Acadia Partners
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Research Report

# Quicksilver from the Skies

## Mercury in Snow at Acadia National Park

### Executive Summary

Sarah Nelson is a Ph.D. candidate at the University of Maine funded by the Canon National Parks Science Scholars Program. She is an associate scientist with the Senator George J. Mitchell Center for Environmental & Watershed Research, an L.L.Bean Research Fellow funded by Acadia Partners for Science and Learning, and an active participant in work with the Schoodic Education and Research Center.

Nelson has spent the last eight years studying the problem of mercury pollution in Acadia National Park. She has worked as a member of a team of scientists who have been constructing a "mercury budget," so that we can understand where the mercury comes from, where it is stored, and how it moves into the watershed and into plants and animals in the Park.

In this brief article, written for non-scientists, Sarah describes her work in tracking the fingerprints of mercury in snowfall – a source of mercury that had been previously overlooked because it was assumed to be negligible. Sarah was troubled by the fact that there is a substantial "flushing" of mercury as the snow melts. How could we be sure that snowfall was not a factor? If snowfall was not part of the picture, where was the spring mercury coming from?

In describing her engagement with this work Sarah provides an excellent introduction to the issues associated with mercury "deposition" – which is to say mercury arriving from the air – at Acadia National Park. This short article will be useful reading for anyone seeking an overview of this problem.

Acadia Partners is proud to be sponsoring a portion of Sarah's work, and we thank her for contributing this paper for our readers.

## An Invisible Problem at Acadia National Park

In the minds of many, the image of Maine is one of pristine coastal waters, sparkling rivers, and tranquil lakes. Loons cry out at dusk while a lazy canoe drifts toward shore, the setting sun glinting off a taut fishing line.

So it is with a bit of irony that I learned that fish from many of Maine's lakes, rivers, and streams are not safe to eat because of mercury pollution. A statewide advisory warns consumers to limit eating certain types of fish to a few meals per month, and others should not be eaten at all.

How does mercury get into fish? Mercury, the only metal that is liquid at room temperature, easily evaporates and is released during burning and chemical manufacturing. The major source of mercury air emissions in the U.S. is coal-fired electric utility plants. Once in the atmosphere, mercury can travel hundreds of miles before settling on the landscape in dust or rain.

Once on land, mercury is washed into lakes and streams, where it feeds bacteria that convert it to the more toxic form, methylmercury. Methylmercury moves up the food chain, increasing in concentration at each step: as algae eat bacteria, microscopic zooplankton eat algae, fish eat zooplankton, and some birds and mammals eat fish.

The entire state is included in the fish consumption advisory, because elevated mercury concentrations are found everywhere, although without an obvious pattern, across Maine's landscape. Fish in one lake can have high levels of mercury, while in a neighboring lake, mercury concentrations are much lower. The problem is, we can't predict which lake (or which fish) will contain too much mercury. Acadia National Park includes a good example: a fish taken from Hodgdon Pond in 1996 holds the state record for the highest mercury level, while fish in Seal Cove Pond—which is directly connected to Hodgdon Pond—only have average mercury concentrations.

What makes mercury levels high in one location relative to others is the subject of intensive study by scientists across the globe.

## Adding Up the Sources of Mercury

At Acadia, I have been part of a group of researchers studying mercury in two watersheds since 1998. My role has been to determine how much mercury from the sky comes into watersheds at Acadia. Trees act as filters, their needles and branch tips collecting mercury particles from the air. We measure this "dry deposition" and add the amount of mercury that comes in with rain and snow ("wet deposition") to determine the total input of mercury to the watersheds.

The sum of wet plus dry deposition, termed throughfall, is measured by positioning a funnel a few feet off the ground below the tree canopy. The funnel collects whatever has fallen through the canopy—rain, snow, and mercury washed from the sky and trees—into a sample bottle. Throughfall is sampled under different types of trees, since they can vary widely in their filtering efficiency.

Our research studies measure how much mercury is in different parts of the ecosystem—soil, fallen leaves and needles, and streams—to understand how mercury moves through the system. During research for my master's thesis at the Senator George J. Mitchell Center for Environmental Research, I realized that we were missing information about the amount of mercury that comes into the Acadia watersheds during winter as snowfall. Maine winters are famously snowy. By not sampling atmospheric deposition in winter, we could have missed much of the annual input.

## Bringing Snow Back Into the Equation

When I started asking other mercury scientists, I found that information about mercury in snow throughfall is fairly scarce. One reason is that it is difficult to sample snow throughfall: the frozen samples are heavy to transport to the lab, and it is cold outside.

Tempted by the thought of snowshoeing across freshly fallen snow at Acadia, I decided to continue my graduate studies at the University of Maine and study snow throughfall at Acadia. For this study, funded by the Canon National Parks Science Scholars Program, we put out snow throughfall collectors—large tubes lined with sample collection bags—across the two watersheds. We had two major goals: first, to determine whether vegetation type or other landscape factors resulted in different mercury concentrations at different points in the landscape, and second, to figure out how mercury was moving into and out of snow on the ground (snowpack). These movements or 'fluxes' in and out of snowpack had not been studied using these methods before, and the results will be new information to the scientific community.

Scientists in Canada have found that mercury re-emits from snowpack as a gas and returns to the atmosphere, much like steam rising from a pot of boiling water. Whereas water boils at 212° Fahrenheit, mercury's boiling point is only about 80° Fahrenheit. Ultraviolet radiation from the sun may cause part of this re-emission. These losses of mercury from snowpack might help explain why mercury in snow traditionally has been viewed as a small piece of the picture. At the same time, researchers in Vermont have found that when snow melts in spring, there is a large flush of mercury into streams. Where is this mercury coming from? To answer this question, we worked with Dr. David Krabbenhoft, a well-known mercury expert with the U.S. Geological Survey Mercury Research Laboratory in Middleton, Wisconsin. We hypothesized that the large amount of mercury trapped in fallen leaves and soils could be moving up from the ground into the snowpack. Our scheme to test this hypothesis: a mercury tracer addition.

## Following the Trace of a Chemical Signature

Before the snow flew in winter 2004-2005, my University of Maine colleague Ken Johnson and I laid out several small research plots and sprayed a tiny amount of labeled mercury—less mercury than what is in a typical button cell watch battery—on soils and leaves. The mercury is labeled with a special chemical signature. Much like using a radio-collar on a large animal to trace its movements, we can trace the labeled mercury's signature at different points in its path through the watershed by measuring soils, leaves, and snow. Dr. Krabbenhoft's laboratory instrument is able to detect these tiny amounts of labeled mercury. Then we waited. And the snow began falling. A lot of snow. In March, just before we expected the snowpack to start melting, we went back out to the plots and collected snow cores from the entire depth of the snowpack, the top, and the bottom half. If mercury was moving upward from litter and soil into the snow, we would expect to find some of the tracer in the snowpack, especially in the bottom half. Although we are just beginning the process of interpreting the results, it appears that there was indeed more mercury tracer in the bottom part of the snowpack, and that even in the whole-snowpack samples, some tracer was present. This phenomenon might help explain why there is a large flush of mercury in spring when snow melts, despite potentially low amounts of mercury in snowfall.

## Mercury's Coming and Going: Re-emission

However, that's not the whole story. This research involved sampling mercury in snow in side-by-side collectors throughout the study watersheds. One collector was allowed to sit out all winter, filling with snow from multiple storms. If there was going to be any loss of mercury by re-emission as a gas, it could easily escape this collector over the winter. Snow from the other collector was sampled after every large storm. Every time it snowed at least six inches, we rallied a crew of field technicians and graduate students to head out in the woods in the early morning just after the snow stopped falling. We collected the samples quickly in order to minimize the loss to re-emission.

By comparing the two sample types, we calculated that about 60% of the mercury that fell with snow on Acadia re-emitted as a gas from the snowpack. In other words, there *is* mercury in snow, but over the course of the winter it evaporates from the snowpack and rejoins the global pool of mercury in the atmosphere.

## Acadia: A First-Rate Location for Research

There are only a handful of research sites in the Northeast that have Acadia's rich and intensive mercury data record. Yet long-term monitoring over many years allows scientists to evaluate how the world responds to environmental changes. For example, long-term monitoring of Maine's lakes was key in evaluating whether the 1990 Clean Air Act Amendments had any effect in reducing acid rain and the acidity of surface waters. Eight years of monitoring data from the Acadia watersheds have revealed differences in mercury loading with droughts, changes in forest regrowth after fire, and patterns that could help sort out the effects of climate change on ecosystems. The project has also served as a locus for other researchers, building momentum for mercury research in Maine. Michael Bank, a University of Maine Ph.D. student, studied mercury in salamanders in the two watersheds, and found higher levels in salamanders where stream data showed greater concentrations of mercury. Research at these sites will help us unravel the mercury mystery, enabling us to evaluate new policies regarding mercury emissions, and ultimately may lead to a day when Maine fish are safe to eat again.

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