CHAPTER THIRTY-THREE

SUBSURFACE INTERACTIONS OF ACTINIDE SPECIES WITH MICROORGANISMS[1]

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33.1 INTRODUCTION

Subsurface microbiological processes have an important role in defining the speciation and mobility of actinide contaminants in groundwater. The relative importance of these processes, especially when groundwater conditions support high microbiological activity, has, however, only been recognized by researchers in the field since the early 1990s. The need to mechanistically understand the key interactions between actinide species and microbial processes becomes greater as we increasingly rely on more passive, long-term containment strategies, such as natural attenuation, where microbial processes are likely to predominate (NRC, 2000a).

The effects and interactions of microbiological processes with subsurface actinide species are complex and often not fully understood. Overall, the subsurface

processes that are influenced and, under many circumstances, controlled by microbial activity have been identified. The most important of these are the ability of microorganisms to influence localized redox and pH conditions, their ability to indirectly and/or directly reduce or oxidize multivalent actinides, the bioassociation by surface complexation or uptake of dissolved actinides that can lead to the formation of bio-colloids, and the biodegradation and utilization of inorganic and organic nutrients present in the subsurface that also form actinide complexes and affect their subsurface speciation and mobility. Conversely, the presence of actinide contaminants in the subsurface can also affect the microorganisms present. Actinide species are radiolytically and chemically toxic towards many microorganisms, and their presence can alter the indigenous microbial ecology. Actinides can also be substrates that provide energy for growth.

In this chapter, we present subsurface microbial effects from the perspective of their potential influence on the speciation, fate, and transport of actinide contaminants. This is discussed in two parts: Section 33.2 discusses the effects of actinide contaminants on key microbial processes in the subsurface; Section 33.3 discusses the effects of microbiological processes on actinide speciation and, correspondingly, actinide subsurface mobility. Section 33.4 provides a brief overview of biogeochemical modeling approaches. Lastly, Section 33.5 summarizes existing observations in natural systems centered on bioremediation and bio-containment field studies to provide some perspective on important microbial issues related to long-term containment of actinide contaminants.

This chapter complements Chapter 32 which focuses on geochemical and chemical actinide subsurface chemistry. It also complements Chapter 31 where the biological interactions of actinides with mammals were reviewed.

33.1.1 Historical perspective

The potentially significant effects of microbiological process on the speciation of actinides in the subsurface were explicitly recognized in the early 1990s. The recognition that actinide speciation is influenced by microorganisms is a natural extension of the analogous observation that many subsurface metal reactions (e.g., Fe and Mn along with contaminants Pb, Ni, Cr, and As), formerly thought to be mostly defined by the site geochemistry, are also predominantly microbially mediated. In particular, the biogeochemical cycling of iron and manganese, along with the many inorganic and organic species that can be microbially generated, combine to define many of the key subsurface reactions where actinide contaminants are often co-located.

Although there are a scattering of papers on actinide interactions with organisms prior to 1990, these are largely focused on health and safety issues related to actinide exposure and uptake. Wildung and coworkers investigated the radiolytic toxicity of plutonium towards soil bacteria in the early 1980s (Wildung and Garland, 1980, 1982; Wildung *et al*., 1987). The discovery of