THE PERFORMANCE OF SILICA SAND FOR LEACHATE TREATMENT

by

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KEUPAYAAN PASIR SILIKA UNTUK MENGOLAH LARUT LESAP

ABSTRAK

Kebanyakan olahan larut lesapan yang biasa adalah dengan menggunakan kaedah yang biasa digunakan dengan karbon teraktif dan zeolit disebabkan dengan ciri-ciri bagusnya luas permukaan, tinggi kapasiti penjerapan, mikro poros kapasiti dan keistimewaan reaktiviti. Walaubagaimanapun, di dalam kajian ini, pasir silika dipilih sebagai media penjerap untuk mengolah larut lesapan disebabkan kesenangan untuk didapati dan kos yang tidak terlalu tinggi. Keupayaan pasir silika sebagai penjerapan media dilakukan dengan melihat keupayaannya untuk menyingkirkan COD, warna, nitrogen ammonia, iron dan zink daripada larut lesapan. Di dalam ujikaji kelompok, kelajuan aruhan optima, pemendapan optima dan kadar media optima yang didapati adalah 90 minit, 60 minit dan 80 g. Peratusan penyingkiran untuk COD adalah yang tertinggi iaitu 52.83% di dalam kajian pengaruh kelajuan aruhan, 55.82% di dalam pengaruh pemendapan dan 67.92% di dalam pengaruh kadar media yang digunakan. Di dalam penjerapan data oleh Freundlich Isotherm, nilai R^2 adalah lebih tinggi daripada Langmuir Isotherm. Masa sentuhan hamparan kosong (EBCT) yang didapati daripada kajian ialah 15.5 minit. Kajian juga mendapati rekabentuk loji penyingkiran dengan keluasan 1 m^2 dan tinggi 1.5 m adalah berkesan untuk menyingkirkan iron dengan kadar aliran $50m^3/d$ dalam masa 23 bulan.

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ABSTRACT

More than a few study of leachate treatment have been done by conventional method such as by using activated carbon and zeolite due to their great surface area, high adsorption capacity, micro porous structure and special reactivity. However in this study, silica sand is chose as an adsorption media to treat leachate because of the availability, easily to be found and low cost media. The performance of silica as adsorption media is conducted by look at the potential of it to remove COD, colour, ammoniacal nitrogen, iron and zinc from landfill leachate. In batch study, optimum shaking, settling and adsorbent dosage were 90 minutes, 60 minutes and 80g. The percentage removal for COD is highest where it gets 52.83% in the effect of shaking time, 55.82% in the effect of settling time and 67.92% in the effect of adsorbent dosage. The equilibrium adsorption data followed the Freundlich Isotherm which indicate by most R^2 value is higher than Langmuir Isotherm. The Empty Bed Contact Time (EBCT) found from the study is 15.5 minutes. The study showed that the design of removal plant by $1m^2$ and 1.5 m depth is effective to remove iron at a flow rate of $50m^3/d$ in duration of 23 months.

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Abstract
More than a few study of leachate treatment have been done by conventional method such as by using activated carbon and zeolite due to their great surface area, high adsorption capacity, micro porous structure and special reactivity. However in this study, silica sand is chose as an adsorption media to treat leachate because of the availability and easily to be found. The performance of silica as adsorption media is conducted by look at the potential of it to remove COD, colour, ammoniacal nitrogen, iron and zinc from landfill leachate. In batch study, optimum shaking, settling and adsorbent dosage were 90 minutes, 60 minutes and 80g. The percentage removal for COD is highest where it gets 52.83% in the effect of shaking time, 55.82% in the effect of settling time and 67.92% in the effect of adsorbent dosage. The equilibrium adsorption data followed the Freundlich Isotherm which indicate by most R^2 value is higher than Langmuir Isotherm. The Empty Bed Contact Time (EBCT) found from the study is 15.5 minutes. The study showed that the design of removal plant by $1m^2$ and 1.5 m depth is effective to remove iron at a flow rate of $50m^3/d$ in duration of 23 months.

1. Introduction

Leachate from landfill is considered as a major pollution when enters rivers and groundwater to cause damage afterwards (Enviros, 2008). Solid wastes that are the source of leachate is said to have negative value and become high problem when the population keeps increasing (Tchobanoglous G. et al, 1993). There is a combination of physical, chemical and microbial processes in the waste that transfer pollutants from the waste material to leachate (Kjeldsen P. et al, 2002).

In this study a research by using silica sand is conducted in order to look at the potential of it to treat leachate. It has a valued for combination of physical and chemical properties (British Geological Survey, 2006). Silica sand deposits, commonly quartz are generally content with 95% silica and impurities may present up to 25%. It has been used for many purposes over many years such as in the manufacturing of glass and ceramics, foundry castings, abrasives, sandblasting material, hydraulic fracture to increase the rock permeability in order to increase oil and gas recovery, production of silicon and as a media for the treatment of water.

The aim of this study is to determine the quality of leachate effluent by testing the parameter such as COD, ammoniacal nitrogen, heavy metals and colour. It also needs to find the effectiveness by using silica sand as filter media and find the perfect adsorption isotherm in order to remove contaminants from leachate. This study can be used to set up the design removal plant that will be beneficial for future used.

2. Materials & Methods

2.1 Materials

Silica sand used in this experiment was taken from ex-mining site in Serdang, Kedah. The raw silica sand was washed many times to remove the impurities, roots, leaves and soils and air dried under sunlight. Then it was sieved to get the size of 0.6 to 1.18 mm particle size. After get the dried silica, the properties of silica sand such as surface area, chemical composition and porosity was found. Before any experiment was done, the sand is activated by using sulfuric acid (H_2SO_4).

Leachate is taken from Pulau Burung Sanitary Landfill (Phase 1) pond by using 10L Teflon bottle. After taking samples, leachate is brought to the USM Environmental Laboratory to preserve in a cold room under temperature 4˚C. The samples were analyzed for pH, COD, colour, ammoniacal nitrogen, iron and zinc.

COD, colour, ammoniacal nitrogen, iron and zinc are analyzed by using DR/2500 Hach Spectrophotometer. It was adapted from Standard Methods for the Examination of Water and Wastewater and approved by USEPA while pH was analyzed by using pH meter.

2.2 Methods

The optimum condition of adsorption in order to find the maximum removal of COD, colour, ammoniacal nitrogen, iron and zinc were determined through series of batch experiments. It was conducted by shaking the leachate with the media in 250 ml conical flask using an orbital shaker at 350 rpm shaking speed. The percentage removal can be found from this equation:

$$\text{Removal (\%)} = \frac{C_0 - C_e}{C_0} \times 100$$

Where,

C_0 = initial leachate concentration (mg/L)
C_e = quality of leachate after treatment (mg/L)

Column study was done to find the Empty Bed Contact Time (EBCT) of a media in a column. By using depth of 50 cm and diameter of 1.2 cm the volume of the column can be found. The EBCT can be found from this equation:

$$EBCT = V/Q$$

Where,

V = volume of column bed (m^3)
Q = flow rate (m^3/s)

3. Results & Discussion

3.1 Quality of Raw Leachate

Table 1: Quality of Raw Leachate

Parameter	Minimum	Maximum	Average[a]	Standard B[b]
pH	8.2	8.31	8.26	5.5 – 9.0
COD (mg/L)	3027	3333	3180	100
Colour (Platinum unit, Pt-Co)	2800	3066	2933	-
Ammoniacal Nitrogen (mg/L)	2010	2090	2050	-
Iron (mg/L)	3.5	7.2	5.35	5.0
Zinc (mg/L)	2.3	4.6	3.45	2.0

From table 1, the higher value of contaminant is COD (3027 – 3333 mg/L) indicate high amount of organic compounds. The higher level of colour usually has the same level of COD in landfill because it has an association with the removal of organic matter. The high amount of Ammoniacal Nitrogen shows leachate is much polluted water. The risk from landfill leachate is due to its high organic contaminant concentrations and high ammoniacal nitrogen.

3.2 Batch Studies

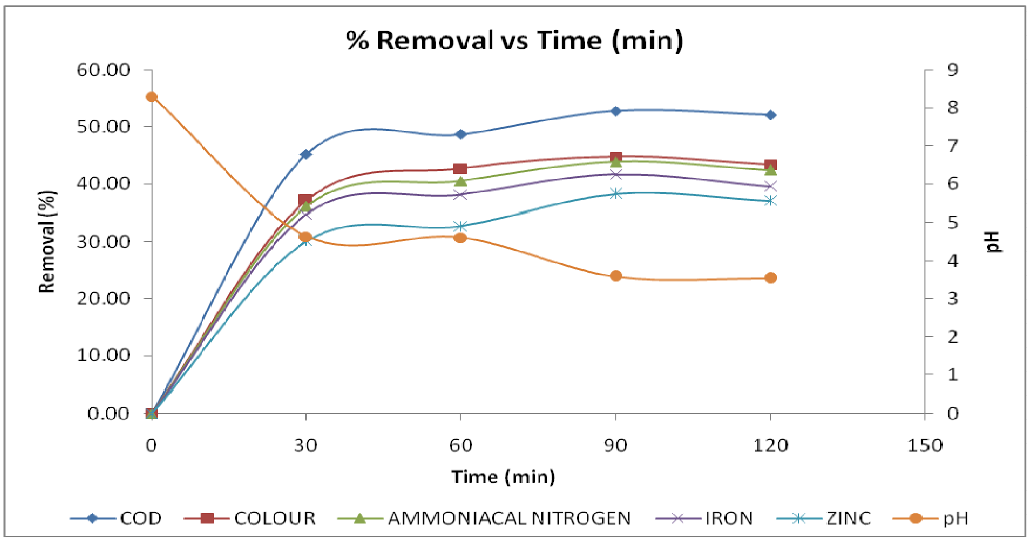

Fig. 1: Effect of Shaking Time

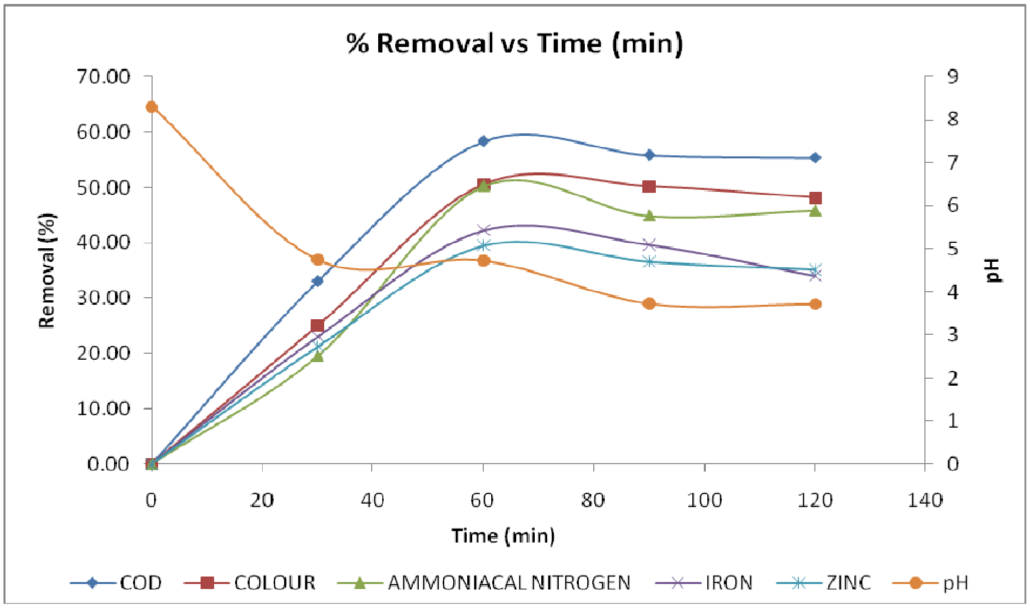

Fig 2: Effect of Settling Time

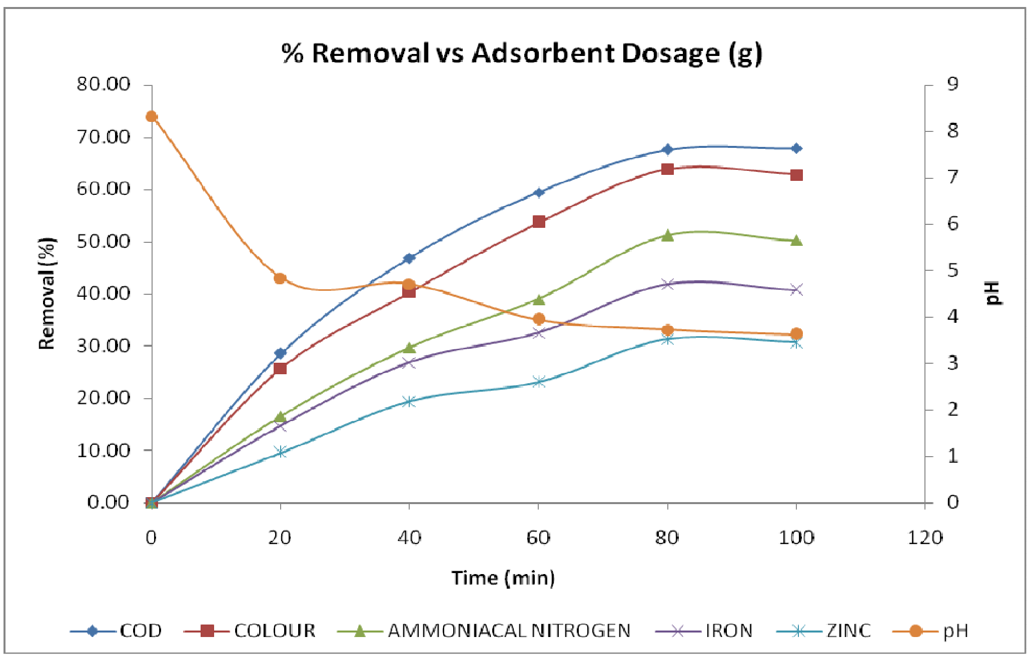

Fig 3: Effect of Adsorbent Dosage

Figure (1), (2) & (3) shows the influence of shaking time for removal of COD, colour, ammoniacal nitrogen, iron and zinc. pH value before and after every test is taken. From the graph a shaking time of 90 minutes is taking as an optimum shaking time in this study. The graph shows the said parameters increased until 60 minutes settling time which determine the optimum settling time in this study. From this analysis too, the optimum dosage for COD, colour, ammoniacal nitrogen, iron and zinc is 80g.

3.3 Freundlich Isotherm

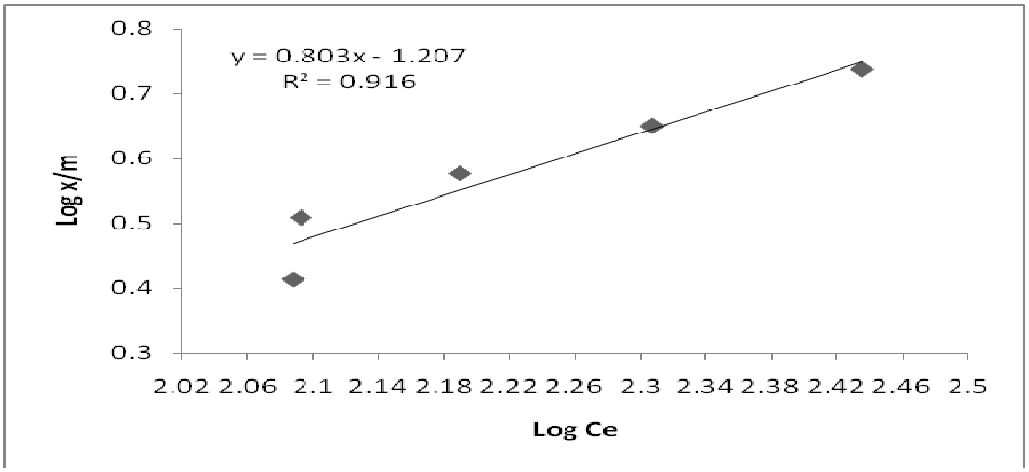

Fig. 4: COD

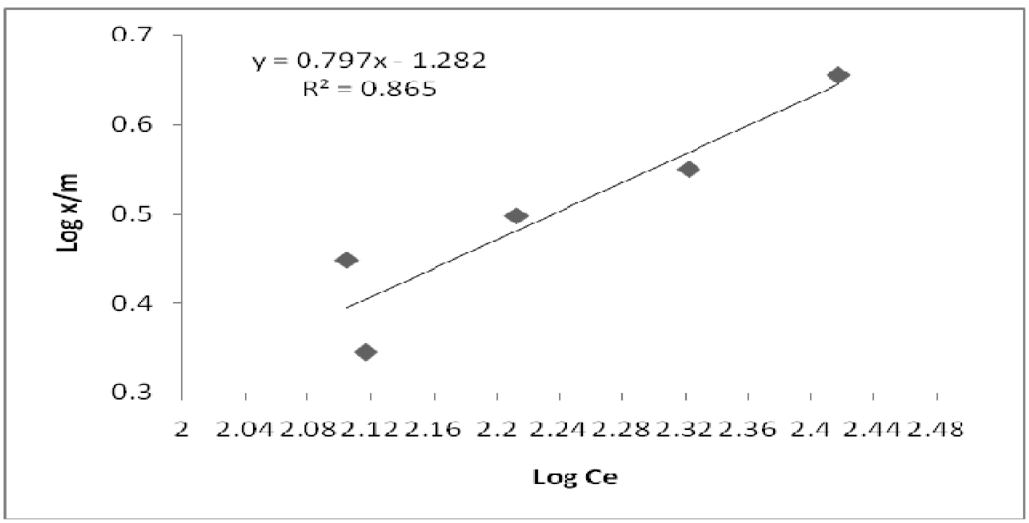

Fig. 5: Colour

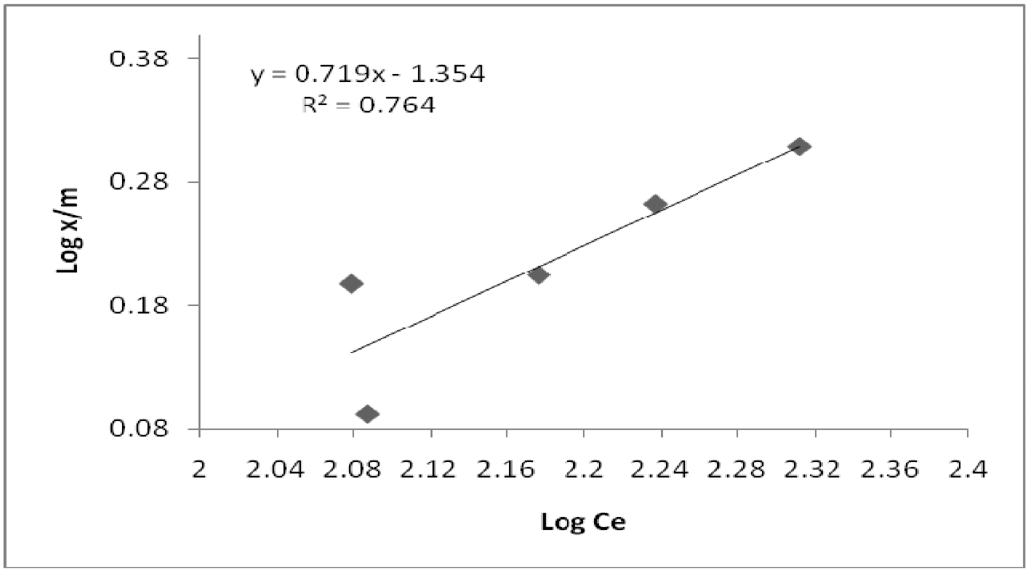

Fig. 6: Ammoniacal Nitrogen

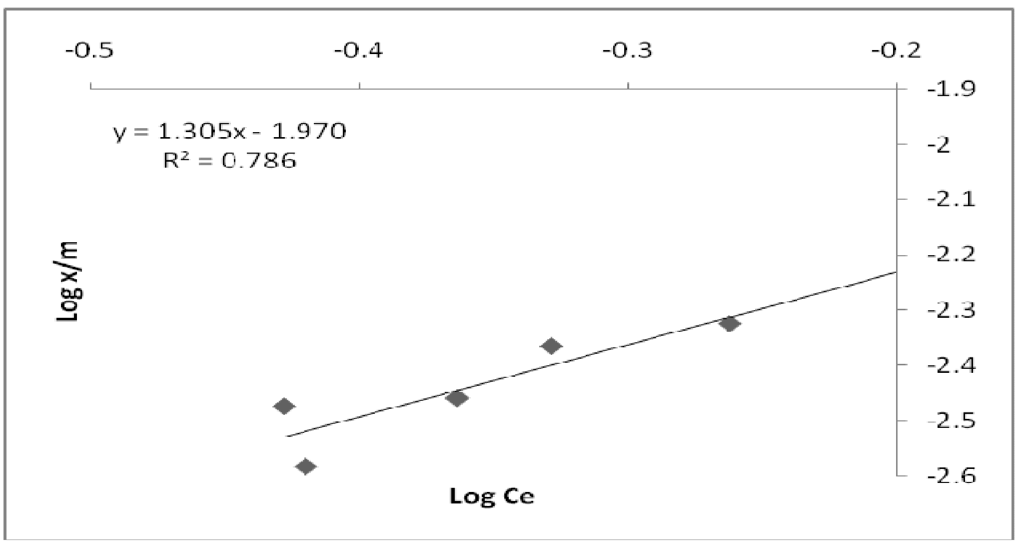

Fig. 7: Iron

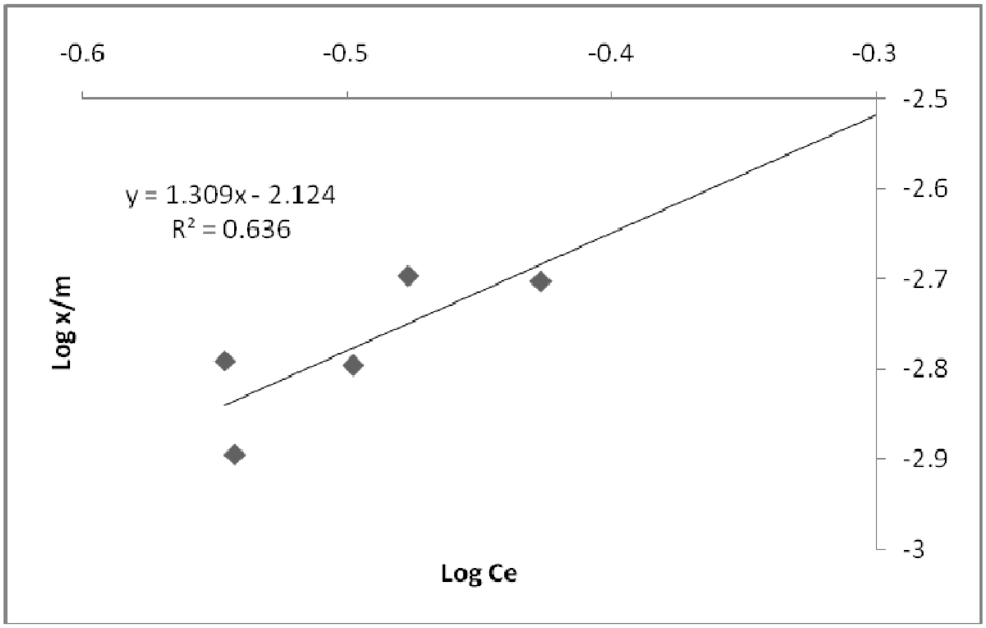

Fig. 8: Zinc

Table 2: List of adsorption constant for different solutes using Freundlich Isotherm

Parameters	Freundlich isotherm coefficients			Freundlich equations
	K	1/n	R^2	
COD	0.06290	0.803	0.916	$x/m = 0.0629C_e^{0.803}$
Colour	0.05224	0.797	0.865	$x/m = 0.05224C_e^{0.797}$
Ammoniacal nitrogen	0.04426	0.719	0.764	$x/m = 0.04426C_e^{0.719}$
Iron	0.0107	1.305	0.786	$x/m = 0.0107C_e^{1.305}$
Zinc	0.00752	1.309	0.636	$x/m = 0.00752C_e^{1.309}$

Figure (4), (5), (6), (7) & (8) show plots of Freundlich's isotherm for COD, colour, ammoniacal nitrogen, iron and zinc in this experiment. The linear equation by logarithmic transform of Freundlich Isotherm can be written as:

$$\log x/m = \log K + (1/n) \log C_e \qquad \text{……………… (4.1)}$$

The Freundlich Isotherm basically in the term of:

$$x/m = KC_e^{(1/n)} \qquad \text{.................. (4.2)}$$

Where x/m is the amount of adsorbate adsorbed at equilibrium (mg/g), Ce is the equilibrium concentration of adsorbate in solution after adsorption is complete (mg/L). The $1/n$ value represents the slope and K value is the antilog of the interception of log C_e. Hence, the Freundlich isotherm equations can be found as shown in table above. According to Weber W. J., 2001, the parameter K is indicative of the sorption capacity at a specific solution phase concentration. Larger values of K mean greater capacities of adsorption. The high value of K shows that COD has a high adsorption capacity compare to other solutes observed in this study. The constant $1/n$ is a function of the strength of adsorbent. The value of 1/n that is closer to 1 has a high adsorption bond. Higher values of $1/n$ shows that the adsorption bond is weak (Aziz H. A. et al, 2004). From the data, the adsorption bond of COD by silica sand is high while iron and zinc has lower adsorption capacity. x/m will determined the breakthrough level of the adsorbent. The higher value of x/m indicates the longer time of the media to remove solutes (Yusoff M. S., 2006). According to the table, the adsorption of silica sand has a longer removal for COD and shorter for zinc. The straight line proves the occurrence of adsorption that contributes to the removal of COD, colour, ammoniacal nitrogen, iron and zinc from leachate. Adsorption mechanism can be identified by calculating R^2 value where the perfect adsorption mechanism happens when R^2 is equal to 1.

3.4 Langmuir Isotherm

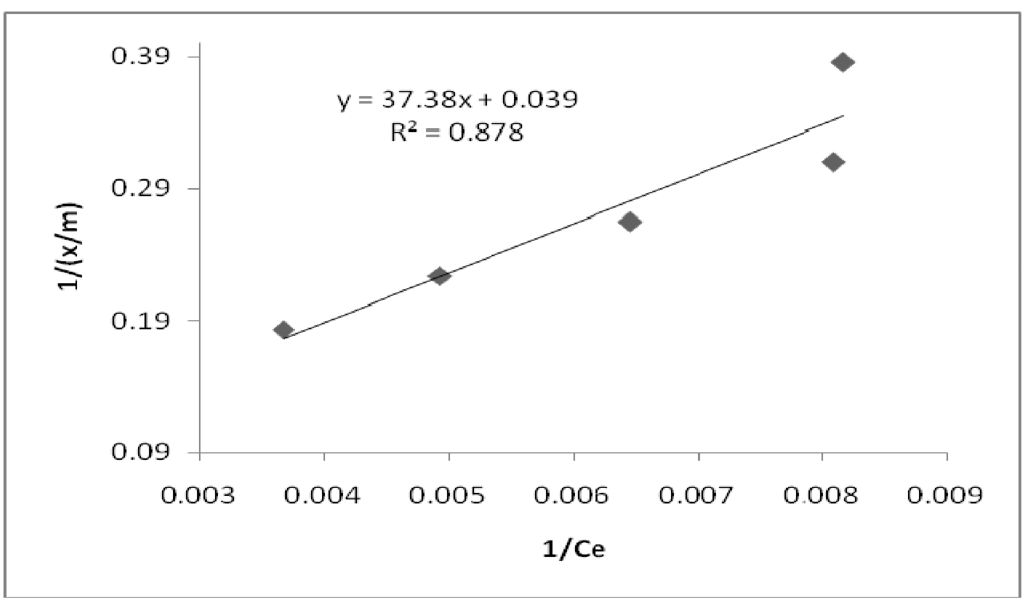

Fig. 9: COD

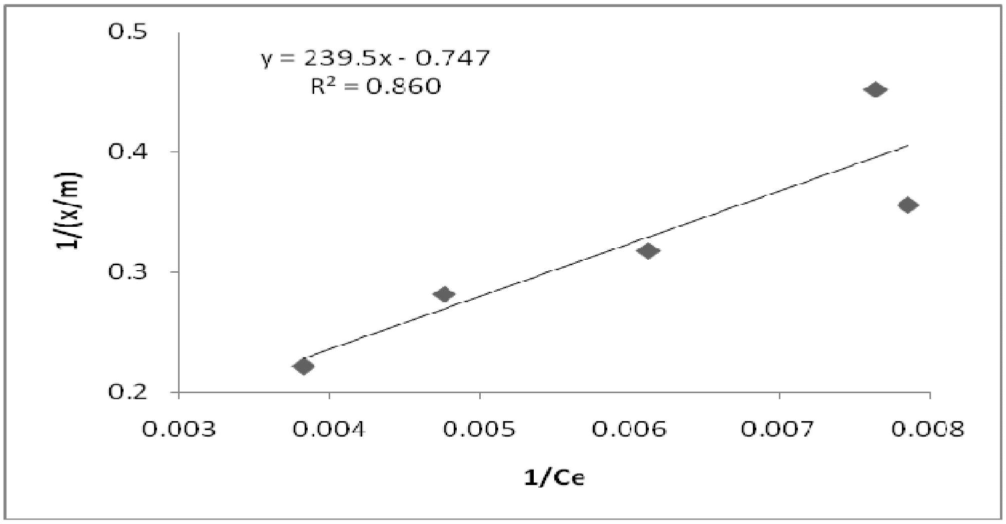

Fig. 10: Colour

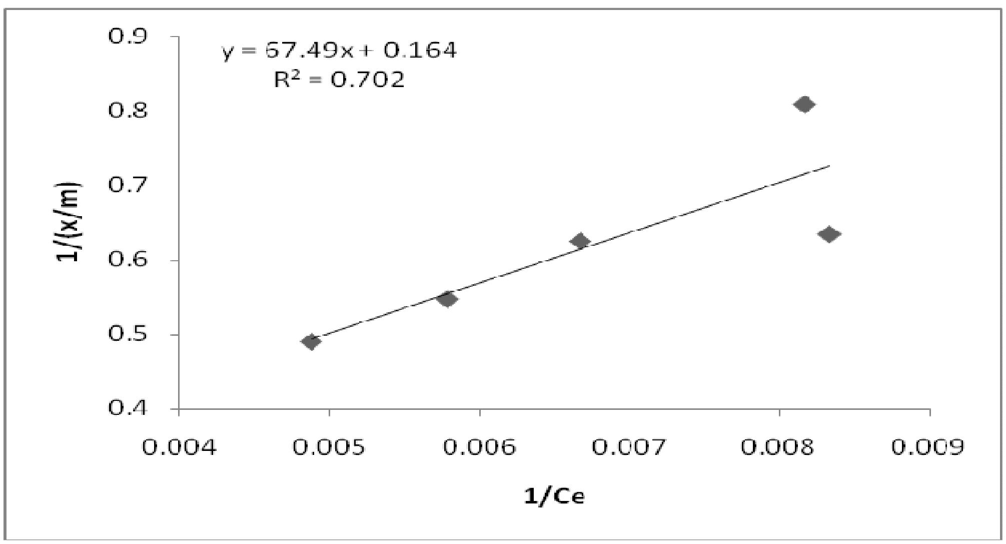

Fig. 11: Ammoniacal Nitrogen

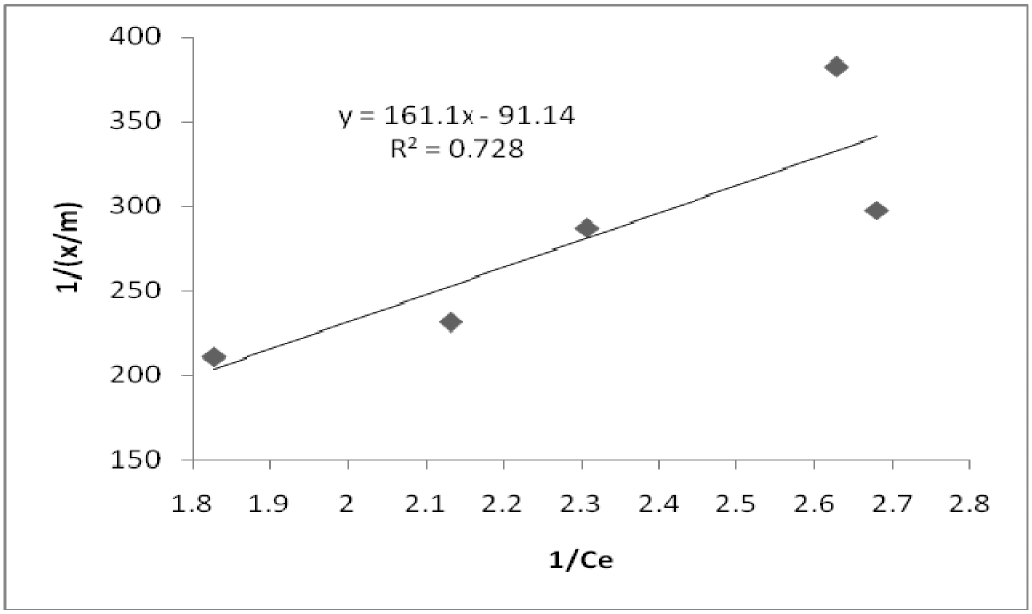

Fig. 12: Iron

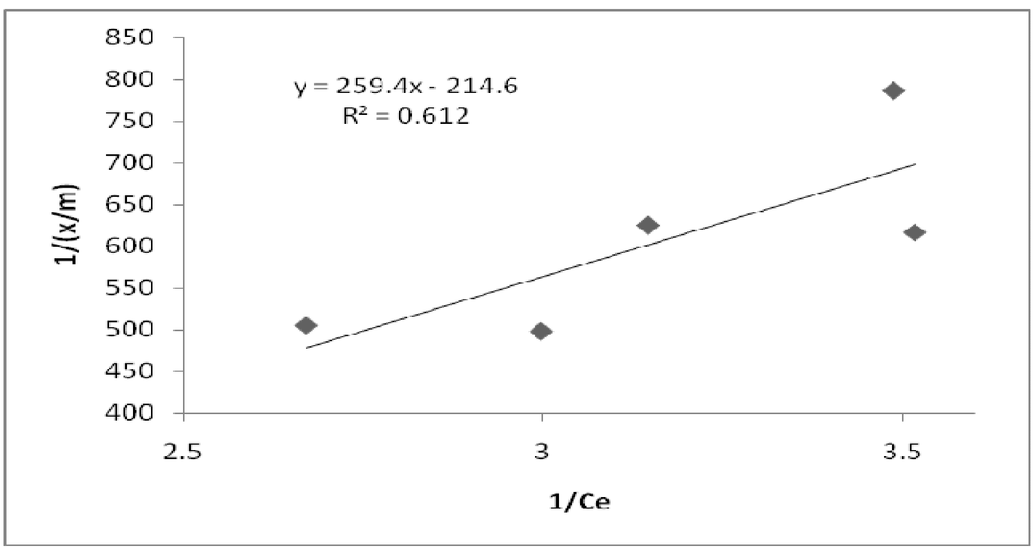

Fig. 13: Zinc

Table 3: List of adsorption constant for different solutes using Langmuir Isotherm

Parameters	Langmuir isotherm coefficients			Langmuir equations
	a (mg/g)	b (L/mg)	R^2	
COD	25.641	0.00104	0.878	$x/m = \frac{0.0268Ce}{1+0.00104Ce}$
Colour	1.33869	0.00312	0.860	$x/m = \frac{0.0042Ce}{1+0.00312Ce}$
Ammoniacal nitrogen	6.097561	0.00243	0.702	$x/m = \frac{0.0148Ce}{1+0.00243Ce}$
Iron	0.01097	0.56574	0.728	$x/m = \frac{0.006207Ce}{1+0.56574Ce}$
Zinc	0.00466	0.82729	0.612	$x/m = \frac{0.003855Ce}{1+0.82729Ce}$

Figure (9), (10), (11), (12) & (13) show plot of Langmuir Isotherm in this study. The equation of Langmuir Isotherm can be written as:

$$\frac{1}{(x/m)} = \frac{1}{abCe} + \frac{1}{a} \quad \text{.................................. (4.3)}$$

The Langmuir Isotherm is basically in the term of:

$$(x/m) = \frac{abCe}{1+bCe} \quad \text{.................................. (4.4)}$$

Where x/m is the amount of adsorbate adsorbed at equilibrium (mg/g), Ce is the equilibrium concentration of adsorbate in solution after adsorption is complete (mg/L). a (mg/g) is the monolayer capacity of the adsorbent and b (L/mg) is the Langmuir constants related to the maximum adsorption capacity and the energy of adsorption. A plot of 1/(x/m) versus 1/Ce yields the values of a and b (Ahmad A. L., 2008). From the table, the maximum monolayer adsorption is COD which is 25.641 mg/g and the lowest monolayer adsorption is zinc which is 0.00038 mg/g. This data shows that the maximum monolayer capacity is proportional to the effect of the adsorbent dosage. Furthermore, the characteristics of

Langmuir Isotherm can be explained by using a dimensionless equilibrium parameter (R_L), by using this equation:

$$R_L = \frac{1}{1+bC_0} \quad \text{...} (4.5)$$

Where C_0 is the initial raw leachate data in mg/L. This equation can denote the value of R_L. if the value of RL is ($0<RL<1$) it indicates the type of isotherm is favorable, if ($RL>1$) it showsunfavorable, when ($RL=1$), it means linear and when ($RL=0$), the type of isotherm is irreversible. By using this equation, the RL value for COD, colour, ammoniacal nitrogen, iron and zinc is in the range of 0 to 1. Then the results show that the type of Langmuir Isotherm is favorable. The adsorption isotherm coefficients obtain from the intercept and slopes are listed in Table 3. The straight line proves the occurrence of adsorption that contributes to the removal of COD, colour, ammoniacal nitrogen, iron and zinc from leachate. Adsorption mechanism can be identified by calculating R^2 value where the perfect adsorption mechanism happens when R^2 is equal to 1. In spite of the fact that, by looking at the R^2 value between Freundlich and Langmuir Isotherm, Freundlich Istherm yields the better fit for adsorption because all the R^2 value is higher than Langmuir Isotherm.

3.5 Column Studies

A column study had been conducted in order to find the Empty Bed Contact Time (EBCT) of the media. The characteristics of the column are:

- Depth = 50 cm
- Diameter = 1.2 cm
- Area = 1.13×10^{-4} m^2
- Volume = 5.65×10^{-5} m^3
- Q = 6.075×10^{-8} m^3/s

After the experiment is carried out, the volume and flow rate is used to get the EBCT of the media by using this equation.

- EBCT =V/Q
  = 930 s
  =15.5min