ISSN 1848-0071
UDC 662.6+546.19=111
Recieved: 2011-10-21
Accepted: 2011-11-18
Review

# THE ISSUE OF BROWN COAL QUALITY ON THE BASIS OF PHYSICOCHEMICAL PARAMETERS

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Coal is expected to remain the dominant fuel for electricity generation in the Slovak republic for a considerable time in the future. Mining of lignite and brown coal is necessary for security and stabilizes the electricity systems of this republic through the heat power Nováky (ENO). Coal combustion processes represent a significant potential for contamination of environmental components. The elemental composition of coal from the mine Cígeľ showed that coal contains variable amount of arsenic which was found due to the presence of sulfide minerals containing arsenic in the coal substance. Close monitoring of the coal quality and composition of coal ashes is therefore essential.
**Key words:** brown coal quality, sampling, arsenic.

**Ocjena kvalitete mrkog ugljena na temelju fizikalno-kemijskih parametara.** Očekuje se da će ugljen ostati dominantno gorivo za proizvodnju električne energije u Slovačkoj republici za dosta vremena u budućnosti. Rudarstvo lignita i mrkog ugljena je potrebno za sigurnost i stabilizira elektro-energetski sustav ove republike radom termoelektrane Novaki (ENO). Procesi izgaranja ugljena predstavljaju značajan potencijal za onečišćenje okoliša. Elementarni sastav ugljena iz rudnika Cígeľ pokazao je da ugljen sadrži promjenjivu količina arsena, koji je prisutan u sulfidnim mineralima kao bitnim tvarima od kojih se sastoji ugljen. Stoga, neophodno je strogo praćenje kvalitete ugljena kao i sastava pepela nastalog njegovim izgaranjem.
**Ključne riječi:** kvaliteta mrkog ugljena, uzorkovanje, arsen.

## INTRODUCTION

Slovakia has more than 1 billion tons of geological reserves of coal. Deposits of brown coal occur in various geological levels of the Horna Nitra fold, the South-Slovakia basin, the Danube basin and the Viena basin. Lignite deposits are known in the Viena basin, marginal parts of the Danube basin, the Žiar fold of central Slovakia and the East-Slovakia basin.

Upper Badenian deposits of the Horna Nitra fold in central Slovakia are of major economic importance concerning the amount of reserves and quality of brown coal. Deposits Nováky, Cígeľ and Handlová extend on the area about 70 $km^2$ and are made up by 2 to 11 m thick coal seams. Caloric value varies from 10,7 to 12,9 MJ per kg.

Domestic brown coal production covered 78 % of demand in the Slovak Republic in 2010; the rest of the amount was imported, almost wholly from the Czech Republic [1- 8].

Mining of lignite and brown coal in Slovakia in recent years has been closely linked mainly to electricity production and the heat power plant Nováky (ENO). The existence of power plant Nováky is necessary for security and stabilizes the electricity systems of Slovakia.

Because of coal combustion processes represent a significant potential for contamination of environmental components, monitoring of the coal quality and composition of coal ashes resulting from its combustion play an important role [10].

## SAMPLING FOR THE DETERMINATION OF PHYSICOCHEMICAL PARAMETERS

Sampling of the lignite seams is determined according to STN 441303 - Sampling of lignite seams [2]. Samples of the extracted coal were taken from the pouring conveyor belt, which are transported to the coal washing, with automatic links to the collection and processing of the extracted coal. Sub-samples are taken every 20 minutes of actual running conveyor belt.

They are taken within 24 hours and the next day they are preparing for the laboratory samples. For samples of drill holes is laboratory samples used to determine the basic characteristics of qualitative chemical analysis of coal.

Samples for chemical analysis of groundwater wells are taken into PVC bags and immediately transferred to the laboratory, which provides crude and residual analysis of water, ash content of the analytical form and calorific value in analytical form. For these values were then calculated the water in its original ashes condition $W^r$, ashes in their original state $A^r$, ash in the dry $A^d$, combustible $V^r$, calorific value of combustible $Q^{daf}$, calorific value of fuel $Q_s^r$, fuel efficiency $Q_i^r$. In most samples from the notches in addition also provides the density of the sulfur content of $S^r$ [3]. Characteristic physicochemical parameters of the Slovak brown coal are shown in Table 1.

Samples of coal sales types are taken for the species:

- "Cube 1 +2" - stopped manually from the conveyor belt, which conveys this kind of coal to shipping containers. Samples were taken every 30 min. net running time of the technological line. Sub-samples were taken immediately after collection to separate adjusting device, which consists of a grinding-mill and a rotating sample divider. The divided sample falls directly into the tank sub-samples.
- "Washed walnut 1 and 2" - using a mechanical sampler with automatic control of slump vibrating feeder, which is the kind of coal sales types loaded into rail cars; the sampler operates in 12 min. intervals.
- "Steam coal" - using straight lines for the collection and processing coal. Sub-samples are taken every 15 min. net time running conveyor belt, from the fall to be sampled.

**Table 1.** Characteristic physicochemical parameters of the Slovak brown coal [4]
**Tablica 1.** Karakteristični fizikalno-kemijski parametri slovačkog mrkog ugljena [4]

| Item | Fuel | Slovak brown coal | | |
|---|---|---|---|---|
| Symbol | | assorted | boiler | average |
| **Elemental fraction in the fuel** | | **[wt. %]** | | |
| $C^r$ | fraction of carbon | 47.29 | 28.35 | 33.80 |
| $H^r$ | fraction of hydrogen | 3.62 | 2.49 | 2.86 |
| $O^r$ | fraction of oxygen | 14.36 | 12.42 | 13.52 |
| $N^r$ | fraction of nitrogen | 0.78 | 0.45 | 0.54 |
| $S^r$ | fraction of combustible sulphur | 1.37 | 1.76 | 1.78 |
| **Amount of combustibles "$V^r$" in the fuel** | | **67.41** | **45.48** | **52.50** |
| $W^r$ | total humidity | 24.26 | 36.04 | 32.00 |
| **Sv (Dm)** | total dry matter | 75.74 | 63.96 | 68.00 |
| $A^r$ | ash in the fuel | 8.33 | 18.48 | 15.50 |
| $A^d$ | ash in dry matter | 11.00 | 28.90 | 22.80 |
| $S_t^r$ | total S in the fuel | 1.51 | 2.58 | 2.38 |
| $S_t^d$ | total S in dry matter | 1.99 | 4.04 | 3.50 |
| $Q_i^r$ [MJ.kg$^{-1}$] | fuel efficiency | 15.27 | 10.76 | 12.04 |
| $Q^{daf}$ [MJ.kg$^{-1}$] | calorific value of combustible | 22.65 | 23.66 | 22.93 |
| $Q_s^r$ [MJ.kg$^{-1}$] | calorific value of fuel | 16.03 | 11.30 | 12.64 |

## MONITORING OF THE COAL QUALITY IN THE MINE CIGEL'

Brown coal is the raw material of Handlovska cage bearings in mining area - the mine Cígeľ. Coal is primarily intended for combustion and heat and steam. Stocks in the mining area of Cígeľ and Handlová are estimated at 5 to 15 years depending on the amount of electricity produced in the heat power Nováky (ENO).

To assess the quality of coal supplies (Table 2) to power plants Nováky in site Zemianske Kostoľany, which is a major purchaser of coal is responsible for laboratory the mine Cígeľ.

**Table 2.** The elemental composition of coal from the mine Cígeľ [3]
**Tablica 2.** Elementarni sastav ugljena iz rudnika Cígeľ [3]

| | **cube 1+2** | | **walnut 1** | | **walnut 2** | | **small** | | **mined coal** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **%** | original | anhydrous | original | anhydrous | original | anhydrous | original | anhydrous | original | anhydrous |
| **hydrogen** | 3,23 | 4,74 | 2,92 | 4,33 | 2,85 | 4,19 | 2,17 | 3,13 | 2,53 | 3,56 |
| **carbon** | 39,53 | 57,97 | 36,34 | 53,86 | 35,68 | 52,42 | 25,27 | 36,37 | 30,14 | 42,41 |
| **oxygen** | 15,07 | 22,09 | 14,46 | 21,43 | 14,06 | 20,66 | 11,39 | 16,38 | 12,56 | 17,66 |
| **nitrogen** | 0,51 | 0,75 | 0,47 | 0,69 | 0,46 | 0,68 | 0,36 | 0,52 | 0,41 | 0,58 |
| **sulphur organic** | 0,73 | 1,07 | 0,72 | 1,05 | 0,72 | 1,06 | 0,47 | 0,68 | 0,52 | 0,74 |
| **sulphur general** | 1,29 | 1,86 | 1,32 | 1,93 | 1,21 | 1,73 | 1,25 | 1,75 | 1,22 | 1,69 |
| **arsenic** ($g.t^{-1}$) | **18,38** | **26,96** | **30,53** | **45,24** | **58,83** | **79,10** | **36,35** | **52,32** | **21,46** | **30,12** |

Chemical composition of ash is highly variable, depending on the type and quality of coal and combustion conditions. Distribution of chemical constituents is in the range of values $SiO_2$: 35 – 55 %, $Al_2O_3$: 20 – 30 %, $Fe_2O_3$: 3 – 30 %, CaO: 1 – 7 %, MgO: 1 – 4 %, $SO_3$: 0,2 – 3 %, $K_2O + Na_2O$: 1 – 8 %.

Toxic elements, which contain significant quantities of ash, in particular: As, B, Be, V and Cd. Ash may be inherently silico-alumina or silico-phosphate. Both types vary in content of active CaO, $SiO_2$ and $Al_2O_3$. The first has pozzolanic properties, the other may have an extra hydraulic properties.

Following the type of coal and combustion conditions ash and fly ash may include from 1 to 20 percentage by weight of unburned gas coal (expressed as loss on ignition in chemical analysis), approximately 35 to 65 percentage by weight of silica, 20 to 40 percentage by weight of oxides aluminum and iron together, 2 to 20 percentage by weight of calcium oxide (CaO containing higher percentages of fly ash as for burning lignite, mostly moving content around 3 % CaO, our case 4 to 7% of the ash of burning).

What is important is the content of alkali (Na, K), which ranges from 2 to 5 percentage by weight (expressed as oxides of sodium and potassium) and sulfur (expressed as sulfur trioxide - $SO_3$), or the content of sulphides ($S^{-2}$) [5].

The elemental composition of coal from the mine Cígeľ showed that coal contains variable amount of arsenic. It is due to the fact that substances in the coal field are examined prevalence of such minerals as pyrite – $FeS_2$, realgar - $As_4S_4$, arsenopyrite - FeAsS, orpiment - $As_2S_3$ [5]

Arsenic gets into the ash in coal combustion process. Coal combustion processes represent a significant potential for contamination of the environment. Upper Nitra Region, which is one of the most fuel-energy complexes of the Slovak republic - ENO Nováky, which is based on mining and burning brown coal with high arsenic, is strongly environmental laden area. Since 1953 (commencement of operations ENO) has been around the plants to a significant contamination of soils airborne ash, which are linked arsenic, depending on the weather conditions and topography [6- 9].

## CONCLUSION

The issue of monitoring the quality of brown coal and combustion products plays an important role in the volatile data confirmed the content of arsenic in brown coal mines Cígeľ.

In order to prevent events which took place in the year 1965, when the dam broke in the original pond Zemianske Kostoľany and the river Nitra missed about 2.5 million $m^3$ ash materials, which also contain arsenic, since the 2007 significant attention is paid to monitoring the two ash electricity disposal site in the role of the Ministry of Environment of Slovak republic "Anthropogenic sediment nature of environmental burdens". The aim is to know the degree of contamination of alluvial soils and sediments arsenic in alluvial areas with ash and also assess the potential for possible mobilization of arsenic [7].

**Acknowledgement**

Research presented in this paper was supported by the Scientific Grant Agency (VEGA) of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences, Grant No. 1/0370/10 No. and Grant No. 1/0165/09.

## REFERENCES

[1] Slovak Minerals Yearbook, 2010, Statistical data to 2009, Ministry of the Environment of Slovak republic, State Geological Institute of Dionyz Stur, Bratislava, 2010

[2] STN 441303, Taking of samples of the lignite seams.

[3] Final Report with the calculation of reserves, mine Cigel, 1994 .

[4] Industry standard of ministry of environment, air protection, 2008.

[5] Š. Zelenák, Use of waste in mining and the impact of this activity on groundwater quality, in, Waste Forum, 2010, no 4, p. 324-330

[6] L. Jurkovič, V. Veselská, V. Gučková, J. Frankovská, Geochemical assessment of arsenic contamination in soils of Zemianske Kostoľany area in, Acta environmentalica Universitatis Comenianae (Bratislava)**,** Vol. 16, no 1(2008), p. 47–55,

[7] L. Jurkovič, K. Peťková, V. Veselská, B. Lalinská, E. Hiller, Arsenic release from anthropogenic sediments using single step extractions in the area of Zemianske Kostolany, in, 11th International Multidisciplinary Scientific GeoConference SGEM 2011, Conference Proceedings, p. 1051-1054

[8] J.Pinka, V. Bauer, Significance of domestic energy raw materials for energy policy and requirements of Slovak republic, In, History and current status of mining of mineral deposits in eastern Slovakia, Conference Proceedings, Solivary, TU of Košice, 2011, p. 228-238.

[9] F. Michalíková, M. Košuth, J.Škvarla, F. Zeleňák, M. Sisol, Properties of lignite fly ash from coal combustion in thermal power Eno Nováky, In: Newsleter lignite, no. 2 (2008), p. 33-41.

[10] L.Vizi, M.Šofranko, Positive influence of planning and controlling of mining process on qualitative parameters of the recovered ore from mineral deposit. In: Metalurgija. Vol. 47, no. 3 (2008), p. 279.