Available online at www.sciencedirect.com
SCIENCE DIRECT®

Chemie der Erde 65 (2005) S1, 7–27

CHEMIE der ERDE GEOCHEMISTRY

www.elsevier.de/chemer

Molecular mechanisms in bio-geo-interactions: From a case study to general mechanisms

Erika Kothe[a,*], Hans Bergmann[b], Georg Büchel[c]

[a]*Institute for Microbiology, Friedrich-Schiller-University, 07740 Jena, Germany*
[b]*Institute for Nutritional Sciences, Friedrich-Schiller-University, 07740 Jena, Germany*
[c]*Institute for Earth Sciences, Friedrich-Schiller-University, 07740 Jena, Germany*

Received 9 March 2005; accepted 17 May 2005

Abstract

The understanding of molecular mechanisms in the cycling of elements in general is essential to our alteration of current processes. One field where such geochemical element cycles are of major importance is the prevention and treatment of acid mine drainage waters (AMD) which are prone to occur in every anthropogenic, modified landscape where sulfidic rock material has been brought to the surface during mine operations. Microbiologically controlled production of AMD leads not only to acidification, but at the same time the dissolution of heavy metals makes them bioavailable posing a potential ecotoxicological risk. The water path then can contaminate surface and ground water resources which leads to even bigger problems in large catchment areas. The investigation of mechanisms in natural attenuation has already provided first ideas for applications of naturally occurring bioremediation schemes. Especially an improved soil microflora can enhance the natural attenuation when adapted microbes are applied to contaminated areas. Future schemes for plant extraction, control of water efflux by increasing evapotranspiration, and by subsequent land use with agricultural plants with biostabilization and phytosequestration potential will provide putative control measures. The mechanisms in parts of these processes have been evaluated and the resulting synthesis

*Corresponding author. Tel.: +49 3641 949 291; fax: +49 3641 949 292.
E-mail address: erika.kothe@uni-jena.de (E. Kothe).

doi:10.1016/j.chemer.2005.06.005

applied to derive a bioremediation plan using the former uranium mine in Eastern Thuringia as a case study.

Keywords: Acid mine drainage; Uranium mining; Eastern Thuringia; Remediation; Element fluxes; Heavy metal transport; Sources and sinks; Rare earth elements; Microbiology; Botany

1. Introduction

In this paper, we present the overall structure of an interdisciplinary portfolio of research projects dealing with ecotoxicological risk assessment in an ecosystem heavily contaminated with metals, give examples of the results, and extract the generally relevant conclusions. Mostly, projects addressing the contamination of landscapes with heavy metals focus only on the large scale processes. However, identification of molecular mechanisms at work in cycling of heavy metals is a prerequisite to any ecotoxicological risk assessment. Thus, our research program specifically is aimed at interdisciplinary research between the fields of geology, plant science and microbiology to understand molecular mechanisms which will add up to determine large scale processes. This example can be used to broaden the view on general mechanisms connected to acid mine drainage (AMD).

Heavy metal contaminations are found as a result from mining activities, especially with sulfidic mine sites. These are the most important ores today making AMD a problem in many areas of the world. Metal sulfides and pyrite contained in the ore are oxidized to release sulfuric acid, a process sped up microbiologically (by up to six orders of magnitude) depending on oxygen availability (Brierley and Brierley, 2002). Therefore, the greatest threat to the environment is posed by waste rock piles where the waste rock still containing pyrite is dumped after enlarging the surface area and thereby accessibility (for review: Ebenå and Kothe, 2005). The large surface area together in combination with oxygen provide an ideal environment for bacteria like *Acidithiobacillus ferrooxidans* which is able to grow on pyrite oxidation (Kelley and Tuovinen, 1988). The resulting formation of sulfuric acid allows heavy metals to be dissolved and thus an acidic, heavy metal rich leachate is produced. The grand scale of AMD (the mining industry in the USA produce about 2.7 million metric tons of acid a year and acid mine drainage pollutes over 26,000 km of streams) has launched many investigations. Most of them, however, are concerned only with the grand scale of geochemical and hydrogeological implications. However, the ecotoxicological risk should warrant research, which has so far been slim with under 10% of publications dedicated to AMD effects on biological subjects.

On the other hand, heavy metal toxicity and impact on human health are well researched. The risk has led to laws for environment protection in general with international conventions for limits above which remediation actions are to be taken. But in order to establish limits of tolerable concentrations of heavy metals in soil in Europe, as well as elsewhere, the scientific basis was poor. Many black boxes had to be assumed to define maximum tolerable concentrations rather than being based on