An Impact Assessment of de-icing Salts: Mapping de-icing Salt Movement into Surrounding Soils from Treated Pathways Across Dalhousie University's Studley Campus

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Executive summary

The use of de-icing salts plays a key role in reducing injury and damage from inclement winter weather. However, repeated applications of salt on roads and walkways throughout the winter takes a toll on the neighboring soil. This paper seeks to examine the effect of de-icing salts on the soil adjacent to pathways on Dalhousie University's Studley campus in Halifax, Nova Scotia. Our findings indicate that de-icing salts do leach through soiled areas and that there is a significant negative relationship between the distance from the point of application and the level of soil salinity. The most impacted soil is within the first 0.5 meters from the salting site. While no extreme salinity pollution was found on the Dalhousie Studley Campus, our team recommends caution be taken when applying de-icing salts immediately adjacent to ecologically important green spaces.

Key Words

Salinity; Road salts; Soil health; Safety; Walkways; Run-off

Introduction

Canadian winters are known for their heavy snowfall and freezing temperatures. These conditions pose a threat to vehicle safety on roads. Without precautionary measures, ice buildup on sidewalks and roads reduces traction and increases potential for pedestrians and vehicles to slide. Loss of traction leads to car accidents and pedestrian falls with a 49% increase in reported collisions in December and January (RCMP, 2017).

To prevent this, de-icing salts or road salts are applied generously to roadways. They work by preventing ice crystal formation and by adding traction to the wet surfaces. Salting practices have proven to be an effective and affordable practice, and have been in continuous use since its invention (Miron et. al., 2022). The most common type of de-icing salt is composed of sodium and chloride, accompanied by small amounts of cyanide, and trace amounts of zinc, phosphorus, nitrogen and copper (Canadian Environmental Protection Act, 2001).

While these have proven to be excellent at keeping roads safe, they come with unintended consequences to nearby ecosystems. When mixed with water run-off, the sodium chloride becomes aqueous in the water solution and can easily permeate into dirt patches and surface water. Yearly winter application of de-icing salts lead to increased soil salinity levels due to contaminated run-off (Tiwari & Rachlin, 2018). Over salinization of soils creates uninhabitable environments for plants, insects, and microbes which inturn affects ecosystem dynamics and can accumulate through the food chain. Research conducted in Edmonton, Alberta, found that trees in areas with high de-icing salt use are found to have impaired chlorophyll levels and higher sodium concentration in leaves across all species (Equiza et al., 2017). Lower chlorophyll levels impaired the trees ability to convert sunlight into nutrients and weakened the trees making them susceptible to pests and disease.

Our goal was to examine the impact of di-icing salt usage on Dalhousie University's Studley Campus. This inquiry was incited by heavy salt usage observed on footpaths across the campus grounds during Halifax's winter months. Knowing the ecological and potential human harms posed by de-icing salts, we questioned how far off the point of application would de-icing salts spread. We investigated: To what extent do de-icing salts leach off of treated footpaths, onto surrounding soiled areas, on Dalhousie University's Studley campus?

Methods

Study Site Description

To answer our question, soil samples were gathered along a 38x39m transect of the grassy field at the center of Dalhousie's Studley campus, commonly known as the quad. The quad is encased by the Henry Hicks Administrative Building, the Chemistry Building, and is adjacent to the Killam Library, thus attracting a high volume of foot traffic. The area is bordered by four sidewalks. Halifax's winters are characterized by 44.8 days of snowfall on average per year and winter temperatures reaching an average high of 2.7°C and [average] low of -6.7°C (Environment Canada, 2023). The Studley quad is partially deprived of sunlight due to the surrounding buildings, so the shade may have contributed to icy conditions.

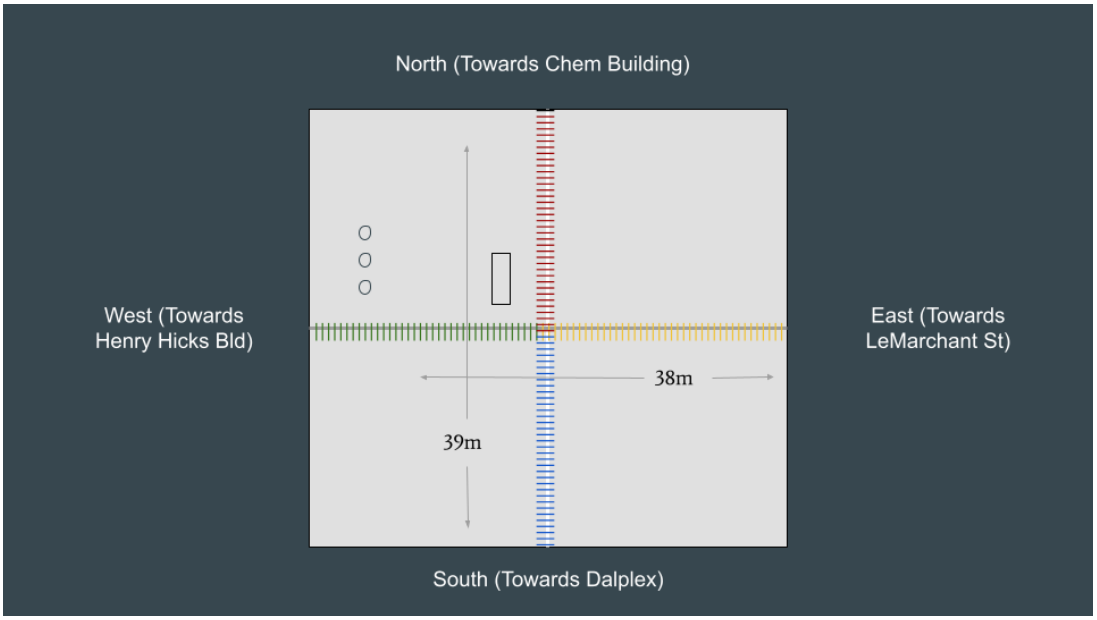

Figure 1. A rough map of the sampling layout, including the flag post and benches in the northwest corner.

Salt Application Procedure

The salt utilized by Dalhousie Groundskeepers is the Windsor® brand's Safe-T-Salt®. This particular model is a rocksalt designed for walkways and driveways, and is capable of melting at temperatures of -15°C and above. Bags of Safe-T-Salt are available in quantities of 10 or 20 kilograms. Mike Wilkinson of the Dalhousie Groundskeeping staff was interviewed for this study to gain insight into how de-icing salt is applied on campus. Wilkinson stated the salt is applied with a machine that is regularly calibrated in accordance with the amount of salt necessary for current weather conditions. Furthermore, the frequency of application is determined by severity of the expected freeze and salt is laid prior to inclement weather events when possible. Wilkinson has also undergone Smart About Salt Certification training in order to make informed and practical decisions about winter maintenance management.

Soil Sample Collection

Samples were collected in early March with sampling occurring between salt applications and snow events. A 30 meter measuring tape was used to plot out the transect across the quad. Every half meter the soil was perforated with a trowel to extract ~45g of soil at grass root depth. The sample was subsequently placed in a press sealed bag marked with the location and direction of the segment (North, South, East or West). After each sample was collected, the trowel was thoroughly wiped in order to prevent cross contamination. Over the four directional segments, 149 soil samples were collected in total. Each segment's samples were collected in a single day to ensure consistency of salt application and potential spread.

EC Testing

A Yellow Springs Instrument (YSI) probe was used to measure the electric conductivity (EC) of each sample. Readings were recorded in microseisms. Inside a plastic cup, 15g of each sample was diluted with 75g of distilled water and stirred with a plastic spoon, then set aside to rest for 45 seconds. After allowing the sediment to settle, the YSI was situated so that the probe hovered above the bottom of the container for optimal accuracy. Following each reading, the YSI probe was placed in a separate cup containing distilled water to clean the instrument. This distilled water was refreshed every couple readings. EC readings were inputted and organized into a Microsoft Excel document for later data analysis. In addition to the samples, a reading of solely distilled water and one of diluted table salt was taken in order to provide a control and expected readings.

Measurement Justification

As previously mentioned, Dalhousie's Studley quad was an ideal location to measure the effects of de-icing salts on soil health. The walkways around the quad attract significant pedestrian activity because of the neighboring parking lots which are utilized by staff, students, and visitors alike. Vehicle roadways are also application sites for de-icing salts. The center of the quad contains a bench, a historic sundial, and is a popular spot for gatherings and informal sport activities, thus salt trekked into the vegetation is unavoidable. Assessing each direction of the segment helped create a better understanding of how salt spreads given multiple variables.

Data Analyses

To assess any relationship between soil salinity levels and adjacent salted pathways, a linear regression analysis was used. This statistical method is used to model a relationship between a dependent variable (salinity levels) and one or more independent variables (distance from the sidewalk). For detecting the presence of a relationship, two indicative values were used, the p-value and R^2 value. The p-value is used to test the null hypothesis against the alternative hypothesis. The null hypothesis is that there is no change in soil salinity across all measured distances. A rejection of the null hypothesis suggests there is evidence of a statistically significant relationship. Only when the p-value is less than the significance level is the null rejected, the significance level for this experiment was 0.05. The R^2 value is used to explain variance in the model, the value is between 0 and 1. Closer to 1 indicates that all variation is explained by the model and closer to 0 suggests no explanation for variation by the model. For this analysis, Microsoft Excel was used to run the regression and the creation of scatterplots that display the data.

Results

North Segment

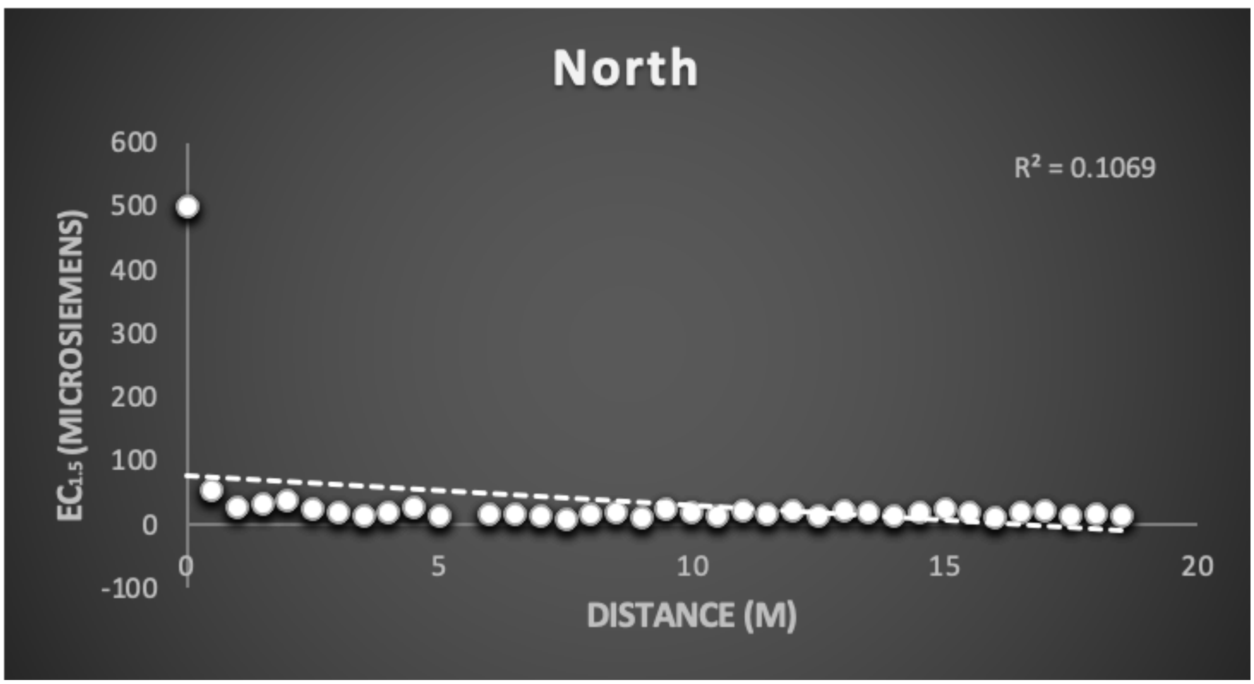

Figure 2a. Scatterplot displaying the relationship between distance and salinity in the northern directional segment.

The North segment of the transect begins at the chemistry building (see Figure 1). A high outlier was found at the 0.0m mark, with the EC reading being 501 microsiemens. The remaining samples ranged between 53 microsiemens and 9.3 microsiemens. A regression analysis was conducted in order to determine a significant or non-significant relationship between distance from the walkway and the soil salinity. The model's R^2 value (0.1069, Fig. 2a), indicates a poor fit to the model and variance not displayed by the model. Additionally, the p-value ($\alpha = 0.05$, $p = 0.0563$) from the regression analysis fails to reject the null hypothesis that the distance from walksways had no effect on the salinity level of the soil.

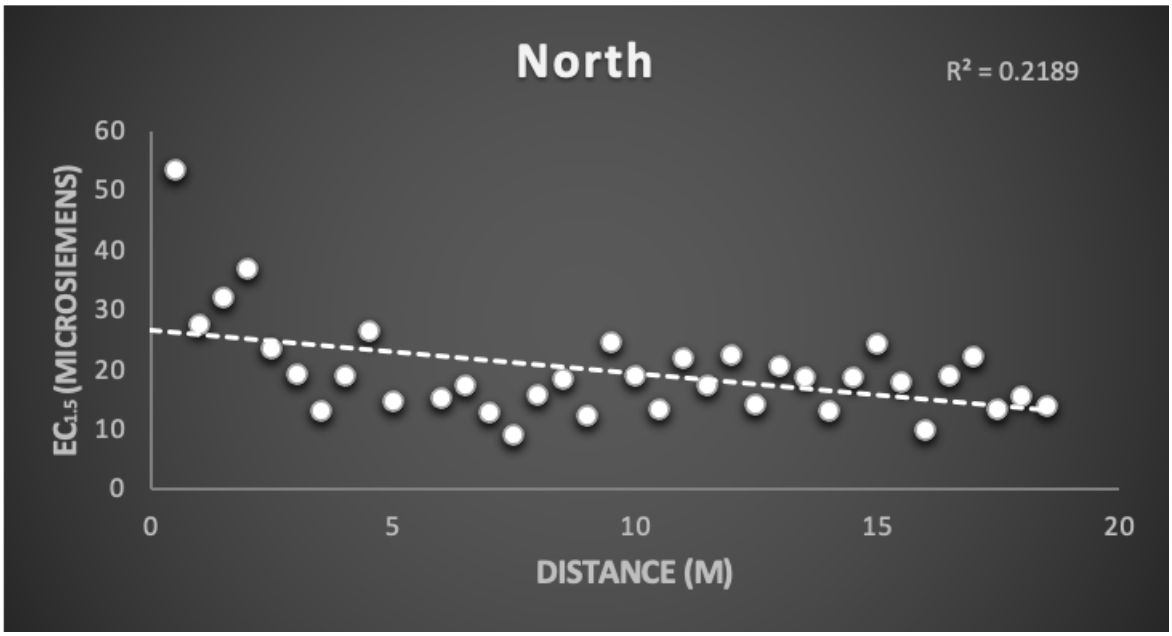

Figure 2b. Updated displaying the relationship between distance and salinity in the northern directional segment

To better help visualize the trend for the northern direction, the outlier (0, 501) was removed and a new scatterplot was created. Upon removal of the outlier, the R^2 value ($R^2 = 0.2189$, Fig 2b) increased, indicating that more variance is explained by the model. Furthermore, the p-value from the adjusted regression ($p = 0.004$) reveals a statistically significant relationship between distance and salinity, allowing for rejection of the null hypothesis.

South Segment

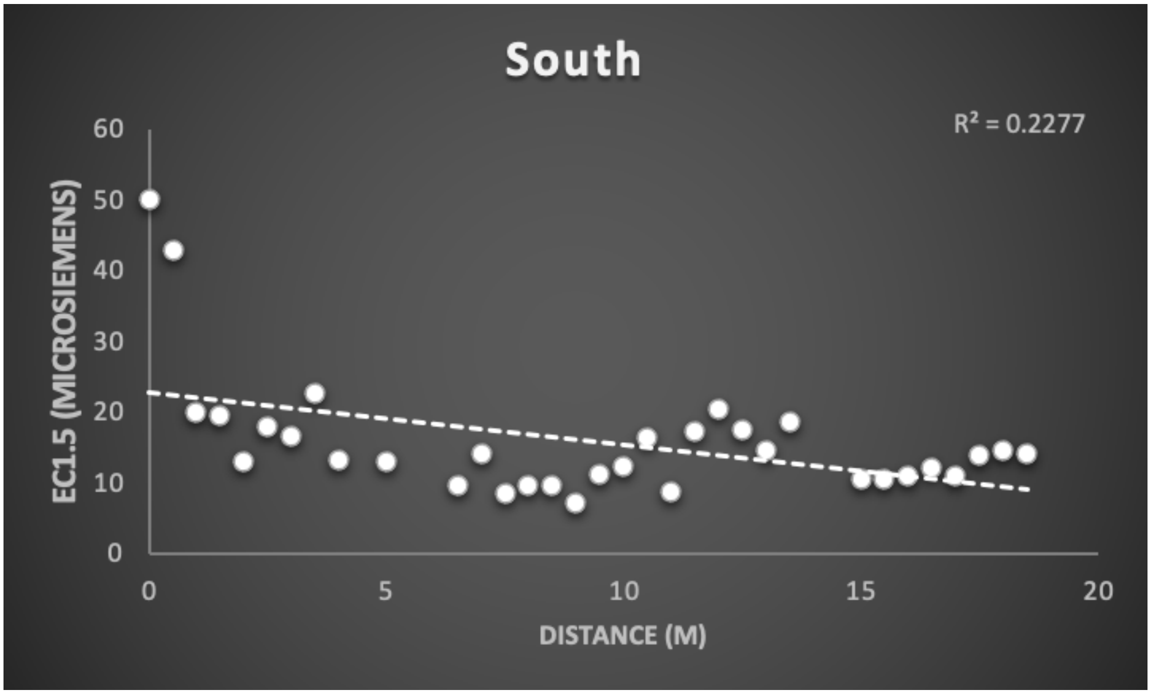

Figure 3. Scatterplot displaying the relationship between distance and salinity in the southern direction of the transect.

The South segment begins from a walkway which leads towards a parking lot and the Dalhousie athletic field. There are two high outliers in the first 1 meter of sampled distance. This suggests the greatest salination pollution happened within the first meter from the pathway. The variation in the regression model explains only a small proportion of the variability in the dependent variable ($R^2 = 0.2277$, Fig 3). This suggests that other factors may be influencing the relationship between the variables. Despite this, our analysis showed a significant relationship ($p = 0.00498$), demonstrating that distance from treated pathways is an indicator of salinity levels.

Eastern Segment

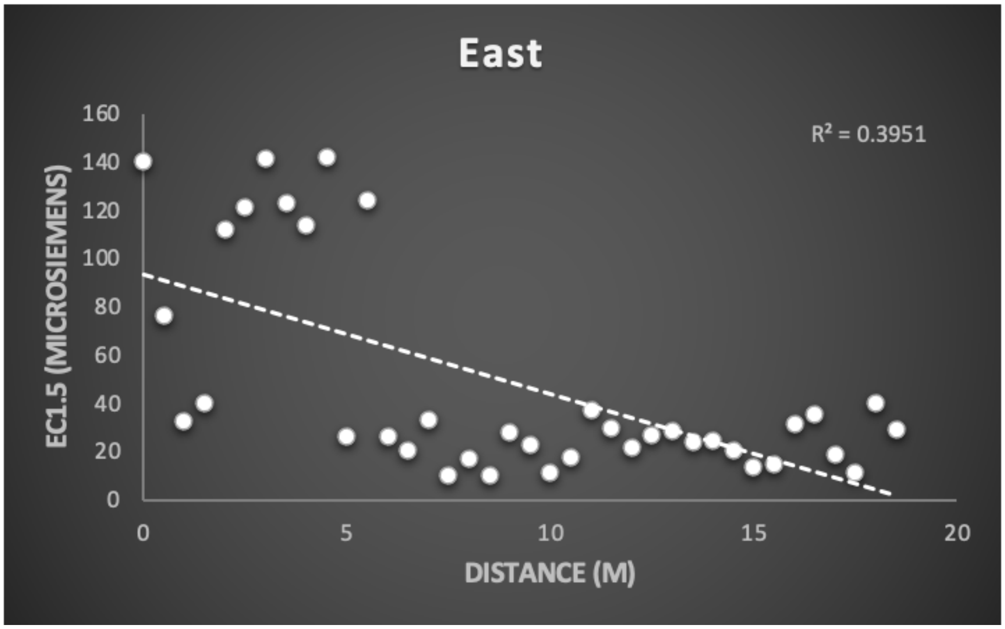

Figure 4. Scatterplot displaying the relationship between distance and salinity in the eastern direction of the transect.

The East segment begins from a path leading from LeMarchant St, the location of student housing, dining halls, and instructional spaces. This segment found the highest levels of sustained salinity up to 5.5 meters from the path. While there is a low fit to the regression model ($R^2 = 0.3951$, Fig 4), the regression analysis suggests a highly significant relationship between salinity levels and the distance from the sidewalk ($p = 2.383E-5$). With this knowledge, there is sufficient evidence to reject the null hypothesis.

Western Segment

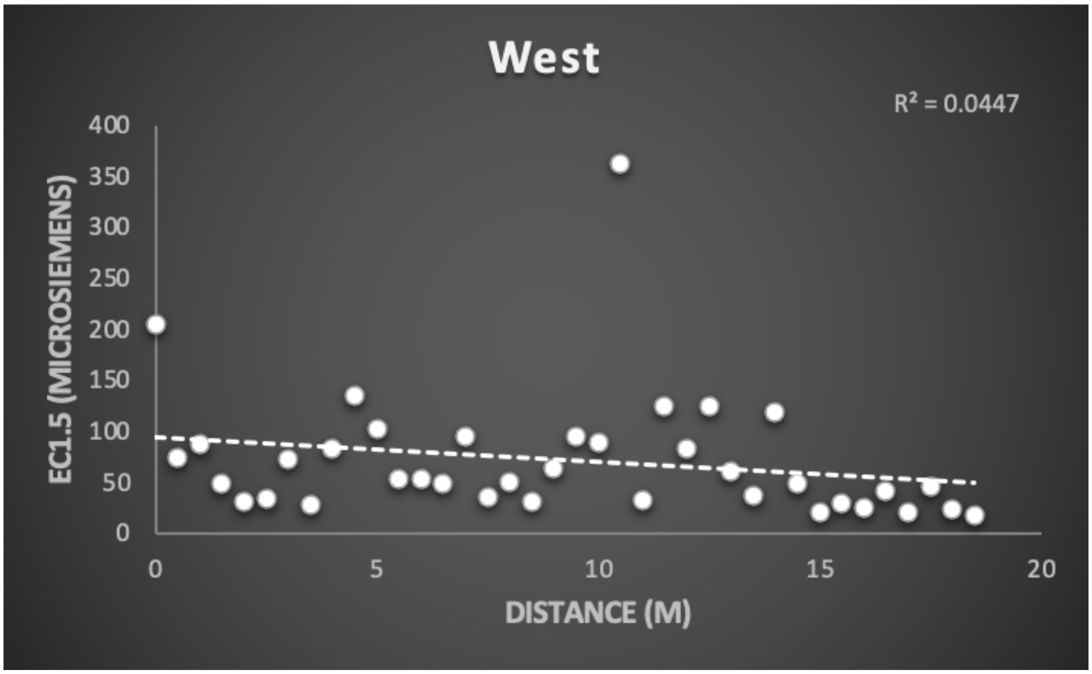

Figure 5. Scatterplot displaying the relationship between distance and salinity in the western direction of the transect.

The West segment of the transect begins from a footpath which crosses through the center of the quad. This West side is also the most elevated side of the sampled area with a slight slope towards the southeast corner. The minute R^2 value demonstrates (0.0447, Fig 5) that the variation within the data is not explained by the model. However, the p-value ($p = 0.2023$) reflects an insignificant relationship between salinity and distance from the sidewalk. Consequently, we failed to reject the null hypothesis. It is important to note that the insignificance may be caused by the outlier at 11 meters.

Average of Segments

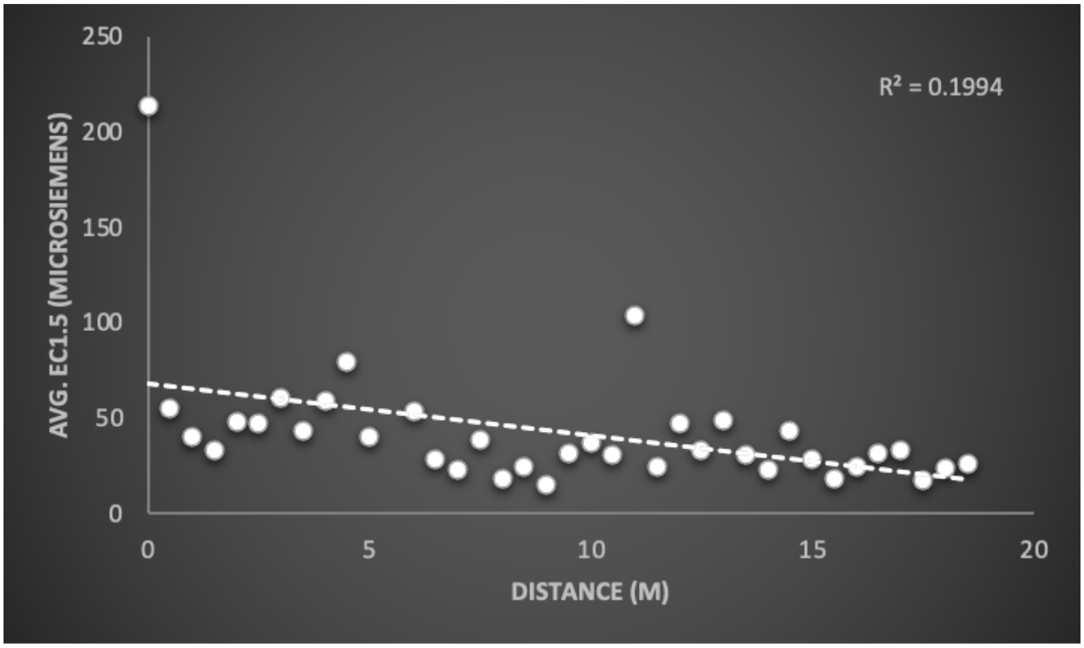

Figure 6. Scatterplot displaying the relationship between the average salinity from all directions and distance.

An analysis using the average of all four segments was run to understand the average relationship between distance and salinity. A high outlier was found at the 0.0 meter, directly adjacent to the sampled pathway. The model does not explain all the variation within the dataset (R^2 = 0.1994). However, the resulting p-value of 0.00104 for the slope of the regression line indicates a significant relationship between the distance and salinity values.

Discussion and Limitations

Discussion

While the salinity levels were not as high as we expected them to be, there is a significant negative relationship between the distance from a treated pathway and the salinity levels. This suggests that de-icing salt does spread across soiled areas from the point of application. High EC at the 0.0m on all segments indicated that the most impacted soils are within the first 0.5 meters from the site of application. The North segment had salinity rates beyond tolerable for plant growth within the first 0.5 meters. These findings indicate that de-icing salts have the potential to negatively impact soil health and plant growth.

Therefore, we recommend that extra caution be used when salting immediately next to gardens and plantlife. This is especially true if the plants are of ecological importance, are used for human consumption or supply food to local wildlife. In these cases, alternatives to sodium chloride based salts, such as sand or beet juice deicer, are recommended. However, each method comes with unique challenges and individuals are encouraged to research what is best for their needs.

In addition, the result of our study did not show any major salt pollution was found from the spread of de-icing salts. However, we will pass along our findings to the Grounds Keeping team and caution that there is spread of the de-icing salts occurring. Pedestrian safety must be kept a priority, but extra caution can be taken around sensitive greenspaces. The pollinator garden to the north of the Henry Hicks building and the Studley campus urban gardens may benefit from more prudent salt applications.

Overall, our study shows the potential negative impacts of de-icing salts on soil health and plant growth at Dalhousie campus, and we recommend that alternative de-icing methods be considered to minimize their impact on the environment.

Salinity Threshold

The objective of this study was ultimately to assess how soil health was impacted by de-icing salts and to determine if this impact is having an effect on vegetation success. In our study area, the prominent vegetation was Kentucky Bluegrass, which is considered 'salt sensitive' (Mastalerczuk et al., 2018). The salinity threshold of this lawn grass in terms of tolerability is less than 4 dS/m (Harivandi et al., 1992), but this does not necessarily mean that growth or related factors such as germination are not negatively impacted at salinity under 4 dS/m (Qian , 2003). Salinity levels were determined by multiplying EC1.5 by a 'conversion factor' (cf) which is a numeric value particular to soil type which facilitates conversions from EC1.5 readings into soil salinity values (Kargas et al., 2022). The soil type we were dealing with in our study area was sandy loam which retains a cf value of 14 with respect to EC1.5 values expressed in dS/m (*Measuring Soil Salinity*, n.d.). After calculating the soil salinity of collected soil samples, it was concluded that only two samples feel above the threshold of tolerability (see figures below); West (10.5 m) and North (0 m). The salinity values were; 5.07 dS/m and 7.04 dS/m respectively. Salinity thresholds, although able to be generally determined for a given species, are highly dependent on environmental factors such as temperature and moisture content (*Measuring Soil Salinity*, n.d.). When considering temperature, it can be seen that a threshold of 0.3 dS/m or lower results in compromised germination (*Measuring Soil Salinity*, n.d.). Exactly 50% of our data entries representing salinity lie above 0.3dS/m (77/154) which means that half of the areas tested maintained soil which has a salinity above the threshold of successful germination.

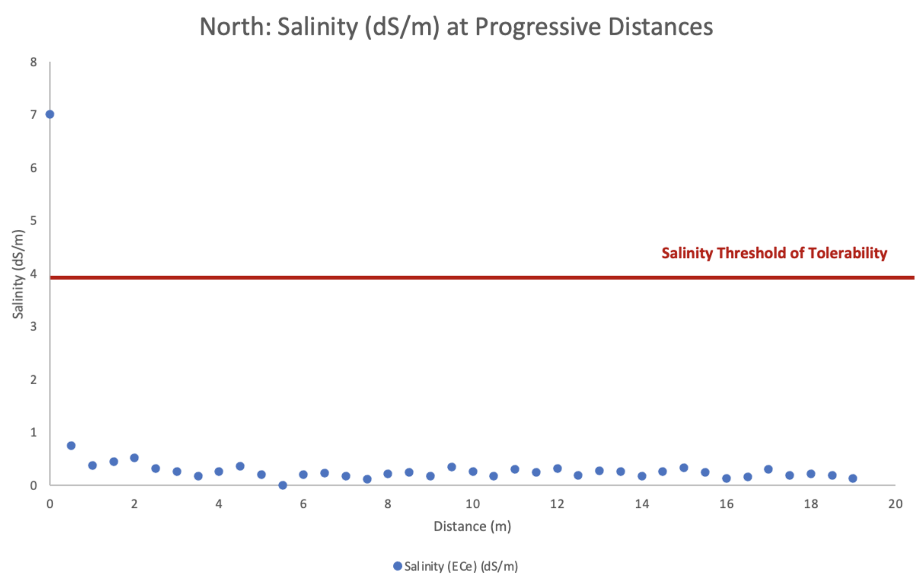

Figure 7. Salinity (dS/m) at progressive distances across the North side in reference to salinity threshold of tolerability

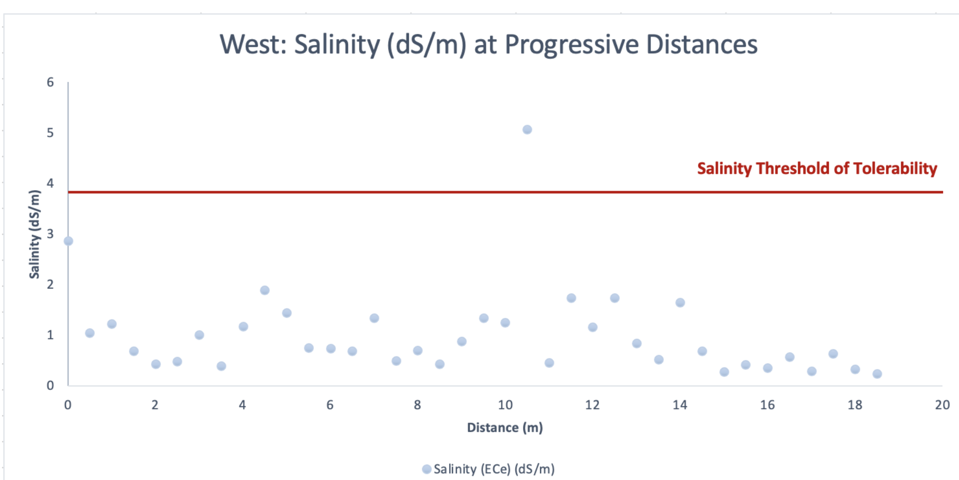

Figure 8. Salinity (dS/m) at progressive distances across the West side in reference to salinity threshold of tolerability

Limitations

This study has several limitations that should be taken into consideration when interpreting the results. Firstly, the study was conducted at only one specific location, the Dalhousie University Studley campus, and which may not be representative of other areas. This limitation is significant since the amount of salt applied at other areas, such as high-density commercial areas or roads, may differ from that applied on the study site. Moreover, the study only analyzed the impact of de-icing salts on soil salinity levels and did not investigate the effects on other soil properties or plant health.

Methodologically, the use of a single instrument, in our study we used the YSI probe, to measure soil salinity levels may limit the accuracy and reliability of the results. Additionally, the study only sampled two vertical lines in each designated area, which may not be representative of the entire area, as the samples did not cover the entire study site.

The study also did not collect samples from areas where the salt was not applied, which is difficult to compare the salinity levels of salted and unsalted areas. Additionally, the data only includes soil samples from the Dalhousie University Studley campus and may not be representative to other areas. The study only used a linear regression analysis, which may not capture complex relationships between variables. The study interprets the results in terms of salinity levels but does not provide any information on the potential impact of these levels on plant health or other ecological factors.

Conclusion

There is a clear balance that must be struck in ensuring safety during icy winter months and maintaining good soil health. The tested footpaths included in the study are only a small case study of the mass amounts of de-icing salts used every winter. Over $1 billion dollars CAD are spent annually in Canada to plow and salt sidewalks, roads, parking lots, and driveways (RCMP, 2019). As found in our research, de-icing salt does leech off of the intended path into surrounding salt ways. While the Groundskeepers at Dalhousie's Studley campus have proven to be efficient in their salt application, there are many other salted roads which may be causing undue salination pollution on the surrounding areas.

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