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THE THERMAL POWER PLANT IMPACT ON THE ENVIRONMENT AND SOME POSSIBILITIES OF REDUCE IT BY ASH AND SLAG RECICLING AND REUSE

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Abstract

The paper aimed to present the impact of thermal power plant from Oltenia Mining Basin and the same time to present some possibilities of valorization of the ash and slag that results from coal (lignite) burning in the large boiler of this thermal power point. The energy production in thermal power plant involves burning of huge amount of coal - lignite. Due to high ash content of lignite, the electricity production in thermal power plants generates significant amounts of slag and ash, which are stored in large deposit that involves the coverage of large areas of land generating environmental impact by air, water, and soil pollution. The reuse of ash and slag as raw material for other industry represent an economic way to reduce the environmental impact and represents an important way to preservation of natural resources.

Key words: *ash and slag, heavy metals, material recovery, thermal power plant pollution.*

INTRODUCTION

The most important lignite reserves of Romania are stationed in the mining basin of Oltenia, across the two counties, Gorj and Mehedinti, in 13 daily surface mining perimeters, by continuous-line extraction technologies using rotor excavators, high capacity belt conveyors and dumpers, which belong to Oltenia Power Complex joint-stock Company (CEO) (RAREASH, 2016).

The quality of lignite production at the existing industrial provision is (RAREASH, 2016):

- Calorific power: Q=1.740 kcal/kg;
- Ash: A=39.5%;
- Moisture: W=41.6%;
- Sulfur: S=1.2%.

Given the existence of these resources, they were built in Gorj County the power plants Rovinari (1975) and Turceni (1979).

The Rovinari power plant - Rovinari Termocentrala is a steam power plant built at the „mine mouth”, that means the coal delivery is made directly from the quarries, on the belt conveyors, the cost being insignificant. At the present time this power plant works 4 power units 330 MW each. The breeze and the ash resulted from the burning of the coal in the caldrons are hydraulic discharged using Bagger pump stations to the plant spoiling dumps: Balta Uncheasului, Cicani-Beterega and Girla (RAREASH, 2016; Racoceanu et al., 2012). The breeze and ash dumps are at 2-5 km distance outside the plant on a surface of 478.9 ha:

- Girla Dump: 160 ha, with a storage capacity of about 32 million m^3;
- Cicani – Beterega Dump: 284.7 ha, with a storage capacity of about 74 million m^3;
- Balta Uncheasului Dump: 34.2 ha, with a storage capacity of about 6 million m^3 (closed dump and covered with natural vegetation).

The breeze and ash dumps Cicani and Beterega are at 4.5 km of power plant, the car access are the technological roads to the above mentioned quarries. Beginning with 2000 year, the two dumps are unified and aggravated in tandem, working united.

The annual breeze and ash amount of Rovinari power plant is about 3 million tones, assuming the operation of four power units.

The Turceni power plant has 6 power units of 330 MW (RAREASH, 2016).

For storing the breeze and the ash of the Turceni Power Plant there are two dumps:

- *The breeze and ash dump number 1* – surface of 250 ha and capacity of 42 million m^3.
- *The breeze and ash dump number 2* – used as buffer or emergency dump. Now this dump is used to discharge the breeze and the ash in coal sludge technology. It has a surface of about 200 ha with a capacity of 32 million m^3 (RAREASH, 2016; Racoceanu et al., 2012).

The annual breeze and ash quantity of Turceni power plant is about 2.3 million tones, assuming the operation of four power units.

Previous works in the LIFE project and RAREASH project (RAREASH, 2016; Project LIFE10 ENVRO 729), proved the high uniformity of the compositional and dimensional characteristics of the ash in entire volume of the dump, considering this as an alternative raw material which can immediately enter into industrial exploitation circuit (Project LIFE10 ENVRO 729).

The electricity production by burning of fossil fuels represents the activity with the most important impact on the environment. We refer here to atmospheric pollution through release of large volume of greenhouse gas, acidifying gas, dusts or it is about of large amounts of wastes (ash and slag) deposited in landfills which are occupying large areas of land, as we already show above.

The fine particle of ash, moved by wind from dry surface of deposit affects all environmental factors: water, growth, living bodies, soil and human settlement. These fine particles of ash affect animal bodies and plants even far from deposit. Are affected, also, digestive and respiratory tract of human and animals.

The flora from deposit area both the spontaneous and the cultivated, specially, suffers negative effects by the fine fractions of ash which will lead to reduce the plant vitality and the crop production. Ash and slag have a high content of heavy metals and other substances that are known to be harmful to health. In relation with this, another effect of pollution is accumulation of quantity of heavy metals (chrome, plumb, arsenic, molybdenum) to toxically level with implication for human and animal's health.

Because of the absence of the impermeability and inappropriate drain of deposit tank, the infiltration from deposit affects ground water sheet. These determine the increased mineralization of ground water sheet and soil salinization considering the cumulative aspect. In the case of damage and other incidents by overflowing of hydro mixture is affected quality of surface water.

The best way to solve the disposal issues of ash is to decrease the quantity for disposal with utilization of ash in the industry (Carlsson et al., 1993).

Currently ash and slag can not find an economic use in Romania, now constituting within the category of harmless industrial waste category. However, the diverse physical, chemical, mineralogical and morphological properties of ash offers an opportunity to use in other industries, leads to reduce the environmental impact and to conservation of the natural resources.

MATERIALS AND METHODS

By the technological process results two kind of ash: fly ash (with a diameter < 0.25 mm), which is collected from flue gases through electrostatic precipitators (ESP), and from there it is mixed with water and sent to a pumping station or is collected in silo in order to delivery in cement industry; bottom ash, with a diameter 0.25 – 1 mm and more, which is collected at the furnace bottom (Figure 1).

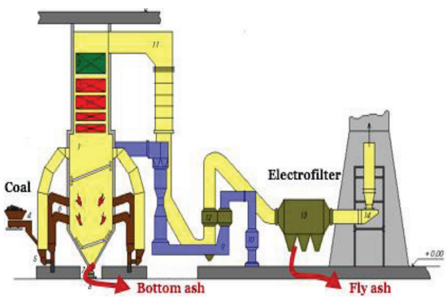

Figure 1. Ash generation in thermal power plant

Both of them - bottom ash and slag (this last one after crushing) and fly ash - are transported in the form of hydro-mixtures (solid/liquid 1:8 and 1:10, respectively) or dense slurry into landfills, generating a strongly impact upon

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environment (LIFE project; RAREASH, 2016; Popescu et al., 2016).

In the project RAREASH the ash stored in Division no. 1 of the Valea Ceplea dump of the Turceni power plant was complex characterized (physical and chemical). In order to ensure the representativeness of the ash samples on the dump surface map it was drawn an equidistant line web which make a squared grid, the crowns of these squares mark 180 points at a distance of 50 m of each other. On this surface were bounded 5 circular areas, each of 9 reference points.

From the sampling points selected in this way there were drill extracted ash samples of 5 m, 10 m, 15 m and 20 m, resulting 180 depth individual samples (named elementary samples), which ensure the representativeness of the entire ash mass of the Division no. 1.

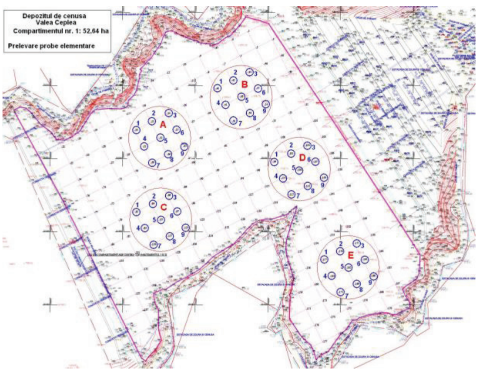


Figure 2. Delimit the circular sampling areas (RAREASH, 2016)

RESULTS AND DISCUSSIONS

In order to identify the use possibilities of ash is essential to know the ash characteristics, in term of physical, chemical and mineralogical characteristics.

1. Physical characterization

The depth level samples were tested to determine the physical parameters of bulk density (non-compressed and compressed) and the dimensional distribution of the component particles (grading).

The total moisture of the ash samples was determinate by using the thermo balance, and the soaking moisture, by oven-dying at 105^{0}C, according to STAS 1913/I-82.

The volume density was determinate using the lab balance according to the STAS 1913/3-76. The determination of the grading composition was made in accordance with STAS 1913/5-85, using the AS 200 Basic sieve machine. The results are presented in table 1, 2 and 3.

Table 1. Bulk density of the average samples

Sample	Bulk density (g/cm^3)	
	Unsettled	Settled
Cota 0	0.70	0.79
Cota -5	0.73	0.81
Cota -10	0.75	0.85
Cota -15	0.72	0.81
Cota -20	0.74	0.82
Total sample	0.75	0.83

Table 2. Grain distribution of the average samples

Sample	Pass (%) throught sieve (mm)							
	4	2	1	0.5	0.25	0.125	0.09	0.063
Cota 0	100	98.6	94.1	84.5	67.2	42.8	30.5	21
Cota -5	98.8	93.6	85.2	73.4	50.5	25.5	14.7	4
Cota -10	100	97.6	91	79.8	60.9	36.6	25	15.7
Cota -15	99.9	97.7	92.2	81.7	61.2	35.3	22.9	13.7
Cota -20	99.9	97.2	91.4	82.8	66.9	44.2	31.7	20.1
Total	99.7	97.2	91.5	81.3	62.7	38.3	25.3	15

Table 3. The moisture of the average samples

Sample	Moisture (%)
A	25.47
B	26.78
C	25.83
D	25.99
E	25.87
ABCDE	25.96

2. Chemical composition

The chemical composition of ash depends on the quality and composition of lignite as well as on combustion condition.

Oxide composition analysis indicates that it consists mainly of Al and Si oxides. The ash type is silicoaluminous with a composition close to clay lands, characterized by 45.6% SiO_2, 18.8% Al_2O_3. Some other constituents are CaO (10.45%), MgO (2.40%), Fe_2O_3 (8.72%) and in smaller quantities Na_2O (0.21%) and K_2O (1.44%). Most of the CaO and MgO are bound in sulfates and mixed oxides with SiO_2 and Al_2O_3.

In terms of basic physical characteristics, the ash can is assimilated to a natural sand aggregate of granular type, except for bulk density characterized by lower values.

Chemical properties of ash samples reveal adequate characteristics in comparison with those of the ceramic raw materials usually used in the ceramic industry.

Some directions of thermal power plant ash using

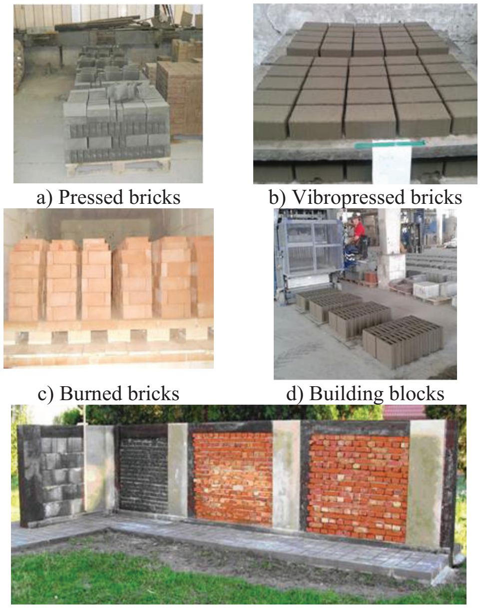
Given the characteristics of the power plant ashes, it could be developed some recovery directions, thus:

1. The first direction supposes their use in the building material industry. The recovery possibility of this industrial waste used as granular aggregate in the manufacturing of building materials based on hydraulic binder (cold-straining briquettes, concrete blocks and precast) proved by researching results in the Project LIFE ENV 729 RO, and by using them in manufacturing of briquettes, concretes, mortars and stamping tables (RAREASH, 2016; Anghelescu et al., 2015; Abagiu et al., 2013). In technological applications tested on technological flows at industrial level in project LIFE (Popescu et al., 2013) were obtained (Figure 3):

a. *using the hydraulic binding technologies („cold-straining”)of the products:*
- briquettes with high ash content (over 60%);
- building blocks (breeze blocks) with a minimum 15% ash content;
- building blocks (precast) with a minimum of 50% ash content and of 20% breeze LF;
- building elements for roads and footways (borders and paving’s);

b. *using high temperature binding technologies (sintering):*
- briquettes with 50-70% ash content, molded of semidried mixtures;
- briquettes with15-35% ash content and 10-20% slurry, molded of plastic and seniplastic mixtures;
- thermal insulating concretes with maximal using temperature of 800-1100 with 40-70% power plant ash content.

On the other hand, the ash can be used to obtain ceramic pellets with high absorption characteristic that can be used to execution of water capture layers in road construction.



a) Pressed bricks b) Vibropressed bricks
c) Burned bricks d) Building blocks
e) Demonstrative building realised in inside of University Student’s campus

Figure 3. The different kind of building material obtained by ash recycling

2. The second direction - the recovery of rare and heavy metals from the power plant ash

The Oltenia lignite bottom ash contains high amounts of some kind of heavy and rare metals, from lanthanide’s group (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu), as well as scandium and yttrium. Also, these industrial wastes show the valuable concentrations of indium, gallium, rubidium and wolfram (RAREASH, 2016; Popescu et al., 2013; Predeanu et al., 2015).

Under the scope of RAREASH project positive anomalies were found in HRM concentrations at Oltenia lignite bottom ashes in relation to those occurring in the upper continental crust, which is a promising result taking into account the huge amounts of bottom ash available, its unconsolidated nature, and the proximity to an industrial complex (Table 4) (Predeanu et al., 2015; Popescu et al., 2016).

Table 4. Average concentration (ppm) of rare earth elements, yttrium and Sc, and other elements of interest in Oltenia lignite bottom ash, and normalized concentration of the trace elements to the upper continental crust (UCC) (Rudnick and Gao, 2014)

Analyte	Bottom ash (average)	UCC	Normalize
Co	22.10	17.30	1.29
Sr	224.08	320	0.69
Sb	2.49	0.40	6.43
W	2.03	1.90	1.07
Be	3.04	2.10	1.47
Sc	11.93	14	0.85
In	0.07	0.06	1.31
Y	20.72	21	0.99
Rb	11.50	84	0.10
Nb	17.37	12	1.47
Ga	26.35	17.50	1.53
La	25.65	31	0.82
Ce	60.48	63	0.96
Pr	6.90	7.10	0.97
Nd	26.49	27	0.98
Sm	5.46	4.70	1.17
Eu	1.15	1	1.15
Gd	5.20	4	1.31
Tb	0.69	0.70	0.89
Dy	4.23	3.90	1.09
Ho	0.87	0.83	1.06
Er	2.40	2.30	1.04
Tm	0.35	0.30	1.16
Yb	2.24	1.96	1.15
Lu	0.34	0.31	1.08

3. The third direction: the recovery of unburned coal and its using

Bottom ashes resulted from Gorj lignite burning process has a high unburned coal content mostly from the xilitique type formations, which due to their characteristic properties (especially the elasticity) are very finely ground in the coal mills and reach the breeze and the bedstone ash in the form of charcoaled particles (majority in the 2 – 4 mm dimensional type), which can be separated by simple methods of calibrated sieving, water floatation or magnetic separation. Thus, it could reach to unburnt coal concentrates with a total ash content of 40-60% which can be utilized to reach the burning briquettes for domestic boilers. The advantage is, unlike the initial coal, this carbonized residue type which suffered a quickly heating at about 1000^{o}C, is characterized by much less volatile substances and generates a more reduced level of burning emissions (Contract UEFISCDI nr. 15/2016).

On the other hand, the unburned carbon from the power plant ash is a potential precursor of the graphitizable carbon, having suitable structural characteristics to be used in industrial applications, like: the developing of new electro catalysts with high catalytic activity, bigger endurance, lower costs, scalability which could greatly facilitates the improvement of the clean energy infrastructure (Contract UEFISCDI nr. 15/2016).

CONCLUSIONS

Ash and slag deposits cover large surface of land having the negative impact on the environmental because of different reasons, that were being expose above.

The recovery of power plant ashes represents an important way to reduce the impact against the environment caused by its dumping.

The use and the reuse of huge power plant ash quantities in accordance with the possible using directions as the above, aim to gain some benefits, in this respect, for example:

- The contribution of developing new domains, economical consolidation, the creation of new high qualified jobs, autonomy and security in supplying with critical materials in UE;
- The preservation of natural resources:
  i) by using the ash as replacement for natural aggregates (sands) used in making of building materials;
  ii) by using the ash to extract strategic materials, as Lantanides: Ga, Sr, Rb, Y and W;
  iii) by using the ash to recovery the unburned coal which after the preconcentrating operations it could be used as precursor of graphite or for briquetting to reborn, as well.
- The raising of life quality in urban and rural areas, reducing the impact against the environment caused by the activities of power and mining industry.

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