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Physico – chemical treatment of Bukit Tagar sanitary landfill leachate using P-Floc775 and Ferric chloride

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ABSTRACT Bukit Tagar Sanitary landfill leachate was characterized and then treated with ferric chloride and P-Floc775, individually. The raw leachate contained high concentration of BOD_5 (27000 mg/L), COD (59000 mg/L), NH_3-N (4300 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). All these parameters exceeded the Malaysian regulatory standard limit of EQA 1974 (Standard A and B). Leachate treatment was optimum with 2g/500ml $FeCl_3$ at pH 7 and mixing speed 100 rpm. It was able to reduce about 100% of Cd, Pb and Cu to below the Environmental Quality (Sewage and Industrial Effluent) Regulation Standard B while Zn was reduced by 89% but was still above standard B. The optimum for P-Floc775 was 2ml/500ml, pH7 and mixing speed 90 rpm. Maximum removal of Cd and Cu was 100% which was below the Environmental Quality Regulation Standard B requirements. P-Floc775 was able to reduce Pb and Zn by 82% and 88%, respectively, which were still above Standard B. Further integrated leachate treatment is recommended to achieve the EQA regulation limits.

ABSTRAK Ciri-ciri larut lesapan dari tapak pelupusan sanitari Bukit Tagar telah dikaji dan dirawat dengan ferric klorida dan P-Floc775 secara berasingan. Larut lesapan mentah tersebut mengandungi kepekatan yang tinggi untuk BOD_5 (27000 mg/L), COD (59000 mg/L), NH3-N (4300 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) dan As (3.6 mg/L). Semua parameter tersebut melebihi tahap piawai Malaysia (EQA' 1974, Standard A dan B). Rawatan larut lesapan adalah optimum dengan 2g/500ml $FeCL_3$ pada pH 7 dan kelajuan campuran 100 rpm. $FeCl_3$ dapat mengurangkan sebanyak 100% Cd, Pb dan Cu sehingga di bawah Piawai B, Akta Kualiti Alam Sekitar (Kumbahan dan Buangan Industri). Sementara Zn dapat dikurangkan sebanyak 89% tetapi masih melebihi Piawai B. Optimum untuk P-Floc775 adalah 2ml/500ml, pH 7 dan kelajuan campuran 90 rpm. Tahap maksima penyingkiran Cd dan Cu adalah 100% di mana ia adalah di bawah keperluan Pengawalan Piawai B, Kualiti Alam Sekitar. P-Floc775 masing-masing dapat mengurangkan Pb dan Zn sebanyak 82% dan 88%, di mana ia masih melebihi Piawai B. Rawatan larut lesapan sepadu selanjutnya dicadangkan untuk mencapai linkungan piawai pengawalan EQA.

(**Keywords**: chemical treatment, landfill leachate, P-Floc775)

INTRODUCTION

Rapid economic growth in Malaysia over the last fifteen years has enhanced the development process of the country. Many changes have taken place due to urbanization and industrialization. Rapid development, an increase in population, rural-urban migration, affluence and the rate of consumption have brought about an increase in waste generation and pollution which has badly affected man and environment. Malaysia has an average waste generation of 0.7 to 1.3 kg per capita and most of these wastes were disposed at 260 landfills through the country [1]. These landfills received around 8 million tonnes/yr of municipal solid waste [2]. Currently, around 31,000 tonnes of municipal solid waste is produced in Malaysia every day and the MSW is highly heterogeneous [3]. The main component is organic kitchen waste which forms about 46% while plastic is 14%.

Landfill leachate is generated when rainwater mixes with the waste in a landfill [4]. It can cause great environmental degradation if it gets into groundwater, because it has large concentration of organic matter (both biodegradable and non-biodegradable carbon), ammonia-nitrogen, heavy metals, and chlorinated organic and inorganic salts. However, some of these pollutants can be degraded by microorganisms [5], while others may not be degraded and may persist in the landfill for long period. It is estimated that the total volume of leacheate generated in Malaysia is 3.0 million per day. The leacheate exhibits extremely high BOD and COD values ramping from 2000 to 30,000 mg/L for BOD and 300 to 60,000 mg/L for COD [3].

Treatment of leachate is an important aspect in municipal waste management system. This is so because of the high ratio of COD/BOD which is 2.2 and ammonia nitrogen (NH_3-N) at 0.43, which posed major difficulties in biological treatment of leachate [6]. The best method of leachate treatment depends on the characteristics of the leachate. There are different methods of treatment of leachate, one of which is the physical - chemical process [7]. In most cases a single technology is not sufficient to achieve permitted level of pollution decrease [8]. Treatment can be a combination of two or more methods such as bio-physico-chemical processes [9, 10, 11, 12]. This combination is popularly used to achieve excellent leachate treatment efficiency [13].

In Malaysia only 10% of the landfills are sanitary while the remaining 90% are either modified dumps or illegal dumping sites. Leachate treatment technique varies with the level of the landfill but is most cases it is still very rudimentary. In Bukit Tagar landfill total integrated system is used, where Physical, Chemical and Biological treatments are in place. Additionally phyto-remediation is employed to enhance the effluent quality to Malaysian standards.

Physiochemical treatments exist for not only removing refractory substances from the leachate, but also, it is counted as a refining pre-step which is required before biological treatment of leachate [14]. These methods are like those used to reduce COD, decrease suspended solids, colloidal particles, floating material, heavy metals, suspended solids and color [15]. For example coagulation and flocculation is used to remove heavy metals and non-biodegradable organic compounds from landfill leachate [16, 17]. In coagulation, the first step destabilizes the particle's charges. Coagulants have opposite charges to those of suspended solids and the coagulants are used in the leachate in order to defuse the negative charges on dispersed solids, which are not settled, like color-producing organic substances and clay [18]. When the charge is neutralized, the small particles which are suspended stick together and increase the size of the particles. Sometimes not all suspended particles are neutralized because the coagulant used is not sufficient [18]. The next step after coagulation is flocculation which effects in the moving particles that are not fixed, to form large flocks so that it can settle down faster.

This study concentrates on leachate generated from Bukit Tagar Sanitary landfill, which is located 50 km from Kuala Lumpur. Bukit Tagar Sanitary landfill received around 1600 tonnes of MSW per day and generated 500-700 m^3 of leachate daily. The landfill has high density polyethylene membrane as the base liner, and a multilayer system is used to ensure complete separation of waste from the ground. The landfill (Bukit Tagar Sanitary Landfill) is 3years old and is 700 acres foot print with 1000 acres buffer zone use, as well as, final cover of 1-meter thickness. The waste disposal here is highly mixed municipal solid waste which is not source separated.

The aim of this study was to establish the leachate characteristics and to investigate the effectiveness of P–Floc775, and $FeCl_3$, as a coagulant (Table 1) to treat the leachate. The study includes physical and chemical characterization and coagulation at different concentration of coagulants, different pH and different mixing speed. This will form the pretreatment before the leachate undergoes more physical and biological treatments.

MATERIALS AND METHODS

Raw leachate samples taken over a period of 5months from Bukit Tagar landfill was analysed to establish the mean characteristics of the leachate. Since Malaysia does not have distinct seasonal variations, the sampling period represents the drier months as well as the monsoon season.

The leachate analysis includes:

1. pH and conductivity, measured using a pH and conductivity probe (Hanna Model, No. 8033).
2. Total suspended solid (TSS), and Colour, determined by using Spectrophotometer, HACH Model (DR/4000).
3. BOD_5, COD, and Total-N were analysed according to Standard Methods APHA, AWWA, and WEF [19].

4. Heavy metals were determined using digested leachate using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES).

Two types of coagulants were used. P-Floc 775 is a relatively new chemical which has not been tested, whereas $FeCl_3$ is a well tested coagulant and it serves as the comparable standard.

Table 1. Characteristics of the Coagulants used

Coagulant	Characteristics
Ferric chloride	Iron (III) chloride is called ferric chloride with the formula $FeCl_3$. It is purple-red and dark green colour. When it is dissolved in water it gives off heat. Iron (III) chloride boils at around 315 °C and it has a relatively low melting point. $FeCl_3$is used in sewage treatment and drinking water production.
P-Floc 775	P-Floc775 is a cationic, polyquatenary amine in water solution. It is a liquid cationic polyelectrolyte of medium molecular weight. It works as a primary coagulant aid in water clarification and as dewatering aid in industrial waste sludge. P-Floc775 affects agglomeration of suspended solids through a combination of various mechanisms such as neutralization and absorption.

Jar Test Trials

1. Six – paddle flocculator from Stuart's scientific (flocculator SW1) was used.
2. 500 mL leachate samples were coagulated using either P – Floc775 (0-12 mL/500mL), or Ferric chloride (0-12g/500mL) as coagulant (Table 1).
3. After establishing the optimum concentration, effect of pH was tested at a pH the range of 4 to 10, for both coagulants.
4. After determining the optimum pH, effect of mixing speed was carried out.
5. The supernatant in all studies were collected and analysed.

All tests were carried out in 4 replicates and the mean results used for discussion.

RESULTS AND DISCUSSION

Raw leachate from Bukit Tagar sanitary landfill (Table 2) contains high concentrations of most of the parameters. The BOD_5 and COD values were 27000 mg/L and 59000 mg/L, respectively and this high readings indicate that there are organic materials in the leachate which are highly biodegradable The ratio of BOD_5/COD of raw leachate was about 2.2 and this value shows that the organic material in the leachate is easily biodegradable [19]. The values of BOD_5 and COD can be considered very high compared to the Sewage and Industrial Effluent Regulation 1979 Standard B requirements [20]. The allowable concentration of BOD_5 and COD Mn (17.85 mg/L), and Se (1.65 mg/L) and all parameters measured also exceeded the regulatory standard limit of EQA 1974 in the regulation is 50 mg/L and 100 mg/L, respectively.

The pH of the leachate sample was 6.6 and this indicates that the landfill is in an acid phase. The acid pH is caused by high production of volatile fatty acids and the high partial pressure of CO_2 [19].

Leachate contains high concentrations of colour 15300 ADMI, total suspended solid (TSS) (13.5 mg/L), and ammonia due to the decomposition of waste mass. The high level of NH_3-N (4300 mh/L) may be due to the decomposition of nitrogenous substances [9], which also indicates that the landfill is in an acidic phase [19]. The leachate also shows high turbidity (3600 FAU) and Suspended Solids as a consequence of organic and inorganic solids present. The presence of high salt concentrations in the leachate are due to the large amount of garbage (food waste) disposed in to the landfill.

Leachate from Bukit Tagar sanitary landfill (Table 2) contain high concentration of heavy metals such as 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 all parameters measured exceeded the regulatory standard limit of EQA 1974 (Standard A and B) [20]. This leachate has also high amount of Ca (397.8 mg/L), K (764.4 mg/L), Na (803.55 mg/L), Mg (29.1mg/L), (Standard A and B)[20] . Sodium is a principle alkalinity metal which tends to stay in solution and is not subject to attenuation. The main reasons for the presence of Na in the leachate are the wide use of Na salts in industry and domestic activity (paper, soap, etc) [19]. Potassium is released during refuse decomposition and the main source of K is plant material and discarded food [19], which is the main component of Malaysian MSW.

The presence of heavy metals in the leachate is due to industrial waste and household non-hazardous waste [21]. Heavy metals if not removed, could cause serious consequences to human beings and the environment. Heavy metals 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). This indicates clearly that need for pretreatment of leachate prior to biological treatment [22].

Some general observations can be made when comparing the Bukit Tagar Landfill leachate with other Malaysian landfill leachate data. For example leachate from Bukit Tagar sanitary landfill and the Taman Beringin Landfill (Table 2) was found to be different. The BOD and COD in Bukit Tagar landfill were 27000 mg/l, 59000 mg/l, respectively which were higher than the BOD and COD in Taman Beringin landfill at 560-1520mg/l, 2050-5230mg/l, respectively. This difference is due to the landfills since BTSC is younger than Taman Beringin Landfill. However, heavy metal concentration in the Taman Beringin Landfill such as Mg, Na and K was higher while the concentration of Ca and Fe in the Bukit Tagar landfill. This could be due to the type of waste disposed, and the phase of the landfill or degradation stage of waste.

Table 2. Characteristics of raw leachate from Bukit Tagar sanitary landfill

PARAMETER	UNIT	Bukit Tagar Landfill Leachate	Taman Beringin Landfill*	EQA 1974 STANDARD	
				A	B
Temperature	°C	29 °C	-	40	40
pH	-	6.6	8.07- 8.5	6.0 – 9.0	5.5 – 9.0
BOD_5 at 20 °C	mg/l	**27000**	**560-1520**	20	50
COD	mg/l	**59000**	**2050-5230**	50	100
Total Solid, TS	mg/l	1719	1380-2070	N.A.	N.A.
NH_3 - N	mg/l	**4300**	**-**	50	100
Turbidity	FAU	3600	-	N.A.	N.A.
Conductivity	μ^5/cm	670	12.6-34.6	N.A.	N.A.
Salinity	(%)	0.3	-	N.A.	N.A.
Colour	ADMI value	15300	-	-	-
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
Aluminium (Al)	mg/l	15.75		N.A.	N.A.
Calcium (Ca)	mg/l	397.8	63-166	N.A.	N.A.
Potassium (K)	mg/l	764.4	1660-1940	N.A.	N.A.
Iron (Fe)	mg/l	**84.3**	**7-9**	1.0	5.0
Sodium (Na)	mg/l	803.55	4200-5640	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	34-81	N.A.	N.A.

*Source: Agamuthu, 2001

Figure 1(a) shows that the optimum concentration of $FeCl_3$ was 2g/500mL. Removal of turbidity was about 75%, while the removal of colour and TSS was 70% and 78%, respectively. However the removal of Cd, Pb, and Cu was 100% using $FeCl_3$ while the Zn removal was 91%. The optimum concentration for P-Floc775 was 2mL/500mL (Figure 1b). Removal of turbidity, colour and TSS were 71%, 66% and 67% respectively while the removal of Cd and Cu was !00% while Pb and Zn was 89% and 87%, respectively.

Figure 1. (a)

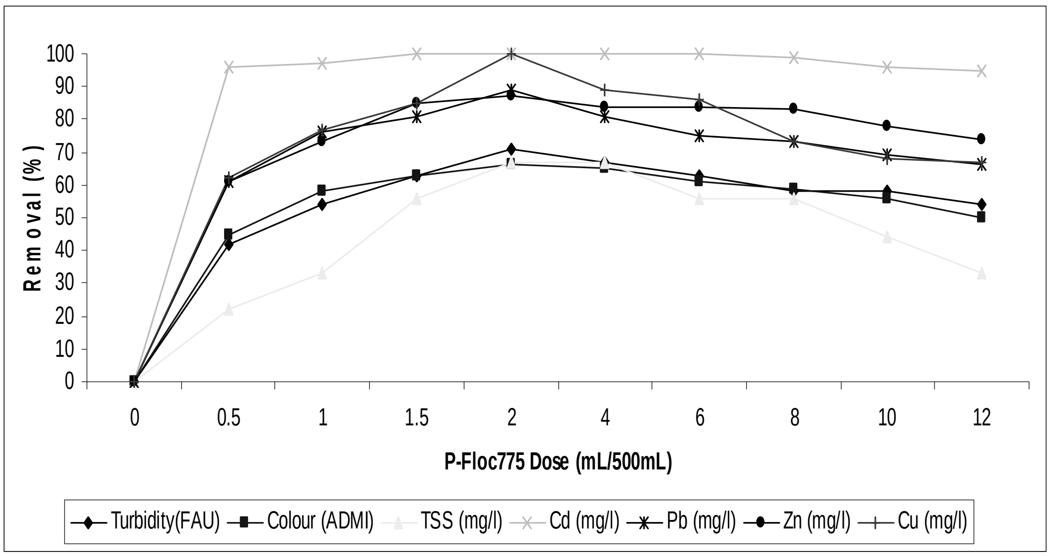
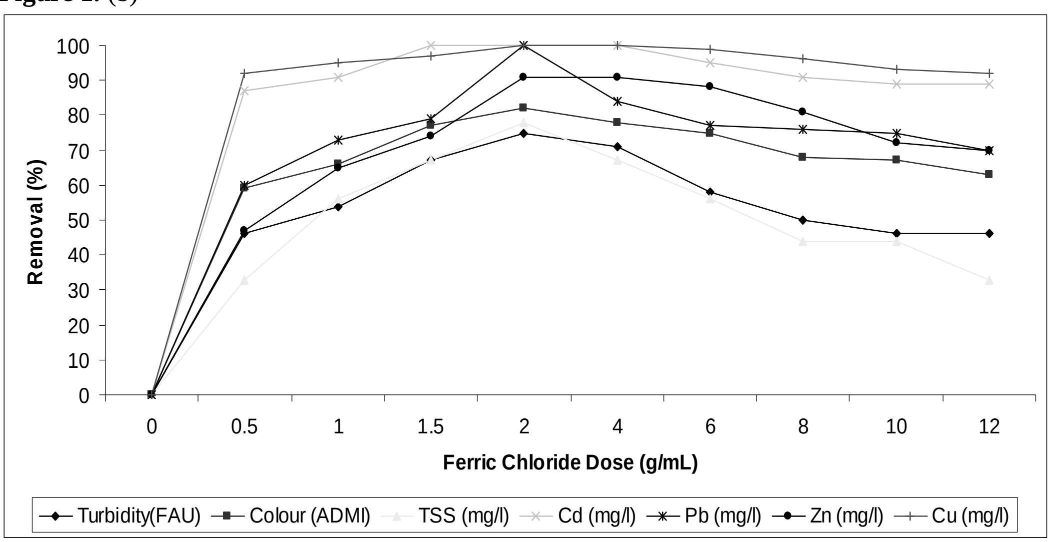


Figure 1. (b)



Study by Hamidi et al., [22] found that the removal of all parameters increased with increased dosage of coagulant (200 mg/L of FeCl3) such as the removal of colour, turbidity, and suspended solids. Similar research was performed by Kargi, and Pamukoglu, [16], who reported that the best removal capacities for TSS was up to 80% at 1.5 g/L (without pH adjustment) when coagulant were added to stabilized leachate. However, Nor Asikir and Agamuthu, [2] stated that $FeCl_3$ was able to remove 85% of Pb, 88% of Cu, 90% of Al, and 92% of Zn at the optimum dosage of was 4g / 500 mL. Also, Jayabala, [23], who used $FeCl_3$, reposted the reduction of Cd at 83.3 % at 60 mg/L. these findings tally with the range of reduction reported in this research.

Figure 2 (a and b) show the effect of pH on various parameters after treatment with $FeCl_3$ and P-Floc775. The maximum removal of pollutants using $FeCl_3$ and P-Floc775 was at pH 7. The finding of this study is similar to the finding by Nor Asikir and Agamuthu, [2] who established that the optimum pH in reducing pollutants by $FeCl_3$ was 7. Ferric chloride was able to remove 97% of Pb, 90% of Cu, 82% of Al, and 80% of Fe. Jayabala [23] found that Ferric chloride reduced 94% of Cd, 99.8 of As, and 94% of Fe at pH 6. However, Tatsi et al., (2003) [16] found that the color removal was almost 100%, during the addition of ferric chloride to stabilized leachate, especially when pH was adjusted at 10. Slightly lower efficiencies (up to 93%) were measured for fresh leachate samples, while Letterman et al., [24], stated that the optimal pH is dependent on the leachate characteristics, and it is normally 7-9 for $FeCl_3$.

Figure 2. (a)

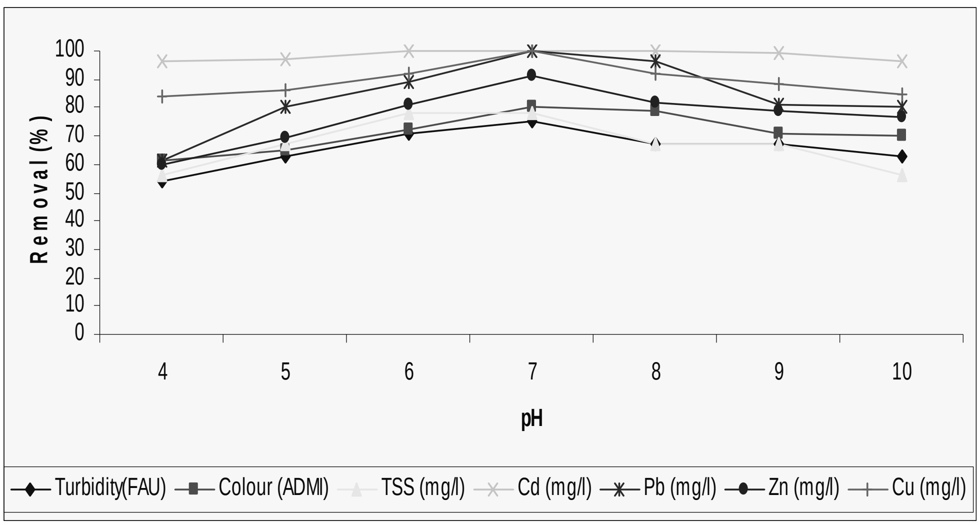
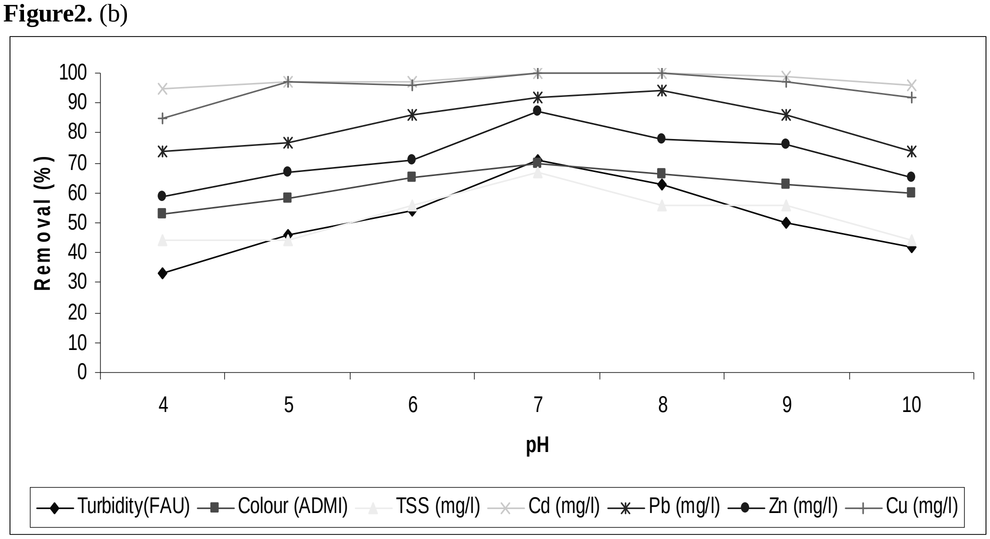


Figure2. (b)



The effects of mixing speed ranging between 60 – 110 rpm are given in Figures 3a and 3b. The optimum mixing speed for removal of pollutants using $FeCl_3$ was 100 rpm while the optimum mixing speed for P-Floc775 was 90 rpm. Rapid mixing ensures the total mixing of the coagulant in the solution whereas slow mixing cause the agglomeration of the flocs produced during the rapid mixing [2]. Nor Askir and Agamuthu, [2], established that $FeCl_3$ was able to reduce about 78% of Pb, 80% of Cu, 74 % of Zn, 70% of Fe and 80 % of Al, at mixing speed of 40-50 rpm, as compared to $FeCl_3$ in this research which reduced 100% Pb, 89% Zn, and 100% of Cu. $FeCl_3$ removal in this study was more efficient, probably due to differences in the leachate composition.

Comparative optimum conditions for the removal of pollutants in terms of concentration, pH and mixing speed for each chemical are shown in Table 3. The pollutant removal efficiency for the parameter studied are also summarized for comparison.

Figure 3. (a)

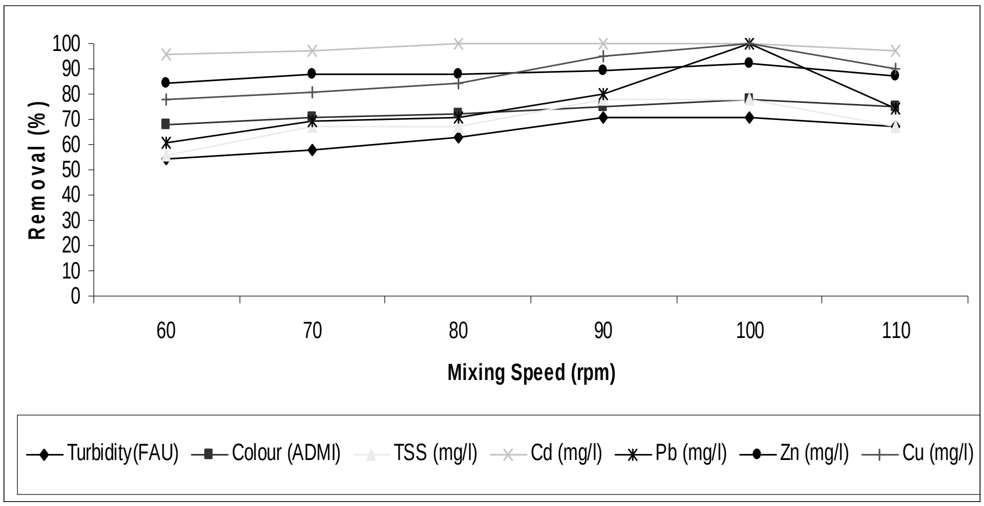


Figure 3. (b)

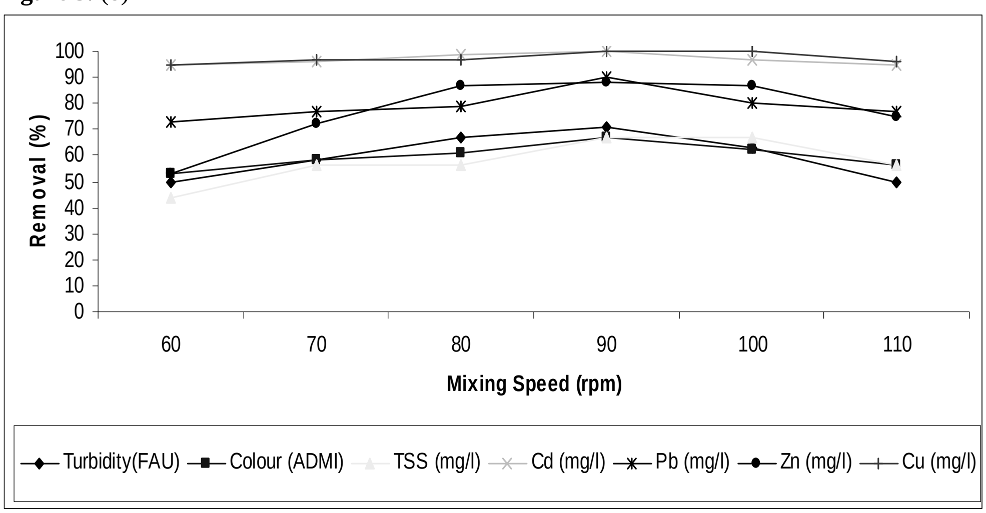


Table 3. Comparative removal of pollutants by each coagulant/flocculant at optimum conditions

Chemical & Optimal Condition		% removal Turbidity	Colour	TSS	Cd	Pb	Zn	Cu
P-Floc 775	Concentration 2mL/500mL	71	66	67	100	89	87	100
	pH 7	71	70	67	100	92	87	100
	Mixing speed 90rpm	71	67	67	100	90	88	100
Ferric chloride	Concentration 2g/500mL	75	82	78	100	100	91	100
	pH 7	75	80	78	100	100	91	100
	Mixing speed 100rpm	71	78	78	100	100	92	100

CONCLUSION

Leachate from BTSL demonstrated high quantity of COD, BOD, NH_3-N, and heavy metals such as Cd, Pb, Zn, and Cu. All the parameters examined were above the EQA 1974 (Standard A and B) limit. Two coagulants/flocculants ($FeCl_3$, and P-Floc775) were able to reduce heavy metal concentration from leachate. In general, $FeCl_3$ was the most effective coagulant. $FeCl_3$ performed optimum at 2g/500ml, pH 7 and 100 rpm mixing speed while the optimum reduction by P-Floc775 was at 2ml/500ml, pH 7 and 90 rpm mixing speed. However after treatment by both coagulants/ flocculants some parameters still exceeded the requirements of Standard A and B of the EQA [24], hence it needs further treatment as is being implemented, to meet the Malaysian Standards requirements.

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