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Influence of Stormwater Management Ponds on Chloride Concentration Dynamics in Headwater Streams

(Influence des bassins de gestions des eaux pluviales sur la dynamique de concentration des chlorures dans les cours d'eau d'amont)

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RÉSUMÉ

Le chlorure de sodium (NaCl) est l'agent de déglacement le plus couramment utilisé en Amérique du Nord et se dissout facilement dans l'eau. Pendant les épisodes de pluie ou de fonte, le ruissellement urbain transporte le sel vers des installations de gestion des eaux pluviales telles que des étangs humides, après quoi il se déverse dans les cours d'eau récepteurs. Des recherches antérieures ont montré que les étangs humides peuvent causer des retards à court terme dans le transport du Cl⁻ en raison de la stratification densimétrique dans l'étang lui-même. Lorsque l'étang rince, le transport du Cl⁻ stocké peut entraîner des impulsions Cl⁻ dans le cours d'eau récepteur qui dépassent les seuils de toxicité aiguë pour le biote aquatique. Dans cette étude, nous étudions la prévalence de ce phénomène dans deux régions urbanisées du sud de l'Ontario, au Canada, où les étangs humides sont la principale méthode de contrôle des eaux pluviales. Six cours d'eau d'amont provenant d'un étang humide, ainsi que deux cours d'eau de référence sans traitement des eaux pluviales, ont été choisis pour cette étude. Une combinaison de capteurs de conductivité électrique (CE) à haute fréquence dans le cours d'eau et d'échantillonnage discret de l'eau pour l'analyse Cl⁻ sera utilisée pour développer une série chronologique continue Cl⁻ pour les sites situés en amont et en aval de chaque sortie d'étang. La différence entre les concentrations de Cl⁻ en amont et en aval sera utilisée pour identifier les contributions de Cl⁻ de l'étang au cours d'eau. Les résultats préliminaires indiquent une variabilité de la réponse du cours d'eau au Cl⁻ entre les sites, ce qui donne à penser que le moment et l'ampleur du transport du Cl⁻ dans les étangs humides ne sont pas uniformes et dépendent des caractéristiques du site.

ABSTRACT

Sodium chloride (NaCl) is the most common de-icing agent used in North America and readily dissolves in water. During rain or melt events, urban runoff transports the salt to stormwater management facilities such as wet ponds after which it discharges into receiving streams. Previous research has shown wet ponds can cause short-term lags in Cl⁻ transport due to densimetric stratification within the pond itself. When the pond flushes, transport of the stored Cl⁻ can result in Cl⁻ pulses in the receiving stream that exceed thresholds of acute toxicity to aquatic biota. In this study, we investigate the prevalence of this phenomenon in two urbanizing regions of southern Ontario, Canada where wet ponds are the primary method of stormwater control. Six headwater streams receiving flow from a wet pond, as well as two reference streams with no stormwater treatment, were chosen for this study. A combination of in-stream high-frequency electrical conductivity (EC) sensors and discrete water sampling for Cl⁻ analysis will be used to develop a continuous Cl⁻ time series for sites located up and downstream of each pond outlet. The difference between up and downstream Cl⁻ concentrations will be used to identify Cl⁻ contributions from the pond to the stream. Preliminary results indicate variability in stream Cl⁻ response across the sites suggesting that the timing and magnitude of Cl⁻ transport through wet ponds is not uniform and depends on site characteristics.

MOTS CLÉS

Aquatic toxicity, contaminants, road salt, winter, water quality

1 INTRODUCTION

Urbanization in Southern Ontario, home to Canada's largest economic hub, has rapidly increased since the early 1900s (Statistics Canada, 2022). As the population in this urban centre continues to grow, however, , so does the extent of urbanization as a means to accommodate. Urban development often results in impervious land cover which alters the natural hydrological cycle by reducing infiltration and increasing surface runoff (Ehrenfeld 2000). To manage post-development water resources, facilities such as stormwater management (SWM) ponds have been widely adopted to address water quantity and quality issues. SWM ponds receive and detain large volumes of runoff which allows contaminants to settle to the bottom of the pond before the water is released slowly into a receiving surface water body (Bishop et al. 2000; Villareal et al., 2004).

Impervious surfaces in colder climates necessitate the use of de-icing agents on roads, sidewalks, and parking lots for public safety. Parallel to the rate of urban growth, the use of road salt (NaCl) as a de-icing agent has increased over the years with an estimated 130,000 – 150,000 tonnes used annually just within the city of Toronto (City of Toronto, 2022). While there are many sources of chloride (Cl-) in the natural environment, many studies have investigated the role of road salt in surface water contamination (Marsalek, 2003; Corsi et al. 2015; Dugan et al. 2017; Baker et al., 2019; Oswald et al. 2019; Moore et al., 2020). Additionally, densimetric stratification of Cl- in wet ponds has been shown to generate concentrated fluxes of Cl- in discharging water (Snodgrass et al., 2017; Lam et al., 2020). Road salt use is not currently regulated in Canada, but the Federal Code of Practice for the Environmental Management of Road Salts (ECCC, 2001) encourages organizations to undertake additional salt management measures in salt-vulnerable areas. The Canadian Water Quality Guidelines for the Protection of Aquatic Life lists the long-term exposure limit of Cl- as 120 mg/L and the short-term exposure limit as 640 mg/L (CCME, 2011). These guidelines are frequently surpassed in smaller receiving streams (Lam et al., 2020), but further investigation, spanning various pond types, streams, and land uses, is required to identify salt vulnerable areas in a rapidly urbanizing landscape.

This study aims to improve our understanding of how commonly used stormwater management control measures affect the timing and magnitude of chloride transport to receiving streams in regions of southern Ontario, Canada where wet ponds are the primary method of stormwater control. This will aid in the identification of salt-vulnerable areas and assist road operations managers in regulating salt usage.

2 METHODS

For this study, six headwater streams receiving flow from a wet pond were selected: three within the Humber River watershed and three in the East Holland River watershed. An additional reference site with no stormwater treatment was selected in each watershed. In the streams that received flow from wet ponds, two high-frequency (15-min) electrical conductivity sensors were installed – one upstream of the pond outlet/outfall and one downstream (Figure 1). While a majority of sites follow this “off-line” setup, one site follows an “in-line” setup with one sensor at the pond inlet and one at the outlet. Discrete grab samples were collected and analyzed for chloride ion concentration. Continuous EC and discrete chloride data were used to develop EC-Cl models for each site, from which continuous Cl- time series will be generated for each site. The upstream concentrations will be subtracted from downstream concentrations to return the contribution of the pond to the stream.

3 PRELIMINARY RESULTS

While the Cl-SC models continue to be developed over winter 2022/2023 through discrete sample collection, the continuous specific conductivity time series provide preliminary insight on pond Cl- dynamics. Some sites thus far suggest minimal differences or contribution from the pond to the receiving stream, while others indicate significant contribution after rain or melt events. In contrast, the in-line setup suggests attenuation of ions within the pond system before exiting as upstream conductivity remains consistently elevated over downstream. This variation in pond chloride dynamics suggests a customized approach to salt management practices based on local stormwater facilities and their predicted responses to chloride inputs.

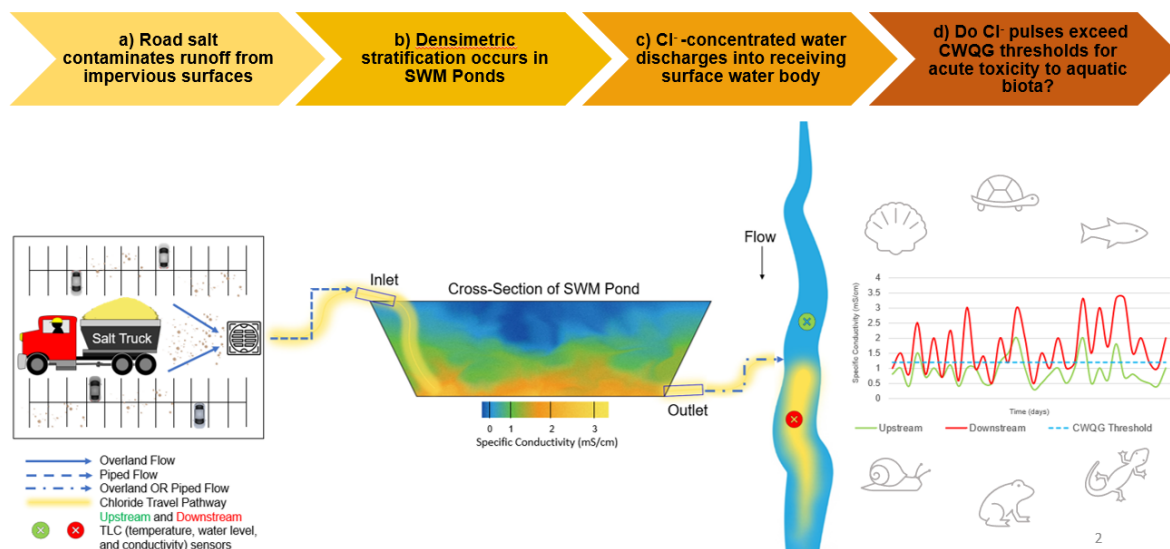


Figure 1 – Study design and context.

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