treatment methods, is therefore well fitted for leachate treatment. The high concentrations of organic matters, low biodegradability ratio, heavy metals, NH_3-N, and other contaminants in leachate clearly affect SBR performance. In the literature, adsorbents were added to activated sludge for the improvement of the biological treatment of landfill leachate (Aziz et al., 2011b; 2011c). To decompose biodegradable organic matter and to nitrify NH_3-N from wastewater/leachate in the SBR process, normally air provides to the reactor. Practically, quantity of supplied air and concentration of dissolved oxygen (DO) inside reactor are the limitations of the SBR process as it increases the treatment cost and affects on SBR performance. Economically, Azimi et al. (2005)

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reported that aeration energy incorporates 50 to 90% of the entire energy consumption and more than 30% of the operational cost.

A gap of knowledge can still be noticed in the extant literature, particularly in the improving removal of unsafe and hazardous pollutants from municipal landfill leachate, increasing DO concentration and saving quantity of supplied air inside reactors using SBR technology. Therefore, the objectives of the current study were to examine the SBR performance in the absence and presence of PAC on the following: 1) the removal of risky contaminants such as phenols, total iron, zinc, NH_3-N, colour, suspended solids, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), and total dissolved salts (TDS) from Kulim landfill leachate, 2) concentration of DO in the reactors, and 3) saving quantity of supplied air inside reactors.

2. Materials and Methods

2.1. Site Characteristics and Leachate Sampling

Raw leachate samples from Kulim landfill site (KLS) were collected throughout May 2009 to June 2010. During such period, 11 samples from KLS were collected. After collection, the samples were immediately transported to the laboratory and stored in a cold room at 4 °C prior to being used for the minimization of biological and chemical reactions (APHA, 2005). KLS is located in the town of Kulim, Kedah, in the northern area of Malaysia, with geographical coordinates of 5°23' N and 100°33' E. The landfill, which has a total area of 56 ha, receives approximately 240 tons of municipal solid wastes daily. This open dumping site began operation in 1996. The characteristics of leachate samples are shown in Table 1. In order to determine the environmental risks of leachate, the achieved parameter values were compared with the Malaysian standard (Environmental Quality, 2009).

Table 1: Leachate characteristics at KLS and PBLS

No.	Parameter	Average value	Standard Discharge limit [a]	No.	Parameter	Average value	Standard Discharge limit [a]
1	Phenols (mg/L)	1.54	0.001	15	Nitrite-N (mg/L NO_2-HR)	54	…
2	Colour (Pt Co)	3029	100	16	Total phosphorus (mg/L $PO4^{-3}$)	32	…
3	E C(m s/cm)	7.66	…	17	Sulfide (mg/L S^{2-})	0.68	0.5
4	TDS (%)	4.17	…	18	T. Hardness (mg/L $CaCO_3$)	1770	…
5	Temperature (^oC)	33.6	40	19	Magnesium (mg/L Mg-$CaCO_3$)	271	…
6	Total solids (mg/L)	4832	…	20	Calcium (mg/L Ca-$CaCO_3$)	1500	…
7	Suspended solids (mg/L)	553	50	21	Chloride (mg/L Cl^{-1})	313	…
8	Acidity (mg/L $CaCO_3$)	1984	…	22	Total iron (mg/L Fe)	3.82	5
9	T. Alkalinity (mg/L $CaCO_3$)	14667	…	23	Zinc (mg/L Zn)	0.33	2
10	BOD_5 (mg/L)	285	20	24	Salinity (g/L)	3.43	…
11	COD (mg/L)	1295	400	25	ORP (mV)	11.3	…
12	BOD_5/COD	0.201	0.05	26	pH	8.02	6 to 9
13	Ammonia-N (mg/L NH_3-N)	562	5	27	Zeta Potential (mV)	-14.9	…
14	Nitrate-N (mg/L NO_3-N)	13.4	…				

[a] Standard B of the Environmental Quality Act-Malaysia (Environmental Quality, 2009)

2.2. Activated Sludge Characteristics

The returned activated sludge used in this study was collected from the Bayan Baru Sewage Treatment Plant in Penang, Malaysia. The mean values for activated sludge characteristics were as follows: total solids of 11540 mg/L, mixed liquor suspended solids (MLSS) of 9893 mg/L, MLVSS/MLSS of 0.84, electrical conductivity (EC) of 2.02 m s/cm, TDS of 1.31%, salinity of 1.03 g/L, oxidation reduction potential (ORP) of –139.6 mV, NH_3-N of 143 mg/L, COD of 4,055 mg/L, pH of 6.75, and zeta potential of –19.1 mV.

2.3. Sludge Acclimatization

The returned activated sludge from the Bayan Baru Sewage Treatment Plant was acclimated in a 2000 mL beaker (working volume of 1200 mL). For this purpose, 90% of activated sludge (1080 mL) was mixed with 10% (120 mL) of collected landfill leachate. After the termination of the reaction and settling processes, 120 mL of supernatant was withdrawn. For the new cycle, an additional 120 mL of raw leachate was added to the reactor. This procedure was repeated for at least 10 days to allow the system to adapt to the new condition. Afterwards, the acclimated sludge was used as seed in the SBRs.

2.4. Operation of the Reactors

This study was conducted using two 2000 mL beakers (working volume of 1200 mL), and mixing ratio of 10% (v/v) was used in the experiments. Thus, the beakers were filled with 1080 mL acclimated sludge and 120 mL of raw landfill leachate from KLS. The experiments, totaling 20, were conducted at room temperature. The sequential operation of the NPAC–SBR and PAC–SBR comprises the fill, react, settle, draw, and idle phases. The time for fill, react, settle, draw, and idle phases in the NPC–SBR was 30, 334, 90, and 26 minutes, respectively, whereas that in PAC-SBR was 30, 330, 90, and 30 minutes, respectively . Consequently, the total cycle time for both SBRs was 8 hours. Air was supplied to the reactors via an air pump (Yasunaga, Air Pump Inc.; air volume: 60 L/min, China). The airflow rate was manually regulated using an airflow meter (Dwyer Flow Meter). The sludge retention time was controlled by the daily manual discharge of a certain amount of mixed liquor from the reactor immediately before the start of the settle phase. Prior to aeration, 1.2 g of PAC (i.e., PAC dosage = 10 g /L) was added to PAC-SBR. PAC was used for adsorbing contaminants in the PAC-SBR. The characteristics of PAC were as follows: BET surface area of 902.04 m^2/g, Langmuir surface area of 1213.85 m^2/g, micropore volume of 0.21 cm^3/g, average pore diameter of 17.51 A, and BJH adsorption average pore diameter (4 v/a) of 44.39 A.

2.5. Analytical Methods

All the tests were performed in accordance with the standard methods for the examination of water and wastewater (APHA, 2005).

3. Results and Discussion

3.1. Leachate Characteristics

Kulim landfill leachate contains high concentration of COD (1295 mg/L) and has high-intensity colour (3029 Pt.Co) due to the presence of high molecular weight organic compounds. The concentration of NH_3–N was also high (562 mg/L). Average BOD_5 of 285 mg /L was recorded, which gave a low biodegradability ratio (BOD_5/COD) of 0.201 as given in Table 1. Moreover, the concentration of phenols, colour, suspended solids, BOD_5, COD, NH_3–N, and sulfide all surpassed the allowable limits set in the Regulations 2009 of the Malaysia Environmental Quality Act 1974 (Environmental Quality, 2009). However, pH, temperature, total iron, and zinc were within the allowable limit. Finally, Kulim landfill leachate considered as low refractory compounds (BOD_5/COD=0.201) and high concentrations of COD and NH_3-N (Foo and Hameed, 2009; Aziz et al., 2010). Based on the characterization of landfill leachates, KLS leachate requires treatment in order to be environmentally accepted.

3.2. Removal of Risky Pollutants

Figure 1 illustrated that the average removal efficiencies of phenols, total iron, zinc, NH_3–N, colour, suspended solids, COD, BOD_5, and TDS parameters inside NPAC-SBR were 25%, 33.33%, 63.48%, 89.40%, 10.2%, –98.08%, –42.90%, 98.5%, and 36.47%, respectively, whereas those inside PAC–SBR were 55%, 83.33%, 65.22%, 89.90%, 65.40%, 13.46%, 27.30%, 99.40%, and 37.32%, respectively. Based on the obtained results, a part of contaminants was removed biologically in NPAC-SBR. Clearly, the presence of PAC (as adsorbent) played a significant role in removing phenols, total iron, zinc, NH_3–N, colour, suspended solids, COD, BOD_5, and TDS from Kulim landfill leachate. The results of the current study agree with the literature (Aktas and Cecen, 2001; Foo and Hameed, 2009; Lim et al., 2010; Aziz et al., 2011c; 2011d).

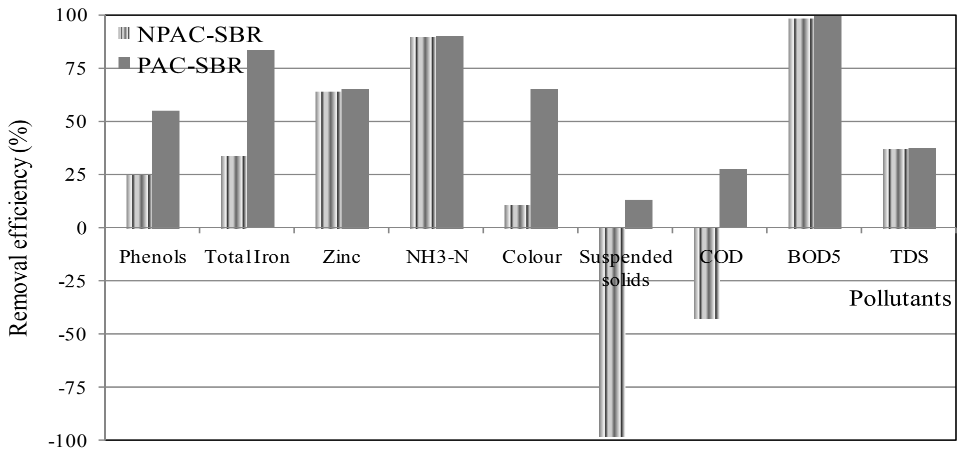

Fig. 1: Removal efficiencies of risky pollutants inside NPAC- and PAC-SBRs

In the current study, low removal efficiencies of COD in NPAC-SBR were due to existence of non-biodegradable organic matters in the landfill leachate (Zouboulisa et al., 2004; Renou et al., 2008). Negative removal efficiencies of COD and suspended solids were obtained in normal SBR. In literature, authors explained that humic acid compounds are resistant to biological treatment and act as non-biodegradable compounds. The present results agree with the literature (Aziz et al., 2011c; 2011d).

3.3. DO Concentration and Quantity of Supplied Air

Figures 2 explained the results of DO variations during treatment process in the reactors. Based on the mentioned Figure, the DO concentration in the PAC–SBR was commonly higher than that in the NPAC-SBR. As an adsorbent, PAC helped decrease the contaminants in the leachates; this was the reason why part of the DO remained in the PAC (compared with NPAC reactor) and DO consumption was less. In the beginning of aeration process, the DO values were high initially followed by a gradual decrease (due to the consumption of biodegradable materials in the reactors). In the end of aeration phase and before settle phase, the DO values increased again due to absence of biodegradable matters.

Compared with react phase in the SBR process, the DO concentration in the beginning (fill phase) and ending (settle, draw, and idle phases) of SBR process generally was less than 1 mg/L; the present result agree with literature (Li et al., 2008). Low DO concentration (<1 mg/L) required to occur denitrification process in SBR technique (Surampalli et al., 1997). DO concentrations of >2 mg/L and < 1 mg/L are essential in SBR process to occur nitrification and denitrification processes, respectively (Surampalli et al., 1997). Based on the obtained DO concentrations, the conditions inside the reactors were appropriate to occur both nitrification and denitrification processes (Surampalli et al., 1997; Rodriguez et al. 2011).

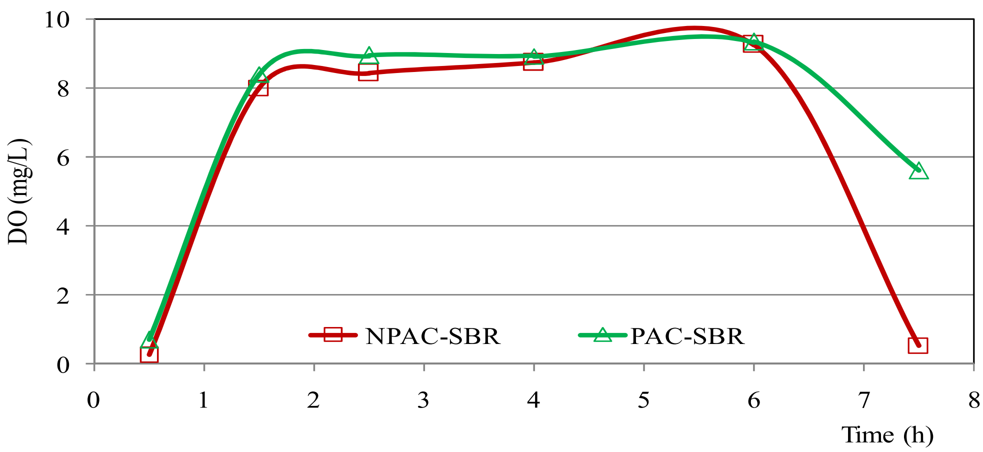

Fig. 2: A sample of DO variation inside the reactors

Table 2 showed that the quantity of supplied air during the SBR process and savings in the quantity of air supplied to the reactors. The amount of air supplied in NPAC- and PAC–SBRs was 668 and 330 L/cycle, respectively. Hence, the air supplied in PAC- SBR was approximately 49.46% (saving quantity of supplied air of 50.54%) of that supplied to NPAC-SBR (Table 2). Azimi et al. (2005) stated that the aeration process brings about 50% to 90% of the entire consumption and more than 30% of the operational cost. From an economic perspective, the addition of PAC in PAC–SBR clearly reduced the amount of air supplied, with savings of more than 50% compared to using traditional SBR processes.

Table 2 : Information about supplied air to the reactors

No.	Type of SBR	Cycle Time (h)	Contact Time (min)	Aeration Rate (L/min)	Quantity of supplied air (L/cycle)	Saving quantity of supplied air (%)
1	NPAC–SBR	8	334	2	668	0.00
2	PAC–SBR	8	330	1	330	50.54

4. Conclusions

The concentration of phenols, colour, suspended solids, BOD_5, COD, NH_3–N, and sulfide all surpassed the allowable limits set by the Malaysian Government. Thus, raw landfill leachate at KLS requires treatment before disposal to the natural environment. The average removal efficiencies of phenols, total iron, zinc, NH_3–N, colour, suspended solids, COD, BOD_5, and TDS parameters inside NPAC–SBR were 25%, 33.33%, 63.48%, 89.40%, 10.2%, –98.08%, –42.90%, 98.5%, and 36.47%, respectively; whereas those inside PAC–SBR were 55%, 83.33%, 65.22%, 89.90%, 65.40%, 13.46%, 27.30%, 99.40%, and 37.32%, respectively. Comparing to NPAC–SBR, quantity of supplied air in PAC–SBR was more than 50%. Finally, PAC as adsorbent improved SBR performance, increased saving quantity of supplied air, and increased DO concentration in side PAC-SBR.

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