Geochemical and Mineralogical Characteristics of Coal Combustion Byproducts Generated from Al-Ga-Li-rich Coal in Inner Mongolia

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INTRODUCTION

The Tuoketuo power plant is the largest one in China, which is mainly fed with the Al-Ga-Li-rich coals from the Jungar coalfield located in Inner Mongolia, northern China. The Jungar coalfield is 65-km long (N–S) and 26-km wide (W–E), with a total area of 1700 km². Coal reserves in the Jungar Coalfield amount to 26.8 Gt, making it one of the richest coalfields in northern China¹. The Jungar coals are enriched in Al, Li, Ga, Sr, and Th. The average Li content in the no. 6 coal at the Haerwusu Surface Coal Mine is 116 mg/kg, with the maximum value of 566 mg/kg ¹. The average Li content in the feed coals from the Jungar Power Plant is 147 mg/kg (Dai et al., 2010).

With the aim of evaluating the quality of the coal combustion by-products (CCPs) generated from the Tuoketuo coal-fired power plants, the geochemical features of the fly ash, slag, and flue-gas desulfurization (FGD) gypsum generated from it were investigated. Special emphasis on leaching potential of trace elements in these CCPs were analyzed for the subsequent determination of potential applications of them.

METHODOLOGY

Two fly ash (TFAc for coarse fraction and TFAf for fine), one slag, one flue-gas desulfurization (FGD) gypsum and one feed coal sample was collected from the Tuoketuo coal-fired power plant in Inner Mongolia.

The mineralogical
The mineralogical characteristics and particle morphology of feed coal, fly ash, slag, and FGD gypsum samples were investigated by Powder X-Ray Diffraction and Scanning Electron Microscope with Energy Dispersive X-ray analyzer (SEM-EDX).

Feed coal, fly ash and slag samples were acid-digested by using a two-step digestion method devised by Querol et al\(^2\). Then most trace element contents were analyzed on the resulting solution by Inductively-Coupled Plasma Mass Spectrometry (ICP-MS), and the contents of major and selected trace elements were determined by Inductively-Coupled Plasma Atomic-Emission Spectrometry (ICP-AES). Specifically, Mercury analysis were directly analysed on feed coal, fly ash and slag samples, using a LECO AMA 254 gold amalgam atomic absorption spectrometer (GA-AAS).

The European Standard leaching test EN-12457\(^3\) was applied to the fly ash, slag, and FGD gypsum samples to determine the leaching potential of major, and trace elements. The pH and ionic conductivity of the leachates were determined by conventional methods. The content of major and trace elements of the leachates were determined by ICP-AES and ICP-MS. The content of Hg was determined directly on leachates by the same procedure as for the solid coal samples using GA-AAS.

**MINERALOGICAL CHARACTERISTICS**

Fly ash samples (TFAf and TFAc) contain Al–Si–Ca–Fe amorphous glass matrix as the main constituent (65% and 51.1%, respectively), with variable contents of mineral crystalline phases (Table 1). The minerals present in two fly ashes are mullite, corundum and quartz, with traces of lime occurring in the coarse fly ash (Table 1). The total amounts of mineral composition in TFAf and TFAc fly ash are 35% and 28.9%, respectively. The coarse fly ash has much higher mineral phases with respect to the fine one (Table 1).

The slag is also made up of a predominant aluminium–silicate amorphous glass matrix (56.7%). The crystalline phases in slag are quartz, mullite and minor amount of tridymite, with a total content of 43.3% (Table 1).

The FGD gypsum are mainly composed of gypsum (92.3%), with traces of quartz and dolomite.

Table 1 Mineral contents (%) in the studied fly ashes, slag, and FGD gypsum. <dl, under the XRD detected limit.

<table>
<thead>
<tr>
<th>%</th>
<th>TFAf</th>
<th>TFAc</th>
<th>Tslag</th>
<th>TFGD Gp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>1.5</td>
<td>5.2</td>
<td>12.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Mullite</td>
<td>32.3</td>
<td>41.2</td>
<td>26.0</td>
<td>&lt;dl</td>
</tr>
<tr>
<td>Corundum</td>
<td>1.3</td>
<td>2.3</td>
<td>&lt;dl</td>
<td>&lt;dl</td>
</tr>
<tr>
<td>Lime</td>
<td>&lt;dl</td>
<td>0.3</td>
<td>&lt;dl</td>
<td>&lt;dl</td>
</tr>
<tr>
<td>Tridymite</td>
<td>&lt;dl</td>
<td>&lt;dl</td>
<td>0.4</td>
<td>&lt;dl</td>
</tr>
<tr>
<td>Dolomite</td>
<td>&lt;dl</td>
<td>&lt;dl</td>
<td>&lt;dl</td>
<td>3.8</td>
</tr>
<tr>
<td>Gypsum</td>
<td>&lt;dl</td>
<td>&lt;dl</td>
<td>&lt;dl</td>
<td>92.3</td>
</tr>
</tbody>
</table>
GEOLOGICAL CHARACTERISTICS

The fine fly ash (TFAf) present higher concentration of most of the major and trace elements than the coarse one (TFAc), with the exception of Al, probably due to the relatively high corundum content in TFAc. This may be attributable to the larger surface area of finer particles of fly ash, which allows for deposition/absorption of volatile elements on the surface of this fly ash.

The slag sample (TS) shows higher Fe content than two fly ashes, and the concentration of the other elements in slag are lower than in two fly ashes.

Compared with European fly ashes reported by Moreno et al. (2005)\(^3\), the fly ash and slag in this study are characterized by low trace element concentration with the exception of Li and Ga, probably due to the relatively high Li and Ga content in the feed coals. When compared with the fly ashes and slag from two power plants in Xinjiang, China\(^4\), with the exception of Fe, K, Na, and Mg, the studied fly ashes and slag present much higher concentration of other elements.

With respect to the FGD gypsum from the Xinjiang power plant\(^4\), TFGD gypsum present high concentration of B, Cr, As, Se, Rb, Sr, Zr, Nb, La, Ce, Ta, Pb, and Hg. When compared with two FGD gypsum from two power plants in Spain\(^5\)\(^-\)\(^6\), the studied FGD gypsum is characterized by high concentration of Cr, Cu, Zn, Ga, As, Se, Rb, Sr, Ba, La, Ce, Ta, Pb, and Hg.

LEACHING CHARACTERISTICS

According to the leaching test, most of the trace elements, including environment-concerned toxic elements (Hg, As, Se, Cr, Ni, Cu, Zn, Mo, Cd, Ba, Sb, and Pb) have very low leachable proportions, with the exception of Li, B, Zn, Se, and Mo in TFAf; Ba, Mo, and Ga in TFAc; and Mn, and Zn in FGD gypsum.

These CCPs are classified as non-hazardous materials according to the limits established by European Council Decision 2003/33/EC\(^7\), which indicating that these CCPs may be utilized with low environmental burden.

REFERENCES


