

Effects of Deicing Agents on Stream Water Chemistry

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Introduction

Deicing agents, which are used to improve driving conditions during winter storms, can have significant effects on the environment. The use of deicers has increased over time, which has led to increased changes in soil and freshwater chemistry as well as changes in local ecology. Rock salt and other deicers have been found to cause chemical changes in fresh water systems, including increased chloride concentrations, changes in carbon, nitrogen, and phosphorus cycles and mobility, and mobilization of trace metals. Changes in salinity in freshwater systems have been observed worldwide (Figure 1).

To test the impact of the deicing agents on natural stream chemistry, three different deicing agents were added to stream water and sediment at various levels and then incubated for 24 hours. The three deicing agents tested were sodium chloride and calcium chloride dihydrate, both of which were lab grade salts, and beet juice deicer, which is a commercially available, organically based deicing agent. The three deicers were tested in stream water and sediment from two locations. pH, total dissolved organic and inorganic carbon, total nitrogen, base cation concentration, and ash free dry mass were measured after the incubations.

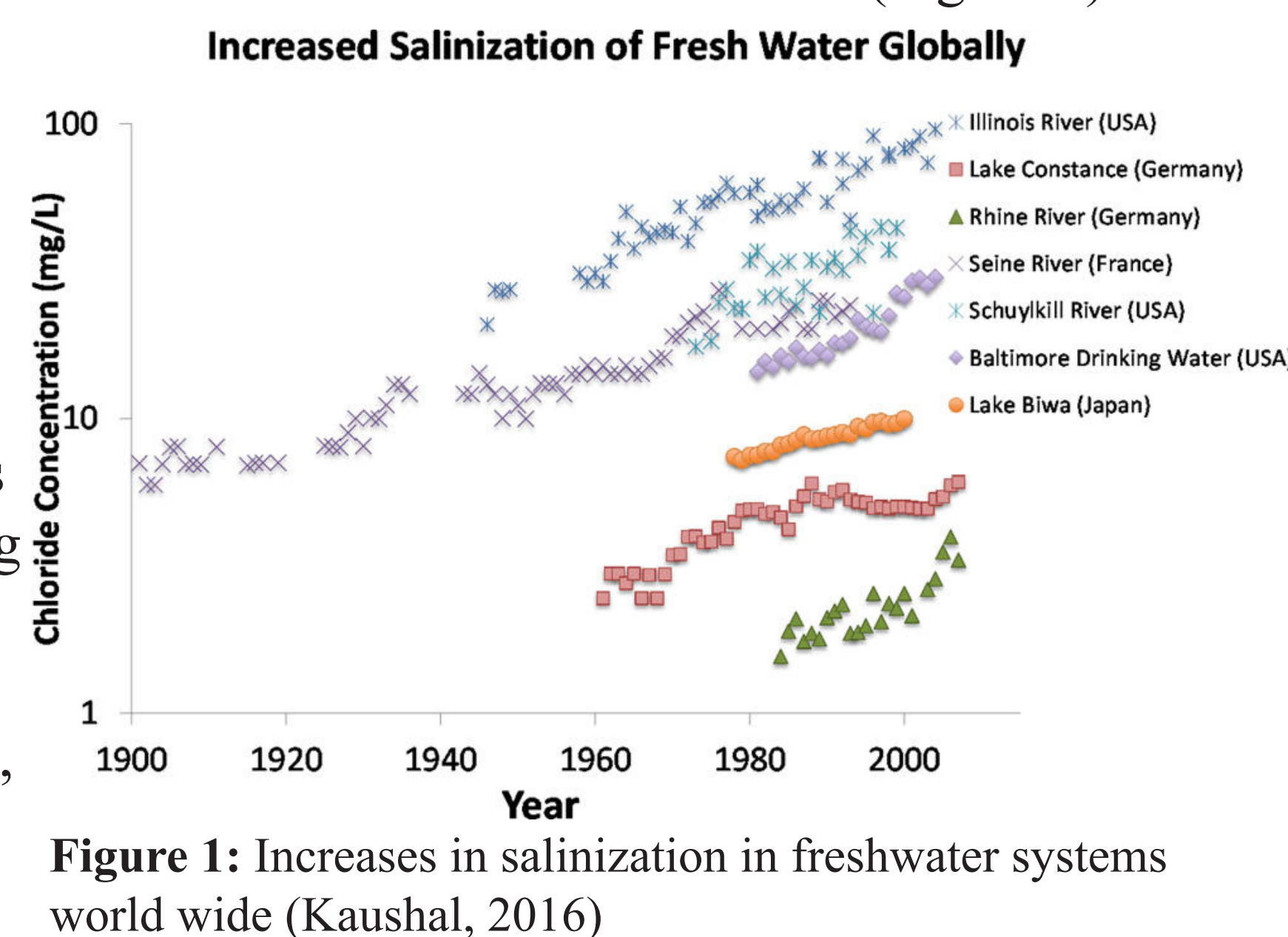


Figure 1: Increases in salinization in freshwater systems world wide (Kaushal, 2016)

Significance

The goal of this research was to help find differences in the way that various deicing chemicals interact with the environment. This knowledge can be used to explore alternative deicing agents for reducing salts in the environment and reducing mobilization of other contaminants. These changes may help support the ecosystems in freshwater systems as well as the surrounding area, potentially improve water quality of fresh water systems which are used for potable water. The use of alternative deicers could also potentially save money and/or make wintertime driving conditions safer.

Sampling Sites

The two sites chosen were along Scott's Level Branch in Randallstown, MD, which is near Baltimore, MD. One site was along a section of the stream that had been previously restored (Figure 2), while another site was degraded and unrestored, which was upstream of the restored section. (Figure 3).



Figure 2: Restored section of Scott's Level Branch which was used for sampling.



Figure 3: Unstored section of Scott's Level Branch which was used for sampling.

References

Kaushal, S.S. (2016) Increased salinization decreases safe drinking water. *Environ. Sci. Technol.* 50 (6), pp 2765–2766.

Sample Collection and Incubations

Three liters of stream water and roughly two liters of sediment were collected at both sites during sampling (Figure 4). The sediment was collected along three points on the cross section of the streambed to create a homogenous and representative mix. The sediment was then sieved and the grains 2mm and smaller were collected.

The incubations were performed at seven different concentrations of deicer; a blank (which had only stream water), a 0g/L deicer solution, and five concentrations starting from an initial composition and increasing to 2, 5, 10, and 20 times the initial concentration. To perform the incubations, 60g of sediment and 100mL of stream water + deicer were added to flasks. The flasks were then lightly capped, put on a shaker table, and left in the dark for 24 hours. After the 24 hours, the water was immediately removed and filtered for chemical analysis.



Figure 4: Collecting sample in the unrestored section of Scott's Level Branch near Baltimore, MD.

Chemical Analyses

Ash free dry mass was measured and used to determine the amount of organic matter in each vial. Ash free dry mass was found by drying the samples then burning the organic content. The vials were dried at 95° C for 24 hours in an oven immediately after the water was removed from the flasks, then the flasks were put in an oven at 450° C for 4 hours. Organic content mass was calculated by subtracting the mass of the burned sediment from the mass of the dried sediment. The organic mass was then divided by the total weight of the dried sediment to determine the organic content percent.

pH was measured immediately after the incubations were complete, but before the water had been removed from the flasks. The pH for each sample was then converted to hydrogen ion concentrations.

Dissolved organic and inorganic carbon concentrations as well as total nitrogen concentrations were measured using a Shimadzu TOC-L, which combusts the sample and measures the carbon dioxide in the infrared spectrum to obtain the concentrations.

Base cation concentrations were measured using inductively coupled plasma optical emission spectrometry (ICP-OES). ICP-OES measures and analyzes the optical emission produced when the sample is injected into a plasma flame of Argon.

H⁺, DOC, DIC, TN Results

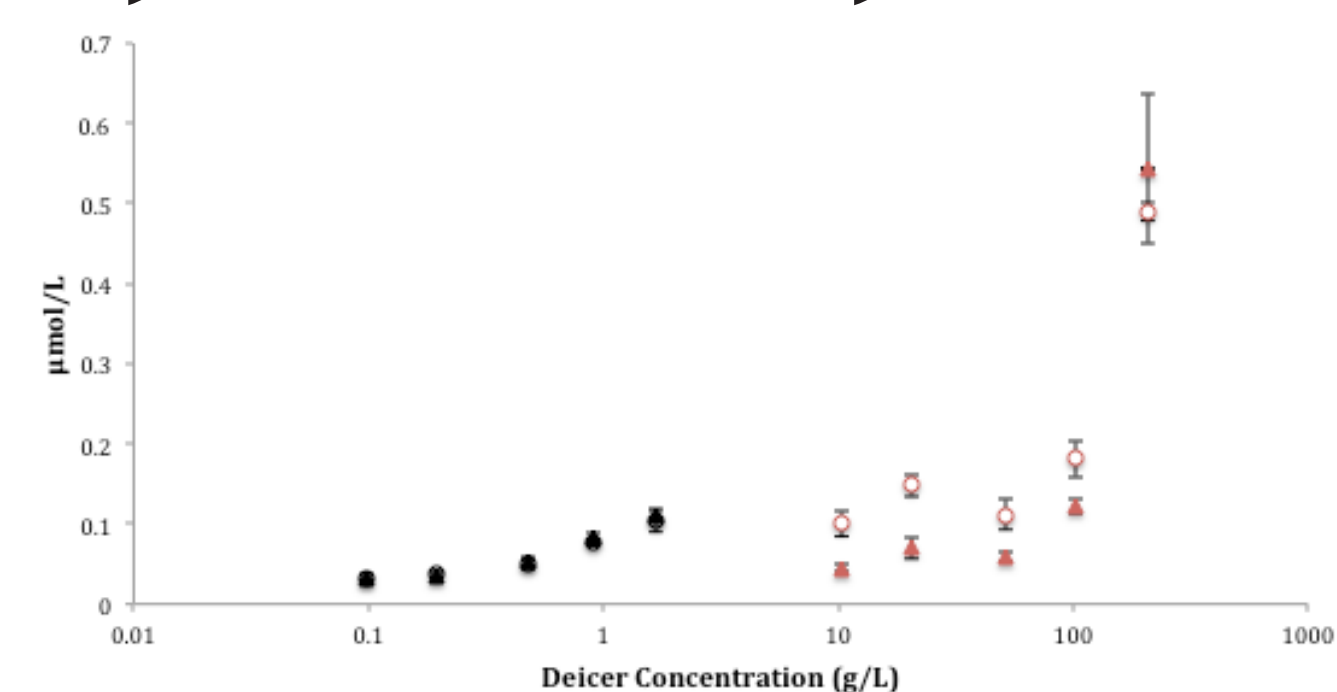


Figure 5: Hydrogen ion concentration.

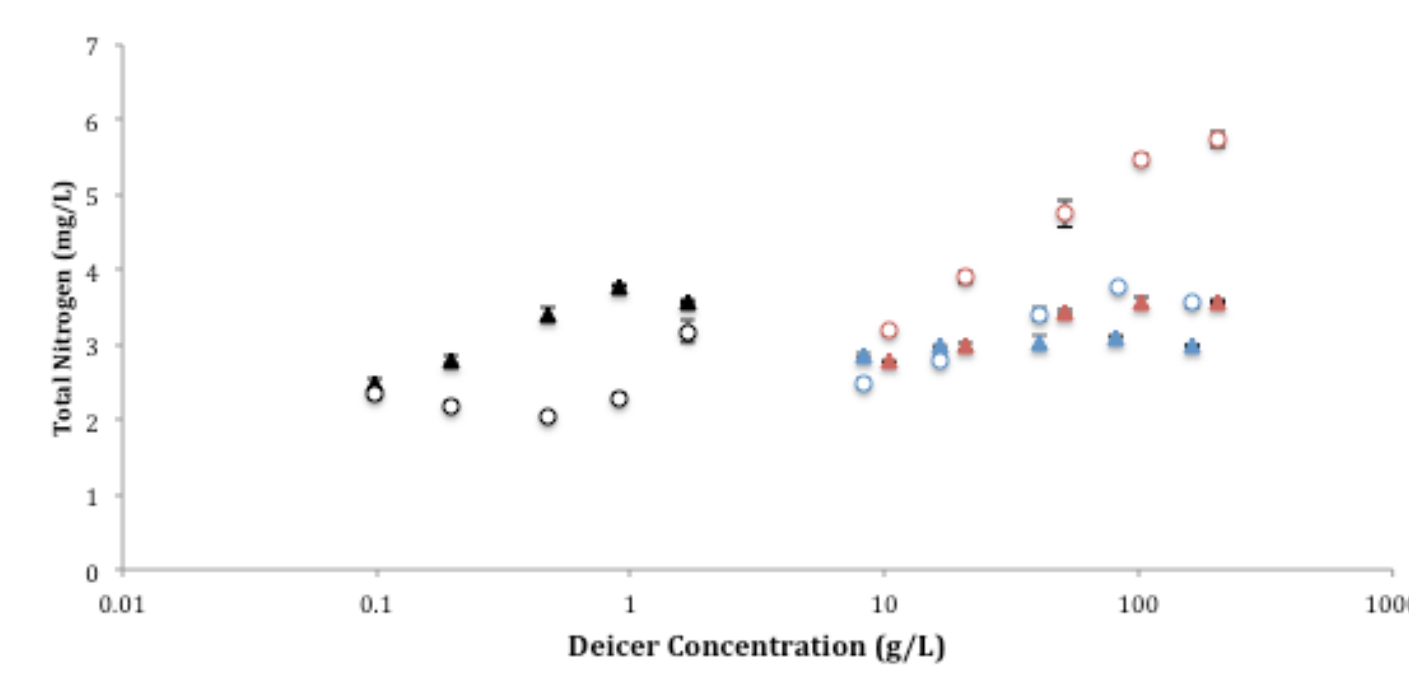


Figure 6: Total nitrogen concentration.

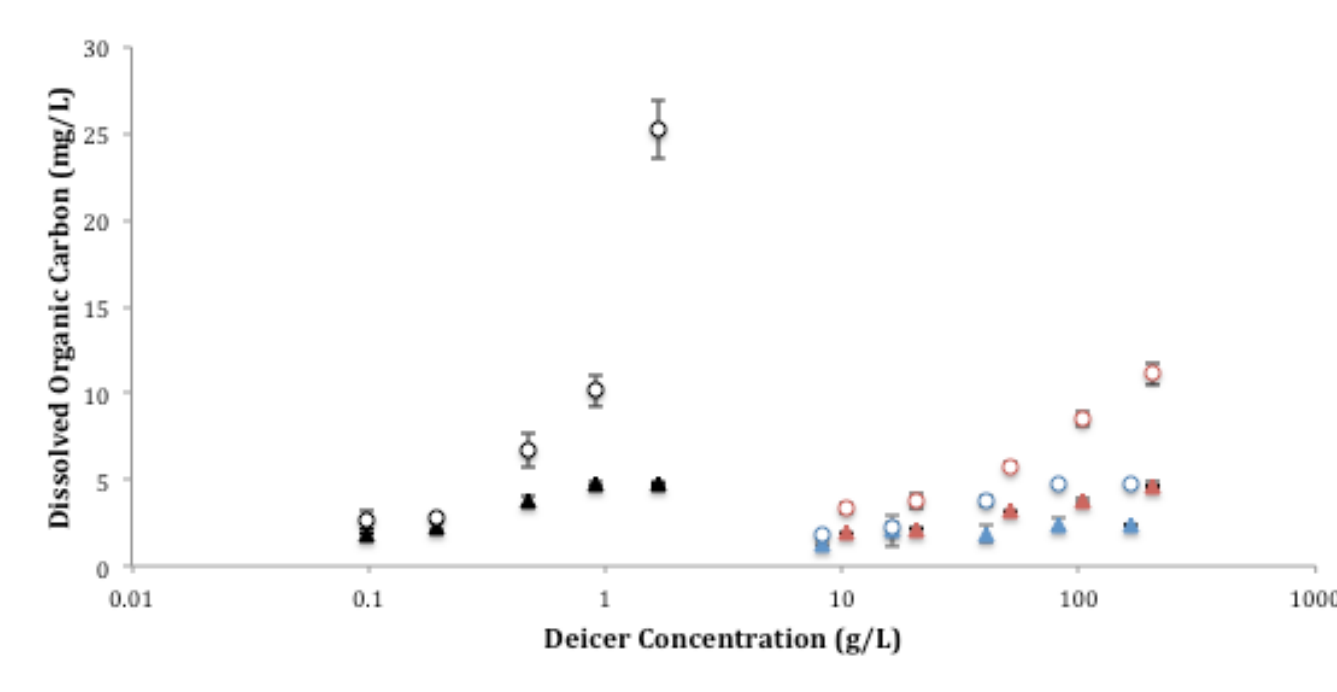


Figure 7: Dissolved organic carbon concentration.

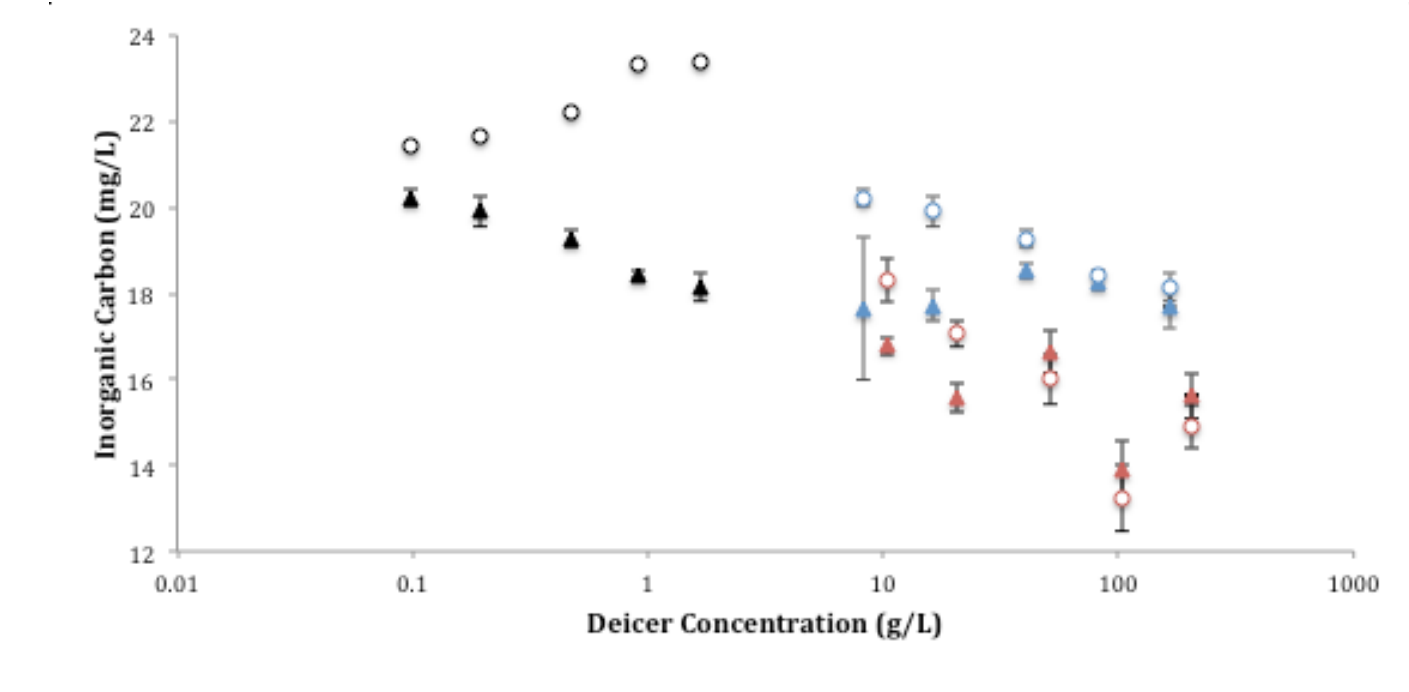


Figure 8: Dissolved inorganic carbon concentration.

Results

Hydrogen ion concentrations were found to increase with higher concentrations of deicer added (Figure 5). This was found for both calcium chloride dihydrate and the beet juice deicer for both the restored and unrestored sampling sites. This indicates that the addition of deicers into natural stream water may increase hydrogen ion concentrations, and thus decrease pH. The increase in hydrogen ion concentration did not taper off, which may suggest that further addition of deicer to the stream may lead to further acidification of the water.

Total nitrogen concentrations (Figure 6) and dissolved organic carbon concentrations (Figure 7) increased with increasing concentrations of deicer, while the concentration of dissolved inorganic carbon (Figure 8) decreased with higher levels of deicer added. This may be due to cation exchange between the sediment and the deicer, or potentially enhanced microbial activity in the water and sediment interacting with the deicer.

The ICP-OES analysis of base cation concentrations showed error, including negative concentration values and concentrations of major elements that were below detection limit. This may have been due excessive salt in the samples from not being fully flushed out of the system throughout the run. Thus, some sets of data were not reported. For K⁺, Na⁺, Mg²⁺, and Ca²⁺ the concentrations of the cations increased to a peak, then sharply decreased (Figures 9 - 12). This might suggest that as deicer concentration increases, the cations are increasing in concentration until they hit their saturation point, after which the concentrations decrease as mineral precipitation starts to occur.

The measurement of ash free dry mass produced no notable results. The changes in organic content were small enough that they fell within the limit of uncertainty of the scale used (less than 1% of the total mass of the flask and sediment). Furthermore, the changes recorded did not have any noticeable trend and did not appear to be impacted by the deicer used.

It should be noted that the measurements for the set of incubations where beet juice deicer was added to the unrestored site sample produced results that often did not fit with the trends observed for all of the other incubation sets. This may have been due to differences in the initial chemistry of the sample (due to storage issues) or the sediments of the unrestored site were different than the restored site and there was an unexpected interaction with beet juice.

Base Cation Results

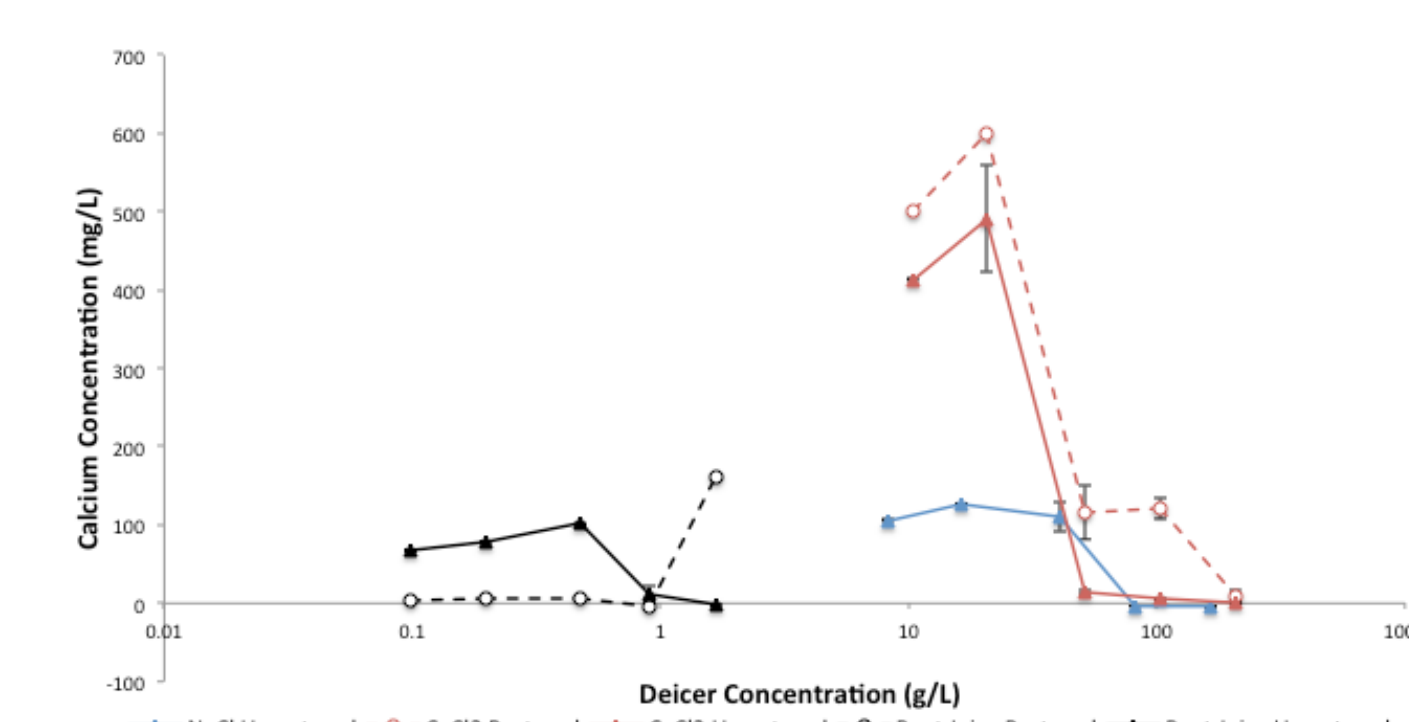


Figure 9: Ca²⁺ concentration.

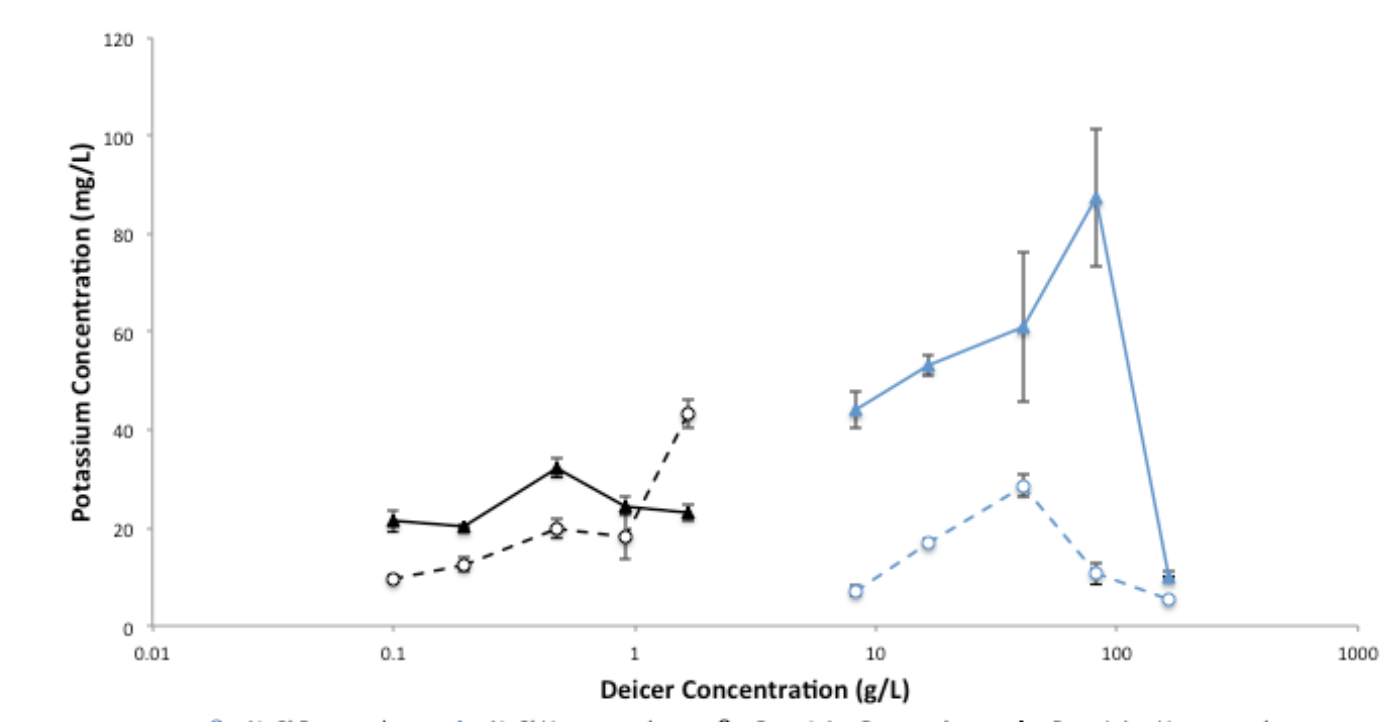


Figure 10: K⁺ concentration.

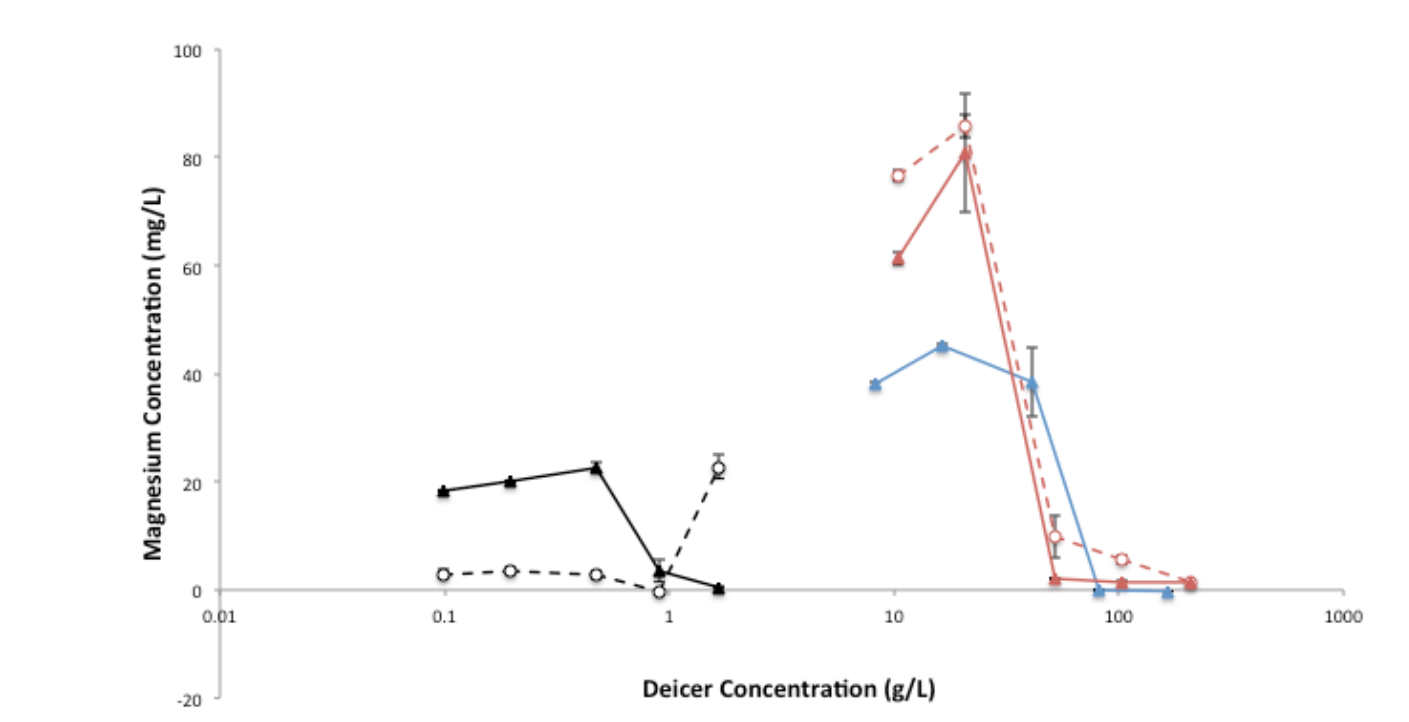


Figure 11: Mg²⁺ concentration.

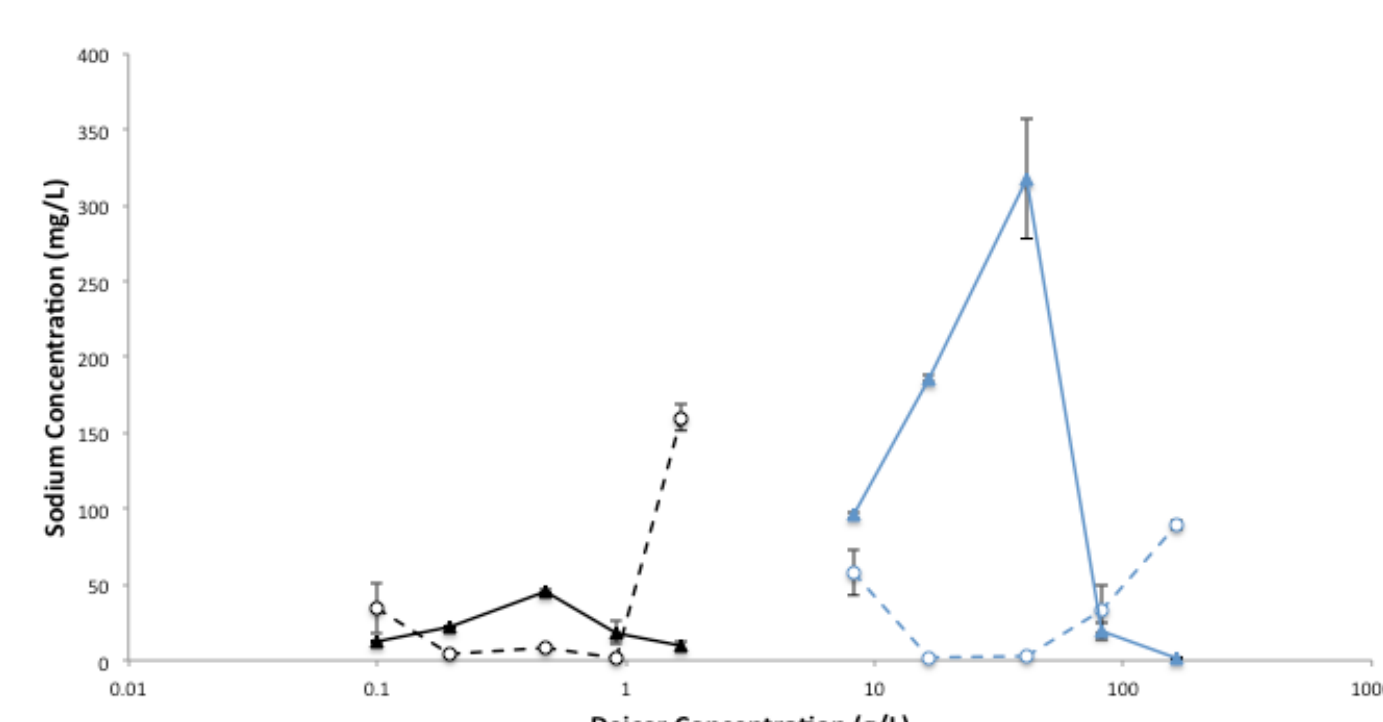


Figure 12: Na⁺ concentration.

Future Work

Fixing the error and uncertainty in the base cation data is important and would help shed light on how these different deicers are impacting water chemistry. Continuing the research and testing more sites and with more repetitions could also help strengthen the data. Further study of additional deicers, both commercially available and lab grade salts, would help further our understanding of how the use of deicing agents impact stream water chemistry.