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HEAVY METAL CONCENTRATIONS IN BITUMINOUS COAL FROM THE "JANINA" COAL-MINE, LIBIĄŻ, USCB, POLAND

Abstract. Samples of coal and barren rocks from No. 118 and 201 seams were investigated. Maceral group composition of coal from No. 118 seam is as follows: vitrinite 52.8%, liptinite 15.1%, inertinite 27.8%, mineral matter 4.4%. In case of coal from No. 201 seam the results are similar: vitrinite 55.5%, liptinite 13.2%, inertinite 27%, mineral matter 4.4%. Reflectance of vitrinite measured in coal from No. 118 seam is 0.42% and in coal from No. 201 seam is 0.43%. A correlation between concentrations of lead and zinc in coal and volatile matter content has been found. In case of lead, the maximum amount of this metal (218.2 ppm) was observed in the coal sample that volatile matter content is lower (34.8%). The maximum concentration of zinc (347.6 ppm) was observed in the coal sample that volatile matter content is higher (41.7%). As for distribution of Cr, Ni, Cd, and Cu, the highest their amounts were determined in the roof of No. 118 seam, in clay rocks. Pb and Zn are exceptions: the maximum concentrations of these metals were observed in the coal, at the bottom of No. 118 seam. In case of No. 201 seam, the highest amounts of Cr, Ni, Cd, Cu and Zn were observed in the floor of this seam, in clay rocks. The maximum concentration of Pb, similar to No. 118 seam, was determined in the coal of No. 201 seam.

Key-words: bituminous coal, barren rocks, maceral group, trace metals, Libiąż, USCB

INTRODUCTION

In Poland coal is the main mineral raw material used in production of energy. Combustion of brown and bituminous coal supplies above 75% of the primary energy which is used in the country (Podgajniak et al. 2001) and for this reason monitoring of coal quality seems to be essential. In addition to the petrographic composition, reflectance of vitrinite or technological parameters, it is important to investigate the content of trace metals. Toxic elements occurring in coal are released during its combustion. Some volatile elements (mercury, cadmium, selenium) escape directly to the atmosphere, others (uranium, rubidium, arsenic, cobalt, zinc, etc.) have tendency to remain in ash (Matl, Wagner 1995). Majority of trace metals (zinc, lead, cadmium, copper, nickel, cobalt) are associated with the mineral matter of coal (Parzentny,

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Różkowska 1989; Parzentny 1989; Parzentny 1990; Staisz et al. 2000) and with barren rocks, thus coal wastes may be a considerable source of these metals.

Along with determination of trace metal distribution in coal from the "Janina" coal-mine, petrographic composition and technological parameters of coal were examined.

SAMPLES AND METHODS

Samples from No. 118 and 201 coal seams and their barren rocks were collected in the "Janina" mine. This coal mine located in the south-eastern part of the Upper Silesian Coal Basin exploits coal with the lowest rank (Makowski 1928–1930; Gabzdyl, Hanak 1984; Kidawa, Jasieńko 1989; Hanak 1993). The samples of coal and barren rocks were prepared according to the Polish Standard PN-90/G-04502. Petrographic analyses were carried out in immersion on epoxy resin pellets by means of a reflected light microscope "Axioskop".

Vitrinite, liptinite and inertinite groups were distinguished under the cross-hair eye-piece, in 500 points, using an "Eltinor 4" point counter. Random reflectance of vitrinite (R_0) was measured according to the ICCP procedure.

Technological analyses of coal included such parameters as: moisture, ash, volatile matter and gross calorific value. Coal and barren rock samples were also tested geochemically to assess the amount of seven trace metals: Fe, Cu, Zn, Pb, Cr, Ni and Cd. The samples were burnt flamelessly in an electric furnace at a temperature of 500–600°C. The ashes were then digested in hot, 40% hydrofluoric acid and solid residues obtained were dissolved in hot, 35–38% hydrochloric acid. Solutions were diluted with distilled water up to the volume of 100 cm^3 and analysed by means of AAS (atomic absorption spectrometry). Total carbon and sulphur contents in the samples were determined with a LECO SC 132 analyser.

RESULTS

The results of petrographic analyses and reflectance measurements are presented in Table 1.

The following technological parameters of coal were determined: moisture (M^d), ash (A^d), volatile matter (V^{daf}), gross calorific value (Q_s^{daf}) and total carbon (C^{daf}) and sulphur (S_t^{daf}) contents. The results are collected in Table 2.

Technological analyses of coal from the "Janina" coal-mine were also carried out by Hanak (1993). Volatile matter (37.6%), total carbon (73.9%) and sulphur (2.81%) contents are similar to the results presented in Table 2, while the moisture (10.6%) and ash (12.5%) contents are slightly different.

Coal and barren rock samples were tested for seven trace metals (Pb, Cr, Ni, Cd, Cu, Zn i Fe) as well as total carbon and sulphur concentrations. The results are presented in Table 3.

Maceral group composition and reflectance of vitrinite of the coal from No. 118 and 201 seams

Sample	Vitrinite group	Liptinite group	Inertinite group	Mineral matter	Reflectance [%]
	wt. %				
1/118	55.2	14.4	26.2	4.2	0.42
2/118	50.6	14.9	29.3	5.2	0.40
3/118	52.5	16.0	27.8	3.7	0.43
Average	**52.8**	**15.1**	**27.8**	**4.4**	**0.42**
4/201	59.3	11.3	23.7	5.6	0.44
5/201	51.7	15.0	30.3	3.0	0.44
Average	**55.5**	**13.2**	**27.0**	**4.3**	**0.44**

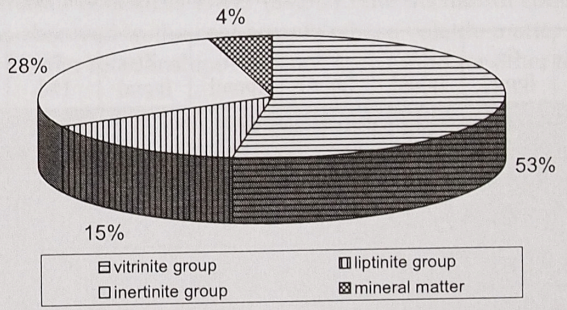

Fig. 1. Maceral group composition of the coal from No. 118 seam

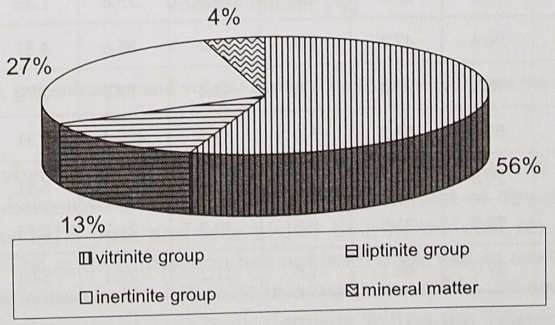

Fig. 2. Maceral group composition of the coal from No. 201 seam

TABLE 2

Technological parameters and carbon and sulphur contents of the coal from No. 118 and 201 seams

Sample	M^d [%]	A^d [%]	V^{daf} [%]	Q_s^{daf} [kcal/kg]	C^{daf} [%]	S_t^{daf} [%]
1/118	17.2	11.4	41.7	4 982	73.8	3.28
2/118	17.8	8.0	41.1	5 303	75.7	3.13
3/118	19.3	4.6	42.4	5 459	75.3	1.76
Average	**18.1**	**8.0**	**41.7**	**5 248**	**74.9**	**2.72**
4/201	15.3	7.2	34.8	5 604	76.8	3.03
5/201	12.1	9.1	36.9	5 788	78.6	3.08
Average	**13.7**	**8.2**	**35.9**	**5 696**	**77.7**	**3.06**

TABLE 3

Trace metal, carbon and sulphur contents in the coal and barren rocks from No. 118 and 201 seams

Sample	Pb [ppm]	Cr [ppm]	Ni [ppm]	Cd [ppm]	Cu [ppm]	Zn [ppm]	Fe [%]	C [%]	S [%]
1/118	63.6	16.1	19.4	0.2	15.5	347.6	2.56	52.7	2.34
2/118	36.4	6.3	9.7	0.3	6.9	14.7	2.83	56.2	2.32
3/118	40.9	6.3	9.7	0.2	5.1	2.1	2.22	57.3	1.34
4/201	218.2	8.0	19.4	0.2	17.2	126.2	3.02	59.5	2.35
5/201	38.6	6.3	13.9	0.2	20.7	9.7	3.2	61.9	2.43
6/118	56.8	19.6	30.6	0.7	27.6	32.4	1.1	2.96	0.33
7/118	34.1	97.3	27.8	0.8	9.5	23.8	1.35	3.91	0.42
8/118	18.2	96.4	47.2	1.0	42.2	85.6	4.81	2.76	0.27
9/201	27.3	75.0	33.3	1.0	41.4	73.8	2.72	0.8	0.02
10/201	147.7	58.0	58.3	3.0	54.3	489.4	2.31	22.14	0.81
11/201	104.5	29.5	45.8	1.3	55.2	65.0	6.41	5.15	3.71
12/201	22.7	75.9	31.9	0.8	10.3	21.2	0.74	14.4	0.18
13/201	68.2	27.7	43.1	1.0	11.2	22.1	5.04	4.77	2.77

Samples: 1/118-5/201 — coal.
Samples: 6/118-13/201 — barren rocks.

As for geochemical results of the coal and barren rock samples, they were interpreted together. Highest concentrations of Cr, Ni, Cd, and Cu were observed in the roof of No. 118 seam, in clay rocks. Pb and Zn are exceptions: the maximum concentrations of these metals were not observed in the clay rocks, but in the coal at the bottom of No. 118 seam. In case of No. 201 seam, the highest amounts of Cr, Ni, Cd, Cu and Zn were observed in the floor of this seam, in clay rocks. The maximum concentration of Pb, similar to No. 118 seam, was determined in the coal of No. 201 seam.

Iron concentrations in the coal samples are similar. In case of No. 118 seam its contents are: 2.22, 2.56 and 2.83%. In No. 201 seam they are: 3.02 and 3.20%. The maximum concentration of iron was observed in the roof of No. 118 seam and in the floor of No. 201 seam, in barren rocks.

Sulphur concentrations in the coal samples from No. 118 seam are higher than in the barren rocks: 1.34, 2.32 and 2.34%. In case of No. 201 seam sulphur concentrations in the coal are almost the same (2.35 and 2.43%), whereas in the barren rocks differ in a wide range from 0.02% to 3.71%.

The authors made an attempt to establish the relationship between the volatile matter content in coal and concentrations of the metals tested. In case of lead, the maximum amount of this metal (218.2 ppm) was observed in the coal sample whose volatile matter content is lower (34.8%). The maximum concentration of zinc (347.6 ppm) was observed in the coal sample whose volatile matter content is higher (41.7%) (Fig. 3). Similar relationships have not been found for other metals.

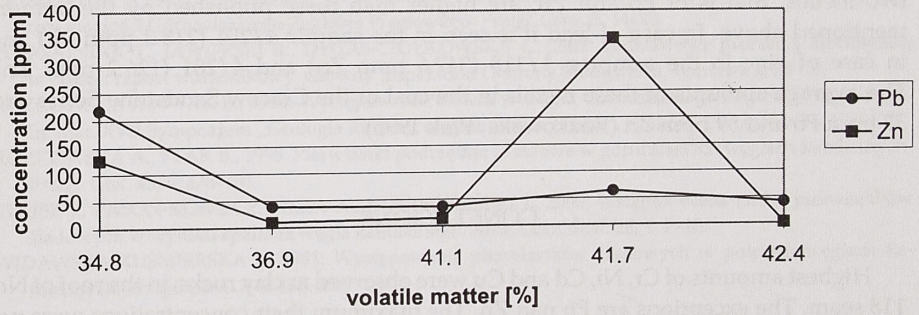

Fig. 3. Lead and zinc concentrations and volatile matter content in the coal from No. 118 and 201 seams

The correlation between concentrations of the metals tested in coal and the position of the seams has been also examined. The average content of zinc in the coal from No. 118 seam was 121.5 ppm and was higher than in the coal from No. 201 seam (68 ppm) (Fig. 4). The same connection has not been observed in case of other metals. Higher zinc concentration in No. 118 seam in comparison to No. 201 seam can probably be linked to the occurrence of Zn-Pb ore deposits within the Triassic overburden of the coal seams (Różkowska, Ptak 1995).

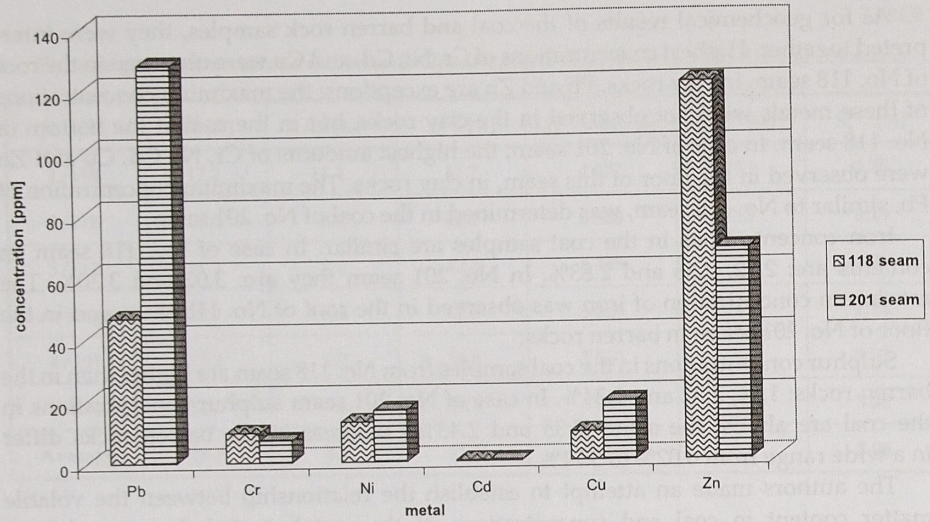

Fig. 4. Trace metal concentrations in the coal from No. 118 and 201 seams

Concentrations of tested metals were compared with the data published by other authors (Widawska-Kuśmierska 1981; Różkowska, Ptak 1994, 1995). The contents of two metals, that is of Pb and Zn, are higher than these published by the authors mentioned above. In case of lead it is seen in the sample 4/201 (218.2 ppm Pb) and in case of zinc in the samples: 1/118 (347.6 ppm Zn) and 4/201 (126.2 ppm Zn). The average amounts of these metals in the coal of the Cracow Sandstone Series are: 32 ppm Pb and 59 ppm Zn (Różkowska, Ptak 1995).

CONCLUSIONS

Highest amounts of Cr, Ni, Cd and Cu were observed in clay rocks, in the roof of No. 118 seam. The exceptions are Pb nad Zn. The maximum their concentrations were not observed in the barren rocks, but in the coal, at the bottom of No. 118 seam. In case of No. 201 seam, the highest amounts of Cr, Ni, Cd, Cu and Zn were observed in the floor of this seam, in clay rocks. The maximum concentration of Pb was determined in the coal of No. 201 seam.

Iron concentrations in the coal samples from No. 118 seam are lower than in the samples from No. 201 seam. The average content of iron in No. 118 seam was 2.54% and in No. 201 seam 3.11%. The maximum content of iron was determined in barren rocks.

The average sulphur amount in the coal from No. 118 seam is 2%, whereas in the coal from No. 201 seam 2.4%.

Geochemical investigations of the coal and barren rocks from the "Janina" coal-mine are to be continued. The results will be used to determine the balance of trace metal concentrations in the coal and its treatment products. These data should also be useful for estimation of eventual negative influence of some elements on environment.

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METALE CIĘŻKIE W WĘGLU Z KWK „JANINA" W LIBIĄŻU (GZW)

Streszczenie

Zbadano próbki węgla i skał płonnych z pokładów 118 i 201. W przypadku węgla z pokładu 118 stwierdzono następujący skład macerałów: grupa witrynitu — 52,8%; grupa liptynitu — 15,1%; grupa inertynitu — 27,8%; substancja mineralna — 4,4%. Dla węgla z pokładu 201 był on podobny: grupa witrynitu — 55,5%; grupa liptynitu — 13,2%; grupa inertynitu — 27%; substancja mineralna — 4,3%. Refleksyjność witrynitu (R_0) zmierzona dla węgla z pokładu 118 wynosi 0,42% a dla węgla z pokładu 201 — 0,44%. Znaleziono zależność pomiędzy koncentracją ołowiu i cynku w węglu a zawartością części lotnych. Maksymalną koncentrację ołowiu (218,2 ppm) stwierdzono w węglu, którego zawartość części lotnych jest niższa (34,8%). W przypadku cynku, maksymalną jego koncentrację (347,6 ppm) stwierdzono w węglu, którego zawartość części lotnych jest wyższa (41,7%). Najwyższe zawartości Cr, Ni, Cd i Cu zaobserwowano w stropie pokładu 118, w skałach ilastych. Ołów i cynk są wyjątkami: maksymalne koncentracje tych metali stwierdzono w węglu, w dolnej części pokładu 118. W przypadku pokładu 201, najwyższe zawartości Cr, Ni, Cd, Cu i Zn zaobserwowano w spągu tego pokładu, w skałach ilastych. Maksymalną koncentrację ołowiu, podobnie jak w pokładzie 118, stwierdzono w węglu z pokładu 201.