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Coagulation and Flocculation of Bukit Tagar Sanitary Landfill Leachate using Alum and PAC

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ABSTRACT Discharge of landfill leachate into the environment without proper treatment may cause severe environmental problems since they can infiltrate the soil, causing surface and ground water pollution. Leachate from Bukit Tagar Sanitary Landfill was characterized and Jar-Test trials were applied in this study to determine the optimum conditions (effective dosage, optimum pH and mixing speed) for the removal of leachate pollutants. Polyaluminium chloride (PAC) at optimum concentration of 4mL/500mL and at pH 7, with a mixing speed of 90 rpm, gave complete removal of Cd, Pb and Cu. It also reduced about 99% of Zn at the same conditions. Aluminium sulfate (alum) at optimum concentration of 8g/500mL at pH 7 and with mixing speed of 100 rpm, gave total removal of Pb and Cu and was able to reduce 98% of Cd and 94% of Zn. Reduction of turbidity, color and TSS from leachate using PAC at optimum conditions ranged from 70% to 80%, while alum at optimum conditions gave reduction of turbidity, color and TSS in the range of 63% to 78%. PAC showed a higher removal of leachate pollutants than alum, and it was able to reduce Cd, Pb, Zn and Cu to below the EQA 1974 Standard B, while alum reduced only Pb and Cu to below the EQA 1974 Standard B. Alum was not able to remove Cd and Zn to below the EQA 1974 Standard B which may require further treatment. It was also found that the treatment using PAC was cheaper by 25% compared to alum. The average estimated cost (per day) of treating 600m^3 of leachate using PAC and alum, was RM1440 and RM1920, respectively.

ABSTRAK Larut lesapan dari kawasan pelupusan sampah yang dibebaskan tanpa rawatan secukupnya boleh mencemarkan tanih dan air permukaan dan air bawah tanah. Larut lesapan dari kawasan pelupusan sampah Bukit Tagar dipercirikan dan Jar-Test digunakan untuk menentukan keadaan optima (dos efektif, pH optimum dan kelajuan campuran) yang boleh digunapakai untuk menyingkirkan bahan pencemar. Polyaluminium chloride (PAC) pada kepekatan optima 4mL/500mL dan pH 7 dengan kelajuan campuran 90 rpm didapati menyingkirkan semua Cd, Pb dan Cu. Ia juga mengurangkan 99% Zn pada keadaan yang sama. Aluminium sulfat (alum) pada kepekatan optima 8g/500mL dan pH 7 dengan kelajuan campuran 100 rpm didapati boleh menyingkirkan semua Pb dan Cu dan mengurangkan 98% Cd dan 94% Zn. Pengurangan kekeruhan, warna dan TSS larut lesapan menggunakan PAC berada pada paras 70 – 80% manakala alum, dengan keadaan optima, mengurangkan kekeruhan, warna dan TSS pada paras 63 – 78%. PAC menyingkirkan lebih banyak bahan pencemar dalam larut lesapan berbanding dengan alum dan ia mengurangkan Cd, Pb, Zn dan Cu ke paras di bawah Piawai B Akta Kualiti Alam Sekitar 1974. Alum mengurangkan kandungan Pb dan Cu ke paras di bawah Piawai B Akta Kualiti Alam Sekitar 1974. Alum tidak dapat mengurangkan Cd dan Zn ke paras di bawah Piawai B Akta Kualiti Alam Sekitar 1974 dan memerlukan rawatan lanjutan. Kos rawatan dengan PAC didapati 25% lebih rendah berbanding dengan alum. Kos purata merawat 600m^3 larut lesapan tiap hari dengan PAC dan alum adalah RM1440 dan RM1920, masing-masing.

(Landfill leachate, coagulation, flocculation, Alum, PAC)

INTRODUCTION

Solid waste generation rate and composition differ from country to country depending on many factors such as the economic condition, industrial types, waste management systems and life style. Malaysia, like other developing countries, is facing problems in solid waste generation as the amount of waste generated increases annually at 3 %. Total municipal solid waste (MSW) generation in 2000 was roughly 8.0 million tonnes/year compared to current MSW generated which is 8.4 million tonnes/year [1, 2, 3]. The average per capita generation of MSW in Malaysia has increased from 0.85 kg/ person/day to 1.7 kg/person/day in major cities [4]. Recycling was 1 - 2 % and the rest was taken to disposal sites

Landfill leachate is generated as a result of the degradation of organic materials and the quantity of leachate generated depends on many factors such as precipitation, surface runoff, evapo-transpiration, final cover and moisture content. The average amount of leachate generated in Malaysia is estimated at 150L/tonne (0.2 m^3/tonne) [1]. Bukit Tagar Landfill, which is three years old, has a total capacity of about 120 million metric tons and is designed to manage and treat municipal solid waste and other non-toxic waste from Kuala Lumpur and Selangor for at least 40 years. It receives about 3000 metric tons/day of municipal solid wastes and the amount of leachate produced per day ranged from 500 m^3 – 700 m^3 [5].

Landfill leachate contains various types of pollutants such as dissolved organic matter (COD, BOD, ammonium-N), inorganic macrocomponents (Na, Mg, Ca, K, Cl), heavy metals (Cd, Pb, Zn, As, Cr, Fe, Cu) and xenobiotic organic compounds (phenols, pesticides, aromatic hydrocarbons) that can cause serious environmental problems [6]. It can contaminate soil and surface water such as rivers, streams and water wells, and it can also migrate into groundwater and cause harmful pollutants. Therefore, the management of leachate is the key to removing potential pollutants and organic materials such as BOD_5, COD, ammonium-N and heavy metals from leachate before being discharged.

A number of options and technologies have been applied for the treatment of leachate. This falls into two basic types: physical / chemical treatment and biological treatment. The efficiency of leachate treatment processes depends on the composition of leachate and concentration of pollutants. Biological treatments such as activated sludge process, attached-growth biomass system, sequencing batch reactor, trickling filters, anaerobic filter and fluidized bed reactor have been used for treatment of leachate. Treatment by biological methods is efficient for leachate of less than 5 years old [7]. Physical / chemical treatment such as flotation, coagulation-flocculation, chemical precipitation, adsorption, chemical oxidation and air stripping are being applied successfully for treatment of leachate to remove color, suspended solids, colloidal particles, floating materials and toxic compounds [8].

Coagulation-flocculation process has been applied to landfill leachate for the removal of organic and inorganic substances in the form of colloids and suspended solids. It is effective for removing or reducing heavy metals such as Zn, Pb, Cd, Cu and Fe. Many studies were carried out using coagulation/flocculation process for treatment of landfill leachate [9]. In coagulation process, very small suspended particles or colloids attract one another when a coagulant such as aluminium sulfate or a polymer is added to the leachate to form larger particles [10]. The coagulant neutralizes the electrostatic charges on the particles, so that the particles can repel each other and permits the destabilized particles to attach together [11]. Flocculation is a slow mixing of the coagulant particles to enhance the formation of larger and heavier particles (floc) that can be easily settled by gravity [12]. This method involves the use of suitable coagulants such as aluminium sulfate (alum) and polyaluminium chloride (PAC), at appropriate dosage and optimum pH to achieve proper treatment.

The process of coagulation can be considered as three sequential steps: coagulate formation, particle destabilization and interparticle collisions. When alum is used in coagulation, the actual chemical species operative in the process are formed during and after the alum is mixed with the water to be treated, while Al^{3+} and SO_4^{2-}, the ions in alum, are not directly involved in the coagulation process [13]. When a salt of Al^{3+} is added to wastewater, it will dissociate to yield trivalent Al^{3+} ions, which hydrate to form aquometal complexes $Al(H_2O)_6^{3+}$. These complexes then pass through a series of hydrolytic reactions in which H_2O molecules in the hydration shell are replaced by OH^- ions. This gives rise to the formation of a variety of soluble species, including mononuclear species (one aluminum ion) such as $Al(OH)^{2+}$ and polynuclear species (several aluminum ions) such as $Al_8(OH)_{20}^{4+}$ [14].

Al^{3+} accomplishes destabilization by two mechanisms: a) adsorption and charge neutralization and b) enmeshment in a sweep floc. If Al^{3+} is added to water in concentrations less than the solubility limit of metal hydroxide, hydrolysis products will form and adsorb onto the particles, causing destabilization by charge neutralization [14]. When the amount of Al^{3+} added to water is sufficient to exceed the solubility of the metal hydroxide, the hydrolysis products will form as kinetic intermediates in the formation of the metal hydroxide precipitate. In this situation, both charge neutralization and enmeshment in the precipitate contribute to coagulation. Interrelations between pH, coagulant dosage and colloid concentration determine the mechanism responsible for coagulation [14].

The aim of this study is to investigate the effectiveness of coagulants, alum and PAC in treating leachate collected from Bukit Tagar Sanitary Landfill. PAC (18 %) is an inorganic polymer and is broadly used as a coagulant in water treatment. It is easily dissolved in water and has light yellow or yellow color. Alum [$Al_2(SO_4)_3$. 18 H_2O] is also widely used as a coagulant for water treatment due to its proven performance and cost-effectiveness. It appears as a white crystalline solid [15].

MATERIALS AND METHODS

Raw leachate from Bukit Tagar Sanitary Landfill was collected in high-density polyethylene bottles at the outlet of the leachate pipe, before its entry into the leachate treatment plant. The bottles were labelled and transported to the laboratory. The leachate samples were analyzed to determine the leachate characteristics. The study includes:

i. BOD_5, COD, and Total-N: analysed according to standard Methods APHA, AWWA, and WEF [16].
ii. Total suspended solid (TSS), and colour, determined using Spectrophotometer, HACH Model (DR/4000).
iii. pH and conductivity, measured using a pH and conductivity probe (Hanna Model, No. 8033).
iv. Heavy metals, determined after digestion of the leachate using Inductively Coupled Plasma Optical Emission Spectrometry (ICP - OES).

Jar Test Trial

Jar test was done using a six-paddle flocculator, from Stuart Scientific (Flocculator SW1 equipped with 6 beakers of 500 mL each) for both chemicals: PAC and alum. The treatment includes dosages of PAC and alum at various pH and mixing speeds to determine the optimum conditions for removal of selected parameters. PAC concentration ranged between 2mL to 12 mL per 500mL of leachate, while alum concentration was between 7g to 12g per 500 mL of leachate. After establishing the optimum concentration coagulant at pH 4, 5, 6, 7, 8, 9, and 10 were carried out. pH values of the leachate samples were adjusted by adding concentrated NaOH or H_2SO_4 solutions. After determining the optimum coagulant concentration and optimum pH, the optimum mixing speed for coagulation was investigated by mixing at 60 – 110 rpm. After mixing, the samples were allowed to settle for 60 minutes. During the settlement process, liquid (supernatant) was siphoned out and tested for heavy metals (Cd, Pb, Zn and Cu), turbidity, colour and TSS.

RESULTS AND DISCUSSION

Leachate Characteristics

Raw leachate from Bukit Tagar Sanitary Landfill (Table 1) contained high concentrations of BOD_5 (27000 mg/L), COD (59000 mg/L), NH_3-N (4300 mg/L), TSS (13.5 mg/L), Pb (15.15 mg/L), Al (15.75 mg/L), Zn (17.55 mg/L), Fe (84.3 mg/L), Cu (10.95 mg/L), Cd (11.25 mg/L) and As (3.6 mg/L) and most parameters measured exceeded the regulatory Standard limit of EQA 1974 (Standard A and B) [17].

The ratio of BOD_5/COD of the raw leachate was 0.46 and this value shows that the organic material in the leachate is easily biodegradable [18]. The acidic pH of the leachate (pH 6.6) was mainly due to the availability of easily biodegradable organic matter and thus the microorganisms produce significant concentrations of H^+ ion [19]. Color (15300 ADMI), TSS (13.5 mg/L), and ammonia were also high and this could be due to the decomposition of waste mass. The high level of NH_3-N may be due to the decomposition of nitrogenous substances [20]. Turbidity (3600 FAU) and TSS (13.5 mg/L) values indicated the presence of organic and inorganic solids. This study indicates high salt (sodium) concentration in the leachate which was 804 mg/L and this could be due to the large amount of garbage (food waste) disposed in the landfill [21].

Heavy metal pollutants (Cd, Pb, Zn, Cu, As, Fe) in the leachate were significantly higher than the EQA Standard (Table 1). The presence of these pollutants in the leachate is usually due to industrial waste and household non-hazardous waste [22]. Heavy metals cause serious consequences to human beings and the environment, if not treated. They can accumulate in the biological tissues of the body and cause serious diseases such as neurotoxic effects, renal failure (lead), genetic anomalies and cancer risk (cadmium, arsenic), which indicates clearly that pretreatment is required.

Characteristics of leachate from Bukit Tagar Sanitary Landfill showed high concentrations of BOD_5, COD and heavy metals compared with other landfills in Malaysia, such as Kundang Landfill and Sungai Sedu Landfill [23] and also leachate from USA and Kuwait [24] (see Table 2).

Table 1. Characteristics of raw leachate from Bukit Tagar Sanitary Landfill compared to Environmental Quality Act (EQA) 1974 Standard A and B

PARAMETER	UNIT	BUKIT TAGAR LANDFILL LEACHATE	EQA 1974 STANDARD	
			A	B
Temperature	°C	29 °C	40	40
pH	-	6.6	6.0 – 9.0	5.5 – 9.0
BOD_5 at 20 °C	mg/L	**27000**	20	50
COD	mg/L	**59000**	50	100
Total Solid, TS	mg/L	1719	N.A.	N.A.
NH_3 - N	mg/L	**4300**	50	100
Turbidity	FAU	3600	N.A.	N.A.
Conductivity	μ^5/cm	670	N.A.	N.A.
Salinity	mg/L	0.3	N.A.	N.A.
Total Dissolved Solid, TDS	mg/L	332		
Color	ADMI value	15300		
Total Suspended Solid, TSS	mg/L	13.5		
Cadmium (Cd)	mg/L	**11.25**	0.01	0.02
Arsenic (As)	mg/L	**3.6**	0.05	0.1
Lead (pb)	mg/L	**15.15**	0.01	0.5
Zinc (Zn)	mg/L	**17.55**	1.0	1.0
Copper (Cu)	mg/L	**10.95**	0.2	1.0
Aluminum (Al)	mg/L	15.75	N.A.	N.A.
Calcium (Ca)	mg/L	397.8	N.A.	N.A.
Potassium (K)	mg/L	764.4	N.A.	N.A.
Iron (Fe)	mg/L	**84.3**	1.0	5.0
Sodium (Na)	mg/L	803.55	N.A.	N.A.
Manganese (Mn)	mg/L	**17.85**	**0.2**	**1.0**
Selenium (Se)	mg/L	1.65	N.A.	N.A.
Magnesium (Mg)	mg/L	29.1	N.A.	N.A.

Table 2. Comparison of landfill leachate in Malaysia and other countries

PARAMETER (mg/L)	KUNDANG LANDFILL *	SUNGAI SEDU LANDFILL*	KUWAIT **	USA **
Alkalinity	-	-	250 – 6340	240 – 8965
pH	7.43 ± 0.04	6.72 ± 0.02	6.9 – 8.2	5.1 – 6.9
BOD_5	27.5 ± 0.66	22.27 ± 0.46	30 – 600	13,400
COD	6232 ± 1824.3	169.3 ± 76.95	157.9 – 9440	1340
Sulfate	-	-	55 – 3650	0.01 – 1280
Zn	0.060 ± 0.044 ppm	0.153 ± 0.102 ppm	0.0 – 4.8	18.8 – 67
Pb	0.027 ± 0.012 ppm	0.147 ± 0.172 ppm	0 – 0.2	0 – 4.46
Cu	0.003 ± 0.002 ppm	0.005 ± 0.004 ppm	0 – 0.2	0 – 0.1
Fe	-	-	0.3 – 54.1	4.2 – 1185
Ca	-	-	5.6 – 122	254.1 – 2300
Mg	4.245 ± 0.420 ppm	7.480 ± 3.780 ppm	5.2 - 268	233 - 410

Sources: [23]* and [24] **

Coagulation / Flocculation Studies

Removal of pollutants from leachate using PAC and alum, at various concentrations

Removal of heavy metals, turbidity, colour and TSS from landfill leachate containing high concentrations of organic and inorganic matter was examined using coagulation with PAC and alum. Figure 1 (a): shows the reduction in pollution parameters after treatment with PAC which showed highest removal at a concentration of 4mL/500mL. Removal of turbidity using PAC was 75% and the removal of colour was 80%, while TSS was removed by 78%. PAC showed complete removal of Cd, Pb and Cu which brought the metals to below the EQA Standard limit. The removal of turbidity, colour and TSS using alum at optimum concentration of 8g/500mL were 71%, 78% and 78%, respectively (Figure 1b). Alum reduced about 98% of Cd, 94% of Zn and gave complete removal of Pb and Cu.

These results tally with the findings of Nor Asikir and Agamuthu [21], that alum was capable of removing Pb, Cu and Zn by 100%, 91% and 100%, respectively, while PAC at 4 mL/500mL gave complete removal of Pb, Cu and Zn in the same study. PAC (4mL/500mL) in this study showed 100% reduction of Cd, Pb and Cu, while alum (8g/500mL) reduced Pb and Cu by 100%. The high reduction by PAC and alum may be due to charge neutralization between the coagulant and the colloidal particles in the leachate. The colloidal particles have a negative charge and when coagulant is added, these particles collide and stick to each other to form a floc [10].

Silva et al. [6] stated that colour removal from sanitary landfill leachate using alum was found to give 70% reduction, while alum (8g/500mL) in this study gave 78% removal of colour. The higher removal of alum in this study may be attributed to the composition of leachate and pH level [6]. Li et al. [25] indicated that using poly-ferric sulfate at an optimum dose of 25 mg/L and optimum pH of 10.0 – 11.5, Cu can be removed from wastewater by 99%. The results in this study using PAC (4mL/500mL) and alum (8g/500mL) gave similar efficiency for removal of heavy metals. A linear relationship was observed between the coagulant dosage and the removal of pollutants (see Figure 2).

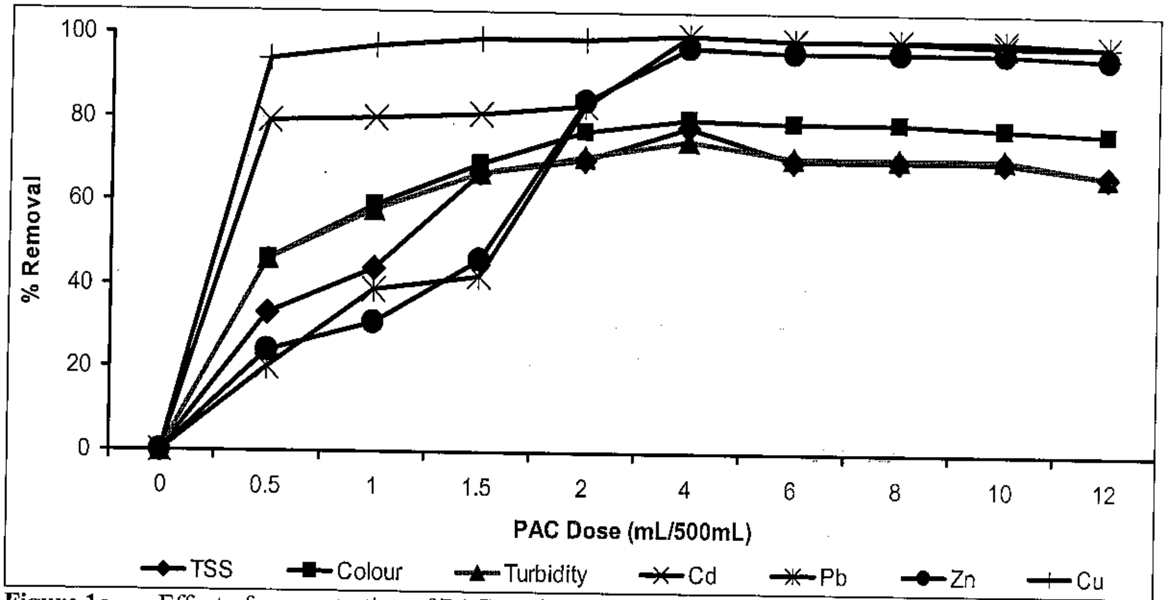

Figure 1a. Effect of concentration of PAC on the removal of pollution parameters in the leachate

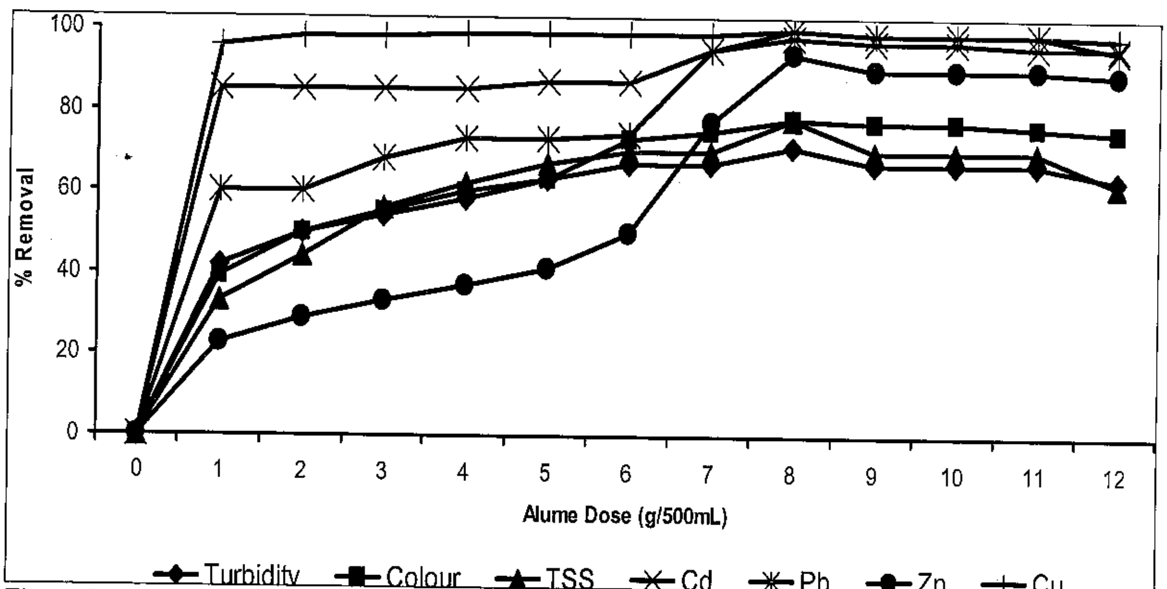

Figure 1b. Effect of concentration of alum on the removal of pollution parameters in the leachate

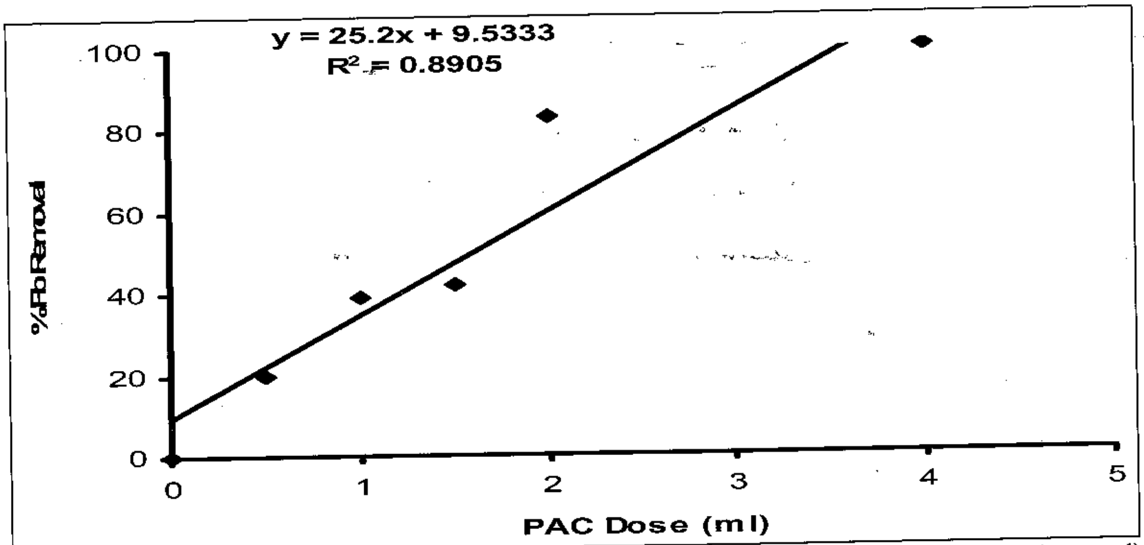

Figure 2a. Correlation between concentration of PAC and removal of Pb in leachate (increasing trend)

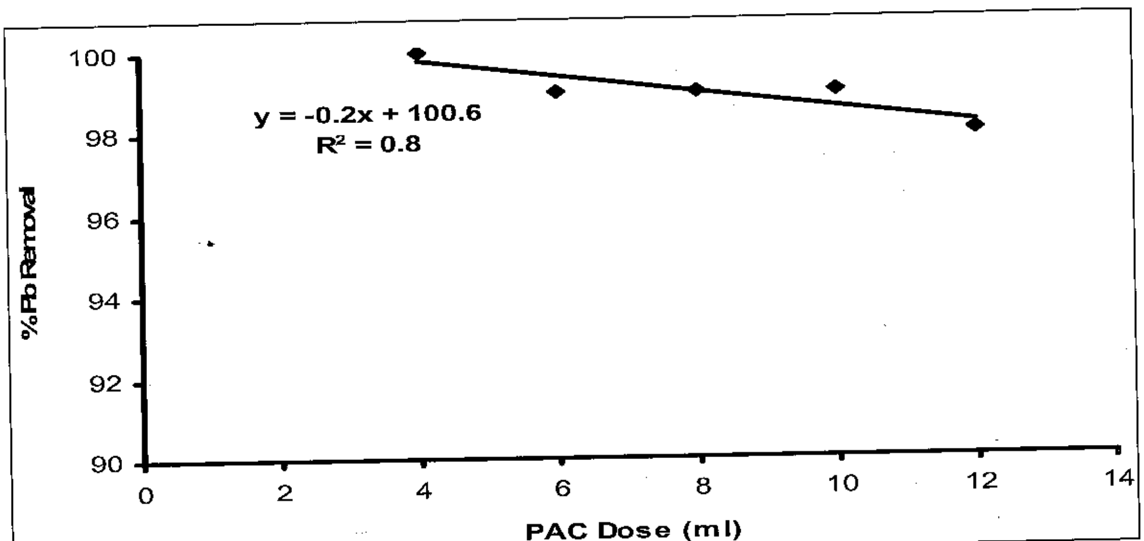

Figure 2b. Correlation between concentration of PAC and removal of Pb in leachate (decreasing trend)

Removal of pollutants from leachate using PAC and alum, at various pH

The effect of pH on the removal of turbidity, colour, TSS and heavy metals is significant in coagulation process. Figures 3 (a) and 3 (b) show the optimum pH for removal of turbidity, colour, TSS and heavy metals using PAC and alum. The optimum pH for both PAC and alum was 7. The optimal pH value is dependent on the characteristics of leachate [24]. Removal of turbidity, colour and TSS using PAC were 75%, 78% and 70%, respectively while Cd, Pb and Cu were completely removed at pH 7. The degree of removal of turbidity, colour and TSS at optimum pH using alum was 71%, 76% and 63%, respectively. At optimum pH, alum showed complete removal of Pb and Cu while Cd and Zn were reduced by 98% and 94%, respectively which were still above the EQA Standard B.

Aziz et al. [26] found that the removal of colour by alum at pH 6 (optimum) was 80% which tallied with results of Larry et al.[14] who stated that most wastewater treatment plants utilizing alum operate between pH 6 to 7.5. The results of PAC (4mL/500mL) and alum (8g/500mL) at pH 7 in this study gave 78% and 76%, respectively. This variation in colour removal is attributed to differences in the pH of leachate, since colour removal is highly dependent on pH [13].

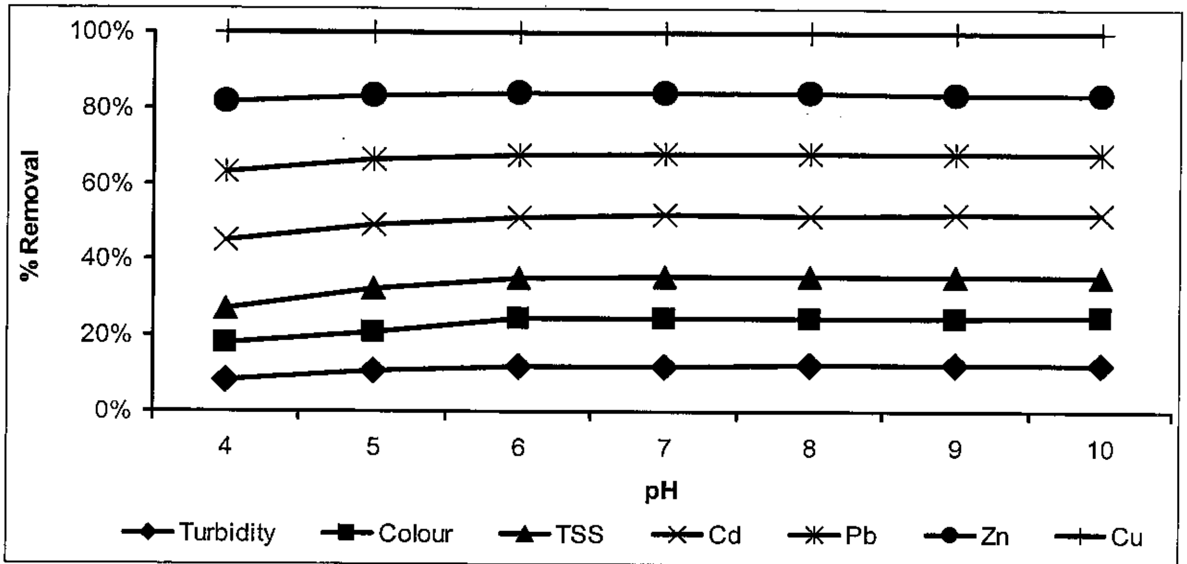

Figure 3a. Effect of pH on PAC and the removal of pollutants in the leachate

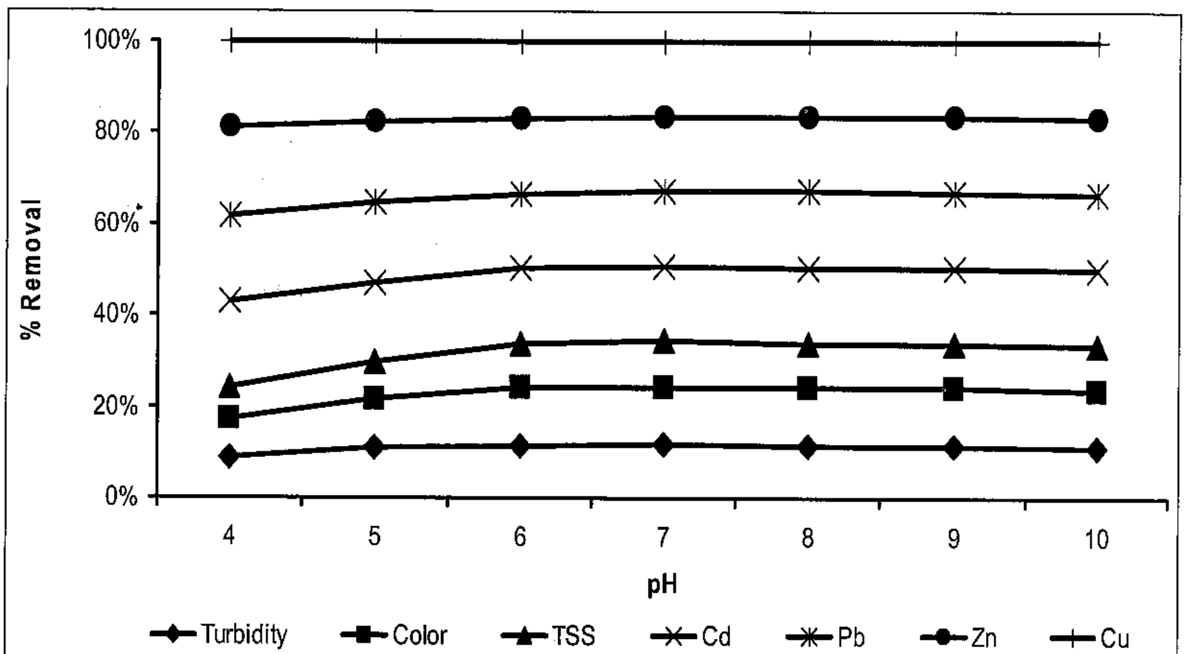

Figure 3b. Effect of pH on alum and the removal of pollutants in the leachate

The result of Cecen and Gursoy [27] showed that $Ca(OH)_2$ was capable of removing Cu and Pb from leachate at pH 11 by 72% and 46%, respectively. The study by Jayabala [28] using 40 mg/L of $FeCl_3$ at pH 6 to reduce As and Cd in the leachate, indicated that As removal was 99.8%, while Cd was removed by 94%. Urase et al. [29] found that $FeCl_3$ (0.3g/L) was able to reduce Cd, Pb and Zn from leachate by 97%, 98% and 95%, respectively at optimum pH 9. When these results are compared with this study, PAC (4mL/500mL) and alum (8g/500mL) at pH 7 were found to give better performance in removing pollutants from the leachate than $Ca(OH)_2$ and $FeCl_3$. The high removal of pollutants using alum may be due to the presence of sulphate in alum. Sulphate acts as an accelerator for the precipitation of aluminium hydroxide [30].

Removal of pollutant from leachate using PAC and alum, at various mixing speeds

Figure 4 (a) shows that the optimum mixing speed for the removal of turbidity, colour, TSS and heavy metals using PAC was 90 rpm. The degree of removal of turbidity, colour, TSS using PAC was 75%, 77% and 78%, respectively. Heavy metals such as Cd, Pb and Cu were completely removed at the optimum mixing speed. Effects of mixing speeds on the removal of turbidity, colour, TSS and heavy metals using alum are given in Figure 4(b). The optimum removal was obtained at mixing speed of 100 rpm. The levels of removal of turbidity, colour, TSS were 67%, 72% and 70%, respectively. Alum was found to give complete removal of Cu only at optimum mixing speed, while Cd, Pb and Zn were reduced by 99%, 98% and 94%, respectively. Alum reduced Pb at optimum mixing speed to below the EQA Standard, while Cd and Zn still exceeded the effluent Standard B. The result of PAC (4mL/500mL) was quite similar to the results obtained by Salim [31] where the maximum reduction of pollutant using (6g/500mL) of aluminium chloride was at an optimum mixing speed of 100 rpm. Reduction of Cd, Pb, and Cu was 100%. Adequate mixing of PAC will break up existing flocs, therefore, disruptive forces and particle collision efficiency decreased, resulting in high removal of heavy metals [10].

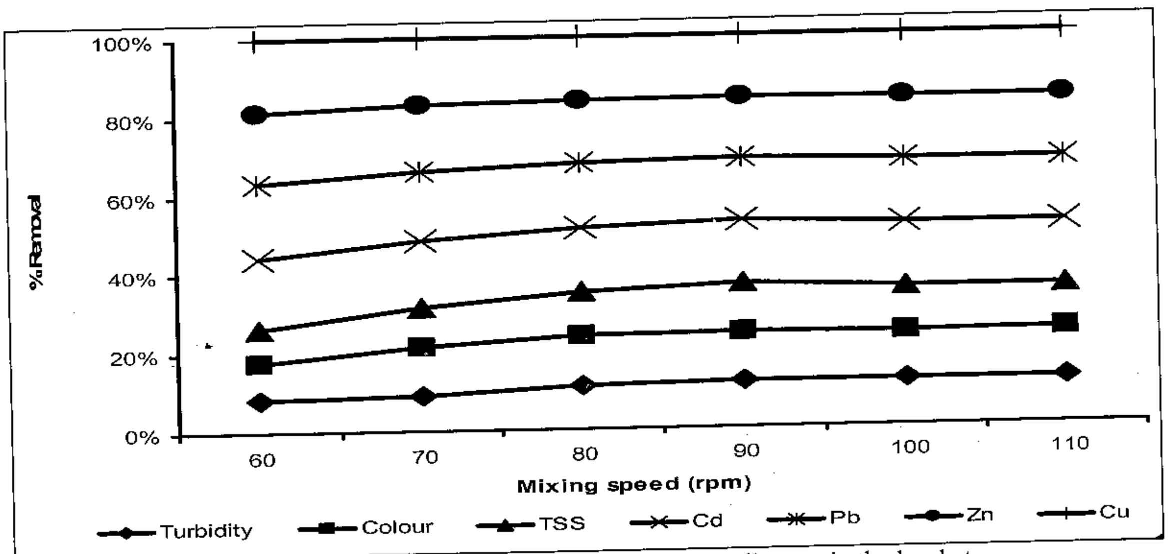

Figure 4a. Effect of mixing speed on PAC and the removal of pollutants in the leachate

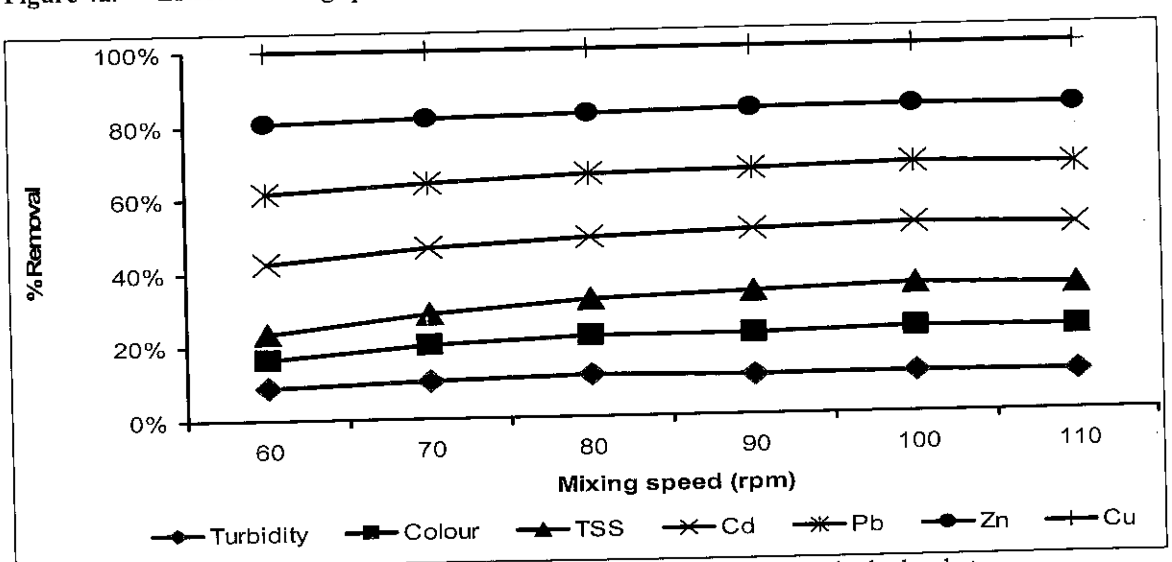

Figure 4b. Effect of mixing speed on alum and the removal of pollutants in the leachate

Said [32] stated that ferric chloride (2g/500mL) at an optimum mixing speed of 100 rpm was able to reduce Cd and Cu by 100%. This tallies with the finding that Cd concentration in the leachate treated with PAC (4mL/500 mL) at 90 rpm mixing speed, gave 100% reduction, while Cu concentration was reduced by both coagulants (PAC and alum) at optimum conditions by 100%. In optimal mixing process, microfloc or low density macrofloc particles stick together and agglomerate to form a size that will settle easily [12].

Table 3 shows the pollutant removal efficiency at optimum conditions using PAC and alum. PAC (4mL/500mL) showed better performance based on the removal of pollutants than alum. It was able to remove Cd, Pb, Zn and Cu to below the EQA 1974 Standard B limit while alum (8g/500mL) reduced only Pb and Cu to below the EQA 1974 Standard B limit. Parameters such as Cd and Zn still exceeded the EQA 1974 Standard B limit which required further treatment to meet the Standard.

According to Salim [31], Praestol 189 K (2mL/500mL) at pH 7 was able to reduce Cd, Pb and Cu in the leachate to 0 mg/L, which was well below the Standard B requirement. The same results were obtained by Said [32] where ferric chloride (2g/500mL) at pH 7 reduced Cd and Cu from the leachate to 0 mg/L, which were well below the Standard B requirement. The results obtained in this study using PAC (4mL/500mL) at pH 7 gave same removal efficiency. PAC reduced pollutants such as Cd, Pb, Zn and Cu to below the Standard B requirement, while alum (8g/500mL) at pH 7 was able to reduce Pb and Cu to below the Standard B requirement.

Economic Consideration

The cost of leachate treatment depends on several factors such as the quantity and quality of leachate, the design of landfill, the level or degree of treatment needed and final removal methods for residues and effluent [33]. The cost of leachate treatment data is not easily available because the landfill operators were uncooperative to reveal the cost of leachate treatment. Therefore, the cost of this comparison for both coagulants (PAC and alum) was estimated based on the chemical used. The treatment of an average of 600 m^3 of leachate from BTSL, using PAC and alum will cost RM 1440 and RM 1920, respectively (see Table 4).

CONCLUSIONS

Leachate from Bukit Tagar Sanitary Landfill contains high amounts of BOD_5 (27000 mg/L), COD (59000 mg/L), NH^3-N (4300 mg/L) and heavy metals such as Cd, Pb, Zn, Cu, Fe, Al and As, since this is a new landfill. These pollutants were above the EQA 1974 (Standard A and B) limit, similar to leachate from other landfills in Malaysia. Both coagulants (PAC and alum) were able to reduce most of the pollutants to below the EQA Standard. However, PAC was more effective in the reduction of pollutants than alum. It showed complete removal of Cd, Pb, Zn and Cu while alum removed only Pb and Cu. Reduction of turbidity, color and TSS between the two coagulants ranged from 63% - 80%. Optimum removal of pollution parameters by PAC was at a concentration of 4mL/500mL at pH 7, while alum showed maximum removal at 8g/500mL at pH 7. Optimum mixing speed for PAC and alum were 90 rpm and 100 rpm, respectively. PAC reduced Cd, Pb, Zn and Cu to below the EQA 1974 Standard B, while Alum was able to reduce Pb and Cu to below the EQA 1974 Standard B but Cd and Zn still exceeded Standard B limit. PAC is cheaper by 25% compared to alum. Positive linear correlations were observed for the coagulant dosage and pollutant removal.

Table 3. Pollutant reduction (%) at optimum conditions for PAC and alum and the final concentration after treatment

PARAMETERS / CHEMICAL AND OPTIMUM CONDITIONS		% REMOVAL AND FINAL CONCENTRATION (mg/L)													
		TURBIDITY		COLOR		TSS		Cd		Pb		Zn		Cu	
		%	CONCENTRATION	%	CONCENTRATION	%	CONCENTRATION	%	CONCENTRATION	%	CONCENTRATION	%	CONCENTRATION	%	CONCENTRATION
PAC	Concentration 4mL/500mL	75	900	80	3000	78	3	100	0	100	0	97	0.54	100	0
	pH 7	75	900	78	3300	70	4	100	0	100	0	99	0.15	100	0
	Mixing speed 90 rpm	75	900	77	3450	78	3	100	0	100	0	99	0.15	100	0
Alum	Concentration 8 g/500mL	71	1050	78	3300	78	3	98	0.20	100	0	94	1.05	100	0
	pH 7	71	1050	76	3600	63	5	98	0.17	100	0	94	1.05	100	0
	Mixing speed 100 rpm	67	1200	72	4200	70	4	99	0.15	98	0.30	94	1.05	100	0

Table 4. Comparison of chemical treatment cost

CHEMICAL	PRICE OF CHEMICAL (RM)	OPTIMUM CONCENTRATION USED	AMOUNT OF CHEMICAL TO TREAT 600 M^3 OF LEACHATE/DAY	COST TO TREAT 600 M^3 OF LEACHATE (RM)	pH ADJUSTMENT
PAC	300/L	4mL/500mL	480,000 L	1440	Required
Alum	200/kg	8g/500mL	9600 kg	1920	Required

RM = Ringgit Malaysia = 3.8 US $

REFERENCES

1. Agamuthu, P. (2001). *Solid Waste: Principles and Management*. Kuala Lumpur, University of Malaya Press, pp. 389.
2. Agamuthu, P. (2007). Solid waste management: Malaysian case studies. Paper presented in Electronic Lecture Seminar. University of Malaya. Kuala Lumpur. Malaysia, 17th December 2007
3. Agamuthu, P. (2008). Waste Management Scenario in Malaysia: An Overview. Paper presented in Electronic Lecture Seminar. University of Malaya. Kuala Lumpur. Malaysia, 7th January 2008.
4. Maseri, N. M. (2004). Environmental Position Paper on Solid Wastes and Incineration. Environmental News, Malaysian Nature Society. http: www.mns. org. my / article
5. KUB-Berjaya Enviro. Sdn Bhd. (2005). http://www.kbenviro.com.my
6. Silva, A. C., Dezotti, M. and Sant'Anna, Jr. (2004). Treatment and detoxification of a sanitary landfill leachate. *Chemosphere* **55**: 207 – 214.
7. Rodriguez, J. I., Castrillon L. P., Maranon M. E. and Sastre, A. H. (2000). Biomethanisation of municipal solid waste in a pilot *Water Res.* 4 (2): 447 – 454.
8. Christensen, T. H., Kjeldsen, P., Bjerg, P. L., Jensen, D. L., Christensen, J. B., Baun, A., Albrechtsen, H. J., and Heron, G. (2001). Biogeochemistry of landfill leachate plumes, *Appl. Geochem.*, **16**: 659 - 718.
9. Tatsi, A. A. A., Zouboulis, A. I., Matis, K. A. and Samaras, P. (2003). Coagulation-flocculation pretreatment of sanitary landfill leachates. *Chemosphere* **53**: 737 - 744.
10. Bratby, J. (2006). *Coagulation and Flocculation in Water and Wastewater Treatment.* 2nd Edition. International Water Association (IWA) Publishing, pp. 450.
11. Rivas, F. J., Beltran, F., Gimeno, O., Acedo, B., and Carvalho, F., (2003). Stabilized leachate: Ozone-activated carbon treatment and kinetics. *Water Resources*, **37**: 4823 – 4834.
12. Tridib, T. and Bhudeb, R. D. (2006). Flocculation: A new way to treat the waste water. *Journal of Physical Sciences* **10**: 93 – 127.
13. Letterman, R. D., Amirtharajah, A., and O' Melia, C. R. (1999). *Coagulation and Flocculation in Water Quality and Treatment.* 5th edition. McGraw-Hill, New York, pp. 166.
14. Larry D. B., Joseph F. J., Barron L. W. (1982). *Process Chemistry for Water and Wastewater Treatment.* Prentice-Hall Inc. Englewood Cliffs, New Jersey 07632.
15. Chagqing, Y., Dongsheng, W., Baoyou Shi., Jianfeng, Y., Jiuhui, Q., Marc, E. and Hongxiao, T. (2007). Alkalinity effect of coagulation with polyaluminum chlorides: Role of electrostatic patch. *Colloides and surfaces A: Physicochem. Eng. Aspects* **294**: 163 – 173.
16. APHA, AWWA, and WEF (1998). *Standard Methods for Examination of water and wastewater.* 20th Edition, Washington, D.C pp 1 - 68.
17. *Environmental Quality Act 1974 (Act 127) and Subsidiary Legislations, Amendment 5 (May 2003).* International Law Book Service, Kuala Lumpur.
18. Mizanur, R., Mohd. Nasir, H., Mohamed, D. and Zohadie, B. (1999). A prototype expert system for characterizing landfill leachate and treatment processes. In: *Proceedings of the Workshop on Disposal of Solid Waste through Sanitary Landfill Mechanisms, Processes, Potential Impacts and Post Closure Management.* University Putra Malaysia 25th – 26th August 1999, pp. 340.
19. Tchobanoglous, G., Theisen H, Vigil S. A. (1993). *Integrated Solid Waste Management: Engineering Principles and Management Issues.* McGraw-Hill Inc., New York, pp 992.
20. Peter, K., Morton, A., Barlaz, A., Rooker, P., Baun, A., Ledin, A. and Christensen, T. H. (2002). Presence and Long Term Composition of MSW Landfill Leachate: A Review. *Critical Reviews in Environmental Science and Technology* **32** (4): 297 – 336.
21. Nor Asikir, M., and Agamuthu, P., (2007). Characterization and chemical treatment of Taman Beringin landfill leachate. *Malaysian Journal of Science* **26** (1): 43 – 55.
22. McBean, E. A., Rovers, F. A. and Farquhar, G. J. (1995). *Solid waste landfill engineering and design.* New Jersey (N J): Prentice Hall pp 500.
23. Fauziah, S. H. and Agamuthu, P. (2005). Pollution Impact of MSW Landfill Leachate. *Malaysian Journal of Science* **24**: 31-37.
24. Al-Yaqout, A. F., Hamoda, M. F. (2003). Evaluation of Landfill Leachate in Arid

Climate – A case study. *Environment International* **29**: 593 – 600.

25. Li, Y. J., Zeng, X. P., Liu, Liu., Yan, S. S., Hu, Z. H., and Ming-Ya. (2003). Study on the treatment of copper-electroplating wastewater by chemical trapping and flocculation. *Sep. Purif. Technol.* **31**: 91 – 95.
26. Aziz, H. A., Alias, S., Adlan, M. N., Faridah Asaari, A. H., and Zahari, M. S. (2007). Color removal from landfill leachate by coagulation and flocculation processes. *Bioresource Technology* **98**: 218 – 220.
27. Cecen, F., and Gursoy, G. (2000). Characterization of landfill leachates and studies on heavy metal removal, *J. Environ. Monit.* **2**: 436 – 442.
28. Jayabala, M. (2005). Removal of Arsenic from Municipal Landfill Leachate. Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Technology (Environmental Management), Institute of Postgraduate Studies, Faculty of Science, University of Malaya, Kuala Lumpur. Malaysia pp. 145.
29. Urase, T., Salequzzaman, M., Kobayashi, S., Matsuo, T., Yamamoto, K., and Suzuki, N. (1997). Effect of high concentration of organic and inorganic matters in landfill leachate on the treatment of heavy metals in very low concentration level, *Water Sci. Technol.* **36**: 349 – 356.
30. Amitharajah, A and O' Melia, C.R. (1990). *Coagulation Processes: Destabilization, Mixing and Flocculation. In: Water Quality and Treatment.* 4th edition. McGraw-Hill, New York pp 270.
31. Salim, S. S. A. M. (2008). Physico-chemical Treatment of Bukit Tagar Landfill Leachate using Praestol 189 K and Aluminum Chloride. Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Technology (Environmental Management), Institute of Biological Science, Faculty of Science, University of Malaya, Kuala Lumpur. Malaysia pp. 132.
32. Said, N. A. A. (2008). Physico-chemical Treatment of Bukit Tagar Sanitary Landfill Leachate using P-floc 775 and Ferric Chloride. Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Technology (Environmental Management), Institute of Biological Science, Faculty of Science, University of Malaya, Kuala Lumpur. Malaysia pp. 120.
33. Qasim, S. R. and Chiang, W. (1994). Sanitary Landfill Leachate: Generation, Control and Treatment. Technomic Publishing, Lancaster, pp. 323.