Research Journal of

Environmental Toxicology

ISSN 1819-3420

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Toxicology 9 (4): 179-187, 2015
ISSN 1819-3420 / DOI: 10.3923/rjet.2015.179.187

Sulfide, Phenols and Chromium (VI) Removal from Landfill Leachate and Domestic Wastewater by ZELIAC, Zeolite and Activated Carbon Augmented Sequencing Batch Reactor (SBR)

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ABSTRACT

Leachate is created, while water penetrates through the waste in a landfill, carrying some forms of pollutants. Sequencing Batch Reactor (SBR) is one of the biological methods for treating wastewater. The current research studied the removal of sulfide, phenols and hexavalent chromium from landfill leachate and domestic wastewater using Powdered ZELIAC (PZ), Powdered Activated Carbon (PAC) and powdered zeolite (PZE) augmented SBR process. The ZELIAC is a new adsorbent, which consists of zeolite, activated carbon, limestone, rice husk ash and Portland cement. Based on batch experiments and optimization experiments, powdered adsorbents dosage (PZ, PZE and PAC dosages = 3 g L^{-1}), settling time (90 min) and leachate-to-wastewater mixing ratio (20%; v/v) were fixed. The results indicated that the PZ-SBR showed higher performance in removing phenols, sulfide and hexavalent chromium compared with SBR, PZE-SBR and PAC-SBR. And also the PZE-SBR showed higher performance in removing Cr (VI) compared with SBR and PAC-SBR. In the PZ-SBR, the removal efficiencies for phenols, sulfide and Cr (VI) were 67.71, 74.13 and 79.24%, respectively.

Key words: Hexavalent chromium, landfill leachate, wastewater, phenols, sequencing batch reactor, ZELIAC

INTRODUCTION

Sanitary landfill leachate is a highly and complex polluted wastewater. Its quality is the result of biological, chemical and physical processes in landfills combined with the specific waste composition and the landfill water regime (Stegmann *et al*., 2005). Accumulated municipal solid wastes in landfills decompose by a combination of physical, chemical and biological processes (Kiayee, 2013). Landfill leachate could be a main foundation of water contamination (Mojiri *et al*., 2013). Landfill leachate is formed by the percolation of rainwater through domestic refuses. The most serious features of leachate are connected of the high concentrations of some contaminants. Some of these contaminants are metals, sulfide and phenols. Many different methods have been investigated to treat leachate generated from municipal sanitary wastes. Since, leachate contains both biodegradable and non-biodegradable components, the studied methods can be divided into two major groups: biological and physical/chemical treatments (Pouliot, 1999). Sequencing batch reactor is a kind of biological method for wastewater treatment. As it can be seen in the literature, in some researches, adsorbents, such as activated carbon were added to activate sludge and SBR to enhancement of the biological treatment of landfill leachate (Mojiri *et al*., 2014; Aziz *et al*., 2011a, b, 2012; Foo and Hameed, 2009).

The presence of heavy metals in wastewaters has become a serious environmental problem in the last decades. Chromium is a metal used in various industrial processes (e.g. textile dying, tanneries, metallurgy, metal electroplating and wood preserving); therefore, large quantities of chromium have been discharged into the environment, especially in the past (Gheju and Pode, 2010). In wastewater mostly the chromium is found in two forms, one is hexavalent and the other is trivalent, whereas the hexavalent form is more common and hazardous to biological activities (Talokar, 2011). To meet environmental regulations, effluents or heavy metals contaminated water must be treated before discharge. Chemical precipitation, oxidation/reduction, mechanical filtration, ion exchange, membrane separation and carbon adsorption are among the variety of treatment processes widely used for the removal of toxic heavy metals from the waste streams (Boddu *et al.,* 2003).

Another contaminant in the landfill leachate is phenols. Phenol is the priority pollutant since it is toxic and harmful to organisms even at low concentrations (Dakhil, 2013).

Another pollutant is sulfide. The corrosive properties of sulfide are apparent in the damage done to concrete walls of reactors, sewer systems and steel pipelines. It also inhibits the methanogenesis process. Soluble sulfide ranging from 50-100 mg L^{-1} can be tolerated in anaerobic treatment with little or no acclimation. Sulfide has high oxygen demand of 2 mols O_2/mol sulfide and causes depletion of oxygen in water (Midha and Dey, 2008).

A number of studies (Talokar, 2011; Boddu *et al.,* 2003; Aggarwal *et al*., 1999) have verified that using biological methods and adsorbents can remove a large amount of metals from wastewater and landfill leachate and also some studies were conducted for phenol removal by biological technique and using adsorbents (Dakhil, 2013; Hameed and Rahman, 2008; Jadhav and Vanjara, 2004; Roostaei and Tezel, 2004; Molva, 2004).

This research evaluates the performance of Sequencing Batch Reactor (SBR) with Powdered ZELIAC (PZ), powdered zeolite (PZE) and Powdered Activated Carbon (PAC) in removing phenols, sulfide and chromium from Sungai Petani landfill leachate and domestic wastewater from Bayan Baru Wastewater Treatment Plant in Malaysia. In addition, this research has introduced a novel inexpensive adsorbent, i.e., ZELIAC.

MATERIALS AND METHODS

Landfill leachate sampling: Leachate samples were collected from the Sungai Petani landfill site from June, 2012 to March, 2013. The landfill site (geographical coordinates, 05°43 N and 100°29 E) is located in Kedah, Malaysia. Sungai Petani landfill receives nearly 350-400 t of solid wastes daily, measured using a weight bridge. This open dumping site has been actively used since, 1990. The total landfill area of Sungai Petani is 11.24 ha (Mojiri *et al*., 2014). Samples were immediately transferred to the laboratory after collection and maintained in a cold room at 4°C to minimize the biological and chemical reactions (Aziz *et al*., 2011b). Table 1 shows the characteristics of the samples. To determine the risks of leachates to the environment, the obtained parameter values were compared with the 2009 Regulations of the Malaysia Environmental Quality Act of 1974 (Environmental Quality Council, 2009).

Table 1: Characteristics of landfill leachate, domestic wastewater and sludge

Parameters	Leachate	Wastewater	Standard discharge limit for leachate[a]
Temperature (°C)	28.5	27.9	40
pH	7.65	6.91	6-9
EC (ms cm^{-1})	3.73	1.13	-
Colour (Pt. Co)	1261	6.00	100
BOD_5 (mg L^{-1})	269.0	64.2	20
COD (mg L^{-1})	726	116	400
Nitrite (mg L^{-1} NO_2-N-HR)	50.18	9.26	-
NH_3-N (mg L^{-1})	417.0	149.0	5.00
Sulfide (mg L^{-1})	0.300	0.600	0.50
Total iron (mg L^{-1})	7.23	2.65	5.00
Total manganese (mg L^{-1})	1.18	0.65	0.20
Total nickel (mg L^{-1})	5.44	0.31	0.20
Chromium VI (mg L^{-1})	0.21	0.17	0.20
Phenols (mg L^{-1})	1.84	0.10	0.001

[a]Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009, under the laws of Malaysia-Malaysia Environmental Quality Act 1974

Domestic wastewater and activated sludge sampling: The activated sludge and domestic wastewater were collected from the Bayan Baru wastewater treatment plant in Penang, Malaysia. Table 1 shows the characteristics of the activated sludge and wastewater.

Reactor characteristics: Six beakers of 2000 mL each were used throughout the study. Each beaker had a working volume of 1200 mL, an inner diameter of 113 mm and a height of 200 mm. A magnetic stirrer placed at the bottom of the reactors was used to mix the media. The experiments were carried out at room temperature and an air pump (YASUNAGA, Air pump Inc.; voltage: 240 V, frequency: 50 Hz, input power: 61 W, model: LP-60A, pressure: 0.012 MPa, air volume: 60 L min^{-1}; Serial no.: 08110014, made in China) was used to provide the reactors with air. The air flow speed was manually regulated using an air flow meter (Dwyer Flow meter, Model: RMA-26-SSV).

Sludge acclimatization: According to the study of Aziz *et al*. (2011b), 120 mL (10%) of the collected landfill leachate was mixed with approximately 1080 mL of the activated sludge (90%). After the termination of the reaction and the settling phases, 120 mL of the supernatant was withdrawn. In another cycle, an additional 120 mL of the raw leachate was added to the reactor. This procedure was sustained for at least 10 day to allow the system to adapt to the experimental condition. The adjusted sludge was later used as seed in the SBRs.

ZELIAC preparation: To prepare the ZELIAC, zeolite, activated carbon, limestone, rice husk ash and Portland cement were ground, passed through a 300 μm mesh sieve and then mixed. The mixture was then evenly poured in the mold after the addition of water. After 24 h, the materials were removed from the mold and soaked in water for three days for the curing process. After allowing the materials to dry within two days, they were crushed and passed through a sieve. The features of the powdered ZELIAC with the autosorb (Quantachrome AS1wintm, version 2.02) test. The result of the XRF analysis of ZELIAC is shown in Table 2. The Zeolite and activated carbon are present in the ZELIAC; thus ZELIAC can act as both adsorbent and ion exchanger. In this study, Powdered ZELIAC (PZ) with a size ranging from 75-150 μm was used as adsorbent in the PZ-SBR (Aziz *et al*., 2011a).

Characteristics of zeolite and activated carbon: Characteristics of powdered zeolite and powdered activated carbon with the autosorb (Quantachrome AS1wintm, version 2.02) test have

Table 2: XRF results for ZELIAC

Compounds/elements	Composition (%)
C	14.350
CaO	32.401
SiO_2	42.002
Al_2O_3	7.300
Fe_2O_3	1.502
K_2O	1.005
MgO	1.000
Na_2O	0.100
P_2O_5	0.030
SO_3	0.030
Others	0.280

Table 3: Powdered ZELIAC, Zeolite and activated carbon characteristics

	Values		
Parameters	PZ	PAC	PZE
Surface area data			
MultiPoint BET ($m^2\ g^{-1}$)	6.760e+01	5.857e+02	4.936e+01
Langmuir surface area ($m^2\ g^{-1}$)	1.328e+02	9.607e+02	9.480e+01
BJH method cumulative adsorption surface area ($m^2\ g^{-1}$)	9.638e+00	1.832e+01	6.404e+00
DH method cumulative adsorption surface area ($m^2\ g^{-1}$)	1.019e+01	1.938e+01	6.770e+00
t-method external surface area ($m^2\ g^{-1}$)	3.421e+01	8.681e+01	2.420e+01
t-method micropore surface area ($m^2\ g^{-1}$)	3.338e+01	4.989e+02	2.517e+01
DR method micropore area ($m^2\ g^{-1}$)	1.153e+02	9.303e+02	8.305e+01
Pore volume data			
Total pore volume for pores with diameter less than 4.06 nm at P/P0 = 0.501894 (cc g^{-1})	4.029e-02	3.283e-01	2.897e-02
BJH method cumulative adsorption pore volume (cc g^{-1})	9.930e-03	1.887e-02	6.639e-02
DH method cumulative adsorption pore volume (cc g^{-1})	1.011e-02	1.921e-02	6.756e-02
t-method micropore volume (cc g^{-1})	1.803e-02	2.714e-01	1.323e-02
DR method micropore volume (cc g^{-1})	4.098e-02	3.306e-01	2.952e-02
HK method cumulative pore volume (cc g^{-1})	3.172e-02	3.051e-01	2.285e-02
SF method cumulative pore volume (cc g^{-1})	3.222e-02	3.071e-01	2.328e-02
Pore size data			
Average pore diameter (nm)	2.384e+00	2.242e+00	2.348+00
BJH method adsorption pore diameter (Mode DV(d)) (nm)	3.652e+00	3.374e+00	3.666+00
DH method adsorption pore diameter (Mode Dv9d)) (nm)	3652e+00	3.374e+00	3.666e+00
DA method pore diameter (Mode) (nm)	1.760e+00	1.180e+00	1.740e+00
HK method pore diameter (Mode) (nm)	3.675e-01	3.675e+01	3.675e-01
SF method pore diameter (Mode) (nm)	4.532e-01	4.532e+01	4.523e-01

been shown by Table 3. In this study, powdered zeolite (PZE) and Powdered Activated Carbon (PAC) with a size ranging from 75-150 μm were used as adsorbent in the PZE-SBR and PAC-SBR, respectively (Aziz *et al*., 2011a).

The aluminosilicate molecular structure with weak cationic bonding sites of zeolite is shown by Fig. 1. This structure is useful for ion exchange. Activated carbon is generally applied to adsorb natural organic compounds, taste and odor compounds and synthetic organic chemicals in drinking water treatment (Dvorak, 2013; Lin *et al*., 2010). Figure 1 shows the SEM image from surface of powdered activated carbon. This figure shows the pores on the surface of activated carbon.

Operation reactors: The SBR consists of five steps, namely, load, react, settle, idle and draw. In all experiments, the loading (20 min), blending (20 min), settling (90 min), idle (10 min) and drawing (10 min) periods were present. Table 4 shows the operation parameters in SBR, PZ-SBR, PZE-SBR and PAC-SBR. The beakers were loaded with 120 mL (10%) of acclimated sludge and 1080 mL (90%) of household wastewater and Sungai Petani landfill leachate. The primary features of activated sludge, wastewater and leachate are shown in Table 1.

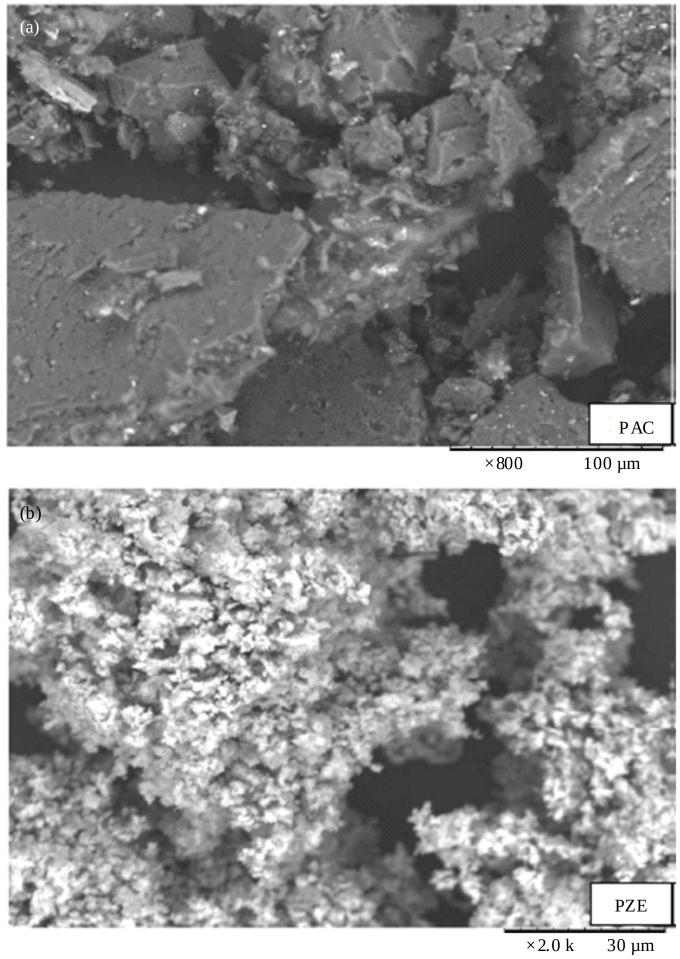

Fig. 1(a-b): SEM images from surface of activated carbon and zeolite, (a) PAC and (b) PZE

Table 4: Operation parameters in repeated experiments

	Values			
Parameters	Normal-SBR	PZ-SBR	PAC-SBR	PZE-SBR
Settling time (min)	90	90	90	90
Adsorbent dosage (g L^{-1})	-	3	3	3
Contact time (min)	760 (12.68 h)	699 (11.65 h)	769 (12.82 h)	756 (12.60 h)
Aeration rate (L min^{-1})	4.32	2.41	3.07	1.82
Leachate/wastewater ratio (v/v, %)	20	20	20	20
Cycle time (min)	930 (15.5 h)	930 (15.5 h)	930 (15.5 h)	930 (15.5 h)
OLR (kg m^{-3} day)	1.00	1.00	1.00	1.00
HRT (day)	0.72	0.72	0.72	0.72
MLSS (mg L^{-1})	1510	7613	6516	6105
F/M	0.25	0.05	0.06	0.06

The reactors were separated into four groups. Six reactors were used for SBR, six reactors were used for PZ-SBR, six reactors were used for PZE-SBR and six reactors were used for PAC-SBR. Based on preliminary experiments, 3.24 g of PZ, PZE and PAC (specifically, PZ, PZE and PAC dosages = 3 g L^{-1}) were added to each PZ-SBR, PZE-SBR and PAC-SBR prior to aeration. The removal effectiveness of sulfide, phenols and chromium was experimentally verified by evaluating objective factors before and after treatment. The following Eq. 1 was used to measure removal effectiveness:

$$\text{Removal}(\%) = \frac{\text{Ci} - \text{Cf}}{\text{Ci}} \times 100 \quad (1)$$

where, Ci and Cf are the first and last concentrations of the factors, respectively.

Analytical methods: All experiments were performed in compliance with the Standard Methods for the Examination of Water and Wastewater (APHA., 2005). YSI 556 MPS (YSI incorporated, USA) was used to record the rates of pH, temperature (°) and electrical conductivity (ms cm^{-1}). A spectrophotometer (DR/2800 HACH) was used to evaluate phenols (mg L^{-1}), sulfide (mg L^{-1} S^{2-}), nitrite (mg L^{-1}), color (Pt. Co), Chemical Oxygen Demand (COD) (mg L^{-1}), total nitrogen (mg L^{-1}), total iron (mg L^{-1} Fe), manganese (mg L^{-1} Mn), chromium (mg L^{-1} Cr) and nickel (mg L^{-1} Ni).

RESULTS AND DISCUSSION

As Table 1 shows, Sungai Petani leachate contained high-intensity Cr (0.21 mg L^{-1}) and high concentration of phenols (1.84 mg L^{-1}) compared with Malaysian standard (Environmental Quality Council, 2009). Also the concentration of sulfide was 0.300. In this study, phenols, sulfide and Cr (VI) removal from landfill leachate and domestic wastewater using the PZ, PAC and PZE supplemented SBR process to decrease the environmental risks have been investigated. Table 5 is shown the Cr, phenols and sulfide removal efficiency by SBRs.

Phenols removal: Landfill leachate contains a large number of dangerous compounds, such as aromatics, halogenated compounds, heavy metals, phenols, pesticides and ammonium, which are considered dangerous even in small amounts. The harmful effects of these compounds are often caused by multiple and synergistic effects. Phenolic compounds released into the environment are particularly of high concern because of their potential toxicity. Kurata *et al*. (2008) measured 41 kinds of phenols in three landfill sites in Japan. The results achieved in the present study agree well with the literature (Aziz *et al*., 2012; Kurata *et al*., 2008). In this study, the 4-aminoantipyrine method was used to measure phenols and determine all ortho-substituted and meta-substituted phenols or naphthols, but not the para-substituted phenols.

Based on the Table 5 and Fig. 2, the phenols removal was 32.56, 67.71, 45.29 and 33.31% in Normal-SBR, PZ-SBR, PAC-SBR and PZE-SBR, respectively. The PZ-SBR is more efficiency in phenols removal. Hameed and Rahman (2008) removed phenols from aqueous solutions by activated carbon. Aziz *et al.* (2012) removed 55% of phenols from landfill leachate by activated carbon augmented SBR process.

Table 5: Removal efficiency of color, COD, ammonia, phenols and sulfide

	Removal efficiency (%)			Removed concentration (mg L^{-1})		
Types	Phenols	Sulfide	Cr (VI)	Phenols	Sulfide	Cr (VI)
Normal-SBR	32.56	39.28	38.15	0.60	0.117	0.080
PZ-SBR	67.71	74.13	79.24	1.24	0.222	0.166
PAC-SBR	45.29	61.32	55.24	0.83	0.183	0.116
PZE-SBR	43.31	56.39	66.37	0.80	0.169	0.139

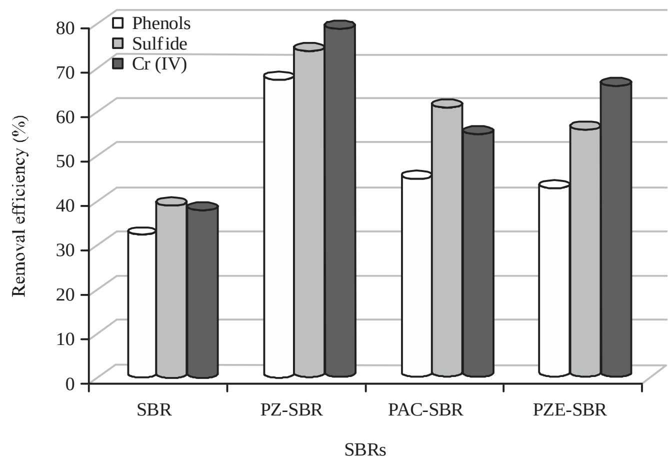

Fig. 2: Removal efficiencies by each reactor

Sulfide removal: High sulfate concentrations are common in wastewaters generated from paper and pulp industries, molasses based fermentation industries, edible oil refineries and in acidic leachates of pyretic waste rock and tailings (Rao *et al*., 2003).

Based on the Table 5, the sulfide removal was 39.28, 74.13, 61.32 and 56.39% in Normal-SBR, PZ-SBR, PAC-SBR and PZE-SBR, respectively. The PZ-SBR is more efficiency in sulfide removal. It is so clear that PZ has a good performance to remove sulfide in comparing with SBR, PAC-SBR and PZE-SBR.

Chaung *et al*. (2014) and Sattler and Rosenberk (2006) studied sulfide removal from wastewater by adsorption method.

Chromium removal: Chromium (Cr) is an environmental pollutant element and ranks seventh in abundance in the earth crust. The major contributors of Cr contamination are the leather tanning, electroplating and stainless steel industries (Karimi, 2013). Hexavalent chromium is known to be toxic to humans, animals, plants and microorganisms. Because of its significant mobility in the subsurface environment, the potential risk of groundwater contamination is high (Gheju and Pode, 2010). Based on the Table 5 and Fig. 2, the Cr (VI) removal was 38.15, 79.24, 55.24 and 66.37% in Normal-SBR, PZ-SBR, PAC-SBR and PZE-SBR, respectively. The PZ-SBR is more efficiency in Cr removal.

Talokar (2011) studied chromium removal from wastewater by adsorption using low cost materials such as powdered activated carbon. Aggarwal *et al*. (1999) removed Cr (VI) from aqueous solution by granular activated carbon.

CONCLUSION

Cr (VI), phenols and sulfide from Sungai Petani landfill leachate and domestic wastewater were eliminated by performing PZ, PAC and PZE-supplemented SBR. The reactors were separated into four groups, six reactors were used for SBR (normal SBR), six reactors were used for PZ-SBR (powdered ZELIAC-supplemented SBR), six reactors were used for PAC-SBR (powdered activated carbon-supplemented SBR) and six reactors were used for PZE-SBR (powdered Zeolite-supplemented SBR). Based on batch experiments and optimization experiments, powdered adsorbents dosage (PZ, PZE and PAC dosages = 3 g L^{-1}), settling time (90 min) and leachate to wastewater mixing ratio (20%; v/v), were fixed. The main conclusions of this study are presented below:

- SBR was able to remove 32.56, 39.28 and 38.15% of phenols, sulfide and Cr (VI), respectively
- PZ-SBR removed 67.71, 74.13 and 79.24% of phenols, sulfide and Cr (VI), respectively
- PAC-SBR was able to remove 45.29, 61.32 and 55.24% of phenols, sulfide and Cr (VI), respectively
- PZE-SBR was able to remove 43.31, 56.39 and 66.37% of phenols, sulfide and Cr (VI), respectively
- This result indicates that PZ-SBR can treat phenols, sulfide and Cr (VI) of leachate more efficiently than SBR, PAC-SBR and PZE-SBR

REFERENCES

APHA., 2005. Standard Methods for the Examination of Water and Wastewater. 21st Edn., American Public Health Association, Washington, DC., USA., ISBN-13: 978-0875530475, Pages: 1200.

Aggarwal, D., M. Goyal and R.C. Bansal, 1999. Adsorption of chromium by activated carbon from aqueous solution. Carbon, 37: 1989-1997.

Aziz, S.Q., H.A. Aziz and M.S. Yusoff, 2011a. Powdered activated carbon augmented double react-settle sequencing batch reactor process for treatment of landfill leachate. Desalination, 277: 313-320.

Aziz, S.Q., H.A. Aziz, M.S. Yusoff and M.J.K. Bashir, 2011b. Landfill leachate treatment using powdered activated carbon augmented Sequencing Batch Reactor (SBR) process: optimization by response surface methodology. J. Hazard. Mater., 189: 404-413.

Aziz, S.Q., H.A. Aziz, M.S. Yusoff and S. Mohajeri, 2012. Removal of phenols and other pollutants from different landfill leachates using powdered activated carbon supplemented SBR technology. Environ. Monit. Assess., 184: 6147-6158.

Boddu, V.M., K. Abburi, I.L. Talbott and E.D. Smith, 2003. Removal of hexavalent chromium from wastewater using a new composite chitosan biosorbent. Environ. Sci. Technol., 37: 4449-4456.

Chaung, S.H., P.F. Wu, Y.L. Kao, W. Yan and H.L. Lien, 2014. Nanoscale zero-valent iron for sulfide removal from digested piggery wastewater. J. Nanomater. 10.1155/2014/518242

Dakhil, I.H., 2013. Removal of phenol from industrial wastewater using sawdust. Res. Inventy: Int. J. Eng. Sci., 3: 25-31.

Dvorak, B.I., 2013. Drinking water treatment: Activated carbon filtration. G1489, University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources, November 2013.

Environmental Quality Council, 2009. Environmental quality (control of pollution from solid waste transfer station and landfill) regulations, 2009. Malaysia-Environmental Quality Act 1974, Laws of Malaysia, December 10, 2009.

Foo, K.Y. and B.H. Hameed, 2009. An overview of landfill leachate treatment via activated carbon adsorption process. J. Hazard. Mater., 171: 54-60.

Gheju, M. and R. Pode, 2010. Removal of hexavalent chromium from wastewater by use of scrap iron. World Acad. Sci. Eng. Technol., 42: 982-987.

Hameed, B.H. and A.A. Rahman, 2008. Removal of phenol from aqueous solutions by adsorption onto activated carbon prepared from biomass material. J. Hazard. Mater., 160: 576-581.

Jadhav, D.N. and A.K. Vanjara, 2004. Removal of phenol from wastewater using sawdust, polymerized sawdust and sawdust carbon. Indian J. Chem. Technol., 11: 35-41.

Karimi, N., 2013. Comparative phytoremediation of chromium-contaminated soils by alfalfa (*Medicago sativa*) and *Sorghum bicolor* (L) Moench. Int. J. Scient. Res. Environ. Sci., 1: 44-49.

Kiayee, S.B., 2013. Impact of municipal waste leachate application on soil properties and accumulation of heavy metals in wheat (*Triticum aestivum* L). Int. J. Scient. Res. Environ. Sci., 1: 1-6.

Kurata, Y., Y. Ono and Y. Ono, 2008. Occurrence of phenols in leachates from municipal solid waste landfill sites in Japan. J. Mater. Cycles Waste Manage., 10: 144-152.

Lin, T., W. Chen and L. Wang, 2010. Particle properties in granular activated carbon filter during drinking water treatment. J. Environ. Sci., 22: 681-688.

Midha, V. and A. Dey, 2008. Biological treatment of tannery wastewater for sulfide removal. Int. J. Chem. Sci., 6: 472-486.

Mojiri, A., H.A. Aziz and S.Q. Aziz, 2013. Trends in physical-chemical methods for landfill leachate treatment. Int. J. Scient. Res. Environ. Sci., 1: 16-25.

Mojiri, A., H.A. Aziz, N.Q. Zaman, S.Q. Aziz and M.A. Zahed, 2014. Powdered ZELIAC augmented Sequencing Batch Reactors (SBR) process for co-treatment of landfill leachate and domestic wastewater. J. Environ. Manage., 139: 1-14.

Molva, M., 2004. Removal of phenol from industrial wastewaters using lignitic coals. M.Sc. Thesis, Department of Environmental Engineering, Izmir Institute of Technology, Turkey.

Pouliot, J.M., 1999. Biological treatment of landfill leachate. M.Sc. Thesis, Faculty of Graduate Studies, The University of Western Ontario, Ontario, Canada.

Rao, A.G., K.K. Prasad, G.V. Naidu, N.C. Rao and P.N. Sarma, 2003. Removal of sulfide in integrated anaerobic-aerobic wastewater treatment system. Clean Technol. Environ. Policy, 6: 66-72.

Roostaei, N. and F.H. Tezel, 2004. Removal of phenol from aqueous solutions by adsorption. J. Environ. Manage., 70: 157-164.

Sattler, M.L. and R.S. Rosenberk, 2006. Removal of carbonyl sulfide using activated carbon adsorption. J. Air Waste Manage. Assoc., 56: 219-224.

Stegmann, R., K.U. Heyer and R. Cossu, 2005. Leachate treatment. Proceedings of the 10th International Waste Management and Landfill Symposium, October 3-7, 2005, Cagliari, Italy.

Talokar, A.Y., 2011. Studies on removal of chromium from waste water by adsorption using low cost agricultural biomass as adsorbents. Int. J. Adv. Biotechnol. Res., 2: 452-456.