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Coagulation-Flocculation of Leachate by Using Single Coagulant Made from Chemical Coagulant (Polyaluminium Chloride) and Natural Coagulant (Tapioca Flour)

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Abstract: Application of coagulation and flocculation in leachate treatment is common nowadays. Chemical coagulant is commonly applied compared to natural coagulant. Thus, this study compared the effectiveness of landfill leachate treatment by single coagulant which are chemical and natural coagulant through the removal of suspended solid (SS), sludge settling rate and sludge volume index. The experiment was carried out using standard jar test method and raw leachate sample was collected from Landfill Simpang Renggam. The chemical coagulant used was polyaluminium chloride and natural coagulant was Tapioca flour. Tapioca flour has characteristic as coagulant where it has sticky characteristic that can remove pollutant in leachate without leaving any side effects latter and it is available in abundance, cheaper, and environmentally friendly. Result of this study shown that, the optimum dosage and pH of PAC was 3g/L at pH 8 and for tapioca flour was 1g/L at pH 4. The percentage removal by PAC as in term of removal of suspended solid, sludge volume index and sludge settling rate were 94%, 5273 mL/gm and 1.58 cm/min, respectively. While, for tapioca flour there was minimal sludge formation and the removal of SS was 13.3%. The particles size for sludge leachate after treatment for optimum dose was in range of 20µm and the floc were arranged compacted, and shaped elongated. Hence, this study shows that PAC is more effective than Tapioca flour as single coagulant in terms of sludge volume index, sludge settling rate, removal of suspended solid and particle size of sludge.

Keywords: Malaysia landfill, bio-coagulant, organic coagulant

1. Introduction

Nowadays, increasing in solid municipal solid waste has causes some serious circumstances to the country. The increase in the population and urbanization resulted in tremendous amount of solid waste generation. This implication requires a better handling solution to reduce the generation of waste. A regular waste management framework in a country demonstrates numerous issues, including low accumulation scope and crucial gathering management, untreated open

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dumping and consuming without air and water contamination control and control of casual waste picking or rummaging exercises [1]. Furthermore, a better classification system for landfills is needed to address inconsistencies in data for sanitary landfill sites. Changes in municipal solid waste generation rates are mostly caused by the demographic factors sand facilities which are provided by the respective department. In addition, the composition of municipal solid waste in Malaysia extremely non-homogenous and varied caused by difference between cities as the level of industrialization and consuming habits. This signify the level of urbanization and rapid development of the country. Leachate is referred to as high quality wastewater framed because of permeation of water and dampness through waste [2] and may cause significant pollution.

Decomposing waste at the landfill site create major environmental problems. Landfill leachate categorized as high strength wastewater with large variables of organic, inorganics and heavy metal. The water quality affected as leachate percolates and mixs surface run off [3]. The high concentration of ammonia and heavy metals in leachate affected the biological process of microorganism [4]. The quality of landfill leachate depends on several factors such as composition and types of waste, moisture and oxygen content, design and operation of landfill sites and age of landfill [4]. Due this problem, Malaysia is facing a difficulty to obtain a satisfactory treatment for landfill leachate.

The primitive pollutant of leachate is dissolved organic matter, inorganic macro components, heavy metals, and xenobiotic organic compounds. To minimize toxicity and hazardous material content of landfill leachate before discharged into the environment, various methods were used to treat leachate such as biological treatment, chemical and physical treatment, and combined treatment [5].

Coagulation/flocculation is commonly applied for water and wastewater treatment. This method is also classified as conventional treatment method. It involved simple process. One of the main factors determining the effectiveness of this system is the coagulant. Coagulant can be divided into chemical and natural coagulant. Chemical coagulant is made from chemical material and commercially available such as alum, polyaluminium chloride, polyferric chloride and ferric chloride [6]. While natural coagulant or natural polymer is organic and consist of polysaccharides and proteins elements [7]. Both types, has difference efficiency performance. Thus, it is important to know how effective each of coagulant react toward leachate. The purpose of this paper is to study the effectiveness of two different coagulant (PAC and Tapioca Flour) on the removal of suspended solid, sludge volume index and sludge settling rate for leachate treatment.

2. Methodology

The landfill leachate used in this study was taken from Simpang Renggam municipal landfill site in Johor. The total area of the landfill is 28 hectares. The landfill has been operating for 10 years. Simpang Renggam municipal landfill received about 250 tonnes of solid waste every day from three different districts. All analytical procedures were performed according to the Standard Method of Water and Wastewater APHA [8]. The collection of leachate was using a pump (submersible pump) which submerged at a depth 0.3m from the surface of leachate. Samples were transported to the laboratory of Civil and Environment Engineering Analysis, Universiti Tun Hussein Onn Malaysia (UTHM) and stored at 4^{o}C for further analyses. Coagulation and flocculation process were performed in a standard jar-test apparatus.

The characteristics of landfill leachate measured in this study is shown in Table 1. The leachate is considered as old leachate and stabilized leachate (Table 2). For this type of leachate, the favorable treatment method is physical/chemical, such as coagulation/flocculation. Thus, Simpang Renggam leachate suit the method proposed for this study.

Sodium chloride and sulfuric acid were used to adjust the pH of the leachate (1000 ml). The prescribed dose of coagulant was added to each jar. At beginning, start stirring rapidly with (200 rpm) for 4 minutes (Rapid mixing stage). After that, reduced the speed to 30 rpm for 15 minutes. Supernatant was collected after 30 minutes of settling time. At the end of settling, sample of sludge was collected for SEM measurement. To determine the sludge volume index (*SVI*) equation 1 was used to plot the graph.

$$SVI = \frac{\left(SV/V\right)}{\sum SS} \times 1000 \quad (1)$$

where *SVI* is in mL/gm, *SV* is the settle sludge volume in (mL), *V* is volume of sample in *L* and *ΣSS* is the total suspended solids in mg/L.

For determination sludge settling rate (*SSR*), the sludge was allowed to settle and measured according to time intervals. Then, plotted sludge height versus time. The sludge settling rate was determine by using following formula:

$$VS = \frac{mh}{V} \quad (2)$$

where *VS* is the velocity sludge, *m* is slope of the graph, *h* is initial height of sludge and *V* is initial volume of sludge.

Table 1 - Characteristics of Simpang Renggam landfill leachate.

Parameter	Initial Characteristics
Suspended Solids (SS)(mg/L)	123-166
Turbidity (NTU)	25- 80.1
Colour (Pt.Co)	2400-7200
pH	7.68-8.60
BOD/COD	0.05
Ammonia (mg/L)	920
Number of sample	6
Duration of sampling	February – April 2018

Table 2 - Characteristic of leachate based on age [9].

Leachate type	Young	Medium	Old
Landfill age area	<5	5-10	>10
pH	<6.5	7	>7.5
COD (mg/L)	>10,000	4,000-10,000	<4,000
BOD_5/COD	0.5-1.0	0.1-0.5	<0.1
TOC/BOD	<0.3	0.3-0.5	>0.5
Ammonia nitrogen (mg/L)	<400	-	>400
Heavy metals (mg/L)	Low - medium	Low	Low
Biodegradability	Important	Medium	Low

3. Results and Discussion

3.1 PAC

The initialization of the experiments was carried out with optimization doses of PAC as single coagulant, the pH of sample was set to 7. Doses of PAC with range 1g/L – 6g/L was used in this study. According to measured data, doses of PAC at 4g/L and 3g/L show great removal as shown in Fig. 1. The removal differences between dose 3g/L and 4g/L were not large. Thus, 3g/L was selected as optimum dose due to economical factor and less dose usage. The optimum dose of PAC in term of SVI and SSR with varied dosage were shown in Fig. 2 and Fig. 3. Hence, the result for optimum dosage of dose 3g/L in terms of suspended solid removal, SVI and SSR were as 98% , 4561mL/gm ,and 0.8cm/min, respectively. Removal of SS in this study is similar with Ghafari et al. [10].

The removal of suspended solid increased as the dosage of PAC increased until the trend reached the optimum at 99% removal (dose 4g/L) and after that the removal gradually decreased. This has been supported with justification by Hamidi et al. [11] as excessive amount of coagulant causes re-stabilization of colloid instead of re-dispersion of the colloidal particles actually occurs.

Moreover, according to Noor Ainee et al. [12] amount of coagulant depends on magnitude of electrical charge on the colloidal particles and if there are more organic matter with negative charges, larger coagulant amount needed. Furthermore, with increasing in coagulant dose, SVI also increased gradually (Fig. 2).

Furthermore, the faster SSR is at dose 1g/L and the slowest SSR is at dose 5 g/L, apparently in terms of removal of SS at dose 1g/L was 49% and dose 5 g/L was at 89% (Fig. 1). However, the highest removal of SS for dose 4g/L and dose 3 g/L were 99% and 98%, respectively (Fig. 1). Based on the data, as more dose of chemical coagulant added, it decreased the SSR and increased the floc growth [13]. High coagulant dose is favorable in removing suspended solid and it is adverse for settling process since it reduces the sludge settling rate, generating larger volume of compacted sludge [14].

After varying the coagulant concentrations of PAC further test was carried out by testing different pH of samples in the range of 3 to 8 at dosage 3g/L and 4 g/L of PAC. For 3 g/L PAC, with the change of the pH, the highest suspended solids removal rate was achieved at pH 7. While, pH 8 recorded 94% removal as shown in Fig. 4. From the result of the analysis, the highest removal of suspended solid was at pH 7, with 99% removal. In terms of SVI, pH 3-6 were neglected due to high acidic content and pH 7-8 were taken into consideration. It was found out that the SVI values for pH 7 is higher than pH 8 and signify that pH 8produced less and thicker sludge, consolidated sludge and the settling rate also was faster than pH 7 as shown in Fig. 5 and Fig. 6. Hence, pH 8 was selected as optimum pH. Optimum pH selected is within the range of initial pH of leachate (Table 1), thus reducing the cost of pH adjustment during treatment.

As for dose 4g/L the highest removal of suspended solid for varied pH was at pH 8 (98%) as shown in Fig. 7. While, pH 7 achieved 97% suspended solid removal. SVI value for pH 8 and pH 7 were 4439 mL/gm and 3886 mL/gm, respectively. As for, SSR value of pH 8 and pH 7 were 0.4 and 0.43, respectively (Fig. 8). The sludge settling rate of pH 7 and pH 8 were not much differs (Fig. 9) and it settles at same rate and as well as SVI too. Hence, pH 7 recorded less value of SVI and higher value of SSR compared to pH 8. Thus, PH 7 is selected as optimum pH for dose 4g/L.

SVI lower value is preferable for coagulation treatment as it able to reduce the sludge volume and directly reduce the sludge treatment cost. While for SSR, highest value is needed for faster treatment duration. However, the selection of optimum condition should consider overall factors, which are suspended solid removal, SSR and SVI. Thus, pH 8 at dose 3 g/L is selected as optimum condition for PAC.

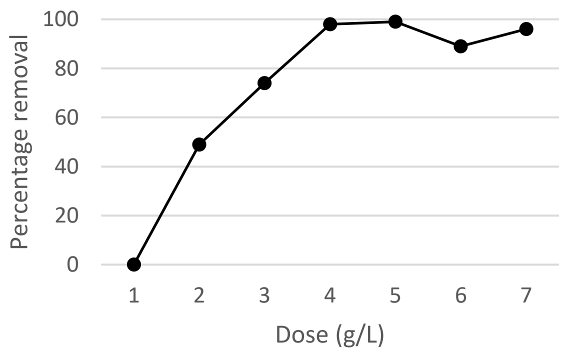

Fig. 1 - Removal of suspended solid of varied dose of PAC at pH 7.

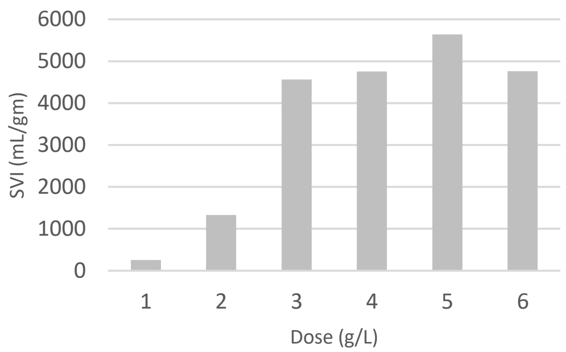

Fig. 2 -SVI of varied dose of PAC at pH 7.

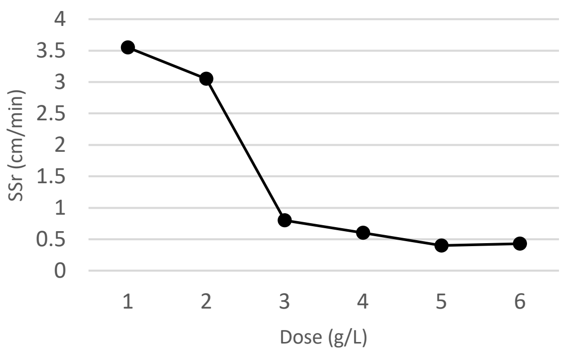

Fig. 3 - SSR of varied dose of PAC at pH 7.

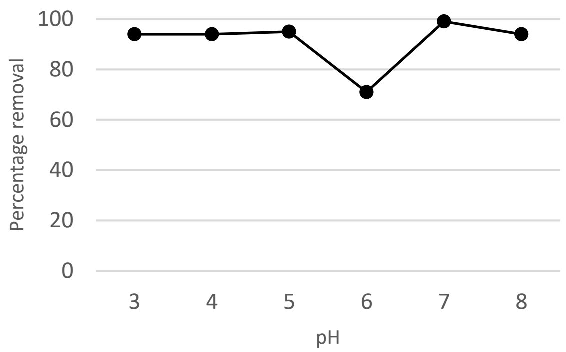

Fig. 4 Percentage removal of suspended solid of varied pH at dose PAC 3g/L.

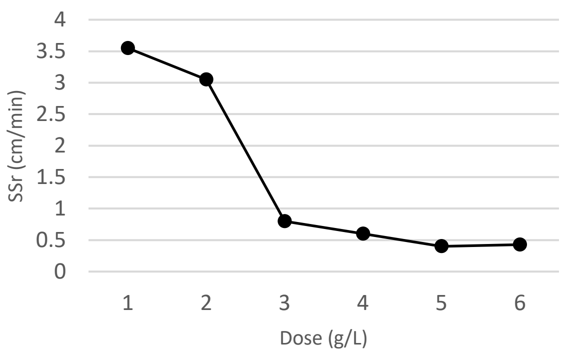

Fig. 3 - SSR of varied dose of PAC at pH 7.

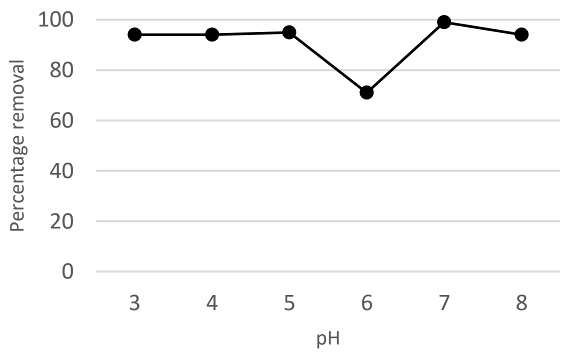

Fig. 4 Percentage removal of suspended solid of varied pH at dose PAC 3g/L.

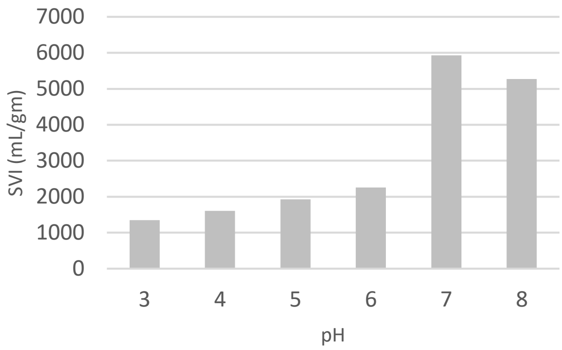

Fig. 5 - Sludge volume index of varied pH at dose PAC 3g/L.

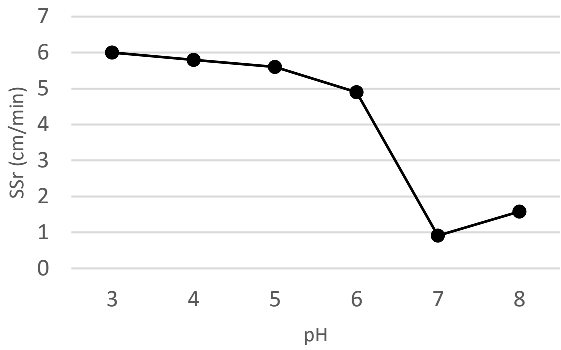

Fig. 6 - Sludge settling rate of varied pH at dose PAC 3g/L.

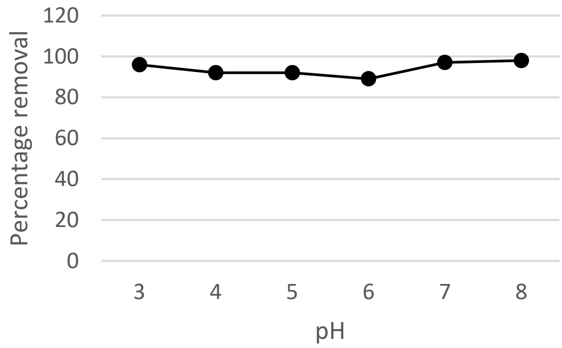

Fig. 7 - Percentage removal of suspended solid of varied pH at dose PAC 4g/L.

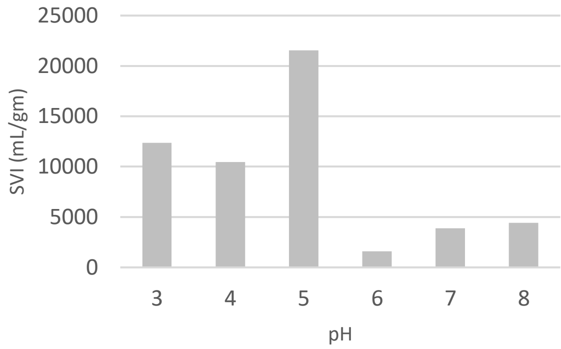

Fig. 8 - Sludge volume index of varied pH at dose PAC 4g/L.

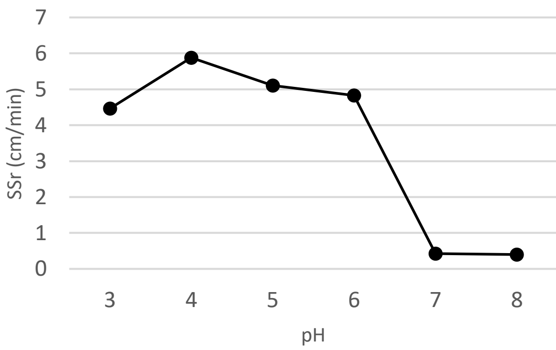

Fig. 9 - Sludge settling rate of varied pH at dose PAC 4g/L.

3.2 Tapioca Flour

In the case of tapioca flour as single coagulant, the experimental runs were conducted at pH 6. According to Zin et al. [15], the starch coagulant seems to be more efficient in acidic condition. Doses of tapioca flour with range 0.2g/L – 1.2g/L was used in this study to identify the optimum dosage. The maximum removal of suspended solids was observed at pH 6 with dose of tapioca flour at 1g/L with percentage removal of 15.4% as shown in Fig. 10. The removal of suspended solid using tapioca flour was low.

Furthermore, it is clearly showing that, tapioca flour is not strong enough to remove the pollutant in leachate. At initial dose of 0.2g/L it seems there was minimal removal occurred and was increasing slightly till it reached the optimum dose and it goes down gradually. According to Alias et.al [16], there was no removal found at dose 0.2g/L and it is approximately similar to this. However, the optimum dosage for tapioca flour was 1g/L.

In terms of settle ability parameters, there was minimal sludge formation when using tapioca flour as a coagulant. This is because starch ions were not highly positive like the chemical coagulant to bond with negatively charged particles in leachate. Tapioca flour produce low floc volume and in terms of mechanism it was not charge neutralization, but it was more into particle bridging [17]. Thus, no data of SVI and SSR were recorded for tapioca flour.

After the varying the dosage of tapioca starch, pH adjustment was done to determine the optimum Moreover, according to Lo [18], a starch coagulant usually works well in highly acidic and alkaline conditions. The highest removal of suspended solid was recorded at pH 4 as 13.3% shown in Fig. 11. The trend of graph was decreasing gradually till pH 7 and then pH 8 the removal was increased slightly. This has proved, the justification of Lo [18] and Zin et al. [15], where the starch coagulant works well in acidic and alkaline condition. PH 4 was selected as optimum condition for TF.

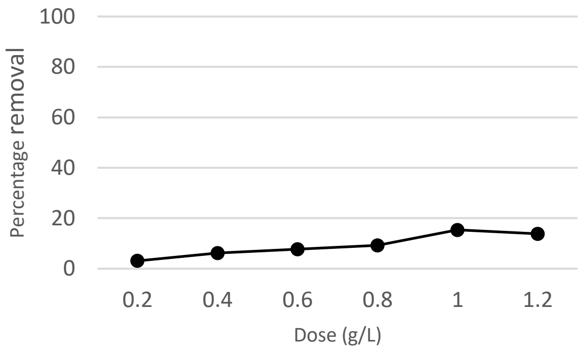

Fig. 10 - Removal of suspended solid of varied dose of tapioca flour at pH 6.

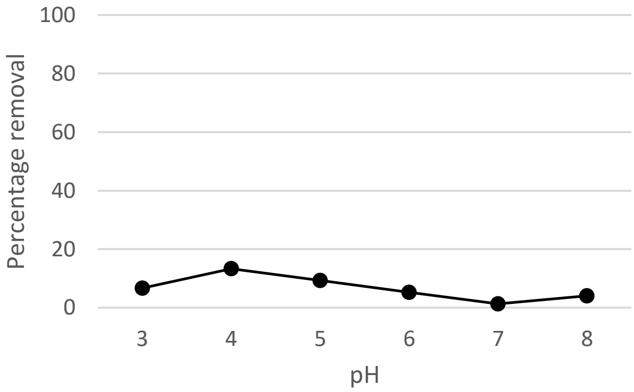

Fig. 11 - Removal of suspended solid of varied pH at dose 1.0g/L of tapioca flour.

3.3 Scanning Electron Microscopic (SEM) of Sludge After Treatment

Fig. 12 is a SEM image of sludge after treatment at dose 3g/L of PAC and pH 8 of leachate. It was found that the floc was agglomerated into various size and shapes and the range size of particles were from 2.5µm to 10µm. The shape of particles were nonuniform and shaped elongated. Furthermore, the floc formation looked compacted.

3.4 Comparison of Percentage Removal of Suspended Solid Between Polyaluminium Chloride and Tapioca Flour as Single Coagulant

Comparison of percentage removal was conducted as shown in Table 2. From Table 3, the most effective dose of PAC as single coagulant is 3g/L at pH 8 and optimum dose for tapioca flour as single coagulant is 1g/L at pH 4. The percentage removal by PAC as single coagulant in term of suspended solid is 94% compared with tapioca flour is only 13.3%. Thus, it shows that PAC is more effectives than tapioca flour as single coagulant.

Polyaluminium chloride as single coagulant is more effective in removing suspended solid of leachate and has better formation of sludge compared to tapioca flour. Even though, there is a lot of advantages of using natural coagulant which has been discussed but in terms of removal of suspended solid and the efficiency is at stake compare the chemical coagulant, polyaluminium chloride. Hence, it is concluded that polyaluminium chloride has shown the potential as best coagulant compare to tapioca starch in terms of removal of suspended solid, sludge volume index and sludge settling rate.

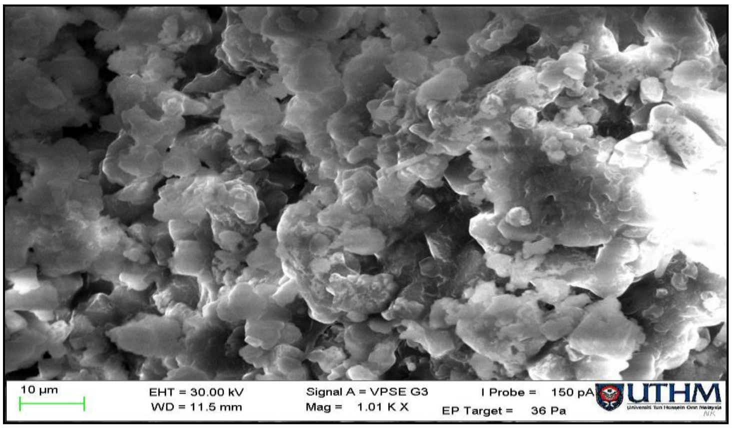

Fig. 12 - SEM image sludge leachate at dose 3g/L of PAC.

Table 3 - Comparison of percentage of removal of PAC and TS as single coagulant.

Coagulant	pH	Optimum Dose (g/L)	Percentage Removal of Suspended Solid (%)	Sludge Volume Index (mL/gm)	Sludge Settling Rate (cm/min)
Polyaluminium Chloride (PAC)	8	3	94	5273	1.58
Tapioca flour/starch (TS)	4	1	13.3	No data	No data

4. Summary

The coagulation - flocculation process has shown the used of PAC as coagulant was more effective in landfill leachate treatment compared to tapioca flour. The optimum of PAC dosage is at 3g/L was observed and yields a good suspended solid (SS) removal and other settleability parameters. The removal of SS, SVI, and SSR for optimum PAC were 94%, 5273 mL/gm, 1.58 mL/min, respectively. Results showed that PAC as single coagulant was more effective for leachate treatment. As for natural coagulant, Tapioca flour was ineffective as single coagulant and might works as coagulant aid in the leachate treatment.

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