Salinity and pH of nearby freshwater puddles and snow were unaltered after roads have been de-iced

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Abstract:

Road salt has been widely used as a deicing agent during winter, but concerns have been raised about its potential impacts on freshwater ecosystems. Road salts can negatively impact freshwater ecosystems by increasing the salinity levels, which can harm or kill aquatic organisms and alter the composition of the food chain. Additionally, road salts can also affect the water quality and decrease biodiversity in the affected areas. In this study, we investigated the effects of road salt on nearby freshwater puddles to determine if road salting influences the salinity and pH of nearby puddles. We hypothesised that de-icing roads by means of salting would increase the salt concentrations in nearby puddles significantly. We measured pH and salinity immediately after deicing measures were implemented. We sampled water from puddles of 5 different locations of varying distances near main roads that were visibly salted. Contrary to our hypothesis, our results did not show a significant correlation between salinity levels and distance from the road. The measured pH levels were also not significantly correlated with distance from the road.

Introduction:

Road salt is a commonly used deicing measure to ensure safe driving conditions during winter months. Typically, halite - the mineral form of NaCl is used as road salts, and the use of this road salt has increased significantly over the past few decades as it is an effective and relatively inexpensive method to de-ice roads. However, the environmental impacts of road salt have been a growing concern due to its potential to cause water pollution, soil contamination, and damage to infrastructure.

The impact of road salt on water quality has been extensively studied. A study conducted by the National Cooperative Highway Research Program (NCHRP) found that road salt was one of the primary sources of chloride pollution in surface waters, with concentrations exceeding safe levels for aquatic life (Hanes, 1970). Similarly, a recent study published in the Proceedings of the National Academy of Sciences (PNAS) found that road salt runoff increased the concentration of chloride and sodium ions in rivers and streams, compromising water quality and threatening aquatic ecosystems (Dugan et al., 2017). The study also reported that salt pollution in water sources could potentially harm human health.

Aside from water pollution, road salt can also damage ecosystems and interfere with plant growth. A report by the Cary Institute of Ecosystem Studies tells us that moderate levels of salt in water can brown plants and decrease the nutrient availability of the soil nearby (Kelly et al, 2010). Another study published in BioScience reported that road salt runoff can increase the bioavailability of heavy metals in soil, potentially leading to increased heavy metal content in food webs (Schuler et al., 2018). Schuler et al. (2018) also reports that this mobilisation of heavy metals deep into soil can eventually be transported to fresh water systems, which undoubtedly would have detrimental effects to aquatic life.

The environmental impacts of road salt extend beyond just water and soil contamination. The use of road salt can also cause damage to infrastructure such as bridges, roads, and vehicles. According to Kelly et al. (2010), road salt can also accelerate the corrosion of steel infrastructure, leading to costly repairs and replacements

In this paper, we aim to narrowly investigate the potential effects of road salt on the environment by measuring the pH and salinity of freshwater puddles nearby main roads immediately after deicing measures were implemented. We hypothesise that salinity and pH levels in puddles and snow nearby de-iced roads will be affected by the presence of salt content.

We predict that salinity levels will be highest in fresh water sources proximal to the de-iced roads due to the high amount of salt sprayed on roads. However, pH levels would remain constant regardless of the distance from de-iced roads.

Methods:

Sampling of water sources:

Sampling of water took place in 5 different locations throughout Canada. 3 locations were in the metro Vancouver area, BC and 2 locations were localized in Toronto. From each location, we found 3 puddles or snow coverings of varying distances from a main road that was visibly salted to collect water samples from. The variation in distance was crucial as we were looking to determine if salinity and pH levels significantly increased the closer the water sources were to the main road as stated in our prediction. Therefore, we made sure to sample from puddles or snow covering with drastically different distance from the main road within each location to prevent accidental contamination of salt content between the 3 puddles/snow coverings. Within each puddle or snow covering, we took 3 samples of fresh water for redundancy and to reduce any errors in sampling. For sampling water from snow coverings, we dug to the base layer of the snow covering and scraped out a bit of snow that was in contact with the ground. Therefore, in total, we had 9 different samples per location.

Measurement of abiotic factors:

We also measured temperature, and noted the date and time of day for each location, but did not include them in any statistical models as we concluded that these abiotic factors would have a minimal role in determining the validity of our hypothesis

Measurement of our variables - salinity and pH:

We measured the salinity of our samples using a handheld refractometer provided by the BIOL 342 lab which provides accurate measurements of salinity in parts per thousand to the nearest ‘ones’. We measured pH using pH strips provided by the BIOL 342 lab. The strips were used to qualitatively analyze the pH of our samples, hence all of our pH measurements were qualitative estimates based on color comparisons with a predetermined color key.

Statistical analysis:

We used the Pearson correlation linear regression test to determine the correlation between salinity vs distance from the road, and pH vs distance from the road for each sample. We completed two different sets of tests (as differentiated by Figures 1 and 2). The first set tested correlation of salinity and pH to distance from the road for each of the locations. The second set also tested the exact same variables, but combined all data points collected from all 5 locations.

We completed a two-tailed t-test for all correlation plots to determine the significance of our statistical model. The Pearson correlation test and two tailed t-test used in this experiment was based on Excel Version 2301 Build 16.0.16026.20214.

Results:

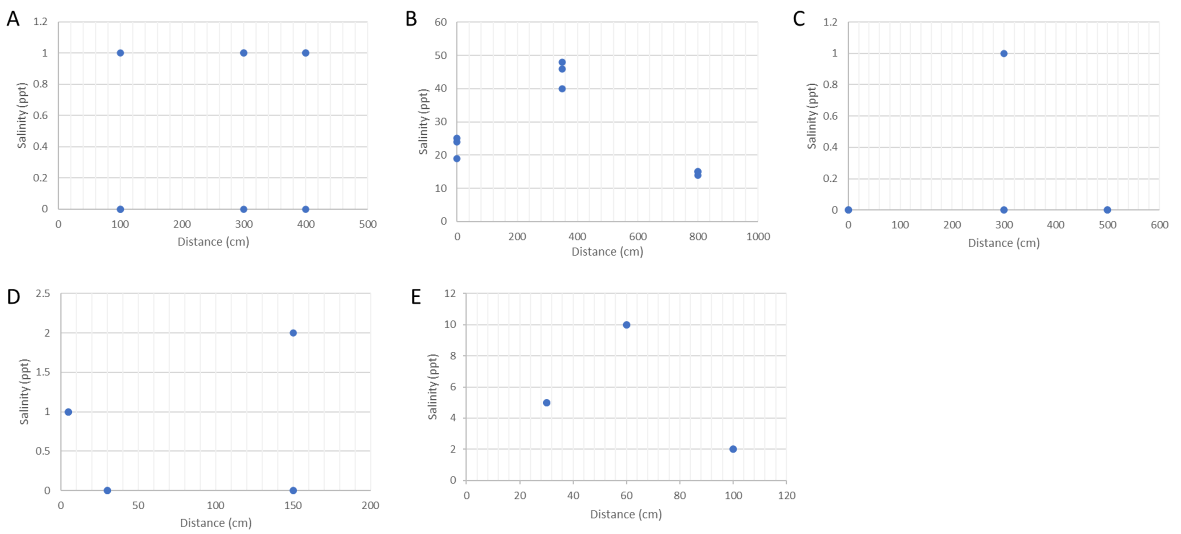

Figure 1. Pearson correlation test testing salinity vs distance from main road for all 5 of our locations. Vertical axis shows salinity levels in parts per thousand (ppt) . Horizontal axis shows the distance travelled away from main road in centimeteres (cm). Correlation coefficients and p-values were: Figure 1a. r: 0.298807152, p: 0.434766847; Figure 1b r: -0.320237551, p: 0.400828916; Figure 1c. r: 0.057353933, p: 0.883479339; Figure 1d. r: 0.017087777, p: 0.965197536; Figure 1e. r: -0.446225823, p: 0.228606301.

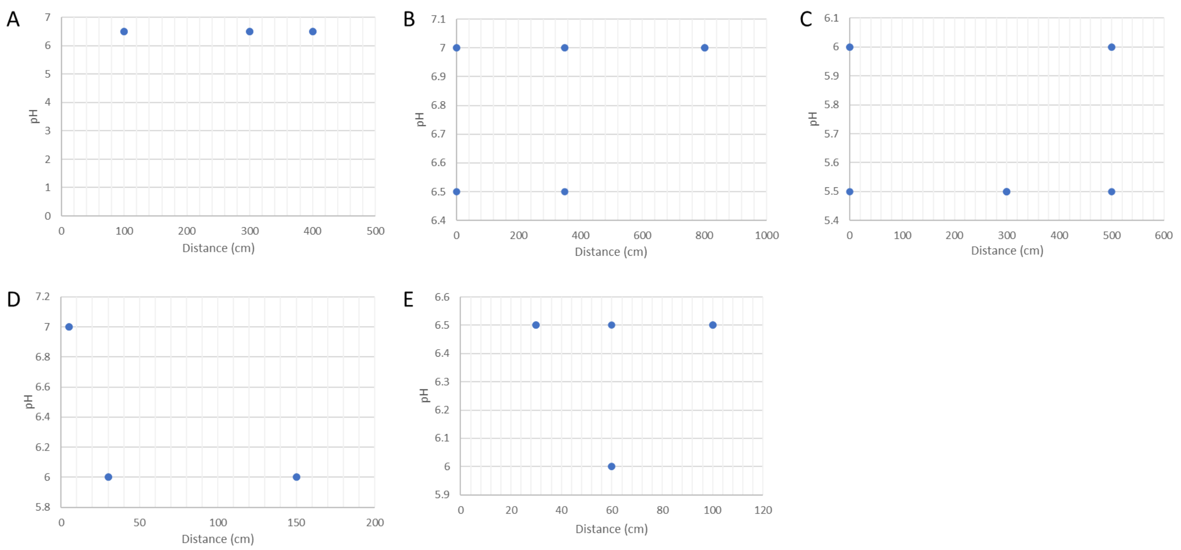

Figure 2. Pearson correlation test testing pH vs distance from main road for all 5 of our locations. Vertical axis shows pH levels and horizontal axis shows the distance travelled away from main road in centimeteres (cm)..

Correlation coefficients and p-values were: Figure 1a. r: 0, p: 1; Figure 1b. r: 0.340080976, p:0.370538208; Figure 1c. r: -0.072547625, p:0.852853872; Figure 1d. r: -0.633113084, p: 0.0672104; FIgure 1e. r: 0.062136977, p: 0.873822169

We carried out 2 Pearson correlation tests for this experiment: one for each of our 5 locations' salinity and pH. Each plot has 9 data points plotted, but some are not seen as they are they hold the same data value, and are duplicated points. There was no clear trend displayed between all 5 of our locations for both salinity vs distance and pH vs distance based on correlation coefficients seen in Figure 1 and FIgure 2. Figures 1a, 1b were taken from Toronto, and samples for Figures 1c - 1e were taken from Vancouver. Figure 2 also followed the same pattern. It should also be noted that there is no discernible difference in data trends between these two cities. However, p-values in all of our plots, including the tests for individual locations, were over 0.05 ($p > 0.05$), and therefore, statistically not significant. .

Discussion:
Our study did not find a significant correlation between pH and salinity levels in water samples collected from puddles near de-iced roads. It is important to note that research comparing salt runoff and distance from the roads will generally measure salinity from lakes and streams. However, in this study, we measured salinity and pH from puddles and snow near the de-iced roads which may have contributed to the lack of correlation in our variables. We were also constrained by weather conditions for our sampling as road salting only occurs on days with freezing temperatures. This left us with limited samples for testing which contributed to lowering the statistical significance of our experiment.

Although our statistical analysis failed to provide significant results, we qualitatively report the notable absence of difference in salinity and pH with increasing distance from the road, especially with pH measurements as all of our samples ranged between 5.5 to 7. This level of consistency is also slightly observed in most of salinity measurements, with most samples ranging from 0.0 to 2.0 parts per thousand

Therefore, we qualitatively state that salt concentrations contrast our prediction while pH levels were in line with our expectations. We Predicted that salt concentrations in puddles and snow would be higher proximal to the de-iced roads due to sprayed salt seeping into the environment around; however, the salt levels remained relatively constant except for a few outliers near the 0.0 - 2.0 parts per thousand range with most of our values ranging below 1.0 ppt. Considering that fresh water salt levels range around 0.5 ppt (Horiba, 2016), and moderately saline water ranges above 3.0 ppt (Halamobeen, 2019), most of our samples indicate that puddles and snow coverages are relatively non-saline. This could be due to the fact that we sampled the same day as snow fell, which may not have given enough time for salt to seep into the environment and affect the surrounding water sources. Our method of collecting water samples from snow and puddles may also have contributed to the deviation from our prediction as snow do not generally contain significantly large concentrations of salt. For example, Figure 1e shows a singular data point for salinity in the 10 ppt range in contrast to the others which are significantly lower. This data point was actually collected from a puddle while the other two were collected from snow fall which may explain its inflated salinity as puddle water will generally hold salt far better than crystalized water (snow).

It may also simply be that salting of roads in Ontario and BC are in fact carried out responsibly and therefore does not harmfully affect nearby environments - although we are hesitant to conclude this as our findings were not statistically significant. If this were the case, however, it would show a great deal of responsibility from these two provinces in taking preventative measures to appropriately preserve the natural environment.

We also predicted to see relatively constant pH in all samples. Qualitatively, this was indeed the case with most pH levels ranging near 6-7 as seen in Figure 1b. However, we cannot conclusively report this due to the lack of statistical significance. But, this result isn't too surprising consider that adding NaCl (which is the base form of road salt - halite) to water will not have a significant effect on the pH of the water because NaCl is a neutral salt that does not contain any acidic or basic ions. Therefore, dissolving NaCl in water will not release any significant amounts of hydrogen or hydroxide ions that could affect the pH of the water.

Future studies may consider the factors that may influence the levels of pH and salinity in water samples and the difficulties we faced with our experiment. For example, sampling methodologies should be standardized to eliminate introduction of other variables and environmental factors that are out of our control should be mitigated. Nevertheless, the results of this study contribute to the understanding of the impact of de-icing salts on nearby water sources and can help in the development of strategies for mitigating any potential negative effects.

Conclusion:
We tested the effect of road salt in nearby environments by sampling water from puddles and snow coverings. We found no correlation in salinity and pH as distance from the salted road increases; however, our results were not statistically significant and therefore, we cannot decisively report our conclusion. However, our experiment will undoubtedly help with the planning of future studies involving de-icing measures and road salts.

Acknowledgements:
Thank you to Dr. Celeste Leander and our TA Tessa Blanchard for general guidance during data collection and statistical analysis. Thank you UBC Faculty of Science for generously allowing us to use your equipment and gear.

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Appendix:

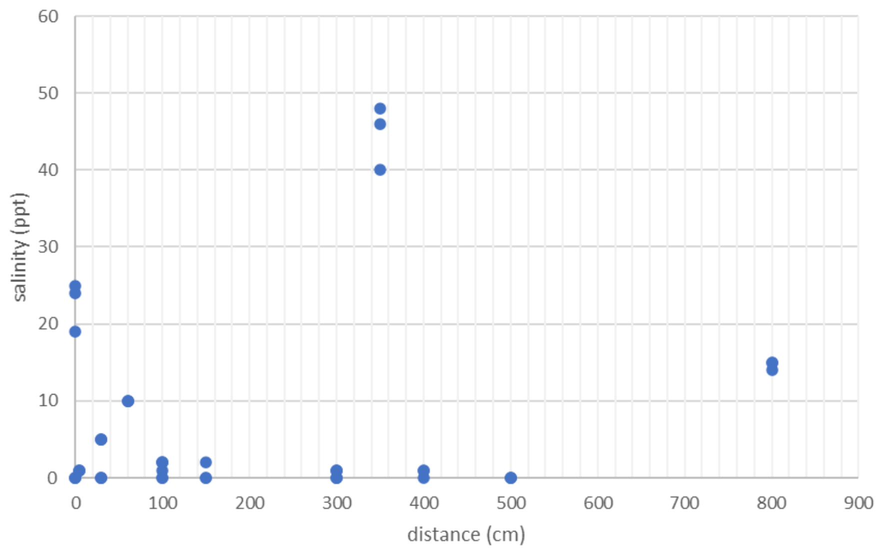

Figure 3. Pearson correlation test testing salinity vs distance combining all data points. Vertical axis shows salinity levels in parts per thousand (ppt) . Horizontal axis shows the distance travelled away from main road in centimeteres (cm). Correlation coefficients and p-values were r: 0.189134342, p: 0.213383301. There are in total 45 points; some points are duplicated data, and therefore not clearly shown.

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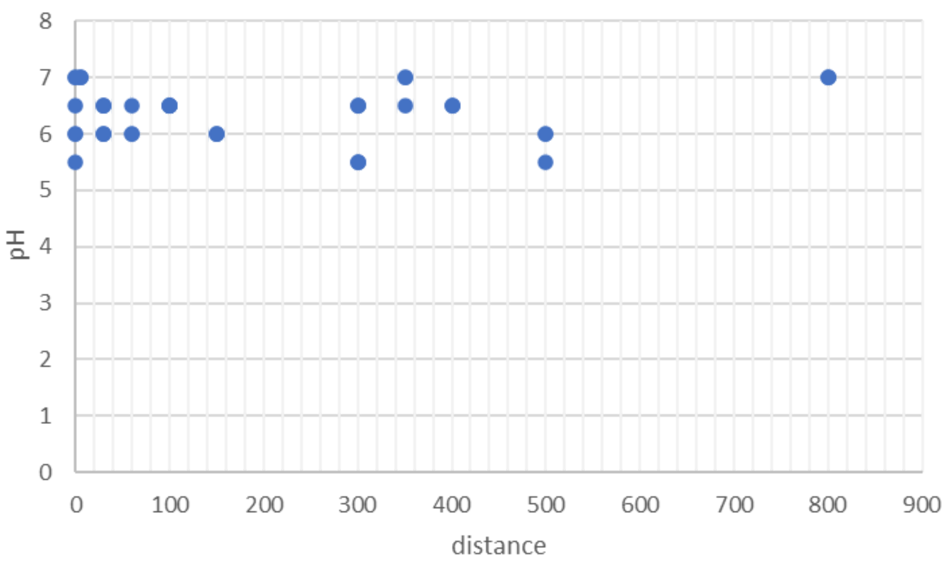

Figure 4. Pearson correlation test testing pH vs distance combining all data points. Vertical axis shows pH and horizontal axis shows the distance travelled away from main road in centimeteres (cm). Correlation coefficients and p-values were r: 0.123666901, p: 0.418312755. There are in total 45 points; some points are duplicated data, and therefore not clearly shown.

Table 1a. Data collection for Celine - Le Germain Hotel, Toronto

	Puddle 1			Puddle 2			Puddle 3		
sample	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**
Sample 1	0	24	7.0	350	40	6.5	800	15	7.0
Sample 2		19	6.5		48	7.0		14	7.0
Sample 3		25	7.0		46	7.0		15	7.0

Table 1b. Data collection for KC - Scarborough, Toronto

	Puddle 1			Puddle 2			Puddle 3		
sample	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**
Sample 1	100	0	6.5	300	0	6.5	400	0	6.5
Sample 2		1	6.5		1	6.5		1	6.5
Sample 3		0	6.5		1	6.5		1	6.5

Table 1c. Data collection for Joseph - UBC Bus Loop, Vancouver

	Puddle 1			Puddle 2			Puddle 3		
sample	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**
Sample 1	5	1	7.0	30	0	6.0	150	0	6.0
Sample 2		1	7.0		0	6.0		2	6.0
Sample 3		1	7.0		0	6.0		0	6.0

Table 1d. Data collection for Celine - Panorama Dr, Coquitlam

	Puddle 1			Puddle 2			Puddle 3		
sample	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**	**distance from road (cm)**	**Salinity (ppt)**	**pH**
Sample 1	0	0	6.0	300	1	5.5	500	0	6.0
Sample 2		0	6.0		0	5.5		0	6.0
Sample 3		0	5.5		0	5.5		0	5.5

Table 1e. Data collection for Shadmehr - Patterson, Burnaby

	Puddle 1			Puddle 2			Puddle 3		
sample	distance from road (cm)	Salinity (ppt)	pH	distance from road (cm)	Salinity (ppt)	pH	distance from road (cm)	Salinity (ppt)	pH
Sample 1	30	5	6.5	60	10	6.0	100	2	6.5
Sample 2		5	6.5		10	6.0		2	6.5
Sample 3		5	6.5		10	6.5		2	6.5

Table 2. Table for data regarding locations

location	date (mm.dd.yy)	time (hh:mm)	air temperature (C)
Le Germain Hotel, Toronto (measured by Celine, Figure 1A.)	01.01.23	11:29 am distance 1 11:30 am distance 2 11:32 am distance 3	2
Scarborough, Toronto (measured by KC, Figure 1B.)	01.04.23	03:50 am distance 1 03:55 am distance 2 03:58 am distance 3	14
UBC Bus Loop (measured by Joseph, Figure 1C.)	01.01.23	04:30 pm distance 1 04:45 pm distance 2 04:50 pm distance 3	10
Panorama Dr., Coquitlam (measured by Celine, Figure 1D.)	03.02.23	08:15 am distance 1 08:17 am distance 2 08:22 am distance 3	0
Patterson, Burnaby (measured by Shadmehr, Figure 1E.)	02.27.23	10:25 pm distance 1 10:30 pm distance 2 10:35 pm distance 3	1