EAST LYME COMMISSION FOR THE CONSERVATION OF NATURAL RESOURCES
REGULAR MEETING MINUTES
FEBRUARY 8, 2023

Present: Penny Heller
Don Danila
Laura Ashburn
Mark Christensen
Harvey Beeman, Alternate
Marjorie Meekoff, Alternate

Absent: Art Carlson

Also Present: Rose Ann Hardy, Ex officio

CALL TO ORDER. Secretary Penny Heller called the East Lyme Commission for the Conservation of Natural Resources of February 8, 2023 to order at 7:00 p.m.

MOTION (1): Mr. Danila moved to seat Marjorie Meekoff for Art Carlson. Seconded by Ms. Ashburn. (4-0) Unanimous.

I. **PUBLIC DELEGATIONS.** There were no guests.

II. **MINUTES -January 11, 2023.** Ms. Heller asked for additions, deletions or corrections to the January 11, 2023 Minutes of the East Lyme Commission for the Conservation of Natural Resources.

MOTION (2): Mr. Christensen moved to accept the January 11, 2023 East Lyme Conservation of Natural Resources Minutes, as presented. Seconded by Mr. Danila. Ms. Ashburn abstained from voting. (4-0-1) Motion carried.

III. **NEW BUSINESS**

A. **Discussion of members attendance at Charter Revision subcommittee January meeting**
No member was able to attend, but plans were discussed for members to attend the next meeting.

Ms. Hardy reported she sent an email to the Charter Revision Commission Chairman. To date she has not received any response.

IV. **OLD BUSINESS**

a. **Discussion of Chloride Sampling Feasibility; possible alternative actions.**

Mr. Danila reported that after a more thorough review of available scientific information he has changed his position about the Commission undertaking any chloride sampling in town, which was discussed at previous meetings. In his opinion, this new information definitively showed that chloride (and sodium as well) concentrations in surface and ground waters have greatly increased since the 1950s, primarily due to increasing amounts of rock salt used to clear ice and snow from roads and other surfaces. This is a serious issue in the U.S. as continued salt input may affect both drinking water and aquatic life as sodium and chloride have increased and may continue to do so. He summarized findings from two short papers published by the Proceedings of the National Academy of Science; one by the U.S. Geological Service, whose study in the northern U.S. included information from East Lyme; and a Master's Thesis by a student at UConn, who also had information from southeastern CT. Mr. Danila provided the first two papers and abstracts for the other two, which are appended to these notes. Discussion followed over what would be the best course of action to reduce salt use in town, including on roads and parking lots, including schools and commercial lots.

Ms. Heller understood that Joe Bragaw is aware of the problem and has taken several mitigating steps. He arranged for Public Works employees to take training in mitigating measures at UCONN. She would like to make sure the Commission receives future well-specific data because this will be an ongoing issue. Ms. Ashburn suggested that Chris Lund, Facilities Director of the school system,is aware of the problem as well.. Ms. Meekoff asked if the town has the authority to ask store owners to reduce the salt they use to deice? Ms. Heller stated it's a matter of education. Ms. Ashburn made the point that if an individual has a medical issue his or her doctor needs to be contacted. Ms. Ashburn reported sodium is increasing, however there are other chemicals going into the ground water. She asked if we should be hosting a meeting with Public Works? Mr. Christensen suggested a video or photo be taken after a rain to illustrate the problem. Ms. Heller agreed to write a memo to Joe Bragaw and Chris Lund to acknowledge their work but encourage further mitigation. Ms. Hardy reported on a recent application for a new car wash expansion in the area of the highest sodium readings which may add to more contaminants entering the aquifer. She felt the developer gave the Planning Agency a through presentation of their proposed filtering and holding facility but some questions remain. Ms. Heller stated that although Mr. Bragaw stated the UCONN training was important for the Town truck drivers, it is private property owners who over-salt their parking and walkways that are as big a problem. Mr. Heller observed the townhouses on Hope Street were completely salted when there has been no snow or ice conditions.

b. **Sustainability CT Program:** Ms. Heller reported the presentation she presented to the Board of Selectmen was very positive. She informed commission members working on this program that we will receive work space at the town hall in the future. She added for the long-term the three-member subcommittee will be addressing energy efficiency in town buildings and funding for sidewalks, bike ways and other alternate transportation (aka a "complete street" program). The Town Engineer is continuing to work on EV charging stations in town. The State of Connecticut has funding for alternate transportation.

Ms. Heller reported the Town of East Lyme wrote a draft Pedestrian Facilities Management Plan dated November 2022. It was opened for public comments until January 22, 2023. She submitted comment in favor of the town's proposed sidewalk projects:

1) Rt. 161 south of Society Road to Roxbury Road;
2) Blackpoint Road to Crescent Avenue at Central Avenue;
3) East Pattagansett Road from Brook Road to Bush Hill and to Rt. 161;
4) Rt. 156 from Niantic Center School to Park Drive;
5) Rt. 1 complete from Mill Road to Pattagansett Lake Boat Launch.

Other upcoming SustainableCT projects include the annual Earthfest, held at McCook Point Park, and utilizing the mobile mural created by the Public Art for Racial Justice and Equality (PARJE) project at this event. . Ms. Ashburn said she and her students plan to participate in Earthfest on May 13. Mr.Christensen stated the tent owned by the commission is stored in the Samuel Smith barn if it is needed. Ms. Ashburn has had discussion about what is needed with Diane Swan who is one of the people in charge of the event.

Ms. Ashburn also stated that she would like to see 'Beach Day' at Hole-in-the-Wall resume for the Town's middle school students. Ms. Meekoff reported that the stormwater catch basins there are not being properly maintained by town workers who are not allowing the vegetation to grow.
Mr. Danila added that the Hole-in-the-Wall stormwater project was meant to be a demonstration project of how properly grown vegetation can trap stormwater runoff. Ms. Ashburn suggested involving the Town Engineer Alex Klose to ensure it is properly maintained and his staff are properly trained.

V. **REPORTS AND COMMUNICATIONS**

a. Communications.

Mr. Danila reported that the Niantic River watershed Committee (NRWC) will finally hold a public meeting sometime later this spring or summer to roll out the revised Niantic River watershed Plan. This meeting was put off for several years due to concerns about COVID. He is nearing completion on a report summarizing the 10 years of water quality sampling he did on behalf of the NRWC, including Latimer and Cranberry Meadow Brooks in East Lyme. When finished he will provide a copy of the report to the Commission, town staff, and the Board of Selectmen. He mentioned that the Southeastern CT Council of Governments is seeking input on a regional open space plan they are preparing. Workshops will be held this coming Saturday at the New London Library and on the evening of February 14 via Zoom. Additional information as well as a short survey on open space needs are available on http://seccog.org/archives/8738. Ms. Meekoff sent Mr. Danila an email that he shared with the Commission about CT DEEP seeking input on the CT Guidelines for Soil Erosion & Sediment Control and the CT Stormwater Quality manual. There will be an online webinar about this on February 22 from 2 to 3:30, with registration available through https://ctdeep.zoom.us/i/83529432314. Mr. Danila also mentioned a new tool available through UConn's CLEAR (Center for Land Use Evaluation and Research). It is an interactive online assessment tool including considerable information on all CT watersheds. It is accessed through https://clear.uconn.edu/2022/10/21/a-new-tool-to-assess-watershed-health-in-ct/

b. Agribusiness Subcommittee. Mr. Christensen reported the Preservationist Potluck Supper had 13 groups represented.

The second winter workshop series will be held Saturday, February 11, at the East Lyme Library at 2 p.m. on Ticks and Tick-Borne Disease Challenges as a Serious Public Health Concern. (February 18 snow date).

On March 18 at 2 p.m. at East Lyme Library the third winter workshop will be on The History of Black Bears. (March 25 snow date).

Mr. Christensen was pleased to report that the Agribusiness Subcommittee has two new members. Its next meeting will be next week.

The Giving Garden Seminar on Probiotics will be held Sunday, February 12. It is listed on the town website. Ms. Heller added the Giving Garden produced 8,000 pounds of food in 2022.

c. Pollinator Pathways.

Ms. Meekoff reported Pollinator Pathways has a display at East Lyme Library for educational purposes. She has requested that information highlighting the Town's Proclamation encouraging the principals of Pollinator Pathways be placed in the Parks and Recreation Events newsletter. A Wildlife Biologist with DEEP will discuss herbicides in June.

She has been contacted by Brookside Farm Museum. They would like to meet with her to discuss plantings adjacent to Brookside Farm Museum. Pollinator Pathways is already in charge of the Senior Center Garden. This group will need many volunteers. Public Works Director Joe Bragaw agreed to remove two dead trees, but the Town is unable to get a truck into that area. Ms. Meekoff's mission is to remove the invasive species, especially Japanese Barberry. Ms. Heller offered to help write a grant through SustainableCT to support this work.

d.Chairman's Report. Mr. Carlson was unable to be present and there was no report.

e. Ex-Officio Report. Ms. Hardy reported the Selectmen are in the budget season. The Town is having trouble filling positions because it cannot hire individuals who want more than what the previous individual was paid. She added the town is fortunate to have help from many volunteers.
The Selectmen are also working on the Board of Education budget issues.

VI. ADJOURNMENT

MOTION (3): Mr. Danila moved to adjourn the February 8, 2023 East Lyme Commission for the Conservation of Natural Resources Regular Meeting at 8:20 p.m. Seconded by Ms. Ashburn. (5-0). Unanimous.

Respectfully submitted,

Frances Ghersi, Recording Secretary

4-29-2011

Salt Contamination of Ground and Surface Water in Connecticut: A Compilation and Synthesis of Historic Data and Local Scale Testing

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Abstract

Throughout much of the past century, salt has been widely used by Connecticut for the deicing of roads, shopping areas, sidewalks and airports. It is also a major constituent in food product waste. By compiling and analyzing historical and modern water quality data, this study has demonstrated the extent and severity of salt impacts to ground and surface water resources in the State. Several suspected sources of salt impact have been spatially compared to the patterns of salt impact in an effort to target the principle contributors. The correlations indicate that road salting is the primary source for salt impacts observed across the State. In order to further detail the processes by which road salting impacts ground water field monitoring experiments were conducted over the course of two consecutive winter seasons. The field monitoring involved observing and recording ground water quality parameters as well as surface temperature, precipitation, and salting activities. The analysis of the field monitoring data reveals that pulses of salinated melt infiltrate into the subsurface when surface temperatures are sufficiently high, preceding a snow event during which salting occurred. The field monitoring demonstrated direct salt pulse impacts occurring within groundwater contained within the overburden. However, field monitoring was not implemented in a fractured bedrock formation. Instead periodic water quality profiling was employed to discern seasonal trends. The distinct lack of seasonal variations in groundwater conductivity suggest that salt may be accumulating within bedrock storage.

Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States

By John R. Mullaney, David L. Lorenz, and Alan D. Arntson

National Water-Quality Assessment Program

Scientific Investigations Report 2009–5086

U.S. Department of the Interior
U.S. Geological Survey

Chloride in Groundwater and Surface Water in Areas Underlain by the Glacial Aquifer System, Northern United States

By John R. Mullaney, David L. Lorenz, and Alan D. Arntson

Abstract

A study of chloride in groundwater and surface water was conducted for the glacial aquifer system of the northern United States in forested, agricultural, and urban areas by analyzing data collected for the National Water-Quality Assessment Program from 1991 to 2004.

Groundwater-quality data from a sampling of 1,329 wells in 19 states were analyzed. Chloride concentrations were greater than the secondary maximum contaminant level established by the U.S. Environmental Protection Agency of 250 milligrams per liter in 2.5 percent of samples from 797 shallow monitoring wells and in 1.7 percent of samples from 532 drinking-water supply wells. Water samples from shallow monitoring wells in urban areas had the largest concentration of chloride, followed by water samples from agricultural and forested areas (medians of 46, 12, and 2.9 milligrams per liter, respectively).

An analysis of chloride:bromide ratios, by mass, and chloride concentrations compared to binary mixing curves for dilute groundwater, halite, sewage and animal waste, potassium chloride fertilizer, basin brines, seawater, and landfill leachate in samples from monitoring wells indicated multiple sources of chloride in samples from wells in urban areas and agricultural areas. Water from shallow monitoring wells in urban areas had the largest chloride:bromide ratio, and samples with chloride:bromide ratios greater than 1,000 and chloride concentrations greater than 100 milligrams per liter were dominated by halite; however, the samples commonly contained mixtures that indicated input from sewage or animal waste. Chloride:bromide ratios were significantly larger in samples from public-supply drinking-water wells than from private drinking-water wells, and ratios were significantly larger in all drinking-water wells in eastern and central regions of the glacial aquifer system than in west-central and western regions of the glacial aquifer system.

Surface-water-quality data collected regularly during varying time periods from 1991–2004 from 100 basins dominated by forested, agricultural, or urban land in 15 states were analyzed to determine maximum measured chloride concentrations. Samples from 15 sites in east, central, and west-central areas, collected primarily in winter, had chloride concentrations higher than the U.S. Environmental Protection Agency recommended chronic criterion concentration for aquatic life of 230 milligrams per liter. Concentrations of chloride in base-flow samples were predictive of maximum measured chloride concentrations, indicating that inputs of chloride from groundwater and (or) point-source wastewater discharges increase the likelihood of samples exceeding the recommended chronic aquatic criterion. Multiple linear regression analyses showed that the density of major roads, potential evapotranspiration, and the percentage of annual runoff from saturated overland flow were significant factors in describing the range of maximum measured chloride concentrations in the basins studied.

Chloride loads and yields were determined at 95 surface-water-monitoring stations in basins dominated by forested, agricultural, or urban land. Annual chloride yield was largest in the urban basins (median of 88 tons per square mile) and smallest in the forested basins (median of 6.4 tons per square mile). The median chloride yield in the agricultural basins was 15.4 tons per square mile. Multiple linear regression analyses showed that the density of highways (roads in U.S. highway system), the number of major wastewater discharges in the basin, potential evapotranspiration, and urban minus agricultural land area were significant factors in describing the range of average annual chloride yields.

Upward trends in chloride loads were apparent in several urban basins for which additional long-term data were available. Increases in chloride loads over time may be related to a variety of factors, including increases in road area and consequent deicing, increases in wastewater and septic-system discharges, recycling of chloride from drinking water, and leachate from landfills and salt storage areas.

Increased salinization of fresh water in the northeastern United States

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Contributed by Gene E. Likens, August 4, 2005

Chloride concentrations are increasing at a rate that threatens the availability of fresh water in the northeastern United States. Increases in roadways and deicer use are now salinizing fresh waters, degrading habitat for aquatic organisms, and impacting large supplies of drinking water for humans throughout the region. We observed chloride concentrations of up to 25% of the concentration of seawater in streams of Maryland, New York, and New Hampshire during winters, and chloride concentrations remaining up to 100 times greater than unimpacted forest streams during summers. Mean annual chloride concentration increased as a function of impervious surface and exceeded tolerance for freshwater life in suburban and urban watersheds. Our analysis shows that if salinity were to continue to increase at its present rate due to changes in impervious surface coverage and current management practices, many surface waters in the northeastern United States would not be potable for human consumption and would become toxic to freshwater life within the next century.

impervious surfaces | land use change

For many years, salinization of fresh water related to agricultural practices has been recognized as an environmental problem in arid and semiarid environments throughout the world (1). Long-term salinization of surface waters associated with increasing coverage by roadways and suburban and urban development has been less considered, although previous research has documented sharp increases in concentrations of sodium and chloride in aquatic systems of the rural northeastern United States over decades due to the use of road salt (2–5). Our analysis shows that baseline salinity is now increasing at a regional scale in the northeastern United States toward thresholds beyond which significant changes in ecological communities and ecosystem functions can be expected.

Salinization refers to an increase in the concentration of total dissolved solids in water and can often be detected by an increase in chloride, an important anion of many salts. In the northeastern United States, chloride derived from salt is commonly associated with runoff from roads at latitudes above ≈39°N, particularly during winter. Concentrations of chloride in soils as low as 30 mg/liter have been found to damage land plants, which typically occur in close proximity to roads (6). Increased chloride concentrations in surface waters, however, can be propagated a substantial distance from roadways, leading to more widespread effects on water quality. Increases in salinity up to 1,000 mg/liter can have lethal and sublethal effects on aquatic plants and invertebrates (7), and chronic concentrations of chloride as low as 250 mg/liter have been recognized as harmful to freshwater life and not potable for human consumption (6, 8). Water with chloride concentrations >250 mg/liter can impart a salty taste and also contain elevated concentrations of sodium and toxic impurities from road salt (9), which are of concern to human health. Road salt is currently not regulated as a primary contaminant to fresh waters of the United States, although a recommended limit exists (8). Regulation of road salt was recently considered by the Canadian government after much controversy (6).

Relatively little is known regarding the relationship between widespread increases in suburban and urban development and long-term changes in baseline salinity across regions of the United States. Impervious surfaces now cover >112,610 km^2 in the United States, an area equivalent to the state of Ohio (10). The amount of impervious surface coverage within the United States is expected to increase sharply with >16,093 km of new roads and 1 million single-family homes being created during the present decade (10). The rate of land-use change may be particularly high in segments of watersheds near surface waters such as streams, rivers, and lakes. As coverage by impervious surfaces increases, aquatic systems can receive increased and pulsed applications of salt, which can accumulate to unsafe levels in ground and surface waters over time (6).

Methods

Rural Sites. We investigated the rate of salinization and increases in the baseline concentration of chloride in inland waters by using long-term data from streams and rivers draining rural watersheds in three locations of the northeastern United States: Baltimore County (Maryland), the Hudson River Valley (New York), and the White Mountains (New Hampshire). Rural sites in these areas have experienced relatively small changes in population growth but contain a low density of roads within their watersheds. The sites in Maryland drain into drinking-water supply reservoirs for Baltimore City and have been monitored over the decades by the municipal government. The sites in the Hudson River Valley have been monitored by the Institute of Ecosystem Studies and the U.S. Geological Survey (2), and the sites in New Hampshire are part of the Hubbard Brook Ecosystem Study (3, 11).

Baltimore Metropolitan Area. Within the Baltimore metropolitan area, we explored long-term changes in chloride concentrations across a broader gradient of land use to determine an empirical relationship between salinization and increasing coverage by impervious surface. The Baltimore metropolitan watersheds drain into the Chesapeake Bay and represent one of the most rapidly developing areas of the northeastern United States. In this region, coverage by impervious surface increased by ≈39% from 1986 to 2000 (12). Streams draining forest, agricultural, suburban, and urban watersheds were sampled as part of the National Science Foundation-supported Baltimore Long Term Ecological Research (LTER) project. Samples were collected weekly from 1998 to 2003 without regard to flow conditions (no

Abbreviation: LTER, Long Term Ecological Research.

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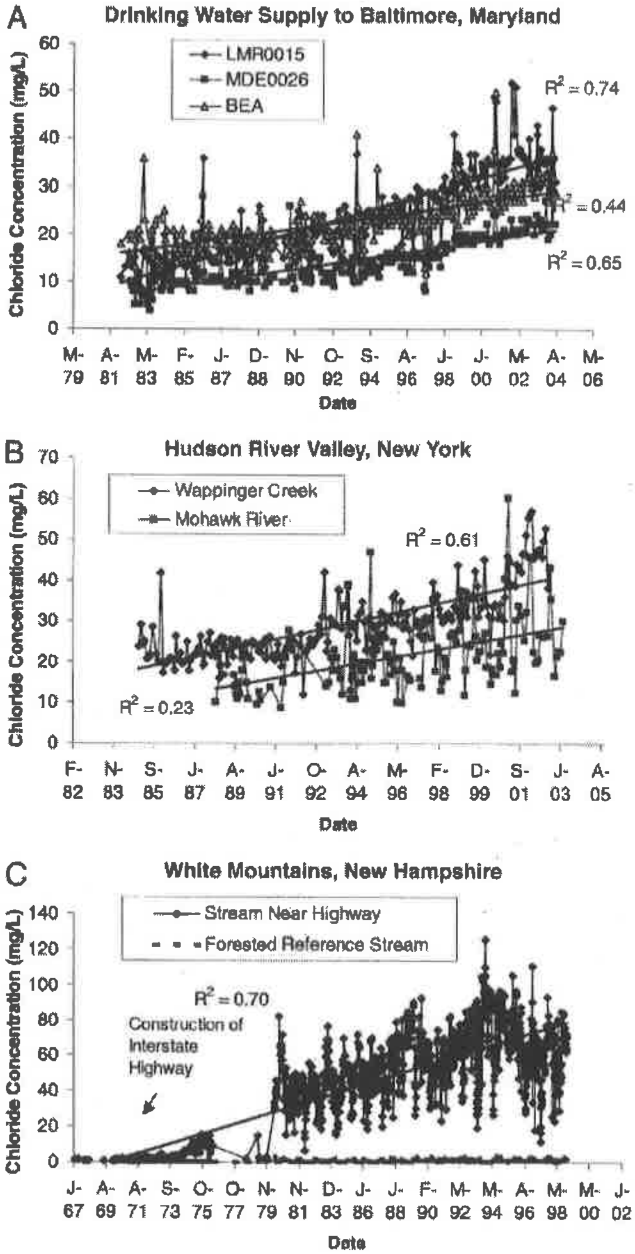

Fig. 1. Examples of significant, long-term increases in baseline concentration of chloride for streams and rivers of the northeastern United States. The R^2 values are given for linear regressions. All streams and rivers are located in rural areas but contain roads within their watersheds. (*A*) LMR0015 (Little Morgan Run), MDE0026 (Middle Run), and BEA (Beaver Run) are sampling stations for tributaries to Liberty Reservoir, a drinking water supply for Baltimore. (*B*) Wappinger Creek and the Mohawk River are tributaries to the Hudson River in the Hudson River Valley. (*C*) The streams in the White Mountains drain into Mirror Lake; one is located near an interstate highway in the Hubbard Brook Valley, and the forested reference stream is watershed 6 of the Hubbard Brook Experimental Forest (10).

bias toward storm flow vs. base flow), filtered in the field (47-μm glass microfiber and 0.45-μm-pore-size nylon filters), and analyzed for chloride by using a Dionex LC20 series ion chromatograph. Detailed site descriptions and sampling protocols are described in ref. 13. Baltimore LTER sites were not downstream of any wastewater treatment plants, which could release chloride. Municipal records indicate that >82,000 metric tons of NaCl were applied to roadways in the city of Baltimore (not including private property and interstate highways) as deicing material during the study period (14).

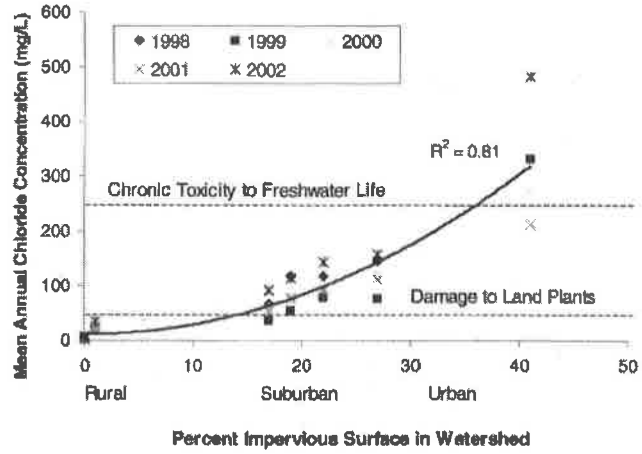

Fig. 2. Relationship between impervious surface and mean annual concentration of chloride in streams of the Baltimore LTER site during a 5-year period ($R^2 = 0.81$). Sites are located along a gradient of urbanization. Dashed lines indicate thresholds for damage to some land plants and for chronic toxicity to sensitive freshwater life (6, 8).

Results and Discussion

Rising Salinity in Rural Streams. Despite temporal fluctuations in precipitation in the northeastern United States throughout the study (11), we observed strong increases in the baseline concentration of chloride in rural watersheds with low density of roadways in Maryland, New York, and New Hampshire over the past 30 years (Fig. 1). In the White Mountains, chloride concentrations in some rural streams now exceed 100 mg/liter on a seasonal basis, which is similar to the salt front of the Hudson River estuary. Streams entering the Baltimore drinking water reservoir and streams and rivers of the Hudson River Valley also showed significant increases in concentrations of chloride over the past several decades ($P < 0.05$). We assumed a conservative linear rate of increase, although it may be possible that salinity is increasing at an exponential or logarithmic rate. If salinization were to continue to increase at its present linear rate (assuming no change in rates of road salt application or impervious surface coverage), we estimate that baseline chloride concentrations in many rural streams will exceed 250 mg/liter in the next century, thereby becoming toxic to sensitive freshwater life and not potable for human consumption.

Impervious Surface and Long-Term Salinization. Across the broader land-use gradient in Baltimore, we found that salinization of inland waters was strongly related to the amount of impervious surface coverage, and that chloride concentrations in many suburban and urban streams now already exceed the maximum limit (250 mg/liter) recommended for the protection of freshwater life. The mean annual concentration of chloride in Baltimore LTER streams increased as a logarithmic function as the relative amount of impervious surface increased within watersheds (Fig. 2). In developed areas with >40% impervious surface coverage, mean annual concentrations of chloride exceeded the thresholds of tolerance for sensitive taxa of freshwater life (6, 8). In suburban and urban streams, chloride concentrations remained elevated throughout winters, with peak concentrations of almost 5 g/liter (25% of the concentration of seawater) (Table 1). Interestingly, concentrations of chloride also remained elevated throughout the spring, summer, and

Table 1. Land use and peak chloride concentrations in streams of Baltimore

Station	Land use	Drainage area, ha	Population density, people per ha	Maximum Cl^- concentration, mg/liter			
				Winter	Spring	Summer	Fall
			With roadways				
Baisman Run	Suburban/forest (≈1% impervious surface)	381	1	38–116	19–29	22–37	23–29
Gwynnbrook	Suburbanizing	1,066	16	181–1,051	34–57	30–216	24–33
Glyndon	Suburban	81	9	229–1,509	79–117	96–469	72–606
Villa Nova	Suburban/urban	8,348	12	341–2,458	45–285	38–54	39–55
Dead Run	Suburban/urban	1,414	13	1,786–4,629	249–336	176–211	101–391
Carroll Park	Urban	16,278	20	960–2,085	63–86	44–86	49–66
			Without roadways				
Pond Branch	Forested	32.3	0	3–6	3–8	3–4	2–3
McDonogh	Agriculture	7.8	0	5–8	4–5	4–5	5–7

Range in the maximum concentration of chloride from 1998 through 2003 during winter, spring, summer, and fall in the streams of the Baltimore LTER site.

autumn and were up to 100 times greater than concentrations found in streams draining forest and agricultural watersheds without impervious surfaces. The relative contribution of salt from additional sources, such as septic effluent and discharges from water softeners, appeared to be low, compared with road deicers, which is reflected by the large peaks in chloride concentration during late fall and winter in both the rural streams from Maryland to New Hampshire and the urbanizing streams of the Baltimore LTER site (Fig. 1 and Table 1).

Ecological Implications. Our observations of long-term increases in chloride concentrations in northern rural areas and in rapidly developing areas located in relatively warm climates, such as Maryland, suggest that chloride pollution may be pervasive across seasons and large geographic areas of the northeastern United States. Over time, a gradual accumulation of chloride in groundwater can lead to elevated concentrations during baseflow conditions in the summer months and can contribute to long-term increases in the baseline salinity of surface waters (3, 5, 15). Related work has shown increasing salinity in the lakes of the midwestern United States due to road salt (16, 17). Even very large bodies of water have experienced increases in salinity, e.g., chloride concentrations in the lower Laurentian Great Lakes have increased to approximately 3 times their original concentration in the 1850s (18).

The concentrations of chloride that we observed in the Baltimore LTER streams are high enough to induce a variety of effects within both aquatic and terrestrial ecosystems. These effects include acidification of streams (19), mobilization of toxic metals through ion exchange or impurities in road salt (9, 20), changes in mortality and reproduction of aquatic plants and animals (21–23), altered community composition of plants in riparian areas and wetlands (23–25), facilitation of invasion of saltwater species into previously freshwater ecosystems (17, 25), and interference with the natural mixing of lakes (15). At relatively lower concentrations, salt also has been shown to alter the structure of microbial communities (26) and inhibit denitrification (27), a process critical for removing nitrate and maintaining water quality in surface waters. The undesirable effects of increasing salinity on particular taxa may influence broader ecosystem processes in aquatic systems related to primary productivity, decomposition, nutrient cycling, and the trophic complexity of food webs.

We also observed very large seasonal fluctuations in chloride concentrations, particularly in suburban and urban streams of the Baltimore LTER (increases in winters to almost 5 g/liter). These fluctuations may be particularly harmful to freshwater life, which may not have adaptations to adjust the osmotic potential of their cells over shorter time scales. Supporting work has shown that chloride associated with sodium can be more toxic than chloride associated with other divalent cations (21), and that minimum tolerance by organisms decreases with increasing temperature (28) and as fluctuations in its concentration increase (21). Thus, the effects of chloride pollution may be particularly pronounced in suburban and urban streams during summer base flow when dilution is minimal. Both elevated ranges and variability in concentrations of salt related to impervious surfaces can be a major influence on aquatic communities, even when other pollutants are absent or present in low amounts (29). Increased salinity should be included as an important ecological variable in explaining the extremely low abundance and diversity of freshwater life observed in inland waters draining rapidly developing landscapes (14, 29).

The increase in mean annual chloride concentration with impervious surface coverage suggests that chloride pollution is an increasing problem not only in rural areas with little population growth, but also in areas experiencing rapid and large changes in land use. Many cities and suburbs of the United States are within the range of impervious surface area reported for sites within the Baltimore metropolitan area. If the construction of roadways and parking lots were to continue to increase at its current rate, there likely would be large changes in baseline salinity across many northern regions of the United States and in other urbanizing areas throughout the world (14, 18, 19, 30). Many large cities receive substantially more snow than the mid-Atlantic region of the United States, which typically only has a mean annual snowfall of 46 cm, and concentrations of chloride presented in this study are not as elevated as those observed in more northern regions (5). Our observations suggest that even small changes in land use have resulted in large changes in the baseline salinity of aquatic systems. Moreover, the accumulation of road salt in aquifers and groundwater has eventually led to increased salinity throughout all seasons and across years in the northeastern United States and may persist for decades, even if use of salt is discontinued (14, 5). Given that land-use change is rapid in many regions of the world (9, 11, 14, 30–32), we suggest that salinization associated with increasing suburban and urbanization deserves attention as one of the most significant threats to the integrity of freshwater ecosystems in the northeastern United States.

We thank William Lewis, Robert Jackson, Jonathan Cole, and Michael Pace for comments on earlier versions of the manuscript; Dan Dillon and Tara Krebs for collecting samples in Baltimore; Catherine Shields for assistance with the figures; Heather Reed for providing encouragement; the U.S. Department of Agriculture Forest Service Northeastern Research Station for site management and in-kind services; the Baltimore County Department of Environmental Protection and Management and the U.S. Geological Survey Cooperative Water Program for partial support of stream-gauging stations; and the City of Baltimore Departments of Parks and Recreation and Public Works, the Baltimore County Department of Parks, and the Maryland Department of Natural Resources for kindly providing access or management of land for our ecological, hydrological, and meteorological field sites. The Hubbard Brook Experimental Forest is operated and maintained by the Northeastern Research Station, U.S. Department of Agriculture, Newtown Square, PA. This publication is a contribution to the program of the Institute of Ecosystem Studies. This work was supported by the National Science Foundation LTER and Long Term Research in Environmental Biology programs, the Environmental Protection Agency–National Science Foundation joint program in Water and Watersheds (Project No. GAD-R825792), and the A. W. Mellon Foundation.

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COMMENTARY

From icy roads to salty streams

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For most of human history, salt was a precious commodity. People prized it for flavoring and preserving food and for use in religious ceremonies and burials. The Roman occupation of Britain peppered the English language with a legacy of salt. We retain those Latin links in words such as "salary" and "salami" and in place names like Greenwich and Sandwich, their suffix denoting a saltworks. Today salt is no longer precious. The U.S. mines ≈36 million metric tons [1 metric ton = 1 megagram (Mg)] of rock salt a year (1). Eighteen million Mg is spread on paved surfaces for deicing, making winter roads safer for people and vehicles (2). However, once the salt dissolves, it washes into streams or soil and is forgotten. A new article by Kaushal *et al.* (3) in a recent issue of PNAS suggested that it should not be.

The use of rock salt (NaCl) on U.S. roads has skyrocketed in the last 65 years (Fig. 1), and chloride (Cl) concentrations in waters of the northeast have risen as a consequence (4–6). The mobility of salt in water leads to its potential problems in the environment. These problems include toxicity to plants and fish, groundwater contamination, and human health interactions, particularly salt intake and hypertension (7–9). In consequence, researchers have been monitoring increased salt concentrations in streams and groundwater for decades (4–6, 10).

The research by Kaushal *et al.* (3) documenting increased Cl concentrations in streams of the northeastern U.S. is important for several reasons. One is the long-term nature of their data sets. They analyzed Cl concentrations for 20–40 years in seven streams and rivers in Maryland, New York, and New Hampshire, showing steady increases over time. The most dramatic changes were seen in New Hampshire, where Cl concentrations have increased by more than an order of magnitude since the 1960s, sometimes topping 100 mg·liter^{-1}. Even more importantly, if results are extrapolated into the next century, the data suggest that many rural streams in the Northeast will have baseline salt concentrations >250 mg·liter^{-1}, the generally accepted cutoff for potable water and a level at which chronic toxicity occurs for many freshwater species.

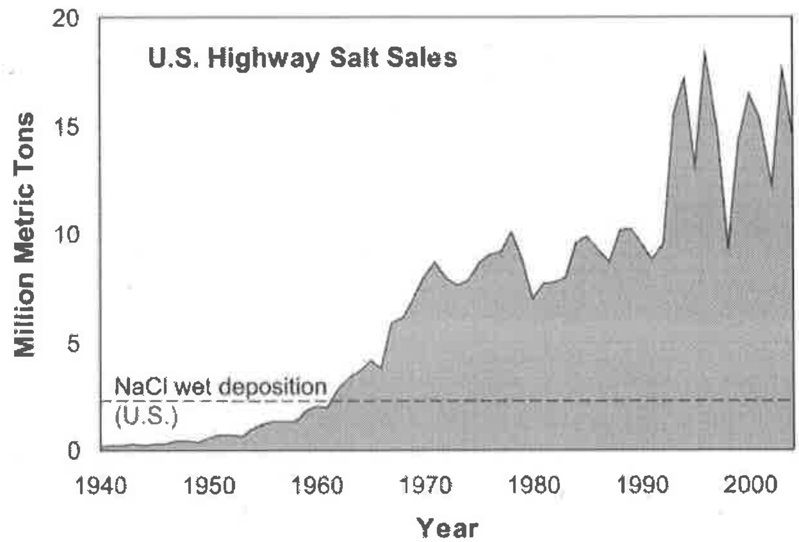

Fig. 1. Sales of rock salt for highway use in the U.S. from 1940 to 2004 in millions of metric tons (Mg) (1, 2). The dashed line denotes our estimate of the calculated annual wet deposition of Na and Cl in the U.S., derived primarily from sea salt. The amount of Na and Cl in road salt topped Na and Cl deposition for the continental U.S. some time in the early 1960s. We estimated U.S. wet deposition of NaCl based on data from 1999–2003 using deposition isopleth maps from ref. 15. The product of mean area and deposition rates for each isopleth interval was calculated by state and summed. For Na and Cl, rates of dry deposition should be smaller than rates of wet deposition.

A second aspect is their intensive focus on streams in the greater Baltimore area. In this rapidly urbanizing region, they found a logarithmic relationship between the proportion of pavement in a watershed and the mean annual Cl concentration in streams. Above 15% impervious cover, Cl concentrations were strong enough to damage some plants, and, above 40%, the streams crossed the threshold of 250 mg·liter^{-1} Cl. Maximum winter concentrations reached >4,600 mg·liter^{-1} Cl, approximately one-quarter of the amount in seawater.

Not surprisingly, the data of Kaushal *et al.* (3) show strong seasonal effects, with the highest concentrations in winter. More surprisingly, Cl concentrations in the rural streams did not return to baseline levels in summer, even when no salt was being applied. One reason is that salt concentrations build up over many years and remain high in the soil and groundwater. Groundwater seeping into streams often keeps water flowing during the driest periods, typically in summer. If the groundwater is salty, the stream will be salty. Increases in groundwater salinity have indeed been observed in the northeastern U.S. and Canada (11, 12). For example, a survey of 23 springs in the greater Toronto area found Cl concentrations topping 1,200 mg·liter^{-1} arising from road salt use (11). This groundwater salinity is the primary concern for long-term potable water supply. Once groundwater becomes salty, it typically will take decades to centuries for the salts to disappear, even when road salt use ends.

Where Is the Sodium?

The current study focused on the fate of Cl, providing clear evidence of its link to road salt and build-up in streams. Two unanswered questions are (*i*) how the road salt gets into the streams and (*ii*) what happens to the accompanying sodium (Na). Na is important for its health effects on wildlife and people and also as a biogeochemical tracer. If road salt takes a fairly direct path to

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streams through surface runoff or drainage systems, the amounts of Na and Cl reaching the streams should be roughly similar (0.65:1 mass ratio). If instead the dominant flow path involves underground transport through soils, where Cl anions are more mobile than Na cations, then the ratio of Na to Cl will be lower. Na will gradually displace Ca, Mg, K, and protons in the soil, altering soil fertility and uncoupling the flow of Na from Cl (13). We suggest that the ratio of changes in Na and Cl concentrations over time in the stream waters described by Kaushal *et al.* (3) could help determine the importance of surface vs. underground pathways of road salt transport to streams. Lower Na:Cl ratios would suggest proportionally greater fluxes through soil.

Human Use Versus Natural Deposition

To understand how much rock salt is now being applied in the U.S., we compared the amount to estimated natural deposition rates of Na and Cl. In 1940, sales of rock salt for highway use were only 149,000 Mg (Fig. 1). Today, the value is a hundred times higher, ≈18 million Mg. This amount dwarfs our calculated estimate for natural wet deposition of Na and Cl for the continental U.S. each year, 2.2 $Mg{\cdot}yr^{-1}$ derived primarily from sea salt (Fig. 1).

Most of the ≈18 million Mg of NaCl used on roads each year is applied in northeastern and midwestern states, with six states using three quarters of the total: New York, Ohio, Michigan, Illinois, Pennsylvania, and Wisconsin. On a statewide basis, applications of deicing salt are 200 $kg{\cdot}ha^{-1}{\cdot}yr^{-1}$ for New York and Ohio and 400 $kg{\cdot}ha^{-1}{\cdot}yr^{-1}$ in the District of Columbia (14). In rural states, such as Vermont, salt loads are still 136 $kg{\cdot}ha^{-1}{\cdot}yr^{-1}$ (14). Focusing just on Cl, the average input from road salt in Vermont is therefore 80 $kg{\cdot}ha^{-1}{\cdot}yr^{-1}$, two orders of magnitude higher than estimated atmospheric Cl inputs of 0.88 $kg{\cdot}ha^{-1}{\cdot}yr^{-1}$ (1999–2003 average; ref. 15).

The increases are equally large for Na, a cation that is often abundant in rocks but tends not to be retained as much as other cations in soils (16). An average Vermont forest soil receiving an annual Na load of 50 $kg{\cdot}ha^{-1}$ from rock salt has the potential to displace other cations and load its entire exchangeable complex with Na in the top 10 cm of the soil in 80 years [based on an effective cation exchange capacity of 15 milliequivalents (meq)/100 g of soil and a bulk density of 1.2 $g{\cdot}cm^3$]. Obviously, rock salt is not applied evenly across a state; some areas will have higher inputs and other areas will have lower or no inputs. The key point is that, compared with natural deposition of Na and Cl, inputs of road salt are now enormous, and water moves that salt around locally and regionally as Kaushal *et al.* (3) highlight.

There are real, long-term consequences to rock salt's use for freshwater systems and soils.

The most difficult aspect of road salt use is knowing what to do about it. Kaushal *et al.* (3) do not discuss policy solutions or suggest alternatives to its use. Scandinavian countries are studying alternatives to traditional road salt, including mixing it with sand or sugar and replacing it with other chemicals, such as potassium formate. Canada took the controversial step in 1995 of placing salt on its Priority Substances List for assessment under the Canadian Environmental Protection Act, and, in 2004, it released a Code of Practice for the Environmental Management of Road Salts. Concerns for drinking water quality in New York have led some cities to use chemical alternatives, including potassium acetate ($C_2H_3KO_2$) and calcium magnesium acetate ($Ca_xMg_y(C_2H_3O_2)_{2(x+y)}$) (17). However, these chemicals are an order of magnitude more expensive than NaCl. The beauty of road salt is that it works well and is cheap.

In summary, no one is suggesting that society should instantly ban rock salt use. Nonetheless, the results of Kaushal *et al.* (3) do suggest that there are real, long-term consequences to its use, particularly for freshwater systems and soils. Understanding which environments are more likely to transfer salt from roads, streams, and groundwater could help managers identify sensitive species and highway segments that need alternative methods of deicing. More generally, a prudent step would be to adopt a "less is more" policy, reducing the amounts of salt applied and considering alternatives where economically feasible. As is so often the case today, society is left to balance a discrete, positive benefit (safer roads) with more dilute environmental costs that build over decades and take decades to recover (18).

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