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Establishing the ratio of rock salts and organic compounds to reduce the number of Chloride and Sodium ions in the soil when de-icing roads

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Introduction

Every winter, thousands of tons of salt are poured onto roads to lower the freezing point of water and melt icy roads. In 2014, the United States used 17 million tons of it, says the president of Salt Institute in Virginia. As a result, salt runoff destroys the surrounding plants, animals, and water sources.

A reason we need to come up with alternatives, other than because of environmental problems, is the rising price. Salt demands have increased and as a result, the price has increased as well. On the open market, when not part of a contract, salt can cost as much as $100 per ton in 2014. Cities do not have budgets large enough to cover this and other problems, so as a result many cities must compromise other projects in order to purchase salt.

Statement of the Problem

As salt is dumped onto roads, it is transferred into the soil of nearby plants and trees. When salt interacts with ice, it causes an exothermic reaction, releasing heat that melts ice and the sodium chloride ions dissociate. These molecules are then transferred into the soil and the salt and water solution runs off of the roads. Chloride is absorbed by the roots due to its negative charge resulting in high affinity or attraction (Elzam 620). As more chloride is absorbed by the roots through the sap stream to actively growing parts of the tree, it creates a toxic environment to the tree because of incredibly high concentrations of chloride ions (Hudler). Sodium harms the root system by causing soil to clump. This removes the natural aerating feature that allows

oxygen and water to be absorbed by the roots. When clumping has completely compacted the soil, the roots become constricted as they cannot absorb nutrients and are placed into a state of dehydration that withers the tree over time. Trees do not require much sodium to function; they require small amounts that are naturally absorbed by the plant from the environment and the excess sodium blocks other essential nutrients like potassium and magnesium from being absorbed. With the millions of tons of salt dumped, trees roots are being suffocated by the excess sodium and chloride ions on a widespread scale.

Statement of Purpose

The aim of the future experiment is to discover the minimum concentration (in ppm) of rock salts that the trees can tolerate and to determine the most efficient ratio of alternatives to rock salts in terms of effects on the trees by analyzing the water content in leaves of the trees and capacity of lowering freezing point. The focus will be on Eastern Hemlock and Red Maple trees since a study shows that the trees are one of the most sensitive trees and are widespread throughout the United States (Beckerman 4, 10).

Review of the literature

Cheese brine is a cheese that is soaked in salt water and the brine is usually made up to a saturated strength (salt). Cheese consists of organic compounds such as difenacoum, denatonium benzoate, most importantly, sugar (propane 1,2 particulates) (The Big Cheese). Compared to other compounds that can be alternatives to rock salt, the saturated strength of cheese brine would have a similar function as the rock salts. Sugar is a prominent compound in cheese and it is soluble in water.

Volcanic minerals are another alternative that will be tested in the experiment as a popular organic salt substitute. Clinoptilolite, which is a manufactured hydrothermal volcanic mineral a member of a special group known as zeolite, will be analyzed in this study as a comparative alternate to rock salt (Earth Innovations Inc.). Clinoptilolite is similar to sand in its molecular formula and provides much better traction containing no harmful chemicals (carcinogens) or additives (Earth Innovations Inc.). The way this product works is by using its natural porous structure and negative anion charge to embed itself in ice providing traction when walked or driven over. As the granules are heated by natural solar radiation, they interact with salt and other chemicals present on the ground absorbing and reducing their presence. The effect diminishes harm caused by excessive salt and deicer chemicals to the environment and providing better safety for driving and passage. When compared to salt, 10 kg of Clinoptilolite provided a total area coverage of 6,336 square ft. while salt only provided 720 square feet for the same amount (Earth Innovations).

Another organic alternative that can be used is sugar beet juice. Sugar beet juice is used to both pre-treat the roads before storms as well as after the snow and ice have fallen. Sugar beet juice is a waste product of the manufacturing of sugar beets, therefore it is low cost and is an easily accessible product. Using beet juice in combination with road salt has many benefits. When road salt is used alone, it bounces off the road as cars drive over it which leads to more salt being placed on the road and more environmental degradation. With the use of beet juice, the texture changes to a much stickier texture that stays put on the roads. According to Arboretum, it lowers the bounce rate from 30% to less than 5% (Kinny). They also found that beet juice reduces the freezing point of water to -32 degrees Celsius. Another benefit of using beet juice compared to other brines it that it is less corrosive to equipment, cars, bridges, rails, and

pavement. Very few cons have been reported with the use of beet juice, although some find the smell to be offensive and to resemble burnt coffee (Pollack). Although the use of beet juice does not eliminate the need for salt to be used altogether, it greatly reduces the environmental impacts and increases the functionality as a de-icer (Gould).

Hypotheses

This study hypothesizes that the alternatives themselves cannot function as well as rock salts in terms of lowering the freezing point of water since the alternatives do not dissociate completely in snow. The alternatives contribute a lesser number of particles than rock salts, meaning that the alternatives do not significantly lower the freezing point with the same efficiency, which is why a ratio between rock salt and alternatives will be investigated for maximum efficiency and minimal environmental impact. Initially, as the concentration of salt decreases and the concentration of alternatives increases, the health of the tree would increase. However, when the alternative exceeds a certain ratio or concentration, the health of the tree would deteriorate because the prominent component of the alternatives is sugar. A study discovered that low concentrations of sugar can help plants grow initially. However, since the sugar molecule is too large to pass through cell walls, it remained in the soil (LeBoeuf-Little). Additionally, watering the plant with the same increment offset the sugar concentration and eventually it had a negative effect on the plants. We also hypothesize that the trees will react differently to concentrations of compounds according to its age.

Methodology

The experimental research method will be designed to find the efficient ratio between alternatives and rock salts that can act like salts that also prevents environmental degradation. There will be several trials for each variable (i.e. different species of trees) to obtain accurate and precise data. Independent variables during the experiment will be the trees and environment factors such as the amount of sunlight and water, and type of soil. Dependent variables will be the concentration of alternatives and rock salts that will be applied to the trees.

Sampling

This future experiment will test the effects of rock salt and alternatives on two species of trees: Eastern Hemlock and Red Maple. We hypothesized that the trees will be damaged and eventually die during this type of experimentation, so we cannot conduct the experiment on trees which have been growing for years. Thus, the research will be performed on tree saplings. The following conditions must be satisfied when selecting the trees:

- The height of the trees must be as similar as possible.
- The age of the trees must be the same.

It is assumed that the amount of nutrients a tree needs will depend on the age and the height of the tree. To maintain the effectiveness of the experiment, at least 26 samples – from age one to three – and the same type of soil will be chosen. There is a range of ages for the trees to investigate the amount of time for the trees' health to deteriorate for each age for varying de-icing concentrations.

Procedure

Step 1: Establishing a baseline

Before performing the experiment to find the ratio, the tolerance of each tree must be determined. The trees' tolerance towards rock salts will be determined by gradually adding rock salt to the tree until it begins to exhibit signs of deterioration – when the leaves record an 80% loss in water content – we will record the results. To find the water content in the leaves, a leaf relative water content (RWC) technique will be used. The concentration of rock salt tolerated will be the baseline for the experiment.

Step 2: Finding the ratio

The concentration of rock salt that can achieve the desirable freezing point can be calculated by using the following formula:

$$\Delta T_f = mK_f$$

where *m* is the molality of the solution and K_f is the molar freezing point depression constant (we are going to refer the 30% of the concentration of rock salt as *x*). Additionally, the concentration of alternatives that can reduce to ideal freezing point will be determined (from now on, the 30% of the concentration of alternatives is *y*). The bounce rate, 30%, is what really effects the trees in reality. Throughout the experiment, the concentration of rock salts in the ratio must be less than the baseline. Initially, neither *x* nor *y* can be applied because the hypothesis states that the trees will be damaged by the concentration.

The procedure of the experiment is as follows:

1. Use RWC technique to find the initial water content on the leaves
2. Apply 50% of *x* and *y* on the trees for each age.

3. Use RWC technique to see the changes of water content on the leaves every two hours. Record the time elapse and the percentage of water content at the point of analysis. The trees have a mechanism in which they regenerate water loss from sudden changes in environment. Once the water content begins to increase again because of the trees' survival mechanism, record the time elapse with the minimum water content percentage the tree tolerated before the increase in water content.
4. When the tree recovers its original water content, increase *y* by 5% and decrease *x* by 5%.
5. Repeat the procedure 3 and 4 until 80% of the original water content is gone.
6. If the tree does not recover to its original state, record the water content as the initial condition.
7. Repeat for two trials.

The table below is one example for data collection.

Type of trees	Age		Concentration ratio of *x* and *y*		
			Initial (no solution added)	50% : 50%	45% : 55%
Eastern Hemlock	1	Water content			
	2				
	3				
Red maple tree	1				
	2				
	3				

From the data that will be collected, the behavior of the trees of each age upon the ratios can be determined.

Limitations

Limitations of this experiment includes the inability to simulate real life conditions by having randomized the time periods between the dumping of the salt and the quantities similar to

what happens with the actual weather. As well as the inability to simulate all of the conditions and factors that affect the tree growth like weather conditions, sunlight, and wildlife. The experiment is also limited because there is an inability to alter the climate like winter conditions due to keeping a limited number of variables. Another potential weakness is that cheese and beet juice have rancid smells that could attract potential wildlife.

Delimitations

We also chose not to focus on more trees, but rather the two most popular in Massachusetts, which gets the most snowfall annually out of any other state. These two trees are also ranked as being extremely sensitive, so therefore it makes them good candidates to base research off of (Beckerman 4, 10). The focus of the research is on these particular organic materials because they are the best rounded and they lacked the research that we would be performing. The experiments contains exactly three trials instead of less or more because three trials is enough to determine a baseline for this research.

Significance of the study

Trees are essential not only for wild animals but also for humans. Tree converts carbon dioxide that is produce by cars, factories, and living organisms into oxygen which is crucial for all living things. It also absorbs unpleasant odors from the environment and produces clean air. Trees can also help to reduce energy use. Houser states that "[b]y planting dense evergreen trees on the north side of a building or home to slow the cold winter winds" (United States). There are a lot other benefits of trees including preventing flooding and soil erosion, saving water, improving water quality etc.

Future work

After the results are found from the research, future work can be done on the effects of potato and corn based alternatives. Potato and corn crop yields are abundant in the US and would be an inexpensive alternative that have more research needed on them.

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