PROBLEMS OF OFFICIAL REGULATION RELATED TO MINE WATER CONTROL IN HUNGARY

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SUMMARY

Due to hydrogeological conditions, one of the most difficult problems of mining in Hungary is the water hazard. Its prevention and control poses tasks not only for mining companies but also for official regulation. The control system as designed in the planning period is developed during the construction and operation of the mine. This practice has been followed in the majority of water control systems of existing mines and the related experiences reflect the degree of knowing natural conditions and of the protection of man and production equipment. Applicability of control methods is governed by two factors: economics and environment. The mining supervisory board has a complex task in the prevention and control of mining hazards, including the regulation of health protection, labour protection, engineering safety, environmental protection, general social and legal requirements. During the last 20 years the board has endeavoured to fulfill the above tasks in a full degree.

HYDROGEOLOGICAL CONDITIONS OF HUNGARIAN MINING

It is well known among Hungarian mining experts that one of the greatest problems in Hungarian mining is the water hazard due to adverse hydrogeological conditions. These conditions can be indicated by various numbers such as the flow of pumped mine water, the specific flow of pumped mine-water as related to production, inrush flow into workings, number of floodings. These numbers reflect both natural conditions and the efficiency of control actions. 80 % of coal production, 95 % of bauxite production and almost the total ore production - except uranium mining - coincide with water hazard. This situation will not change in the future, moreover it is expected that even more adverse natural conditions will be faced as a result of increasing raw-material shortages. Consequently, water related cost may be as high as 5-30 % of total cost.

Table 1. shows observed past and expected 1985 year amount of pumped minewater originating from karstic, porous media and fissured aquifers. Table 1. indicates that the greatest amount is being pumped from karstic and porous-media aquifers, while water hazard from fissured rocks, abandoned mines and surface waters is of less importance.

Between 1960 and 1975 the flow of pumped mine water increased from 275 m/min to 770 m/min and is expected to be 825 m/min by 1985. According to its origin, withdrawal from karst increased about four times, from porous aquifers about twofold and from fissured rocks about 15 times. This considerable increase can be explained by the combined effects of the following factors:

- large-scale application of more efficient control methods;
- mining in greater depths;
- mining under more adverse hydrogeological conditions.

In 1960, the overwhelming part of pumped minewater stemmed from roadways and faces, but after ten years, 46 % of the total water was drained in drillings, water shafts and tunnels separated from workings. This ratio is expected to increase to 81 % by 1985 as a result of the planned water control measures. This increase of sperated water ratio can mostly be expected in karstic and porous-media aquifers.

In ore mines under water hazard from fissured aquifers, no considerable change can be reckoned with since neither safety nor economic considerations do not call for more effective control methods.

During the last 20 years, the application of more effective control methods has resulted in a major decrease in mine water hazard. The observed reduction of the ratio of "wet" mines demonstrates that the water hazard can be decreased even in case of more adverse natural conditions by preventive control methods.

EFFICIENCY OF MINE WATER CONTROL

Control of mines against water hazard commences with the exploration of hydrogeological conditions. This activity includes the estimation of the degree of water hazard, and the preliminary analysis of the following control options:

a./ preventive control by
   - water table lowering
   - grouting and other methods

b./ subsequent /passive/ control or

c./ combined /passive-preventive/ control.

The control system as designed in the planning period is developed during the construction and operation of the mine. This parctice has been followed in the majority of water control systems of existing mines and the related experiences reflect the degree of knowing natural conditions and of the protection of man and production equipment.

The application of more effective methods of mine water control in Hungary started at the end of the fifties or the beginning of the sixties, the period when mechanized mining was spreading in larger scale. Earlier, passive-preventive methods such as the utilization of the protective layer and proper mining sequence had been mostly applied. Water table lowering and grouting had been hardly used and only locally.

Water became even a greater problem when the full mechanization of mining started since water hindered the operation of machines, decreased the efficiency of equipment and thus led to higher production costs.

To overcome these problems, first in underground bauxite mining then in open-cast coal mining large-scale dewatering activity was initiated. As a result of dewatering, working conditions improved, efficiency increased and production became safer and more economic.

The considerable achievement in the control of water from karstic and porous aquifers has been related to the increasing technological possibilities and new scientific results.

As contrast to the earlier situation when aquifer hydrodynamic conditions were not properly understood, in the last 10 years those relationships in porous and karstic aquifers have been clarified which are necessary for the design, construction and operation of advanced preventive mine water control.

Recent research results have offered more information than ever before on the protective layers explored by mining activity. Investigations have shown that it is not sufficient to characterize protection by the specific thickness of the protection layer. This number reflects only the packing effect in case of constant pierometric head. On the other hand, the sealing effect depends on the effective protection-layer thickness, while the resistance against erosion depends on material properties. It has also been revealed that the protection effect of these layers cannot be regarded as perfect. Present safety regulations refer to specific protection as the number governing mine inflow and conditions of water hazard. This principle and the resulting calculation method does not seem correct since it leads to either overdesign or underdesign.

In the Dorog coalfield 54 partial or total mine flooding events have occurred during the last 100 years. Observation data show that the underdesign of pumping stations and inproper sediment control have caused partial or total mine floodings. This was known in the past too, but the magnitude of design inflow was unknown.

Safety regulation in the sixties prescribed a minimum capacity of 20 m/min for pumping stations. The modified regulation in 1975 refers to a capacity of 80-120 m/min for the main pumping station of an average Dorog mine. This would protect the mine against inrushes of 60-80 m/min.

The repeated supervision of hydrogeological conditions has shown that mine water is sufficiently controlled in Dorog mines only if pumping station capacity reaches 160-180 m/min. No flooding would have occurred with such capacities.

The lack of proper knowledge of hydrogeological conditions caused a number of problems in the Transdanubian mining under karstic water hazard.

For sandy aquifers generally sufficient experiences and methods are available but the protection against quicksand inflows has not been satisfactorily solved.

The 1973 year Putnok quick-sand inflow event warns that this aspect should be further investigated in the future. Also, safety regulations should draw a greater attention to this topic.

Operational experiences of passive-preventive control demonstrate that the main pumping station should be located at the deepest point of the mine, where water can be conveyed gravitationally from any part of the mine. Presettlers should be constructed in water cuts and fine settlers with continuous sediment removal should be placed before the pumping station. In order to increase pumping safety, submergible pumps should be used instead of traditional centrifugal pumps.

Protection of faces will be developed if the conveyance system is already protected. Borings are effected in deeper coal seams under mining openings to be protected, or from face water cuts driven in the protective layer in order to perform preventive grouting or preceding drainage at lower level than the facing level.

If, in spite of preventive grouting, a water inrush occurs or the drained water flow in the instantan borings is higher than the permitted one, subsequent grouting, sealing or draining may be used.

The application of preventive grouting is possible mostly in karstic rocks of high conductivity. Instantan protection may be useful in rocks of lower conductivity where grouting is not straightforward.

A considerable technological achievement can be the Kipko-type clay-slurry grouting procedure applicable in karstic limestone and dolomite of smaller fractures as well.

During the last 15 years, most of the operational experiences have been gathered in karstic water table lowering. Now, Hungarian mining has all the necessary information and experiences for the planning of karstic water lowering operated with mining schedule in a coordinated way. This is examplified by the operation of the Nyirád, Rákhegy and Tatabánya systems.

There is passive control in Hungarian mines under fissure water hazard. Planning of passive control means the sizing of the conveyance system; a basic data thereof is the prediction of mine water flow.

The protection against water from abandoned mine openings requires the map of the mine since one can avoid or perform in a controlled way to tap this water. No such geophysical instruments are available at present by which these filled abandoned openings can be traced from the necessary distance. As a result, strict measures are necessary how to approach abandoned openings of unknown location.

The protection from surface waters requires information on flood levels and discharges which can be estimated from direct measurements. As a consequence, this type of hazard has caused problems during the last 17 years only in two cases: 1./ 1963, Ecsed open-pit mining, due to underdesign of the drainage system, 2./ 1974, Thorez open-pit mining due to management defects.

The applicability of control methods is constrained by two factors: economics and environment.

In ore mining under fissure water hazard passive control will be predominant in the future, too. Here, subsequent protection is the most economic, satisfying the necessary safety and causing minimal environmental disruption.

In mining of coal, bauxite and minerals under porous-media water hazard, environmental protection does not mean any constraint. Thus, the control method can be selected according to economics and safety.

No life-hazard is caused by gravitationally drainable sands, except those inclined to quick-sand flows. As a result, both subsequent and preceding control can be contemplated.

Naturally, passive protection worsens working conditions, it is harmful for health, decreases the amount and increases the cost of production.

Control of miningunder karstic water hazard, mostly in the Transdanubian Mountains, requires the consideration of both economic and environmental aspects.

Nyirád mines of the Bakony Mining Company apply large-scale water table lowering by withdrawing 300 m/min or 150-200 water/ton bauxite. As a result, "dry" mining is possible. There is an economic limit of the continuously increasing mining depth.

On the other hand, there is also an environmental limit connected to the safe yield of the neighbouring Hévíz thermal bath. If any of these limits are surpassed, other control methods must be sought, or in lack of these, mining should be stopped.

Such a dewatering activity in the Dorog coal field would be economic only if annual coal production were $10\text{-}12 \cdot 10^6$ tons at least, let alone the environmental constraint related to the safe yield of Budapest thermal baths.

In the Transdanubian Mountains, the amount of karstic water withdrawn reached and periodically even surpassed the amount of natural recharge. As a conseuqence, not only local but regional karstic water level sinking has occurred, endangering the safe operation of famous thermal baths in the region.

The same high social interest is attached to avoiding these disturbances as to preserve the safety of mining; consequently control methods with less withdrawal should come into prominence.

Short-range planning does not permit a comprehensive preventive control. All essential measures should be coordinated with mining production and environmental protection.

TASK AND AUTHORITY OF THE MINING SURVEILLANCE BOARD IN THE PREVENTION OF WATER HAZARD

The Mining Law /ML/ denotes the task authority and place of the mining surveillance board /MSB/ in the hierarchy of national administration. The main organization framework and operational conditions are also regulated.

Task of MSB is formulated in ML as follows: "MSB observes life, security and health of miners, safe operation and the regulations referring to mineral resources, mine property and land preservation. MSB may take measures for the protection of other social interests related to mining".

ML assures the authority and conditions for MSB in order to fulfill the above tasks. Among the conditions of high importance are its authority in decision-making of mining development /modernization, expansion/, and its authority and duty related to the issue of safety regulations.

However, this duty does not mean that the development and continuous improvement of safety regulations would be the task of the MSB exclusively. It is well known that any safety regulation is satisfactory only if it does not reflect solely the ideas of few experts, but evaluates the messages of practical cases and utilizes experiences of mining practice, e.g. on water control.

On the other hand, the necessity of involving practical mining experts in the development of regulations is expressed in one of the principles of ML: mining company must protect miners from mining hazards such as water hazard.

Reviewing mining design

It is an important duty of MSB, enforced by ML to supervise whether the necessary measures against natural hazards are properly designed and accomplished during the construction. As an example, the MSB statement on the water control of the Mányi mine was issued in 1979 when the investment proposal was prepared.

In the planning period great care is taken in every case to supervise the fulfilment of the following ML principle: such a technical level is to be strived at in the design of a new mine or the development of an existing one which is higher than the average level in mining.

Official regulation of main issues of water control

It has already been referred to that mining work pertains to the authority of MSB according to section 59 of ML.

I and II issues /1963 and 1969/ of "Water hazard" in ABBSz

As known, the issue III of water control regulation from 1975 was precede by the issues I and II from 1963 and 1969. Earlier, more important water related regulations were formulated in the "General Mining Safety and Health Protection Regulation /ÁBBESz/". This regulation contains tasks in 18 cases for the head of the mining company. Regional Mining Supervision has tasks in 17 cases related to approval, review and exemption, but even the Ministry responsible for mining has tasks.

The 1963 issue has detailed regulations facilitating the authority supervision of accomplishment. At the same time, the too much detail poses unjustified tasks for chief engineers of mining companies and for the Regional Mining Supervisions. In spite of these, the regulation was in force for 5 years.

The issue II from 1969 can be regarded also as a detailed regulation but it was shorter; e.g. regulations related to the planning and realization of measures in case of water inrush are given in the appendix.

The issue III from 1975 of chapter XIII of ABBSz

Research Institute /BKI/ took part intensively in the preparation of this issue III.

Mining was defined to be under water hazard if the specific thickness of the protective layer between mining space and the aquifer is less than a given value. In case of a karstic aquifer the necessary thickness of the protective layer is prescribed.

Though figures, or limit numbers were determined by systematic data processing and scientific analysis, some experts claim that related regulations strive to "perfect safety". As a result, an unjustified great number of mines are considered to be under water hazard, when prescribed water control measures must be taken.

This regulation aims at the maximam protection of miners' life. Naturally, development possibility of the water control system is an economic question after all which is not officially regulated.

The evaluation of the three earlier issues of water control regulations shows that, in spite of their shortcomings, they have served the requirements of life protection in a useful way. During the last 15 years mines have been left flooded due to excessive inflow or economic reasons /5 mines in Dorog, 2 mines in Tatabánya/, but fortunately total accident due to water inrushes has occurred only once /Gyöngyös mine/ when related regulations were strongly violated.

The last regulation differs from the earlier two issues also in some principles such as the sizing of the safety pillar for water control, the definition of water hazard, the capacity determination of water control systems for mines under water hazard.

The realization of this regulation has required greater expertise from those responsible for water control activity in the mine and the MSB as well.

Principles of a new regulation

The National Planning Commission decided in 1976 to supervise safety regulations in order to increase economic efficiency of investments. All those items must be ceased or modified, whose lack does not decrease working safety. According to that central principle, mining companies have proposed the amendment of some 21 issues in chapter XIII.

The development of the planned new regulations started at two places /MSB and the Hungarian Coal Mining Trust MSZT/

A first version of the new regulations was prepared in 1977 by MSzT. Though this text seemed to be too general, the definition given for economic property protection was a novelty. In fact, only this can be followed in water control together with the maximum life protection requirement. It seemed also useful that the draft regulated abandoned mines and required the construction of a water control organization tree. According to this draft, responsibility of those working directly on the design and operation of water control would decrease. In turn, authority and responsibility of technical deputy directors of the mining companies would increase, namely by:
- qualification of mines under water hazard;
- determination of geohydrological observation activity;
- initial location and length of preliminary borings;
- water control pillars;
- relief and modification of water control pillars;
- location and mode of drainage drillings;
- capacity of the water control station;
- warning system.

Also, the draft planned to increase MSB tasks related to permission and approval considerably, but partly unreasonably.

BKI, in its dicussion, supported the necessity of an independent water control expert for a mine. This recommendation can be agreed if the responsibility of the technical chief of the mine will not be decreased.

The draft regulation proposed by MSB includes detailed instructions how to control unexpected events, mostly from life protection aspects, and general ideas referring to long-range problems /mixed regulation/.

A codification committee developed a modified text by considering:
- useful elements of the MSzT proposition,
- amendment propositions of the mining companies,
- the MSB practice and experiences on exemptions,
- discussion material of BKI water control section.

Since the regulation in force had been prepared, futher information on karstic aquifers and protective layers has been gained. As a consequence, numerical data and calculation methods are often absolate. As and example, inrush flow c n be given as related to the aquifer, protective layer and control method. Also, the simultaneous total flow can be calculated and, thus, pumping stations and water conveyance systems can be sized more reliably than before. As a consequence, instead of detailed regulation of capacity calculation of the pumping stations, it is suffice to mention that the pumping station be capable of pumping the expected discharge.

There are no operational experiences on the reliability of grouted protective layers. As a result, even in case of grouting the possibility of inrush occurence should be assumed, and the water conveyance system should be sized to as high as in the no-grouting case. This assumption leads evidently to overdesign, but as long as sufficient experiences are not available the capacity reduction cannot be determined.

Further hydrological investigation is necessary in deeper deposits such as the ore in Recsk and Mecsek.

As special problems are mentioned the blow-out of gas traps and the hot water inrushes leading possibly to accidents. Protection measures are e.g. the jet-breaker shield, and the fixation of drilling equipment.

In our present level of knowledge, the amount of water inrushes can be predicted and the control can be timely designed, thus severe disturbances of operation can be eliminated. Necessary preconditions are the proper information on natural conditions, and a water control plan throughout the whole mining period.

Regulation would not fix the control system, the sizing of its elements and detailed construction technology but prescribe quantitative and qualitative requirements the various system elements must satisfy. Greatest care should be devoted to the safety and health protection of miners.

New water control methods, such as instantan protection, preventive grouting and the combinations thereof are being applied in the majority of new mines. Details of hazard stemming from these methods are not known yet.

Deeper deposits/such as in Recsk, Nagyegyháza, Mány and Lencsehegy/under water hazard poses extra problem due to the greater piezometric head of inrushes. Special care is to be taken there for the accomplishment of preliminary drillings.

In the framework of the eocene program, a number of new shafts, exploring mine openings, sloping shafts crosses various aquifers. Hydraulic failure and quick-sand inrushes should be taken care.

Delineation of the water control pillar and the sizing procedure of the water control dam should be standardized. Instead of the present detailed regulation, it would be more appropriate to state as follows: the candidate surface area of a new mine should be explored by borings in such a degree that the grade of water hazard could be estimated with the necessary accuracy, and an economic and safe control system could be designed.

It is suggested to include the following new points in the modified regulation:

- The water authority will advise on the design surface water flood.
- The water control expert should be a mining, geological or water control engineer with at least 3 year practice in a mine under water hazard.
- It is the task of the deputy technical director of the mining company to qualify new and existing mines according to water hazard, to determine the number of borings necessary for the safe and economic design of water control, and to determine the capacity of the water control system.
- The mining company should supervise
  - after the modified regulation is in force - the grade of water hazard for the different mines, and
  - to supervise the capacity of water control systems, and decide on the economic and safe development.
- The necessary capacity expansion of water control systems should be completed after 2 years from the issue of the modification.

Construction of standards

National standards /MSz/ are issued by the Hungarian Standardization Office directing and supervising the way how branch standards obligatory in various industries are prepared.

A relative new area of standardization refers to the equipment, sampling , measurement and calculation methods used to labour safety. There is an endevour that technical regulations, permitted values connected to labour protection be determined by the help of national /or branch/ standards.

According to these principles, MSB developed in 1979 conditions of preparing mining labour protection standards.

As a result, instead of the 7 appendices of the present regulation 2 mining standards will be issued:
- spacing, sizing and construction of water control dams /MSz-14 01033/,
- delineation and sizing of water control pillars /MSz-14 01034/

There are some inportant features of these standards.

MSz-14 01033 considers the sizing of water control dams which can be built in circular roadways. This calculation can be accomplished by simple calculators available in mining offices. However, it is also possible to size water-control dams to be built in other cross-section by the help of computers.

It is permitted to use not only compacted concrete but also shot-concrete or contact-concrete for levelling out.

In addition to cement grouting, bentonite grouting or a special grouting procedure after a soviet licence can be used.

The explosion activity in connection with the dam construction has not been justified to be included in a standard.

MSz-14 01034 prescribes that the water-control pillar can be delineated only in such rocks which can satisfy its duty in given thickness in the long-run.

If conditions of the water control pillar are satisfied but requirements of maximum life protection and economic property protection can be attained by other methods, it is a decision problem whether to apply water-control pillars /see mines of the eocene program/.

The draft standard calls for special expertise of delineating water-control pillars in some more complicated cases, such as the sizing for seepage flow or limited inrushes.

In the appendix, useful advices are given to practical users on how to construct the map of specific protective layer thickness pertaining to the design seepage path, and how to size water control pillars.

The technical committee judged the proposed standard as up-to-date in principles. It will be necessary to modify some parts along the following lines:

- the sealing effect of the clay protective layer depends on stress conditions; this was not considered in the original draft.

- Equivalent coefficients of day protective layers can be directly measured and not only taken from the given tables.
- Non-fissured sandstone or marl is quite stable rock. Equivalent coefficients of resp. 0,4 and 0,8 are too low for such rocks.

Experiences of official invetigations related to severe operational disturbances

ML considers emergency situations when in spite of preventive measures, operational disturbance or accident happens. Such items are: the requirements of preparing emergency relief plans and information therefrom for those interested, organization and operation of mine relief service.

MSB investigates causes of severe disturbances of operation or accidents, personal responsibility and takes the necessary technical or other measures.

There are some experiences of operational disturbances and accidents due to water inrushes from the last five years.

The Sárisáp XIX-XX mine had to be given up on 20 January, 1976 as an effect of 80 m^3/min inflow and 56 m^3/min pumping. Mining capacity of 300 x 10^3 t/year has been lost since endevours have not succeeded in to reopen the mine.

In mine XII of the Tatabánya Coal Mining Company an inrush of 11 m^3/min accurred from the overlying rock on September 25, 1976. Investigation showed that longwall mining drained the stored water in the overlying limestone.

In the Kányás mine, a quick-sand inrush of 3 m^3/min occurred in 1976. Investigation showed that the piezometric head was higher than 100 m in the overlying rock I, and the protective layer was missing in parts or narrower than 0,6 m. Areal protection, that is safety against seepage is less than 0,1 m/at. As a consequence, MSB ordered to perform piezometric head relief in the overlying aquifer of the southern mine I.

In 1977, only one water-related disturbance of operation occurred in coal mining causing 10 day production stop of one longwall mining systems. However, in 1978 the following six disturbances of operation were caused by water inrushes.

- In mine XV/b, Tatabánya a 58 m^3/min inrush caused mine flooding.
- In the Csordakut mine, Tatabánya the longwall mining system had to be evacuated due to a karstic water inrush.

- In the flooded /in 1976/ Dorog mine XIX-XX, the restoration efforts proved to be unsuccessful and were stopped. Karstic water hazard has considerably increased in the Dorog coalfield.
- On May 15, an inrush occurred in the Borsod Szeles mine and the production was stopped until 1st August.
- In the Nógrád Kányás mine, the pressured air section had to be evacuated, due to the inflow of metan connected with water.
- In the Recsk mining exploring work, inrush of water, sulphur and CO_2 occurred, hindering the above activity.

In 1979 the situation was more positive, since only three inrushes of less importance happened. Nonchalant working caused a severe disturbance of operation and the lack of observing safety regulations led to the loss of one life.

Some data on the 1979 events are as follows:

- In the Hunyadi mine of the Középdunántuli Coalmining Company, a water inrush occurred from the overlying eocene limestone. Sediment carried by the flow of 4 m^3/min silted the transportation equipment. As a consequence of sediment deposit in one part of the roadway, the airflow stopped and the operation of the longwall mining system was provisionally also stopped.

- In the Gyöngyösoroszi mine of the National Ore Mines, an unexpected inrush from an uncontrollable mine openings caused one death. This casualty could have been avoided if working had been more carefully effected, and safety regulations had been observed.

- In the Recsk region of BAV, one of the outlets of the mine became impassable.

- A smaller inrush happened at the mine XV/c, Tatabánya in September, 1979.

In 1980, no water inrush to be reported occurred. It is no doubt that water related safety of mining has been improved during the last five years. However, the decrease of unexpected inrushes is attributed also to the fact, that mines under the greatest water hazard /Dorog/ are not in operation due to earlier mine floodings.

Experiences of supervision of mine safety regulations

MSB has the right to supervise regularly how safety regulations are observed in mines. This task is performed mostly by the district offices of MSB. Experiences of these supervisions show that existing mines generally have the pumping capacity necessary for life protection and economic water control, and equipment required for water control safety.

Water control pillars have been delineated according to geologic conditions.

Drainage of over-and underlying aquifers for piezometric head reduction has been successful in the coalfields of Borsod, Középdunántul and Salgótarján.

The great number of water-control predrillings protect life from unexpected inrushes. Research and development has been going on to attain the necessary safety of water control for mines in the eocene program.

It has been a problem that the actual capacity of pumps in mines has gradually been decreased, due to large-scale wear-out.

It is and important task to supply mines with drilling equipment applicable to underground work. There is a scarcity in drilling equipment for predrilling and drainage, there is no choice since national production stopped and import is slow. The situation has been worse from year to year.

Table 1.

	Karstic water		Porous water		Fissure water		Total	
	Q m^3/p	%	Q m^3/p	%	Q m^3/p	%	Q m^3/p	%
1960	171	100	92	98	12	100	275	100
1970	486	50	121	65	18	100	625	54
1975	602	30	150	40	18	100	770	34
1985	650	15	150	25	25	100	825	19

/%/ : the ratio of water drained by roadways and facings