HYDROGEOLOGICAL PROBLEMS CONNECTED WITH CLOSURE OF UNDERGROUND COAL MINES

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ABSTRACT

The method of analysis of the impact of mine closure upon the water environment has been presented. This impact will depend on whether the workings will be completely flooded or only up to the level of connection with a neighbour mine. The way of approach to the problem of water hazard to neighbour mines, being an effect of mine flooding, has been discussed. The way to calculate the predicted time of flooding mine workings has been given and the original computer simulation program has been presented. The expected effect of mine flooding upon water conditions on the ground surface and in the near surface occuring water-bearing strata has been discussed, as well as the way of forecasting the ground surface inundation resulting of mine flooding. The range of monitoring the changes in hydrogeological conditions resulting of mine closure has been presented.

INTRODUCTION

The scope of problems connected with mine closure is very vast and comprises such topics like: correct reserves management, limitation of natural hazards and appropriate technical undertakings. Among all processes that may be initiated in the region of a mine under closing very important are changes of water flow conditions in the rock mass and on the land surface. Stoppage the draining pumps in a mine causes flooding up the workings with water inflowing from the surrounding rocks. The water level in workings stabilizes in dependence on the geological structure as well as the hydrogeological and mining conditions.

Till now the research works concerning the influence of a mine closing on changes of underground water flow conditions and water quality are very scarce. The sporadically occuring problems of a water hazard connected with mine closing have been solved on a base of individual reports. Since 1991 at the Central Mining Institute in Katowice the systematic research has been carried on the hydrogeological problems connected with mine closing, taking into consideration the up to date experiences in that domain.

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The hydrogeological problems connected with mine closing has an important practical meaning for the sake of the occuring thereby water hazard to the active mine workings, especially in the adjacent mines, and, in some cases, for the ground surface and thereon situated objects. Important is also influence of mine closing on the existing within the mine water intakes, that can be destroyed by contamination of the drinking water with highly mineralized mine water.

The closure of particular mines may cause the changes of hydrogeological conditions on large areas and especially occurence of the uncontrolled water flow from the mine under closing to the adjacent mines, creating the water hazard for these mines. Therefore, before stopping the pumps in a mine, the analysis of consequences of ceasing the water pumping should be carried out. Such analysis should take into consideration the problem of water hazard for adjacent mines, as well as the impact of mine flooding on the environment and water management.

In the framework of the water hazard's evaluation there are to be determined:

1/ the forecasted water level in the workings, based on the analysis of hydraulic connections with adjacent mines and possibilities of water flow in workings and fissure zones,

2/ the forecasted course of flooding up the workings in time, based on the calculated capacity of workings and drained rock mass as well as on the actual and forecasted rate of water flow into the mine,

3/ possibilities of water hazard for the adjacent mine, based on the analysis of tightness and strength of border pillars, probable paths of water flow, conditions of creating the uncontrolled water reservoirs in goaf, as well as on the analysis of forecasted rate of water inflow from the mine under closing, taking into account the capacity of draining system reserve in the adjacent mine.

In the framework of evaluation the impact of a flooded mine on environment, the following should be determined:

1/ predicted mineralization and chemical composition of water accumulated in goaf of flooded mine and of water flowing from that mine to the adjacent one,

2/ predicted impact of mine flooding on existing water intakes and evaluation of the possible changes of water management in the region of flooded mine,

3/ predicted impact of mine flooding on the water conditions in strata occuring close to the land surface and on the surface,

4/ ways of filling shafts to close the hydraulic connections between water-bearing strata containing chemically different waters.

HYDRAULIC CONNECTIONS BETWEEN MINE WORKINGS AND MAXIMUM LEVEL OF WATER RISING IN GOAF

For the correct evaluation of the course of flooding up the mine, substantial meaning has the distinction between separate mines and groups of mines.

The separate mines are the ones having one drainage system and no connections with another mines. The group of mines composes of parts of a mine independently drained and/or of mines connected between them by the controlled or/end uncontrolled flow paths.

To evaluate the water hazard for mines adjacent to the mine being flooded and to elaborate the forecast of the course of flooding the group of mines, the identification of all connections between the flooded mine and the adjacent mines is necessary, as well as the determination of the datum of lowest connection. Thereby the possibility of occurence of uncontrolled paths of water flow between mines has to be taken into consideration.

Substantial may be here zones of weakening of border pillars. Most important factors influencing the strength of a border pillar are mine workings, that locally may cause decreasing of its width. Thereby the possibility of some error of map projection of workings allways has to be taken into consideration, chiefly caused by independent mapping of flooded and adjacent mines. Sometimes may occur cases of workings not marked on mine maps.

The weakening of a border pillar may be also caused by fracturation of rocks induced by mining and by tectonik deformations, especially in the case of differently situated mine borders in different coal seams. The fault fissures thought to be closed may open under influence of a great hydraulic gradient caused by the water level rise in flooded mine. The many years lasting exploitation of coal seams in the Upper Silesian Coal Basin has damaged in majority of mines the border pillars, which therefore have lost their initial strength and isolation properties.

The strength of border pillars may be evaluated with help of the formulas used to calculate the dimentions of safety pillars between underground water bodies and mine workings, but also the additional factors have to been taken into consideration, that could reduce their strength or tightness. The width of a border pillar should be checked for the water pressure in flooded mine on the level of working being protected with the pillar.

Stoppage of the mine drainage in a separated mine causes flooding the mine workings with water inflowing from the surrounding rock mass. The water table gradually rises till the hydrodynamical balance with water-bearing strata in surrounding formations is achieved. Theoretically the water table in goaf should stabilize on the level of static water table in the Carboniferous water-bearing horizon.

If the static water table stabilize close to the land surface, the inundation of the ground is possible and it needs the additional analysis.

Ceasing the mine drainage in a single mine within the group of mines causes flooding of mine workings till the level of lowest connection with an adjacent mine. Thereafter the water flowing into the flooded mine will flow over to the adjacent mine. If the pump station of the adjacent mine has the sufficient reserve of the drainage capacity and can pump out the additional water, the flooding process will finish and the water table in flooded mine will stay on the level of connection. In opposite case, the drainage of the adjacent mine will have to be switched off, the adjacent mine will be flooded too till the water level in its workings equals with the one in the first mine. Further on the both mines will be flooded simultaneously. Water will rise in the workings of both mines till the lowest connection with another adjacent mine and thereafter the process will repeat.

FORECAST OF THE COURSE OF MINE FLOODING

The evaluation of the time of flooding the particular mine levels needs the determination of goaf capacity, it is the common volume of all empty spaces in goaf that can be or are filled with free water. Owing to the partial compression of goaf by subsiding overlying layers, its water capacity is allways lower than the volume of extracted coal. It is calculated as the product of the volume of extracted coal and the coefficient of water capacity of goaf [1].

Whithin the depression cone induced by the mine workings, rocks are deprived of water. It concerns as well the pore spaces, from which water has been filtered off, as the fissures and layers separation in rocks occuring above the caving zones. Evaluation of the water capacity of rocks is generally difficult. Usually it is determined basing on the general hydrogeological reconnaissance of the region. In the rock mass with predominance of sandstones, the water capacity of rocks may be much higher than the one of goaf itself.

The capacity of mine workings and of surrounding rocks is calculated in some depth intervals, which are usually determined by the particular mine levels and the levels of connections with adjacent mines. Constant depth intervals, for instance every 50 or 100 m, may be also accepted.

To predict the course and dynamics of the process of flooding the mine workings, apart from the analysis of workings geometry and their capacity, elaboration of the water inflow characteristics of the mine is indispensable. The characteristics should contain informations of the disposition of water inflows in the workings, location of the concentrated inflows and their rates, as well as the determination of total inflow rates to particular mine levels or mine parts. Moreover the rates of water flow to pumping stations in separated drainage systems should be given. The characteristics should also contain informations on the location and capacity of actually existing water reservoirs in goaf and on the chemical composition of mine water.

Owing to the complicated configuration of mine workings and complex hydrogeological cinditions of the drained rock mass, the construction of an accurate numeric model, that would allow the exact prediction of the changes of inflow rates in the course of flooding the mine, would be very labour-consuming and often quite unfeasible. For the practical evaluation of these changes some simplifications are necessary. There is accepted usually the simplified calculation scheme based on the following assumptions:

1. when the flooding of a mine progresses, the water table rises in the mine workings,
2. in the every phase of flooding, the rates of water inflows situated above the water level stay unchaged, while the rates of water inflows situated below the water level decrease proportionally to the decreasing of the depression caused by workings in the alimenting water-bearing horizon,
3. all water inflows to the mine origin from the confined horizons, belonging to the Carboniferous water-bearing system and their static water table stabilize on the same hight.

The time of flooding the mine workings is the quotient of their capacity by the inflow rate. Owing to the complicated geometry of mine workings, irregular lay-out of mine workings in vertical profile and differenciated rates of water inflows, being function of the depth of water table, the calculation of flooding time is usually burdened with some error. To decrease this error, the capacities of workings and times of their flooding are calculated in the specified depth intervals, for which the average water inflow rates are determined.

In the Central Mining Institute the special computer program has been elaborated [2] that enables the construction of a group of interconnected mines. Such model enable the simulation of the timing of flooding the group of mines starting by ceasing drainage in an optional mine of the group.Thereby the flow rates between particular mines are calculated.

The flooding of a mine can be disturbed if in the workings occur closed water dams or other tight stoppings. Such dams or stoppings have definite strength to the water pressure in the dammed space. When the mine workings become flooded, the water pressure on one side of a dam may exceed its strength causing its damage and unpredicted sudden water flow. Therefore, before closing the mine, the free flow of water across dams and stoppings of all kinds should be ensured.

WATER HAZARD FOR ADJACENT MINES

In the conditions of very complicated net of mine workings, layd-out on various levels and in various coal seams, and in the rock mass heterogeneous and disturbed with tectonic and mining deformations, the uncontrolled water flow from a flooded mine to lower situated workings of an

adjacent mine is allways possible. Such possibility concerns the majority of mines in the Upper Silesian Coal Basin and especially the mines situated in the northern part of the Basin. The flooding of some of these mines will cause the flooding of adjacent mines, despite existing therein the efficient drainage system. This results from the difference of inflow rates and the reserves of pumping capacities in both mines. This problem needs every times the detailed analysis of the flow paths and rates of flow from the flooded mine to the adjacent one.

The analysis of water migration paths in mine workings should also take into consideration the possibility of forming the uncontrolled water reservoirs in goaf. Such reservoirs, of unknown range, may endanger the active mine workings. There is to be emphasized that in the mining practice the most dangerous for human life are water inrushes from unidentified flooded workings.

Taking into consideration the anticipated rate of water inflow from the flooded mine, the existing reserve of the drainage system as well as the location of workings and pump stations should be analysed. It is especially substantial in mines having lower water inflow than the adjacent mine. Such mines have usually small reserves of pumping capacities, adequate to their natural inflow rates, therefore in the case of important additional inflow from an adjacent mine, such mine can become flooded too.

PREDICTION THE ENVIRONMENTAL IMPACT OF FLOODING A MINE

Rate of water inflow to a mine after its flooding will depend on the hight, on which the water level in mine workings will stabilize. In the case of separate mine, in which the water table will stabilize on the average hight of piezometric level of the Carboniferous water-bearing horizon, the water inflow will disappear. The water in mine workings will be in hydrodynamic balance with underground water in the Carboniferous water-bearing strata. In the case of existing hydraulic connections with water-bearing strata in the overburden of Carboniferous measures, the water table in mine may stabilize on the intermediate level, being the resultant of water pressures in the Carboniferous and overburden formations. In the mine workings and their surrounding a new hydrodynamic equilibrium system will be formed.

In the case of a group of mines, the water table will stabilize on the hight of the lowest connection with an adjacent mine and the water inflow will be function of this hight.

The mineralization of water inflowing to mine workings and its chemical composition will be resultants of water inflows to the mine by the given position of water table in the mine workings. The prediction of the mineralization and contain of particular ions may be determined approximatively as the weighted means of the values of these parameters determined for particular inflows. The weights should be the predicted inflow rates.

The partial flooding of a mine up to the level of the lowest connection with an adjacent mine won't cause any substantial decreasing of the range of depression cone of the closed mine. Within reach of the draining influence of the mine will continue the mixing of waters flowing from different hydrochemical zones. In dependence on the adopted solutions of water management in the flooded mine, the water appropriate to economic utilization may be further pumped out of the workings that have not been flooded. In other case, the mixed water will flow to the adjacent mine and only below the connection level in the flooded workings will appear conditions to form the natural hydrochemical stratification of water.

After the total flooding of the closed mine the average mineralization of water in the workings will be first lower than in the surrounding rocks, especially on the deep mine levels. With time the mineralization of water in mine workings will differentiate. On the deep levels it will increase and

on shallow ones - decrease. The changes of the mineralization will tend to its differentiation with depth according to the natural hydrochemical gradient in the region.

Within time the water stagnating in flooded workings will enrich with sulphates and dissolved hydrogen sulfide. This process is caused by dissolving the products of pirite oxidation and timber decaying. Possible is also an increase of iron content as well as a bacterial pollution of the water.

The shafts of closed mine should be filled with rock material. From the point of view of water hazard the kind of filling material has no meaning, however it can't be waste material harmful for the environment. The design of mine closure should foresee the installation of piezometric tubes in some shafts for monitoring the process of flooding the workings. The shafts choosen to install the piezometer tubes should be therefore filled on distinct intervals with permeable material.

The material filling the shafts may with time consolidate and subside, therefore its replenishment may be necessary. All filled shafts should be marked fast in the terrain and they should be temporary surveyed.

The total flooding of a mine causes the rising of water table to the hight close to the initial hydrostatic level in the ground. The effects of changes of the water flow patterns in the river basin will be in such case differentiated, depending on the kind of hydraulic connections of the phreatic waters with the water-bearing strata that formerly have been drained by the mine workings. These connections may have following forms:

- the phreatic horizon is completly isolated from the water-bearing horizons drained by mine workings,
- the phreatic and Carboniferous waters form the common water-bearing horizon,
- the contacts of phreatic waters with Carboniferous ones are limited to the faulting zones, dwindling of the isolating layer and other similar structures.

In the first case the the hight of the piezometric level, that would stabilize after flooding the mine, won't have any influence on the water conditions in phreatic horizon and on the surface. Possible are only water outflows from outlets of some workings like shafts, drifts or bore-holes if they are not correctly sealed.

In the second case, in the subsidence troughs water may appear on the surface. Such phenomenon took place in the region of some old mines in the Silesian Basin, where coal seams have been exploited up to their outcrops and the mines have drained Quaternary deposits. After flooding the mines the local land inundations appeared in some parts of the terrain, where some subsidence occured due to the mining. The land inundations have been then liquidated by means of land drainage.

In the third case, the former zones of drainage of the phreatic water may become zones of its alimentation.

The predicted influence of the planned closure of a mine may be evaluated on the base of following analysis:

- analysis of changes of the hydrostatic level and the forecast of stabilized water level in Carboniferous formation after flooding the mine,
- analysis of the total subsidences of earth surface and changes of its morphology due to the mining,
- analysis of changes of the outflow conditions and water retention in the river basin.

The total subsidence of the land surface in the regions, where mining has been carried out often since the last century, usually may be determined only approximatively. Especially important is

determination of subsidence values in the zones of alimentation and drainage of Carboniferous water as well as in the zones of alimentation and drainage of phreatic water in the surface river basin.

The analysis of changes of water outflow and retention conditions in the river basin should enable to point out the areas, where water table will rise, the range of areas endangered with flooding and moreover to determine the ways of disposing the increased quantity of water from the river basin.

MONITORING

The course and dynamics of the process of mine flooding should be monitored to verify the forecast and introduce eventual corrects. The minitoring should comprise:

- observations of water level depth in all stages of mine flooding,
- observations of the water table changes in water-bearing strata within the depression cone,
- observations of water quality in mine workings,
- observations of water quality in the intakes of underground water,
- observations of surface water outflow and its quality (in the case of total flooding of the mine)

In the first stage the measurements and water sampling may be effectuated in mine workings, but for further monitoring the piezometric tubes should be installed in some shafts or bore-holes.

In the mines adjacent to the flooded one, the rate of water flow in workings should be monitored, especially in the regions of stated or suspected hydraulic connections with the flooded mine. Such monitoring should be started before the mine closure to enable subsequently determining of the rate of water flowing from the flooded mine. The changes of this flow rate may prove the formation of uncontrolled water reservoirs in the mine.

The water flowing from the closed mine to the adjacent one should be tested with regard to its chemical composition. The inflow of important quantity of water of different mineralization may disturb the actual way of water selection and management in the mine adjacent to the flooded one.

The above mantioned monitoring should be carried on during the process of flooding the closed mine. When the process is terminated, the range and frequency of observations and sampling should be determined by the mining geological survey adequately to the mining needs and regulations concerning the hydrogeological reporting and fighting the water hazard in the underground coal mines.

SUMMARY

As an effect of closure a mine and ceasing its drainage the mine workings are flooded with waters inflowing from the surrounding rock mass. The mineralization and chemical composition of the inflowing waters depend on the hydrochemical characteristics of drained water-bearing horizons. During the mine flooding inflowing waters will be mixed and when the hydrochemical equilibrium will be acieved the water stratification will be formed according to the regional hydrochemical profile.

The water level in the closed mine depends on whether occur hydraulic connections with adjacent mines or not. In the separated mine the water level will stabilize on the hight of free water table in the surrounding rocks. In the mine that has connections with other mines the water in workings will

rise till the lowest connection level is achievedand then the gravitational flow to the workings of neighbour mine will occure.

The majority of coal mines in the Upper Silesian Coal Basin are connected between them. For the safety of active mines adjacent to closed ones it is necessery to maintain the pumping of water in the mines after their closure. Therefore the mine closures planned for the nearest years won't cause any substantial decreasing of mine water disposed into rivers.

Before starting the mine closure the hydrogeological report should be elaborated to determine the consequences of stoppage the mine drainage under the aspects of water hazard for adjacent mines and its influence on the environment, water intakes and so on.

In the region of closed mine and in adjacent mines the monitoring of the process of mine flooding and its influence on the environment should be carried on. In the case of the total flooding the mine and rising the water table to the level of phreatic water, the monitoring should comprise observations of the water table oscillations and rates of ground and surface waters flow in properly designed points.

REFERENCES

1. Rogoż M., 1978 - Water capacity of abandoned workings in underground coal mines. Proc. Int. Conf. „Water in Mining and Underground Works". SIAMOS, Granada (Hiszpania). @ zawkop
2. Rogoż M., 1994 - Computer simulation of the process of flooding up a group of mines. Proc. 5th International Mine Water Congress, Nottingham (U.K.). @ prokom, likop