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Persistence of artificial sweeteners in a 15-year-old septic system plume

W.D. Robertson [a,*], D.R. Van Stempvoort [b], D.K. Solomon [c], J. Homewood [a], S.J. Brown [b], J. Spoelstra [a,b], S.L. Schiff [a]

[a] University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
[b] Environment Canada, Burlington, Ontario, Canada
[c] University of Utah, Salt Lake City, UT, United States

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SUMMARY

Groundwater contamination from constituents such as NO_3^-, often occurs where multiple sources are present making source identification difficult. This study examines a suite of major ions and trace organic constituents within a well defined septic system plume in southern Ontario, Canada (Long Point site) for their potential use as wastewater tracers. The septic system has been operating for 20 years servicing a large, seasonal-use campground and tritium/helium age dating indicates that the 200 m long monitored section of the plume is about 15 years old. Four parameters are elevated along the entire length of the plume as follows; the mean electrical conductivity value (EC) in the distal plume zone is 926 μS/cm which is 74% of the mean value below the tile bed, Na^+ (14.7 mg/L) is 43%, an artificial sweetener, acesulfame (12.1 μg/L) is 23% and Cl^- (71.5 mg/L) is 137%. EC and Cl^- appear to be affected by dispersive dilution with overlying background groundwater that has lower EC but has locally higher Cl^- as result of the use of a dust suppressant ($CaCl_2$) in the campground. Na^+, in addition to advective dilution, could be depleted by weak adsorption. Acesulfame, in addition to the above processes could be influenced by increasing consumer use in recent years. Nonetheless, both Na^+ and acesulfame remain elevated throughout the plume by factors of more than 100 and 1000 respectively compared to background levels, and are strong indicators of wastewater impact at this site. EC and Cl^- are less useful because their contrast with background values is much less (EC) or because other sources are present (Cl^-). Nutrients (NO_3^-, NH_4^+, PO_4^{3-}, K^+) and pathogens (*Escherichia coli*) do not persist in the distal plume zone and are less useful as wastewater indicators here. The artificial sweetener, acesulfame, has persisted at high concentrations in the Long Point plume for at least 15 years (and this timing agrees with tritium/helium-3 dating) and this compound likely occurs at uniquely high concentrations in domestic wastewater. As such, it holds considerable promise as a powerful new tracer of wastewater impact in groundwater.

1. Introduction

Groundwater contamination from constituents such as nitrate often occurs where multiple sources are present making source identification difficult. Groundwater impacted by agricultural fertilizer and manure applications often has domestic wastewater disposal occurring in the same area and their compositions can be similar. Also in semi-arid regions such as the US southwest, infiltration basins that use reclaimed wastewater are widely used to augment aquifer recharge. Here there is a need to quantify the fraction of wastewater-sourced groundwater reaching adjacent production wells so that the extent of subsurface renovation can be established (Quast et al., 2006). Thus, there is an interest in identifying constituents that serve as intrinsic tracers of wastewater input. Nutrients and pathogens can be affected by a variety of subsurface immobilization and degradation reactions such as vadose zone immobilation (pathogens), denitrification (NO_3^-), anammox (NO_3^- and NH_4^+) and adsorption (PO_4^{3-} and K^+), making these parameters generally less useful as wastewater indicators. The minor constituent Boron (B) is mobile and persistent in groundwater and is usually elevated in domestic wastewater by a factor of about five (0.3–1 mg/L) compared to background groundwater, as a result of its use in laundry detergents. Wastewater B is also usually isotopically distinct from natural sources (Barth, 1998) and has been used successfully as an intrinsic wastewater tracer in both groundwater (Vengosh et al., 1994; Bassett et al., 1995; Bussey and Walter, 1996) and surface waters (Chetelat and Gaillardet, 2005). However concentration contrasts with background values are relatively small, and wastewater B isotopic signatures can overlap with those of other sources, such as natural B occurring in saline groundwater (Bassett et al., 1995).

* Corresponding author. Address: Dept. Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, Canada N2L 3G1.
E-mail address: wroberts@sciborg.uwaterloo.ca (W.D. Robertson).

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Some trace organic constituents that are relatively unique to domestic wastewater persist during sewage treatment and have been used successfully as wastewater tracers in both surface waters and groundwater. These include compounds such as carbamazapine and crotamiton found in pharmaceutical and personal care products (Clara et al., 2004; Heberer et al., 2004; Nakada et al., 2008; Sabourin et al., 2010), ibuprofen (Carrara et al., 2008), caffeine (Buerge et al., 2003) and estrogen active compounds (Quanrud et al., 2004). However, the degree to which these compounds persist in groundwater flow systems over multiyear and decadal timeframes has not yet been well established.

More recently, several artificial sweeteners widely used in the food and beverage industry have also been shown to resistant breakdown during sewage treatment and to persist quantitatively in surface water and groundwater environments (Buerge et al., 2009; Scheurer et al., 2009; Van Stempvoort et al., 2011a,b). These have also been suggested as potential wastewater tracers, however their longer term persistence in subsurface environments has not yet been established. In this study, our objective was to assess a spectrum of wastewater related parameters within a septic system plume that could be traced over a longer term, multiyear timeframe. The site selected was a large septic system servicing a seasonal use campground at Long Point, ON, Canada, where a well defined groundwater plume is present in an unconfined sand aquifer. Groundwater monitoring in the Tile Bed 2 area (Fig. 1) has been ongoing since it was commissioned in 1990 and the fate of a variety of constituents in the groundwater plume have been reported previously including; NO_3^- and NH_4^+ (Aravena and Robertson, 1998; Robertson et al., 2012), PO_4^{3-} (Robertson, 2008); pharmaceutical compounds (Carrara et al., 2008; Sabourin et al., 2010) and the artificial sweeteners, cyclamate, saccharin, sucralose and acesulfame (Van Stempvoort et al., 2011b). Several pharmaceutical compounds including carbamazapene and ibuprofen and several of the sweeteners, particularly acesulfame, which was approved for use in Canada in 1988 (Gougeon et al., 2004), persist in the plume, but the monitoring network used previously only extended 17–25 m from the tile bed and only intercepted the portion of the plume that was about 1 year old. However, because the septic system is 20 years old, a much longer plume is present at the site. For the current study the groundwater monitoring network was expanded in 2010, by the installation of an additional 23 multilevel, bundle piezometers extending up to 200 m downgradient from the tile bed. Then, on October 27, 2010, a detailed sampling sweep was initiated for a suite of parameters including EC, nutrients (NO_3^-,

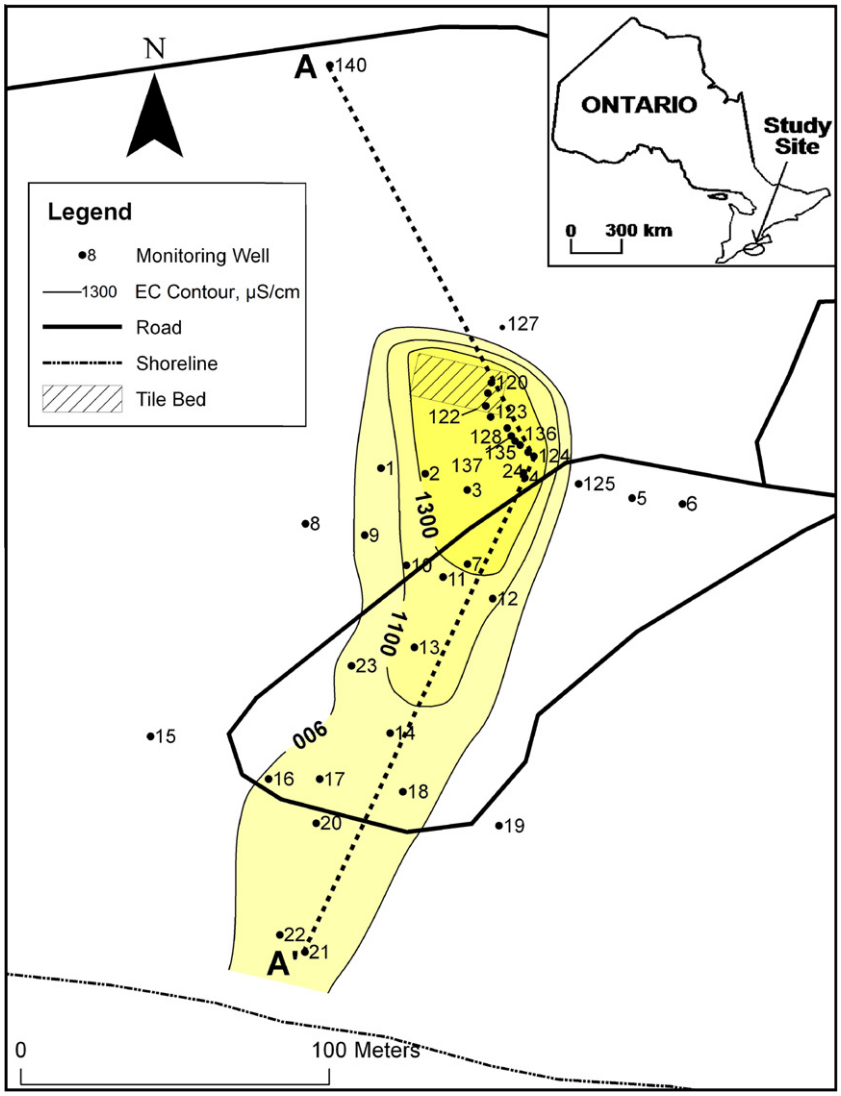

Fig. 1. Long Point septic system site showing location of the tile bed, multilevel monitoring wells and contours of maximum electrical conductivity (EC) measured in the monitoring wells October, 2010.