

## Behaviour of Leaching Trace Element From Pulverised Coal fly Ash

Mohamed A. Altaher<sup>1,2</sup> Mohamed M. Zandi<sup>2</sup>

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#### Authors affiliation

1. Chemical Eng Dept, F/O Engineering,,  
Sebha Uni (altahermoh@gmail.com).
2. Chemical Eng Dept , Sheffield uni,UK

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### ABSTRACT

Coal is a source of energy and one type of fossil fuel which is being used worldwide for long time in many applications such as electricity production and industrialised area. Combustion of fossil fuels is and will probably continue to be an important part of the heat and power production systems of many countries. Thus, depending on type and origin of the coal, about 5-15% of the total remains as ash formed from mineral matter. Many elements such as B, Cr, Cu, Ni, Mo, S, V, etc occur in the coal during its formation and condensed to the ash when is burnt. Leaching these hazardous elements from bottom and fly ash will cause environmental problems. Two different types of fly ashes (PEA1, PFA2) were leached with deionised water and nitric acid. The results showed that most of the elements of environmental concern in fly ash are present in small quantities and high leaching rates can be found in acidic conditions (lower pH).

### سلوك ارتشاح العناصر الثقيلة من مسحوق رماد الفحم المتطاير

محمد م. الطاهر<sup>1</sup> محمد أ. زاندي<sup>2</sup>

الفحم هو مصدر للطاقة ونوع واحد من الوقود الأحفوري الذي يستخدم في جميع أنحاء العالم لفترة طويلة في العديد من التطبيقات مثل إنتاج الكهرباء والمنطقة الصناعية. إن احتراق الوقود الأحفوري كان وربما سيظل جزءا هاما من نظم إنتاج الحرارة والطاقة في العديد من البلدان. وبالتالي، اعتمادا على نوع وأصل الفحم، يبقى حوالي 5-15% من المجموع كرماد يتكون من المواد المعدنية. العديد من العناصر مثل B و Cr و Cu و Ni و Mo و S و V وما إلى ذلك تحدث في الفحم أثناء تكوينه وتتكثف إلى الرماد عند حرقه. إن ترشيح هذه العناصر الخطرة من القاع والرماد المتطاير سيسبب مشاكل بيئية. تم ترشيح نوعين مختلفين من الرماد المتطاير (PEA1، PFA2) بالماء منزوع الأيونات وحمض النيتريك. أظهرت النتائج أن معظم العناصر ذات الاهتمام البيئي في الرماد المتطاير موجودة بكميات صغيرة ويمكن العثور على معدلات ترشيح عالية في الظروف الحمضية (انخفاض درجة الحموضة).

### INTRODUCTION

Coal is one of the most important electrical generation fuel sources and represents about 56% of the electrical energy in the world. Each year around 800 million tonnes of coal are consumed (Dusing. *et al* 1991). However, burning coal in power stations has negative consequences on the environment and human health. These are not only gases and particulate emissions, but also large quantities of bottom and fly ash (Brigden. *et al* 2002, Sear 2001). Thus, depending on type and origin

of the coal, about 5-15% of the total remains as ash formed from mineral matter. This mineral matter is altered into different minerals which are responsible for chemical composition of the ash (Lederman. *et al* 2003, Spears 2000). Many elements such as B, Cr, Cu, Ni, Mo, S, V, etc occur in the coal during its formation and condensed to the ash when is burnt. Leaching these hazardous elements from bottom and fly ash will cause environmental problems (Iwashita. *et al* 2005).

Experimental results have shown that toxic trace elements may leach if the bottom and fly ash contact

with water (Baba. *et al* 2004). When it contacts with surface or ground waters can lead to release major(calcium, aluminium, ions, magnesium and so on) and trace elements(arsenic, chromium, mercury, nickel, lead, zinc and so on) which can cause contamination for both human health and environment (Brigden. *et al* 2002, Sear 2001). However, the distribution of each element within fly ash particle is different from each other. Some elements (Ti, Na, K, Mg, Hg, Fe) are found in the aluminosilicate matrix, while others (As, Se, Mo, Zn, Cd, W, V, U) are determined at the surface (Iwashita. *et al* 2005, Lederman. *et al* 2003). Elements include Mn, Be, Cr, Cu, Co, Ca, Ba, and Pb are dispersed between the matrix and the mineral matter (Iwashita. *et al* 2005, Lederman. *et al* 2003). The minority of fly ash is used in many applications such as concrete, grouting, fill material and road construction (Sear 2001). However, as the rate of production of fly ash is greater than consumption, the majority is disposed (Iyer, 2002). In addition, leaching studies are important to predict the environmental impacts which are associated with fly ash applications.

Thus, there are many factors which have been found affecting leachability of trace elements from fly ash. Some of these related to the fly ash itself are called primary factors. These include: size, composition and properties of fly ash which depends on the type and origin of the fuel as well as the combustion conditions (Swaine 1995, Karr 1979). The second group which is called secondary factors controls release rate. These include: liquid to solid ratio, pH of the leachant, contact time, temperature leachant solution and redox potential of leachant (Swaine 1995, Karr 1979, Zandi. *et al* 2004).

Trace elements are important due to their association with environmental problems and human, plants and animal health. It is important to consider the essential, non-essential and toxicity which depend on concentrations, the form of the elements, pH, and oxidation-reduction and so on (Swaine, 2000). These elements could be from natural sources or anthropogenic sources. Natural sources include volcanoes, lake and river sediments, vegetation and forest fires. Whereas, combustion of oil, coal and wood, metal mining and smelting, waste disposal, industrial activities and agricultural activities represent anthropogenic sources (Swaine, 2000). Many elements are considered to be of environmental interest such as Arsenic, Chromium, Lead, Mercury, Zinc, Nickel and so no. About 2-3% by weight of fly ash is soluble in water which is usually alkaline in reaction and mainly calcium and sulphate ions (Sear 2001, Sear. *et al* 2003). Fly ash initially has low pH when water is added as the sulphate deposited on the surface of the particles and hydrolysed to form sulphuric acid. This is a transient situation and pH rapidly rises as calcium is leached into solution. Thus, fly ash has pH typically 9-11(Sear 2001). Moreover, investigation has been carried out shown that, all of the oxyanionic trace elements such as As, B, Sb, Se, Mo and V behaved similarly with maximum solubility at neutral

to slightly alkaline pH and reduced solubility at higher and lower pH values. Also for cationic elements such as pb, Cd and Zn behaved with minimum solubility occurred at pH 9 with a maximum near pH 4 (Swaine, 1995).

The objective of this paper to investigate effect of leaching trace elements from coal fly ash. Two types of pulverised fly ash will be analysed using extracted leaching mechanism. Deionised water and nitric acid were used and compared for all extracted elements.

## Experimental

Two ash samples were collected from electrostatic precipitators of UK power stations and used for this study. These samples have small particle size less than 4mm to increase the specific surface area and then leaching rate. No attention has been paid to type of coal or combustion condition of fly ash samples. Table 2 shows the major and trace elements which are present in these two types of fly ash (PFA1 , PFA 2) respectively.

Blank leaching tests are carried out in order to investigate if there are contamination from magnetic bars and borosilicate glass bottles which are used in this project. 200ml of deionised water was placed in borosilicate with magnetic bar and shaken for 24 hours. Two leachants were analysed after filtration using ICP-MS analysis. The procedure of shake leaching test is a relatively simple and quick. An amount of 4g sample material was placed in a 250ml borosilicate glass bottle followed by 200ml of deionised water and agent in a ratio of L/S with magnetic bar as shown in Table1. The bottle was subjected to horizontal shaking for 24h in an oscillating shaker at room temperature, followed by 15minuts settlement. The leachate was separated over 0.45µm filters and then stored for analysis after measuring pH. Also, every test was repeated two times and the average was taken for pH and ICP analysis.

**Table1: Characteristics of Batch leaching tests.**

| <i>Leachant</i>         | Deionised water | Acetic acid buffer |
|-------------------------|-----------------|--------------------|
| <b>LS</b>               | 10              | 20                 |
| <b>Leaching time(h)</b> | 24              | 18                 |
| <b>Temperature(°C)</b>  | 18-25           | 18-25              |

**Table2: Major and trace element PFA 1, 2 (Zandi. et al., 2004).**

|                                    | PFA 1 | PFA 2 |
|------------------------------------|-------|-------|
| Major oxides (%)                   |       |       |
| <b>Al<sub>2</sub>O<sub>3</sub></b> | 31.80 | 30.60 |
| <b>SiO</b>                         | 47.30 | 49.10 |
| <b>Fe<sub>2</sub>O<sub>3</sub></b> | 4.12  | 5.90  |
| <b>MnO</b>                         | 0.08  | 0.05  |
| <b>CaO</b>                         | 7.37  | 5.97  |
| <b>MgO</b>                         | 1.60  | 1.31  |
| <b>K<sub>2</sub>O</b>              | 1.03  | 1.52  |
| Trace elements<br>(mg/kg)          |       |       |
| <b>As</b>                          | 19.8  | 44.7  |
| <b>B</b>                           | 24    | 12    |
| <b>Be</b>                          | 8     | 6.9   |
| <b>Ca</b>                          | 45109 | 38507 |
| <b>Cd</b>                          | <0.2  | <0.2  |
| <b>Co</b>                          | 21.4  | 30.9  |
| <b>Cr</b>                          | 71    | 40.5  |
| <b>K</b>                           | 7323  | 11389 |
| <b>Mg</b>                          | 8263  | 7129  |
| <b>Mn</b>                          | 42    | 42    |
| <b>Mo</b>                          | 11.4  | 11.5  |
| <b>Na</b>                          | 2960  | 3769  |
| <b>Ni</b>                          | 51.6  | 68    |
| <b>Se</b>                          | 3     | 4.2   |
| <b>Ti</b>                          | 9806  | 9198  |
| <b>V</b>                           | 187.6 | 148.9 |
| <b>Zn</b>                          | 50.1  | 42.1  |

## Results and Discussions

The amounts of metals leached from both fly ash samples are shown in Figures 1 & 2 respectively. The results are expressed in terms of percentage of extracted heavy metals to their original content. Comparison also is given for the leached amounts of metals from fly ash samples using two different leaching agents. In general, the leachability of most elements increases under acetic acid buffer (highly oxidised state) than deionised water (low oxidised state). Thus, some elements include (K, Mo, and Sr) their leachability are similar under both agents. This happened, because the solubility of these elements are high and dissolve under low or highly oxidised state. However, high concentration of chromium from PFA 1, 2 using deionised water (low oxidised state). Thus, analysis of the results also showed significant differences in Ca leached both solutions. In each case the acetic acid buffer leached the most Ca. Although, calcium is major and highly soluble element and dissolve under any condition, but the results show that the leaching rate of calcium from most samples increased under highly oxidising state.

In additions, most of the heavy metals of environmental concern in fly ash such as Mg, Ni, V and Zn, their leachability increased under highly oxidising conditions with low level leached (0.002%-58%). This may attributed to low Ph value as well as high liquid to solid ratio comparing to conditions of deionised water test. Moreover, the levels of metals leached were relatively low in all fly ashes under both agents with a tendency for increased leaching under acetic acid buffer (highly oxidising acidic).

## CONCLUSIONS

The leachability of trace elements from coal fly ash (PFA1&2) were studied using two leachants, deionised water and nitric acid and the overall conclusions are summarised as follows:

- Most of the elements of environmental concern in fly ash are present in small quantities;
- Elements on the surface of fly ash particles such as As, B, Ca, Cr, Mg and Sr cause the greatest problems than the others captured inside fly ash matrix;
- High leaching rates can be found in acidic conditions (lower pH)
- The levels of metals are leached are relatively low in both fly ashes under both agents with a tendency for increased leaching under acetic acid buffer (highly oxidising acidic);
- Some elements include (K, Mo, and Sr) their leachability are similar under both agents, because the solubility of these elements are high;
- Leaching of chromium increased under low oxidising condition and decrease under highly oxidising conditions;
- Leaching rate of calcium from most fly ash samples increased under highly oxidising conditions.

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