Evaluation of the mine gases hazard in the closed hard coal mine „Niwka-Modrzejów"

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Hodnotenie nebezpečnosti banských plynov v uzavretej čiernouhoľnej bani „Niwka-Modrzejów"

Closing of hard coal mines, especially stopping the process of mine water pumping, results in a reconstruction of the Carboniferous water-bearing horizon, leading to the intensification of gas flux to the near-surface zone („piston effect"). Stopping the fans considerably enhances the movement of mine gases towards the surface in closed mines. Stopping the fans results in an accumulation of gases in workings and old workings.

The results of geochemical analyses performed in the area of the hard coal mine „Niwka-Modrzejów" are presented in the paper. The obtained results and their comparison with the existing geological-reservoir model prove that the intensification of the mine gases flow towards the surface continues through the zones of tectonic discontinuities, crackings, and loosened zones in the Upper-Carboniferous sedimentary rocks. The thickness and lithology of the onlying overburden plays a decisive role in the limitation of the mine gases migration.

Key words*: gas flux, geological-reservoir model, gases migration*

Introduction

Closing of coal mines, particularly stopping pumping mine waters, restructures the Carboniferous water-bearing horizon, which in turn, is related with the intensification of gas flow to the surface zone (the so-called „piston effect"). The movement of mine gases towards the surface in abandoned workings also considerably intensifies owing to the stopped operation of fans.

The method of surface geochemical mapping is especially useful for detecting the migration of methane and toxic gases in hard coal mines that are closed [1], [2], [3].

Geochemical analyses in the hard coal mine „Niwka-Modrzejów were carried out during July - September 2003 [2]. They were devoted to the evaluation of the scale of occurrence of formation gases in the surface zone of the analyzed area.

Methodics of geochemical analyses

On the surface of some coal mines, especially the closed ones, an increased content of mine gases is observed, mainly of methane and carbon dioxide. The emission of these gases depends on a number of factors:

- Geological conditions of the area,
- Methane content of the beds and methane content in old workings;
- Tectonic disturbances up to the top of the Carboniferous strata;
- Thickness of the overburden and its filtration properties;
- Connection of workings and the surface with shafts and drilling wells;
- Flooding of old workings.

The above factors decide about the permeability of the rock mass and the possible pathways for the mine gases.

The migration of mine gases to the surface in closed mines is intensified owing to the stopped operation of fans. The gases are accumulated in old workings. The lack of air circulation in abandoned workings spurs out a gas migration under the influence of gradients of pressure, temperature and natural depressions. This is a two-phase process. At the first stage, the gas is desorbed from the coal, then it flows to the old workings. The consecutive gas migration to the surface depends on the thickness and permeability of the rocks.

The process of gas outflow can be intensified by flooding of abandoned workings when the water pushes the atmosphere upwards. On the other hand, flooding of specific levels also cuts off the levels, thus disabling a further desorption of methane.

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A gas hazard in the post-mining areas is possible especially in mines having a permeable overburden. Moreover, it may also occur in the area of shafts and drilling wells. This effect will be probably limited to the time in which the mine is being closed [1], [2].

Realization of geochemical analyses

The closed mine „Niwka-Modrzejów" is localized in the NE part of the Upper Silesian Coal Basin. The mining area covers 19.8 km^2. The surface is nearly flat and the height datums range between +240 m asl to +260 m asl [2].

In the area of the former coal mine „Niwka-Modrzejów" the Carboniferous beds are covered with a thin layer of quaternary sediments, i.e. 1 m to ca. 52 m. The quaternary sediments in the form of sands and gravels are locally interbedded with clays.

The methane content in the coal beds in the coal mine „Niwka-Modrzejów" ranges from 0.0 m^3 CH_4/Mg csw to 5.5 m^3 CH_4/Mg csw. Unlike the N part of the area which has a low methane content, the SE and S parts have an increased methane content from 2.0 m^3 CH_4/Mg csw to 5.5 m^3 CH_4/Mg csw (near the shaft Brzêczkowice).

The levels 405, 407 and 501, having a methane content up to 2.5 m^3 CH_4/Mg csw, were exploited at a depth of – 50 m to + 150 m asl. The level 510 (1.169 m^3 CH_4/Mg csw to 3.0 m^3 CH_4/Mg csw) was exploited near the shaft Brzêczkowice. The levels 400 and 500 were exploited over the whole area of the coal mine „Niwka-Modrzejów". The exploitation had the broadest range in the north and central part of the mine, in the city of Sosnowiec. A long term exploitation resulted in degassing of the coal beds [2].

The surface geochemical analyses were divided into two stages: the reconnaissance (stage I) and the detailed analyses (stage II). At the first stage of geochemical analyses, a detailed geochemical mapping of the surface was made.

The reconnaissance geochemical analyses were made along two selected profiles I-I' and I-II' of total length of 3450 m, as well as the analyses in the immediate vicinity of the shafts (Figs. 1, 2). Basing on the results of reconnaissance geochemical analyses of the surface along the selected profiles, detailed analyses of the surface were made for areas, where an increased formation of gas flux to the surface was expected.

The course of reconnaissance analyses of the selected profiles was determined on the basis of existing geological and hydrogeological data on the methane and carbon dioxide content in the coal beds, the mining data, the topographic data and the city plans. Profiles were localized along the lines perpendicular to the Carboniferous outcrop and to the course of large tectonic dislocations. Moreover, they were localized in the areas considerably varying in the thickness of the overburden and the in coal-bed methane content [2]. The free gas method was employed for the reconnaissance. The measurement step was 25 m. The probes were disposed at about 2 m of depth.

Detailed geochemical analyses were made for selected subareas within the mining areas of specific coal mines. The sampling places were localized within the basic and densified grid. Piezometers (probes) disposed in a regular square grid of a measurement step of 50 m were localized in the nodes of the basic grid. The probes were installed at about 2 m of depth. Detailed geochemical analyses were performed by the profile method in the direct vicinity of mine's shafts. Their task was to establish the degassing role of the shafts.

In all soil gas samples, the gas content was measured for: CH_4, C_2H_6, C_3H_8, ΣC_nH_{2n+2}, O_2, N_2, H_2, He, Ar, CO, CO_2, H_2S.

Interpretation of geochemical results

The obtained results of the geochemical analyses and their relation with respect to the existing geological-formation model prove that the formation gas flow to the surface intensifies through the zones of tectonic discontinuities, cracks and loosenings in the Upper Carboniferous sedimentary rocks. The range and intensity of the surface gaseous exhalations depends on the structure, compactness and the thickness of the near-surface layers (Figs. 1, 2, 3, 4).

Figs. 1 and 2 illustrate the surface changes of methane and carbon dioxide concentration along the profiles I-I' and II-II', on the background of the geological cross-sections.

The maximum methane concentration in the profile I-I' was about 0.0008 %, and of carbon dioxide about 2.68 %. Evidently anomalous gas concentrations in the near-surface zone are related with the faults. The highest increase of carbon dioxide in the near-surface zone can be observed in the east part of the profile (fig. 1).

The maximal methane concentration in the profile II-II' was about 0.0012 %, and carbon dioxide about 8.3 %. The apparently anomalous are concentrations in the surface zone, related with faults. The highest

methane and carbon dioxide concentrations can be observed in the central part of the profile, in the area of thin Quaternary beds and intensive tectonics in the Carboniferous series (fig. 2).

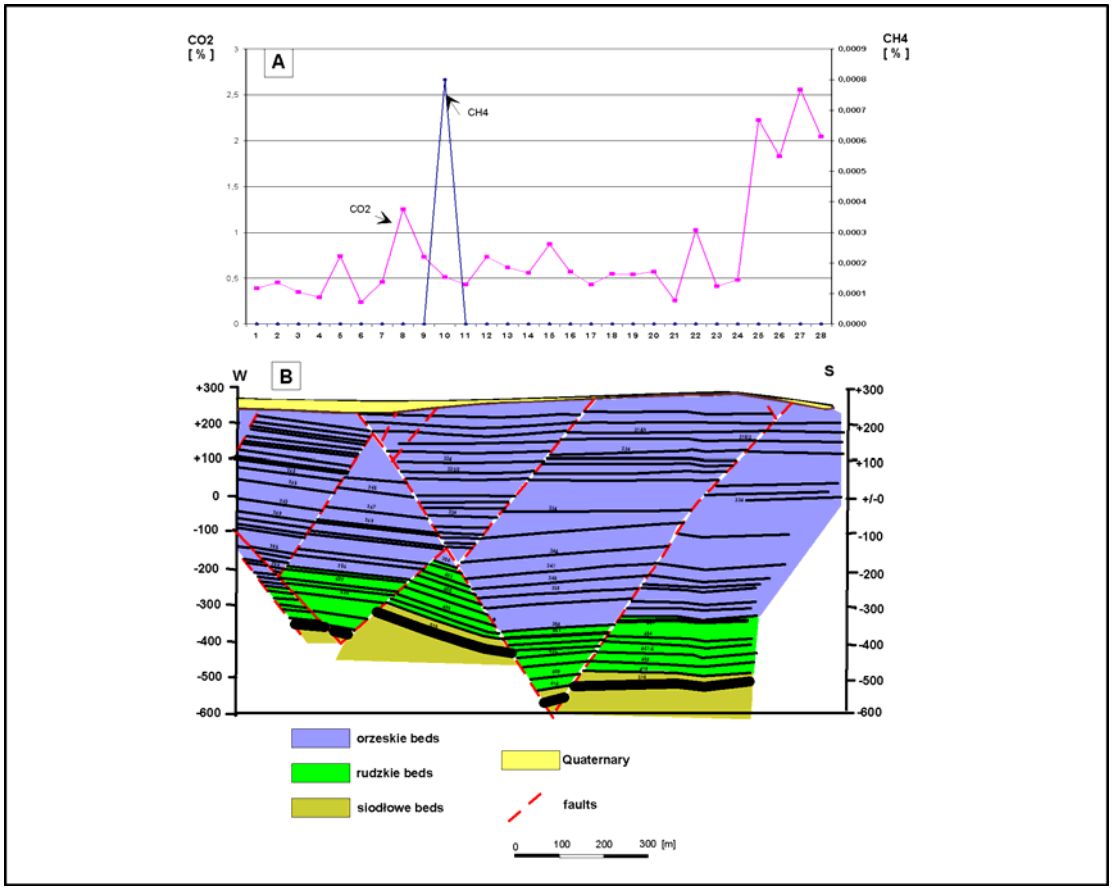

Fig. 1. (A) content of methane and carbon dioxide and (B) the geological cross-section along the analyzed profile I-I' in the area of closed coal mine „Niwka-Modrzejów".

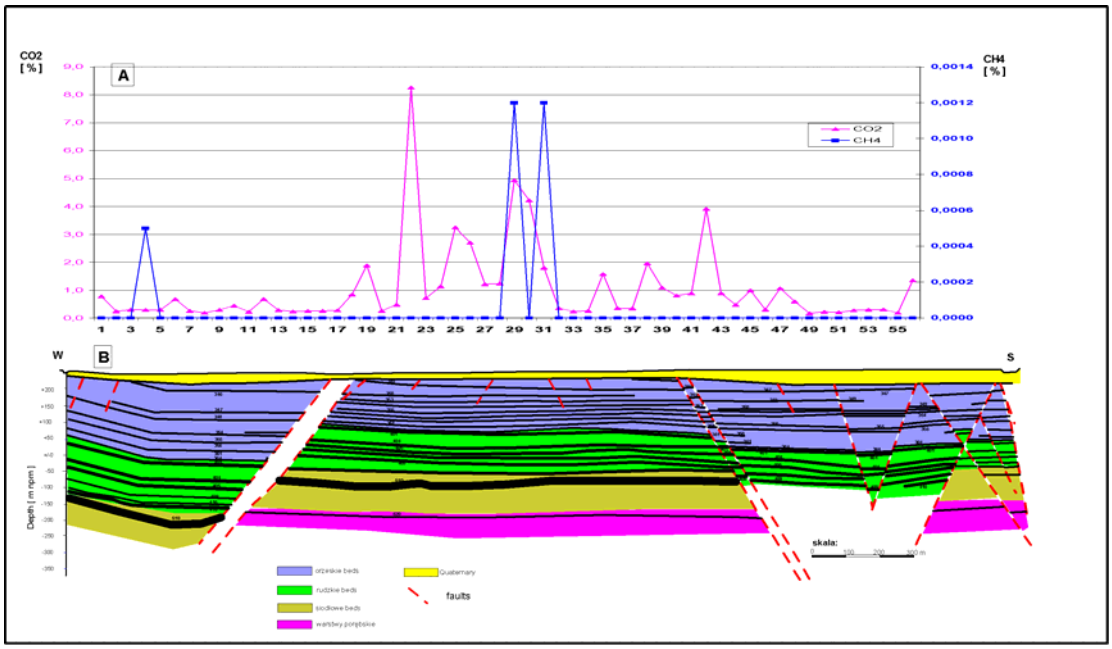

Fig. 2. (A) content of methane and carbon dioxide and (B) the geological cross-section along the analyzed, profile II-II' in the area of closed coal mine „Niwka-Modrzejów".

The results of detailed geochemical analyses in the area of the coal mine „Niwka-Modrzejów" are presented in maps of methane and carbon dioxide concentrations (figs. 3 and 4).

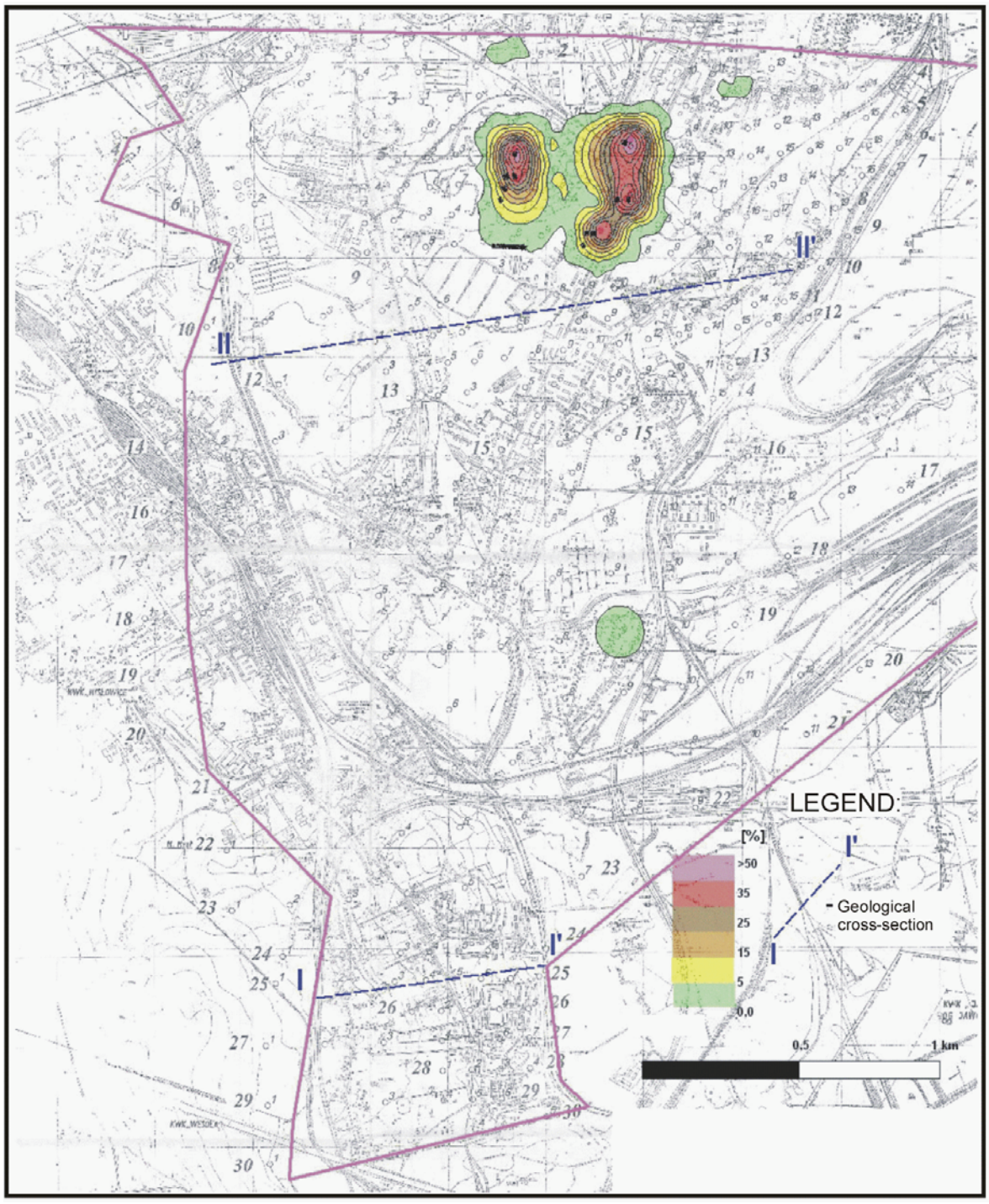

Fig. 3. Map of methane concentrations in the near-surface zone of the coal mine „Niwka – Modrzejów".

It follows from the methane concentration in Fig. 3 for the area of the hard coal mine „Niwka-Modrzejów" that the maximal methane concentration is observed in the north part of the area and equals to over 60.00 % (64.981 %). The Quaternary overburden thickness in this area is below 5.0 m. The observed anomaly is related with a rapid expulsion of gas caused by the moperational mine ventilation system. Stopping the ventilation causes gas accumulations in old workings. The lack of air in the old workings enhances a laminar movement of gases under the influence of gradients of pressure, temperature and natural depression. This is a two-phase process. First, the gas is desorbed from the coal, then it flows to the old workings. The resulting gas migration to the surface depends on the thickness and permeability of rocks.

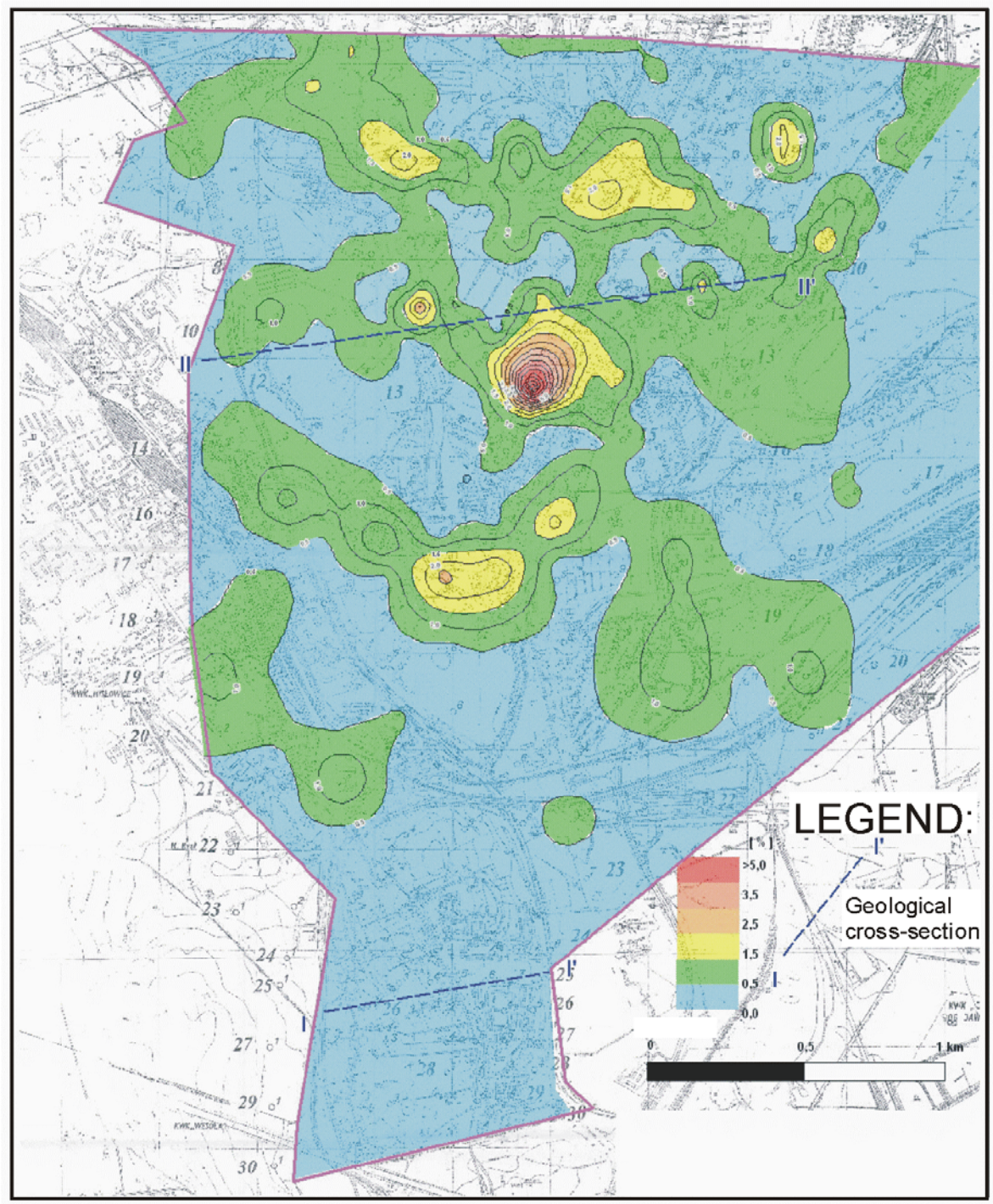

Fig. 4. Map of carbon dioxide concentration in the near-surface zone of the mine „Niwka – Modrzejów".

The map of carbon dioxide concentration (Fig. 4) shows that a maximal concentration of carbon dioxide occurs in the north part and central parts of the analyzed area, in a zone of thin Quaternary overburden. The carbon dioxide concentration ranges from 0.00 to over 8.00 % (8.258 %). Moreover, the high carbon dioxide concentration is observed near the shafts Bobrek (4.833 %), Henryk (5. 752 %), Jerzy (4. 655 %), Mieczys³aw (7.629 %).

The highest increases of methane and carbon dioxide concentrations can be observed in the north and central part of the area, in the zone of thin Quaternary overburden.

In the course of geochemical analyses, the water table was at –140 m on datum.

Conclusions

1. Closing of coal mines, especially stopping of pumping of mine waters, results in the reconstructing of the Carboniferous water-bearing horizon, which in turn, is related with the intensification of gas flux to the near-surface zone (the so-called "piston effect"). The movement of mine gases to the surface in old mines intensifies owing to the stopped operation of ventilation systems.
2. The method of geochemical mapping of surfaces is especially useful for detecting the migration methane and toxic gases in coal mines under closing.
3. Geochemical analyses of the surface consisted of the reconnaissance analyses (stage I) and the detailed analyses (stage II). During the first stage, the analyses were made along the selected profiles and, during the second one, the detailed geochemical mapping of the surface was made.
4. The obtained results of geochemical analyses and their relation with respect to the existing geological-formation model prove that the formation gas flow to the surface intensifies through the zones of tectonic discontinuities, cracks and loosenings in the Upper Carboniferous sedimentary rocks. The range and intensity of the surface gaseous exhalations depends on the structure, compactness and the thickness of the near-surface layers.
5. Gas hazard in the post-mining areas is possible especially in mines having a permeable overburden, e.g. in the coal mine „Niwka-Modrzejów", occurs in the area of shafts and drilling wells. This effect will be probably limited to the time in which the mine is being closed.

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References

[1] Barker, C.: Thermal modeling of petroleum generation: theory and applications. *Developments in Petroleum Science. 45 Advisory Editor G.V. Chilingarian, Elsevier, Amsterdam, 1996.*

[2] Frolik, A., Zawisza, L. i inni: Prognoza skutków wpływu elementów środowiska geologicznego na środowisko naturalne w związku z likwidacją kopalń węgla kamiennego. *Praca sfinansowana ze środków Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej. Katowice-Kraków, 2005*.

[3] Klusman, R., W.: Soil Gas and Related Methods for Natural Resource Exploration. *Wiley, 1993*.