A spatial-temporal study of the microbial-geochemical responses associated with groundwater heat pump systems

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Abstract

This project investigates the microbial and chemical responses to an eventual development and operation of groundwater heat pump systems, which make use of aquifer fluid for energy-efficient cooling of buildings in Quebec City. This involves understanding the change in microbial and chemical properties of the aquifer fluid as it travels through the system, along with the associated implications toward groundwater quality and equipment performance. Optimization of potential resource and equipment performance will also be investigated. Due to the early stage of this project, this short paper outlines the current overall concept and plan for the project.

1. Introduction

A substantial amount of heat is released into the atmosphere as a result of conventional building cooling methods. This contributes to the formation of urban heat island over time, which is expected to become a significant issue with climate change. Akbari (2005) shows that for every 1°C increase in air temperature above 22°C in Los Angeles, smog incidence is increased by 5%. This project investigates the potential of groundwater heat pump (GWHP) systems as a form of energy efficient cooling in Quebec City, with a specific focus on microbial and chemical responses resulting from the development and operation of such technology (Figure 1).

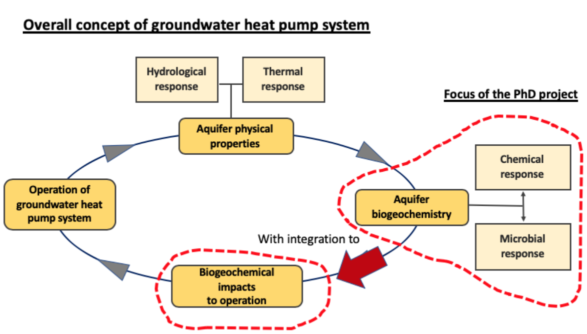

Fig. 1 Biogeochemical impacts to groundwater heat pump systems

With the operation of GWHP systems, aquifer fluid is extracted from groundwater wells and is used for cooling buildings, before being injected back into the aquifer. Because the fluid warms up as it cools the buildings, fluid temperature in the injection well is higher than in the extraction well. While open-loop systems are more efficient and more economical than closed-loop systems, potential concerns with this type of design include microbial-induced corrosion and clogging, mineral precipitation, and growth of pathogenic microorganisms, both in the system components themselves, and in the aquifer. These impacts may result from: 1) an increased temperature of the injected fluid, 2) mixing of fluids with different redox conditions during pumping, 3) changing redox conditions of the fluid as it flows through the system, 4) microbial dispersal due to injection, and 5) changes in the chemical-physical environment of microorganisms in the aquifer (Bonte et al. 2013, Griebler et al. 2016 and Burté et al. 2019). In order to assess the potential implications, it is important to understand how the different controlling factors influence the chemical and microbial properties of the fluid as it travels through the system.

2. Project concept and research objectives

This project is organized into three parts.

Part 1 aims to understand the chemical and microbial responses as aquifer fluid travels through different stages of an GWHP system (Figure 2), taking into consideration different factors such as seasonal variation (Zhou et al. 2012), aquifer formation type (Bai et al. 2016; Maamar et al. 2015), flow rate (Taylor et al. 2004), relation between bacterial cell properties and transport/retention (Bai et al. 2016, McBumett et al. 2018), and suspended versus attached bacteria in aquifer (Lehman et al. 2001). This will be achieved through various laboratory experiments.

Part 2 aims to integrate the knowledge of biogeochemical responses gained through the laboratory work and use it to predict impacts on groundwater quality (i.e. pathogenic bacteria *legionella*) and equipment performance (e.g.: microbially-induced corrosion/ clogging).

Part 3 aims to propose avenues for mitigating implications and optimising potential resource and equipment performance. This will be done by applying knowledge obtained towards developing criteria for appropriate system design and optimal operational regime (such as optimal injection fluid temperature with consideration of mineral solubility or well casing depth to avoid mixing of shallow oxic and deeper anoxic fluids (Possemiers et al. 2016).

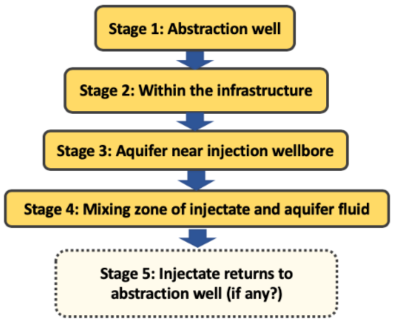

Fig. 2 Transportation of aquifer fluid through different stages of the GWHP system

3. Methods

In order to achieve the objectives mentioned above, this project will involve fieldwork (including aquifer characterisation and pilot tests), laboratory column experiments and reactive transport modelling (Figure 3).

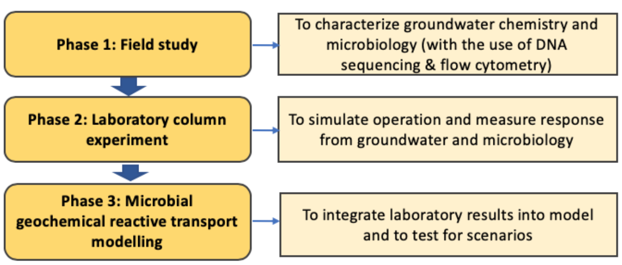

Fig. 3 Three main phases of the project

4. Conclusions

To mitigate the presence of urban heat islands which are amplified as a result of conventional cooling methods, the potential of groundwater heat pump system as a form of energy efficient cooling method will be investigated. This project will assess the microbial and chemical responses of such heat pump systems within the system components, and in the surrounding aquifer. This project aims to:

- Determine the controlling factors that influence the chemical and microbial properties of the aquifer fluid as it travels through the system.
- Understand the associated microbial and chemical impacts towards groundwater quality and equipment performance.
- Apply knowledge obtained towards mitigation of implications and optimization of resource and equipment.

5. Acknowledgments

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