Subsurface Microbial Ecosystems

Community Composition and Interactions with the Geosphere

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Abstract

Subsurface microbial ecosystems were investigated at ten different sites around the world. Methods were developed for sampling groundwater from boreholes without microbial or atmospheric contamination. Tracers were used to quantify the extent of contamination of sediment and rock cores from the sea floor of the Pacific Ocean, and samples were successfully collected without contamination. Forty-six groundwater samples were collected from seven sites in the Fennoscandian Shield and from one site in Gabon, Africa. Groundwater was collected from depths of 6 to 1425 m below the surface. Groundwater salinity ranged from fresh to very saline. Groundwater contained 10^4 to 10^6 total cells ml^{-1}, and trend of cell numbers were stable with depth, which indicates that the igneous subsurface contains sufficient carbon and energy sources to support microorganisms. Several physiological groups of microorganisms were widespread in Fennoscandian Shield groundwater. Iron-reducing bacteria and homoacetogenic bacteria were cultured from 90 and 85% of samples tested, respectively. Sulfate-reducing bacteria were cultured from every Fennoscandian Shield sample tested from depths of 34 to 721 m, but not from deeper samples. Sulfate-reducing bacteria may be inhibited by energetic restrictions in very deep groundwater where iron-reducing bacteria are found because use of iron as terminal electron acceptor yields more energy than sulfate. Homoacetogens are well suited to subsurface aquifers because they are metabolically versatile and capable of switching between autotrophic and heterotrophic growth. One sample of sulfate-depleted saline groundwater contained culturable methanogens and homoacetogens and carbon stable isotope data indicate that biological processes consume dissolved inorganic carbon and hydrogen. The microbial ecosystem in this groundwater may be independent of photosynthetic organic carbon. Groundwater samples from two sites in Finland that were analysed by fluorescence *in situ* hybridisation contained 44 to 57% *Bacteria* and 29 to 34% *Archaea*, but only bacteria were cultured from these samples. Microorganisms grew in some culture media without producing detectable metabolic products. These results help to identify members of subsurface microbial communities that should be targeted in future studies. Two sites containing uranium, Palmottu in Finland and the Bangombé natural nuclear reactor in Gabon, Africa, were investigated as natural analogues for radioactive waste. Microorganisms were cultured from these two sites, as well as from the other Fennoscandian Shield sites, that carry out reactions involved in buffering the redox potential. Redox potential affects the mobility of uranium and other radionuclides, which precipitate in their reduced forms. By affecting redox potential, subsurface microorganisms may help to stabilise nuclear waste disposed of in the subsurface. The Earth's subsurface contains similar microbial ecosystems in different hydrogeochemical environments that interact with the geosphere.

Keywords: contamination, groundwater, homoacetogenic bacteria, igneous rock, iron-reducing bacteria, methanogenic archaea, sulfate-reducing bacteria, uranium.

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