geoconvention
Virtual Event
September 21-23 2020
CSPG • CSEG • CWLS • GAC • MAC • IAH

Contaminants from an old closed landfill impacting an urban stream

Victoria R. Propp[1,2,], Amila O. de Silva[1], Christine Spencer[1], Susan Brown[1], James E. Smith[2], James W. Roy[1,2]*
[1]Water and Science Technology Directorate, Environment and Climate Change Canada
[2]School of Geography and Earth Sciences, McMaster University

Summary

Municipal waste landfills can contain leachate with many harmful contaminants, including contaminants of emerging concern (CECs). Many of the older landfills, of which there are many thousands across Canada, were operational prior to the current stringent environmental regulations and had no engineered liners or leachate collection systems. Therefore, old landfills have potential to be continuous long-term sources for contaminants to leach into groundwater, potentially then impacting nearby wells and surrounding surface water ecosystems. The objective of this study is to assess the processes and effects of leachate-impacted groundwater discharging to a stream. A detailed field site investigation was performed on an urban stream adjacent to a closed municipal landfill. This site was chosen based on a recent survey of CECs in 20 old closed municipal landfills. Contaminants of emerging concern that have recently been detected in municipal landfill leachate, including per- and polyfluoroalkyl substances (PFASs), flame retardants, plasticizers (such as bis-phenol A and substitutes) and artificial sweeteners, were sampled along with common landfill leachate constituents in order to characterize the potential risk of leachate-impacted groundwater as it enters a stream. Shallow groundwater and surface water concentrations, temperature profiles, water table levels and stream discharge were evaluated along multiple sections of the stream seasonally to capture variation in the flux of landfill leachate into the stream. Although analytical data is still being processed, preliminary work has shown that total PFAS and total OPFR concentrations in groundwater discharging to the stream can be as high as 12.7 µg/L and 19 µg/L, respectively. Analysis of surface water upstream and downstream of the study site show that the mass flux of leachate-impacted groundwater does appear to have an impact on the surface water quality. Through the investigation of groundwater-surface water interactions at this site, this study will provide insight into how landfill monitoring strategies and regulations can be improved to protect surface water ecosystems from harmful contamination.

Theory and Method

Various contaminants of emerging concern (CECs) have been detected in municipal landfill leachate. Many of these CECs are synthetic organic compounds, including per- and polyfluoroalkyl substances (PFASs), organophosphorus flame retardants (OPFRs), and plastisizers (e.g., bisphenol A and substitutes). These CECs are often unregulated in groundwater, despite many being classified as ubiquitous, persistent, bioaccumulative, and toxic in the environment. The investigations on CECs in landfill leachate have mostly been limited to large, modern, operational landfills, whereas there is much less data on CECs in leachate of old closed landfills (≥3 decades since closure), of which there are many thousands across Canada. Most of these old landfills lacked engineered liners or leachate collection systems, and many were operational prior to the current stringent environmental regulations. Therefore, old landfills may have a greater potential to leach harmful contaminants to groundwater, potentially impacting nearby wells and surrounding surface water ecosystems.

A survey of 20 old landfills, which were operational from the 1920s - 1990s, was completed in order to characterize the presence of 81 contaminants of emerging concern, and 122 common leachate constituents, in closed landfills in Ontario. These sites were chosen based on their proximity to a surface water body, and often by their lack of infrastructure, such as engineered liners or leachate collection systems, in place to prevent the transport of contaminants off-site. From this survey, an urban stream was selected to investigate in more detail, as there is known leachate input from the adjacent landfill site. This site also has extremely elevated levels of CECs, particularly PFASs, making this gaining stream an ideal site for a detailed analysis of leachate-impacted groundwater discharge. The objective of this study was to assess the processes and effects of leachate-impacted groundwater discharging to a stream. The spatial and temporal variability of these processes was investigated to determine the effect of various sampling locations, seasonality and precipitation events on the flux of contaminants across the streambed and mass loading into the surface water.

The approach used by this study was to quantify contaminant mass fluxes by measuring contaminant concentrations in shallow groundwater and the groundwater flux across the streambed. Differences in these processes was investigated both spatially and temporally. Two stream stretches (20m and 40m in length), each with a landfill cell located on only one shore, allowed for comparison between different areas of the stream. Transects across the stream allowed for investigation of spatial variation between the leachate-contaminated and clean shores (see Figure 1 discussed below). Surface water samples, measured upstream and downstream of the study site, were used to indicate effects of mass loading to the stream from leachate-contaminated groundwater (see Figure 2 discussed below). Emerging contaminant concentrations were sampled each season as well as during precipitation events to investigate temporal impacts on mass flux.

Initial screening of groundwater concentrations near the stream (max. depth=1m) was performed using the temporary drive point sampling method developed by Roy & Bickerton (2010). Streambed temperature measurements (depth=10cm) were taken at intervals of 10-50cm across the stream and every 1m along the stream to identify areas more strongly influenced by groundwater. This was performed in the peak of summer, when groundwater is notably colder than surface water, and repeated in the winter when the opposite is observed. Both the temperature map and initial groundwater screening concentrations were used to select study locations with notable leachate-impacted groundwater discharge, but also with areas of suspected lower discharge to cover spatial variability.

Based on the initial stream assessments, permanent groundwater samplers (length 2.5cm) were installed to ~15cm depth beneath the streambed in transects to cover both high and low discharge areas (Figure 1). Transects across the stream allowed for a comparison of groundwater concentrations from the landfill-impacted shore to the cleaner shore. Groundwater samples testing for CECs and common leachate constituents were collected seasonally in order to determine temporal changes to contaminant concentrations over the course of a year.

To determine groundwater flux, 1D temperature profiles were continuously measured at discrete depths up to 90cm beneath the streambed. Heat, which travels through conduction in porous media, is also transported through advection when groundwater is flowing. Therefore, deviations from a conduction-dominated, stagnant system can provide information about the direction and magnitude of groundwater fluxes. Using several different spreadsheet-type models (e.g., Flux-LM by Kurylyk et al., 2017) groundwater flux across the streambed can be determined. At each study site, four temperature rods were installed, two on each bank, to quantify differences in the groundwater flux spatially (Figure 1). Temperature was measured every 15 minutes continuously for nearly one year, allowing temporal variability to be examined on fine or larger (e.g. seasonal) scales.

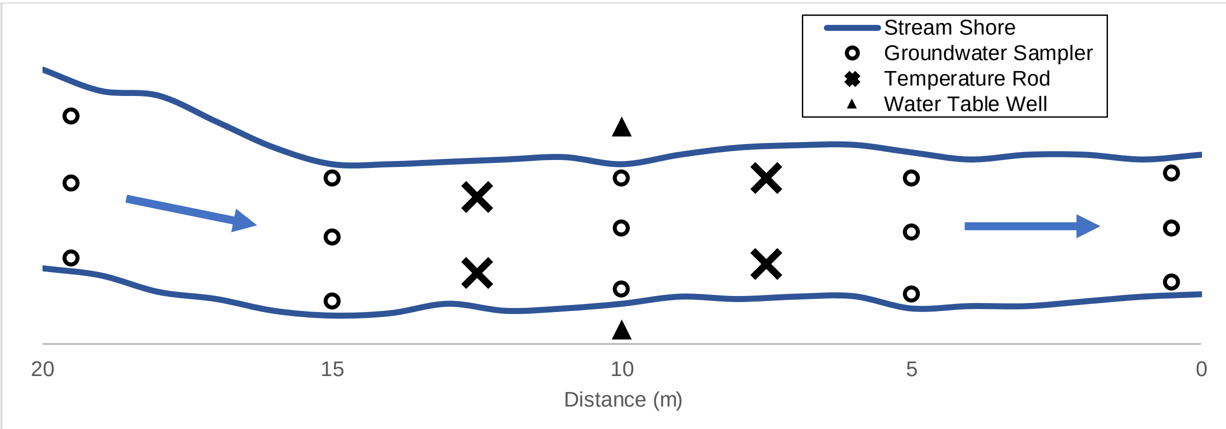

Figure 1: Top view of stream instrumentation. Arrows indicate stream flow direction

Surface water concentrations were measured bi-weekly to monthly to measure ammonium, a common landfill leachate indicator, as well as the artificial sweetener saccharin, an emerging landfill leachate tracer (Roy et al., 2014). Approximately twice each season, surface water was sampled for CECs. Continuous stream level data recorded every 15 minutes with data loggers, and bi-weekly discharge measurements measured with a flow meter, were used to produce a stream rating curve. These surface water analyses were performed both upstream and downstream of the study site, allowing for direct comparison and insight into the influence of leachate-impacted groundwater on the stream.

Results and Conclusions

Results from the leachate survey show that many old landfills, at least back to the 1960s, still contain elevated levels of CECs. Some of the notable CEC maximum values include total PFASs (Σ_{17} PFASs), total OPFRs (Σ_{24} OPFRs), and bis-phenol A (BPA), which were 12.7 µg/L, 81.4 µg/L, and 29.0 µg/L, respectively. These levels are comparable to modern, operational landfills, and show that old landfills must be considered as potential sources for harmful CECs to the environment (Hamid et al., 2018; Masoner et al., 2014; Qi et al., 2019). Due to the greater risk of leachate migrating off-site in older landfills, the elevated levels detected here show that there is a serious potential threat of CEC transport in groundwater and discharge to wells or surface water bodies. This study provides insight into how landfill monitoring strategies and regulations can be improved to protect Canada's surface water and groundwater from harmful contamination. Authorities and landfill owners should consider the inclusion of the CECs that were detected in this study as these CECs can exist in other old closed landfills at levels potentially at least as high as detected in this study.

The site chosen for the detailed stream impact study had the highest total PFASs concentration seen across all the sites, as well as a total OPFR concentration of 19 µg/L and a BPA concentration of 6.1 µg/L. The site consists of two separate landfill cells, located in the same city along the same creek, and were operational from 1961-1963. The one site is currently used as recreational park space and the other site is barren.

Analytical data is still being processed, however surface water concentrations for the landfill leachate tracers ammonium and saccharin are shown in Figure 2. Both compounds tend to persist in anaerobic leachate, making them effective tracers for landfill-impacted groundwater. However, considering them together is important as both could have other sources, such as natural or agriculture sources of ammonium and wastewater for saccharin. Figure 2 shows how the concentrations of ammonium and saccharin are typically higher downstream than upstream of the study sites. This indicates a potential mass flux of these contaminants into the stream from the landfill. It is expected that CECs will follow a similar trend as the landfill leachate tracers, with

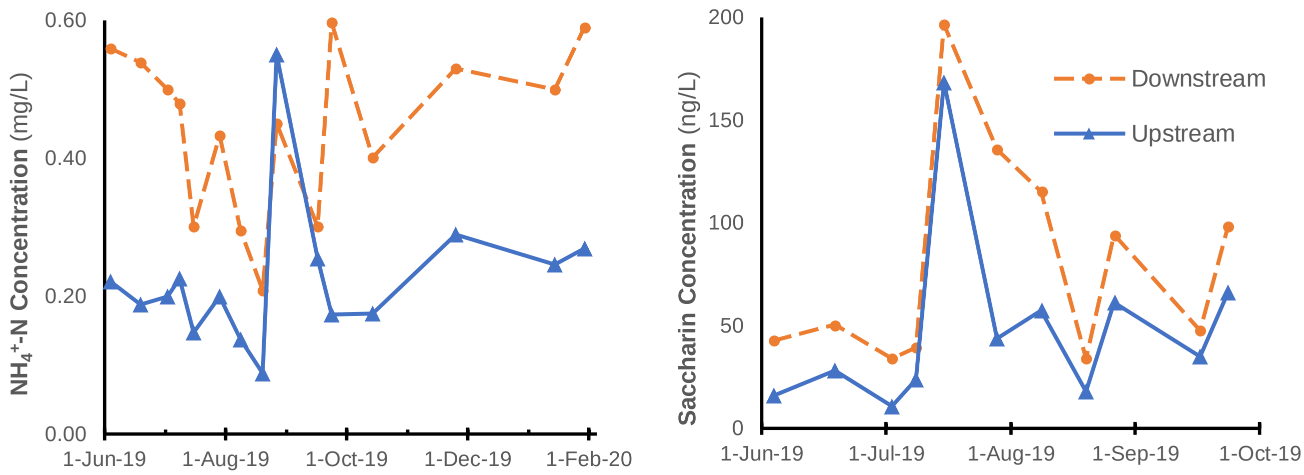

Figure 2: Comparison between upstream and downstream surface water concentrations of ammonium (NH_4^+-N) and the artificial sweeter saccharin over time.

higher concentrations in the surface water downstream of the landfill. As more data is processed, greater detail about the mass flux of contaminants over time, and at various locations will be revealed.

This detailed study provides more insight for landfill operators and regulating authorities regarding the various CECs that should be added to sampling campaigns. Additionally, the temporal analyses, across all seasons and during precipitation events, provides information about the ideal sampling times in order to capture peak contaminant inputs to the stream. The spatial analyses show how when selecting stream sampling locations, considerations should be made to target high discharge zones in order to properly identify risk to the stream.

Acknowledgements

A special thanks to the field, laboratory and administrative support provided by Pam Collins, Ross MacKay, Tammy Hua, Grant Hodkins, and Shannon James.
Funding was provided by the Ministry of the Environment, Conservation and Parks (MECP), Environment and Climate Change Canada (ECCC), Natural Sciences and Engineering Research Council of Canada (NSERC), and Ontario Graduate Scholarship (OGS)

References

Hamid, H., Li, L. Y., & Grace, J. R. (2018). Review of the fate and transformation of per- and poly fluoroalkyl substances (PFASs) in landfills, *Environmental Pollution, 235*, 74–84. doi: 10.1016/j.envpol.2017.12.030

Kurylyk, B. L., Werkema, D. D., Irvine, D. J., Carey, S. K., & Briggs, M. A. (2017). Heat as a groundwater tracer in shallow and deep heterogeneous media: Analytical solution, spreadsheet tool, and field applications, *Hydrological Processes, 31*, 2648–2661. doi:10.1002/hyp.11216

Masoner, J. R., Kolpin, D. W., Furlong, E. T., Cozzarelli, I. M., Gray, J. L., & Schwab, E. A. (2014). Contaminants of emerging concern in fresh leachate from landfills in the conterminous United States. *Environmental Sciences: Processes and Impacts, 16*, 2335–2354. doi:10.1039/c4em00124a

Qi, C., Yu, G., Zhong, M., Peng, G., Huang, J., & Wang, B. (2019). Organophosphate flame retardants in leachates from six municipal landfills across China. *Chemosphere, 218*, 836–844. doi:10.1016/j.chemosphere.2018.11.150

Roy, J. W., Stempvoort, D. R. Van, & Bickerton, G. (2014). Artificial sweeteners as potential tracers of municipal landfill leachate. *Environmental Pollution, 184*, 89-93. doi:10.1016/j.envpol.2013.08.021

Roy, J. W., & Bickerton, G. (2010). Proactive screening approach for detecting groundwater contaminants along urban streams at the reach-scale. *Environmental Science and Technology, 44*(16), 6088–6094. doi:10.1021/es101492x