Effects of road salt applications on soil physiochemical characteristics

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Introduction

Since the 1940s, road salts have been used to deice roadways because they lower the freezing point of water, thereby making travel safer during the winter months. The most commonly used road salt is NaCl, which, once in solution, easily dissolves and can be transported to nearby soils and waterbodies. Soils can store road salt ions (Na+ and Cl-) for months at a time, eventually releasing them into surface water and groundwater. This has led to increased soil compaction and infiltration rates in surface waters over the last 10-30 years. Road salts also impact soil structure and health. The replacement of soil carbonates (CaCO3, MgCO3) with NaCl has the potential to create larger macropores, which can lead to the degradation of organic matter and reduce the release of toxic metals. The movement and residence of road salt contamination in soils are not well understood and need to be researched further to fully understand their impact.

The objective of this study was to understand the impacts of road salt applications on a roadside soil over time using a frequent (i.e., monthly) sampling regime at a high density to the road. We measured Cl- concentrations, pH, OM, and gravimetric soil water content (GWC) to document changes in soil physicochemistry as a result of road salt applications. Additionally, soil compaction and infiltration rates were used to better understand the movement of road salt through the soil.

Field site and methods

Field site

- Soil samples were collected at Rockwood Reservation (Fig. 1) in Wildwood, MO, which features carbonate lithology and karst topography.

Methods

- Samples were collected along a transect near a road (Fig. 2) that is regularly salted during the winter months. Samples were collected monthly from May 2019 to July 2020.
- Samples were collected using a trowel at 5 sites at distances of 0.25 m, 0.50 m, 0.75 m, 1.00 m, and 1.50 m from the road. One site at 13.00 m from the road was used as a control. We collected samples at two depth intervals of 0.5 cm and 5.15 cm.
- We measured Cl- concentrations using an ion chromatograph (IC) and GWC and OM using standard methods.
- Soil compaction measurements were taken with a FieldScout penetrometer and infiltration rates were determined using the method seen in Fig. 1A.

Soil chloride concentrations

- Median pH for both the road salting and non-road salting seasons decreased with increasing distance from the road, except for the control site (Fig. 4). The site closest to the road (0.25 m) had a significantly higher pH (+0.05 pH unit difference) during the road salting season than all other sites (including the control).
- During the non-road salting season, the 0.25 cm site had similar pH to the other sites (Fig. 4), but this changed over time. In detail, following the first road salting event in November 2019, the pH of the 0.25 cm site increased to levels above the control site (Fig. 5). The pH remained higher at the 0.25 cm site than the control for the remainder of the road salting season. High pH during the road salting season in soils near the road could be due to Na+ dominance on soil exchange sites, leading to the release and loss of H+ from the soil.

Soil pH

- During the study, 36.3 cm of snow fell from mid-November 2019 to February 2020, during which time road salts were applied at the site.6
- Throughout the non-road salting season, Cl- concentrations remained consistently low (<13 mg/kg; Fig. 3).
- Immediately following a large snowfall event in December 2019 (1.3 cm in 3 days), Cl- concentrations peaked at 388 mg/kg at the surface and 344 mg/kg at depth (i.e., 23 December 2019).
- A week later, Cl- for the same locations decreased to 15 mg/kg (95.6% loss) at the surface and 104.7 mg/kg (69.6% loss) at depth.
- These results suggest that Cl- is flushed relatively quickly from shallow soils near the road, but may potentially be stored longer deeper in the soil profile.

Soil infiltration rates

- Soil infiltration rates were highest at the sites closest to the road (Fig. 7), which corresponds with the higher compaction at these sites. The highest infiltration rate occurred at 1.5 m from the road, likely due to high vegetative cover at this site creating pathways for the water to infiltrate quickly.
- The slow infiltration rates near the road could increase road salt-related Cl- and Na+ retention in the soil near the road. The higher infiltration rates away from the road could lead to faster ion flushing, particularly for Cl-.

Soil OM

- GWOC was highest and most variable closest to the road, but both the medium GWC values and variation generally decreased with increasing distance from the road (Fig. 8).
- High OM near the road may help retain salt-related ions through cation exchange of OM and cation exchange processes.

Conclusions

Because of the widespread use of road deicing salts in the winter months, understanding the effect on the surrounding environment, in soils, is crucial. We tested how road salts move through soils by examining physicochemical properties like Cl- concentrations, pH, OM, GWOC, compaction, and infiltration. Soil Cl- concentrations were highest closest to the road, reaching a peak value of 388 mg/kg. However, a week after this high level was observed, Cl- concentrations decreased by 95.6% at the site, suggesting Cl- was rapidly flushed from the soil. Soil pH was most impacted by road salting at the site closest to the road (0.25 m), with the road salting season pH being significantly higher than the non-road salting season pH. This could indicate that Na+ becomes dominant in the soil during the winter, leading to pH loss. Na+ concentration analyses are ongoing so this theory cannot be confirmed yet. Soil GWOC and OM varied the most at sites closest to the road, indicating that the road may play a role in transport and loss of Cl- to the soil. Understanding the impacts of road salts on soils is necessary to aid in our ability to develop road management practices that minimize the effect of winter deicing events on the surrounding environment.

Works Cited


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