

**Control of Groundwater Pollution from Bottom Ash Electro-Precipitation  
Process**

by

Muhammad Nur Dahlan bin Abd Razak

Dissertation submitted in partial fulfillment of  
the requirements for the  
Bachelor of Engineering (Hons)  
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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(MUHAMMAD NUR DAHLAN BIN ABD RAZAK)

## **ABSTRACT**

Coal combustion technology is an alternative to cut down emission level caused by combustion of energy. The use of coal will produce waste called bottom ash which may contain heavy metal and can cause hazard if being exposed to the acid rain. Acid rain directly can lead to groundwater pollution if the waste is being disposed directly into water bodies without adequate treatment to remove harmful compounds. Contaminated water by bottom ash is called leachate which can dissolve into ground water. Leaching test is conducted to produce leachate from bottom ash. Electro-precipitation process is a process to treat bottom ash by reducing heavy metals before being disposed. Through this process, about 4.5% of heavy metals leached from bottom ash after react to acid rain are determined. As the sample solution is more acidic (pH of 3.4), the amount of heavy metals leached are up to 6.9%. This indicated that electro-precipitation is the processes that can help in controlling bottom ash from pollute the groundwater.

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## CHAPTER 1 INTRODUCTION

### 1.1 Background of Study

The Manjung coal-fired power plant, sponsored by Tenaga Janamanjung, is located on a man-made island off the coast of Perak in Malaysia. It generates 2,100MW from its three 700MW units. The plant is located 4.5m above sea level, making coal imports easier. The plant was built to meet the 80% electricity demand of Malaysia on natural gas. The three 700MW units, with a rotating speed of 3,000rpm, use clean coal combustion technology and environmental control systems provided by Alstom to cut down emission levels. Manjung coal-fired power plant make-up

Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater). Water pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds. Water pollution affects plants and organisms living in these bodies of water. In almost all cases the effect of damage not only to individual species or populations, but also to the natural biological communities. The natural communities must be protected because it has roles in our human life.

Bottom ash is a part of the non-combustible residue of combustion in a furnace or incinerator. In an industrial context, it usually refers to coal combustion and comprises traces of combustibles embedded in forming clinkers and ticking to hot side walls of a coal-burning furnace during its operation. The portion of the ash escapes up the chimney or stack is, however, referred to as fly ash. The clinkers fall by themselves into the water or sometimes by poking manually, and get cooled. This is called as water pollution by bottom ash.

An electro-coagulation-flotation process has been developed for water treatment. This involved an electrolytic reactor with aluminum electrodes and a separation /flotation tank. The water to be treated passed through the reactor and was subjected to coagulation/flotation, by Al(III) ions dissolved from the electrodes, the resulting flocs floating after being captured by hydrogen gas bubbles generated at cathode surface. Apparent current efficiencies for Al dissolution as aqueous Al(III) species at pH 6.5 and 7.8 were greater than unity. This was due to additional reactions occurring in parallel with Al dissolution: oxygen reduction at anodes and cathodes, and hydrogen evolution at cathodes, resulting in net (i.e. oxidation+reduction) currents at both anodes and cathodes. The water treatment performance of the electrocoagulation process was found to be superior to that of conventional coagulation with aluminium sulphate for treating a model-coloured water, with 20% more dissolved organic carbon (DOC) being removed for the Al(III) dose.

## **1.2 Problem Statement**

Industrial waste from the leachate that comes from industrial waste is considered as hazardous and may be toxic or radioactive (WHO, 1996). Managing it calls for a heavy responsibility, as it is dirty, foul, difficult, expensive and technically complicated task. If not one properly can cause significant inconvenience and become a health risk (WHO, 1996). Risk is a probably that a particular adverse event occurs during a stated period of time (Ford et al.; 2004). Risk must be highly considered when want to do any actions and need to satisfy rules and regulations stated by Health, Safety and Environment Department.

The management practice may pose as a risk, and may very likely pollute the environment through emitted smoke and improperly disposed of bottom ash from the incinerators. Incineration of industrial waste with no treatment option is viewed as dangerous (B, 2004). The practice is worsened by operation of incinerators by untrained or improperly trained operators (S, 2004). The ashes that remain at the bottom of the



incinerator after burn contain heavy metals. Heavy metal is the chemical substances that can affect human and environment.

The residue bottom ash is then being dumped in landfill. The big problem comes when the rain that contain acidic pH comes and cause the bottom ash to react and produced hazardous heavy metals which is the flow and go into the groundwater stream and polluted them. The polluted groundwater can harm aquatic organisms, human and also plants. For example, Cadmiun, a heavy metal also common in red bags used to store infections waste (MK, 1997; GL, 2002) if incinerated and taken by humans, bio-accumulates in kidney with the content increasing with age. It causes human kidney damage and emphysema.

For Manjung Power Station, the plant uses low sulphur and low bitumen coal (pulverised for burning) to minimise pollution. The resulting ash is valuable for the cement industry, while most of the ash is caught by electrostatic precipitators. Dust control is also an important feature (the conveyor belt is covered and sprinkler systems remove up to 99.9%).

The plant has a wastewater treatment facility to treat its effluent before it is released into the sea. The plant also helps in reinvigorating decayed mangrove swamps in the area. The plant exceeds the emission standards set by the World Bank in Malaysia. It operates to particulate levels of 50mg/Nm<sup>3</sup> while the expected ASEAN level is 400mg/Nm<sup>3</sup>. It uses low NO<sub>x</sub> burners and a flue gas desulpherisation facility, to keep NO<sub>x</sub> and SO<sub>x</sub> emissions low.

### **1.3 Objectives and Scope of Study**

The objective of this research is to investigate whether the use of bottom ash can pollute the groundwater system or not after being react to acid rain. Through this experiment, we can also determine at what pH the leachate causes the worst pollution to groundwater. After that, this research also aims to treat the leachate by electro-precipitation process as to remove heavy metal.

In this study, the main subjects under investigation are:

- i. pH of the water used
- ii. Heavy metal content in the leachate
- iii. To examine bottom ash from TNB Power Station in Manjung

## CHAPTER 2 THEORY

### 2.1 Bottom Ash Contaminants

Bottom ash is the co-firing of coal with the waste/ biomass in PF boilers which frequently associated with coarse unconverted waste/biomass particles (Senneca, 2013). Physically the bottom ash is dark black in color. The characteristics of ground bottom ash (GWA) with strength and durability assessment as cement replacement in mortar (Garcia, 2013). It has many level of particle size. Bottom ash is differentiating from fly ash by looking into its particle sizes. The fly ash microsphere (FAM) is a superfine fly ash. Being finer than cement, it can fill into the voids between cement grains (Kwan, 2013).

Since coal contains trace levels of arsenic, barium, beryllium, boron, cadmium, chromium, thallium, selenium, molybdenum and mercury, its ash will continue to contain these traces and therefore cannot be dumped or stored where rainwater can leach the metals and move them to aquifers.

Bottom ash contains trace concentrations of heavy metals and other substances that are known to be detrimental to health in sufficient quantities. Potentially toxic trace elements in coal include arsenic, beryllium, cadmium, barium, chromium, copper, lead, mercury, molybdenum, nickel, radium, selenium, thorium, uranium, vanadium, and zinc. Approximately 10% of the mass of coals burned in the United States consists of unburnable mineral material that becomes ash, so the concentration of most trace elements in coal ash is approximately 10 times the concentration in the original coal. A 1997 analysis by the U.S. Geological Survey (USGS) found that bottom ash typically contained 10 to 30 ppm of uranium, comparable to the levels found in some granitic rocks, phosphate rock, and black shale.

In 2000, the United States Environmental Protection Agency (EPA) said that coal bottom ash did not need to be regulated as a hazardous waste. Studies by the U.S. Geological Survey and others of radioactive elements in coal ash have concluded that bottom ash compares with common soils or rocks and should not be the source of alarm. However, community and environmental organizations have documented numerous environmental contamination and damage concerns.

A revised risk assessment approach may change the way coal combustion wastes (CCW) are regulated, according to an August 2007 EPA notice in the Federal Register. In June 2008, the U.S. House of Representatives held an oversight hearing on the Federal government's role in addressing health and environmental risks of fly ash.

## **2.2 Leachate from Bottom Ash**

The control of soluble metal species in the sub-product leachate generated in electricity production processes is of great concern from an environmental and health point of view. The leaching test can be done to identify the underlying chemical processes that led to the release of toxic elements (Fuente-Cuesta, 2013). The presence of heavy metals in municipal solid waste incineration (MSWI) fly ash is of environmental concern due to their leaching potential in landfill environments. Acid extraction is a conventional method of safe treatment of fly ash (Zhang, 2013). After the treatment, large amount of Co, Cu, Pb, and Zn were leaching at pH 5. As a function of pH (5-12) using for the pH static leaching test (CEN/TS 14997) (Vítková, 2013).

## **2.3 Groundwater Pollution**

Managing groundwater quality to its specific measurement is a must because groundwater is an essential resource for people and ecosystem (Kim, 2012). The research objective is carried out to assess the changes in mine water quality as a groundwater mine flooded from July 2005 to October 2008 (Cheong, 2012). Across the

forest landscape, the severity in seasonal and episodic acidification events varies due to interbasin groundwater flow (IGF) (Ardón, 2013). For example, the rainfall erosivity is an essential factor to describe the potential soil loss caused by rain, which can be expected to change in correspondence to climate changes (Ma, 2012). Besides acid rain, mining activities also highly contribute to groundwater pollution because it results in significant environment and ecological degradation and can be pose serious risks to human health through contamination of food and drinking water (Byrne, 2012).

Due to pollution of groundwater, the water quality also affected. Water quality criteria can be used as a basis to set legal and enforceable water quality standards or objectives in accordance with the Clean Water Act (Palumbo, 2012). Water quality criteria are numeric concentrations for chemicals in water bodies that, if not exceeded, should protect aquatic wildlife from toxic effects of those chemicals (Palumbo, 2012). Hence, the key hydrological variables of rainfall, river discharge and water quality (suspended solids, phosphorus and nitrogen) (Mcmillan, 2012) must being manage very well.

The suspended solids that penetrated into groundwater also classified as heavy metals. Heavy metals that leach from contaminated soils under acid rains are of increasing concern (Zheng. S.-a, 2012). Arsenic and Sb showed the highest Igeo values, corresponding to Igeo 3-4. Hence, the area is characterized as “being heavily contaminated to polluted” by As and Sb. Arsenic contamination has been reported from all over world. Arsenic-related pollutants enter the groundwater system by gradually moving with the flow of groundwater from rains and irrigation. Gediz Plain forms the main groundwater supply of Izmir city (Colak, 2012). Besides Ar and Sb, Fluoride is among the bigger contaminant. Fluoride contamination in groundwater in parts of Jaipur district, Rajasthan state, and to assess the origin and genesis of fluoride in groundwater (Vikas, 2013) is to be taken care seriously. Occurrence of fluoride in natural water resource and the associate health hazards have been reported from many parts of India during the last decade (Vikas, 2013). Contamination of aquatic environments as a consequence of deep metal mining for Pb, Zn, Cu, C, and Fe is of widespread

international concern (Byrne, 2012). For human safety, we investigated how metal (aluminum, cadmium, copper, lead, manganese and tin) are leaked from fused slags by contact with acid rain and basic concrete effluent. A number of 13 fused slags were prepared from general garbage (Kobayashi, 2012). Moreover, rainwater harvested from rooftops is nearly as clean as pure water; a number of contaminants can be present in such water (Abbasi, 2011).

Furthermore, high spatial variation in the groundwater nitrate concentration, reaching 42mg/l, was observed (Bossa, 2012), and the pH decrease from 5.6 to 3.0 significantly enhanced such effects (Zheng. S.-a, 2012). Our results elucidate the different buffering mechanisms in tropical streams and suggest that low-solute poorly buffered streams might be particularly vulnerable to episodic acidification (Ardón, 2013). A number of 19962009 data from four Swedish Integrated Monitoring catchments are used to evaluate how the declining sulfur deposition has affected sulfate, pH, acid neutralizing capacity, ionic strength, aluminum, and dissolved organic carbon in soil water, groundwater and runoff (Löfgren, 2011).

## **2.4 Electro-Precipitation Process**

In this research project, eutrophication and acidification is the method used to be carried out. Eutrophication and acidification are among the major stressors on freshwater ecosystems in northern Europe and North America, but possible consequences of interactions between pH and nutrients on ecological status assessment and species richness patterns have not previously been assessed (Schneider, 2013). The effect of air injection with a blower into the water was used to evaluate the potential to convert ferrous to ferric iron and to provide in situ treatment and precipitation (Cheong, 2012). All samples were analyzed for pH, major anions (F<sup>-</sup>, Cl<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>), major cations (K<sup>+</sup>, Na<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, NH<sub>4</sub><sup>+</sup>), Sr<sup>2+</sup> and Sr isotope (Han, 2011).

## 2.5 Leachate Treatment Results

As the result, the pH increase is due to the result of neutralization caused by the alkaline dust which contain large amount of  $\text{CaCO}_3$  (Han, 2011). It also indicated episodic acidity/alkalinity loss in headwater stream, despite significant reductions in acid deposition (Feeley, 2013). There is also reaserch that suggest that episodic acidification in Ireland is primarily driven by organic acids (Feeley, 2013). However, the primary driver of acidity was strong organic anions, which generally increased with increasing forest cover (Feeley, 2013). As quantified from this study, observed changes in stream acidification in Ireland may provide a better understanding of future chemical responses to declining acid deposition and climate change elsewhere (Feeley, 2013). Analysis of the effect of fertilizer type and water management on direct  $\text{N}_2\text{O}$  emissions (Aguilera, 2013) proved that fertilizer can also produce polluted contaminants. High pH as well as alkalinity and low levels of Ca, Mg and total hardness suggest favourable chemical conditions for the fluoride dissolution process (Vikas, 2013). The individual and combined effects of acid rain and EDTA increase the environmental risk of metals, by increasing the soluble content of metals on soil solutions and the relative distribution of the exchange fraction (Wen, 2013). From these results, we may conclude that the biochar derived from OP and WS can be reused as an economical and effective adsorbent for fluoride removal in acidic aqueous phase (Oh, 2012).

## CHAPTER 3 METHODOLOGY

### 3.1 Research Methodology and Project Activities

The methodology for conducting this research project is exploration and discovery. As this project is mainly an empirical research, the results obtained from this research can be used to compare with other literature results. Besides, the result obtained from this research using different configuration and the setup of the equipment electro-precipitation process can be used as a basis of comparison with other research done. The result can hence further enhance the research and development of bottom ash residual.

The project activities in this research are mainly experimental work. After thorough literature review is done, the first thing need to do is check the characteristic of the bottom ash. Then, the bottom ash needs to undergo leaching test to release the waste components from solidification agent. Then, the leachate will be filtered; the liquid that penetrate the filter paper is symbolic to the pollution from leachate that penetrates into groundwater. The liquid is then being test for heavy metal removal. The initial pH of the leachate is measure to prove the hypothesis. The precipitate is then described for characteristic.

Lastly, the results obtained from the experiment were comparing to the literature review. The hypothesis is analyzed whether it is correct or wrong. The conclusion was made based on both finding and experiment.



## 3.2 Experimental Procedures and Materials

### Materials

- Bottom Ash samples
- Distilled water
- Rainwater sample
- Acetic Acid (HAc)

#### **A) Checking physical characteristics of bottom ash**

- 1.1. The bottom ash sample was dried before the experiment begins.
- 1.2. The colour, texture, pH was observed and recorded.

#### **B) Prepare sample solution of different pH value**

- 2.1. The bottom ash was prepared into three (3) separated beakers. Each beaker was weighted to have 200g of bottom ash.
- 2.2. The first beaker containing bottom ash was filled up with 200mL of distilled water, second beaker was filled with 200mL rainwater and the third beaker was filled with 200mL of distilled water plus 1 drop of Acetic acid solution (HAc).
- 2.3. The mixtures were stirred by using the rod or stirrer.
- 2.4. The pH for every sample solution was measured by using pH meter and results were recorded in the result table.

#### **C) Leaching Test**

- 3.1. The leaching test apparatus was setup with three (3) different cylinders.
- 3.2. For every cylinder, filtrate paper of 0.6mm in size was placed at the bottom.
- 3.3. The bottom ash solution is poured into the filtrate paper in filtration cone. The bottom ash was let to leach and the leaching solution was collected in the beaker.

- 3.4. The collection was made for 1-hour, 2-hours, 6-hours, 12-hours, 1-day, 2-days, 5-days and 7-days.
- 3.5. After completed, the characteristic of collected samples were observed and recorded in the result table.
- 3.6. The bottom ash trapped in the filter paper was weighted and the results are recorded.

#### **D) Electro-Precipitation Process**

- 4.1. The electro-precipitation apparatus was setup by using carbon as the electrode for anode and cathode.
- 4.2. The electrodes were immersed into the beaker containing collected bottom ash solution.
- 4.3. The electric current was allowed to flow through the solution.
- 4.4. The changes of bottom ash solution (colour, precipitation, bubbles produced) and electrodes were observed and recorded.
- 4.5. The precipitate produced (if any) for every beaker was collected and weighted. The results are recorded.

### **3.3 Result Analysis**

1. The results recorded in the tables were analyzed.
2. The weight of the bottom ash trapped in the filter paper is weighted and calculated its trapped percentage from the actual weight.
3. The weight of bottom ash precipitated at carbon rod is weighted and calculated its precipitated percentage from the actual weight.
4. The free amount of bottom ash in each beaker is determined.
5. The colour change, existence of bubble is recorded.
6. The result is compared to the literature findings and the conclusions are made.

### 3.4 Key Milestones

Several key milestones for this research project must be achieved in order to meet the objective of this project:



**Figure 1.1: Key Milestones**

### 3.5 Gantt Chart

#### Final Year First Semester

NO	DETAIL	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14	
1	Selection of Project Title		*														
2	Preliminary Research Work and Literature Review					*											
3	Submission of Extended Proposal																
4	Preparation for Oral Proposal Defence																
5	Oral Proposal Defence Presentation																
6	Detailed Literature Review																
7	Sample Collection																
8	Experimental Design													*			
9	Preparation of Interim Report																
10	Submission of Draft Interim Report																
11	Submission of Final Interim Report																

Table 1.1: Gantt Chart 1

Project Progress

\* Suggested Milestone

**Final Year Second Semester**

NO	DETAIL	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14	
1	Experimental Work																
2	Analysis and Final Report Writing										*						
3	Submission of Final Report Draft																
4	Submission of Final Report													*			
5	Final Presentation																

**Project Progress**

\* Suggested Milestone

## CHAPTER 4 RESULTS AND DISCUSSION

### 4.1 Data Gathering and Analysis

#### (A) Ash Characteristics

- Colour: Dark black
- Texture: Rough surface
- Size: 0.1mm – 5.0mm
- Source: Stesen Janakuasa Manjung
- pH: 7.5

#### Sample Characteristics:

- Sample A: Bottom ash + distilled water
- Sample B: Bottom Ash + rain water
- Sample C: Bottom Ash + distilled water + 1 drop of Acetic acid solution (HAc)

#### (B) Table 1.3: Results from Leaching Test

Sample	pH (Initial)	pH (Final)	Weight (Initial) (g)	Weight (Final) (g)
A	7.1	7.2	200.00	198.75
B	5.2	6.0	200.00	190.54
C	3.4	5.3	200.00	185.28

**Note:** Based on 5-days (Theory)

#### (C) Table 1.4: Results from Electro-Precipitation Process

Sample	Weight of Bottom Ash Leachate (g)							
	2-hr	7-hr	24-hr	2-d	3-d	4-d	5-d	7-d
A	0.75	0.76	0.81	0.82	0.86	0.91	0.94	1.26
B	7.94	8.05	8.18	8.21	8.26	8.38	8.46	8.97
C	13.22	13.24	13.28	13.31	13.35	13.40	13.49	13.84

**Note:** hr: hour, d: day

### (D) Calculations

Calculate the amount (weight) of bottom ash leaching by using the following formula:

$$\begin{aligned} & \text{Weight of bottom ash leaching} \\ & = \text{Weight (initial)} - \text{Weight (final)} \end{aligned}$$

For Sample A:

$$\begin{aligned} \text{Weight Bottom Ash (A)} & = 200.00\text{g} - 198.75\text{g} \\ & = 1.25\text{g} \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Weight Bottom Ash (B)} & = 200.00\text{g} - 190.54\text{g} \\ & = 9.46\text{g} \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Weight Bottom Ash (C)} & = 200.00\text{g} - 185.28\text{g} \\ & = 14.72\text{g} \end{aligned}$$

Calculate the percentage (%) of bottom ash leaching over original amount by using the following formula:

$$\begin{aligned} & \text{Percentage of bottom ash leaching} \\ & = [\text{Weight of bottom ash leaching} / \text{Weight (initial)}] \times 100 \end{aligned}$$

For Sample A:

$$\begin{aligned} \text{Percentage Bottom Ash (A) Leaching} & = [1.25\text{g} / 200.00\text{g}] \times 100 \\ & = 0.63\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage Bottom Ash (B) Leaching} & = [9.46\text{g} / 200.00\text{g}] \times 100 \\ & = 4.7\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage Bottom Ash (C) Leaching} & = [14.72\text{g} / 200.00\text{g}] \times 100 \\ & = 7.35\% \end{aligned}$$



Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} & \text{Percentage of heavy metal reduced} \\ & = [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 2 hours leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} &= [0.75\text{g} / 200.00\text{g}] \times 100 \\ &= 0.38\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} &= [7.94\text{g} / 200.00\text{g}] \times 100 \\ &= 3.97\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} &= [13.22\text{g} / 200.00\text{g}] \times 100 \\ &= 6.61\% \end{aligned}$$

Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} &\text{Percentage of heavy metal reduced} \\ &= [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 7 hours leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} &= [0.76\text{g} / 200.00\text{g}] \times 100 \\ &= 0.38\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} &= [8.05\text{g} / 200.00\text{g}] \times 100 \\ &= 4.03\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} &= [13.24\text{g} / 200.00\text{g}] \times 100 \\ &= 6.62\% \end{aligned}$$

Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} &\text{Percentage of heavy metal reduced} \\ &= [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 24 hours leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} &= [0.81\text{g} / 200.00\text{g}] \times 100 \\ &= 0.41\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} &= [8.18\text{g} / 200.00\text{g}] \times 100 \\ &= 4.09\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} &= [13.28\text{g} / 200.00\text{g}] \times 100 \\ &= 6.64\% \end{aligned}$$

Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} & \text{Percentage of heavy metal reduced} \\ & = [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 2 days leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} &= [0.82\text{g} / 200.00\text{g}] \times 100 \\ &= 0.41\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} &= [8.21\text{g} / 200.00\text{g}] \times 100 \\ &= 4.10\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} &= [13.31\text{g} / 200.00\text{g}] \times 100 \\ &= 6.66\% \end{aligned}$$

Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} & \text{Percentage of heavy metal reduced} \\ & = [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 3 days leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} &= [0.86\text{g} / 200.00\text{g}] \times 100 \\ &= 0.43\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} &= [8.26\text{g} / 200.00\text{g}] \times 100 \\ &= 4.13\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} &= [13.35\text{g} / 200.00\text{g}] \times 100 \\ &= 6.68\% \end{aligned}$$

Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} &\text{Percentage of heavy metal reduced} \\ &= [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 4 days leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} &= [0.91\text{g} / 200.00\text{g}] \times 100 \\ &= 0.46\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} &= [8.38\text{g} / 200.00\text{g}] \times 100 \\ &= 4.19\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} &= [13.40\text{g} / 200.00\text{g}] \times 100 \\ &= 6.70\% \end{aligned}$$

Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} & \text{Percentage of heavy metal reduced} \\ & = [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 5 days leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} & = [0.94\text{g} / 200.00\text{g}] \times 100 \\ & = 0.47\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} & = [8.46\text{g} / 200.00\text{g}] \times 100 \\ & = 4.23\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} & = [13.49\text{g} / 200.00\text{g}] \times 100 \\ & = 6.75\% \end{aligned}$$

Calculate the percentage (%) of heavy metal reduced over original amount by using the following formula:

$$\begin{aligned} &\text{Percentage of heavy metal reduced} \\ &= [\text{Weight heavy metal reduced} / \text{Weight (initial)}] \times 100 \end{aligned}$$

**For 7 days leaching:**

For Sample A:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (A)} &= [1.26\text{g} / 200.00\text{g}] \times 100 \\ &= 0.63\% \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (B)} &= [8.97\text{g} / 200.00\text{g}] \times 100 \\ &= 4.49\% \end{aligned}$$

For Sample C:

$$\begin{aligned} \text{Percentage of Heavy Metal Reduced (C)} &= [13.84\text{g} / 200.00\text{g}] \times 100 \\ &= 6.92\% \end{aligned}$$



Forecast the amount (weight) of heavy metal reduction in a year by using the following formula:

$$\begin{aligned} & \text{Amount of heavy metal reduced per year} \\ & = \text{Percentage heavy metal reduced (24-hr)} \times (200\text{g}) \times (365\text{-d}) \end{aligned}$$

For Sample A:

$$\begin{aligned} \text{Amount of Heavy Metal Reduced per year (A)} & = (0.41 \times 100) \times 200\text{g} \times 365\text{-d} \\ & = 8,200\text{g} \end{aligned}$$

For Sample B:

$$\begin{aligned} \text{Amount of Heavy Metal Reduced per year (B)} & = (4.09 \times 100) \times 200\text{g} \times 365\text{-d} \\ & = 149,285\text{g} \end{aligned}$$

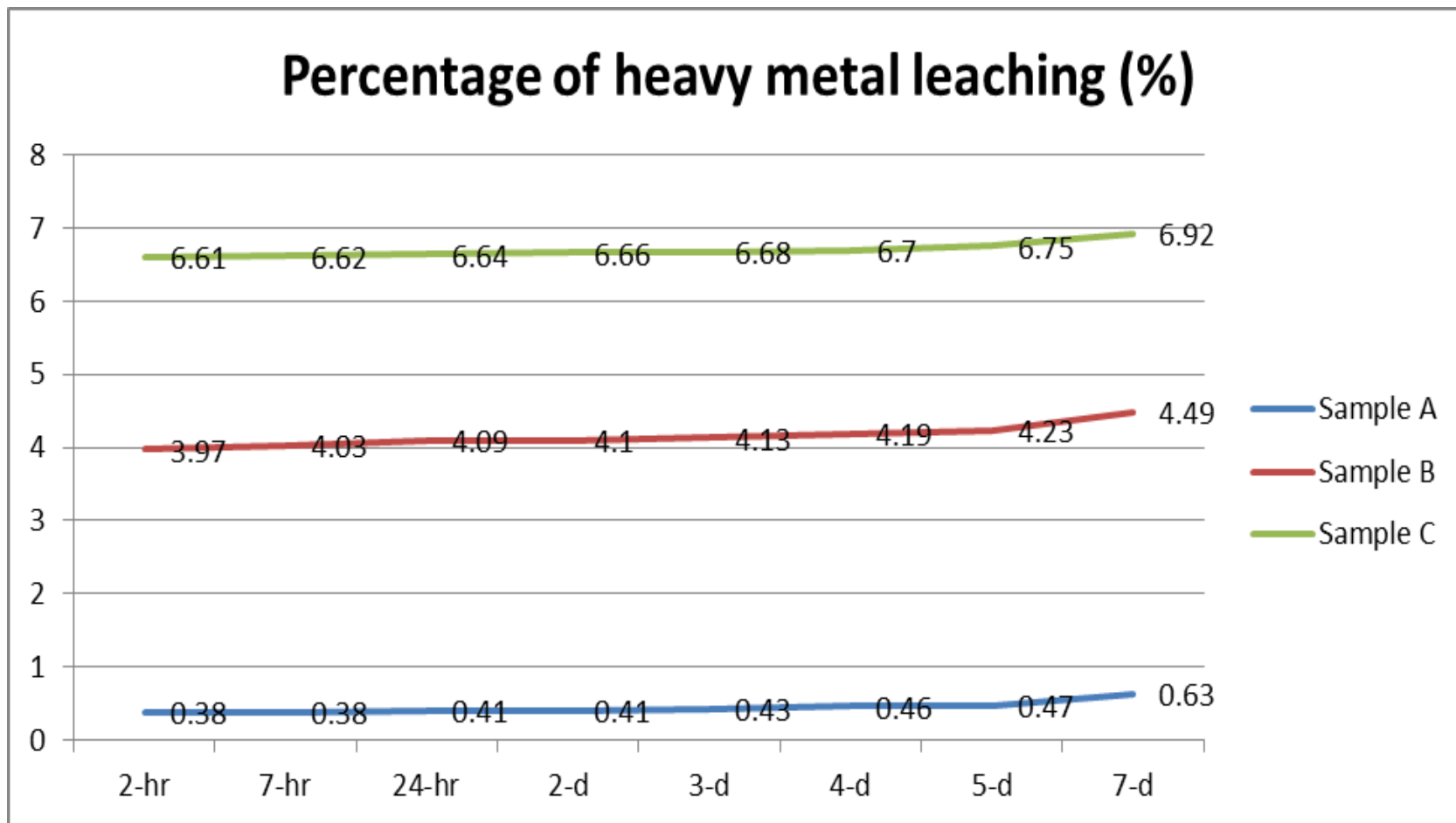
For Sample C:

$$\begin{aligned} \text{Amount of Heavy Metal Reduced per year (C)} & = (6.64 \times 100) \times 200\text{g} \times 365\text{-d} \\ & = 484,720\text{g} \end{aligned}$$

**(E) Table 1.5: Summary Result Table:**

<b>Sample</b>	<b>Weight of Heavy Metal Reduction (g)</b>							
	<b>2-hr</b>	<b>7-hr</b>	<b>24-hr</b>	<b>2-d</b>	<b>3-d</b>	<b>4-d</b>	<b>5-d</b>	<b>7-d</b>
A	0.38	0.38	0.41	0.41	0.43	0.46	0.47	0.63
B	3.97	4.03	4.09	4.10	4.13	4.19	4.23	4.49
C	6.61	6.62	6.64	6.66	6.68	6.70	6.75	6.92

(F) Graph 1.1: Graph for Heavy Metal Reduction:



## **4.2 Discussion:**

### Ash characteristics:

The ash was first dried before start the experiment so that the weight not included the water weight. The physical characteristic of the bottom ash was recorded. For this experiment, the size of the bottom ash particles to undergo experiment was selected to 0.6mm particles and below only. This is to provide more surface area for reaction to the solution. The smaller the bottom ash particles, the more surface area exposed to reaction. To make sure this particles selection, the dried bottom ash was sieved to classify them into group particles size.

### Leaching test:

Leaching test is the process of reducing the samples from solid state into liquid state. In this experiment, bottom ash was used to leach, and the bottom ash leachate is produced. The bottom ash leachates produced in this research were from three (3) different source or catalyst. The three types of leachates indicate three different conditions of leachate (manipulated variable). The bottom ash of sample B was mixed with rain water to investigate the heavy metal reduction when being exposed to the rain water. The bottom ash of sample was then indicated the leachate of higher pH. Then the bottom ash of sample C then represent leachate being exposed to more acidic acid rain.

From the leaching test, it showed that normal rain water can caused 5% of heavy metal reduction bottom as when being exposed to rain water. Rain water has the pH of 5.2 already showed that it is dangerous due to its corrosive and acidic properties which can reach with the bottom ash. The experiment was continued to see the reduction in heavy metal of more acidic solution. After the sample solution procedures, it showed that normal rain water can caused 4.7% of metal reduction in an amount of bottom ash samples.

The calculations made to see the forecasted amount of heavy metal reduction if the same amount and rate of reduction. The results showed the rate of metal reduction decrease in time, but increase in cumulative amount for one (1) years. Although the rate of reduction per year less than when compared to 1-day leaching result, but still the amount are very high. It is important to forecast the amount of heavy metals per solid waste produced per year so that the expected effects can be handled by now.

The calculations also made to determine the amount of percentage of heavy metal reduced from day to day. The percentage was increased from day to day showed that the probability of heavy metal to reduced was increase if continue being let to react to acid rain. Thus, it called for the treatment to prevent the bottom ash from leaching and caused heavy metal contaminants to penetrate into groundwater stream.

After further research, it can be a probability that heavy metals existed in the bottom ash was not derived bottom ash itself. It may come from the rain water which carried the haze particles contained many types of contaminant particles. But, the solution proposed still valid as the process can help in trapping the water particles contaminants from being released into water stream.

The bottom ash also differs in contents due to a few factors. The factors lead to different of bottom ash contents are types of waste, the incinerator operation condition and the nature of the samples. Every single type waste contains different type of elements. The incineration operation condition can affect the sample contents. And lastly, the nature of the sample can also affects the bottom ash heavy metals contents. Different nature (place and weather) may consist of different type of bottom ash.

### Electro-precipitation process:

To serve as the groundwater treatment for water pollution from bottom ash, electro-precipitation was introduced as it can reduce the heavy metals in the leachate. The leachate produced after certain days are taken to undergo electro-precipitation to determine the amount of heavy metals inside.

From this research, it was determined that the heavy metals exist in the leachate after being reacted to the acidic solution. The heavy metals reduction due to reaction of bottom ash to acidic solution can be treated to be separated from leachate before being disposed to the water stream.

After being undergo electro-precipitation process, the result of heavy metals reduction was increased from day to day. This strongly showed that a treatment was strongly needed to treat the leachate. From the graph of percentage of heavy metal reduced, it showed that the normal rain water can reduce heavy metal from bottom ash for about 4% of the original contents. The process was repeated for bottom ash that reach to solution of less and more in pH value from rain water to investigate the effect of water pH to leaching process. For bottom ash that being react to high pH value, the heavy metals reduced was lesser and only about 0.5% of original. But for the bottom ash that being react to water of lesser pH (more acidic condition), the reduction of heavy metals seems to increase to 6.5% of the original bottom ash contents. This indicated that pH value of the solution directly affected the heavy metal reduction in bottom ash.

During electro-precipitation process, the electrode release electron to form ion. The anion from the acid (sample solution) reacts to the cations to form precipitate and water. The precipitate is the form of heavy metal inside the samples. The precipitate was dried and weight to get its respective weight. The percentage of heavy metals inside was then determined. To see the precipitate formed clearly, large amount of sample solution need to be used.

## CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusions:

- Bottom ash used in combustion technology has potentially to contain heavy metal, either from internal or external factor
- Electro-precipitation process is the water treatment process that should be undergo before leachate having heavy metals disposal
- pH play important role in producing leachate that can lead to groundwater pollution by bottom ash

### 5.2 Recommendations:

- Large amount of sample should be used to obtain better result
- To obtain a good precipitation of heavy metal, the apparatus should have a well-planned system with large tank, electrodes and strong current flow
- Power generator plant or any industrial plant that used coal as combustion material should have proper bottom ash treatment before being released to the disposal site

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## APPENDICES

A) Figure 1.2: Bottom Ash Sample



## B) Leaching Test



## C) Electro-Precipitation Process

