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# Effect of pumping on the spatio-temporal distribution of microbial communities in a water well field

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ABSTRACT

A water well field adjacent to the North Saskatchewan River (City of North Battleford, Saskatchewan, Canada) with a history of rapid deterioration of both well water quality and yield was selected to study the spatial and temporal distribution of subsurface microbial communities and their response to water pumping. A range of conventional cultural, microscopic and molecular techniques, including confocal laser scanning microscopy (CLSM), Biolog, qPCR and Denaturing Gradient Gel Electrophoresis (DGGE), was used during this study. Redox data and water and sediment chemistry showed that the aquifer was anoxic and harbored substantial amounts of Fe and Mn. CLSM analyses of incubated coupons indicated extensive biofilm growth in the zone immediately surrounding the well and was coincident with reduced water well yield. PCR screening and qPCR analyses showed that the potential for iron- and sulfate-reducing activity increased with proximity to the well. Bacterial communities inhabiting the zone closest to the well showed the greatest changes and differences in metabolic activities and composition as revealed by PCA (Principal Components Analysis) of the Biolog and DGGE data. The sequence analysis of all the samples revealed that *Sulfuricurvum spp.*, *Methylobacter spp.*, *Geobacter spp.* and *Rhodobacter spp.* were most commonly detected in this aquifer. Overall the findings demonstrated that the microbial numbers, metabolic activities and the community composition changed in response to water pumping but effects did not extend beyond 1–2 m zone from the well.



## 1. Introduction

Water wells installed parallel to a river, accessing the adjacent aquifers for the production of drinking water, are employed by most of Europe and certain regions of North America (Haveman et al., 2005; Hiscock and Grischek, 2002; Weiss et al., 2003). Water infiltrates into these aquifers from the neighboring river through its bottom and bank sediments by a process called bank filtration (Hiscock and Grischek, 2002; Kuehn and Mueller, 2000; Tufenkji et al., 2002; Weiss et al., 2003). The introduction of river water into the bank sediment may result in physical, chemical and biological changes in terms of concentrations of metals, carbonates, and organic matter which in turn can affect a range of biogeochemical processes in the aquifer (Bourg and Bertin 1993; Goldschneider et al., 2007; Lovley, 2006; Tufenkji et al., 2002).

Microbial heterotrophic activity in the aquifer may metabolize the dissolved organic carbon (DOC) using (and depleting) dissolved oxygen (DO) as terminal electron acceptor, leading to the reductive dissolution of Fe and Mn

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oxides present in the aquifer sediments and the infiltrated river water (Lovley, 1987; 2006). Conversely, aquifers may experience recharge by infiltration of surface water rich in DOC and oxygen by pumping of water near production wells, leading to a shift from anaerobic to aerobic processes. These conditions could result in the oxidative precipitation of dissolved metals such as Fe and Mn and stimulation of microbial growth (Bourg and Bertin 1993; Haveman et al., 2005; Hiscock and Grischek, 2002; Tufenkji et al., 2002; van Beek, 1989). Generally, the above biogeochemical processes would contribute to the plugging of flow paths, riverbed and well infrastructure (Howsam, 1987; Goldschneider et al., 2007; van Beek, 1989), the extent of which may vary seasonally and in response to pumping fluctuations (Kwon et al., 2008; Tufenkji et al., 2002).

The city of North Battleford is a community situated in western Saskatchewan, Canada, which depends in part on groundwater extracted from wells installed adjacent to the North Saskatchewan River for drinking water. Historically, these wells have undergone rapid deterioration in both well yield and water quality; however, the underlying cause is unclear. Continuous pumping of the well may draw water from disparate portions of the aquifer changing the physical and chemical parameters like temperature, pH, DO, DOC and various biologically-sensitive parameters including concentrations of Fe (II), sulfide and sulfates, with time (Kwon et al., 2008). A shift in these parameters could then directly affect cell density and variations in the composition of the microbial community (Kwon et al., 2008). To date, only a few studies have examined the spatio-temporal distribution of microbial communities in aquifers (Brad et al., 2008; Tiquia et al., 2008; Velasco et al., 2009) using combinations of installed piezometers and production wells, and they demonstrated spatial heterogeneity and temporal variability in microbial distribution. Accordingly, the main objectives of this research were to characterize the aquifer's microbial communities at various locations from riverine recharge to the production well, and to evaluate their potential for contributing to altered biogeochemistry, their response to pumping and fouling of the aquifer, and their effect on water well yield. The microbiology of water, sediment and biofilms was thus evaluated using a range of conventional culture, microscopic and molecular techniques.

## 2. Materials and methods

### 2.1. *Study location and well installation*

The water well capture zone site is located at the western end of North Battleford's well field (SE ¼-12-44-17-W3 and NE ¼-1-44-17-W3). The aquifer is unconfined in alluvial sand and silt, consisting of fluvial deposits of reworked sand and incorporated organic matter. A 20 m deep research production well with a water conducting screened zone from 12 m to 18 m below surface (6 m total screen length) was installed and operated in parallel (continuous operation, approximately 90 igpm (Imperial gallons per minute) pumping rate) to the existing wells run by the City of North Battleford. An array of piezometers, consisting of 2 inch internal diameter PVC pipe with a screened section similar to the production well were installed at different horizontal distances along a transect from the riverine recharge zone up to the production well for sample collection and incubation of coupons. In the present study, two pairs of piezometers were installed in two zones (1–2 m and 5–10 m from the production well). One piezometer was for groundwater collection and the other for incubation of coupons for biofilm growth (Fig. 1).

### 2.2. *Sample collection and chemical analyses*

Water samples were collected from piezometers in the well system at eight intervals over a period from June 2007 to January 2009 using peristaltic pumps. Biofilm samples were obtained by incubating polycarbonate strips (1 × 10 cm) in holders positioned at the top (12.2–13.2 m), middle (14.7–15.7 m) and bottom (17.3–18.3 m) of the water column in piezometers corresponding to the screened length of the

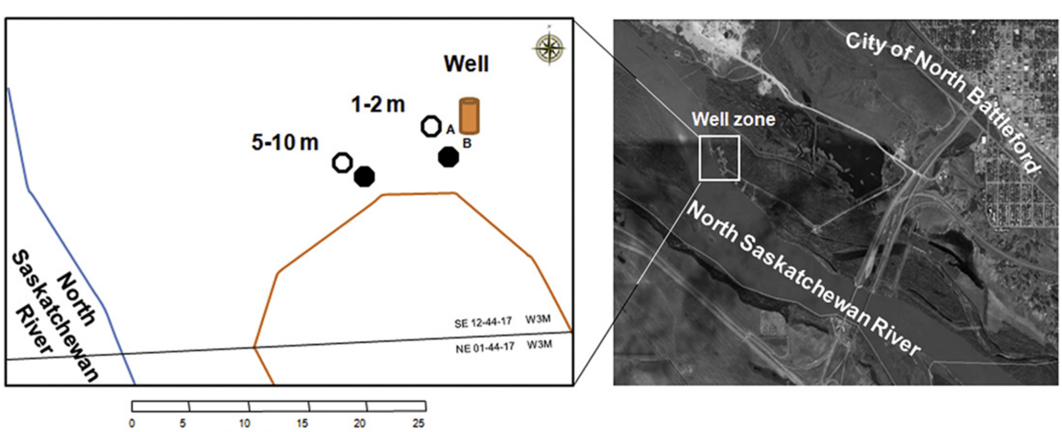


**Fig. 1 – Location of the North Battleford well field showing the production well and sample collection sites situated adjacent to the North Saskatchewan River (Google Earth image). Letters A (*T* = 0) and B (*T* = Final) indicate the sediment core locations. At the 1–2 m and 5–10 m zone the open circles and solid circles indicate the piezometer locations for water collection and biofilm coupon incubation, respectively.**