Geochemistry and Microbial Communities in Iron- and Manganese-Enriched Cold Groundwater Biofiltration Units

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INTRODUCTION

On-site pilot-scale biofiltration experiment

The groundwater in Langham, Saskatchewan is a crucial drinking water source. However, it appears that the local groundwater source is frequently rich in iron (Fe) and manganese (Mn), and often does not meet drinking water standards (Fe: 0.3 mg/L and Mn: 0.05 mg/L).

In general, ***Fe (II)-oxidizing (FeOB)*** *and* ***Mn (II)-oxidizing bacteria (MnOB***) are ubiquitous in subsurface environments. Indigenous cold-adapted FeOB and MnOB are potentially present in the local groundwater. Therefore, a pilot-scale ***biofiltration technology*** that uses anthracite (coal-based filter media) was assessed for the *in situ* treatment of groundwater at the Langham Water Treatment Plant.

Objective: In particular, the groundwater temperature at the site is consistently low, between 4 to 8 °C, which likely hinders on-site microbial activity in the biofiltration unit that continuously receives cold influent groundwater.

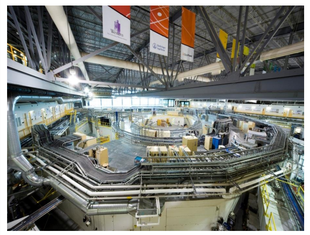
The objective of the study is to ***elucidate the geochemical responses and identify cold-adapted FeOB and MnOB populations in the cold groundwater biofiltration unit***.

On-site pilot-scale biofiltration unit at the Langham Water Treatment Plant (Filter-1: Fe-biofilter; and, Filter-2: Mn-biofilter)

Anthracite was used as a biological supporting material and to immobilize Mn, provide surface area, and promote Mn-oxide-enhanced autocatalytic Mn oxidation.

ANALYTICAL METHODS

Synchrotron-based X-ray Absorption Near-Edge Structure (XANES)



Canadian Light Source (CLS)

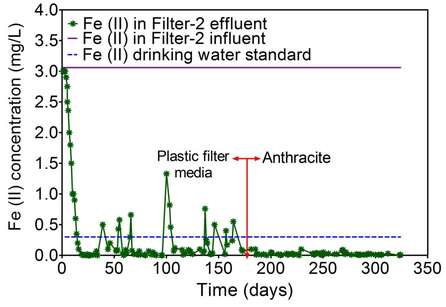
Synchrotron-based XANES spectroscopic analyses were performed at the CLS to assess **the oxidation states of Mn** in groundwater collected from the pilot-scale biofiltration unit.

Illumina next-generation sequencing

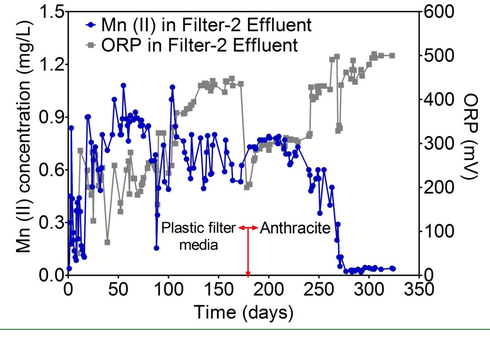
Changes in microbial community compositions were assessed based on **16S ribosomal RNA gene amplicons** in influent and effluent groundwater samples collected from the biofiltration units.

RESULTS AND DISCUSSION

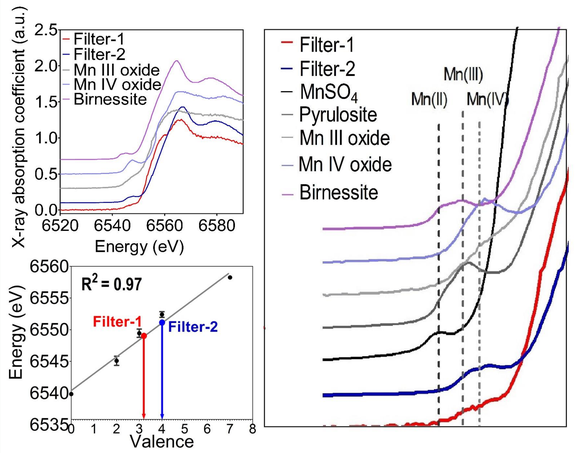
Rapid Fe (II) oxidation at 8 ºC



Strong correlation between Mn (II) oxidation and Oxidation-Reduction Potential (ORP)

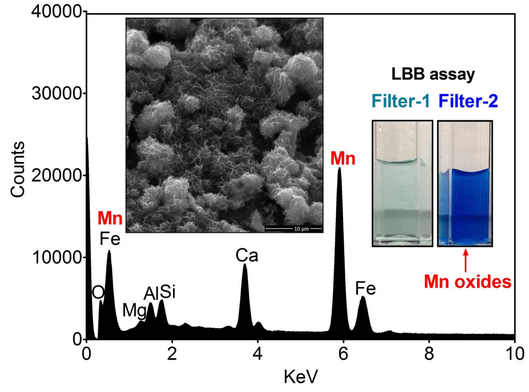


The Mn K-edge XANES spectrum shift: the occurrence of Mn oxidation

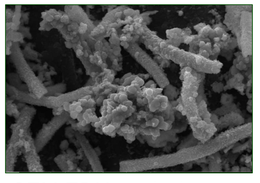


Mn oxides in the Mn-biofilter (Filter-2)

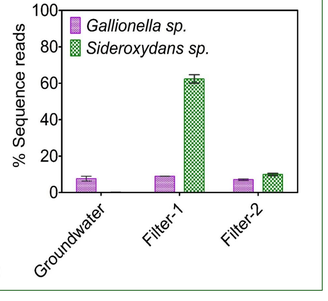
Scanning Electron Microscopy - Energy Dispersive X-ray (SEM/EDX) analysis and Leucoberbelin Blue (LBB) colorimetric assay



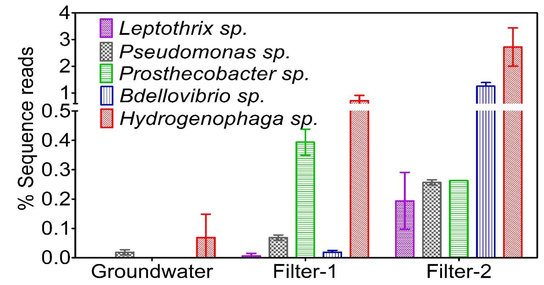
Increased abundance of Fe (II)-oxidation-related bacteria

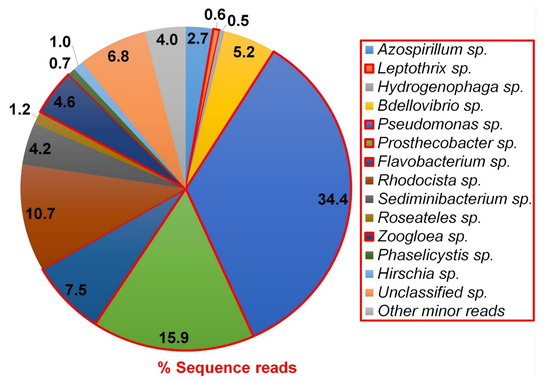


SEM/EDX analysis: Fe oxides and bacteria in the Fe-biofilter (Filter-1)



Increased populations of relatives of MnOB in the Mn-biofilter (Filter-2)





CONCLUSION

- Both Fe and Mn were removed at the *in situ* groundwater temperatures (8 ºC) through the pilot-scale biofiltration unit.
- The Fe oxidation was very rapid; however, a significant acclimation period for Mn oxidation was observed.
- The onset of Mn oxidation occurred as the ORP reached over +300 mV, at which point the removal efficiency for Mn was consistent at 97%.
- The XANES analyses identified the changes in Mn oxidation states from Mn (II) to Mn (III and IV). The formation of Mn oxides on the anthracite filter media was further confirmed.
- The *Illumina* sequencing analyses identified significant bacterial populations related to FeOB and MnOB in the biofiltration units.

Acknowledgements

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