Research on ash pollution resulting from coal-firing power plants

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***Abstract*—** This paper presents a case study on pollution with ash resulted by burning lignite in the boilers of power units of 330 MW operating in the Oltenia Energy Complex. Large quantities of ash and slag produced have negative effects on the environmental factors and also on human health. The objectives of the paper were to determine the concentration of heavy metals in ash harvested from surface deposits to depths of 5 to 20m, in groundwater and also to evaluate the dispersion of ash dust. Samples were collected from the Valley Ceplea of the Turceni power plant.

The heavy metals concentrations were determined by atomic absorption spectroscopy.

In order to assess the ash particles dispersion into the atmosphere, the EMPOLI modeling and simulation software was used.

The experimental measurements revealed that 94.98% from ash contains particles of 40 μm. Ash concentration in chimney flue gases (48 mg / Nm^3 and 46 mg / Nm^3) comply with the maximum permissible limit of 50 mg / Nm^3. Ash particle dispersion calculated showed that hourly concentrations of total suspended particles do not exceed the maximum permissible concentration. Soil and groundwater pollution tests have shown that the heavy metals contained in the ash are normal for Cd, Co, Zn, exceed normal levels for Cu, Ni, Pb and in leachate samples was solubilized only Cd with values within the limits imposed in NTPA 001/2001.

***Keywords*—**dense slurry, pollutants dispersion, software Empoli, steam boiler Benson.

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I. Introduction

BY burning the coal in the boilers of the power units of 330 MW is resulting large amounts of ash and slag. The boilers of the energy units of 330 MW are Benson type, with forced circulation of water. The flow of steam of the boiler is 1035 t/h. The Benson boiler works with lignite dust. It is equipped with six fan hammer mill type DGS 100 arranged around the boiler.

The mills dry, grind and transport the mixture of lignite-combustion gas to the burners arranged on the walls of the furnace.

Table I presents the characteristics of lignite in Oltenia basin.

Table I. characteristics of lignite

No	Characteristic	UM	Value
1.	Lower calorific power	kcal/kg	1550 -1700
2.	The ash content in relation to the initial mass	%	27,9 – 46,6
3.	The moisture content relative to the initial mass	%	36,5 – 42,1
4.	The content of volatile matters in relation to the initial mass	%	18,6– 22,5

Table II presents the technical characteristics of the mill of coal.

Table II Technical characteristics of the coal mill

No	Characteristic	UM	Value
1.	Grinded coal flow	t/h	96
2.	Fineness of grinding R 1,0	%	5
	Fineness of grinding R 0,09	%	55
3.	Concentration of coal dust	g/m3	296
4.	Ventilated debit	m3/s	45

The ash and slag exhaust system cools and transports the slag to the crusher and the resulted ashes to the burning lignite in the Benson boiler of 1035 t/h. The transporting of slag and ashes is performed by a conveyor with blades located at elevation -3.45 m below the afterburner grate. The transporter conveyor of slag and ash also has the role to seal the combustion chamber by immersing the post-combustion grate funnels with 220 mm in the water tank transporter.

Table III indicates the main technical characteristics of the ash and slag conveyor

Table III. Technical characteristics of the conveyor

No	Characteristic	UM	Value
1.	Specific dry slag and ash gravity	daN/dm3	0,6
2.	Temperature slag and ash at the conveyor entrance	^{o} C	600-800
3.	Maximum flow of dry ash and slag	t/h	45
4.	Maximum flow of wet ash and slag	t/h	120

The flue gas leaving the Benson combustion chamber and the overheating area, are crossing the two air pre-heaters, the electric de-dusting plant, two fans for flue gas and then enter the chimney where they are discharged into the ambient. The de-dusting electrical installation consists of 2 electro filters. The ash collected in these electro filters, together with the ash and slag discharged from the boiler furnace hopper are mixed with water and transported to storage sites.

II. Results of Experimental Measurements

Table IV presents the experimental results on the ash particle size analysis obtained by burning lignite powder in the Benson boiler of the energy group no.3 of 330 MW from the thermoelectric plant Turceni.

Table IV. Ash particle size analysis

No	Granulation category	U.M.	Value
1.	> 0,5	%	3,36
2.	0,5 -0,2	%	4,17
3.	0,2 – 0,125	%	14,58
4.	0,125 – 0,09	%	17,87

It results that the percentage of 94.98% presents ash of size of 40 μm, so the ash is formed of relatively large crystals.

Table V presents the results of experimental measurements performed on the electro filters of the boiler No.3 in Turceni thermal power plant.

Table V

No	Measured variable	Unit Measure	Value electro filter 1	Value electro filter 2
1.	Boiler's thermal power	MW	280 - 300	270 - 300
2.	Flue gas temperature	0 C	154 - 162	158 -160
3.	Average speed combustion gases	t/h	18,60	19,20
4.	Flue gas flow	Nm3/h	846.369	812.491
5.	Average concentration of ash in the gas at 6% O2	mg/ Nm3	48	46

Table VI presents the results of experimental measurements effectuated in the lab for determination of heavy metals in ash. They were used samples of ash from the ash deposit of Valley Ceplea of the Turceni power plant. The samples were collected from surface to depths of 5m, 10m, 15m and 20m.

Table VI

No	Place of sample collection	Cu (mg/kg s.u.)	Zn (mg/kg s.u.)	Fe (mg/kg s.u.)	Pb (mg/kg s.u.)	As (mg/kg s.u.)
1.	Surface of deposit	40,00	59,00	30.300,00	22,17	18,09
2.	Depth 5 m	48,50	54,50	58.500,00	34,45	18,51
3.	Depth 10 m	46,00	59,00	39.350,00	39,41	22,65
4.	Depth 15 m	49,00	58,00	27.250,00	30,11	20,16
5.	Depth 20 m	45	62,5	65600	33,42	24,16

No	Place of sample collection	Cd (mg/kg s.u.)	Ni (mg/kg s.u.)	Cr (mg/kg s.u.)	Co (mg/kg s.u.)
1.	Surface of deposit	0,87	80,00	35,06	5,513
2.	Depth 5 m	0,90	76,50	38,28	5,600
3.	Depth 10 m	0,94	93,00	39,77	5,390
4.	Depth 15 m	0,90	67,50	35,48	0,072
5.	Depth 20 m	0,90	100,5	34,28	5,55

In Tables VII, VIII and IX are presented the results of the experimental measurements on groundwater quality from the ash deposit of Valley Ceplea on the 3 compartments of the deposit.

Table VII Compartment I

No	Name charge	Unit measured	Result obtained in LCA	Values covered by the autho-rization	Values regulated under reference document	Analysis method
1.	Cr total	μg/l	<2	-	50	SR EN ISO 15586/2004
2.	Ni	μg/l	<2 (0,283)	-	20	SR EN ISO 15586/2004
3.	Zn	μg/l	<50	-	5000	SR EN ISO 15586/2004
4.	Cd	μg/l	<0,2	-	5	SR EN ISO 15586/2004
5.	Pb	μg/l	<2 (0,146)	-	10	SR EN ISO 15586/2004

Table VIII Compartment II

No	Name charge	Unit measured	Result obtained in LCA	Values covered by the autho-rization	Values regulated under reference document	Analysis method
1.	Cr total	μg/l	<2	-	50	SR EN ISO 15586/2004
2.	Ni	μg/l	<2	-	20	SR EN ISO 15586/2004
3.	Zn	μg/l	<50	-	5000	SR EN ISO 15586/2004
4.	Cd	μg/l	<0,2	-	5	SR EN ISO 15586/2004
5.	Pb	μg/l	<2	-	10	SR EN ISO 15586/2004

Table IX Compartment III

No	Name charge	Unit measured	Result obtained in LCA	Values covered by the autho-rization	Values regulated under reference document	Analysis method
1.	Cr total	µg/l	<2	-	50	SR EN ISO 15586/2004
2.	Ni	µg/l	<2	-	20	SR EN ISO 15586/2004
3.	Zn	µg/l	<50	-	5000	SR EN ISO 15586/2004
4.	Cd	µg/l	<0,2	-	5	SR EN ISO 15586/2004
5.	Pb	µg/l	2,692	-	10	SR EN ISO 15586/2004

To calculate the dispersion of ash dust in the Turceni power plant was being used the EMPOLI software for dispersion modeling and simulation. The data entry in the program were: the characteristics of the source of pollution, weather conditions and topography of the area.

In Fig. 1 and 2 are shown the maps of the dispersion generated by the Empoli soft for particles in suspension for the hourly maximum concentration and maximum concentration in 24 hours.

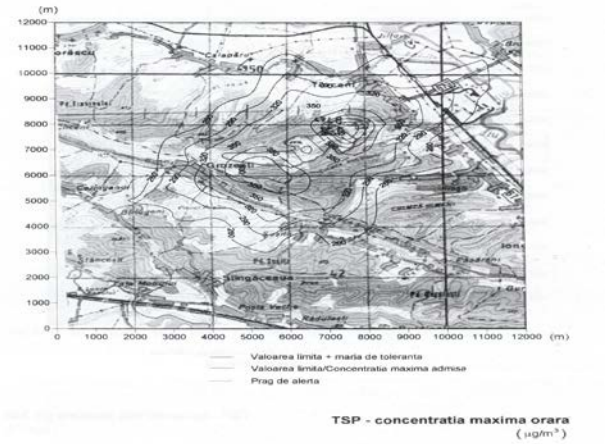

Fig. 1 Total particles in suspension – hourly maximum concentration

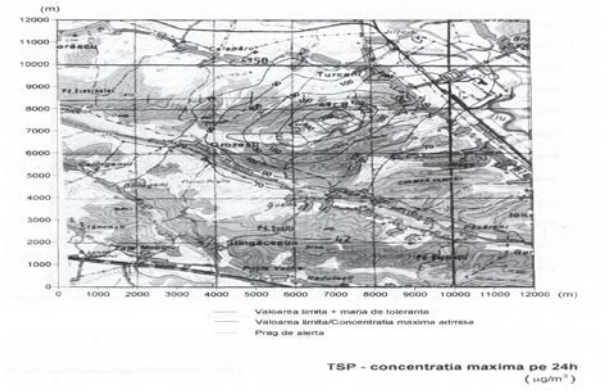

Fig.2 Total dust in suspension – maximum concentration per 24 h

A. Technical measures to reduce pollution

When operating the ash dump, the pollutant emissions include only the ash particles entrained from the surface of the dump and dispersed in the air or deposited on soil later.

A.1. Reducing air pollution

The modeling results from the dispersion of ash and ash deposit from the chimneys of the power units from the thermoelectric power plants Turceni are shown in Table X.

Table X

Pollutant	Time media-tion model	Maximum concentration C_{max} [µg/m^3]	Alert threshold (PA) [µg/m^3]	limit value or CMA= intervention threshold [µg/m^3]	Observations
TSP	1 h	426	350	500(3)	< CMA, > PA
	24 h	224	105	150	< CMA, > PA

(1) VL+ Margin of tolerance to 01.01.2005 (time mediation 1 h)
(2) VL of 01.01.2010
(3) Time mediation 30 minutes

Hourly concentrations of total suspended particulates do not exceed the maximum permissible concentration (CMA), but exceed the distance alert of 1000 m (NE and SV) , while the 24-hour average concentration exceeds CMA to distances of 1000 m (NE) and only the alarm threshold (PA) to distances of de 750 m (SV) .

To reduce the phenomenon of whipping by stabilization of dry crust that forms on the surface of the active deposit, it is proposed the application of a control solution for dissipation (splashing, bitumen coating process, and polymerization) during the periods in which the conditions of this phenomenon are in occurrence, in order to prevent them. Skinning solution of the surface can be made with solutions that harden and form a crust of around 2-3 cm thick.

This, coupled with the existence of tree curtains all around the deposit is considered sufficient to reduce the amount of slag and ash blown by the wind, at a minimal level of risk to human health. The vegetable curtains will be kept and maintained in the immediate vicinity of the deposit, the species which will eventually be planted being, possibly, the same as the one initially chosen.

A.2. Soil pollution by heavy metals

The quantitative analysis of metals from ash, soil and vegetable products was in compliance with the Handbook MICROWAVE MA079 Re.0/2006.

Cu: exceeded normal levels, hovering limit alert threshold for sensitive soils;

Ni: exceeded normal levels, but not alert in soil, falling in the alert threshold for soils sensitive to ash

Pb: exceeded normal levels, falling within the alert level for

sensitive soils;

Zn: normal to the upper limit;

Co: normal;

Cd: normal.

A.3. Water pollution

The transport of slag and ash from the furnace to the deposit is carried out by hydro-mechanization (ash/water mix in ratio of 1:10), being thus involved large quantities of water, which can be partially recirculated. The water from the transport mixture solubilized the chemical compounds presented in the slag and ash transported and presents a significant load of these compounds.

The transport or weather water can seep into the ground, represented a source of pollution for groundwater and surface water. In good correlation with the chemical composition of slag and ash, the ash tests conducted for leachate for the Turceni area showed that, of the analyzed substances contained in GD 118/2002, in the samples of leachate was solubilized only Cd, but the determined values for this indicator are below the limit imposed in NTPA 001/2001.

III. CONCLUSION

Burning lignite in boilers of 330 MW of the energetic groups leads to considerable quantities of ash and slag. The ash has harmful effects on the environment factors water, air, soil and also on human health. The ashes from the burning of lignite is retained in the electro filters of Benson boilers.

The concentration of ash in the combustion gases discharged through the chimney does not exceed the permissible maxim value of 50 mg/Nm3. This is due to modernization and to increased efficiency of electrostatic de-dusting. In the classical system for discharge slag and ashes, water was used in the proportion: 1 part of ash and slag to 10 parts of water.

Nowadays, the exhaust system uses slag and ashes in dense fluid that significantly reduces pollution with ashes. From the surface of storage dump the ash is blown by the wind. Modelling and simulation of the dispersion of the ash particle with the software Empoli found out that the hourly concentrations of total suspended particulates is greater than the alarm threshold over a distance 1000 m (NE and SV), while the average concentration per 24 hour exceeding the MAC to a distance of 1000 m (NE), and the alarm threshold (IP) over a distance of 750 m (SV). Heavy metals contained in ash have either normal values (Mn, Cd, Co, Zn) or exceed normal values but are still below the alert threshold (Cu, Ni, Pb).

REFERENCES

[1] Racoceanu, C., Popescu, L.G., Popescu, C. *Research on the impact of the application of clean technologies for burning coal on air quality in the area of Rovinari and Turceni power plants*, 16th International Multidisciplinary Scientific GeoConference &EXPOSGEM 2016, 28 June -7 July 2016, Albena, Bulgaria, conference WSEAS

[2] Popa, R.G., Popescu, L.G., Șchiopu, E.C., Racoceanu, C., Pecingină, I.R. *Research on the concentration of the sediment powders in the air of the industrial area of Targu Jiu Municipality*, 15th International Multidisciplinary scientific GeoConference Energy and Clean Technologies SGEM 2015, 18-24 June 2015, Bulgaria, Conference WSEAS, Conference Proceedings Volume Nuclear Technologies, Renewable Energy Sources and Clean Technologies,, Recycling Air Pollution and Climate Change, pag.1024-1032, ISBN: 978-619-7105-38-4, ISSN:1314-2704.

[3] Popescu, L.G., Cruceru, M., Racoceanu, C., Predeanu, G. *Reduction of Turceni Thermal Power Plant Impact upon Environmental by Superior Valorization of Ash and Slag*, 2nd International Conference on Energy and Environment Technologies and Equipment (EEETE '13), Brasov, Romania, 1- 3 June 2013, conference WSEAS, pag.112-117, ISBN: 978-1-61804-188-3.

[4] Cruceru, Mihai, et al. "Study of lignite quality parameters during storage" *International Multidisciplinary Scientific GeoConference: SGEM: Surveying Geology & mining Ecology Management* 1 (2012): 835

[5] Racoceanu, C., Popescu, L., Filip, V., Popescu, C. *Research regarding environmental risks due to complex operation Rovinari*, Proceedings of the 12th International GeoConference SGEM 2012**,** 23 June, pag.715 - 722.

[6] Racoceanu, C., Popescu, C., Popescu, L.G., *Research on factors affecting auto-ignition of coal energy***,** IAASAT and WSEAS Environment, Economics, Energy, Devices, Systems, Communications, Computers, Mathematics, International Conferences, University Center, Drobeta Turnu Severin, Romania, October 27-29, 2011, conference ISI, ISBN 978-1-61804-044-2, pag.79-84.

[7] Racoceanu, C., Luca, L. *Environmental performance of classics thermal power plants*, 8-th *International conference on industrial power engineering* CIEI 2011, April 14-15, 2011, Bacău, Romania, Proceedings of the International Conference on Industrial Power Engineering, pag.263-267, ISSN 2069-9905.

[8] Racoceanu, C, Şchiopu, C., *Environmental protection and remediation of air*, Publishing House Academica Brâncuşi; Targu Jiu, 2010.

[9] Popa, R.G., Racoceanu, C., Şchiopu,E.C., *Techniques for air monitoring and de-contamination*, SITECH Publishing House, Craiova, 2008.

[10] Racoceanu, C., Popescu, C. *Analysis of environmental impact of energy complexes*, Publishing House Sitech, Craiova, 2007.

[11] Popescu, C., Racoceanu, C., *Improve the efficiency of power plants under environmental protection*, Publishing House Sitech, 2006.

[12] Racoceanu, C., Popescu, C., *Assessment of pollutant emissions from burning of lignite in power CTE*, Publishing House Sitech, Craiova, 2006.

[13] Racoceanu, C., Căpăţînă, C., *Emissions of power stations*, Publishing House Matrix Rom, Bucureşti, 2005.

[14] Racoceanu, C., *Power plants environmental impact*, Publishing House Focus, Petroşani, 2001.