



Faculty of Engineering

**LEACHING STUDIES OF PULVERISED FUEL ASH FROM
LOCAL THERMAL POWER PLANT**

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**Bachelor of Engineering with Honours
(Civil Engineering)
2009/2010**

UNIVERSITI MALAYSIA SARAWAK

R13a

BORANG PENGESAHAN STATUS TESIS

Judul: LEACHING STUDIES OF PULVERISED FUEL ASH FROM LOCAL THERMAL POWER PLANT

SESI PENGAJIAN: 2009/2010

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Dedicated to my beloved parents, family and friends who had supported me all the
time

Thank you for all the support and encouragement

**LEACHING STUDIES OF PULVERISED FUEL ASH FROM LOCAL
THERMAL POWER PLANT**

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This project is submitted in partial fulfilment of
The requirements for the degree of Bachelor of Engineering with Honours
(Civil Engineering)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2009/2010

ACKNOWLEDGEMENTS

I would like to take this wonderful opportunity to say my appreciation to everyone who has helped me a lot from beginning until completion of my final year project.

First of all, I would like to thank my supervisor, Assoc. Prof. Dr. Prabir Kumar Kolay for his guidance, advices, motivations and supports from the beginning until the completion of the project.

Next, I would like to thank God for his blessing that is given to me and for always giving me positive energy to face the hard times in completing my final year project.

Not forgotten, my sincere gratitude to Miss Zetty, Mr Tomy and Mdm Ting from the Faculty of Science and Resources Technology (FSRT), UNIMAS for providing me Atomic Absorption Spectrometry (AAS) instrument for the trace elements analysis and their willingness to guide and help for my project.

Last but not least, I would like to thank my mother and my friends for their moral and financial support as well in completing my project. Thank you and may God bless you all.

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LIST OF ABBREVIATIONS

PFA	-	Pulverised Fuel Ash
FBA	-	Furnace Bottom Ash
Mt	-	Mega tones
EPA	-	Environmental Protection Agency
TCLP	-	Toxicity Characteristic Leaching Procedure
TC	-	Toxicity Characteristic
SPLP	-	Synthetic Precipitation Leaching Procedure
MEP	-	Multiple Extraction Procedure
LEP	-	Leachate Extraction Procedure
EP	-	Environmental Protection
MS	-	Mass Spectrum
ICP	-	Inductive Coupled Plasma
ICP – MS	-	Inductive Coupled Plasma – Mass Spectrometry
ICP – AES	-	Inductive Coupled Plasma – Atomic Emission Spectroscopy
AAS	-	Atomic Absorption Spectrometer
MHz	-	Mega Hertz
FSRT	-	Faculty of Science and Resources Technology
UNIMAS	-	University Malaysia Sarawak
ASTM	-	American Society for Testing and Materials
DI	-	Deionised
ppm	-	Parts Per Million
Pb	-	Lead

Zn	-	Zinc
Cd	-	Cadmium
Cu	-	Copper
Ni	-	Nickel
Fe	-	Iron
Al	-	Aluminum
Ca	-	Calcium
As	-	Arsenic
P	-	Phosphorus
Na	-	Sodium
Si	-	Silicon
S	-	Sulfur
K	-	Potassium
B	-	Boron
Mo	-	Molybdenum
Se	-	Selenium
V	-	Vanadium
CO ₂	-	Carbon Dioxide
CH ₄	-	Methane
O ₂	-	Oxygen
HNO ₃	-	Nitric Acid
NaOH	-	Sodium Hydroxide
L/S	-	Liquid-to-Solid

ABSTRAK

Kebanyakan produk sekunder dari stesen janakuasa tenaga arang batu adalah abu terbang (PFA) dari arang batu. Kaedah umum pembuangan abu berasaskan arang batu di stesen janakuasa adalah melalui kaedah pembuangan basah. Dalam kaedah pembuangan basah PFA (dikumpulkan daripada Elektro Statik Presipitator, ESP) dan abu dasar (dikumpulkan dari bawah tungku) dicampur dengan air, suspensi padat dalam cairan, dan dibuang ke dalam kolam abu atau laguna. Jika laguna ini tidak direka dengan kesesuaian tempat pembuangan PFA atau jika terdapat tumpahan daripada kolam abu, maka logam toksik yang terkandung dalam abu arang batu boleh menyebabkan pencemaran pada lapisan permukaan tanah dan air bawah tanah. Oleh demikian, kajian ini menumpukan tentang proses larut resap PFA yang terdapat di Stesen Janakuasa Sejingkat Sarawak, Malaysia. Kebolehan larut resap PFA telah dikaji dengan menggunakan ujikaji kolom dengan bantuan sebuah model rekaan sendiri. Tindak balas larut resap PFA telah dianalisis dengan nisbah cecair dan nilai pH yang berbeza. Kepekatan unsur kimia PFA telah dianalisis dengan bantuan mesin Peresap Atom Spektrometer. Sebanyak enam unsur kimia telah ditemui, iaitu Kadmium (Cd), kromium (Cr), Kuprum (Cu), Nikel (Ni), Plumbum (Pb) dan Zink (Zn). Kepekatan unsur kimia didapati meningkat dengan meningkatnya keasidan larutan dan penurunan nisbah cecair. Kepekatan unsur kimia yang terkandung dalam PFA telah dibandingkan dengan Piawaian Kualiti Air Minuman oleh Kementerian Kesihatan Malaysia. Didapati bahawa, unsur kimia seperti Cd, Cr, Ni dan Pb adalah melebihi piawaian tersebut dan berbahaya kepada alam sekitar.

ABSTRACT

Major by-product of coal fired thermal power plants is Pulverised Fuel Ash (PFA). The common method of disposal of ash from coal based power plant is wet disposal method. In wet disposal method PFA (collected from Electro Static Precipitator, ESP) and bottom ash (collected from bottom of the furnace) mixed with water, made slurry, and disposed in ash pond or lagoons. If the lagoons are not properly designed with a landfill liner or if there is spillage from the ash pond, the toxic heavy metal present in coal ash can result in the contamination of the subsurface soil and the ground water. Hence, this study concentrates about the leaching of PFA sample collected from Sejingkat Thermal Power Plant, Kuching, Sarawak, Malaysia. The leachability of PFA was investigated by using column test with aid of a fabricated designed model. The leaching behaviour is analysed with different liquid-to-solid ratio (L/S ratio) and pH values. The concentration of trace elements was determined with the aid of Atomic Absorption Spectrometer (AAS) analysis. There are six elements were found, namely Cadmium (Cd), Chromium (Cr), Copper (Cu), Nickel (Ni), Lead (Pb) and Zinc (Zn). It was found that the concentration of trace elements is increased with increases in acidity and decreases in L/S ratio. The trace elements concentrations present in PFA were compared with the Drinking Water Quality Standard by The Ministry of Health Malaysia. The trace elements such as Cd, Cr, Ni and Pb exceeded the standards and are hazardous to the environment.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

About 1.7 billion metric tons of coal has reserved in Malaysia (Pui, 2008). There are seven coal-fired stations in Malaysia which consume coal resources to produce electricity. Those seven coal-fired stations are located at Manjung (Perak), Kapar (Selangor), Jimah (Negeri Sembilan), Tg. Bin (Johor Bahru), Sejingkat (Kuching, Sarawak), Mukah (Sarawak) and Lahad Datu (Sabah) (Jaffar, 2009). Most of the coal produced was used at the Sejingkat Power Station in Sarawak, which consumed about 300,000 tonnes per year (Pui, 2008). According to Ismail *et al.*, 2007, different types of ash are produced during the combustion of coal at high temperatures and pressures in thermal power plants. The 'fine' ash fraction is carried

upwards with the flue gases and captured before reaching the atmosphere by highly efficient electro static precipitators. A study carried by Lee and Spears (1994), shows approximately 80% of the ash produced in thermal power plant carried through the combustion chambers and the ash is fall into ground surface as a waste material known as Pulverised Fuel Ash (PFA) (Figure 1.1).

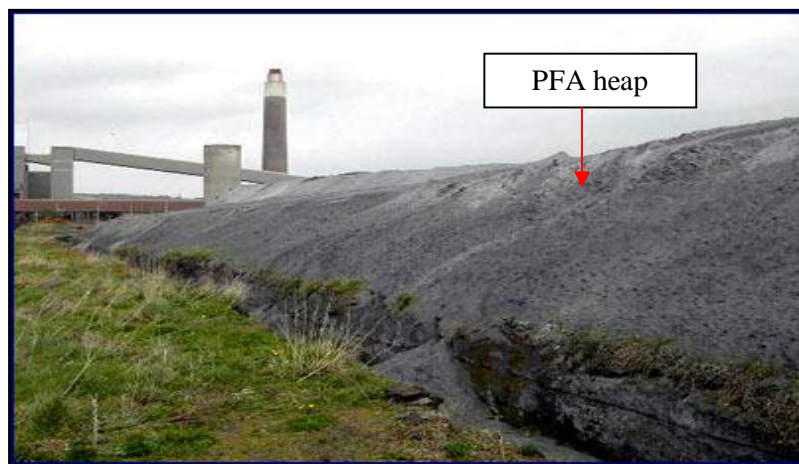


Figure 1.1: The Fallen PFA on Ground Surface (Radley Paris Council, 2009)

The physical characteristic of PFA can be described as a fine powder alumina-silicate material consists of predominantly spherical particles and varies in colour from cream to grey, which looks similar to cement (Department of Trade and Industry, 2002). The chemical composition of PFA depends on the quality of coal used and the operating condition of the Thermal Power Plants. About 95- 99% of PFA consists of oxides of Si, Al, Fe and Ca, about 0.5 to 3.5% consists of Na, P, K and S and the remainder is composed of trace elements (Gatima *et al.*, 2005) . PFA represents the largest proportion of the ash produced from power station.

Alternatively, PFA is useful in construction works as cementations material in concrete, simple fill material or lightweight aggregates and minerals, self-compacting backfill material (admixture), roads, embankments, cement, bricks, and building blocks. (Department of The Environment Industry Profile, 1995; Ismail *et al.*, 2007). In addition, PFA is also has great potential for agriculture. The use of PFA is related to modification of soil texture and bulk density, improvement of water holding capacity of soil, optimisation of soil pH, increase crop yield, as a micronutrient supplement to soil, creation of conducive conditions for better plant growth and reduction of soil crusting (Gatima *et al.*, 2005).

However, huge amount of PFA was produced every year from power plants, yet, not all of the PFA is well utilised and still disposed or dumped in landfill. Thus, this phenomenon is likely to increase the contamination of PFA in soil with the passage of time through the leaching process. This contamination contains heavy metals that lead to environmental problems. The potential problems and their consequences due to PFA disposal have been well studied around the world. It has been reported by Zandi & Russell (2007), leaching may occur if PFA in contact with water and some constituents will dissolve to greater or lesser extent and become mobile due to weathering process. These constituents will migrate to the soil and subsequently to the groundwater over a period of time. The product of this contact is known as the leachate.

According to van der Sloot *et al.* (2003), leaching is define as a process by which constituents in a solid material, either soil, contaminated soil, sludge, sediment, compost, waste or a construction material, are released into the environment through contact with water. The leachate generated from these landfills contains various trace elements such as Pb, Zn, Cd, Ni, Cu and Cr (Baba & Kaya, 2004). These trace elements can leach out and contaminate soils as well as groundwater. Thus, the amount of the trace elements has to be known in order to take appropriate measurements to prevent groundwater contamination.

This study is about the leaching of PFA collected from a local coal-fired thermal power plant which is known as Sejingkat Thermal Power Plant Sarawak, Malaysia. The leachability of PFA was investigated using column test with aid of a fabricated model. The leaching behaviour was analysed with different Liquid (L)-to-Solid (S) ratio (i.e. L/S) and pH values. These parameters gave significant effect to the concentration of the PFA trace elements. The concentrations of trace elements were determined with the aid of Atomic Absorption Spectrometer (AAS) analysis. The trace elements concentrations presents in PFA were compared with the Drinking Water Quality Standard by The Ministry of Health of Malaysia (Engineering Service Division, 2009).

1.2 Statement of Problem

There are some issues and problems on the disposals of the PFA from power plant at the landfills. The issues and problems include the following:

- i) The leaching of trace elements from the PFA into the soil ground.
- ii) The concentrations of the trace elements that leachate into the soil.
- iii) The health effects of environmental contaminants cause from the leaching of the trace elements.
- iv) The effects of the high concentrations of trace elements on the plantation and aquatics.

1.3 Objectives of Study

The aim of the study is to identify the leaching behaviours of PFA from local thermal power plant. The specific objectives of the study include the following:

- i) To develop a model to test the concentration of the trace elements in the PFA.
- ii) To study the L/S ratio and pH effect for the PFA
- iii) To study the trace elements present in the PFA and its concentration.
- iv) To compare with Drinking Water Quality Standard by The Ministry of Health Malaysia.

1.4 Scope of the Study

To examine and analyze the current issues and problem of the study, in relation to:

- i) The leaching study of the PFA from local thermal power plant.
- ii) Controlling the dumping of the PFA at the landfills.
- iii) Develop a model to test the PFA from local thermal power plant and obtain the type of elements and percentage of elements in the PFA.
- iv) Comparing the percentage of the elements in the groundwater with the Drinking Water Quality Standard by the Ministry of Health Malaysia.