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Removal of Ammoniacal Nitrogen, Colour and Suspended Solids from Leachate using Aerated Electrochemical Coagulation (AEC) Under the Influence Factors of Electrolyte Concentration and Aeration Rate

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Abstract: In this study, aerated electrochemical coagulation (AEC) was used to treat leachate. This study was conducted to determine the best conditions for the AEC method to remove ammoniacal nitrogen, colour and suspended solids from leachate. Electrolyte concentration and aeration rate were the variable operating parameters of this study. Al and Fe electrodes were aerated with an air pump, and polyaluminium chloride (PAC) was added simultaneously to the leachate sample. The optimum value obtained from the AEC was 60ml of electrolyte concentration and an aeration rate of 1.0 L/min. Based on the optimum conditions, the experimental results removed 38%, 93%, and 95% of ammoniacal nitrogen, colour, and suspended solids, respectively. This indicates that the AEC method enhanced the removal of ammoniacal nitrogen, colour and suspended solids from leachate. However, only suspended solids comply with the effluent standard.

Keywords: Landfill, electrolysis, wastewater treatment

1. Introduction

Malaysian population growth promotes solid waste generation, affecting its management indirectly. The landfills in Malaysia were small-scale operations with various designs [1]. However, many of these sites are poorly maintained and resulted in environmental distress such as incidence of leachate leakage into nearby water body. As a result, percolating water becomes contaminated when it encounters decomposing solid waste, referred to as leachate [2]. With improper leachate management, water in a nearby stream or groundwater became contaminated [3]. Leachate from a landfill can contaminate the environment (ie: leachate intrusion into ground, inflow of leachate into river and unpleasant odour) and endanger human health (ie: congenital disabilities, cancer and blood disorder)

Landfill leachate is a dark-coloured liquid created mainly through precipitation percolating through an open landfill or the completed site's lid. Organic matter breakdown, such as humic acid, can turn leachate into yellow, brown, or black [4]. It contains high levels of ammoniacal nitrogen [5]. Suspended solids were also one of the pollutants contained in landfill leachate. Because of their instability and repulsion, the suspended particles in leachate are frequently scattered,

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negatively charged, and do not settle by gravity [6]. Therefore, removing ammoniacal nitrogen, colour and suspended solids from the leachate is crucial before it is released into the water source.

There are several methods for treating leachate, such as electrocoagulation, coagulation, aerobic and anaerobic. However, leachate needs to meet leachate emission standards. Based on the previous leachate treatment study, it isn't easy to eliminate the ammoniacal nitrogen content to meet the emission standard. Besides, leachate treatability will change with the ageing process [7].

Hence, the approach utilized in this study is aerated electrochemical coagulation (AEC). Many factors influence AEC efficiency, including electrolyte concentration and aeration rate. Electrolyte generates an electrically conducting solution where electrolyte separates into cations and anions, which are uniformly distributed throughout the solvent [8]. Adding electrolytes to landfill leachate electrolysis improves the process performance [9]. The aeration rate is an essential variable in removing organic matter and nitrogen removal. Aeration rate influences the transformation of ammoniacal nitrogen into nitrate-nitrogen and nitrate-nitrogen during the nitrification process [10]. Integration of aeration in the treatment system enhanced the removal of colour in wastewater treatment [11]. This study was conducted to determine the best conditions of electrolyte concentration and aeration rate for the AEC method to remove ammoniacal nitrogen, colour, and suspended solids from leachate.

2. Material and Methods

2.1 Sampling and Characterization

The leachate sample was taken from CEP Simpang Renggam Plantation landfill, located at Simpang Renggam, Johor, Malaysia (1°53'41"N 103°22'35"E). Leachate sampling and storage were conducted following American Public Health Association (APHA 2008) standard method shown in Table 1. Leachate samples were taken by the grab sampling method using High-Density Polyethylene (HDPE) plastic bottles. Samples taken from the site were stored immediately in a chiller at a temperature of 4°C in the wastewater laboratory, Faculty of Civil Engineering and Built Environment (FKAAB), Universiti Tun Hussein Onn Malaysia (UTHM). Leachate was characterized by measuring temperature, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen, colour, turbidity, and suspended solids. The samples were collected within three months, from March to May 2022. Table 2 shows the list of used standard methods in this study.

Table 1 - Recommended storage conditions for analytes in water samples

Parameter	Container	Preservative	Storage time
BOD	P, G	Cool 4°C	48 hours
COD	P, G	H_2SO_4 to pH < 2, Cool 4°C	28 days
Ammoniacal nitrogen	P	H_2SO_4 to pH < 2, Cool 4°C	28 days
Suspended solids	P, G	Cool 4°C	7 days
pH	P	Cool 4°C	Immediately
Colour	P, G	Cool 4°C	48 hours
Turbidity	P, G	Cool 4°C	48 hours

Table 2 - List of standard methods

Characteristic parameter	Method
Ammoniacal nitrogen	HACH 8038
Colour	HACH 8025
pH	APHA 4500-HB
Chemical Oxygen Demand (COD)	HACH 8000
Biochemical Oxygen Demand (BOD)	Standard Method 5210(B)
Turbidity	APHA 2130
Suspended Solids	APHA 2540D

2.2 Experimental Design

The influence operating parameters selected for this experiment were electrolyte concentration andaeration rate. Each experiment was carried out using 750 mL of leachate sample. The AEC process was conducted using Aluminium and iron (Fe) electrodes and was immersed 9 cm into the leachate, and the distance between the electrodes was 5.5 cm [12]. The electrolyte used was sodium chloride (NaCl) [9].

The sample was aerated using an air pump. The airflow meter was connected to the air pump and served as a controller to change the pressure. The fixed parameters were the current density of 200 A/m^2, PAC dose of 400 mg/L, pH 5, and electrolysis duration of 30 minutes [12]. At the bottom of the beaker, a magnetic stirrer was used. Samples were allowed to settle for 30 minutes after the electrolysis duration ended. Fig. 1 shows the AEC experimental setup.

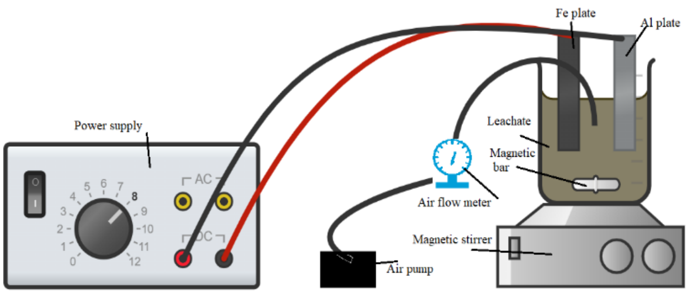

Fig. 1 - AEC experimental setup

2.3 Optimization Factors

The experimental optimization work was conducted to determine the optimum value of electrolyte concentration and aeration rate, which is based on the highest removal percentage for ammoniacal nitrogen, colour and suspended solids. The removal percentage was calculated using equation 1: The concentration of ammoniacal nitrogen, colour and suspended solids from the treated sample were compared with effluent Malaysia Environmental Quality (Control of Pollution from Solid Wastewater Transfer Station and Landfill) Regulation 2009.

$$Percentage\ of\ removal,\ \% = \left(\frac{Initial\ data\ value - Final\ data\ value}{Initial\ data\ value}\right) x\ 100 \tag{1}$$

3. Result and Discussion

3.1 Leachate Characteristic

Leachate in Simpang Renggam is categorized as old leachate based on landfill age and average parameter [12]. The data shown was the data taken from March to May 2022. The characteristic data taken from the sample were temperature, pH, BOD$_5$, COD, suspended solids, turbidity, ammoniacal nitrogen and colour as shown in table 3. BOD$_5$, COD, suspended solids, ammoniacal nitrogen and color were exceeded the Malaysia Environmental Quality Act (EQA) 2009) permissible limit. Through characterization, AEC (physical-chemical method) is a suitable method to treat old leachate and removal of ammoniacal nitrogen, colour and suspended solids is essential for this old leachate.

Table 3 - Characteristics of Simpang Renggam landfill raw leachate

Parameter	Unit	Average Value	Standard Deviation	EQA (2009)
Temperature	°C	30	±2.35	40
pH Value	-	8.19	±0.08	6.0-9.0
BOD$_5$ at 20°C	mg/L	30	±9.03	20
COD	mg/L	845.2	±101.36	400
Suspended Solids	mg/L	102.97	±16.50	50
Turbidity	mg/L	26.61	±8.84	-
Ammoniacal nitrogen	mg/L	1611.54	±568.47	5
Colour	ADMI	2776.53	±712.50	100

3.2 Effect of Electrolyte Concentration

NaCl concentration in the range of 0 – 100 mL was tested in this study. The control sample concentration of NaCl was 0 mL (Fig. 2). The highest removal of colour and suspended solids were at a concentration of 10ml with 90% and 94% of removal, respectively. Based on the data, the removal of colour and suspended solids do not influence by NaCl concentration. However, NaCl concentration influence the removal of ammoniacal nitrogen. At a concentration of 60 mL, the highest percentage of ammoniacal nitrogen removal was observed (46%). The chloride concentration increment increases ammoniacal nitrogen oxidation [13]. NaCl assists the attraction of ammoniacal nitrogen particles by adding ions to the leachate [13]. The removal of ammoniacal nitrogen in this study is parallel with a study conducted by Mussa et al. (2018), as they obtained 48% of ammoniacal nitrogen from leachate by using electrochemical oxidation. Therefore, 60 mL was selected as the optimum concentration of electrolyte for AEC.

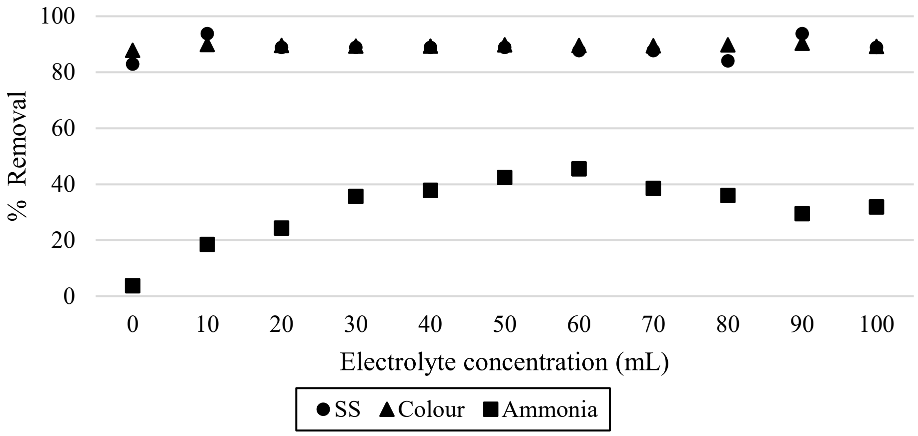

Fig. 2 - Percentage removal of ammoniacal nitrogen, colour and suspended solids vs electrolyte concentration

3.3 Effect of Aeration Rate

Based on fig. 3, the highest percentage removal for ammoniacal nitrogen, colour and suspended solids was recorded at an aeration rate of 1.0 L/min with 38%, 93%, and 95% removal, respectively. The enhancement of ammoniacal nitrogen removal can already be seen at 0.5 L/min of aeration rate. Aeration enhanced the removals of the three parameters compared to the removal at a zero-aeration rate. However, for ammoniacal nitrogen removal, better removal by AEC was recorded at 0.5-1.0 L/min, but beyond that, the decrement of removals was below then electrocoagulation without aeration (refer to zero aeration rate in figure 3). This experiment indicates that aeration rate did affect the removal of ammoniacal nitrogen, colour and suspended solids. This finding fits the Rudianasari et al. [14] results where better pollutant (TDS 34%, TSS 81%, COD 54%, BOD5 54%, and turbidity 93%) removals were recorded from leachate for aerated electrocoagulation with the addition of salt compared to electrocoagulation without aeration and salt. Hence, a rate of 1.0 L/min was selected as the optimum aeration rate for AEC.

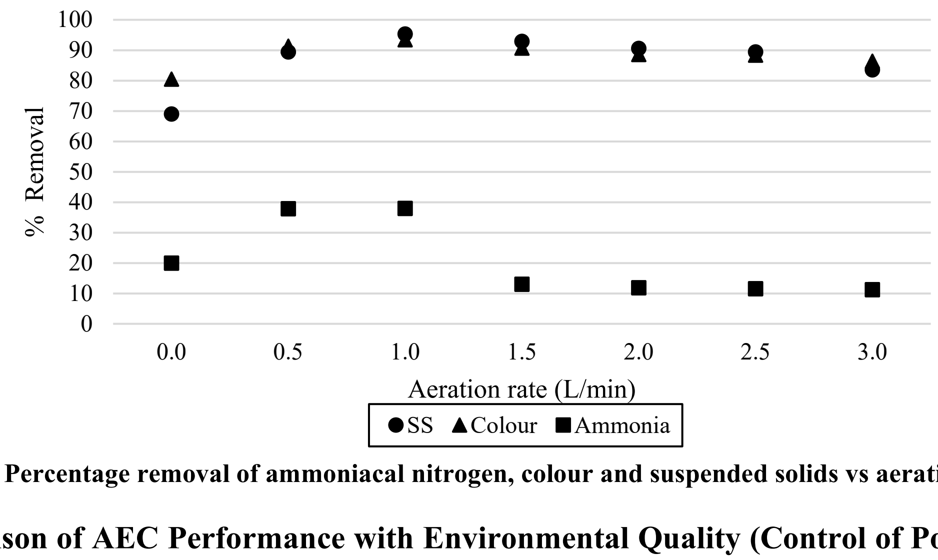

Fig. 3 - Percentage removal of ammoniacal nitrogen, colour and suspended solids vs aeration rate

3.4 Comparison of AEC Performance with Environmental Quality (Control of Pollution from Solid Wastewater Transfer Station and Landfill) Regulation 2009

Table 4 shows the comparison of AEC with EQA 2009. Based on table 4, only the removal of suspended solids meets the permissible limit stated. While the removal of ammoniacal nitrogen and colour resulting from this experiment still does not meet the permissible limit, probably because of undetermined other operating factors such as pH, aeration duration and leachate dilution factor that were not covered in this study.

Table 4 - Comparison of AEC performance with Environmental Quality (Control of Pollution from Solid Wastewater Transfer Station and Landfill) Regulation 2009

Parameter	Removal after AEC	EQA 2009
Ammoniacal nitrogen (mg/L)	609	5
Colour (ADMI)	118	100
Suspended Solids (mg/L)	4	50

4. Conclusion

Electrolyte concentration of 60 mL and aeration rate of 1.0 L/min were the optimum conditions for AEC. At the optimum condition, 38%, 93%, and 95% removal for ammoniacal nitrogen, colour, and suspended solids were achieved. However, compared to Environmental Quality (Control of Pollution from Solid Wastewater Transfer Station and Landfill) Regulation 2009, the removal value of ammoniacal nitrogen and colour still has not met the permissible limit except for suspended solids. Integration of other operating factors such as duration of aeration, pH as well as dilution factor of leachate is recommended for future study to improve the efficiency of the aerated electrocoagulation method.

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