Impacts of fugitive methane from energy resource development on shallow groundwater chemistry

A. G. CAHILL[1], B. L. PARKER[1], J. A. CHERRY[1], B. MAYER[2], K. U. MAYER[3], K. KULOYO[2] AND A. HAGMANN[1]

[1]G360 Centre for Applied Groundwater Research, University of Guelph, Ontario, Canada (Email: aarc@g360group.org)

[2] Applied Geochemistry Group, Department of Geoscience, University of Calgary, Calgary, Alberta, Canada

[3] Department of Earth, Ocean and Atmospheric Science, University of British Columbia, BC, Canada

Development of natural gas resources has propensity to mobilize methane (CH_4) from deep and intermediate depths resulting in gas contamination of fresh groundwater resources. During groundwater contamination, CH_4 may be attenuated by microbially mediated redox reactions, changing the chemistry of groundwater fundamentally. Whilst attenuation removes CH_4 mitigating explosion hazards, it also degrades groundwater quality by inducing reducing conditions, generating undesirable bi-products (e.g. NH_4^+, H_2S, Fe^{2+}, Mn^{2+}) and potentially releasing harmful trace metals. To the best of our knowledge, no field or laboratory studies of such processes have been undertaken in an energy resource development context. Consequently, a controlled methane release experiment was conducted in 2015 at the Borden research aquifer in Ontario, Canada. During the experiment 51.4 m^3 of methane (34.9 kg at 1.013 bar and 15 °C) were injected into an unconsolidated, phreatic beach-sand aquifer over 72 days (at 3 rates) at depths of 4.5 and 9 m. During and following injection, aqueous chemistry was monitored in 32 observation points using multilevel groundwater wells with approximately 1000 samples collected over 300 days. Additionally, targeted sediment extractions were performed before and after CH_4 release to quantify and characterize mineral alteration related to CH_4 oxidation reactions. Results show gas injection caused stratigraphically controlled, erratic and variable increases in $[CH_4]_{(aq)}$ with little attenuation evident. Following cessation of injection, $[CH_4]_{(aq)}$ initially continued to increase signficantly then appeared recalcitrant with indication of only weak attenuation after 127 days. Throughout the experiment groundwater chemistry evolved in complex and dynamic patterns including fluctuating pH, changes in major and minor ion concentrations, mineralogical alteration and signficant shifts in microbial communities (i.e. increased methanotrophs). Results have profound implications for potential risks posed to groundwater by fugitive CH_4 and its attenuation potential.