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De-icing salt transport from the street through a roadside bioretention basin

Transport de sel de déneigement à travers un bassin de biorétention

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RÉSUMÉ

Pendant les mois d'hiver, la région médio-atlantique des États-Unis est soumise à des mélanges de neige, de pluie verglaçante, de grésil et de pluie, parfois en une seule tempête. Il en résulte la nécessité de nettoyer les rues et d'appliquer du sel de voirie pour la sécurité routière. La fonte de la neige se produit en raison de températures plus élevées et/ou de pluie tombant sur la neige, transportant le sel appliqué dans l'eau de fonte. Ce cycle peut se produire plusieurs fois durant l'hiver. Ce projet a étudié les impacts de ce cycle climatique sur la salinité de l'eau entrant et dans les pores du sol d'un bassin de biorétention dans la ville de Lancaster, Pennsylvanie, États-Unis. Les résultats ont montré que, pendant les périodes de neige et de températures froides, aucun débit d'eau substantiel n'entrait dans le bassin et la salinité du sol ne changeait pas dans les 20 premiers centimètres du sol. La pluie a eu un effet significatif sur la salinité du sol. Lorsque la pluie a suivi une application de sel de déglacage, la salinité du sol a augmenté considérablement, puis a rapidement diminué jusqu'à une concentration supérieure à la ligne de base, puis a lentement diminué à mesure que davantage de débit pénétrait dans le bassin. Au cours de l'hiver 2020-2021, les concentrations de salinité dans le sol et le débit ont augmenté après chaque application de sel de déglacage, le temps de réponse au pic de salinité diminuant à mesure que l'intensité de la pluie augmentait et que la température de l'air augmentait. À la fin de l'hiver, les mesures de la salinité du sol dans ce sol plus sablonneux ont pris au moins 60 jours après la fin de la dernière application de sel enregistrée pour diminuer aux concentrations de référence. Des tendances similaires ont été observées à l'hiver 2021-2022 où le même nombre d'événements de salage s'est produit, même si les chutes de neige totales étaient inférieures à 50 % de l'hiver précédent.

ABSTRACT

During winter months, the Mid-Atlantic region of the United States is subject to mixtures of snow, freezing rain, sleet, and rain, sometimes all in one storm event. This results in the need to clear streets and apply road salt for traffic safety. Melting of the snow occurs due to higher temperatures and/or rain falling on the snow, transporting the applied salt in the meltwater. This cycle may occur several times during the winter. This project investigated the impacts of this weather cycling on the salinity of the water entering and in the soil pores of a bioretention basin in the city of Lancaster, Pennsylvania, USA. The results showed that, during periods of snow and cold temperatures, no substantial water flow entered the basin and the soil salinity did not change in the top 20 cm of the soil. Rain had a significant effect on the soil salinity. When the rain followed a deicing salt application, the soil salinity increased substantially and then rapidly decreased to a concentration above baseline, and then slowly decreased as more flow entered the basin. Over the course of the winter of 2020-2021, the salinity concentrations in the soil and flow increased after every deicing salt application with the response time to peak salinity decreasing as the rain intensity increased and as the air temperature increased. At the end of winter, soil salinity measurements in this sandier soil took at least 60 days after the end of the last recorded salt application to decrease to baseline concentrations. Similar patterns were seen in the winter of 2021-22 where the same number of salting events occurred, even though the total snowfall was less than 50% of the prior winter.

KEYWORDS

Road salt, bioretention, soil electrical conductivity, deicing salts, snowmelt runoff

1 INTRODUCTION

In areas world due to cyclic freeze-thawing in the winter, road salt (primarily sodium chloride) is applied to streets and sidewalks to melt snow and ice in order to prevent vehicle accidents and injury to people. When snow and ice melt, this salt migrates into and through the drainage system. With the increasing implementation of green stormwater infrastructure (GSI) that treats roadway runoff, the movement of these road salts in these systems needs to be better understood.

As noted in Kakuturu and Clark (2015a and b), road salt can have two impacts. First, sodium chloride, especially the sodium component, will interact with the soil, resulting in the formation of cementitious soil where water can no longer penetrate. The progression from an infiltrating soil to a non-infiltrating soil is often measured using the sodium adsorption ratio (SAR), which is the ratio of the sodium concentration to the square root of the sum of the calcium and magnesium concentrations. The second impact is the potential to “clean” the media by replacing previously captured pollutants with sodium, similar to the cleaning operations of an industrial resin. Road salt has the potential to accelerate the downward migration of previously captured metals.

While there are many discussions about replacing sodium chloride with salts that may be less environmentally problematic, the low cost of sodium chloride when combined with the high use will continue to make it appealing to municipalities responsible for thousands of kilometers of roads to maintain in the winter. Therefore, continuing to improve the understanding of the impacts of road salts on the soils and mixtures found in GSI is important.

2 METHODS

2.1 PROJECT SITE

Lancaster, Pennsylvania, USA has a long-term plan to install GSI to manage their stormwater and reduce flows into their combined sewer system. This project has studied one bioretention system at Brandon Park on Wabank Street for two years. The watershed area draining to this bioretention basin is primarily single-family residential. The slopes range from 2% to 5% with the primary street and sidewalk having a 5% slope. (Figure 1). The basin is located at the entrance to the park at the bottom of the yellow highlighted area in Figure 1 Left.

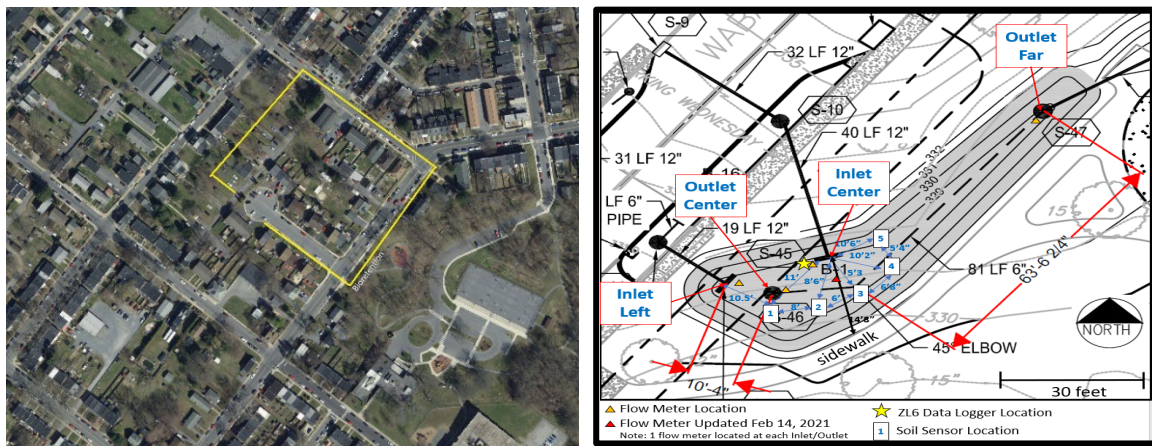


Figure 1. Left: Drainage area for the bioretention basin highlighting the land use. Right: The basin schematic showing the locations of soil and water sensors.

2.2 SENSOR DEPLOYMENT FOR WATER LEVEL/CONTENT AND ELECTRICAL CONDUCTIVITY

Figure 1 Right shows the location of the sensors deployed in the project. Five TEROS® 12 soil sensors were buried in the bioretention media at a depth of approximately 7 cm with an attempt to understand the horizontal movement of salt-laden water in the basin. Moisture content, soil temperature, and soil electrical conductivity data was recorded to a Zentra® ZL6 datalogger every 15 minutes. Solinst® Levellogger 5 LTC sensors were installed near the inlets and outlets of the basin. They collected water level, water temperature, and water electrical

conductivity every 5 minutes. The data were downloaded approximately every 6 weeks, well before the sensor's datalogger's memory was exceeded.

2.3 WEATHER DATA

Weather data was obtained from the weather station at Millersville University or at the Lancaster Airport. Both stations reported weather information every hour. The Millersville station was approximately 4.5 km from the test site and the airport was approximately 10 km from the test site. Since this project used coarser weather data, these two stations were considered suitable for collecting weather data.

3 RESULTS AND DISCUSSION

This analysis focuses on the results near the Inlet Center and uses the data from the Center Inlet levellogger and from the two soil sensors closest to the inlet. Figure 2 illustrates the flow paths in both autumn and winter seasons.



Figure 2. Inlet Center during the autumn (left) and winter (right).

To illustrate the response in the bioretention basin, the second major storm of the 2020-21 season resulted in an application of approximately 450 kg of salt on this stretch of Wabank St and its cul-de-sac as the result of 9 passes of the salt truck on January 31 and February 1, 2021 (Figure 3). The response of the salt movement in the bioretention basin is highlighted in Figure 3. The storm started off as a mix of light rain and snow with a conversion to all snow. As a result of freezing temperatures, measurable salt did not reach the soil sensors until 4 days later. The water sensor was not triggered by this because of the offset depth of the sensor which cannot pick up flows trickling through the pipe. Only when rain occurred on February 5th was there sufficient water in the system to activate the water sensor. During that peak, the soil and water sensors registered similar maximum electrical conductivity values indicating that there was little attenuation in the upper part of the bioretention media. The final movement of salt occurred on February 8th with light rain was mixed with snow. After February 8th, the salt content of the soil continued to slowly decrease. Similar results were seen for all storm events.

Figure 4 compares the 2020-21 winter season with the 2021-22 winter season. Both seasons had 3 major salting events. However, the 2021-22 winter season had approximately 50% of the snow depth (2020-21 total snow depth = 860 mm and 2021-22 total snow depth = 380 mm). The 2021-22 season was slightly warmer overall (approximately 0.5C), but most importantly, it had more days with the highs above 0C. The 2020-21 season had 2 events where the soil electrical conductivity exceeded 3.5 mS/cm (with a maximum EC of approximately 4.0 mS/cm) while the 2021-22 season had only one peak that exceeded 3.5 mS/cm (with a maximum EC of approximately 5.0 mS/cm).

These results highlight two issues. First, it is more likely that salt application is a function of temperature (and its cycling) and potential for ice, which is not well documented by weather stations and may be localized so that distant gauges may not reflect the ice/sleet/freezing rain depths. Movement of the salt from the pavement surface to the bioretention system requires unfrozen water (rain, melting temperatures). Second, the EC drops slowly between storm events in the winter and spring as residual salt is washed through the system. In winter 2020-21, the soil EC dropped to the pre-snow/salt levels after approximately 90 days after the last salting event of the season with similar results seen in winter 2021-22. Salt levels will be elevated in the bioretention media during the early vegetative growth season.

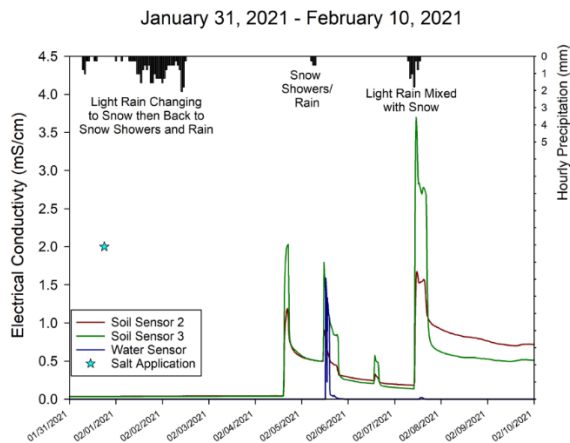


Figure 3. Second storm of Winter 2020-21 highlight water and soil electrical conductivity.

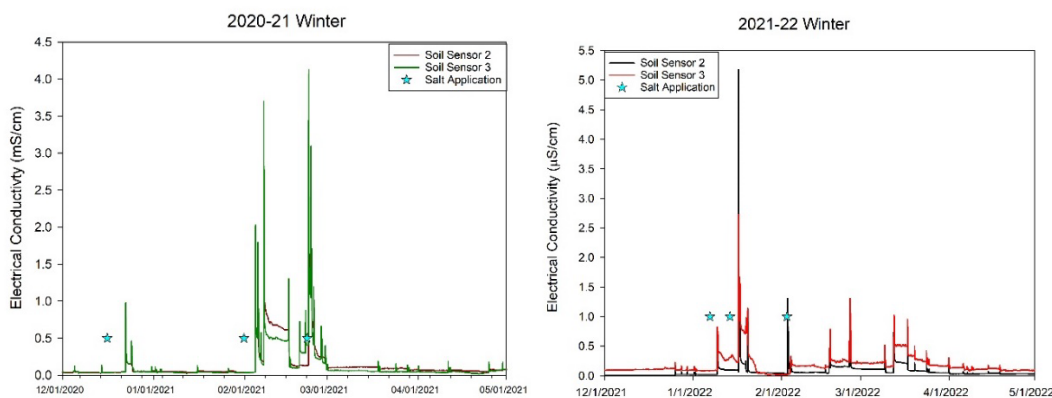


Figure 4. Comparison of Winter 2020-21 and Winter 2021-22 seasons, each with three city salting events.

4 CONCLUSIONS AND ONGOING MONITORING

During the winter season, the salt slowly built up in the infiltration media because there was no “clean” water to rinse out the media. Bioretention media, such as that used in Brandon Park, is typically a mixture of soils and sand. The addition of sand to improve hydraulics also provides a benefit of reducing fines that will react with salt and potentially clog the media. This allowed the EC of the soil to return to background levels within 2 – 3 months after the last salting event.

When compared to an infiltration pond on native soil at the Penn State Harrisburg campus, the pond soils required at least 3 months to return to background. The date at which the system returns to background concentrations is vital to ensure that plant growth and infiltration rate are not impacted by retained salts. This could be reduced by incorporating more sand into the mixture; however, there is a limit to the amount of sand that can be used because the organic matter is required both for vegetation growth and for treatment of pollutants in the stormwater runoff.

During the 2nd year of this project, a second basin in Brandon Park, which is expected to have a lower salt loading, was instrumented and lysimeters were added in the basin highlighted in this abstract. In both basins, infiltrating stormwater is sampled periodically using lysimeters and soil samples are taken twice yearly and analyzed for soil fertility parameters (pH, EC, phosphorus, calcium, potassium, magnesium, copper, and zinc). The analysis of the soils and infiltrating stormwater is ongoing.

LIST OF REFERENCES

Kakuturu, S.P., Clark, S.E. (2015a). Effect of deicing salts on clogging of stormwater filter media and on media chemistry. *Journal of Environmental Engineering*. 141(9): 04015020-1-7. [https://doi.org/10.1061/\(ASCE\)EE.1943-7870.0000927](https://doi.org/10.1061/(ASCE)EE.1943-7870.0000927).

Kakuturu, S.P., Clark, S.E. (2015b). Clogging mechanisms of stormwater filter media by NaCl as a deicing salt. *Environmental Engineering Science*, 32(2):141-152. <http://doi.org/10.1089/ees.2014.0337>.