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Future water-rock interaction in deep repository of spent nuclear fuel

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Abstract

A deep geological repository of spent nuclear fuel has to be safe for at least 100 thousand years. During this time, water–rock interaction on surface as well as in the rock around the repository will progress. All exogenous processes will depend on future evolution of climate. Based on the research of Quaternary sediments, three limiting scenarios of future climate evolution are considered: Maximum cooling and drying in glacial periods; maximum warming and moistening in interglacial periods and climate evolution affected by elevated concentrations of CO_2 in the atmosphere. Formation of permafrost, infiltration of melted water and oxidation will influence chemical composition of ground water. Two analogues of the changes are presented. They are ground waters in two mines in the Bohemian massive: (1) Mine "Svornost" in an abandoned historical uranium deposit Jáchymov (Joachimstahl), (2) underground research facility of "Bukov" near the uranium deposit of Rožná. Ground water was sampled from surface to a depth of 1200 m. The water–rock interaction during the infiltration and flow of ground water is the cause of the observed stratification of the chemical composition. The chemical composition of the collected samples indicate a probable future composition of ground water within the repository.

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Keywords: Repository; spent nuclear fuel; climate change; ground water; hydrochemical zoning; future of repository

1. Introduction

Future water–rock interaction will influence properties and thermodynamic state of the deep repository of spent nuclear fuel in the Bohemian Massif of Central Europe. The climate development will influence water–rock interaction, which is the motor of exogenous changes. These processes include weathering of rocks, erosion of

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weathered material, changes in hydrodynamic system and permeability in the overburden of the repository and changes related to the geochemical and mechanical stability of engineering barriers. Important pieces of information for a risk analysis of the repository are how fast the overburden rock will weather, how much of the rock material will be removed from the place of the repository by erosion, how will the rate of the weathering and erosion change due to climatic variations and what will the influence of the changes be on chemical and physical-chemical properties of ground water in the repository during the next one hundred thousand years.

The principal factors shaping the future climate will be insolation determined by the Earth's orbital parameters and greenhouse gases concentrations. Our projection of possible climate development in the next 100 thousand years is based on two presumptions: (1) Some periods in Earth's history may be taken as analogues for future climate; (2) orbital parameters that control insolation and climate may be predicted with certain reliability in long term context. It is not possible to predict evolution of the climate with certainty. However, we can outline three scenarios of future climate determined by orbital forcing and a scenario influenced by future human activities. The scenarios are: (1) Maximal cooling and drying of the climate known form Quaternary glacial periods, (2) maximal warming and moistening of the climate known from Quaternary interglacial periods and (3) evolution of the future climate affected by human activities resulting in elevated concentrations of CO_2 in the atmosphere. The models of exogenous changes depend on various time scales of the climate evolution. We consider three time scales. They are the following: Several centuries, the next 10 thousand years and the next 100 thousand years. The scenarios assess also the influence of permafrost occurrence on the deep geological repository sites by its effect on hydrogeological and hydrochemical regime.

2. Future of climate

Future climate during the next 100 thousand years will probably stay within the limits defined by[1]:

2.1. Maximal cooling and drying

Based on the principle of analogues that takes past climate as a possible scenario for the future climate projection this scenario corresponds to the peak of pleniglacial conditions. The mean annual air temperatures in the non-mountain areas were between –7 and –2 °C. The conditions correspond to the present High Arctic and marginal part of Antarctica. The period was the driest within the Quaternary climatic cycles. The mean annual precipitation reached 250–350 mm in Central Europe. Pleniglacial conditions lasted 6 to 20 thousand years during the climatic cycles of the last million years. This represents 5–17 % of the duration of the Quaternary glacial-interglacial cycles. The glacial conditions, which prevailed in Central Europe for 60–80 % of the glacial-interglacial cycle, were characterized by temperature ranged from –2 to 5 C and annual precipitation from 300 to 600 mm. The glacial conditions in non-glaciated regions of Central Europe may result in a layer of permafrost in the future. The maximal thickness of the permafrost in previous ice age reached 200 to 250 m[1]. According to model simulations of the future evolution of the Earth's orbital parameters, the onset of glacial conditions in the Northern Hemisphere will occur after 40 to 50 thousand years. The glacial conditions should persist for the following 50 to 60 thousand years. However, the above-mentioned limiting climate conditions will probably not be reached during the coming 100 thousand years because of a slight decrease in insolation for the Northern Hemisphere high latitudes and especially an increase in temperature due to higher atmospheric concentration of CO_2.

2.2. Maximal warming and moistening

The scenario corresponds to the peak interglacial conditions. The mean annual air temperature in non-mountainous areas was between 8 and 11 °C. The mean annual precipitation was in the range of 800 to 900 mm. The interglacial conditions were rare within the Quaternary glacial-interglacial cycles. They lasted 1 to 3 thousand years only, which is 1 to 3% of the duration of the cycles. Recent climatic conditions in Europe, with mean annual air temperatures reaching 6 to 9 °C and annual precipitations being 550 to 700 mm, correspond to the intermediate interglacial conditions. Therefore, a formation of permafrost is highly improbable in the scenario of maximum warming and moistening of the climate. A climate moistening by 20–30% in this scenario will cause greater