Treatment of a Malaysian Leachate Sample Using Electrocoagulation

Masoumeh MoayeriKashani, Salman Masoudi Soltani, and S. Sobri

Abstract—A real leachate sample, taken from a Kuala Lumpur suburban area, was used in order to investigate the efficiency of electrocoagulation using Fe electrodes as both cathodes and anodes to reduce chemical oxygen demand (COD) and color of the sample. The effects of pH value and current density on the efficiency of the leachate treatment were investigated. Meanwhile, it was well understood that using this approach for the treatment of the studied leachate could successfully lower the COD value and color of the leachate wastewater by 81% and 72%, respectively. To the knowledge of the authors, to date, no real leachate samples have been treated by electrocoagulation methods elsewhere.

Index Terms—Chemical oxygen demand, color, electrocoagulation, leachate

I. INTRODUCTION

Landfill leachate is a major source of pollution caused by the wastewater generated from solid waste buried underground [1]. It can readily pollute soil and penetrates into the underground layers of ground resulting in severe underground water contamination [2] which is one of the major water sources for human societies. Leachate from landfills represents an extreme wastewater which requires intensive treatment before discharge [2]. Leachate can be categorized a liquid waste inheriting high chemical oxygen demand (COD), high biochemical oxygen demand (BOD), high levels of colloidal particles and total suspended solid (TSS) as well as elevated values of total dissolved solid (TDS) [3]. In order to reach environment-friendly criteria for landfill leachate, one must bring these values to an acceptable discharge limit. There have been numerous approaches in attempts to handle landfill leachate due to its potential hazards to the environment. Amongst these, one can in general highlight leachate transfer, biodegradation [2], chemical and physical methods [2] as well as membrane processes [2] as the main categories in leachate handling. To date, chemical precipitation [4], magnetic field separation [3], adsorption [5], chemical oxidation [6], electrochemical oxidation, coagulation-flocculation [7] and electrocoagulation (EC) [8] have been namely investigated.

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Reference [2] has extensively covered the advantages and drawbacks of various contemporary approaches in landfill leachate treatments. Compared to current treatment processes available today, electrocoagulation can benefit from equipment simplicity; potable, clear, colorless and odorless treated product [6]; much larger and stable flocs containing less bound water showing sufficient acid resistance compared to chemical flocs which enables them to be filtered by means of membranes; production of effluents with less total dissolved solids (TDS) content compared to chemical treatments which results in lower water recovery cost in case of water reuse [8]; the capability of removing the smallest colloidal particles due to the facilitated coagulation by means of applied electric field [5]; the absence of chemicals and as a result no secondary pollution which is common in membrane cleaning processes and many other treatment systems. Reference [6] investigated the use of electrocoagulation to treat landfill leachate using surface response methodology. They studied the effects of current density, pH, time and fluid conductivity and the interaction between them to get an optimal turbidity removal. Reference [7] used aluminium plates to electrocoagulate a leachate which had showed low biodegradability and high concentration of macromolecules and then made a quantitative comparison with classical coagulation-flocculation with aluminium ions and also electrolysis alone. This article investigates the application of electrocoagulation in the treatment of a real sample of landfill leachate. The experiments in this study were all carried out in a batch mode in order to evaluate the effects of different operational variables including leachate pH and current density and their effects on the COD and color removal of the leachate wastewater.

II. MATERIALS AND METHODOLOGY

A. Sample Collection

The real leachate sample was collected from an old leachate detention pond located in Seri Kembangan, Malaysia and was transferred into clean plastic sample bottles which were immediately transported to the laboratory to be properly stored for the future use. The samples were kept in a refrigerator operating at 4 $^{\circ}$C for the future use. Before carrying out any experiments, the samples were taken out and were left in the ambient temperature for 3 hours until they completely reached the ambient temperature.

B. The Reactor and Electrodes

A 1000 ml glass beaker was used as the reaction media for the leachate treatment. 500 ml real leachate sample was used as the untreated influent into the reactor. The reactor was placed on a magnetic stirrer during each run to keep the

mixture homogeneous. The reactor was operated in batch mode in each run. Two iron electrodes were used as both cathode and anode in order to treat the leachate. Each electrode was 100 mm in height, 50 mm in width and 1 mm in thickness corresponding to an effective surface area of 50 cm². The electrodes were spaced 65 mm from one another and were installed opposite of each other close to the reactor wall. Both electrodes were then connected to a direct current (DC) power supply. A schematic diagram of the setup is presented in fig 2.1.
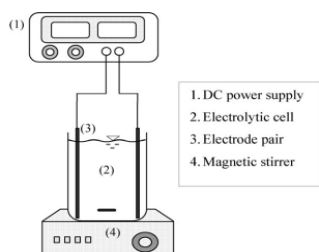

Fig. 1. Experimental set up (adopted from [9]) .

C. Analytical Analysis and Methods

To investigate the raw leachate properties, real leachate sample were analyzed to evaluate its initial TS, TSS, VSS, BOD, COD, DO, turbidity, color, and pH. Also, the concentration of 23 heavy metal elements were measured using inductively coupled plasma (ICP) instrument. To evaluate the electrocoagulation treatment efficiency, COD, color and turbidity of the treated effluent were immediately measured after the filtration of the reactor mixture through Whatman filter paper (Whatman, Germany) after each batch run. Leachate color was measured using a HACH Odyssey DR 2500 Spectrophotometer and Pt/Co scale or Apha-Hazen Scale. The pH was measured by a pH meter (Cyber scan/pH tutor) and was adjusted using concentrated H_2SO_4 and NaOH (Merck, Germaby). Chemical oxygen demand (COD) was measured following titration method according to the Standard Methods for Examination of Water and Wastewater [8]. Biological Oxygen Demand (BOD) and Dissolved oxygen (DO) were estimated by standard dilution technique methods [8]. Turbidity was determined by mean of a HACH 2100 N portable turbidity meter (NTU based on EPA Method 180.1, Standard Method 2130). Total suspended solid (TSS) was measured by Standard Methods 2540D [8] while Volatile Suspended Solids (VSS) was measured by standard method 2540 E [8]. Fixed and Volatile Solids were ignited at 550°C [8]. All chemicals and reagents were of analytical grades.

D. Batch Studies

Each batch experiment was run at three different pH values of 3, 6 and 9. To evaluate the effect of reaction time, each batch was operated for three different reaction times of 10, 20 and 30 minutes, respectively. To investigate the effect of current values in the treatment efficiency, each experiment was carried out at two different current density values of 40 and 60 mA/cm^2. All the experiments were uniformly repeated with the same operational conditions using Fe electrodes (both cathode and anode). The treated effluent COD value and color intensity were measured according to Standard Methods [8] and HACH Odyssey DR 2500

Spectrophotometer, respectively, after each batch run.

E. Raw Leachate Characterization

To investigate whether the collected leachate sample meets the discharge standard, eight critical parameters as well as the concentration of a wide range of 23 heavy metals in the untreated sample were analyzed. Heavy metal concentrations of the leachate sample are presented in table I and are compared to discharge standard in table III. The Malaysian discharge standards for leachate wastewater [10] and the corresponding collected leachate sample properties are both illustrated in table II.

TABLE I: Heavy metal Concentration in the Collected Sample

Sample Qty: Analyte	g Corr.Intensity	Prep. Vol.: Conc(Calib)	Dilution: Std. Dev. Calib unit (mg/L)	Conc(sample)	Std. Dev Sample units (mg/L)	Date: 2011/08/12 15:54 5` RSD
Ag328.068	3073.2	0.016	0.0006	0.016	0.0006	3.82%
Ba233.527	12598.5	0.075	0.0004	0.075	0.0004	0.54%
Ca317.933	3734542.6	9.476	0.0733	9.476	0.0733	0.77%
Cd228.802	197.6	0.010	0.0003	0.010	0.0003	2.78%
Co228.616	2314.5	0.053	0.0002	0.053	0.0002	0.41%
Mg285.213	9514062.0	15.95	0.178	15.95	0.178	1.12%
Mn257.610	101549.6	0.188	0.0010	0.188	0.0010	0.55%
Zn206.200	9312.4	0.147	0.0003	0.147	0.0003	0.23%
Sr407.771	1623520.0	0.080	0.0007	0.080	0.0007	0.88%
Al396.153	96379.5	0.496	0.0093	0.496	0.0093	1.87%
B249.677	78005.4	1.670	0.0025	1.670	0.0025	0.15%
Cr267.716	16025.0	0.168	0.014	0.168	0.014	0.85%
Li670.784	335000.1	0.079	0.0005	0.079	0.0005	0.57%
Ni231.604	7183.7	0.184	0.0010	0.184	0.0010	0.52%
Ti190.801	6.5	0.024	0.0007	0.024	0.0007	2.81%
Bi223.061	8.4	0.054	0.0025	0.054	0.0025	4.70%
K766.490						
Pb220.353	-35.7	0.054	0.0024	0.054	0.0024	4.41%
P213.617	117663.5	30.64	0.062	30.64	0.062	0.20%
As188.979	270.7	0.744	0.0357	0.744	0.0357	4.80%
Sr189.927	622.8	0.052	0.0018	0.052	0.0018	3.54%
Cu327.393	848.8	0.024	0.0006	0.024	0.0006	2.54%
Fe238.204	480920.3	4.035	0.0082	4.035	0.0082	0.20%

TABLE II: Untreated Leachate Properties

Property	TS(mg/l)	TSS(mg/l)	VSS(mg/l)	BOD(mg/l)
Collected sample	6800	1450	850	240
Malaysian Discharge Standard	4000	300	Not available	250

Property	COD(mg/l)	DO(mg/l)	Turbidity(NTU)	Color	pH
Collected sample	30000	2.3	54.3	3600	9
Malaysian Discharge Standard	100	Not available	Not available	Not available	5.5-9

TABLE III: Untreated Leachate Properties

Heavy metal	lead	copper	nickel	Zinc	iron
Collected sample (mg/lit)	0.054	0.024	0.184	0.147	4.035
Malaysian Discharge Standard (mg/lit)	0.5	1	1	1	5

As can be seen, the parameters which need to be improved so that the leachate can meet the discharge standards include COD and TSS. Other parameters including heavy metals concentrations fall into the acceptable standard range.

III. RESULTS AND DISCUSSIONS

A. The Effect of Ph and Current Density on Cod Removal Efficiency

Fig. 2 illustrates the effect of pH values on the reduction of COD during the 30 minutes of the batch run at a current density of 40 mA/cm^2. It is clear that in all three pH values, the COD declines almost sharply with time. However, at pH value of 6, the optimum reduction in COD is observed. At this pH, COD was reduced from 30,000 mg/l to 6176 mg/l within the 30 minutes of the reaction period, while, when moving towards a more acidic mixture of pH=3, the COD decreased from 30,000 mg/l to 12,000 mg/l. When no pH adjustment was applied and the raw leachate sample was used directly, the COD was lowered from 30,000 mg/l to 9600 mg/l.
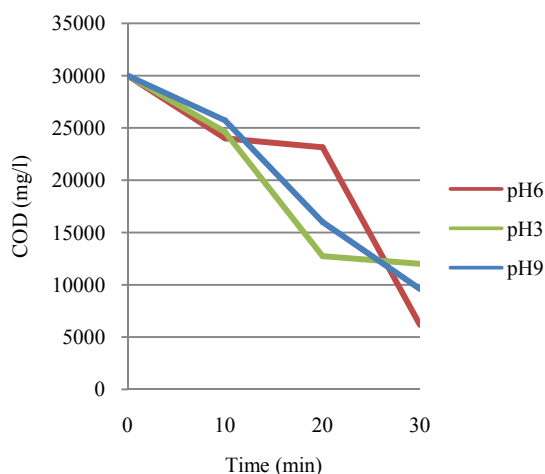

Fig. 2. Effect of pH on COD removal at current density of 40 *mA/cm^2*

Fig. 3 shows the effect of pH on COD removal during the batch runs at a current density of 60 mA/cm^2. At all three pH values, the COD declined continuously. It is observed that at this current density, pH value of 6 is capable of reducing the COD of the leachate more effectively than the other two pH values. Meanwhile, when current density was set at the new elevated value of 60 *mA/cm^2,* COD was lowered by approximately 81% within 30 minutes compared to 79% within the same period when current density was adjusted at 40 mA/cm^2. It is concluded that current density does not have a noticeable effect on the COD removal of the leachate sample.
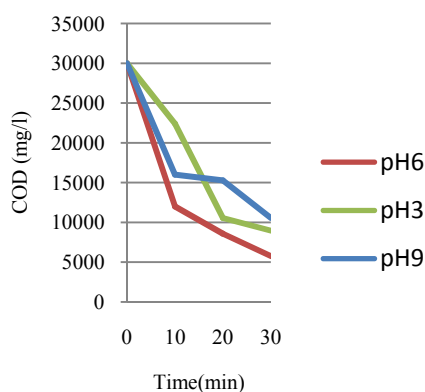

Fig. 3. Effect of pH on COD removal at current density of 60 *mA/cm^2*

B. The Effect of Ph and Current Density on Color Removal

Fig. 4 demonstrates the effect of pH on the color removal of the leachate sample at a current density of 40 mA/cm^2. At all three pH values color was lowered gradually with almost the same pattern. However, it is clearly seen that when pH=9 (raw leachate), color has removed more efficiently (around 50%) compared to the other two pH values; 42% and 19.54% at pH=3 and pH=6, respectively.
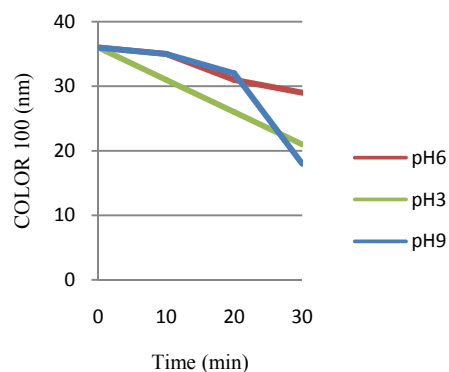

Fig. 4. Effect of pH on color removal at the current density of 40 *mA/cm^2*.

Fig 5 illustrates the pH effect on color removal when a current density of 60 *mA/cm^2* was applied. It is seen when pH was adjusted to 6, color was removed by 72% in 30 minutes. However, color was removed 69% and 36% at pH values of 3 and 9, respectively.
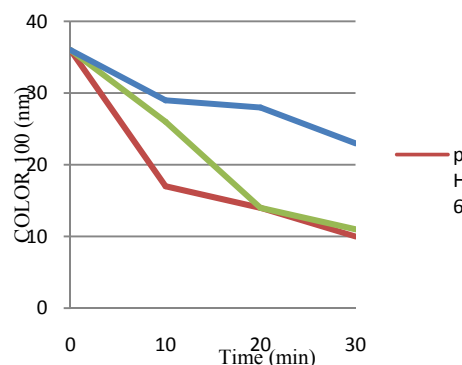

Fig. 5. Effect of pH on color removal at current density of 60 *mA/cm2*

IV. CONCLUSION

It is concluded that when current density increased from 40 mA/cm2 to 60 mA/cm2, COD and color removal efficiency was more successful at pH values of 3 and 6. However pH=9, the lower current density value of 40 mA/cm2 was more effective in the reduction of leachate COD value. This can be due to the presence of Fe ions in the leachate sample which could possibly result in the formation of FeOH2+, Fe2(OH)$_2$ $^{4+}$, FeOH^{4-}, Fe(H$_2$O)$^{2+}$, Fe(H$_2$O)$_5$OH^{2+} which were finally transformed into Fe(OH)$_3$ [3]. In the mean time, it seems that reaction time may be a critical parameter in the efficiency of COD and color removal of the leachate sample by electrocoagulation approach. Thus, it is worth studying the effect of reaction time in future studies.

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