Petrographic Assessing of Combustion Waste Products Quality Resulting from Berbești Lignite Burning in Govora Power Plant

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The paper aims to establish the relationship between Berbești lignite composition and of the combustion waste products (CWP) formed during combustion in Govora power plant. Besides physico-chemical methods, the petrographic research confirms the CWP quality dependence on feed lignite characteristics (rank and maceral composition) and their behaviour during thermal treatment, the optical texture providing information on the organic/inorganic ratio. The composition of combustion residues, evaluated microscopically, offer a better knowledge of combustion process and CWP quality (wastes having an increased environmental impact), but the choice of the best ways of recycling, including for new construction applications.

Keywords: lignite, thermal treatment, recycling combustion waste products, optical microscopy, construction materials.

A variety of combustion residues are generated during burning coals in the power plants which exhibit complex composition depending mostly on coal type and thermal treatment. Coal combustion waste products (CWP), fly-ash, bottom ash and slag are, as generated amounts, the major wastes which are produced in the world, including Romania [1].

Coal bearing deposits of Oltenia Mining Basin belong to upper Pliocene represented by Dacian and Romanian floors and basal part of the Quaternary (lower Pleistocene). The perimeters of the working opencast pits spread over three counties: 10% Mehedinți (Mehedinți coalfield), 82% Gorj (Motru, Jilț, Rovinari and Albeni Roșia de Amaradia coalfields) and 8% Vâlcea (Berbești coalfield) are shown in figure 1 [2].

The geological structure of the deposit, exploitation type, nature of sterile intercalations of typically Pliocene origin and characteristics are well known from previous researches [3]. They were focused on the geological setting of Oltenia Coal Deposits, as well as on lignite main component (xylite), its size characteristics and petrographical structural composition [4]. It is well known that in the grinding process for coal dust preparation, xylite’s elasticity cause the premature damage of the mills and increased energy consumption. After burning in the combustion chamber, xylite is found almost unchanged (as weakly pyrogenated particles) in the bottom ash and partially burned in fly-ash [3-6].

Currently, large quantities of ash are used for landfilling which cause negative environmental impacts such as air and soil pollution, and leaching of potentially toxic substances into soils and groundwater. The best way to solve the disposal problem of ash is to decrease the quantity for disposal with utilization of ash in the industry [7, 8]. The increasing demand of energy production leads to the world production of about 600 million tons of fly-ashes, and this value will increase in the near future [9].

In Romania, the impact due to lignite burning in thermal power plants represents a major environmental and economic concern. Waste disposal by landfill represents in our country the most important way to eliminate industrial waste, 75% of which being stored every year, with considerable costs for storage places construction. Govora coal power plant is producing electricity and thermal energy using as main fuel Berbești lignite (2 mil t/year), the surface of ash deposits totaling 60 ha. Within Govora power plant the residues from the combustion of lignite are stored or reused, thus: (i) Bottom ash and slag are stored; (ii) ash - eliminated from number two gas funnels route is hydraulically extracted or dry, as three types: (1) Ash before regenerative combustion air pre-heater; (2) Ash-cement - mixture of fly-ash collected in the electrofilters; (3) Ash-concrete - certified according to the concrete standard [10].

The main constituents of ash are Al2O3, Fe2O3, CaO, MgO and in smaller quantities Na2O and K2O. However, the diverse chemical, mineralogical and morphological properties of ash offer an opportunity to process it and

Fig. 1. Location of lignite exploitation perimeters of Oltenia Mining Basin in South West Romania [2].
recovered various fractions with particular attributes. A variety of fly-ash has been converted into useful ceramics and glass-ceramics (GCs) used as architectural components in buildings, by several research groups [7, 11, and 12].

Information on chemical and petrographical characteristics of Romanian coals and CWP [13-15], including Oltenia’s lignites were published, including the use for ceramic composites manufacturing [16-18]. Information provided by characterizing of fly-ash, about un-burned carbon content and inorganic fraction, prove to be of great importance in describing associations between different components or individual particles in order to predict its behaviour. For commercial use (such as constructions) fly-ash quality with low carbon content is requested. Petrographic composition analysis provides important details about the texture of coal particles or partially burned/degassed (char), of porosity and wall thickness of cenospheres components, aspects that can be related to the origin and their behaviour during combustion process [19]. Investigation of the use of bottom ash as an alternative source of lightweight granular aggregate [20], high temperature behaviour and sintering mechanism of fly ash based concretes [21] including some other authors reports on ash utilisation in construction have also published [22-24]. The use of CWP in new construction application represents a real approach that includes Oltenia’s lignites were published, including the chemical and petrographical characteristics of Romanian coals and CWP [13-15], as in table 1. For ash average samples general physico-chemical characteristics (ash, volatile, fixed carbon) and elemental analysis were carried out, as in table 1. For average samples general physico-chemical characterization was focused to establish the limits variation of the basic parameters, shown in table 2, and dimensional distribution of particles as appears in figure 2.

In table 3 are shown the results of reflectance measurements for Berbesti lignite samples and their repartition on half steps of identified huminite B (bands and bands of 6-10 μm). The average reflectance, shown in Figures 3 and 4, can be rounded at two decimals, the maximum error being in the range of ±1×10⁻². It was found that huminite reflectance corresponds to low rank coals, respectively of the range of 0.2-0.3%. Coalification process

Table 1
PROXIMATE AND ULTIMATE ANALYSIS OF LIGNITE SAMPLES, % WT.

<table>
<thead>
<tr>
<th>No.</th>
<th>Sample</th>
<th>Proximate analysis</th>
<th>Ultimate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ash (%)</td>
<td>Vol (%)</td>
</tr>
<tr>
<td>1</td>
<td>CA1</td>
<td>41.49</td>
<td>35.92</td>
</tr>
<tr>
<td>2</td>
<td>CA4</td>
<td>38.21</td>
<td>37.25</td>
</tr>
</tbody>
</table>

Table 2
PHYSICO-CHEMICAL CHARACTERISTICS OF THE AVERAGE ASH SAMPLES, % WT.

<table>
<thead>
<tr>
<th>No.</th>
<th>Characteristics</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ash, A&lt;sub&gt;ash&lt;/sub&gt;, %</td>
<td>CE1</td>
</tr>
<tr>
<td>2</td>
<td>Volatiles, V&lt;sub&gt;vol&lt;/sub&gt;, %</td>
<td>99.39</td>
</tr>
</tbody>
</table>

Fig. 2. Grain size distribution of the CWP samples, %
Sample | Open pit mine | Distribution on rank half steps, % | RmH, %
---|---|---|---
| | 0.16-0.20 | 0.21-0.25 | 0.26-0.30 | 0.31-0.35 |
1 | Berbesti | 2 | 66 | 32 | - | 0.2416 |
2 | | 10 | 68 | 22 | - | 0.2384 |

### COMPONENTS REPORTED AT

<table>
<thead>
<tr>
<th>Maceral group</th>
<th>Maceral subgroups and macerals</th>
<th>Total carbonaceous material</th>
<th>Organic material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huminitic</td>
<td>Textinite</td>
<td>27.1</td>
<td>36.9</td>
</tr>
<tr>
<td>Structured wooden material</td>
<td>Ulmine</td>
<td>17.8</td>
<td>24.2</td>
</tr>
<tr>
<td>Textohuminite</td>
<td>Attrinite</td>
<td>44.9</td>
<td>61.1</td>
</tr>
<tr>
<td>Densinite</td>
<td></td>
<td>2.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Detrohuminite</td>
<td></td>
<td>7.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Corpohuminite</td>
<td></td>
<td>15.1 (13.8)</td>
<td>20.5 (18.8)</td>
</tr>
<tr>
<td>Gelohuminite</td>
<td></td>
<td>22.1</td>
<td>30.1</td>
</tr>
<tr>
<td>Liptinite</td>
<td></td>
<td>3.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Inertinite</td>
<td></td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>TOTAL ORGANIC MATTER (CARBOMINERITE)</td>
<td></td>
<td>73.5</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Clay minerals</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ferrous minerals</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>TOTAL MINERAL MATTER</td>
<td></td>
<td>26.5</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3
AVERAGE HUMINITE REFLECTANCE OF LIGNITE SAMPLES

### Table 4
QUALITATIVE AVERAGE MACERAL COMPOSITION OF COAL SAMPLES, % VOL.

### Table 5
TOTAL COAL CONTENT IN ASH SAMPLES, DETERMINED MICROSCOPICALLY.

Fig. 3, 4. Lignite samples reflectograms

Fig. 5 Microstructural aspects of Berbesti coal samples, reflected light (RL), fluorescent light (FL), glycerine immersion, 32X. (a). textinite with specific porous structure, cuticle (black) and small ferrous impregnation (white). (b). ulmine with alternating bands of textinite and porous corpohuminite (left side, up). (c). cuticles (black) including corpohuminite as bands in ulmine. (d). cuticle and liptinite impregnation (center, left side) in huminitic porous matrix. (e). cellular ulmine in bands with liptinitic intercallations, FL (CA1). (f). textinite having cell walls impregnated with liptinite, FL (CA4).

is a result of the conditions of storage and processing of vegetable material in the pit swamp deposit under the influence of metamorphic phenomena and mineralogical structure of layers intercalations. The huminite reflectance shows that due to the genetics and diagenesis factors, almost identical, the average value of the two samples are almost similar. For this reason, the petrographic composition (maceral analysis) was performed on the representative average sample made of the two lignite samples.

The petrographic composition shown in table 4, was determined by maceral analysis, using the huminite classification established by the ICCP [27]. The low coalification degree of lignite is represented either by the proportion of total wooden components of about 37%, in particular of those structured (textinite with liptinite filling
highlighted by the fluorescent light) figure 5a, b, f. Another confirmation of lignite low rank is the presence of ulminite, corpohuminite and gelinite components, as in figure 5b, c, e. Maceral groups of liptinite are present up to 4.7% and are highlighted also in fluorescent light, figure 5e, f. The mineral matter appears as impregnation of the constituents as carbargilite structures and ferrous minerals which frequently and heavily impregnate the textinite.

Present research helps to assess the coal macerals transformation during burning into the power plant boilers. The investigation shows aspects of ash behaviour in close dependence on lignite structural features - rank, petrographic composition and physico-chemical characteristics. This develops specific technological features in terms of thermal process, adsorption chemical reactions, combustion - transformation in gas, ash and slag. As a result of structural and chemical-technical determinations made, was found that the carbonaceous material having ash under 45%, achieve a proper combustion process that allows the formation of a minimum of un-burned or partially burned waste products, favourable to obtain a quality of ash accepted by potential users of new construction applications, tables 5 and 6. The microstructure aspects of charcoal granules (char of fly ash), is illustrated in the micrographs of figure 6.

Conclusions

The results of petrographic analysis, non-destructive, representative and reproducible outlines aspects of physical phenomena that develop during lignite combustion studied, and the factors that determine a particular type, structure and quality of the intermediate or final products (CWP).

Determinations of rank and petrographic composition reveal low degree of coalification and specific maceral composition which can influence the thermal treatment (of combustion). Very low rank of the xylitic coals is compensated by liptinitic impregnation, of bituminous origin, which helps burning and increases the combustion yield, aspect visible in fluorescent light.

In addition to the physico-chemical analysis, structural microscopy reveals that a coal having ash lower than 45% favours the development of a properly combustion process, allowing the formation of a minimum of un-burned or partially burned particles in the CWP that does not affect the use of ashes in new construction applications.

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