Biologically mediated reductive dissolution of Mn oxide in river-recharged aquifers: groundwater geochemistry results from laboratory investigations

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The City of Fredericton obtains all of its drinking water from the Fredericton Aquifer, a glacio-fluvial deposit located in the Saint John River Valley in the downtown area of the city. Pumping began from a single production well in 1955, and currently there are eight wells installed in the aquifer. Manganese (Mn) concentrations in some of the production wells have increased over the years to levels above the Canadian drinking water guideline, prompting the construction of a Mn treatment plant in 1989. The Saint John River and the Fredericton Aquifer are hydraulically connected and it is hypothesized that Mn oxides in the aquifer undergo reductive dissolution due to the influx of dissolved organic carbon (DOC) with infiltrating river water. The reductive dissolution of Mn oxides may also cause trace metals, commonly associated with oxides, to be released into the drinking water. This study focuses on the Mn-oxide reduction zone that may develop in aquifer systems that become anaerobic. Laboratory sand columns were constructed to provide an estimate of Mn reductive dissolution rates for Fredericton Aquifer sand, and to identify the geochemical processes that occur as a result of Mn-oxide reduction. The columns were filled with a mixture of silica sand and Mn oxide from the Fredericton Aquifer. One column was inoculated with microorganisms from Saint John River sediment, and a second control column was not inoculated. For a period of 250 days, a continuous flux of DOC-containing water (CH3COOH) was passed through the columns under anaerobic conditions. Results from the column experiments indicate that Mn(II) concentrations in the groundwater can be expected to increase (to a range of 3 to 4 mg/L) as a result of microbiologically mediated reactions involving DOC. Also, the data indicate that cation exchange reactions are an important control on Mn and other cation concentrations in the groundwater system. Based on the laboratory experiments, the influx of DOC with infiltrating water causes an initial increase in the aqueous Mn(II) concentration that results from the combined effects of reductive dissolution of Mn oxide and cation exchange reactions. This is followed by an asymptotic decline to a lower but still elevated Mn(II) concentration that is limited by the rate of the microbial Mn-oxide reduction reactions.

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