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Underground Disposal of Excess Brines of Potash Processing: Substantiation of Possibilities

Podziemne składowanie solanki z przetwórstwa potasu: studium możliwości

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Abstract

Approaches and requirements concerning geological investigation of potash deposits for substantiation of a possibility of underground disposal of excess potash processing brines are discussed. The main stages of geological investigation are defined, and a complex of studies to be carried out at the first stage is considered in details. Mathematical modelling of the injection of excess brines has been carried out. Potential intake capacity of collector-beds has been evaluated, and necessary amount of injection wells has been justified.

Key words: excess potash processing brines, collector-beds, hydrochemical compatibility, collector capacity parameters, environmental compatibility of a potash project.

Streszczenie

W artykule przedyskutowano możliwości podziemnego składowania solanki z przetwórstwa potasu. Zdefiniowano główne stadia poszukiwań geologicznych i złożoność rozpoznania. Przeprowadzono matematyczne modelowanie wtłaczania solanki oraz przeanalizowano potencjalną pojemność warstw przeznaczonych do magazynowania.

Słowa kluczowe: solanka z przetwórstwa potasu, warstwy magazynowe, hydrochemiczna przyswajalność, pojemność magazynowa, ochrona środowiska

The issue of the disposal of significant amounts of excess brines produced during ore processing becomes very important in terms of environmental and economic concerns, while designing and operating potash mines. The annual output requiring disposal of waste brines amounts to 0.8-1.0 mln m^3 at the capacity of the processing flotation plant of 2.0 mln tons of potash fertilizers per annum. Environmental safety, economic efficiency and comprehensive land use are the governing factors that should be addressed, while selecting the means of waste disposal. At present, the underground disposal of liquid industrial waste in deep strata has become a widespread practice. Those strata must possess proper natural isolation from land surface, as well as surface and ground waters that are used for industrial and drinking water supply. Such a technique of excessive brine disposal provides reliable isolation from biological chains and is considered to be environmentally safe. The alternative way of excess brine management concerns the disposal and storage of brines in various types of brine and waste dumps, storages, and evaporation ponds, which are situated on the surface, occupy significant areas, and unavoidably become the sources of negative impact on the environment of surrounding landscapes.

Investigation of deep strata with the purpose of evaluation of a project to inject excess brines includes several stages: preliminary studies, prospecting works, and industrial-experimental injection. Only positive results of the studies at that stage can be the basis of the commencement of the next stage of investigations. The commencement of full-scale industrial injection of brines is expedient after achievement of positive results at the stage of industrial-experimental injection. A set of investigations conducted at the preliminary stage of geological studies is considered in this paper (Requirements, 2003).

The set of studies intended to substantiate injection of excess brines aims at collecting the most reliable basic data necessary for making the decision on a possibility of injecting excess brines within the project area (Requirements, 2003).

Injection of excess potash processing brines into water-absorbing strata is possible only under the conditions of favourable combination of certain geological, structural-tectonic and hydrogeological factors.

The necessary conditions for possible disposal of excess brines in underground collectors include the following:

1. The occurrence, within the cross-section of the deposit, of the collector that is capable to accommodate necessary amount of brines during a certain estimated period of plant operation.
2. Hydrochemical compatibility between the natural composition of waters in the collector and the composition of brines to be injected.
3. Existence of the conditions for proper isolation of the collector layer from the active exchange zone waters within the area where alteration of natural hydrodynamic regime caused by the injection of excess brines will take place.
4. Absence of freshwater aquifers in the brine injection zone that are being used or may be used for industrial, drinking, and medicinal water supply.
5. Economic feasibility of excess brine disposal in underground aquifers.

Example of lithological and hydrogeological conditions for potential underground disposal of excess brines printed in Figure 1.

In general, geostructural features that form natural boundaries of the collector layer in plane and cross-section determine the storage capacity parameters of the collector. Confinement of the collector layer depends on tectonic, stratigraphic, and lithologic factors. Together with the borderline conditions of the collector layer, which determine the area of occurrence and thickness of geological structure designated for brine disposal, the other important characteristics of the collector include its capacity parameters, which depend on porosity, fracturing, cavernosity, karst, and other elastic properties of water-bearing rocks and enclosed waters (Grabovnikov, 1993).

In terms of petrography, terrigene and carbonate deposits are the most suitable water-absorbing rocks for the disposal

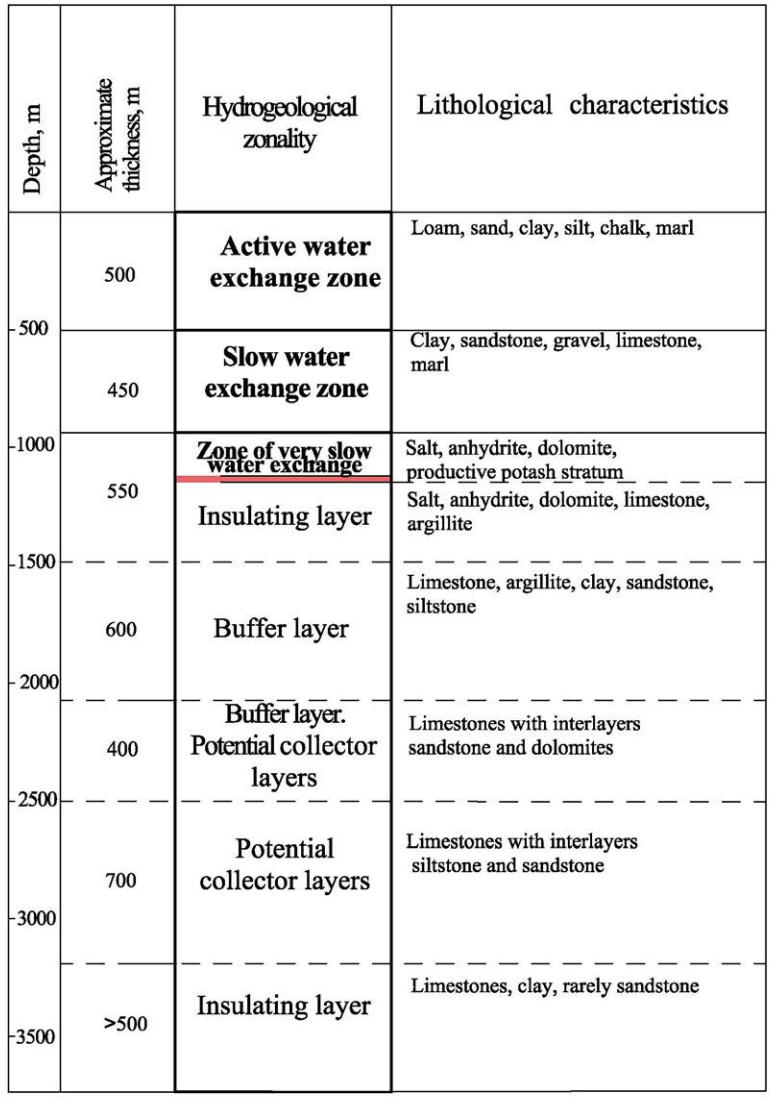

***Fig. 1**. Example of lithological and hydrogeological conditions for potential underground disposal of excess brines*
Ryc. 1 Przykład litologicznych i hydrogeologicznych warunków dla potencjalnego składowania solanki

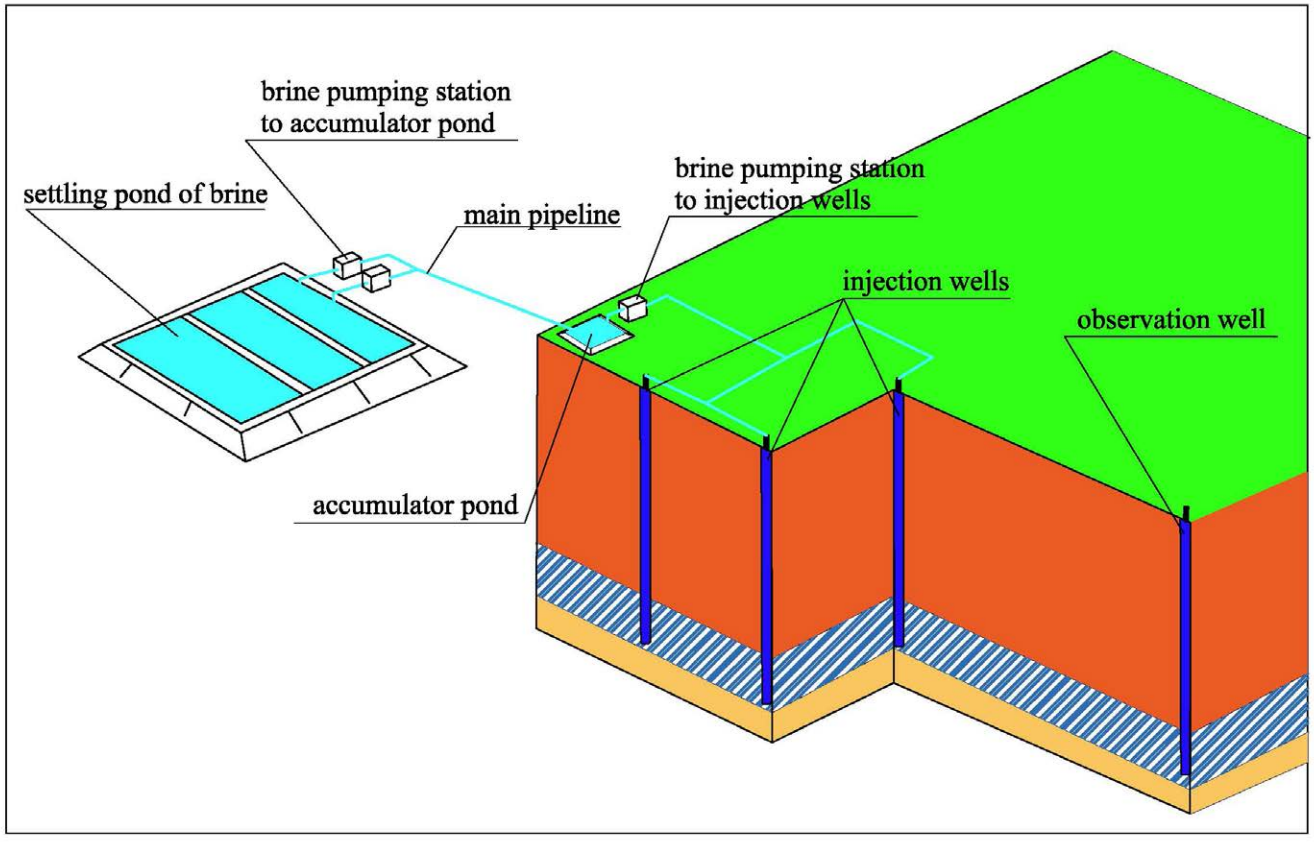

***Fig. 2**. Principal construction scheme of underground disposal objects excess brines*
Ryc. 2. Schemat konstrukcyjny podziemnego składowiska solanki

of excess brines in sedimentary platform artesian basins. The following values are characteristic for the migration parameters of the most common rocks, forming collector layers: for sands – effective porosity 0.15-0.25, filtration coefficient 2×10^{-4}–2×10^{-1} m/day; for sandstones, limestones, and fractured dolomites – effective porosity 0.01-0.03, filtration coefficient 4×10^{-1} m/day; for fractured and karstic limestones and dolomites – effective porosity 0.03-0.05, and filtration coefficient up to 5 m/day (Grabovnikov, 1993; Gaev, 1981).

It is very important to take into account the influence of chemical composition of disposed brines placed in the collector in order to evaluate the layer's intake rate and the capacity properties of the collector. When assessing a possibility of underground disposal of brines, it is necessary to consider the conditions of hydrogeochemical interaction of those brines with the original brines of the collector layer. Precipitation of solid mineral forms (crystallization) from the solution may take place due to mixing of brines with high mineralization. Precipitation of mineral solids from brine affects permeability of the layer in the near-filter area of injection wells in case of the injection of brines into the porous matrix of the collector. Chemical colmatage of the collector will ultimately lead to a decrease of the porosity of the layer and of the injection wells' intake capacity.

Proper hydraulic confinement of the collector horizon from the overlying geological strata and aquifers is the necessary condition for disposal of brines in underground collectors. Deposits formed by clays, claystone, anhydrite, non-fractured clayey limestones, dolomites and marls, with gas transmission coefficient $\leq10^{-11}$ cm^2 and filtration coefficient $\leq10^{-4}$ m/day, possess favourable sealing (waterproof) properties (Grabovnikov, 1993; Gaev, 1981).

Pre-feasibility study of the underground disposal of potash production waste is the final stage of evaluation of the possibility of brine disposal in underground collectors. Principal construction scheme of object of underground disposal of excess brines printed in Figure 2.

The set of studies conducted at the preliminary stage for substantiation of excess brine injection, depending on particular hydrogeological conditions and the knowledge of the project area, usually includes collection and analysis of the following data of geological exploration:

- Geological characteristics of the cross-section, which allow for drawing conclusions on lithological and physical-mechanical properties of rocks;
- Information on the hydrogeological investigations of different boreholes that characterizes basic hydrogeological parameters of the target horizons;

- Results of downhole geophysical surveys;
- Data on the ground geophysical survey (seismic, gravity, electrical), based on which the conclusions on tectonic structure of the area can be drawn (Requirements, 2003).

The principal possibility of excess brine injection, as well as a possibility of environmentally-friendly, economically efficient construction and sustainable operation of an underground disposal facility is being assessed, based on the results of analysis and interpretation of these data. Depending on the geology of the area, the plan of mining operations, and land-use structure, the most suitable area will be determined for brine injection, and exploration borehole drilling for the purpose of special geological investigation of the collector strata (RD 51-31323949-48-2000).

Mathematical modelling of brine injection is carried out at the first stage of geological investigations in order to assess the intake capacity of the stratum, visualize the distribution of hydrostatic pressure, and make preliminary decisions on the necessary number of injection wells.

The experience of excess brine underground disposal has shown that it takes about 5-7 years from the setting of the task to the beginning of full-scale industrial injection. Taking into account the long period necessary for the implementation of the studies, it is reasonable to start investigations on the substantiation of brine injection feasibility into deep strata at the stage of mine construction (design). This would enable timely solving of the task of excess brine injection into deep strata, and, in turn, reducing load on waste dump facilities and increasing environmental compatibility of a potash project.

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