RELATION BETWEEN THE HYDROLOGICAL REGIME OF A SPOIL BANK AND CHEMISM OF GROUNDWATERS IN THE NORTH-BOHEMIAN BROWN-COAL BASIN

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ABSTRACT

The effect of the hydrological regime of a spoil bank on the occurrence of polluted effluents is discussed in connection with the chemism of neighbouring water-bearing collectors in the North-Bohemian brown-coal basin.

The origin and development of the spoil-bank's hydrological regime is connected with simultaneous action of both the natural and anthropogenic factors.

The degree of pollution of spoil-bank effluents depends on the retention time of water within the spoil-bank's body. The pollution of spoil-bank waters can be limited by suitable control of the hydrological regime within the spoil bank by adequate hydrotechnical measures.

INTRODUCTION

The constantly extending opencast mining in the North-Bohemian brown-coal basin calls forth several problems with the construction and operation of spoil banks /waste dumps/ and their subsequent re-introduction in the ecological system of the landscape.

One of the problems resulting from the insufficient evaluation of the spoil-bank's hydrological regime is the interaction of effluents with the surrounding environment, namely the contamination of neighbouring water-bearing collectors by polluted spoil-bank effluents. In order to reduce such a contamination, some technological and hydrotechnical measures must be taken prior to the foundation and during the operation of a spoil bank.

In order to accumulate sufficient data for the solution of this problem, systematic hydrological measurements and continuous water analyses should be effectuated in the spoil bank and in their relevant neighbourhood.

HYDROLOGICAL REGIME OF THE SPOIL BANK

The spoil bank is an earth structure formed by dumping the overburden, low-grade minerals, unusable waste rock, and, eventually, other wastes. It constitutes an anisotropic heterogeneous mixture. The spoil-bank body is a certain system, defined by the complex of its elements, ranging from 1 to ∞, which react to external stimuli in a known or assumed manner.

A specific hydrological regime is formed within the spoil bank as in an anthropogenic formation. Let the hydrological regime of the spoil bank be defined as a process of water exchange within the spoil-bank body and between it and the surrounding biosphere /environment/. The hydrological regime of the spoil bank affects the regime of the environment, being, the other way round, affected by it. That means that an alteration of the hydrological regime of the spoil bank brings about a definite effect on the hydrological regime of the neighbouring environment, this effect being time-dependent. As a rule, it does not appear immediately, but with a certain time lag. The interaction between the hydrological regime of the spoil bank and that of the surrounding environment can be expressed by the equation:

$$HR_{SE}\ (t) = f\ /\ HR_{SP}\ (t)\ /\ , \qquad (1)$$

where

HR_{SE} = hydrological regime of the surrounding environment,

HR_{SP} = hydrological regime of the spoil bank,

t = time.

The spoil bank body with its own hydrological regime is affected by natural and anthropogenic factors, some of them having a stochastic character. If at least one factor of an exactly defined relation is stochastic, the whole relation will appear stochastic. The stochastic factors are variables within a certain range of values, each of them having the possibility to attain a certain probability /Domenico, 1972/. The spoil bank with its hydrological regime represents therefore a stochastic system, which is defined by a finite number of relations of causes and consequences /effects/. Of primary importance, for practical applications, is the fact that the assumed effects result from certain given causes. This means that certain external stimuli /causes/ enable the probable behaviour of the system to be deduced and possible consequences to be evaluated/.

FACTORS AFFECTING THE SPOIL BANK´S HYDROLOGICAL REGIME

The hydrological regime of a spoil bank is originated by the action of natural and anthropogenic factors. These factors are constantly developing in mutual interaction. Their action is not statical, but a dynamical one, which means that the hydrological regime of a spoil bank is subjected to continuous development in time and space.

Factors affecting the hydrological regime in a spoil bank may be divided into:

1/ Natural factors - geographical, geological, hydrological, hydrogeological, hydrochemical, and biogenic factors;

2/ Anthropogenic factors /affecting the regime through the activity of man/ - technolgoical a hydrotechnical factors.

PROTECTION OF SURROUNDING WATER-BEARING COLLECTORS

The hydrological regime controls, in the spoil bank, the continuously occurring physico-chemical reactions between water, spoil-bank soil /earth/, and the atmosphere /Hanzlík, Moravec, 1986/. These reactions result in a heavily polluted spoil-bank effluent. The interaction between the hydrological regimes of the spoil bank and the neighbouring environment affects mutually the chemism of spoil-bank effluents and the water in neighbouring water-bearing collectors.

The degree of pollution of the spoil-bank water depends on the chemical composition of the inflowing water /in the spoil-bank body/, such as the atmospheric precipitations, inflows from the subsoil, and on the mineralogical composition of the spoil-bank rocks and soils. Further, it depends on the residence time of water within the spoil bank.

The pollution of effluents and its propagation into neighbouring water-bearing collectors can be limited by a suitable regulation of the spoil bank´s hydrological regime by means of hydrotechnical measures.

HYDROTECHNICAL MEASURES

Drainage of the spoil banks in all phases of their construction belongs to important hydrotechnical measures. These important precautions can significantly contribute to the protection of water-bearing collectors against contamination by polluted effluents.

Hydrotechnical measures can be classified into three main groups involving several partial problems:

1. Protection of spoil banks against groundwaters;
   - drainage of the unburied part of the dumping ground, which has a preventive character, protecting the future spoil banks against groundwater inflow from the subsoil /construction of a water-drainage system/,
   - subsequent drainage of the spoil-bank subsoil /drainage of the buried part of the dumping ground/.
2. Protection of spoil banks against surface waters and atmospheric precipitations;
   - prior to the establishment of the spoil bank /surface treatment of the spoil bank for the reduction of the infiltration of atmospheric fallout into the spoil-bank body and for the subsequent reclamation/.
3. Drainage of spoil-bank bodies constructed on undrained ground /bedrock/.

The purpose of these measures is to favour quick draining of atmospheric precipitation water from the surface of the spoil bank, thus preventing the infiltration in its deeper parts, further the captation of groundwaters and water springs in the subsoil as well as the percolation and infiltration waters, which penetrate into the subsoil from the spoil-bank body. These measures reduce the residence time of water in the spoil bank, thus shortening the time of interaction between water, dumping soils, and the atmosphere. This results in the occurrence of less polluted spoil-bank effluents.

SPOIL BANKS CONSTRUCTED ON UNDRAINED GROUND

Heavy pollution of effluents is encountered in spoil banks constructed on an undrained ground, without any drainage system in the subsoil of the spoil-bank body. In these spoil banks a hydrological regime is established, which can be differentiated according to the residence time and degree of pollution of water within the spoil bank. The pollution of these effluents is given, above all, by high concentrations of Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, and the total mineralization.

For example, material deposited in the spoil bank of the opencast mine "Merkur" is formed, above all, by the overlying kaolinitic-illitic-montmorillonitic clays to claystones. The prevailing mineral is Ca-montmorillonite. Average mineralogical composition of these clays is: montmorillonite 38%, illite 26%, kaolinite 15%, quartz 8%, calcite + dolomite 6%, siderite 4%, accessorics 3%. The dumping soils contain also iron disulphides and recent sulphates. Basing on chemical analyses and measurements of the tritium activity in water samples from the spoil bank of the opencast mine "Merkur", it could be established that the degree of pollution of effluents depends strongly on the residence time of water within the spoil bank /see Tab. 1/.

Table 1: Dependence of the chemical composition of spoil-bank effluents on the residence time of water within the spoil bank

	sample No. 5 age: 3-4 months mg/l	sample No. 12 age: 2 years mg/l	sample No. 11 age: 6 years mg/l
Ca^{2+}	86,77	393,69	440,35
Mg^{2+}	77,00	188,00	460,00
Na^+	87,00	720,00	340,00
K^+	12,90	53,00	51,00
SO_4^{2-}	179,15	2.594,52	2.515,27
HCO_3^-	561,36	400,27	1.266,10
total mineralization	1.076,27	4.815,62	5.430,42
pH	7,1	7,8	7,2
tritium activity /T.U./	61 ± 8	54 ± 8	36 ± 6

Note: T.U. = 3,2 x 10^{-12} Ci/l.

It is evident, from ther Piper´s trilinear diagram /Fig. 1/ that the overall mineralization of spoil-bank effluents differs within broad limits. The most polluted effluents /samples 9, 11/ attain the total mineralization of 5232-5430 mg/l. This concerns the water with the longest retention time in the spoil-bank body /6 years/. Samples No. 6 and 12 reveal the total mineralization within 4100-4816 mg/l. The tritium activity in these samples corresponds to the age of about 2 years. In samples No. 10 and 24, the mineralization within 3202-3540 mg/l was established. The total mineralization of water samples No. 3, 4, and 5 varies within 1076-1627 mg/l. According to the tritium activity and chemical composition, these waters concern the atmospheric fallout with residence time /after precipitation/ of 3-4 months.

The water from the neighbouring water-bearing collectors has a substatially lower mineralization than the polluted spoil-bank effluents. Its value varies within 1000-1540 mg/l.

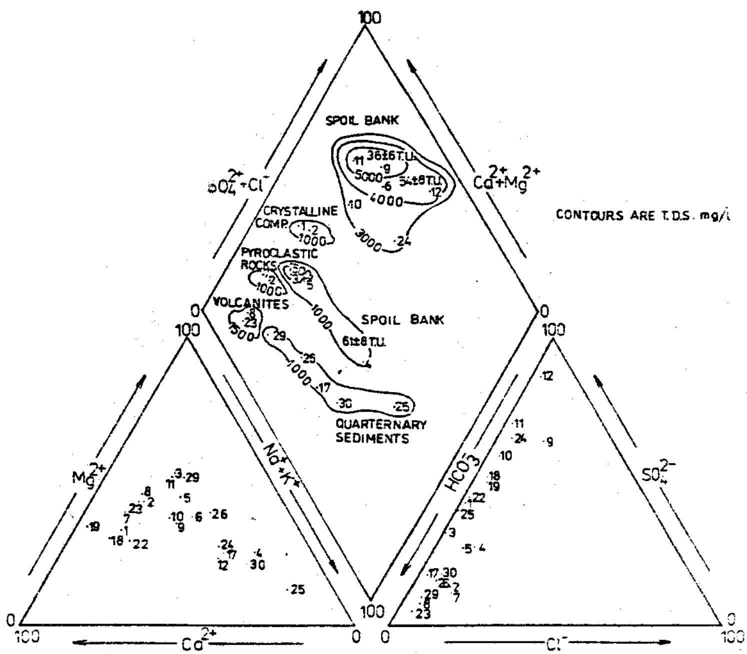

Fig. 1

Piper trilinear diagram for spoil-bank waters; mine "MERKUR"

The age of spoil-bank waters is indicated according to the piston-flow model, which, however, does not apply exactly to the hydrological regime of water in the spoil bank.

REACTIONS TAKING PLACE IN SPOIL BANKS CONSTRUCTED ON UNDRAINED GROUND

Effluents from spoil banks constructed on undrained ground /subsoil/ are characterized by increased contents of Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, and by high overall mineralization.

The increased content of SO_4^{2-} is due to the oxidation of iron disulphides. These reactions result in acidic effluents with $pH < 4,5$. Acidic waters are neutralized by circulation within the spoil bank. H^+-ions are consumed during the dissolution of carbonates, yielding HCO_3^--ions.

The concentration of SO_4^{2-} in spoil-bank effluents is also increased by the dissolution of recent sulphates. In these reactions, an increased concentration of Na^+ ions is also encountered.

The weathering of the organic substance in the unsaturated zone of the spoil bank produces carbon dioxide, CO_2 which reacts with the infiltrating water from the atmospheric fallout, forming the carbonic acid. This acid dissolves calcite and dolomite, increasing the concentration of Ca^{2+}, Mg^{2+}, and HCO_3^- in the effluent.

There occurs, in the spoil bank, also an ion exchange between the effluents and the clay minerals. Investigation of these reactions is a new research topic.

SUMMARY AND CONCLUSIONS

The spoil bank is an anisotropic heterogeneous mixture. It is formed by the deposition of the quaternary cover, overlying clay rocks, uneconomical residual reserves of the useful mineral /coal/, and, eventually, ashes and cinders.

A specific hydrological regime is being formed within the spoil bank. Under this regime, the method of water exchange within the spoil bank and between the spoil bank and the surrounding biosphere is understood. The formation and development of this hydrological regime depends on the simultaneous action of both the natural and anthropogenic factors.

Some factors affecting the spoil-bank body with its own hydrological regime have a stochastic character. Such a spoil bank is therefore a stochastic system, defined by a finite number of cause-to-consequence relations. The hydrological regime affects significantly the chemism of spoil-bank effluents. There occur, in the spoil bank, various physico-chemical reactions between the water, spoil-bank soils, and the atmosphere. These result in the formation of polluted effluents. The degree of pollution depends on the residence time within the spoil-bank body, on its origin and on the mineralogical composition of dumping soils.

The effluent from the spoil-bank of the opencast mine "Merkur", with the tritium activity of 36 ± 6 T.U., is characterized by increased concentrations of Na^+, Ca^{2+}, Mg^{2+}, and SO_4^{2-}. The total mineralization of this water is several times higher than the overall mineralization of water from the neighbouring water-bearing collectors. The concentration of SO_4^{2-} attains 2515 mg/l and the total mineralization 5430 mg/l.

The reduction of the pollution of spoil-bank effluents and their expansion into the neighbouring water-bearing collectors is possible by suitable control of the hydrological regime in the spoil bank. Various hydrotechnical measures /various forms of drainage/ and the subsequent reclaiming /recultivation/ of the spoil bank can be used to this purpose.

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