Cary Institute
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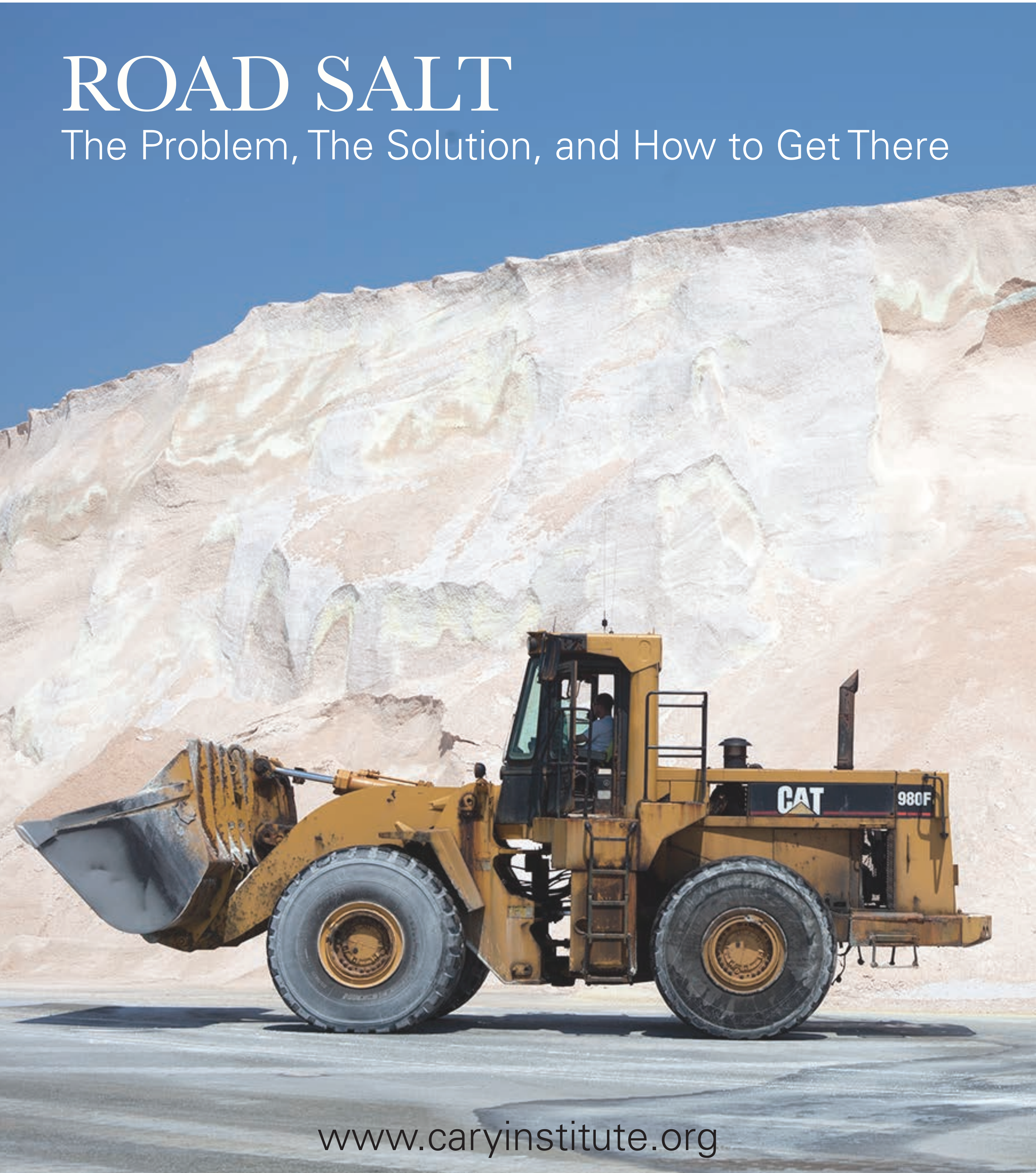
ROAD SALT

The Problem, The Solution, and How to Get There



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A Publication of
Cary Institute of Ecosystem Studies
www.caryinstitute.org

IN PARTNERSHIP WITH

Dutchess County Environmental Management Council

SUGGESTED CITATION

Kelly, V.R., Findlay, S.E.G., Weathers, K.C. 2019. Road Salt: The Problem, The Solution, and How To Get There. Cary Institute of Ecosystem Studies.

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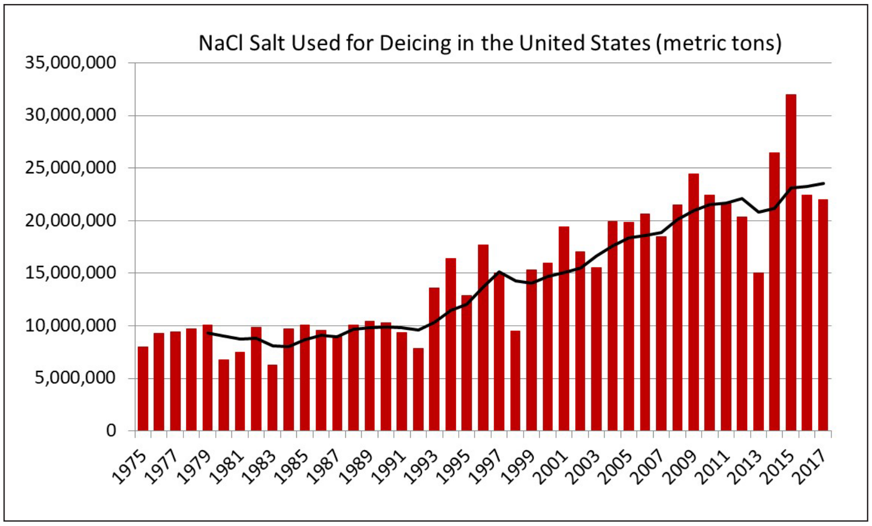
Introduction

In snow belt regions we now consider road salt to be vital for the safety of drivers and necessary to sustaining our business community in the winter. Residents and operators of service and emergency vehicles expect and often need to travel during winter storms. Yet the environmental and structural damage caused by road salt is reaching unacceptable levels. The need to reduce road salt is greater now than ever. To accomplish this while maintaining a reasonable level of service is achievable, but will require adoption of a variety of methods and management plans. Here we describe the environmental problem of road salt, and outline steps that can be taken to reduce its impact. Also outlined are roadblocks to implementing best management practices and suggestions for how to overcome them. We end with a call to action for the public, policymakers, and practitioners to pay more attention to the way we use road salt. This report is motivated by environmental science and is intended to provide public and private road managers, citizens, and decision makers with the information needed to reduce road salt pollution.

The Problem

A steady rise in road salt use

Since 1975, road salt use in the US has doubled. This rise parallels an increase in roads and other pavement requiring winter maintenance. In addition to being used on paved roads, road salt is applied to parking lots, sidewalks, driveways, and service roads. There is a growing scientific understanding of where this salt ends up and how it is harmful to ecosystems.



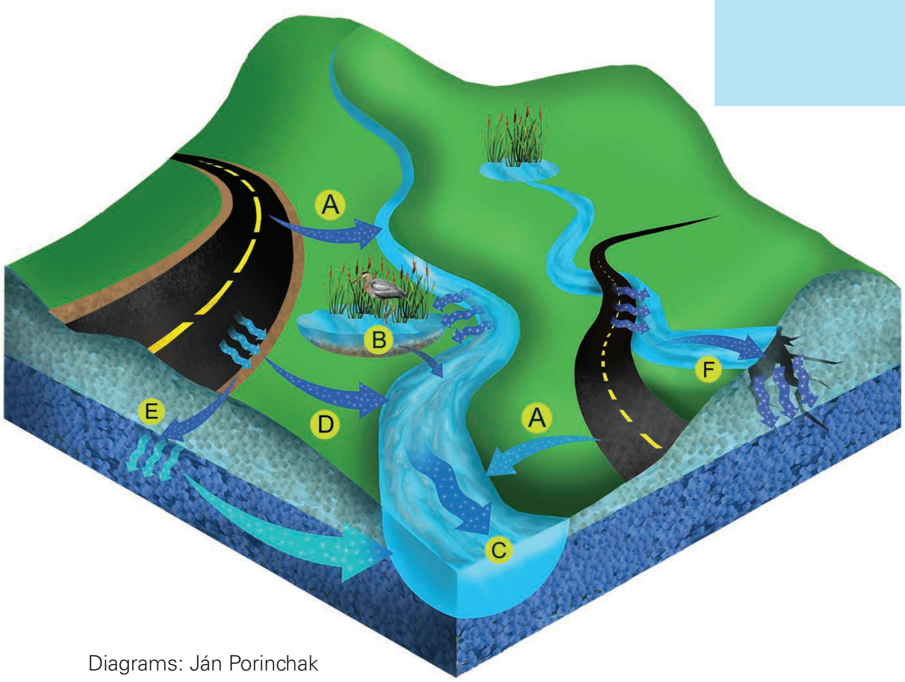
(US Geological Survey, 2017, Salt statistics, in Kelly, T.D., and Matos, G.R., comps., Historical statistics for mineral and material commodities in the United States: US Geological Survey Data Series 140, available online at http://pubs.usgs.gov/ds/2005/140/)

Road salt washes into streams and groundwater

Long-term monitoring of streams and watersheds has allowed researchers to understand how road salt behaves in the environment. For example, by measuring the total amount of salt applied to a watershed and comparing this with the amount of salt that drains from the watershed via a stream, we can estimate how much salt is retained within the watershed's soil, groundwater, and sediments. By studying different types of watersheds, we have developed an understanding of how landscape features and climatic events affect the retention and flushing of salt from watershed systems.

Most road salt makes its way from treated surfaces to nearby ditches, culverts, and streams, causing salinity spikes in affected water bodies. Some of the salt enters soil and groundwater. Not all the road salt simply washes downstream to the ocean; it can be retained in local ecosystems for decades. Studies show that salt accumulates in roadside soils, groundwater, and the sediments of lakes and wetlands. It can also be found dissolved in the stratified layers of lake water.

Salt applied to a watershed can come from a variety of sources. In the watershed that feeds the East Branch of Wappinger Creek at Cary Institute of Ecosystem Studies in Millbrook, NY, we estimate that 90% of the salt comes from road salt, 3% comes from water softeners, and 3% from septic and sewage discharge. The rest originates from natural sources such as eroding rocks and rainfall. Some salt is retained in the watershed – likely in groundwater – and some flows out of the watershed via the stream.



Road salt can take several pathways after it is applied to roads. Some runs directly into streams and rivers (A), which carry it downstream where it can be deposited in wetland sediments, ponds, or lakes (B). Some of the salt is carried by rivers to the sea (C). Much of the salt runs off roadways to adjacent soil where it is carried by soil water toward nearby streams (D). Or, it infiltrates the soil and is carried deeper into groundwater (E). Some salt can move directly into deep bedrock groundwater via fracture zones (F).

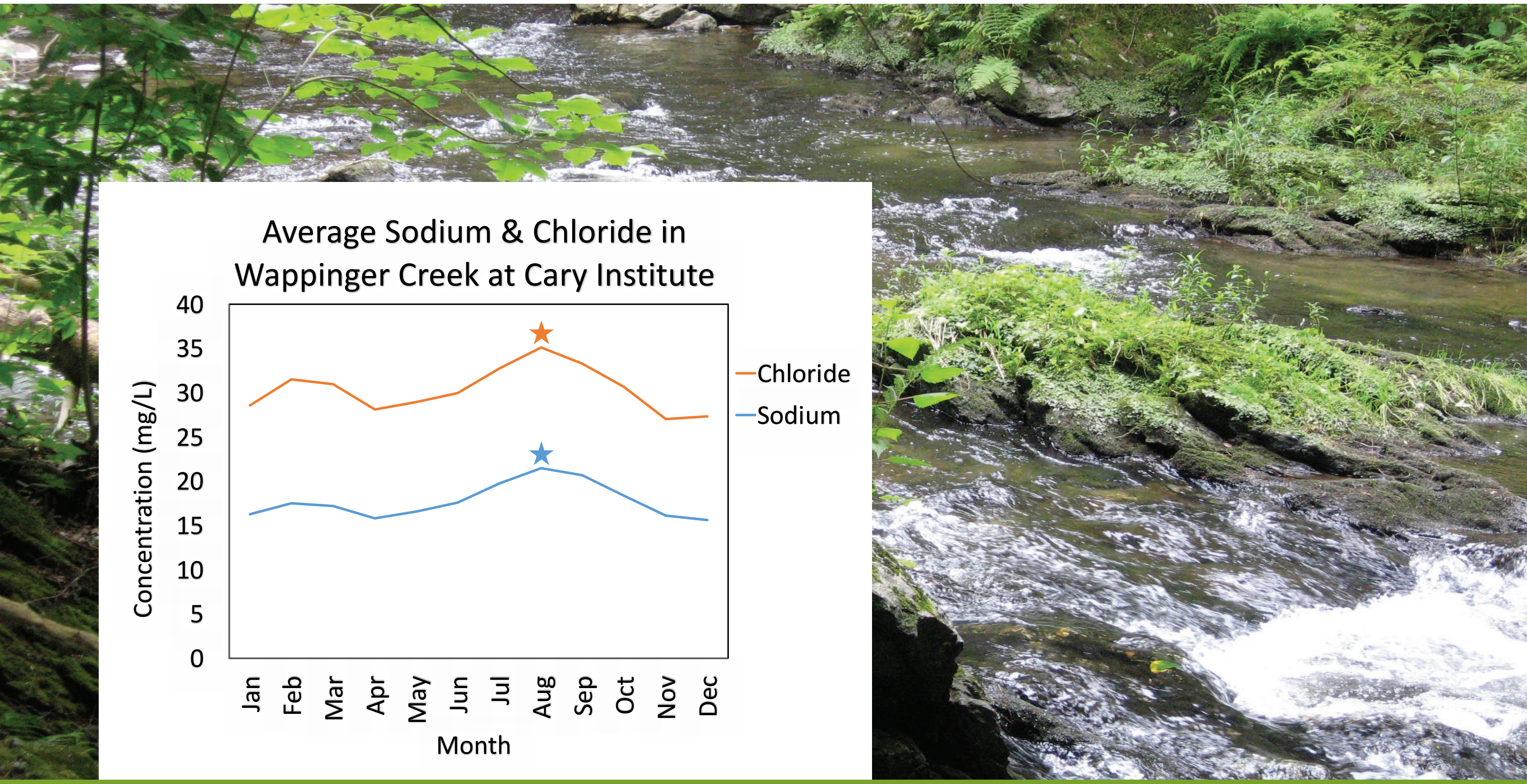
Diagrams: Ján Porinchak

Rising salinity in the winter and summer

Recent studies show that salt has already reached levels of concern in many freshwaters. Groundwater, a source of drinking water for many people, is vulnerable to salt pollution. In some places, it has become salty enough to affect people on low sodium diets. In winter, salinity spikes, caused by salt running from treated surfaces directly into streams, are common. These short but concentrated salt inputs can temporarily make stream water as salty as seawater. More worrisome are salinity concentrations in the summertime. Scientists believe that these elevated concentrations in surface water are from highly concentrated groundwater. During this period, when aquatic animals and plants are most active, streams can have elevated salinity levels that can last for days or even weeks. This sometimes results in average salt concentrations that are higher in summer than in winter.

Allison Cekala

Rebecca Allan



Average concentrations of sodium and chloride, or salt, in the East Branch of Wappinger Creek at Cary Institute were higher in summer than winter. Averages were calculated from samples collected from 1986-2017.

Salt impairs the health of aquatic life

Animals and plants that live in freshwaters can tolerate a range of salinity. Lethal levels are rarely reached, except in some urban water bodies, or intermittently during the winter right after road salt application. However, sublethal salt levels present in many streams can impair the health, reproduction, and behavior of many organisms – especially with extended exposure.

Ecosystem effects of salt accumulation can be subtle. When salt accumulates at the bottom of a lake, it can inhibit spring turnover – the natural cycling of water caused by temperature changes in the lake. This process facilitates aeration and helps maintain oxygen levels needed to support aquatic life. Without turnover, oxygen levels in the briny bottom waters of the lake drop and become inhospitable for organisms. High salt concentrations in soils can have a flushing effect, reducing the amount of other nutrients in the soil. This limits availability of nutrients needed for plant growth and can have a damaging effect on vegetation.

Examples of chloride concentrations and associated effects on aquatic organisms. Background concentrations are typically 0.5-10 mg/L. The US EPA recommends that to maintain aquatic life, continuous salt concentrations in freshwaters should not exceed 230 mg/L and should never exceed 860 mg/L. (See Findlay S.E., V.R.Kelly, 2011)

Chloride Concentration (mg/L)	Effects on Aquatic Organisms
0.5 - 10	No environmental effects
100 - 1000	Reproduction & development inhibition, community structure altered
>1000	Mortality

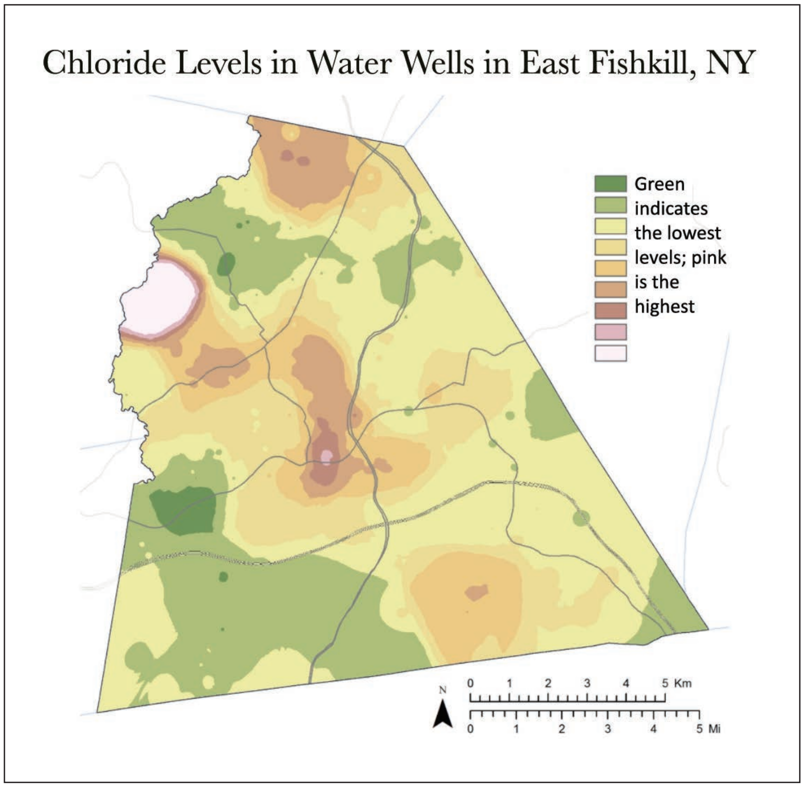
Nick Jakubek/Maya Almarez

High concentrations of road salt in freshwaters can result in sex reversals in frogs, causing 'masculinization' of some frog populations. (See Lambert et al. 2017)

Salty wells threaten drinking water supplies

The accumulation of salt in groundwater and drinking water reservoirs is perhaps the biggest environmental concern related to road salt pollution. Recent studies have shown that the levels of salt in groundwater are related to proximity to roads and the total coverage of pavement and other surfaces that are impervious to water. Hotspots of road salt in groundwater can be associated with long-term and improper salt storage, frequent salting on steep or heavily used sections of roads, or high density of narrow roads which are too small for modern, efficient, salt trucks.

Big Stock Photo/Anpet2000



Chloride levels in groundwater-fed drinking water wells in East Fishkill, NY were sometimes found in 'hotspots' associated with heavy road salt use. Low chloride levels coincided with areas of minimal road salt use. (See Kelly, V.R. et al. 2018)

How does road salt affect human health?

The average sodium intake for most Americans is between 4,000 and 6,000 mg per day, most of which comes from food. A person on a sodium-restricted diet will probably be limited to 1,000 to 3,000 mg per day. A person drinking two liters (about 8 glasses) of water per day would get a total of 100 mg of sodium from drinking water if the concentration of sodium in that water were 50 mg/L. This seems reasonable based on the median well water concentration of 30 mg/L found in a 2018 study done in Dutchess County, NY. However, the highest sodium concentration measured in that well study was 860 mg/L. A person would take in 1720 mg of sodium daily if that person drank two liters of water from that high sodium well. This is significant if a person is on a sodium-restricted diet.

Road salt can take decades to leave a watershed

The accumulation and retention of road salt in groundwater, lakes, ponds, wetlands, sediments, and soils lengthens the lag period between when salt is applied and when it is flushed from the system. As described earlier, aquatic life can be exposed to high concentrations of road salt long after winter has ended. Current estimates predict that it will take decades or more for salt levels to stabilize in freshwater systems, but that will only occur if we stabilize or reduce our use of road salt. Due to legacy effects, we should expect salt levels to continue to climb even after we initiate road salt reduction strategies. Year-to-year variability in weather can also 'mask' the effectiveness of salt reduction strategies. Monitoring efforts can help reveal when salt pollution begins to abate. It is critical that we tackle the salt pollution problem now, before streams, lakes, and rivers become highly impaired and salt in our drinking water reaches unpotable levels.

Be a Part of the Solution

In the 1970s, transportation agencies began to recognize that using large quantities of road salt could harm the environment and infrastructure. Since then, much research has been done to document and improve best management practices for maintaining ice-free roads. Remaining on top of the latest equipment and techniques can be challenging. However, organizations such as Clear Roads have improved opportunities for discovering and implementing accessible methods of salt reduction.

Best management practices for reducing road salt

- **Anti-icing** – Many departments of transportation have begun using a 23% salt brine solution to pre-treat roads before the onset of storms. Estimates suggest that road pre-treatment with brine can yield a 75% savings in total salt applied.

- **Pre-wetting** – Pre-wetting salt before roadway application can reduce salt infiltration to aquifers by 5%. Pre-wetting salt allows it to stick better to the road, which minimizes spray and kick-up of salt grains.

- **Calibration of equipment** – Calibration allows you to measure the exact amount of material you apply, facilitating more accurate and efficient deicing, with less total salt used. You don't need a regulator to calibrate your equipment. Calibration procedures – which are readily available in online manuals – should be a standard component of trainings for salt truck operators.

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- **Variable application rates for salt distribution systems** – Automated spreader controls allow salt truck operators to program salt application rates so that the amount of salt being applied changes with ground speed, which reduces bounce and scatter. These programs can also account for curves and hills, which require more salt than flat or straight roads. Vehicle location sensors can target salt distribution to a precise location along a route. This kind of information can allow for fine adjustments and keep track of total salt distribution for salt monitoring purposes.

- **Proper salt storage** – To minimize salt loss and pollution, salt piles should be contained. Municipalities and privately-owned facilities can protect salt investments and the environment by adopting storage best practices. These include building salt storage sites on impervious surfaces, implementing secondary containment measures, completely enclosing salt piles, and regularly inspecting structures for breaks or tears.

- **Good housekeeping** – Unintended spills and releases of road salt from vehicles are inevitable. Allowing time to clean up spills will reduce unwanted release of salt to the environment. Also, collection systems are now available to promote the recycling of vehicle wash water, which can be used to produce brine for anti-icing applications.

- **Road condition information systems** – High quality data on road and weather conditions should be shared between transportation officials and weather forecast providers to facilitate targeted, coordinated road salt application. In addition, smart phone apps, cell phone text alerts, and web-based platforms are increasingly allowing travelers to make informed decisions about road conditions before travelling.

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- **Plow types** – Modern plows are designed to reduce the amount of road salt needed to maintain ice-free roads. For example:

Live edge blades have articulated segments that conform to uneven road surfaces.

Flexible plow blades conform to uneven surfaces thus reducing the overall amount of salt needed. They also extend the life of a plow.

Metal Pless ©2018

- **Pavement temperature sensors** – Pavement temperature determines whether frozen precipitation will stick and how much salt is needed to maintain safe roads. They can help guide salt application by road crews and inform the public about the safety of road conditions.

- **Adjusting levels of service** – Several states adjust levels of service to conditions. For example, the Vermont Transportation Department seeks to provide 'safe roads at safe speeds' – not necessarily bare roads. New Hampshire, Ohio, Colorado, and other states define varying levels of service based on traffic volume. Surveys can help gauge the public's expectations and comfort level with varying levels of service. For example, after surveying the public, the Minnesota Department of Transportation was able to adjust its practice of maintaining bare pavement during a storm to maintaining bare lanes. Expanding the practice of adjusting levels of service to match expectations and traffic volume has the potential to drastically reduce the overall amount of salt released into the environment.

- **Identify no / low salt areas** – Some road service agencies have identified areas of low or no salt near sensitive freshwater bodies such as reservoirs, lakes, rivers, streams, and well fields that feed public water supplies. Educating travelers in these areas is critical.

Claire Nemes

Claire Nemes

Road salt alternatives

Alternative salt-based deicers have changed very little in recent years. Interest in agro-based alternatives has expanded greatly although salt is the active ingredient in most of these products. Products include:

- Corn steepwater (a byproduct of wet corn milling)
- Cheese and pickle brine
- Fermentation byproducts (i.e., from beer and wine waste)
- De-sugared molasses (a byproduct of sugar beet processing)

Agro-products can lower the freezing point of chloride-based salts and increase the amount of time salts remain on pavement. They can also improve sunlight absorption and reduce the corrosivity of salt solutions. When washed into streams and lakes, many agro-based deicers have an impact, as would be expected when any organic material (such as wastewater) is released into a water body. High levels of organic material can deplete oxygen, stimulate algae, and cause fishkills. These agro-based deicers also tend to be more expensive. Other alternatives to rock salt include different types of salt or sand, which vary in effectiveness and impact.

Product	Relative Direct Cost	Effective Lower Limit (degrees F)	Corrosive?	Aquatic Toxicity	Other Environmental Impacts
Road Salt or Rock Salt	Low	15	Yes	Moderate	Roadside tree damage
Potassium Chloride	Moderate	12	Yes	High	Potassium fertilization
Magnesium Chloride	Moderate	5	Yes	High	Magnesium addition to soil
Calcium Chloride	Moderate	-25	Very	Moderate	Calcium addition to soil
CMA - Calcium Magnesium Acetate	High	-17	No	Indirect	Decreased aquatic oxygen
Potassium Acetate	High	-15	No	Indirect	Decreased aquatic oxygen
Sand	Low		No	Indirect	Sedimentation

Salt application tips for homeowners

Adding too much salt to an icy surface is a waste of money and increases damage to concrete, metal, drinking water, and vegetation. It is a good rule of thumb to use deicers sparingly. Deciding how much to use depends on the deicer. Use about a handful of rock salt per square yard. For calcium chloride, use about a handful for every three square yards. Here are some precautionary steps you can take to decrease the amount of deicer you'll need:

- Shovel the snow early and often. If the temperature drops it will turn icy and be harder to remove.
- Deicers work best on a thin layer of ice, so remove as much ice as you can before spreading deicer.
- As the temperature rises and the deicer melts the ice, a slushy mixture will form. Remove this before the temperature drops again and you should have an ice-free surface until the next storm.

Impediments to best management practices and suggestions for how to overcome them:

Up front cost of new equipment – Even with an attractive cost-benefit analysis, some municipalities or contractors may not have the financing to cover the costs of new equipment. Suggestions:

- *Consolidate services.* Share the cost and use of a new salt storage facility or piece of equipment.
- *Concessionary financing*. Low- or no-interest rate loans from public or private sources could allow municipalities to purchase new equipment. Savings from the reduction of salt use would allow for a short time frame for pay back.

Private contractors – Snow maintenance at shopping centers, hospitals, schools, apartment complexes, and private businesses is largely handled by contractors who may have a disincentive to reduce salt use for a variety of reasons. Suggestions:

- *Liability relief*. New Hampshire instituted a program that provided private contractors relief from liability in exchange for attending classes on responsible salt use.
- *Customer education*. Encourage businesses to develop sustainability practices for storefronts, including reduced salt use. If businesses have sustainability plans, encourage the addition of salt reduction strategies.
- *Consider regulations of salt storage for all entities*. For example, Wisconsin requires salt/sand piles greater than 1000 pounds to be stored in a structure with a roof and walls substantial enough to prevent precipitation from contacting salt, or wind from carrying salt into surface waters. Connecticut requires salt piles in place for more than 180 days per year to be kept in a permanent, roofed structure.

Level of service – Public expectation and laws that mandate the level of service required of road service agencies often dictate the amount of salt that is used. For example, Section 12 of the New York Highway Law says that snow and ice should be controlled to provide reasonable passage and movement of vehicles. This ambiguous language can be interpreted widely by travelers and highway crews. Suggestions:

- *Survey the public*. Find out if a lower level of service would be acceptable on some roads.
- *Engage policymakers*. Refine or change the laws to allow for flexibility in level of service and to clearly indicate expectations and reduce liability costs.

Salt purchasing – Annual budgeting requirements, especially for some small municipalities, may result in standardized salt use every year, even if conditions in some years don't warrant use of the standard amount of salt. Suggestions:

- *Consider a multi-year contract.*
- *Expand storage capacity*. Allow for annual variability in severity of conditions. Storage capacity expansion would allow excess salt to be stored for future use. (See examples in: Clear Roads BMP for road salt in winter maintenance.)

Research – In order to assess the efficacy of new technology and practices, data collection and monitoring are needed. Suggestions:

- *Join or follow consortia like Clear Roads*.
- *Build data collection into management plans*.

The Path Forward

Over-dependence on road salt has come at a cost to infrastructure and the environment. Scientific evidence is piling up: when salt-treated roads occur near lakes, streams, reservoirs, wetlands, and well fields, there is a trend toward freshwater salinization. Road salt use continues to rise, just as we are recognizing that salt pollution has a legacy effect in the environment, taking decades to flush out. It is a problem we are handing down to future generations.

It is easy to get discouraged. Road salt is still the number one deicer used in maintaining safe winter roads. Yet there is much we can do to reduce salt pollution. Practices worthy of immediate widespread adoption include pretreating roads with brine and properly storing salt. There have also been advances in plow technology, salt spreading equipment, and pavement sensors that allow for much more efficient calibration and application.

Balancing environmental stewardship with safety and fiscal responsibility is possible. Creating a culture of change will be necessary. This includes changing public attitudes about levels of service, investing in research on best management practices, and continuing education programs and training to ensure the best practices are accessible. The time to act is now.

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