Hydrochemical and/or microbial impact on transfer of radionuclides in groundwater

Katja Burow1, Anja Grawunder1, Sven Gärnter1, Ralf Erhardt1, Erika Kothe2, Georg Büchel3

1Institute of Geosciences – Applied Geology, 2Institute of Microbiology – Microbial Communication

Introduction

The migration of radionuclides in mining and urban sewage waters depends on the processes of reactive transport in groundwater aquifers. Microorganisms may alter and even control these processes. Consequently, this study focuses on the hydrochemical and/or microbial transport of radionuclides from rock into groundwater. Therefore, two sites were sampled for water, rocks and partially secondary phases. One of them, Bad Kreuznach, is located in Paleozoic ‘Saar-Nahe-Becken’ in the south of the ‘Rheinische Schiefergebirge’, where groundwater flows through the local ‘Kreuznacher Rhyolith’. The other site, the Morassina cave, being a former alum mine with Silurian black shale, is situated in the Thuringian forest.

Hydrochemistry of groundwater

At Morassina, water chemistry shows Ca-Mg-SO4 water with an acidic pH 2.6-3.7, lower electric conductivity (670-850 μS/cm) and redox potential from (670 - 850 mV).

Bad Kreuznach show a different hydrochemistry with a pH 6.6-6.9, a low oxygen saturation (<4%) [1], a high electric conductivity (25-31 mS/cm) and high concentration of methane (40 Vol-%). The highly mineralized groundwater (16-27°C) contains – aside from approximately 18 L/m NaCl – high radon (222Rn) concentrations up to 85-328 Bq/L. The spectrometric analysis of two wells shows a higher 234Ra concentration compared to 226Ra and consequently a low 234Ra/226Ra ratio. Other isotopes like 210Pb and 210Th are below detection limit.

The REE patterns are enriched in HREE being a typical feature for salinar water [2]. Enrichment of MREE and a slightly positive Eu anomaly further indicate interactions of the salinar groundwater and rhyolite. All groundwater wells show a Gd-anomaly indicating infiltration of river water or interaction processes with Fe-phases.

Microbiology of groundwater

From the groundwater samples of Bad Kreuznach 32 different strains, primarily appropriate to Firmicutes, Actinobacteria and Proteobacteria, could be isolated. The groundwater of the Theodorshaller Thermalquelle shows the highest bacterial diversity. Bacillus sp. and Pseudomonas sp. are the dominant strains in the groundwater of the other wells.

Geochemical, mineralogical & microbial investigation of solid material

In the Morassina cave, ponds collect the seepage water. Red and white phases have built in situ and appear as crusts and muds. These precipitates were investigated by total digestion, X-ray fluorescence and X-ray diffractometry mainly as schwertmannite [Fe5O(SO4)(OH)](SO4)δ+2(H2O)δ- (red phase) and X-ray amorphous Fe-phosphates [Fe5O(P2O7)(OH)](OH)δ+ (red phase), previously discussed to be diadochite [3]. These minerals accumulate high proportions of Mo (1 mg g⁻¹) and especially V (4.5 mg g⁻¹). Contents of U and 3REE are with maximum values of 51.3 and 81.4 μg g⁻¹ comparable low.

For subsequent microbial characterization the DNA of different precipitates was isolated and the 16S DNA amplified. It was possible to determine the DNA of bacteria and archaea.

Next to the geochemical and mineralogical analysis of the precipitates, the rhyolite from Bad Kreuznach was investigated by gammaspectrometry. In contrast to the water analysis the results show a higher 226Ra/228Ra ratio indicating that the local rhyolite is not the (only) Rn-source for the high Rn-accumulation in groundwater.

Summary

Both sampling sites shows different water chemistry. At Morassina, the acidic water is rather low concentrated in Mo, U, V and REE in contrast to the secondary phases, where these elements are accumulated. The impact on microbes on release of metals and precipitation of Fe-phases will be examined particularly. Furthermore the radioisotopes (U, Th, K, Ra, Rn, Pb) in rock, water and precipitates will be investigated.

The REE patterns of groundwater of Bad Kreuznach points to rock-water-processes. However, the variance in radioactive ratio 226Ra/228Ra in groundwater and rhyolite of Bad Kreuznach indicate that the Ra originates not exclusively from rhyolite. Maybe the Ra will be transported with the saline water or originates from other geological formations. Therefore the radioactive ratios of rhyolite-tuff and bituminous clay, found within the sampling area, will be analyzed.

References:

Acknowledgments
This work is part of a DFG-funded project (2116/4-3) on the transfer of radionuclides in aquatic ecosystems (TransAqua). We would like to thank the group members of the project, especially Norman Dietrich (MTA Dresden, gammaspectrometric analysis), and the collaborators of the ‘Kreuznachschule’. We also want to thank the colleagues of the Mineralogical Communication and Applied Geology group, Jena, especially Dirk Merner for the good cooperation.