Microscopic particulate analysis as a means of assessing river bank filtration in granular and fractured rock aquifers

Craig Johnston, Lesley Veale
Stantec Consulting Ltd., Kitchener, Ontario, Canada
Tammy Middleton, Eric Hodgins
Regional Municipality of Waterloo, Kitchener, Ontario, Canada

ABSTRACT
River bank filtration is recognized as an effective water treatment process in a number of jurisdictions. We present the results of in-situ filtration assessments at two municipal well fields along the Grand River, Ontario as an approach for assessing in-situ filtration. Bio-particle concentrations in the size range of Cryptosporidium were consistently 3-log lower in the Woolner wells than in the river. In comparison, bio-particle concentrations from wells at Middleton showed concentrations >4-log lower than the river, suggesting higher removal rates in the fractured rock. The bio-particle data support effective in-situ filtration processes in both the granular and fractured rock aquifers.

RÉSUMÉ
L'effet de filtration des berges riveraines est reconnu dans de nombreux territoires comme étant un processus efficace pour le traitement de l'eau. Nous présentons ici les résultats d'une étude de filtration in-situ pour deux champs de captage des eaux souterraines situés le long de la rivière Grand en Ontario. Nous avons démontré que les concentrations de bio-particules du même ordre de grandeur que la bactérie Cryptosporidium étaient inférieures de 3 log dans les puits Woolner par rapport aux concentrations mesurées dans la rivière, et ce avec régularité. En comparaison, les concentrations de bio-particules dans les puits Middleton étaient inférieures de plus de 4 log par rapport aux concentrations riveraines, ce qui suggère un taux d'extraction plus élevé dans le roc fracturé. Ces données supportent la présence d'un processus efficace de filtration in situ au niveau des aquifères granulaires et rocheux.

1 INTRODUCTION

Since the early 1900s infiltration or collector wells have been recognized as a source of high quality water due to the reduced treatment requirements created by natural filtration processes within the aquifer system. With the passing of the Long Term 2 Enhanced Surface Water Treatment Rule in the United States (USEPA, 2006), river bank filtration is now recognized in the United States as an effective water treatment process and treatment credits can be obtained for wells completed in granular aquifers meeting specific criteria.

In Ontario, under Regulation 170/03, a drinking water system that is classified as groundwater under the direct influence of surface water (GUDI) is considered a surface water supply unless it can be determined that the aquifer is providing effective in situ filtration. The current methodology in Ontario for assessing in situ filtration (MOE, 2001) is based on the effect of particle shielding on UV or chlorine disinfection treatment processes and not on science-based methods for assessing in-situ or river bank filtration.

In this study we present the results of in-situ filtration assessments at two municipal well fields along the Grand River as an approach for assessing in-situ filtration processes. The well fields are completed in contrasting geologic environments, providing evidence of filtration efficacy in both granular and fractured rock aquifers.

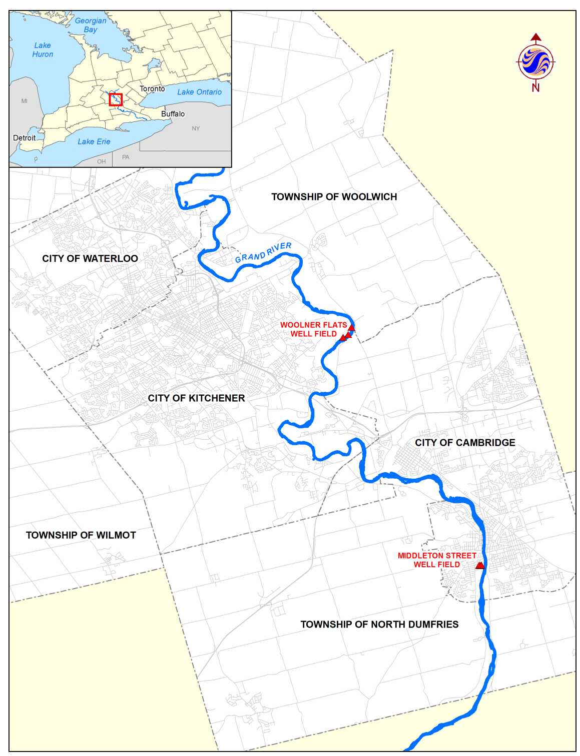

Figure 1. Study area and well field location

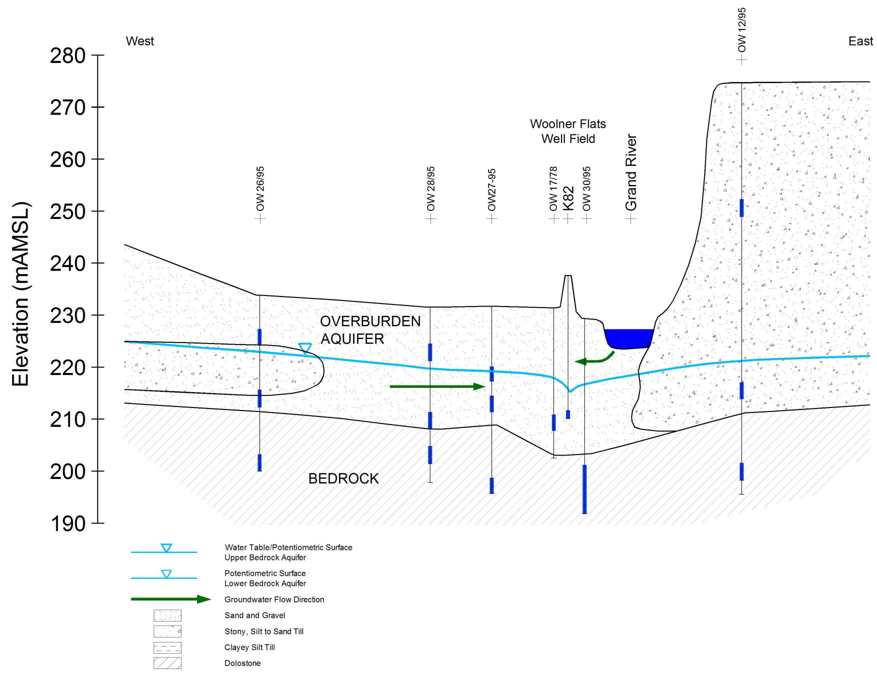

Figure 2. West-East hydrogeologic cross-sections between Grand River and Woolner Flats Well Field

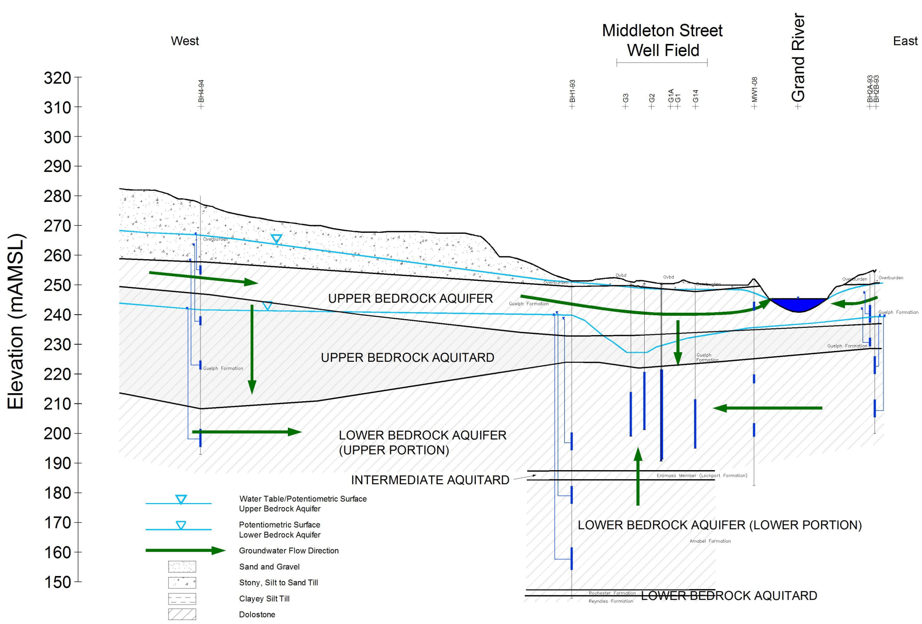

Figure 3. West-East hydrogeologic cross-sections between Grand River and Middleton Street Well Field

2 BACKGROUND

In the late 1970s a series of horizontal and vertical collector wells were installed within alluvial sands and gravels adjacent to the Grand River. One of these wells fields, the Woolner Flats Well Field, consists of three horizontal collector wells (K80, K81, K82) installed parallel to the Grand River (Figure 1). The collector wells are located within 20 m of the Grand River and are completed at depths of 6 m to 9 m below ground surface within alluvial sand and gravel deposits (Figure 2). These wells are classified as groundwater under the direct influence of surface water with effective filtration (GUDI-EF). Groundwater modelling, aquifer testing, and water quality data were used to estimate the percentage and travel time of water captured by the wells from the Grand River (Stantec, 2002). Approximately 80% to 85% of the water produced from wells K80 and K81 was estimated to originate from the Grand River, with travel times in the range of 2 to 10 days. For K82, up to 14% of the water was estimated to originate from the Grand River, with a travel time of approximately 20 days. The balance of water to the collector wells is obtained from regional groundwater flow within the shallow overburden and deeper bedrock aquifer systems.

The second well field investigated as part of this study is the Middleton Street Well Field, which is located in the southern portion of the City of Cambridge within 300 m from the Grand River (Figure 1). The well field consists of five bedrock production wells (G1, G1A, G2, G3, G14) that provide approximately 40% of the total water demand for the City of Cambridge. In the immediate vicinity of the well field, the overburden is typically between 1 m and 2 m thick, and is underlain by carbonate bedrock corresponding to the Guelph Formation of late Silurian Age. Figure 3 presents a cross-section between the well field and the Grand River. The production wells from the Middleton Street Well Field are completed in the Lower Bedrock Aquifer, which is separated from the Grand River by an Upper Bedrock Aquifer and Aquitard unit.

Water level data collected by Stantec (2007) confirmed previous data and the interpretation that in the local area of the Middleton Street Well Field, the Upper Bedrock Aquitard provides a hydraulic barrier to pumping, with water level responses attenuated by up to 99%. Based on particle tracking simulations, particles that originate from the Upper Bedrock Aquifer in the area of the Grand River reach the production wells within 160 days to 1 year, with all of the particles captured by the production wells within a 10 year time of travel. Based solely on the geologic and hydrogeologic data, the source water for the production wells at the Middleton Street Well Field would be classified as a groundwater source in accordance with MOE (2001).

3 STUDY APPROACH

MPA is used throughout the United States (USEPA, 1992), and all provinces within Canada where GUDI protocols exist (Alberta Environment, 2006; Nova Scotia, 2002; Saskatchewan, 2004), to determine groundwater/surface water influences and to estimate the filtration efficacy of aquifer materials. Microscopic particulate analysis (MPA) data provide a quantitative method for determining seasonal variations in water quality and aquifer filtration efficacy as they provide actual measurements of particulate matter that may be directly attributed to a surface water source.

Samples for MPA were collected from the individual production wells at the Woolner Flats and Middleton Street Well Fields and the Grand River between 1992 and 2008. The MPA sampling equipment was connected to a dedicated raw water sampling tap at each production well, with samples generally collected over a 24-hour period. The MPA samples from the Grand River were collected adjacent to the well fields within the Grand River by placing a submersible pump in the Grand River approximately 2 m to 5 m from the bank of the river, and slightly off the bottom of the river to avoid disturbance of sediment. MPA samples were collected using an in-line 1.0 µm nominal porosity filter contained within a flow-controlled filter housing. MPA samples were stored on ice in coolers and shipped directly to Clancy Environmental Consultants Inc. for analysis.

4 RESULTS

Of the particulate matter characterized during MPA analysis, algae provide one of the best indicators of surface water influences when repeatedly present in groundwater samples (USEPA, 1992). Figure 4 presents the algae data collected from the production wells at the Woolner Flats Well Field and the Grand River between 1995 and 2006. Algae was detected in all samples from the production wells, with no Giardia lamblia cysts or Cryptosporidum oocysts identified in any of the samples. Overall log reductions between the Grand River and the production wells were calculated by subtracting the 10th percentile algae concentration in the Grand River from the 90th percentile algae concentration from each of the production wells. The data indicate log reductions of 3-log to 4-log, with slightly higher log reductions (2-log to 6-log) for algae particles in the in the size range of *Cryptosporidium* oocysts (4-6 µm) and *Giardia* cysts (6-10 µm).

Figure 5 presents the algae data collected from the production wells at the Middleton Street Well Field between October 2005 and January 2008. Algae was detected in 5 of 8 samples (62%) from Production Well G1, 4 of 5 samples (80%) from Production Well G1A, all 9 samples (100%) from Production Well G2, 7 of 9 samples (78%) from Production Well G3, and 2 of 6 samples (33%) from Production Well G14. No *Giardia* lamblia cysts or *Cryptosporidum* oocysts were identified in any of the samples from the production wells. Log reductions were generally similar for Production Wells G1, G1A, and G14, ranging from 6-log to 8-log, while slightly lower reductions were evident at Production Wells G2 and G3, ranging from 4-log to 5-log. Size specific algae data indicated log reductions of greater than 4-log for particles in the size range of *Cryptosporidium* oocysts and *Giardia* cysts.

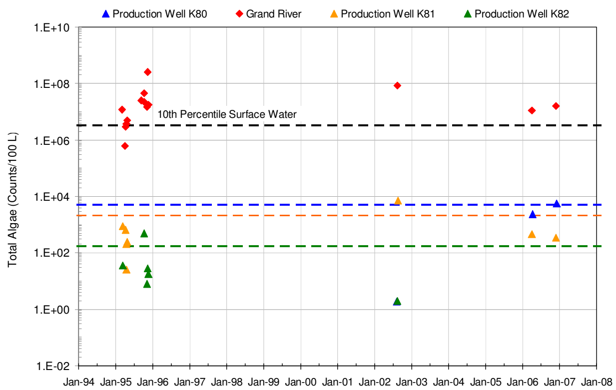

Figure 4. Algae concentrations from Woolner wells versus Grand River

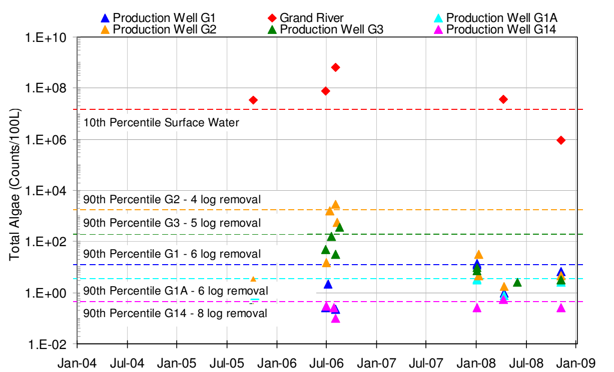

Figure 5. Algae concentrations from Middleton wells versus Grand River

5 CONCLUSIONS

The algae data from the Woolner Flats and Middleton Street Well Fields indicated log reductions of 4-log to 8-log for particles in the size range of *Cryptosporidium* oocysts and *Giardia* cysts. Travel time from the Grand River and the percentage of river water that is captured by the wells do not seem to significantly affect the algae data, with similar reductions in concentrations in both fracture bedrock and granular aquifer material. The algae data are consistent with other MPA data, indicating that despite the differences in hydrogeologic setting, similar reductions in surface water indicator particles were achieved over long time periods and under variable seasonal and climatic conditions. The MPA data support effective in-situ filtration processes in both the granular and fractured rock aquifers. Together with detailed hydrogeologic and water quality data, the approach provides a science-based methodology for determining the effectiveness of in-situ filtration processes.

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