Chlorides in Fresh Water

THE UNIVERSITY OF RHODE ISLAND
COLLEGE OF THE ENVIRONMENT AND LIFE SCIENCES

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Introduction

Chlorides are present in both fresh and salt water, and are essential elements of life. Salts such as table salt are composed of **ions** that are bonded together. When table salt is mixed with water, its sodium and chloride ions separate as they dissolve. Chloride ions in the environment can come from sodium chloride or from other chloride salts such as potassium chloride, calcium chloride and magnesium chloride. The concentration of chlorides has sharply increased in many bodies of water since the widespread adoption of road salt as a deicer in the 1970s, and the ecological implications of this change have yet to be fully determined. Scientists who study watersheds use elevated chloride levels as one indicator of pollution in a body of water.

Chloride in Road Salts

The use of road salts for deicing in snow-belt states such as Rhode Island began in the 1940s and sharply increased in the 1970s. Chlorides are the “active” ingredient in most commercial deicers, whether they are made with sodium chloride or new alternatives like potassium chloride. When ice and snow begin to melt in the winter and spring, chloride concentrations spike in roadside streams due to road runoff. When roads are pretreated in anticipation of snow and ice but precipitation comes as rain, chloride from pretreatments is washed off with stormwater. Uncovered salt storage piles lose about 20% of their salt each year, much of which finds its way into nearby waterways.

Chloride concentrations tend to be higher in areas with pavement and other treated surfaces because stormwater and snowmelt runoff does not have a chance to soak into the ground before entering rivers, lakes, and streams. Road salts travel farther from roads when the speed limit is high; they have been observed traveling over 40m (130 ft) from the side of major highways (Karraker, 2008). Concern over the release of sodium into the environment has prompted many communities to switch to other chloride road salts; however, these salts may be more toxic to aquatic organisms than sodium chloride road salts (Mount et al., 1997). Commercial road salts have phosphorus compounds added to keep them from clumping, contributing nutrient increases in lakes and streams. Road salts often have heavy metal additives, so high chloride concentrations may indicate the presence of other harmful substances in lakes and streams.

Natural Chlorides

Chlorides constitute approximately 0.05% of the earth’s crust. Chloride concentrations of between 1 and 100 ppm (parts per million) are normal in freshwater. Chloride ions come into solution in water in underground **aquifers**, geological formations that contain groundwater. In coastal areas, chloride from saltwater aquifers, sea spray, and coastal flooding can also find its way into freshwater waters. Seawater has a natural chloride concentration of 35,000 ppm. Plants and animals that live in salt or **brackish** (mixed salt and fresh) water are adapted to live with high chloride concentrations. Once chlorides are in a water body, there are no biological processes that remove them. They are not typically removed at water treatment plants due to restrictively high cost. Natural spikes in chloride concentration can occur during summer “low flow” periods when evaporation exceeds precipitation. However, recent increases in chloride concentrations nationwide are thought to be due to **anthropogenic**, or human-caused, factors such as road salt, sewage contamination, and water softeners.

Figure 1 (left): Uncovered salt piles such as this will lose 20% of their salt to local waters each year.

Measuring Chlorides

At URI Watershed Watch, volunteers collect water samples for chloride analysis in the spring and fall. In the lab, chloride testing is performed by Watershed Watch staff using a sophisticated autoanalyzer, which can quickly test a large number of samples. Chloride test strips are also commercially available for home use.

URI Watershed Watch volunteers monitoring use salinity refractometers or meters for estuaries, bays and the ocean. These devices measure concentration in parts per thousand and are therefore not sensitive enough for measuring chlorides in fresh water. (A part per thousand is 1000 time more concentrated than a part per million.)

Figure 2 (left) and Figure 3 (below): Chloride concentrations tend to be higher in bodies of water surrounded by large developed areas with lots of impermeable surfaces. Photos courtesy of Ken Wagner.

Other Chloride Sources

Chlorides can also enter a watershed through water softener discharge or sewage contamination. **Water softeners** remove magnesium and calcium ions from hard water by performing an ionic exchange reaction with sodium chloride. Small amounts of sodium enter water that has passed through the softener, while magnesium chloride and calcium chloride are stored in the device and eventually discharged as brine into a sewer or septic system.

As salt intake continues to increase in the American diet, more chlorides are entering groundwater through human waste. Sodium chloride is added to many processed foods to delay spoilage while bringing out flavor. However, chlorides are not removed from waste by septic tank treatment processes and enter the leach field with the rest of the **effluent**, or wastewater. From there, chlorides can enter groundwater through septic systems and find their way into lakes, ponds, streams, and wetlands. URI Cooperative Extension Water Quality Program has assembled informative fact sheets about home wastewater treatment, septic system maintenance, and drinking water quality that can be found online at www.uri.edu/ce/wq.

A third anthropogenic source of chlorides in groundwater is fertilizer made with **potash**, or mined salts. Potassium chloride is the salt most commonly used in potash fertilizer, and potassium (K on fertilizer bags) is one of three essential nutrients (along with N - nitrogen and P - phosphorous) that are added to increase soil fertility on farms and home gardens and lawns. However, like nitrogen and phosphorous, chloride can leach from fertilized soils into rivers and streams.

Too Much Chloride?

High chloride concentrations in freshwater can harm aquatic organisms by interfering with **osmoregulation**, the biological process by which they maintain the proper concentration of salt and other solutes in their bodily fluids. Difficulty with osmoregulation can hinder survival, growth, and reproduction. In Rhode Island, the Department of Environmental Management (DEM) has set acceptable chloride concentration exposure limits for freshwater organisms at 860 ppm to prevent acute (immediate) exposure effects and at 230 ppm to prevent chronic (long-term) exposure effects. For drinking water, DEM has set a maximum contaminant level of 250 ppm chloride, which is the point at which water starts to taste salty.

Some research suggests that, with certain exceptions, fish are less sensitive to chloride exposure than small, free-floating **planktonic** crustaceans (Evans and Frick, 2001). These planktonic animals are a food source for fish and amphibians and help control the algae that contribute to **eutrophication,** nutrient accumulation that depletes lakes of oxygen. Recent published research suggests that high chloride concentrations are harmful to many aquatic animals. Meador and Carlisle (2007) found chloride tolerance levels for some brook trout species to be as low as 3.1 ppm. Rhode Island's native spotted salamander has a 40% reduction in survival when spawned in a **vernal pool** with a chloride concentration over 162 ppm (Karraker, 2008). Vernal pools, temporary bodies of water, tend to have high chloride concentrations in early spring, when eggs are laid, and in summer, when larvae and tadpoles undergo **metamorphosis** and become adults, two especially delicate times in their lifecycle (Karraker, 2008).

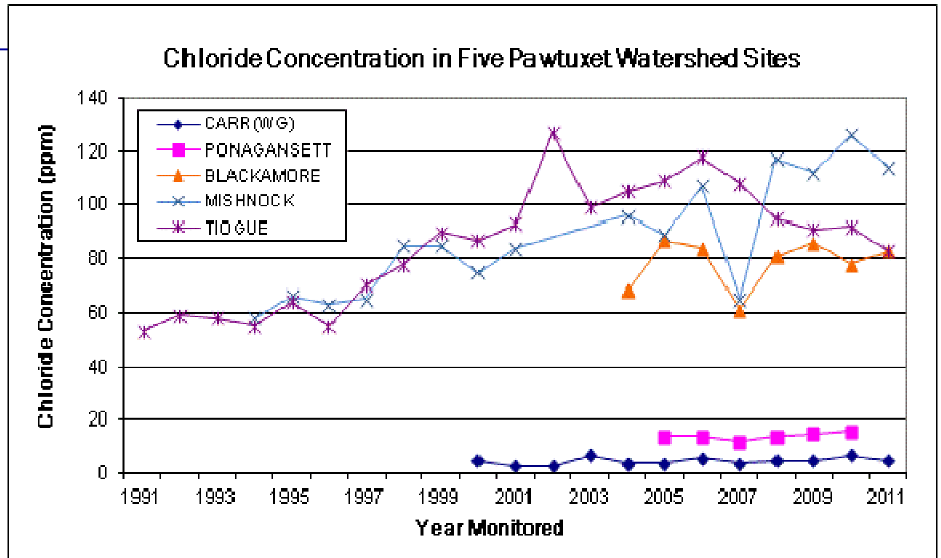
Invasive and fast-growing Eurasian water milfoil is more tolerant of high chloride levels than native plants, thus increasing chloride levels could help them out-compete native fauna (Evans and Frick, 2001). Hale and Groffman (2006) found that elevated chloride levels interfered with the processes by which bacteria break down nitrogen in suburban stream **debris dams**, naturally-occurring barriers of sticks, rocks, and other debris. The use of road salts in the northern United States is not likely to end in the near future, the long term effects of chloride in aquatic communities remain to be seen.

Figure 4 (above): Frogs and other amphibians lay their eggs in vernal pools, which are isolated from other water sources and do not have any process that flushes out chlorides. Amphibians such as these are especially vulnerable to high chloride levels as eggs and during metamorphosis. Photo by Thomas Tetzner.

How Can I Help Keep Chlorides Out Of Our Waterways?

- Shovel early after a storm to minimize the need for deicers.
- If you must use a deicer, consider a pre-wetted 1:1 sand and road salt mixture to minimize the amount of chlorides released.
- Apply deicers early and sparingly; extra salt will not melt ice faster!
- Do not deice with kitty litter, ashes, or any product containing urea.
- If you need a water softener, consider a portable exchange water softener. A company will periodically pick up your brine to dispose of in a controlled manner.
- Upgrade your water softener to a newer model with an on-demand setting.
- Set your water softener to the correct hardness level for your water, and connect it so only inside water is being softened.
- Consider using permeable pavement for paved surfaces on your property. For more information, see URI Cooperative Extension's Porous Pavement fact sheet at http://www.uri.edu/ce/wq/publications.htm.

Chlorides in Rhode Island



This chart shows chloride concentration trends for five bodies of water in central Rhode Island. Ponagansett Reservoir and Carr Pond, which show consistently low levels of chloride, are surrounded by large areas of undeveloped land. Blackamore Pond is in a heavily developed area close to Rte 2, making it susceptible to large chloride spikes from roadway runoff. Mishnock and Tiogue Lakes, which are both close to interstate highways and retail areas with large parking lots, have shown a steady increase in chloride concentration over the last twenty years. These five water bodies illustrate that chloride concentrations tend to be higher in areas with lots of residential and commercial development. Chloride data from a small sample of suburban streams compiled by the URI Watershed Hydrology Laboratory in 2008-2009 shows chloride levels ranging from 17 ppm with occasional spikes as high as 84 ppm (Addy, personal communication). Seasonal concentration trends varied among the streams sampled.

To learn more about the URI Watershed Watch program or our chloride monitoring, please contact:

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