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Removal of Ammonia and Colour from Stabilized Leachate by using Aerated Chemical Coagulation

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Abstract: The amount of Municipal Solid Waste (MSW) produced in Malaysia increased from year to year due to urbanization. This causes the landfill to receive a large amount of MSW beyond its capacity. As a result, landfill produce leachate which contains various substances. This study utilized an Aerated Chemical Coagulation (ACC) technique as a leachate treatment to cope with leachate management. This method remove ammonia and colour from stabilized leachate under the influence of Polyaluminium Chloride (PAC) dosage, pH and aeration rate. Samples of leachate have been analysed to get the characteristics of leachate. In addition, the efficiency of ACC was compared to single aeration and single chemical coagulation in removing ammonia and colour. This comparison was determined based on influence of aeration rate, aeration duration, PAC dosage, pH and mixing duration. Based on the result, the optimum value for ACC under the influence of PAC dosage, pH and aeration rate were 400 mg/L, pH 5 and 1.0 L/min. ACC showed the best removal of ammonia with 77% while single chemical coagulation removed colour better than ACC and single aeration with 83%. The optimum colour and ammonia removal obtained from ACC was not achieve the standard of EQR 2009. If other treatment can be integrated with ACC, probably it can achieve the effluent standard for colour and ammonia. As conclusion, ACC has a potential to treat old leachate based on the removal parameters which were ammonia and colour.

Keywords: Landfill, Leachate, Aeration, Coagulation

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1. Introduction

Malaysia was one of the developed countries in the South East Asia region. In 2016, the Gross Domestic Product (GDP) of Malaysia was 4.2 %, which is significantly higher than the global average of 2.49 % and almost equal to South East Asia's average of 4.62 % [1]. The effect of this generated a massive amount of Municipal Solid Waste (MSW). MSW waste comprises as food waste, building waste and plastic discarded by the public [2]. To manage the situation due to the increase in the amount of MSW produced, the number of landfills also increased to balance the amount of MSW produced and the community's well-being. However, each landfill produced leachate that was capable of having an adverse impact on the environment. Landfill leachate is also defined as a highly polluting liquid that will damage the groundwater and surface water in the area around a landfill [3]. The characteristic of leachate consists of moderate – high Chemical Oxygen Demand (COD), pH, and heavy metals concentration [4].

Ammonia was one of the pollutants with a high concentration compared to other substances in the landfill leachate [5]. Therefore. leachate needs to be treated before being discharge as it could pollute environment and harm the population in the landfill area. In addition, ammonia impacted the efficiency of leachate treatment when the ammonia content is still high even after going through the leachate treatment process [5].

For this study, an improvement has been used to treat leachate combined with chemical coagulation and aeration. Based on a recent study, ACC can reduce chemical substance in wastewater such as Total Suspended Solid (TSS) and colour [6]. Therefore, ACC be used as leachate treatment in the leachate treatment plant. The parameters which have been taken as removal parameters were ammonia and colour. In this study, the optimal value of ACC has been taken under the influence of PAC dosage, pH and aeration rate. In addition, the efficiency of ACC has been compared with single chemical coagulation and single aeration. Lastly, the ACC optimal removal parameter were ammonia and colour compared with Environmental Quality (Control of Pollution from Solid Waste Water Transfer Station and Landfill) Regulation 2009.

2. Materials and Method

The study is divided into two parts. The first involves assessing leachate characteristics by conducting laboratory tests with parameters and landfill tests. The second part includes improvised chemical coagulation and aeration method as leachate treatment using Polyaluminum Chloride (PAC) as a chemical coagulant.

2.1 Location of study

For this study, the raw leachate sample was taken at CEP Simpang Renggam Landfill (SRL), located in Kluang District, Johor, Malaysia. SRL is near the village areas of Kampung Sungai Sayong, which was about 3 kilometres from the landfill, and Bandar Renggam, which was around 2 kilometers from the landfill.

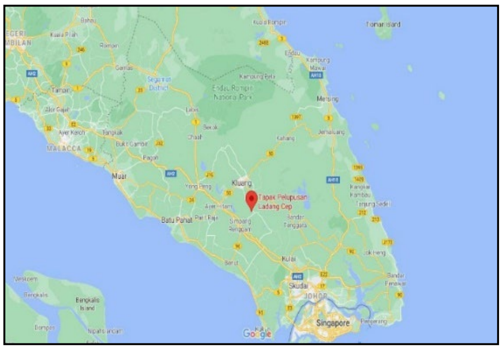

Figure 1: Location of CEP Simpang Renggam Landfill

2.2 Leachate sampling and storage

The sampling and storage of leachate samples were performed according to the Standard Method for the Examination of Water and Wastewater. The raw leachate samples were obtained from SRL using High-Density Polythene (HDPE) bottle. The sample of raw leachate was sent to the Universiti Tun Hussein Onn Malaysia (UTHM), Micro Pollutant Research Centre (MPRC) and kept at 4 ºC in cold room for analysis. Each sample of the bottle was labeled and stored in the cold room.

2.3 Leachate characteristics

The purpose of leachate characteristics is to determine the type of leachate in the location of the study. The leachate sample was taken for three months. In this study, pH, Chemical Oxygen Demand (COD), Suspended Solid (SS), Dissolve Oxygen (DO), turbidity, ammonia and colour were determined using multi-parameter probe and DR6000 HACH spectrometer for characteristics of leachate [7]. The chemical reagent used for this study were reagent Nessler, polyvinyl alcohol and mineral stabilizer for ammonia parameter while for COD parameter, Sulphuric Acid, Potassium Dichromate and Mercuric Sulphate.

2.4 Experimental work

In this study, Aerated Chemical Coagulation (ACC) method had been implied to remove ammonia and colour in the leachate. According to Zailani and Zin, ACC method was a combination of the chemical coagulation method and aeration [7]. Before the experimental work started, ammonia and the colour of the leachate were measured first to get the initial reading. A 750 ml sample using 1Litre beaker for leachate sample has been used in this study. The leachate sample was poured into the beaker, and the magnetic stirrer was placed as a stirrer controller at 200 rpm. Polyaluminium Chloride (PAC) has been used as chemical coagulant for chemical coagulation to determine optimum conditions. Air from the air pump was pumped into the beaker containing the leachate sample. The air flow meter attached to the air pump as controller for adjusting purpose. Figure 2 shows the setup of the aerated chemical coagulation process.

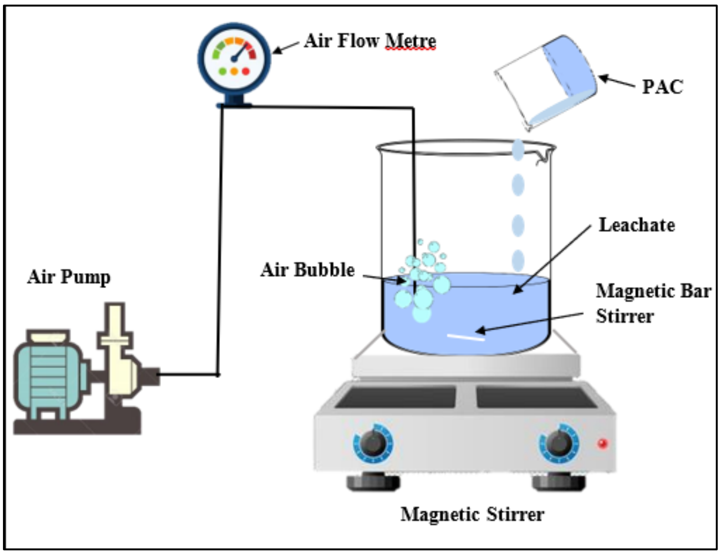

Figure 2: Schematic diagram for aerated chemical coagulation

2.4 Optimization of aerated chemical coagulation, single chemical coagulation and single aeration.

Table 2 shows the optimization under the influence of PAC dosage, pH, mixing duration, aeration rate and aeration duration for every method.

Table 2: The value of optimization for ACC, single chemical coagulation and single aeration

	ACC	Single chemical coagulation	Single aeration
PAC dosage	100 mg/L – 600 mg/L	100 mg/L – 600 mg/L	-
pH	4 - 9	4 - 9	-
Aeration rate	0.5 L/min – 3.0 L/min	-	0.5 L/min – 3.0 L/min
Mixing duration	-	5 min – 60 min	-
Aeration duration	-	-	5 min – 60 min
References:	[9],[10],[11]	[9],[10],[12]	[11],[13]

2.5 Comparison of Aerated Chemical Coagulation (ACC) with single chemical coagulation and single aeration

The efficiency of Aerated Chemical Coagulation (ACC) was compared with single aeration and single chemical coagulation. This comparison was determined based on the influence of aeration rate, aeration duration, PAC dosage, pH and mixing duration.

2.6 Comparison of aerated chemical coagulation performance with effluent Environmental Quality (Control of Pollution from Solid Waste Water Transfer Station and Landfill) Regulation 2009.

The parameters measured in this study which were ammonia and colour. These two parameters were compared to Environmental Quality (Control of Pollution from Solid Waste Water Transfer Station and Landfill) Regulation 2009.

3. Results and Discussion

In this section, the results of the experiments have been assessed using the parameters that have been set.

3.1 Characteristic of landfill leachate

The parameter that has been taken to determine the characteristic of leachate and the sample was taken on October 2021, November 2021 and December 2021. Table 3 show landfill leachate characteristics at CEP Simpang Renggam Landfill (SRL). The data were obtained within the range stated by past studies pH more than 7.5 and COD less than 4000 mg/L. [14]. Based on a recent study, the value of pH and COD obtained was within the characteristic of old leachate [15]. The pH range was obtained greater than the required characteristic value which was 7.5 [16] The average COD value was obtained was greater than the recent study. As a conclusion, this leachate was suitable for this study. ACC was a physical - chemical treatment method ideal for intermediate and old leachate.

Table 3: The characteristics of Simpang Renggam Landfill

Parameter	Range	Average
pH	8.10 – 8.31	8.18
DO (mg/L)	1.67 – 2.66	2.21
COD (mg/L)	520.50 – 782.00	664.50
Ammonia (mg/L)	818.70 – 2092.30	1438.23
Colour (ADMI)	1584 - 2922	2244
Turbidity (NTU)	19.63 – 41.70	28.08
Suspended Solid (mg/L)	77 – 282	156

No of sampling: 3 samples for three months

3.2 Optimum value for Aerated Chemical Coagulation (ACC) under the influence of PAC dosage, pH and aeration rate.

Figure 3 shows the result of ACC influence of PAC dosage. In ACC, three influence parameters were tested which were PAC dosage, pH and aeration rate.

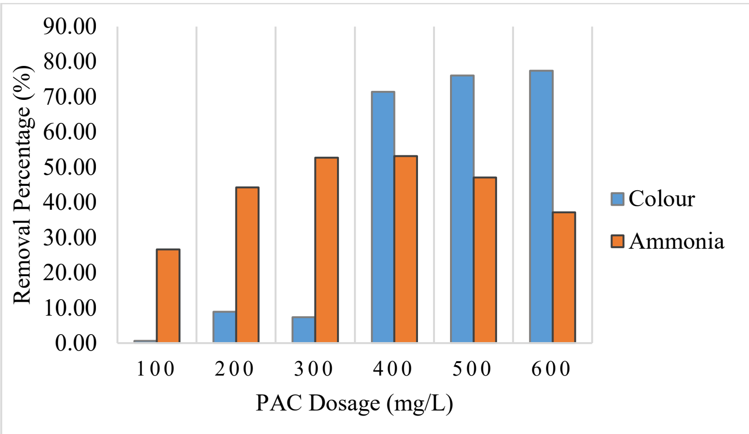

Figure 3: Percentage removal for ACC under the influence of PAC dosage

Based on the data, the higher removal percentage of colour was 77% in dosage 600 mg/L while the higher removal percentage of ammonia was 53% in dosage 400 mg/L. According to Liang [17], the PAC dosage to remove ammonia and colour was 400mg/L in coagulation and nanofiltration. Based on this statement, combining the method it can increase the efficiency of ammonia and colour with 400 mg/L as optimum PAC dosage. Therefore, the optimum PAC dosage for ACC was 400 mg/L.

Under the influence of pH, the PAC dosage has been used 400 mg/L. The value of pH has been started by pH 4 until pH 9. Figure 4 shows the percentage of removal parameters for ACC under the influence of pH.

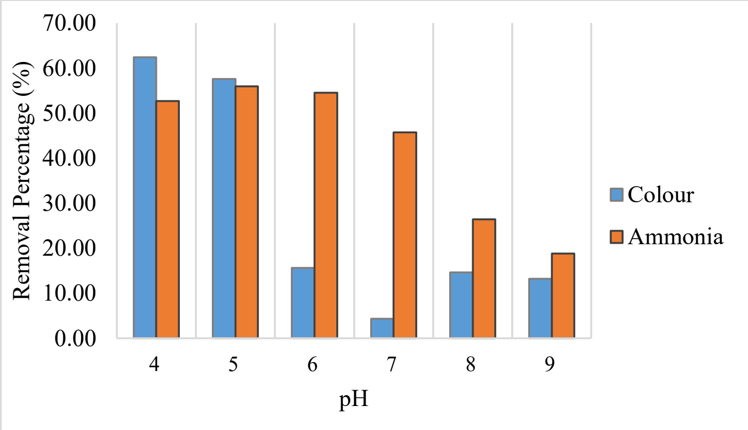

Figure 4: Percentage removal for ACC under the influence of pH

Based on figure 4, the higher removal for colour and ammonia were 62% in pH 4 and 56% in pH 5 respectively. Based on the previous study, the efficiency of removing ammonia and colour was increased when started at pH 3 but decreased after pH 5 in combination with coagulation and nanofiltration in leachate treatment [17]. Based on this statement, the optimal value for combination method was pH 5. Therefore, the optimum pH for ACC was pH 5.

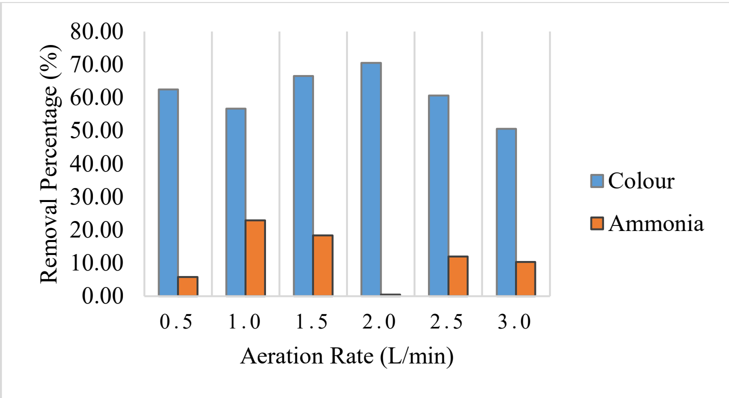

Figure 5: Percentage removal for ACC under the influence of aeration rate

For ACC influence of aeration rate, the pH has been used pH 5. Figure 5 shows the result for ACC under the influence of aeration rate. Based on the figure, the higher value for colour removal was 71% at 2.0 L/min, while ammonia removal was 23% at 1.0 L/min. Based on a previous study, the optimal aeration rate to remove ammonia is between 1.0 L/min to 3.0 L/min for sequencing batching and coagulation in leachate treatment [18]. Based on that statement, the optimal aeration rate obtained by ACC is parallels a study by Luo [18]. Therefore, the optimum aeration for ACC is 1.0 L/min because the percentage of ammonia removal was higher at this point.

3.3 Comparison of the efficiency of Aerated Chemical Coagulation (ACC) with single chemical coagulation and single aeration.

The purpose to comparing the efficiency of single aeration, single chemical coagulation and Aerated Chemical Coagulation (ACC) was to identify which method could remove ammonia and colour in better condition. The comparisons were made based on the various factors and the removal percentage for each technique. Figure 6 and 7 shown the comparison percentage removal of colour and ammonia under the influence of PAC dosage between single chemical coagulation and ACC. Based on a recent study, when single method combines with another technique in leachate treatment, it can increase the efficiency of ammonia removal better than a single method under the influence of PAC dosage [19]. Based on the result, the efficiency of ACC to remove ammonia was better than single chemical coagulation. For colour removal, single chemical coagulation was better than ACC. This data has been further strengthened by a recent study when Polyaluminum chloride (PAC) was used as a chemical coagulant in single chemical coagulation is good in removing colour in wastewater treatment compared to the combination method [20].

The efficiency percentage removal for colour and ammonia under the influence of pH between single chemical coagulation and ACC was shown in Figures 8 and 9. Based on this data, single chemical coagulation was removed colour better than ACC. On other hand, ACC removed ammonia better than single chemical coagulation. Based on Nasir and Daud [20], when the value of pH increased in single chemical coagulation, the efficiency of removing colour and ammonia decreased. Therefore, it can be concluded that, single chemical coagulation was better in removing colour, as shown in the data. According to Aoudj [21], the combination method electrocoagulation and electroflotation can increase the efficiency to remove ammonia removal better than coagulation only. Therefore, ACC was better than single chemical coagulation in eliminating ammonia.

Figures 10 and 11 show the comparison between single aeration and ACC to remove ammonia and colour from the leachate sample based on the percentage of removal. The efficiency ACC to remove colour was better than single aeration. Based on Iskurt [22], aeration can remove ammonia in wastewater better than electro-chemical oxidation. For ammonia removal, single aeration was more efficient better than ACC. Pigue's [23] studies further reinforced this statement where aeration can lower the ammonia content in wastewater treatment.

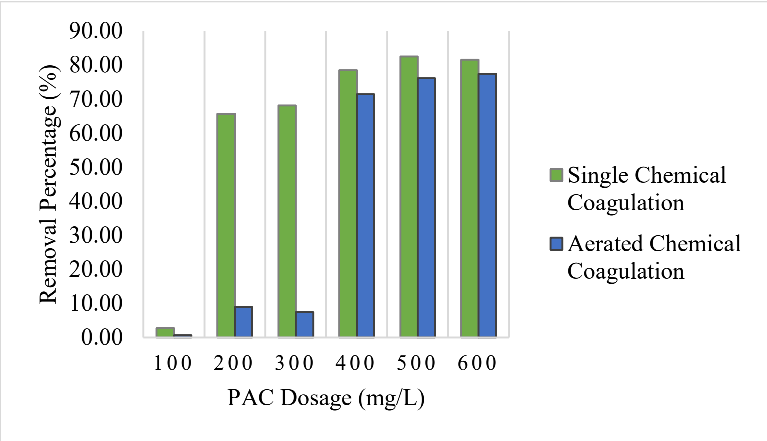

Figure 6: Comparison percentage of colour removal under the influence of PAC dosage between single chemical coagulation and ACC

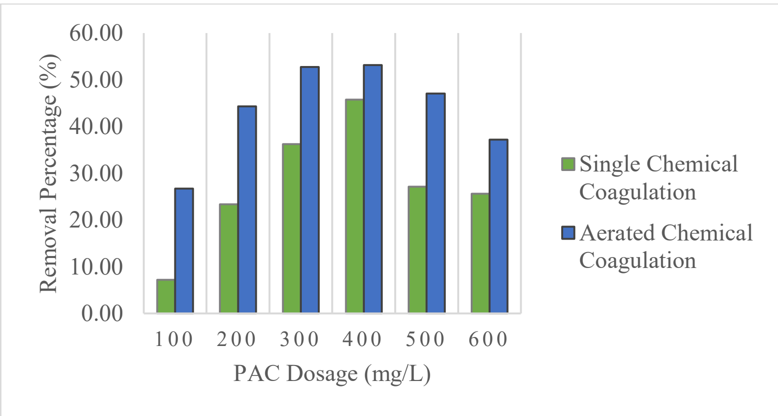

Figure 7: Comparison percentage of ammonia removal under the influence of PAC dosage between single chemical coagulation and ACC

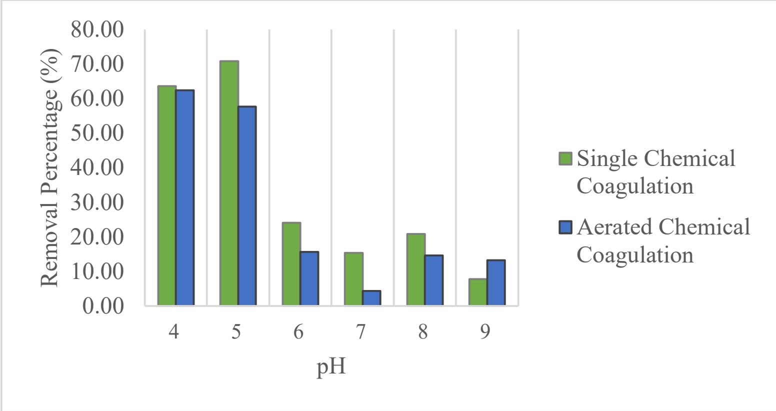

Figure 8: Comparison percentage of colour removal under the influence of pH between single chemical coagulation and ACC

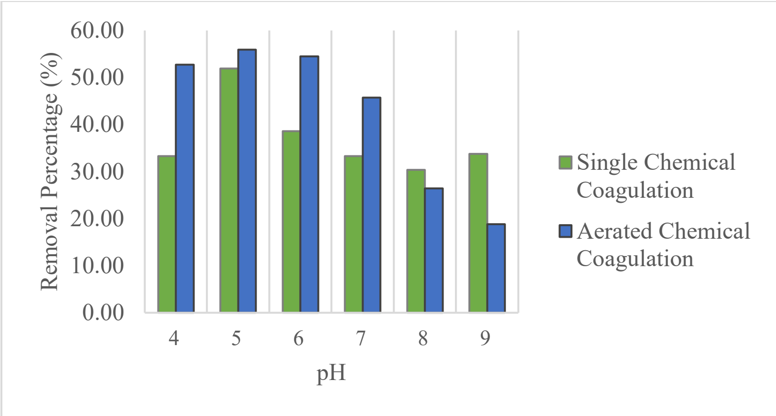

Figure 9: Comparison percentage of ammonia removal under the influence of pH between single chemical coagulation and ACC

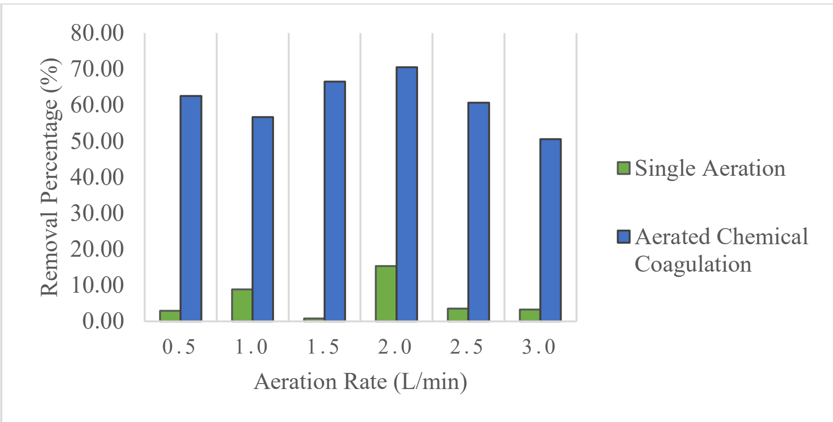

Figure 10: Comparison percentage of colour removal under the influence of aeration rate between single aeration and ACC

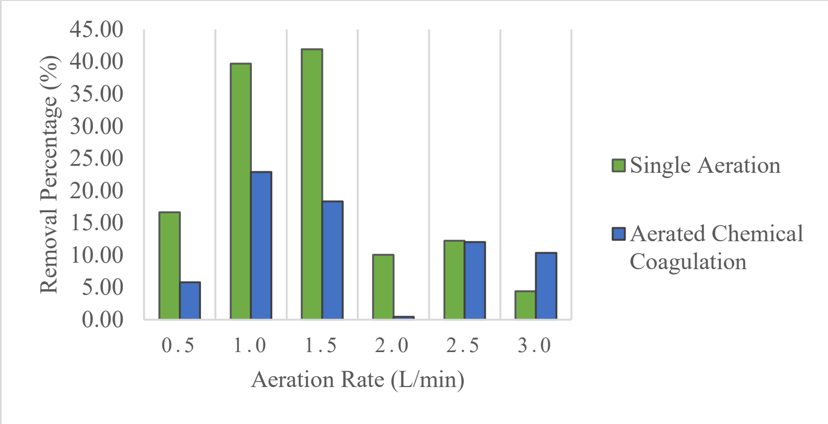

Figure 11: Comparison percentage of ammonia removal under the influence of aeration rate between single aeration and ACC

3.4 Comparison efficiency of Aerated Chemical Coagulation (ACC) ammonia and colour removal with Environmental Quality (Control of Pollution from Solid Waste Water Transfer Station and Landfill) Regulation 2009

The purpose of comparing the efficiency of Aerated Chemical Coagulation (ACC) for ammonia and colour removal with Environmental Quality Regulation (EQR 2009) was to make sure the parameter removal was within the acceptable limit. Based on EQR 2009, ammonia and colour concentrations before discharge were 5 mg/L and 100 ADMI respectively. Table 4 shows the optimum value for ammonia and colour removal in ACC. Based on the data, the optimum colour and ammonia removal obtained from ACC did not achieved the EQR 2009. Based on the statement from Keyikoglu [24], some treatments need to be added to ensure that the removal parameters reach the standard such as filtration, anaerobic treatment and others. In addition, this study has been used raw leachate. Conventionally, leachate treatment plant consists of many stages of treatment. Therefore, if other treatment can be integrated with ACC, it can probably achieve the effluent standard for colour and ammonia.

Table 4: The comparison of ACC and EQR 2009 at optimum condition for colour and ammonia removals

Influence	Optimum colour removal (ADMI)	Optimum Ammonia removal (mg/L)
PAC dosage	577	672.64
pH	889	592.82
Aeration rate	1054	621.66

4. Conclusion

In a conclusion, ACC can treat old leachate based on the removal parameters which were ammonia and colour. Based on this study, the optimum ACC to remove ammonia and colour were 400 mg/L of PAC dosage, pH 5 and 1.0 L/min of aeration rate. ACC obtained the best removal of ammonia while single chemical coagulation removed colour better than ACC and single aeration. The optimum value for colour and ammonia removal in ACC was higher than the standard of EQR 2009. ACC integrated with other treatment, probably it can achieve the effluent standard for colour and ammonia.

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