

# Evaluation of Heavy Metal Contamination and Geochemical Characteristics of CCPs in Korea

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## ABSTRACT

The coarse solid residues resulted from burning of coal are called coal combustion products (CCPs). As coal-fired power generation increases, the amount of CCPs is about 10 million tons per year in South Korea. These CCPs have been recycled and reused in several ways, but about 3 million tons of these byproducts have been stored in retention ponds or sent to landfills every year. There are lots of researches to increase the recycling rate of CCPs. However, due to concerns about environmental safety, recycling of CCPs has been limited. To increase its recycling rates, it is needed to understand the characteristics of CCPs and to evaluate its influence on environment.

In this study, basic geochemical characteristics and heavy metal contaminations of CCPs from two coal-fired power plants in South Korea were evaluated. In order to find out the geochemical properties of CCPs from each power plant, various test including XRF, XRD and SEM analysis were performed. The heavy metal contamination was measured by heavy metal contents test and leaching test to evaluate environmental safety.

The results showed that the contents of CaO and K<sub>2</sub>O in CCPs are higher than in normal soils. It was found that the levels of heavy metal contamination of CCPs from all power plants were below the safety standards of soil pollution. Leaching test also showed that the contents of heavy metals of CCPs were lower than the safety standards.

## 1. Introduction

Due to the rapid development of society, the use of electricity and the use of fossil fuels have been steadily increasing. Especially coal is the fuel for power generation accounted for the highest percentage in Korea. According to the Korea Electric Power Market Statistics (2011), the amount of power generation through coal-fired power generation is 191,008Gwh and it is the largest part (43.8%) of the entire generation. The

amount of coal-fired power is expected to increase steadily. But the increase in coal-fired power, byproduct remaining after coal combustion will increase, too. The coarse solid residues resulted from burning of coal are called coal combustion products (CCPs). As coal-fired power generation increases, the amount of CCPs is about 10 million tons per year in South Korea. These CCPs have been recycled and reused in several ways, but about 3 million tons of these byproducts have been stored in retention ponds or sent to landfills every year. There are lots of researches to increase the recycling rate of CCPs<sup>1-6</sup>. However, due to concerns about environmental safety, recycling of CCPs has been limited. To increase its recycling rates, it is needed to understand the characteristics of CCPs and to evaluate its influence on environment.

In this study, basic geochemical characteristics and heavy metal contaminations of CCPs from two coal-fired power plants in South Korea were evaluated. In order to find out the geochemical properties of CCPs from each power plant, various tests including XRF, XRD and SEM analysis were performed. The heavy metal contamination was measured by heavy metal contents test and leaching test to evaluate environmental safety.

## 2. Materials and Method

### 2.1 Materials

There are 10 coal-fired power plants along the shoreline in South Korea. The coal type used in each plant is different that is divided into two kinds - domestic anthracite coal and imported bituminous coal. In this study, two power plant samples depending on the type of coal are used. Young-Heung(YH) coal-fired power plant is located on the west coast near Seoul. Imported bituminous coal has been used as a fuel in this plant. Seo-Chon(SC) coal-fired power plant is located on the southwestern coast of the Korean peninsula and use domestic anthracite coal. The sampling locations are shown in Fig. 1

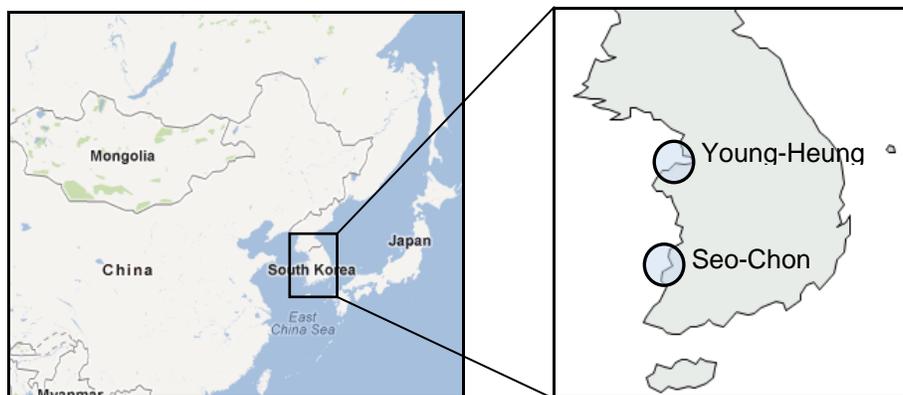


FIGURE 1: Locations of sampling sites

## 2.2 Measurement of heavy metals content

The each CCPs particles sample was dried while more than 24hr in oven which can be kept inner temperature constant about 110°C to remove moisture. And then the dried soil is passed through a sieve #100 (150µm) and is taken 10g in passing. The heavy metal items are measured are Cd, Cu, Pb, As, Zn, Ni, Hg, Cr<sup>+6</sup>. The method to measure of heavy metal content is the inductively coupled plasma mass spectrometer (ICP) method and the atomic absorption spectrometry (AAS) method.

## 3. Results and Discussion

### 3.1 Heavy metals contents of CCPs

The results of heavy metal content for each sample are shown in the following Table 1

As shown in the Table 1, the most heavy metal contaminations of SC were higher than YH samples except Cd. However the heavy metals contaminations of all samples meet the safety criteria.

TABLE 1: The heavy metal contaminations of particle samples

Site	Cd	Cu	Pb	As	Zn	Ni	Hg	Cr <sup>+6</sup>	Unit
YH	0.40	8.33	0.83	2.03	8.23	9.07	ND <sup>1</sup>	ND	
SC	0.23	19.97	5.20	9.60	12.27	9.10	0.388	ND	mg/Kg(L)
STANDARD <sup>2</sup>	4	150	200	25	300	100	4	5	

1. ND : Not Detected

2. Standard : Korean Soil Environmental Conservation Act (for soil)

The values in the Table 1 are expressed as the graph in Fig. 2

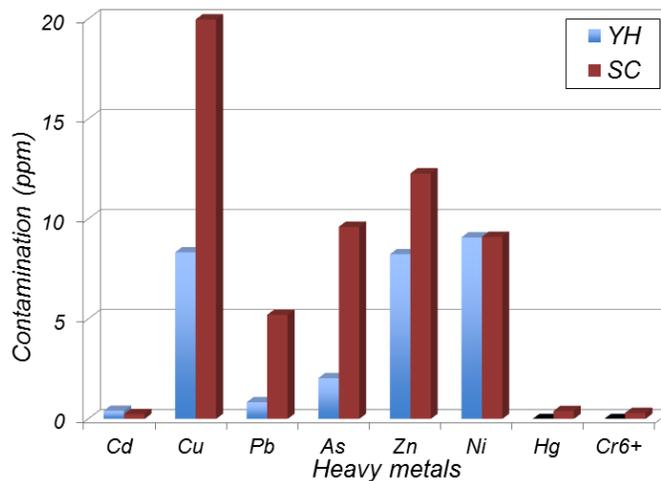


FIGURE 2: The graphs of degree of contamination

The results of heavy metal content by leaching test for each sample are shown in the following Table 2 and Fig.3. This results show that the CCPs of two plants meet the safety standard and the contamination of SC sample is high than YH sample except As. Cd, Hg and Cr<sup>6+</sup> were not detected in all samples.

TABLE 2: Results of leaching test for YH and SC sample

Site	Cd	Cu	Pb	As	Hg	Cr <sup>6+</sup>	Unit
YH	ND <sup>1</sup>	ND	ND	0.081	ND	ND	
SC	ND	0.003	0.017	0.03	ND	ND	mg/Kg(L)
STANDARD <sup>2</sup>	0.02	0.5	0.1	0.1	ND	0.1	

1. ND : Not Detected
2. Standard : Korean Waste Management Act

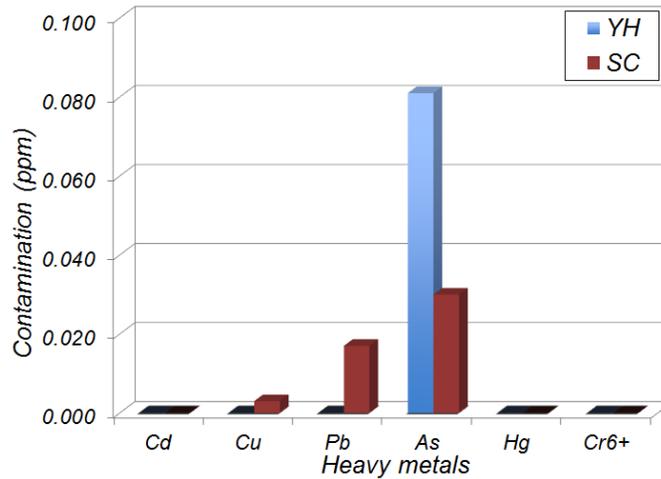


FIGURE 3: The graphs of degree of contamination by leaching test

### 3.2 XRF and XRD Results

The results of XRF analysis for each sample are shown in the following Table 3

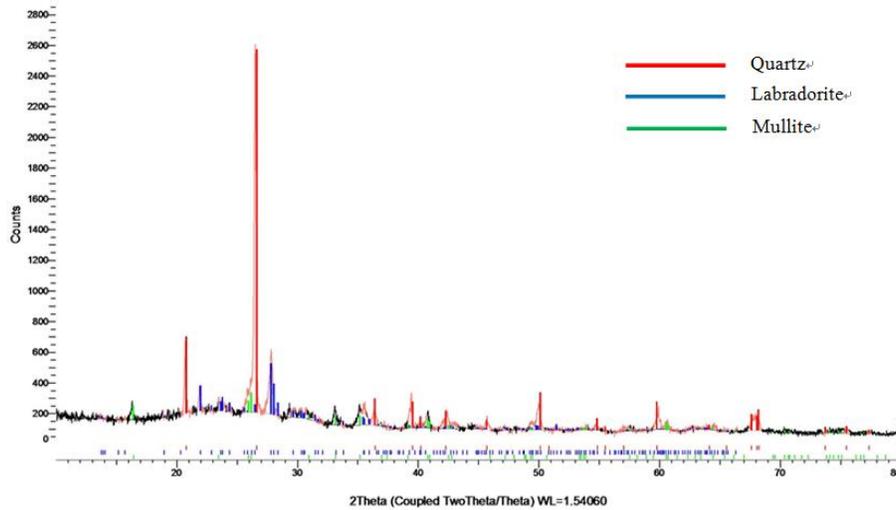
TABLE 3: Results of XRF analysis for YH and SC sample (%)

Site	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	CaO	Na <sub>2</sub> O	MgO	TiO <sub>2</sub>	SO <sub>3</sub>	P <sub>2</sub> O <sub>5</sub>	MnO	LOI <sup>1</sup>
YH	52.17	21.46	8.04	1.44	<b>7.65</b>	2.12	1.42	1.19	0.95	0.59	0.05	2.06
SC	51.12	28.98	7.08	<b>5.32</b>	1.21	0.43	0.74	2.40	0.22	0.26	0.07	1.56

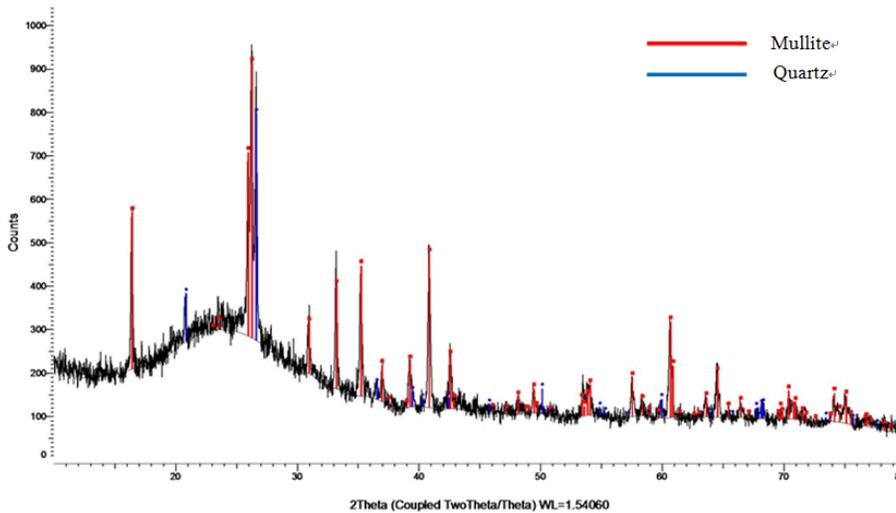
1. LOI : Loss on ignition

As shown in this result,  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  in both samples were major elements. Alumina-silica ratio ( $\text{Al}_2\text{O}_3 / \text{SiO}_2$ ) of SC sample was higher than YH sample. It means that the CCPs of SC is the more fireproof material. CaO ratio of YH and  $\text{K}_2\text{O}$  ratio of SC were significantly high. These components could effect on properties of each CCPs.

The mineralogy of the samples was determined by powder X-ray diffraction (XRD). The results of XRD analysis for each sample are shown in the following Fig. 4. The XRD patterns from Fig. 4 show that the main minerals present in the CCPs are Mullite and quartz.



(a) YH



(b) SC

FIGURE 4: Results of the XRD analysis for YH and SC sample

### 3.3 Results of SEM image

The results of XRF analysis for each sample are shown in the following Fig.5. As a result, CCPs of SC sample are smaller than YH sample and have more round shape. This photograph shows that the CCPs are very porous material.

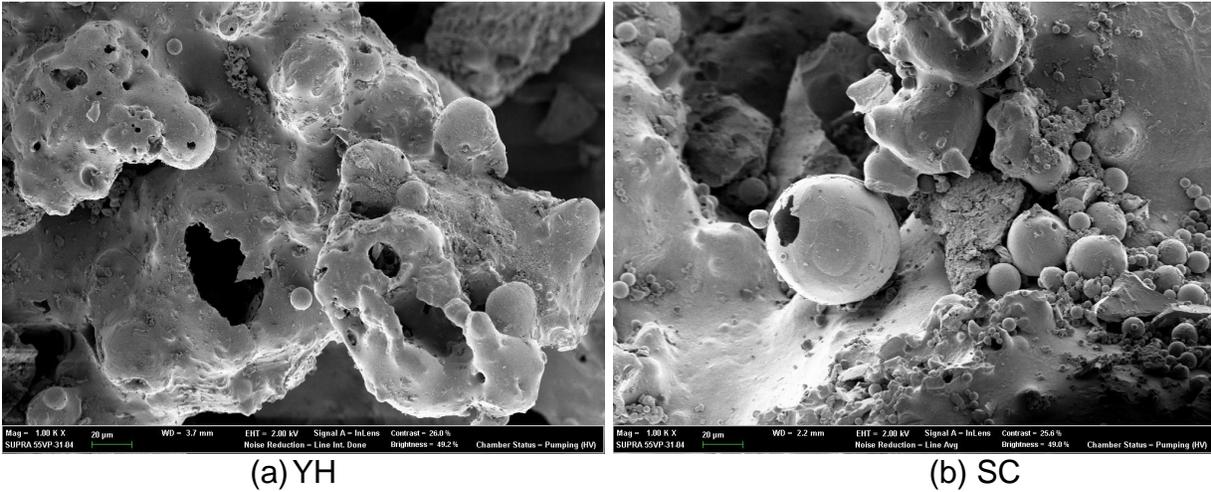


FIGURE 5: Photographs using SEM of YH and SC sample (x1,000)

### 4. Conclusions

In this study, the CCPs were sampled from two coal-fired power plants (YH and SC), measured heavy metals contents by AAS, ICP method and leaching test in lab. XRF, XRD and SEM analysis were performed, too. As a result, it was found that the contents of CaO and K<sub>2</sub>O in CCPs are higher than in normal soils and major mineral components are Mullite and quartz. The levels of heavy metal contamination of CCPs from all power plants were below the safety standards of soil pollution. Leaching test also showed that the contents of heavy metals of CCPs were lower than the safety standards.

### 5. Acknowledgment

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## REFERENCES

- 1 Chai Jaturapitakkul, and Raungrut Cheerarot, 'Development of Bottom Ash as Pozzolanic Material', *Journal of materials in civil engineering*, 15 (2003), 48-53.
- 2 K Kayabal, and G Buluş, 'The Usability of Bottom Ash as an Engineering Material When Amended with Different Matrices', *Engineering Geology*, 56 (2000), 293-303.
- 3 Bumjoo Kim, Monica Prezzi, and Rodrigo Salgado, 'Geotechnical Properties of Fly and Bottom Ash Mixtures for Use in Highway Embankments', *Journal of Geotechnical and Geoenvironmental Engineering*, 131 (2005), 914-24.
- 4 Yun-Tae Kim, and Thanh-Hai Do, 'Effect of Bottom Ash Particle Size on Strength Development in Composite Geomaterial', *Engineering Geology*, 139-140 (2012), 85-91.
- 5 Sanjeev Kumar, and James Stewart, 'Evaluation of Illinois Pulverized Coal Combustion Dry Bottom Ash for Use in Geotechnical Engineering Applications', *Journal of energy engineering*, 129 (2003), 42-55.
- 6 Ş Targan, A. Olgun, Y. Erdogan, and V. Sevinc, 'Influence of Natural Pozzolan, Colemanite Ore Waste, Bottom Ash, and Fly Ash on the Properties of Portland Cement', *Cement and Concrete Research*, 33 (2003), 1175-82.