Bioremediation of Chlorate and Chromate Contaminated Groundwater in Cold Climate

Mehdi Motevasselin, Beata Gorczyca and Richard Sparling, University of Manitoba Indra Kalinovich, Dillon Consulting

Objective and Problem Statement

Chlorate (ClO₂-) and chromate (CrO₂²-) are two widespread groundwater and soil contaminants of pulp and paper mill industries. Guidelines for Canadian Drinking Water Quality (GCDWQ) specify maximum allowable concentration (MAC) for chlorate and chromate at 1 mg/L and 0.05, respectively. Bioremediation of these chemicals, utilizing local, native microorganisms is preferred as it has the least side effects and negative impacts. The cold climate of Canada makes it necessary to investigate the potential efficacy of in-situ soil bioremediation under low-temperature conditions. This research evaluated the ability of the local microbial community to degrade chlorate and chromate in groundwater using microcosm tests. The availability and role of carbon sources (acetate), nitrogen, phosphorous (macronutrients), and minerals (micronutrients as ATCC 1191 media) were also studied to optimize the process.

Methodology

Microcosm experiments were conducted with synthetic water prepared with 1000 mg/L of chlorate and 3 mg/L of chromate based on Manitoba's site-specific groundwater analyses (Table 1). Five series of triplicate bottles were filled with 400 mL of synthetic groundwater. Each bottle received 2 g of soil and 0.5 mL of groundwater as inoculum from the site. Test conditions included the following: a Control (C) with a carbon source only, (CM) a carbon source and minerals, (CNP) a carbon source with macronutrients, and two final sets with a carbon source, minerals and macronutrients (CNPM), run at room temperature (21°C) and cold conditions (10°C). An aliquot of water from the microcosm was filtered to analyze chlorate and chromate concentrations, with IC and HACH machines, over a test period of 80 days.

Table 1 - Contaminants concentrations based on sitegroundwater analysis

Component	Max. Concentration	
	(mg/l)	(mMol/l)
Chlorate	3900	46.71
Chromium(VI)	3.03	0.058
Ph <mark>osphorus</mark>	4.16	0.134
Sulfate	672	9.73
рН	7.25-8.07	

Results and Discussion

Chlorate and chromate were entirely removed in microcosms containing acetate, nitrogen, and phosphorous (CNP, CNPM) at 21 and 10°C. The lower temperature was observed to slow the reaction rate, taking 80 days to reaction completion instead of approximately 35 to 50 days (Figures 1, 2).

Chlorate and chromate concentrations in water did not change in samples containing additional acetate (C) or acetate and minerals only (CM) (Figures 1, 2).









It was found that chloride concentration in water could be used as an indicator for chlorate reduction completeness. Figure 3 shows the increasing chloride concentration in water. Stoichiometric calculations comparing chlorate loss and chloride production confirmed a mass balance.

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Figure 3- Chloride production by time

This research study demonstrated that the local microorganisms already present at the site could reduce chlorate and chromate below the applicable drinking water criteria, provided that they receive the organic carbon, nitrogen and phosphorous. An in-situ remediation approach of enhanced bioremediation was proven to be a suitable option to remediate chlorate and chromate impacted groundwater under cold conditions.

Mehdi Motevasselin

Mehdi Motevasselin has a master's degree in chemical engineering, minor in biotechnology from Iran. He studied oil-contaminated sites bioremediation in his first master and worked for seven years in the oil and energy industries as a process engineer. He is currently an M.Sc. student in the Civil Engineering Department at the University of Manitoba and working on remediation methods of chemically contaminated soil and groundwater sites in Canada.