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# Roles of Microbes in the Radioactive Waste Disposal and Identification of Aerobic Microbes in a Groundwater

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## 1. Introduction

A radioactive waste repository is not a sterile environment and microbial effects could potentially occur at many locations. The possible effects of microbes on the radioactive waste disposal have been considered as one of research programs for the radioactive waste disposal by many countries since the mid and late 1980's [1, 2]. Until now, however, researches on the effects of microbes on the radioactive waste disposal have rarely been carried out.

Thus we investigated the research status on the roles and various effects of microbes in the radioactive waste disposal. We also identified aerobic microbes found in the groundwater sampled from the KAERI Underground Research Tunnel (KURT) located at the KAERI site.

## 2. Roles of Microbes in Radioactive Waste Disposal

### *2.1 Definition and Classification of Microbes*

A microbe is a living entity which contains all that it needs in order to perform a life cycle, including feeding, growth and reproduction, in a single cell. The size of a microbe varies significantly, from the smallest bacterium with a diameter of about 0.2 μm to some unicellular animals and plants which may reach 1 mm or more in diameter.

The organisms cluster in three major domains, i.e., Bacteria, Archaerea and Eukarya. All organism in the domains of Bacteria and Archaea are microbes. Most of the branches of the Eukarya domain are microbial as well. Thus, microbes can be found virtually everywhere in the tree of life.

### *2.2 Waste Containers and Engineered Barriers*

Carefully-chosen laboratory studies have suggested that the main microbially-induced corrosion (MIC) effects would occur from sulphate-reducing bacteria (SRB)-produced sulphides at some distance from a container surface. Microbial transport through a buffer is unlikely because studies have shown that bacteria is not able to move significantly in such a compacted environment [3]. The pore size of the clay is 100-1000 times smaller than the average-sized microbes, meaning that after the microbes have died, no new microbes can enter the buffer. Microbial transport through clay-based barriers only seems feasible for a less hydraulically-tight backfill. Significant microbial activity in a backfill could have the advantage of plugging pores, thereby reducing the hydraulic conductivity of the backfill environment and reducing or preventing a radionuclide migration through this barrier.

### *2.3 Natural Barriers and Natural Analogue Studies*

Several projects, using experimentally independent methods, have pointed out the oxygen reduction capacity of microbes in hard rock aquifers and tunnels [3]. All indicate that a large benefit of microbes for a repository performance is their capacity to protect the host rock and repository from oxygen, and their production of groundwater components which lower the redox potential. Some natural analogue studies have also shown that the microbial activity decreases the redox potential but it is premature to conclude whether the redox of the groundwater is coupled with the reduction activities of the found microorganisms. Sometimes, however, microbes are directly involved in a radionuclide reduction like the reduction of U(VI) to U(IV).

## 3. Microbial Effects on Radionuclide Migration

Microbial processes can significantly alter the mobility of radionuclides in the environment. Microbial processes will be immobilizing or mobilizing, depending on the type of process and the state of the microbes (Figure 1). Especially, bacteriogenic iron oxide (BIOS) accumulates various metals. Distribution coefficients ($K_d$ values) extend from 1 to $10^5$ suggesting that a metal uptake is strongly influenced by the relative proportion of the bacterial organic matter in the composite solids.

Microbial effects in a waste repository can have both positive and negative effects on the migration of radionuclides [4]. Positive effects include

- sorption of radionuclides on microbes in biofilms, which would remove the radionuclides from groundwaters,
- precipitation of radionuclides because of microbial changes to the geochemical environment in a disposal vault (i.e., changes to pH and Eh), and
- pore clogging by a profuse growth in porous materials, thereby reducing the hydraulic conductivity of the materials.

Negative effects include

- transport of radionuclides sorbed on mobile cells through engineered barriers and in a groundwater,
- dissolution of radionuclides and waste forms that contain radionuclides because of microbial changes to the geochemical environment,
- MIC of waste containers (under biofilms or as a result of corrosive metabolites), and
- gas production(e.g., methane), causing a pressure buildup in a repository environment.

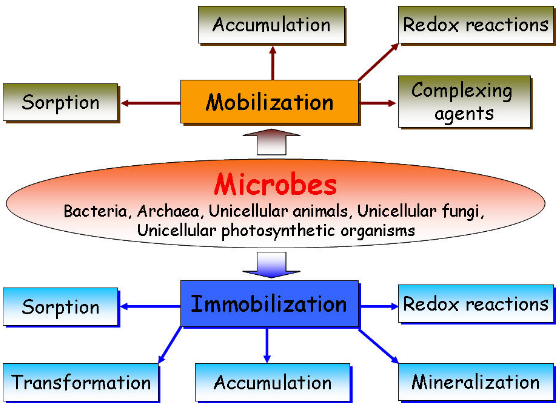

Figure 1. Schematic view of the influence from microbes on radionuclide migration.

## 4. Identification of Aerobic Microbes

Identification by a genetic analysis of selected major microbes and a characterization of the identified microbes was performed for aerobic microbes found in a groundwater sampled from the KAERI Underground Research Tunnel (KURT) located in KAERI site.

The used groundwater was sampled from a borehole at the KURT (pH=8.5, Eh=-90 mV, EC=142.6 μS/cm, DO=3.5 mg/L). Microbes were isolated from the sampled groundwater and cultivated at 25°C for 1 week in an appropriate medium. The total number of microbes sampled from the KURT groundwater was determined as $8.3\times10^4$ CFU/mL.

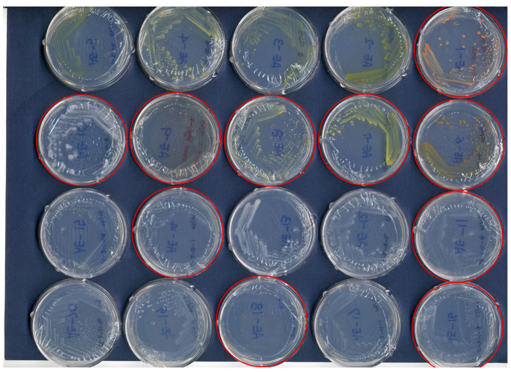
Figure 2. The used microbe samples (the samples marked with red circles are selected samples for genetic identification).

After a cultivation, a total of 80 different microbes were separated. Among them, 10 microbes were classified into 10 groups and then a major microbe was selected from each group. The 10 microbes selected from the 10 groups were identified by using a 16S rDNA genetic analysis and their major characteristics were also investigated. The used microbe samples are shown in Figure 2 and the results of the genetic identification for the 10 selected aerobic microbes are given in Table 1.

Table 1. Results of genetic identification for the selected aerobic microbes sampled from the KURT groundwater.

| Sample | Determination | Similarity (%) |
|---|---|---|
| AE-1 | *Gordonia alkanivorans* | 100.00 |
| AE-6 | *Porphyrobacter sanguineus* | 99.80 |
| AE-7 | *Parkia alkaliphia* | 99.69 |
| AE-8 | *Rhodococcus fascians* | 100.00 |
| AE-9 | *Acidovorax defluvii* | 100.00 |
| AE-10 | *Phenylpbacterium falsum* | 100.00 |
| AE-11 | *Pseudomonas sp.* | 96.61 |
| AE-15 | *Hydrogenophaga defluvii* | 99.12 |
| AE-16 | *Acidovorax temperans* | 99.11 |
| AE-18 | *Limnobacter thiooxidans* | 99.41 |

## 5. Conclusions

This study has been performed as a preliminary study (or as a feasibility study) for an evaluation of the effects and roles of microbes on the high-level radioactive waste disposal. Further studies should be carried out for an evaluation and analysis of the effects of microbes on a radionuclide migration and their interactions with minerals in subsurface environments.

## REFERENCES

[1] J. M. West, J. M., A review of progress in the geomicrobiology of radioactive waste disposal, Radioactive Waste Management Environ. Restor., Vol. 19, p. 263-283, 1995.

[2] S. Stroes-Gascoyne, K. Pedersen, S. Daumas, C. J. Hamon, S. A. Haveman, T. L. Delaney, S. Ekendahl, N. Jahromi, J. Arlinger, I. Hallbeck, K. Dekeyser, Microbial Analysis of the Buffer/Container Experiment at AECL's Underground Research Laboratory. Report AECL-11436, COG-95-446, Atomic Energy of Canada Limited, Pinawa, 1996.

[3] K. Pedersen, Microbial processes in radioactive waste disposal, SKB TR-00-04, Swedish Nuclear Fuel and Waste Management Co., Stockholm, 2000.

[4] S. Stroes-Gascoyne, F. P. Sargent, The Canadian approach to microbial studies in nuclear waste management and disposal, J. Contam. Hydrol., Vol. 35, p. 175-190, 1998.