geoconvention Virtual Event 2020 September 21-23
CSPG • CSEG • CWLS • GAC • MAC • IAH

Investigating the long-term effects of thermal recovery operations on arsenic in groundwater

Cassie M. Stead, Andrew T. Craig, and Richard T. Amos
Carleton University

Summary

Steam assisted gravity drainage is a form of thermal recovery technology used for unconventional oil. It can result in the heating of surrounding sediments and associated porewater and has the potential to mobilize otherwise immobile groundwater contaminants, such as arsenic. The current study was conducted to analyze geochemical reactions within a column to gain a better understanding of the long-term effects of thermal recovery operations on groundwater contamination, with an emphasis on arsenic. A temperature range of 50 °C to 90 °C was implemented within a heated section of the column to mimic thermal influence on an aquifer adjacent to a steam assisted gravity drainage well. The column was cooled to 18 °C to 25 °C in a separate section to mimic more natural temperatures. During the year-long study, aqueous concentrations of silica, arsenic, aluminum, titanium, and zinc were found to increase within the heated section of the column and decrease within the cooled section of the column. This behavior was primarily the result of changing pH and surface complexation processes.

Method

Overall, the experiment was designed to mimic a fully saturated aquifer unit in contact with an in-situ thermal recovery well; accomplished by using aquifer sediments collected from the Athabasca Oil Sands (In-Situ) area in Alberta and by conducting the experiment entirely in an anaerobic chamber. A section of the column was heated using cartridge heaters. This section was followed by a cooled section, which consisted of stainless-steel cooling lines that ran inside the column to circulate cold water. Inflow water to the column was sourced from a 25 L Nalgene carboy of deionized water, which was flushed with nitrogen gas to remove dissolved oxygen. Both aqueous and sediment samples were collected at various sampling ports along the length of the column. Aqueous samples were analyzed for pH, dissolved oxygen, sulphate, sulphide, alkalinity, and metal concentrations. The sediment was analyzed using X-ray powder diffraction and electron microprobe analysis to characterize the sediment. Modelling was performed to determine the saturation indices of particular minerals detected within the sediment to determine the likelihood of precipitation and/or dissolution reactions.

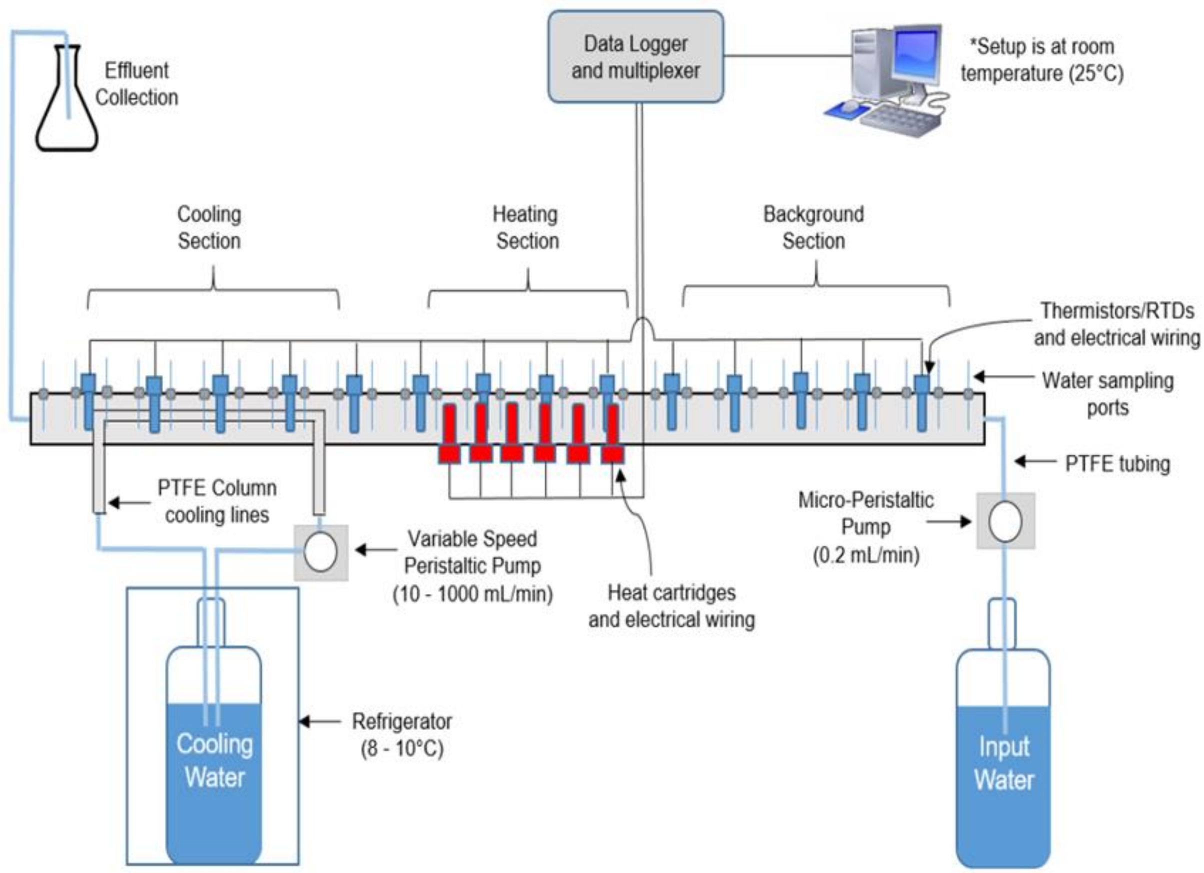

Figure 1. Schematic design of the column set-up used throughout the duration of the experiment (Craig, 2017).

Results, Observations, Conclusions

While many of the parameters measured were quite varied during the study, some important trends were observed. The pH, as well as aqueous concentrations of arsenic, aluminum, titanium, and zinc, generally increased in the heated section of the column and decreased in the cooled section of the column. This trend was attributed to mineral solubility and surface complexation. The silicates that were modelled during this study, including quartz, microcline, albite, and muscovite, were all generally undersaturated within the heated section of the column, suggesting they could have been dissolving in that part of the column, leading to the release of alkaline ions. Calcite, however, was oversaturated in the heated section during parts of the study. The resulting increase in pH in the heated section of the column likely resulted in the release of arsenic. In the heated section, pH was neutral-basic and cation adsorption was likely favored. Competition for surface sites likely lead to the desorption of anions, such as arsenic. In the cooled section, the pH dropped and was neutral-acidic. Here, anion adsorption was likely favored, leading to the attenuation of arsenic through adsorption. Arsenic was detected in the column by electron microprobe analysis in sulphide and phosphate grains. In conclusion, the results demonstrated that temperatures from 50-90 °C have the potential to release contaminants, such as arsenic, primarily through sorption processes.

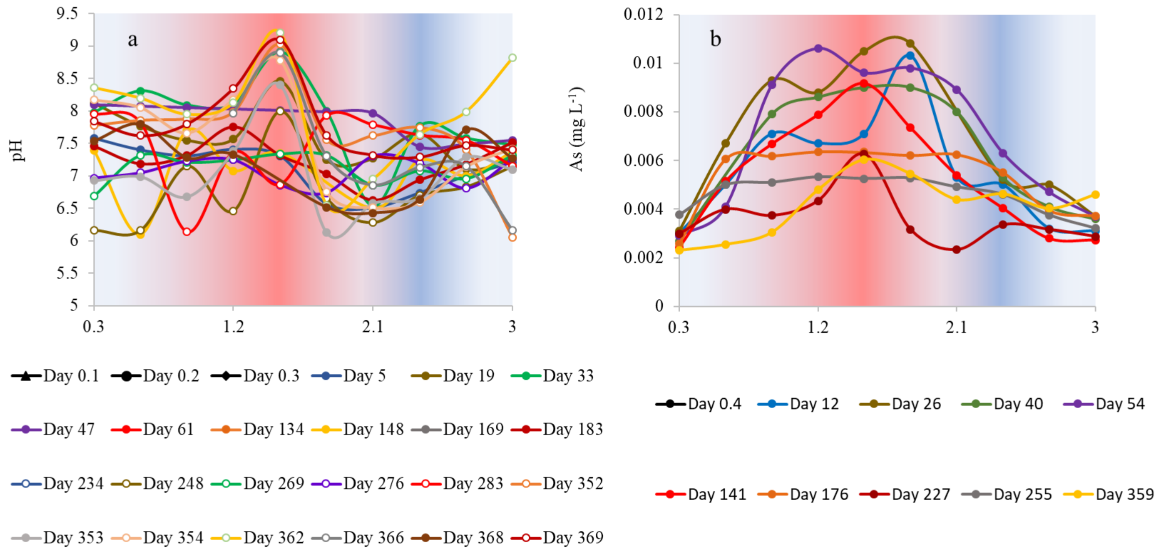

Figure 2. Measured pH (a) and aqueous concentrations of arsenic (b) along the length of the column, underlain by a gradient highlighting the heated (red) and cooled (blue) sections of the column.

Acknowledgements

We would like to thank Dr. Tom Al (University of Ottawa) and Dr. Paul Gammon (Geological Survey of Canada) for helpful insights. For the preparation of thin sections, we would like to thank Timothy Mount (Carleton University). For the prompt and quality geochemical analyses of various samples we would like to thank Dr. Nimal De Silva (University of Ottawa), Dr. Maryam Shahabi Far (Carleton University), and Lilianne Pagé (University of Ottawa).

References

Stead, C., (2020). Using a heated column experiment to investigate the long-term effects of thermal recovery operations on the release, mobilization, and attenuation of arsenic in groundwater. Carleton University.

Craig, A., (2017). Using heated column experiments to investigate the effects of in-situ thermal recovery operations on groundwater geochemistry in Cold Lake, Alberta. Carleton University.