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Contribution of phosphorus to Georgian Bay from groundwater of a coastal beach town with decommissioned septic systems

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ABSTRACT

Groundwater inputs of phosphorus (P) to the Laurentian Great Lakes are poorly known, but may contribute to eutrophication and algal bloom issues. This study's objective was to assess the contribution of P to Nottawasaga Bay from the surficial sand aquifer at Wasaga Beach, representing a coastal cottage area with decommissioned septic systems, and how this might change with time. The first part of the study involved site-scale groundwater sampling beside 4 provincial park public washrooms. Legacy P plumes were detected at two of these sites, with one being >30 years since decommissioning. P transport calculations including sorption onto aquifer sediments indicate the majority of P plumes from the town's decommissioned septic systems have likely not yet reached the shoreline, >50 years since installation, and will likely contribute P to the bay for many decades. The second part of the study consisted of broader-scale (town-wide) surveys of shallow beach groundwater. Dissolved P concentrations were ~50 μg/L for background groundwater (in town and reference area), which is similar to literature values. This P may have been sourced from degrading organic matter, bird droppings, or soil-aquifer minerals. Sporadic elevated concentrations up to 420 μg/L may be from legacy septic systems and/or natural sources. A rough calculation suggests groundwater P loading along Nottawasaga Bay's eastern shore (Wasaga Beach, 10-km; adjacent similar beaches, 40-km) is a few percent at most of that from the Nottawasaga River. Thus, it more likely affects localized periphyton and macrophyte growth rather than significantly affecting the Nottawasaga Bay P budget.

Introduction

It has long been recognized that domestic wastewater treatment systems (i.e., septic systems) can supply nutrients, including phosphorus (P), to nearby lakes (Dillon and Rigler 1975; Dillon et al. 1993). Phosphorus is generally perceived as the nutrient most limiting to primary production in lakes, with excess inputs leading to eutrophication and algal blooms (Schindler et al. 1971; Correll 1998; Schindler et al. 2016). This was especially a concern for small freshwater lakes of the Canadian Shield, the catchments of which typically have shallow soils on bedrock. As a result, in the 1970s, the Lakeshore Capacity Model (LCM) was developed to predict the ice-free total phosphorus (TP) concentration in such lakes, considering natural and anthropogenic (largely human wastewater from septic systems) inputs (see review by Paterson et al. 2006). In the subsequent decades it has been modified to account for new knowledge on P sources and cycling processes and to accommodate changes in human activities (e.g., per capita water use, P removal from detergents). This empirical model does not distinguish different pathways for septic P transport to the lake (i.e., relatively slow groundwater flow through overburden sediments versus more rapid flow through or over fractured bedrock) and may not be applicable in other geologic areas (Paterson et al. 2006), such as those with thick unconsolidated-sediment aquifers in southern Ontario. Furthermore, other inputs of P with groundwater are ignored (Paterson et al. 2006), as has been common in many lake P balance studies in the past (Lewandowski et al. 2015).

Many studies have reported on groundwater plumes of P derived from septic systems (e.g., Rea and Upchurch 1980; Robertson et al. 1991; Harman et al. 1996; Ptacek 1998; Robertson et al. 1998; Roy et al. 2009), and wastewater lagoons (McCobb et al. 2003) in permeable sediment aquifers. In a review, Robertson (2003) explained how mineralogy of soil-aquifer materials controls whether P in leachate reaches the water table, with acidic conditions generated in non-calcareous materials promoting phosphorus mineral precipitation in the oxidized unsaturated zone below the septic infiltration bed. In contrast, septic system effluents do not become acidic in calcareous aquifer materials, due to their acid neutralizing ability. These systems tend to leach a substantial portion of their P to the water table and, thus, produce P plumes in groundwater. Dissolved P that reaches the groundwater zone is known to sorb to aquifer materials (e.g., Robertson 1995; Harman et al. 1996; Robertson 2008), retarding the P plume compared to other

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wastewater components such as chloride. Sorption may fit a linear equilibrium model, being rapid and reversible (Robertson 2008). Other processes may present as less reversible or irreversible sorption-like reactions, including intra-particle diffusion, incorporation into the mineral phase, or precipitation of phosphate minerals, though these were not apparent in the P plume study (Long Point site; 16 years post-installation) of Robertson (2008).

In urbanizing areas, individual septic systems are often decommissioned in favor of community wastewater treatment facilities. Decommissioning involves pumping out the septic tank, disconnecting from the dwelling, and connecting to the communal sewer network. Robertson and Harman (1999) reported on 2 septic system plumes on calcareous sand aquifers and noted essentially unchanged concentrations of dissolved phosphorus in groundwater 2–4 years after decommissioning. For one plume, all other major dissolved plume constituents (e.g., Na, Ca, Cl, NO_3) returned to background levels within one year (these were not measured for the other plume). The maintenance of dissolved phosphorus concentrations was attributed to rapid and reversible sorption reactions in the groundwater zone retarding P transport, and suggests potentially long-term persistence of the P plumes.

Phosphorus has been targeted as a key driver of algal blooms in the Laurentian (Canada-U.S.) Great Lakes (International Joint Commission 2014). In general, groundwater contributions of nutrients to the Great

Fig. 1. Maps showing the location of the town of Wasaga Beach a) in the Great Lakes Basin and b) along the shore of Nottawasaga Bay; along with c) its current footprint, showing urban areas (shaded grey) and the years when certain areas had sewers installed and cottage septic systems decommissioned; also shown are the comfort station sites (profiling groundwater transects) and areas of groundwater sampling with multi-level wells (WA1–10) and shoreline surveys (WA1–12).

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