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IMPACTS OF SLAG AND ASH DEPOSITION ON SURROUNDING AGRICULTURAL SOIL

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ABSTRACT

Significant quantities of slag and ash are produced as side burning products in thermal power plants. It concerns a solid technological waste that requires proper disposal. The slag and ash produced by coal combustion contain various elements including heavy metals with toxic properties. Soil used for agricultural purposes in the vicinity of the deposition sites (for production of food for humans and animals) was examined for its fertility properties and content of heavy metals at a location closest to the deposition site that is in the final phase of usage. Analyses of pH value analysis at representative samples show that acidic reaction of soil was detected. Content of phosphorous and nitrogen was within the permitted limits, whereas potassium level was below levels required for proper plant growth. Concentrations of majority of heavy metals were below limit values, while concentrations of chromium, nickel and zink were manyfold above the permitted limits.

Keywords: slag and ash deposition sites, soil, fertility, heavy metals

1. INTRODUCTION

Enormous quantities of slag and ash are produced in the process of electricity generation in thermal power plants, thus creating a major deposition problem. Based on Regulation on categories of waste (1) slag and ash fall under category No: 10 01 01 and 10 01 04 as technological harmless waste.

Annual quantities of slag and ash produced in the proces of coal burning in Thermal Power Plant Tuzla (TPP Tuzla) are estimated at 1,066 x 10^3 cubic meters. Technology of their deposition include hydraulic transport whereby the material is mixed with water in ratio 1:7 up to 1:15. Transport is conducted using pumps and pressure pipelines**,** conveying waste materials to the deposiition sites.

There are five deposition sites in the vicinity of TPP Tuzla covering the area of aprox 170 ha, namely: Drežnik, Plane, Divkovici I, Divkovici II and Jezero (Figure 1). Drežnik, Plane and Divkovici I sites were reclaimed, Jezero deposition site is filled up but still not reclaimed whereas Divkovici II site is in the final stage of usage.

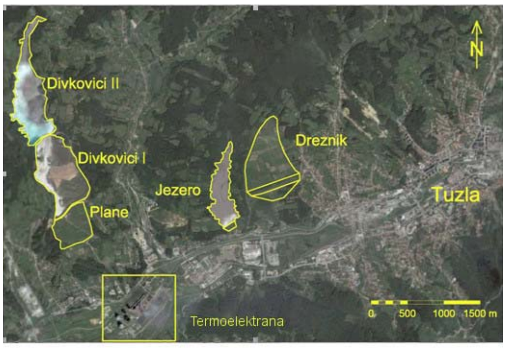

*Figure 1. Disposition of slag and ash deposition sites of TPP Tuzla (source-*Google Earth)

Slag and ash produced in coal burning process present a mixture of oxides, dominantely silicate, aluminum and ferro oxides, along with earthen-alkali metals, and certian quantities of heavy metals, known by their toxic properties. The land in the vicinity of Divkovici II site is in private property and used for agricultural purposes and food production for humans and animals. Control was conducted in order to determine fertility properties and content of heavy metals in soil at location close to the deposition site.

Identification of negative environmental impacts of slag and ash deposition was carried out analysing the following components of the environment; alteration of land configuration, general soil pollution, and infiltration of contaminating toxic metals from ash - heavy metals into soil and potential infiltration of contaminants into food chain.

2. DOCUMENTARY BASIS AND WORK METHOD

Soil tests were conducted in conformity with valid Regulations on determining permitted quantities of harmfull and hazardous matters in soil and their tests methods (5). Research polygon was a 5000 square meters parcel that bounders with the Divkovici II deposition site. Sampling for soil quality purposes was carried out from the depth of 25 cm. Total of 20 samples were taken from a square network and four representative samples were made out of them.

Instruments used for the tests:

- pH-meter type Eutech Instruments pH 510, Malaysia,
- Scheibler-ov calcimeter, manufacturer EIJKELKAMP HOLANDIJA,
- Spectrometer UV/VIS type LAMBDA 25 manufacturer Perkin Elmer USA.
- Optical emission spectrometer– type ICP–OES OPTIMA 2100 DV, manufacturer Perkin-Elmer USA,
- Atomic absorption spectrometer, type AANALIST 200, Perkin Elmer, USA.

3. RESULTS AND DISCUSSION

Average chemical content of elements in slag and ash of TPP Tuzla, disposed off at the mentioned deposition sites is shown in table 1 (3). Grain size analysis of slag and ash is shown in table 2.

Table 1. Total content of elements in slag and ash

Elements (quality indicators)	Unit	Determined contents
Ca	g/kg	9,875 – 11,500
Mg	g/kg	0,315 – 0,425
K	mg/kg	187,50 - 229,17
Na	mg/kg	18,75 - 62,50
Cu	mg/kg	16,00 - 17,00
Zn	mg/kg	5,60 - 5,90
Fe	mg/kg	956,25 - 1.388,75
Mn	mg/kg	67,67 - 81,67
B	mg/kg	5,96 - 10,55
Mo	mg/kg	0,96 - 1,76
Pb	mg/kg	1,50 - 5,00
Cd	mg/kg	1,00 - 1,37
S	mg/kg	1.614,00 - 2.600,00
Moisture	%m/m	1,00 - 1,10
Mineral matters	%m/m	96,39 - 96,73
Organic matters	%m/m	3,27 - 3,61

Table 2. Grain-size analysis

Grain size mm	Mass content % m/m	Classification by size
2 – 0,06	86 – 96	Sand fines
0,06 – 0,002	3 – 10	Dust
< 0,002	1 – 4	Clay

Control of soil fertility and determination of heavy metals content in soil was conducted at research site in order to determine impacts of active and non-reclaimed deposition sites on soil in vicinity of deposition sites. Tests include basic chemical elements in soil, required for proper plant growth and pH value parameters (table 4), along with content of heavy metals in soil (table 5).

Table 3. Chemical composition of slag and ash from deposition site„Divkovići II"

Chemical composition	Quantity % m/m
Annealing loss	10,33
SiO_2	47,24
Al_2O_3	18,47
Fe_2O_3	7,90
CaO	9,90
MgO	2,79
SO_3	1,37
Moisture	33
$SiO_2 + Al_2O_3 + Fe_2O_3$	73,61

Table 4. Analysis results – basic soil chemical properties

Parameter		value		Note
		min-max	mean	
pH - value	Active in water	5,72 – 5,86	5,80	Weak acid*
	Substitutional in KCl	4,50 – 4,87	5,71	Moderately acid
Nitrogen, % m/m		0,27 – 0,33	0,30	0,21-0,30 ⇨ well supplied**
Phosphorus, % m/m		0,0415 – 0,0460	0,0433	0,02 – 0,2 % ⇨ poorly supplied**
Potassium, % m/m		1,01 – 1,13	1,08	0,2 – 3 % ⇨ moderately supplied**

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*** Bureau for Plant Nutrition of Agricultural Faculty – Zagreb University*

Table 5. Mean value of heavy metal content in soil

Chemical element	value min – max	Mean value	Limit value* (5)	Note
	(mg/kg)			
Arsenic, As	0	0	15	
Copper, Cu	15,36 – 41,7	28,82	65	
Chromium, Cr	54,06 – 209,8	129,79	80	Above limit value
Cadmium, Cd	0	0	0,5	
Cobalt, Co	12,56 – 35,43	25,47	45	
Nickel, Ni	63,6 – 224,16	88,96	30	Above limit value
Lead, Pb	11,73-19,10	16,47	80	
Zinc, Zn	706,33-1695,0	1146,75	100	Above limit value

**Limit value of heavy metals in soil*

Chemical analysis of slag and ash indicates dominant presence of silicium, aluminium and ferro oxides. Slag and ash from Divkovici II deposition site contains 73 % of these oxides. Common property of these oxides is that they are not soluble in water.

Other feature of deposited materials is their high alkalinity, originating from alkali and earthen-alkali oxides soluble in water. Significant sources of alkality of slag and ash are carbonates in mineral matter of coal, that convert into oxides of alkali and earthen-alkali oxides (CaO, MgO, Na_2O, K_2O) during the burning process. Once disolved in water, these oxides produce easily dissociated base, that increase pH above value of 8,5, thus creating the direct negative effect of ash on soil and indirectly on plants in the soil (2). Slag and ash further contain a part of unburned coal organic matter. Slag and ash are mostly composed of particle size 0.006 – 2 mm – sand fines, in lesser percent of particles 0.006 – 0.002 mm – dust and particles below 0.002 mm – clay. Based on determined texture the tested soil falls under category of dusty-clay soils. Such materials upon deposition are prone to water and eolian erosin. One of the important properties of dry ash is a high absorption of water without significant volume change. Electric-filter ash is capable of absorbing quantity of water equal to its own mass, i.e. total absorbed and chemicaly bounded water can reach a mass equal to the mass of ash itself (2). Due to significant presence of alkali and earthen-alkali oxides in slag and ash, the character of these materials are slightly basic, and that fact was substantiated by measurement of pH values in water filtered from deposited materials. The research polygon is composed of non-permeable clays with filtration ratio of $<10^{-8}$ cm/s, thus it concerns hydrogeological insulators, with no capability of acummulating ground waters in form of springs, therefore there are no ground water courses from deposition site toward the surrounding area nor vice versa.

The study shows that the most detrimental effect on surrounding soil is produced by wind dispersed finest particles of slag and ash. This occurs more frequently in summer during the hot months, without rain and when winds are stronger. Giving the fact that the deposition site is in the final stage of usage, measures have to be undertaken to prevent this problem with proper land reclamation. The major impacts produce winds coming from northwest, west, southwest and south direction.

4. CONCLUSIONS

Analysis of soil samples from the research polygon shows:

- Active and substitional pH value of soil samples indicates that the soil is characterised with weak acidic reaction. pH value plays a major role in all processes in soil. Chemical wearing in soil decreases with increase in pH. Biological activity is most productive in neutral soil, and that is logical since such pH value is favourable for majority of organisms. Since slag and ash produce alkali reaction with water, it is expected that their presence in soil, characterised with weak to moderately acidic reaction, will neutralize acidity, i.e. make soil to be neutral depending on ash content. Occurence of soil acidification is mostly determined in vicinity of thermal power plants and developed industrial activities, especially chemical (6).

- Consequence of soil acidification comes with cations, especially of Ca and Mg, wash-out from soil and reduction of its fertility. Signified soil acidity results in loss of nutritive elements in soil, i.e. K and P, and that was confirmed by the conducted analysis. Solubility of other chemical compounds bound in adsorbtion complex of soil depend on soil reaction. When active acidity is increased, especially when it goes under 5.0, then Al and Fe ions occur in soil solution along with phosphates and other microelements (Cd, Zn, Cu, Co,...). Apart from wash out of nutritive elements from soil, increased soil acidity results in release of heavy metals from adsoption complex of soil, and ones converted into liquid phase – soil solutions become mobile and prone to migration toward deeper soil horizons whereby ground water collectors can be polluted. Soil with increased acidity have to be treated by calcification process to regulate soil reaction, based on requirements of certain crops, in order to enable proper growth of plants along with higher yields.
- Shortage of phosphorus is characteristic for most of the soils in BiH. Phosphorus content is between 0.01 and 0.1 %, i.e. average value is 0.05 %. At the research polygon phosphorus content was between 0.0415 and 0.0460 %, indicating that soil is poorly supplied with this nutritive element. Acidic character of soil brought to wash out of this element from soil adsorption complex.
- Pottasium (K) content in sandy soils is low, around 0.05 %, whereas in heavy soils it goes up to 3 % (average value is 1.5 %). K content at research polygon goes from 1.01 to 1.13 %, i.e. the soil is moderately supplied with this element. Generally, K was washed out from the soil adsorption complex due to the acidic soil reaction. Giving the fact that the minimum K content required for proper plant growth is 1.4 %, it points on deficit of this nutritive element in soils around Divkovici II deposition site.
- Content of nitrogen (N) in BiH soils goes from 0.02 to 0.4 %, predominantely in the upper layers, while in deeper layers in suddenly decreases. Content of N at research polygon was 0.27-0.33 % thus the soil is well supplied with this element. Since the N in soil predominantely comes as organic- originating from humus and as mineral but in negligible quantities for plant growth, it concerns an organic type of N, since there was no intense agricultural activities in the vicinity of the deposition site, thus the soil is rich in N due to decomposition of weed plants.
- Analysis of heavy metals shows absence of As and Cd, while concentration of Cu, Co and Pb were uneven, but still below limit values at all analysed samples. The exemption is Cr, Ni and Zn with values significantly above limit values. The content of these metals is of antropogenic origin, not geochemical, since all three elements are embeded in coal mineral matter. Comparison with world trends concerning concentration of trace elements in coal (7) shows that coal burned in TPP Tuzla is significantly rich in Cr and Ni. It is well known that major soil pollutant with Cr, Ni and Zn is ash released from TPP chimneys.

The tests proved that all three elements that exceed limit values originate from sedimentary dust of Divkovici II deposition site and that they were spread out by eolian erosion onto surrounding area. Soil fertility analysis, carried out on the research polygon, placed close to Divkovici II depositon site, shows that soil due to low content of nutritive elements and high concentration of toxic elements, is not favourable for intense agricultural purposes and plant growth used as human and animal food. It is advisable to carry out land reclamation upon usage of the deposition site, while surrounding soil will have to be treated with proper agro-technical measures to be favourable for production of healthy food.

5. REFERENCES

[1] Regulations on category of waste with their lists included (Offical Gazzete FBiH, No: 9/05);

[2] Project - Recoal „Reintegration of slag and ash deposition sites and minimisation of pollution within the area of Western Balkan, INCO-WBC-1-509173, 2007;

[3] Environmental compliance plan, Tuzla Mining Institute, 2007;

[4] Proceedings from seminar on application of electric-filter ash in road construction Tuzla, 2003;

[5] Regulations on determining permitted quantities of harmfull and hazardous matters in soil and methods of their testing (Official Gazzete FBiH, No. 72/09);

[6] Action plan for environmental protection in BiH, March, 2003;

[7] Kortenski, J. i Sotirov, A.: Main elements and trace elements and their distribution in Neogene lignite in water catchment area of Sofia, Bulgaria, International Magazine on Coal Geology, 52, 1-4, 2002.