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HISTORY AND ENVIRONMENTAL IMPACT OF MINING IN THE OSTRAVA – KARVINÁ COAL FIELD (UPPER SILESIAN COAL BASIN, CZECH REPUBLIC)

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(7 figures)

ABSTRACT. This paper deals with the history of underground mining and with quantities of mined hard coal, mine water and methane in the Czech part of the Upper Silesian Coal Basin between 1782 and 2000. The effect of the closure of mines on selected part of the coal field with respect to surface streams and landscape, as well as new activities connected with potential utilisation of coal bed methane and methane trapped in gobs of closed mines is examined. This paper is a presentation of selected results from project N° S3086005: "Effect of winding-up of underground mining on processes in lithosphere and on environment" which is financed within frame of Program of Aimed Research and Development of Academy of Sciences of the Czech Republic.

Keywords: Upper Silesian Coal Basin, coal mining, waste rock, mine water, methane, mine closure, subsidence.

1.Introduction

The Ostrava-Karviná coalfield (OKR) forms the southern part of the Upper Silesian Coal Basin located within territory of Czech Republic, which is and has been the subject of mining activity. It is split into Ostrava, Petřvald, Karviná and a southern (Paskov, Staříč and Frenštát-Trojanovice) area. Furthermore, the Czech part of the Upper Silesian Basin is divided, according to the level of geological exploration, mining utilisation, into mine takes and into survey and exploration fields. The area of coal bearing Carboniferous strata located within the territory of the Czech Republic is 1 550 km^2 according to Dopita et al. (1997). The total area of mine takes amounts to 320 km^2. The surface area as defined by a zero isoline of surface ground subsidence, actually affected amounts to about 80%, i.e. 260 km^2.

The history of the Ostrava-Karviná coalfield began by the discovery of hard coal at Ostrava - in 1763 and the very first mine claims were granted in 1776. This period of exploitation lasting more than two hundred years was influenced in the 18th century and early 19th century by a number of circumstances connected with rise of capitalism and suppression of the feudal system. These involved changes of ownership and development of large enterprises, in the Austrian-Hungarian monarchy as elsewhere in Europe. Detailed information relating to the history of the mining industry within this period is given by Matějíček (1984) and Dopita el al. (in print).

The viability of coal deposit exploitation has always been dependent upon natural conditions, together with the technological advancement in the corresponding historical period coupled with economic situation in the European market (and more in recently the world market). For instance, the depth to which coal seams were mined ceased to be a decisive problem after the introduction of steam engines and more efficient mine fans; whilst coal seam thickness together with geological conditions remained decisive factors for mine work productivity.

Technological development influenced all spheres of mine work and is demonstrated by the growth of coal output and by the improvement of mine safety. However, it also had negative impacts such as, an increased proportion of waste rock in the run-of-mine coal output or an increased proportion of fine coal. The changes in technology are reflected equally in the variety and quantity of materials and energy consumed by underground mine enterprises. A similar trend can be seen in social conditions and underground safety.

In the post war period the development of the OKR has been marked by several stages connected both to the economical and political development of the former Czechoslovakia and the application of new developments and improvements to mining machinery and to mine safety requirements.

The period 1945 – 1955 was marked by the restoration and renewal of operating mines after the period of a war economy. It was necessary to replace a workforce that during the Second World War consisted mainly of „Totaleinsatz" forced workers, to substitute equipment removed by the Germans, and in particular to accelerate the development of coal reserves exploitation. Heavy industries were nationalised and considerable organisational changes and the amalgamation of mine enterprises proceeded. During

1951-1953 the so called "1 st OKR General Plan" (1953) was published, defining a prospective plan of the OKR development. In the course of geological exploration within the Czech part of the Upper Silesian Basin from 1953 to 1998 about 1200 deep surface boreholes were drilled as well as a many more underground survey drill holes.

During the period 1956 – 1965, an intensive investment programme of new underground mines proceeded in the Karviná area as well as the reconstruction of existing mines. An enterprise organisation was founded, supporting industrial schemes as well as research institutes and geological survey. Coal winning was protected in an extensive way; steel support was installed in longwalls, and wide-web shearers were imported from the Soviet Union.

The period 1966-1975 was influenced during its first three years by the upturn in utilisation of crude oil which was accompanied by a slight decrease in coal output, followed by a gradual return to coal utilisation during the following years. This stage was marked by the intensification of mining processes and pronounced growth in productivity, by the introduction of drum shearers and powered support, by the application of scraper loaders and belt conveyors, and the introduction of more efficient overhead loaders and roadheaders with boom cutting heads. New underground mines were built up in the areas of Paskov and Staříč.

After 1975 more selective mining of coal was introduced, coal production plans were scaled down and output decreased. The liberalisation of price policy after 1990 resulted in an increase in investment costs, retardation of construction of the new underground mine Frenštát and non-fulfilment of the aims of new "OKR General Plan" of 1980 concerning the concentration of underground mines.

The period 1992-2000 featured the privatisation of state-owned enterprises and was accompanied by the winding-up of coal mining due to the reduction in coal demand (the effect of a decrease of steel production). During this period closure of all the underground mines in the Ostrava and Petřvald areas of the OKR took place. At the same time a marked reduction in geological survey activities occurred.

In 1990 96 shafts were operating in the OKR, of which 82 had hoisting equipment. Out of the total number of hoisting installations there were 20 skip installations (17 with automatic control) and 87 cage hoisting installations (4 with semi-automatic control). The number of underground mine locomotives amounted to 1062, whilst were 107209 mine cars (3806 were big-capacity cars). The average number of shearers in operation was 96 and coal ploughs 45; powered support units utilised in longwall operations was 6071 and hydraulic props 122193. In roadways, drifts and entries an average 53 roadheaders, 192 overhead loaders, 68 driving complexes and 32 ripping machines were operated (all data from the Statistical Yearbook of the OKD).

Naturally, numbers of plant were reduced as a result of the winding-up process. During 1997 61 shafts (56 with hoisting installation), 15 skip installations and 59 cage hoisting installations operated. The number of mine locomotives had been reduced to almost a half (525) and the number of mine cars almost to a quarter (27194). 659 belt conveyors were operated and the total length of installed overhead railways amounted to 363736 m in 1997. The average number of shearers operated was 29 and coal ploughs 13; powered support units averaged 3586 and hydraulic props 30755. In roadway workings on average 39 roadheaders, 29 overhead loaders, 20 driving complexes and 22 ripping machines were operated (all data from the Statistical Yearbook of the OKD).

At end of the XXieth century there is now full mechanisation of the coal winning process, particularly after the termination of mining activity in the Ostrava part of the coalfield in which non-mechanised longwall faces had survived, in particular for the mining of inclined and steep coal seams. Although coal output from inclined and steep coal seams had no substantial impact on overall coal production, its termination resulted in an increase in the proportion of mining with powered supports and the concentration of fully mechanised mining in the Karviná part of the OKR.

The concept of coal preparation was formulated at the onset of 20th century. Due to the large number of mine owners no rational technological unification occurred. In particular coal preparation plants were of low capacity because they were attacked to small mines. Equally, further development after World War Two was accompanied by organisational scattering – preparation plants belonged organisationally to mines, but their technological development was not attractive to manufactures (Vítkovice Steel Factory) due to the low frequency of deliveries and the non-centralised nature of individual units. Retardation of technology was demonstrated especially in the high production of coal slurries, by unclosed slurry circulation and by the discharge of slurries to slurry settling tanks (Kučera, 2002).

In the OKR 14 coal preparation plants operated in 1991 with more than 70 settling ponds at different stages of filling-up, recovery, sedimentation, reclaiming etc. Their capacities, according to their type, were:

- cyclic settling tanks for raw slurries: total volumetric capacity 989000 m^3;
- big capacity tanks for raw slurries 1939000 m^3;
- big capacity tanks for mixture of flotation waste and raw slurries: 20415000 m^3;
- tanks for flotation waste without redepositing: 2497500 m^3;
- final sedimentation tanks: 3143 m^3.

The total capacity of slurry settling tanks in the OKR (excluding ČSM Colliery owned by ČMD, a.s.) amounted to 31046000 m^3 in 1991(all data from the Statistical Yearbook of the OKD).

2. Production of materials

2.1. Coal

It is impossible to assess accurately the total quantity of coal produced from the OKR between 1782 and 1945. Such data as exist are available in Dopita et al. (in print). During the early years an increase in coal output due to expansion of the Vítkovice ironworks in Ostrava (built in 1829) is evident (coal production increased from approximately 6000 tonnes in 1822 to 16000 tonnes in 1832). Also relevant is the construction of the railways - the first part of the Northern Railway was completed in 1847 (coal output increased from 60000 tonnes in 1842 to 168000 tonnes in 1852) and the Main Railway started operations in December 1862 (coal output of 610000 tonnes coal in December 1862 reached 1200000 tonnes in 1872) – (Anon. 1928).

During the following period total coal production of the coalfield was ever increasing. At the beginning of the 20th century it reached 6 million tonnes annually and in 1930 it exceeded 10 million tonnes. The impact of the thirties crisis is demonstrated by a drop in coal production to less than 8 million tonnes in 1935. In contrast coal production from the coalfield during World War Two rose to more than 20 million tonnes in 1943. Such a level was achieved again as late as 1959. The biggest volume of coal produced was reached in 1977 in 24.6 million tonnes. – Fig.1. (all data from the Statistical Yearbook of the OKD).

The total hard coal output of the OKR from 1782 to 2000 can be estimated as amounting to some 1.6 billion tonnes.

2.2. Waste rock

The quantity of waste rock extracted between the start of coal mining in the OKR and 1900 can be estimated only approximately. Based on the assumption that mostly manual winning of coal took place prior to World War Two the quantity of extracted waste rock represented about 20% of coal output, that is 12 million tonnes up 1900 and between 1901 and 1946 92 million tonnes. The output of extracted waste rock in the OKR has been monitored since 1973. For earlier periods an approximation was made by means of the data from run-of-mine coal output, volumes of driven development workings, and of waste rock quantities resulting from investment construction activities (if such indices were available). For the period from 1947 until 2001 the total waste rock output can be estimated as amounting to 2 545 million tonnes. During the whole life of the coalfield almost 0.65 billion tonnes of waste rock was extracted. About 65% of this waste rock was used by the building industry, in the reclamation of surface ground or as filling of gobs; the rest has been deposited in pit heaps (Fig.2).

2.3 Pumped water

Obtaining reliable data on the quantity of water, which has flown into mines or was pumped out by them during the life of the coal field is a very problematic task, even for the more recent period when such data formed part of the statistics of the OKR. Apart from natural sources of water (such as the Quaternary, Lower Baden, aquifers on the boundary of Carboniferous and overburden formations, and Carboniferous) a considerable quantity of

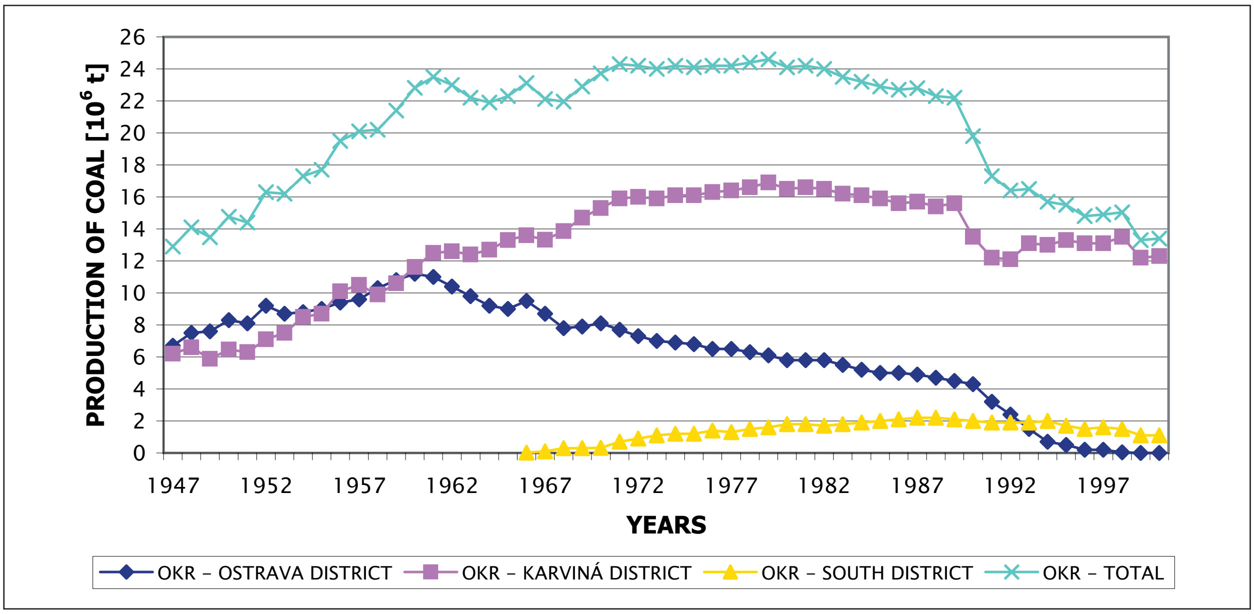

Figure 1. Total annual coal output from the OKR (1947-2000).

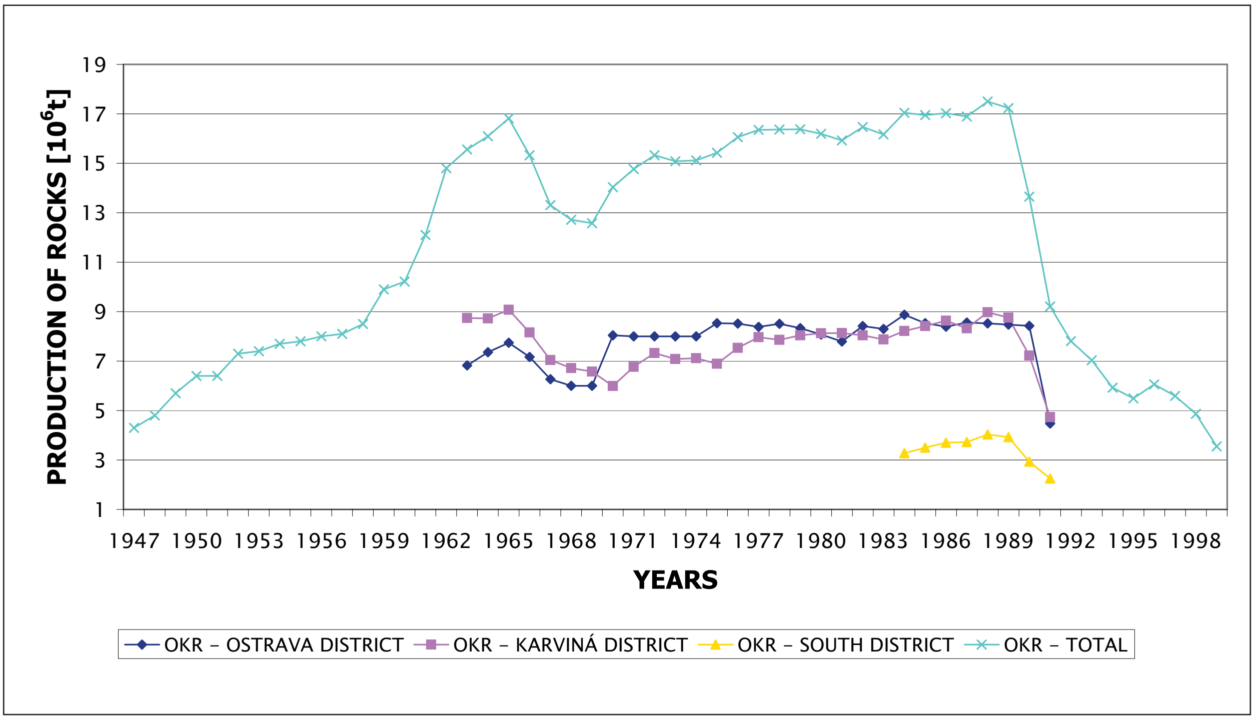

Figure 2. Quantities of extracted waste rock from the OKR (1947- 1999).

industrial water (needed for drilling, wetting etc.) was supplied to mines. A large part of the water was carried away as steam by mine ventilation air. Data about inflows from particular sources according to hydrogeological results are available to a lesser extent, but in reports mostly pumped-to-surface water statistics, appears. This was determined predominantly by means of output from mine pumps. Measurement of water inflows was made twice a year, once in the time of the biggest water inflows, from which an average value was calculated. Data from water management and data from hydrogeologists are frequently different and it is not always evident from older documents, which has been used.

A water yield coefficient was also calculated and this is the ratio between pumped-out water (m^3 per year) and extracted coal (t). With the exception of start-up and wind-up periods of mining there is a certain ratio between pumped water quantity and quantity of coal extracted which is different at each mine, depending upon local hydrogeological conditions and the technology utilised. This coefficient was applied for estimating the total amount of mine water pumped out. This amounted to nearly 2000 million m^3 during the period 1900-2000. According to Dopita et al. (1997) during the total period of mining activity almost 3 km^3 of saline mine water was pumped out.

The total weight of substances withdrawn from lithosphere, i.e. coal, waste rock and mine water, during hard coal mining between 1782-2000 amounted to approximately 4.25 billion tonnes.

2.4. Methane and mine gases

Methane of coal seams has continuously degasified from subsurface parts of the Carboniferous throughout geological history (290-300 million years). Only during the last 15-12 million years was the Carboniferous covered and insulated by West Carpathian nappes and sediments of the Outer Carpathian foredeep as well as by the Quaternary sediments. The distribution of methane in the Carboniferous massif depends on the morphology of the palaeotopography of the Carboniferous massif, on coalification, and on the faulting of coal seams. It is zoned and very irregular due to the complicated tectonic structure and weathering of the crust.

Even at the beginning of mining activity in the OKR methane emissions were dangerous in view of the explosion risk of a methane-air mixture. Alongside intensive exhaust systems for mine ventilation controlled gas drainage of coal seams has been introduced since the end of the 1950´s, aimed at the utilisation of methane. Methane concentration in upcast mine air was monitored and recorded in statistics of the OKD reports as „absolute CH_4 emission“ in thousand m^3 methane per day. Together with the quantity of recovered gas from gas drainage this gave a total gas yield of active underground mines.

Between 1965 and 1997 the total quantity of withdrawn methane, both by mine air and controlled extraction (gas drainage), amounted to more than 20 815 million m^3 – Fig.3 (all data from the Statistical Yearbook of the OKD).

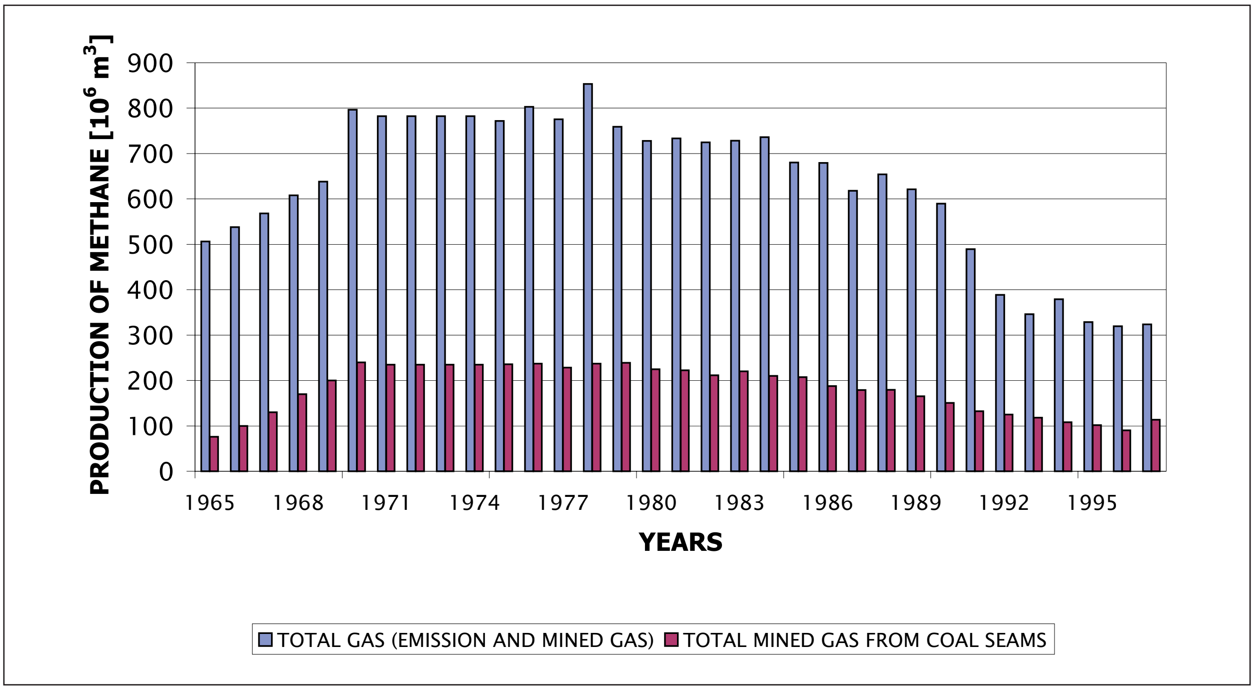

Figure 3. Gas yield and quantity of recovered methane in the OKR (1965-1997).

3. Effects of closure

3.1. Influence of mining on surface level

During mining over a period of two hundred years subsidence of the ground surface has occurred. At sites of historical mining situated near outcrops conical depressions, so called pinks, are evident even nowadays. In areas with from 200 to 1200 m underground mining deformations of the surface are continuous and proceed with a workings months to tens delay of years. The overburden is formed in most territories by Lower Baden strata (mudstones, siltstones) and by West Carpathian nappes with relatively plastic rocks. The structure and thickness of the overburden of the Carboniferous affects both the dynamics and nature of subsidence. The intensity of subsidence is different across the OKR, and is also influenced by the total thickness of extracted seams. The least subsidence occurs in the Ostrava part of the coalfield (max. about 1.5-2 m) where thin coal seams (up to 120 cm thick) were extracted or there are thick zones without coal seams. The biggest subsidence effects (approximately 15-20 m deep, max. 50 m) can be observed in the Karviná part of the coalfield where coal seams approximately 4 m thick with thick sandstone bodies were extracted (see Fig.4). In the Karviná area development of a specific landscape morphology occurred. On the one hand surface depressions arise (undrained or less frequently with natural draining; sometimes used as slurry settling ponds): whilst on the other hand new distinct elevations arise in places (where protective shaft pillars were located with their highest parts at the original above-sea elevation of the terrain). The original morphology of a glacial plain is thus newly reorganised due the to pronounced anthropogenic influence (inverse relief, see Figs. 5, 6, 7). In the Ostrava and Petřvald areas of the OKR subsidence effects are almost completed and a gradual reverberation of subsidence effects is anticipated in future decades.

In view of the density of population in the area of interest (mine shafts of the Ostrava part of the coalfield were located within the town area) considerable damage to buildings, civil engineering networks, roads and railways occurred due to subsidence effects. About 300 km of water streams were damaged and artificial interventions to restore their courses were necessary.

3.2. Change of hydrogeological regime

In the Ostrava part of the coalfield all underground coal mines were closed and vertical mine workings were filled and pumping of mine water terminated. The dynamic equilibrium between inflow and pumped water, which had developed during mining, was disturbed due to the cessation of mine water pumping. Having reached piezometric levels of individual aquifers inflows from them were closed. However, inflows of Quaternary water into previously unfilled mine workings, in places where Carboniferous reaches the surface, cannot be stopped by any technological measure. It can be anticipated that due to termination of mine water pumping from closed

Figure 4. East part of the Ostrava - Karviná coal field (2002; photo O. Mikulík). Recently a surface depression has been reclaimed by infilling with waste carboniferous rock. Beyond, elevated land around ČSM mine is formed on the protective pillar around the shaft. On the horizon is the range of the Beskydy Mts.

Figure 5. East part of Ostrava - Karviná coal field, Orlová town (2002; photo O. Mikulík). Church of St. Peter from Alcantary tilt towards road on account of the subsidence on the slope of protective pillar of Mine Doubrava.

Figure 6. East part of Ostrava - Karviná coal field (2002; photo O. Mikulík). The main railway corridor from Ostrava (Czech Republic) to Žilina (Slovakia) crossing a large subsidence depression north of ČSM mine. This railway line is periodically renovated . Behind the railway line is a flooded subsidence depression.

Figure 7. East part of Ostrava - Karviná coal field (2002; photo O. Mikulík). Typical view of landscape influenced by coal mining with flooding of large subsidence depressions and destruction of road (in front). Over large areas waste carboniferous rocks have been used as reclamation material for filling the depressions.

collieries mine water will be stratified according to water composition and thus quality of pumped mine water will be improved by the gradual sweetening of mine water.

It is necessary to protect active mines in the Karviná part of the coalfield against undesirable water inflows. Since these are connected by means of abandoned workings with the closed Fučík Mine and with other closed mines in the Ostrava part of the OKR, pumping in the Ostrava part of the coalfield has not been stopped altogether.

Centralised mine water pumping continues at the Jeremenko Mine in Ostrava at an elevation of – 388 m. This mine water pumping was started in August 2001 and by November of the same year output of monthly 365000 m^3 achieved. It is roughly half of the desired monthly pumping volume. Regulation of mine water discharge into the Ostravice river was dawn up according to flowrates and composition of mine water (Michálek & Tabášek, 2002).

Where subsidence below local ground water level has occurred due to undermining, flooding of the subsidence depression or soaking of the soil profile (usually in adjacent ground of river or brook) occurs.

3.3. Methane emissions

During the period of mine closure, especially in the Ostrava part of the coalfield after 1990, gas extraction fell and in the OKR as a whole dropped to approximately 100 million m^3 per year. Absolute gas emission in mine ventilation air amounted, for instance in 1994 to 271 million m^3 and in 1997 to 210 million m^3. An immediate consequence of the closure of mines and the termination of mine ventilation and water pumping (rising water fills out cavities in rock and forces out gas) was the uncontrollable surface emission of methane. Emissions of methane to the ground surface and to buildings in the Ostrava area occurred as long as three years after the closure of mines. Due to penetration of methane into premises and to the development of methane-air mixture, gas explosions took place within buildings with serious or fatal injuries to people.

To locate surface methane emissions a surface atmogeochemical survey was carried out. Furthermore, shafts of abandoned mines have been filled and monitoring of the composition of mine gases emitted from the shafts has been performed. Safety zones around such shafts have been defined and measures for capturing the methane emissions in their vicinity have implemented. Old abandoned underground roadways and shallow mine shafts have been located and their ventilation safeguarded. For the OKR a map of potential methane emission risk has published. Research and modelling of methane emissions is currently being conducted.

3.4. Pit heaps and settling ponds

The influence of pit heaps on the environment can be assessed from various points of view. By the filling of depressions or the creation of new elevations – mine waste heaps - the morphology of the terrain is transformed. In many cases they dominate the industrial mining landscape. Waste rocks deposited in pit heaps are unstable in open air climatic conditions and they disintegrate. From a petrologic point of view sandstones and conglomerates exceed siltstones and mudstones. Equally a proportion of coal is also present (up to 10 - 15% depending on the date of coal production) especially from flotation waste. The grain size of waste rocks in pit heaps is very variable. From the point of view of their effect on the environment it is necessary to distinguish the following:

- pollution of the atmosphere due to low-temperature oxidation of coal and coal bearing substances dispersed in rocks which leads to the burning of pit heaps. During combustion of the waste materials in pit heaps thermal destruction of sandstones, mudstones and siltstones proceeds. Burning of the coal is accompanied by the release and propagation of carbon, sulphur and nitrogen oxides, of tar substances, of dust and aerosols into the atmosphere;
- contamination of the surface or ground water by leaching from pit heaps comprising in particular sulphates of pyrite; composition of the leachate depends on the degree of disintegration of rock structure, on porosity and on primary mineralogical structure of rocks.

As the penetration of leached substances may last decades or even hundreds of years, it cannot be anticipated that the effect of mine waste heaps on the environment will be short-lived.

Mine waste rocks are utilised intensively (about 65% of all mine waste rocks) by the building industry (embankments, dams) and for filling of large subsidence depressions for agricultural or forestry reclaiming.

3.5. Induced seismicity

While in the Ostrava and Petřvald parts of the OKR no mining induced seismicity occurred, except for some isolated events, in the Karviná part of the coalfield mining induced seismicity is an important factor. Annually, more than 30 000 seismic events are registered by the local seismic monitoring network of which there are 100-500 events with seismic energy exceeding 10^4 J (local magnitude greater than 1). Many such events have negligible seismic effect on the surface ground (see e.g. Kaláb & Knejzlík 2002). In the Ostrava and Petřvald parts of the OKR the probability of seismo-acoustic events after the closure of mines is very low.

4. Future utilisation of coal deposits

4.1. Coal bed methane

Between 1991 and 1998 a survey of coal bed methane (CBM) proceeded in the territory of the Czech part of the Upper Silesian Basin. Four licensees participated. Twenty surface boreholes were drilled. The aim of wast to collect coal samples in gas-tight containers and to determine the gas bearing capacity of coal seams. The quantified reserves of methane are approximately 70 to 370 billion m^3. Under favourable geological conditions, hydrofracturing (water with sand) was carried out in order to stimulate gas flow. However the quantities of gas extracted by hydrofracturing did not fulfil the requirements for commercial gas extraction and the boreholes have been conserved (Němec & Hemza, 1998). It was evident, that the quantity of gas held in coalbeds depends on degree of coalification, degree of faulting and on local palaeotopography of the Carboniferous massif. A further stage of explotation activity is being prepared.

4.2. Methane extracted from gobs of abandoned underground mines

A borehole survey, investigating methane held in gobs within abandoned mining fields of the Ostrava part of the OKR, indicated promising results (Němec & Hemza, 1998, Golicyn et al., 2002). For this reason the survey has been continued. The extraction of methane from gobs of closed underground mines could be a very positive measure in view of the reduction of surface methane emissions and complementing the existing system of safety measures.

5. Mining landscape as new biotopes

By creating a new relief on the landscape, characterised on the one hand by subsidence depressions with new lakes and new waste heap bodies, and on the other hand by the depopulation and afforestation of previously settled landscape and by changes in streams and water reservoirs, quite new opportunities have been created for biological expansion (both of previously suppressed animal and plant species or of new species). The landscape ranks in the Czech Republic nowadays among those with the greatest number of plant and animal species. Equally it has a potential for creating new protected natural territories (birth protection area "Heřmanice Pond") or national reservations (Landek Hill in Ostrava).

6. Conclusion

By examining the balance of substances extracted from underground mines in the OKR from 1782 to the present day the extensive utilisation of the landscape has been documented. It provides equally a general framework of data for further considerations connected with the wind-up of the underground mining industry and with the cultivation of mining influenced landscape (Martinec et al., 2003). Further activities following mine closure will be aimed at the prevention of surface methane emissions, regulation in water level in aquifers tied to mining, and the revitalisation of abandoned areas, so called brownfields. New technology could permit the extraction of methane from gobs of closed mines or eventually the extraction of coalbed methane.

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