Membrane-dependent microbial inhibition during CO_2 sequestration: Implications for the alteration of subsurface community composition

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Background

When CO_2 is stored in deep saline aquifers, many geochemical changes will occur due to CO_2 dissolution [1]. High PCO_2 will also perturb the existing microbial communities that influence the geochemistry of the reservoir through their metabolic activities.

The CO_2 molecule itself is toxic to microorganisms. It is easily permeable through cell membranes changing membrane fluidity, the proton pump, and intracellular pH [2]. Adaptations that slow the diffusion of CO_2 into the cell, like biofilms and thick cell walls, will be selected for in the new environment.

In this study, we assessed the tolerance of several representative organisms to high PCO_2 based on their membrane morphologies: the Gram-negative bacterium *Shewanella oneidensis*, the Gram-positive bacterium *Bacillus subtilis* sp0A mutant, the Gram-positive endospore forming bacterium *Geobacillus stearothermophilus*, and the methanogenic archaeon *Methanothermobacter thermoautitrophicus*.

Results and Conclusions

Results show the Gram-negative organism is the most susceptible to CO_2 toxicity surviving a maximum pressure of 25 atm for 2 hours. However, when grown in the presence of a mineral, survival time increases beyond 8 hours due to biofilm formation. Archaea can withstand 50 atm of CO_2 for 8 hours and Gram-positive endospores can handle 50 atm of CO_2 for at least 24 hours potentially due to thick and rigid cell membrane or wall compositions.

Images taken by transmission electron microscopy show all experimental organisms have a threshhold tolerance to CO_2. We observed clumping of cytoplasmic contents at differing CO_2 pressures suggesting CO_2 plays an effect in altering intracellular activity. Lipid profiles of the bacteria also show a decrease in concentrations of monounsaturated or of short-chained fatty acids during CO_2 exposure indicating CO_2 causes a loss in cell viability.

Our findings suggest that during CO_2 sequestration, biofilms, Gram-positive endospores, and methanogens are organisms that will survive in the new environment. Because each organism varies in their CO_2 tolerance, regions surrounding the CO_2 plume may eventually form where different organisms are most active This in turn can have effects on mineral precipitation catalyzed on cell membranes and the geochemistry of the greater subsurface.

[1] Kharaka et al. (2006) *Geology* **34**, 577-580. [2] Hong and Pyun (1999) *Journal of Food Science* **64**, 728-733.

In situ remediation and pedogenesis in bauxite residue ('red mud')

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Introduction

'*In situ*' approaches to tailings management typically address unfavourable properties of the tailings after deposition in storage areas by surface application of treatments. In the case of bauxite residue, *in situ* remediation means selecting treatments that will aid in lowering pH from values of >12 to <9, lowering electrical conductivity from values of >4 dS/m to <1 dS/m, and that will stimulate biological activity in the initially sterile tailings. Treatments including sewage sludge, tillage, green waste, dredge spoil, and topsoil were applied at a bauxite residue ('red mud') storage area in Corpus Christi, Texas.

Results and discussion

Rainfall leaching (for 40 years) prior to amendment removed excess soluble salts, but not all residual sodalite ($Na_8(AlSiO_4)_6Cl_2$) and calcite ($CaCO_3$) which slowly dissolve and continue to buffer pH at values >8. Substantial replacement of Na^+ with Ca^{2+} has occurred on cation exchange sites, particularly in surface residue layers. Calcite dissolution, facilitated by rainfall leaching and organic acids and $CO_{2\,(g)}$ from plant roots, may provide Ca^{2+} for this exchange.

Bauxite residue pore water was high in Al, Ca, Fe, Na, and Si. Formation of gravel in the residue was attributed to precipitation of aluminosilicate coatings on surfaces exposed to the atmosphere during drying and cracking of residue (Figure 1). Some pores in the gravel contained nordstrandite or bayerite (both $Al(OH)_3$). Given that silicate inhibits crystallisation of aluminium hydroxides from solution [1], it appears that the aluminosilicate coatings formed first, lowering Si content of pore water, which then allowed precipitation of nordstrandite/ bayerite inside the gravel pores after further drying.

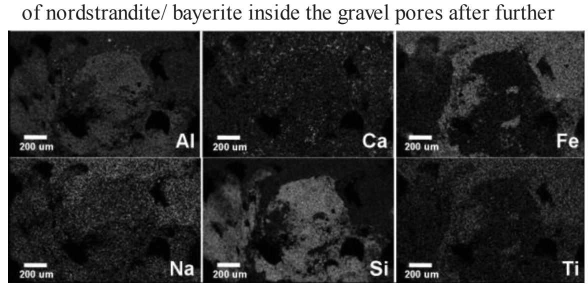

Figure 1: Element maps from gravel with aluminosilicate coating.

Sewage sludge was more effective than dredge spoil or topsoil in lowering bauxite residue pH, and increasing total N and extractable NH_4^+. Sewage sludge outperformed other treatments in terms of generating a suitable soil-like medium for plant cover, and addressing high pH and lack of plant nutrients such as organic C and N, K, Mg, and P in bauxite residue. Applied treatments can influence bauxite residue chemistry and mineralogy, and improve soil formation and *in situ* remediation.