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Road Salt Impacts on Drinking Water



Many studies during the past 30 years have linked increased salt concentrations in drinking water with highway salting operations. Concerns about road salt as a potential contaminant in drinking water date back to the 1950s, when it was discovered that salt was contaminating

drinking water supplies because of improper storage and, in some cases, highway runoff. One objection to salt in drinking water is its taste; a more serious concern is its impact on health. In recent years, considerable attention has been focused on the effects of salt on hypertension, or high blood pressure. Recommendations by government and private health care organizations for moderate salt restriction to prevent hypertension have made people more aware of sources of salt in the diet, including drinking water. Accordingly, salt's relevance to health, road salt's impact on drinking water, and measures being taken to mitigate the contamination of drinking water by road salt are reviewed in this chapter.

RELEVANCE OF SALT TO HEALTH

Salt is relevant to health primarily because it is a principal source of sodium in the diet. Salt is about 40 percent sodium and 60 percent chloride by weight. The quantity of dietary sodium is often expressed in milligrams per day. For healthy adults, the recommended minimum safe intake of sodium is 500 mg/day (NRC 1989a, 253). Sodium

is necessary for the body and cells to regulate fluids and for the transmission of electrical impulses in the nervous system and muscles (NRC 1989b, 413).

Though it is a dietary essential, sodium has been negatively associated with health primarily because of concerns related to hypertension. Hypertension is a major risk factor for cardiovascular disease and death in the United States (NRC 1989b, 414). Definitions of hypertension vary, but it is believed that between 12 and 30 percent of the U.S. population have borderline to pronounced hypertension (NRC 1989b, 550). No single factor is thought to cause hypertension; it is widely believed that several factors have an influence, including age, weight, lifestyle, family history, race, gender, and diet (NRC 1989b, 550). For most individuals with high blood pressure, the exact causes are unknown (DHHS 1988, 144).

The hypothesis that excess sodium causes or contributes to high blood pressure has dominated nutritional and dietary research in hypertension. At present, most medical researchers who have examined the evidence agree that moderate sodium restriction will reduce the prevalence of hypertension in this country by benefiting a portion of the population with the disorder and reducing the number of new cases (DHHS 1988, 152–153). The Food and Nutrition Board of the National Academy of Sciences and several governmental and private health care organizations (including the Surgeon General and the American Heart Association) recommend that Americans reduce their sodium intake by eating fewer sodium-rich foods and limiting the use of salt in cooking and at the table (NRC 1989b, 16).

Sources of Sodium in the Diet

The average daily sodium intake of adults is estimated to be 4000 to 6000 mg/day (DHHS 1988, 150). Intake of sodium is influenced almost entirely by the presence of salt in food. Salt is found naturally in varying concentrations in both vegetables and meats and is used as an additive in many foods for flavoring and preservation. Other sodium salts, such as sodium bicarbonate and monosodium glutamate, are sometimes added to foods.

The contribution of major food groups to daily sodium intake is shown in Table 5-1. According to this survey by the Food and Drug Administration (FDA), food accounts for 98 to 99 percent of daily sodium intake, and all beverages, including drinking water, account for the remaining 1 to 2 percent.

TABLE 5-1 PERCENTAGE CONTRIBUTION OF MAJOR FOOD GROUPS TO DAILY INTAKE OF SODIUM (Pennington and Young 1991)^a

Food Group	Age and Sex Group (%)									
	6-11 months		2 years		14-16 years		30-35 years		60-65 years	
	F	M	F	M	F	M	F	M	F	M
Vegetables	6	7	8	8	10	9	9	9	9	9
Fruits	1	0	0	0	0	0	0	0	0	0
Grain products	21	26	25	25	24	22	26	28	26	28
Nuts	0	1	1	1	1	1	1	1	1	1
Dairy products	35	16	12	12	12	11	10	9	10	9
Eggs	4	3	1	2	2	2	2	3	2	3
Animal flesh	8	16	17	17	19	23	20	22	20	22
Mixed dishes	17	18	20	20	18	17	16	14	16	14
Desserts	5	7	9	9	7	7	7	8	7	8
Sweeteners	0	1	2	2	1	2	1	1	1	1
Fats and sauces	3	4	5	4	6	5	6	6	6	6
Beverages, including drinking water	1	1	2	1	2	2	2	2	2	1

NOTE: F = female, M = male. Columns may not sum to 100 because of rounding.

^aDietary intakes of sodium by specific age and sex group in the United States as determined by the Food and Drug Administration's Total Diet Study from 1982 to 1989. The foods selected for the Total Diet Study represent the core foods of the U.S. food supply as determined by the U.S. Department of Agriculture. Discretionary salt that is added to food during cooking and at the table was not included in the study. All regions of the country are represented in the study.

Sodium Concentrations in Drinking Water

Sodium concentrations in drinking water are variable. For example, a study conducted by the U.S. Environmental Protection Agency (EPA) during the 1970s found that concentrations in tap water varied from 1 to 90 mg/L (EPA 1975). Likewise, in a survey of 354 public water systems conducted by the New York State Department of Public Health, sodium concentrations ranged from 5 to 20 mg/L in 265 communities to as high as 220 mg/L in two communities (New York State Department of Public Health 1977). Craun et al., in an analysis of tap water nationwide, reported a mean sodium concentration of 28 mg/L (Craun et al. 1977).

Among the reasons for the wide variability is that sodium can reach water supplies through a number of sources, including seawater, natural salt deposits, oil field brines, sewage and industrial waste, and agricultural chemicals, as well as road salt (Hanes et al. 1970, 28). Water in arid and semiarid regions is naturally high in soluble salts compared with regions where rainfall is abundant (Hanes et al. 1970, 4). Also, water treatment is frequently a source of sodium in drinking water. For example, sodium fluoride is often added to water supplies during fluoridation, sodium hypochlorite during chlorination, sodium carbonate for corrosion control, and sodium carbonate or sodium hydroxide for pH adjustment (New York State Department of Public Health 1977). Likewise, sodium is often added to tap water from residential wells by softening units that exchange sodium ions for “harder” calcium and magnesium (NRC 1980, 285). Even efficient central water-softening systems at the treatment plant can add more than 25 mg of sodium to 1 L of treated water (Van der Veen and Graveland 1988, 52).

Recommended Levels of Sodium in Drinking Water

No federal regulatory standards for sodium concentrations in drinking water have been established in the United States, although some states have standards for public water supplies. In diet booklets for patients restricted to 500 to 1000 mg sodium per day, the American Heart Association (AHA) recommends that distilled water be used if drinking water contains more than 20 mg/L (AHA 1957). This recommendation is based on the assumption that people use about 2 L of water daily for drinking and cooking and that, accordingly, water does not contribute more than 10 percent of sodium consumed

daily. AHA has no position on sodium concentrations in drinking water for the general public.

The federal Safe Drinking Water Act requires EPA to periodically update drinking water quality criteria. The criteria, which generally reflect the latest scientific knowledge, are announced through Federal Register notices for explanation of rationale and for public comment. EPA does not regulate sodium because of the normally minor contribution of drinking water to daily sodium intake (*Federal Register* 1985, 46,890; *Federal Register* 1988, 1,894). As a general guidance level, EPA recommends that sodium concentrations in drinking water not exceed 20 mg/L for the higher-risk population (i.e., persons on low-sodium diets), on the basis of dietary recommendations by AHA. Currently, EPA requires that all public water systems monitor sodium levels and report levels greater than 20 mg/L to local health authorities so that physicians treating people on sodium-restricted diets can advise patients accordingly (40 CFR 141.4).

For comparison, regulatory norms in the European Economic Community allow sodium concentrations in drinking water of up to 125 mg/L (Van der Veen and Graveland 1988, 52). If contributed by sodium chloride, this level is equivalent to roughly 250 mg/L chloride, at which level dissolved salt can usually be tasted.

ROAD SALT CONCENTRATIONS IN DRINKING WATER

Road salt can enter water supplies by percolation through soil into groundwater or runoff and drainage directly into reservoirs. Upon entering fast-flowing streams and larger rivers and lakes, salt runoff usually has little effect, because concentrations are quickly diluted (Hanes et al. 1970, 19). Road salt infiltration is more common for groundwater-based supplies, such as wells, springs, and reservoirs that are recharged primarily by groundwater.

Road salt can reach groundwater in several ways. For example, many highways, especially in rural areas, use "open" drainage systems, whereby highway runoff is not collected and diverted by gutters and catch basins but instead flows off the pavement into unlined ditches and roadside soil (Pollock 1990, 2). In addition, road salt applied during snowstorms often mixes with snow that is plowed completely off the roadway and paved shoulder. When the snowbanks melt, the meltwater, together with the dissolved salt, can migrate through the soil and move to the water table (Pollock 1990, 2). In colder regions where large snowbanks accumulate during the winter,

spring thaws can produce high concentrations of salt. For example, meltwater samples near several large snowbanks in Wisconsin contained sodium concentrations exceeding 1000 mg/L (Schraufnagel 1965).

The ability of road salt to reach groundwater depends on a number of factors, including the frequency of precipitation and the texture and drainage characteristics of roadside soil. Only a portion of the sodium ever reaches the groundwater. Moreover, whether the saltier groundwater beneath the highway will eventually migrate into nearby wells depends on several factors, including the depth of the well and its distance from the highway, the permeability of the aquifer material, and the direction and rate of groundwater flow (Pollock 1990, 5). Wells most likely to be affected are those within 100 ft down-gradient of the roadway in the direction of groundwater movement. In locations where groundwater moves slowly (e.g., a few feet per year), road salt concentrations may have originated, at least in part, from highway runoff generated several years earlier (Pollock 1990, 5).

Perhaps the state most actively monitoring the effects of road salt on drinking water is Massachusetts, which has done so regularly for the past 25 years. Sodium concentrations of 10 mg/L are natural throughout much of the state (Pollock 1988). The number of public water systems reporting sodium levels twice the natural level jumped from 69 in 1970 to 95 by 1973, the period during which road salt use peaked (Massachusetts Department of Public Health 1973; Murray and Ernst 1976, 15). After several years of investigating and resolving salt contamination complaints, however, the number has dropped to 63 (Pollock 1990, 2). Of the 363 public water systems in the state, 45 are within the range 20 to 40 mg/L and 18 are greater. The single highest concentration is 95 mg/L (Pollock 1990, 2). The highest sodium concentrations in Massachusetts are currently in the more urban, eastern half of the state, where road salt use is heaviest.

In addition to monitoring public water systems for sodium, Massachusetts investigates complaints of salt contamination in private water supplies. Since 1973, for example, the state has regularly monitored seven residential wells located along a section of highway where salt contamination complaints are common. The average median sodium concentration in these wells was 79 mg/L between 1973 and 1983, before any remedial action (Pollock 1990). Since 1983, in response to complaints by residents, the state has instituted a reduced-salting program along this section of highway. Straight salt was replaced by sand and a mixture of salt and calcium chloride. The state believes that this program has succeeded in both identifying and diminishing the effect of salt runoff on roadside wells (Pollock 1990). Four years

after the program began, average sodium concentrations in the wells dropped by more than 50 percent, from 79 to 36 mg/L (Pollock 1990).

The experience in Massachusetts indicates that highway runoff can elevate sodium levels in water supplies. Because so few states routinely monitor the effect of road salt on water supplies, however, it is difficult to characterize the impact of salt runoff nationwide. In the survey of state highway agencies conducted for this study, seven other states reported that they periodically investigate and monitor runoff in water supplies. Of these states, the most active are New Hampshire, Connecticut, and New York. Altogether, 16 states reported receiving complaints related to road salt contamination of drinking water during the past 10 years. The number ranged from one or two per year in Maryland, West Virginia, and Ohio to several dozen per year in the New England states and New York. As might be expected, most states that reported complaints are located in the Northeast and Great Lakes regions, where population densities are highest and road salt use is heaviest.

MITIGATION MEASURES

The first complaints of road salt contamination of water supplies were during the 1950s and stemmed mainly from improper salt storage. At that time, salt piles were often left uncovered and lacked drainage and flooring adequate to prevent salt from migrating into surrounding soils and groundwater.

During the past 20 years, many highway agencies have made efforts to improve storage. They have constructed facilities with contained drainage and leakproof covering and placed impervious pads under stockpiles and salt-handling areas (TRB 1974, 6–7). In Massachusetts, for example, road salt used by state agencies is stored in covered buildings with bituminous concrete flooring; in addition, highway crews pay special attention to minimizing salt spillage during loading and immediately clean spills in salt-sensitive areas (Pollock 1988, 11). Results from the survey of highway agencies for this study indicate that most states that have taken such remedial action have done so primarily because of complaints related to poor storage. Michigan, Ohio, Indiana, and New York, for example, have done so following litigation. In New England, Vermont and Maine spend about \$35,000 and \$75,000 per year, respectively, to upgrade storage facilities and replace nearby contaminated wells when necessary. At least one state, Illinois, has enacted legislation requiring all storage sites to be located at least 200 ft from water supplies.

Though it appears that most egregious salt storage problems are now being corrected, during the past 20 years concerns about the potential for salt contamination of water from highway runoff have increased (Murray and Ernst 1976, 14). Highway surface runoff seldom results in sodium concentrations as high as those associated with poor salt storage, but it can be a difficult problem to redress because of the widespread use of road salt and the potential for numerous water supplies (e.g., public and private wells) to be affected. Measures taken to remedy road salt runoff problems vary widely by state and local jurisdiction, depending on the extent of the problem and the level of awareness and concern by the community and government agencies. Typical remediation measures include highway drainage changes, reduction of salt use near water supplies, delivery of bottled water, and connection of well users to public water systems.

In the survey of state highway agencies, nine states reported taking action to mitigate salt runoff into water supplies during the past 10 years. For the most part, these states are in the Northeast and Great Lakes regions. For instance, New Hampshire has replaced private wells contaminated by road salt for more than 30 years. During the 1960s and 1970s, when its well-replacement program was at its peak, about 40 wells per year were replaced at a typical cost of \$2,000 per well (Murray and Ernst 1976, 59–60). Today, the state spends about \$200,000 per year to divert highway runoff from sensitive areas (through drainage improvements) and replace wells when necessary. The program operates on a complaint basis only, when it is determined that road salt is responsible for chloride concentrations in well water exceeding 250 mg/L, which indicates sodium concentrations of about 125 mg/L.

Again, perhaps the most active mitigation program is that of Massachusetts. Between 1982 and 1988 the state spent nearly \$1.5 million to investigate and remediate the 119 complaints it received about salt contamination of private wells (Pollock 1988, 1). Among the actions taken were

- Well replacement,
- Connection to public water supplies,
- Water treatment (temporary use of reverse-osmosis filters),
- Improvements in highway drainage, and
- Use of salt substitutes.

Table 5-2 shows expenditures in Massachusetts between 1982 and 1988 by mitigation measure. By far the most common measure was connection of well owners to public water systems. In 1984 and 1985,

TABLE 5-2 DISPOSITION OF ROAD SALT CONTAMINATION COMPLAINTS BY PRIVATE WELL OWNERS IN MASSACHUSETTS, 1982-1988 (Pollock 1988)

Year	Well Replacement	Public Supply Connection	Water Treatment	Drainage Change	Salt Substitute	Other	Annual Expenditure for Fiscal Year (\$)
1982			7				55,150
1983	2						67,548
1984	1	32		1			442,260
1985		2					27,085
1986	1	1				3	416,347
1987	10	12				2	118,672
1988 ^a	<u>9</u>	<u>14</u>	-	<u>1</u>	<u>20</u>	<u>1</u>	<u>349,750</u>
Total	23	61	7	2	20	6	1,476,812

^aHalf-year total.

for example, 34 wells with sodium concentrations exceeding 20 mg/L were connected to public water systems at a cost of \$430,000, or about \$13,000 per complaint. Well replacement (whereby wells are drilled deeper and carefully sealed) is the next most common method of remediation, accounting for the resolution of 23 complaints, at a cost of \$5,000 to \$30,000 per well. Remediation expenditures averaged about \$12,500 per complaint for the 119 complaints resolved.

In addition to remediating the effects of salt contamination on private water supplies, Massachusetts has acted to reduce sodium levels in some public water systems. Remediation measures include reduced salting in the vicinity of water supplies and, in a few cases, construction of special drainage systems to divert highway runoff. As mentioned previously, the reduced-salting program in Massachusetts generally involves greater use of sand and a deicer “pre-mix” of 80 percent sodium chloride and 20 percent calcium chloride. The reduced-salting program was initiated when a reservoir near several state highways was found to have sodium concentrations fluctuating from 30 to 60 mg/L. In another instance, a special highway drainage system was constructed that collects meltwater from plowed snowbanks on the median and highway shoulders (Pollock 1984). The system, constructed on a 2-mi section of freeway near Cape Cod, cost about \$2.5 million/mi more to build than a conventional system (Pollock 1988).

Other mitigation (and in some cases prevention) measures adopted by state highway agencies include a special \$2 million drainage system in Pennsylvania—constructed on an Interstate highway passing several large water supplies—and the installation of test wells in Ohio and New Jersey to monitor sodium concentrations in groundwater near salt-treated highways.

COST

Two cost items related to road salt contamination of drinking water are mitigation expenses and potential public health effects.

Mitigation Costs

Only nine state highway agencies reported annual spending on prevention and remediation of salt-contaminated water supplies. How-

ever, the nine states apply about one-half of all salt used by states, and their reports are useful reference points for estimating nationwide spending on prevention and remediation. All nine states—Illinois, Indiana, Maine, Massachusetts, Michigan, New Hampshire, New York, Pennsylvania, and Vermont—are located in the north-eastern and central United States, where concerns about salt contamination of drinking water are greatest.

Mitigation spending by these states totaled about \$1.8 million in 1989, or, on the average, about \$1 per ton of salt applied (Table 5-3). Accordingly, a rough estimate of national expenditures on mitigation measures is that about \$10 million is spent each year for the 10 million tons of salt applied annually by state and local highway agencies.

Public Health Costs

Ideally, an estimate of the total cost of salt contamination of drinking water would include not only those resources spent on mitigation but also any adverse effects on public health when mitigation is inadequate. Such a thorough determination of costs, however, is complicated by the lack of evidence linking salt in drinking water

TABLE 5-3 STATE SPENDING ON PREVENTION AND REMEDIATION OF DRINKING WATER CONTAMINATION BY ROAD SALT, 1989

State	State Expenditures ^a (\$)	Amount of Salt Spread Annually by State ^b (tons)
Illinois	200,000	275,000
Indiana	175,000	240,000
Maine	75,000	60,000
Massachusetts	500,000	225,000
Michigan	200,000	350,000
New Hampshire	195,000	125,000
New York	175,000	450,000
Pennsylvania	200,000	425,000
Vermont	35,000	100,000
Total	1,755,000	2,250,000

^aFrom survey of state highway departments.

^bFrom survey of state highway departments and Salt Institute data.

with a health risk to the general public. As a result, no attempt was made in this study to estimate public health risks and costs.

SUMMARY

Road salt can enter drinking water supplies by migrating through soil into groundwater or by runoff and drainage directly into surface water. In general, only wells or reservoirs near salt-treated highways or salt storage facilities are susceptible to salt infiltration. Susceptibility depends on many factors, such as salting intensity, soil type, climate, topography, and water volume and dilution. Sources of salt in drinking water other than road salt include natural brines and salt deposits, industrial and agricultural chemicals, and water treatment and softening processes.

During the past 30 years, communities in several states, primarily in the Northeast, have reported higher sodium and chloride concentrations in private wells and public water supplies that have been linked to road salt. Many of these problems have resulted from improper salt storage. Most of the more egregious salt storage problems are being corrected. Some communities continue to report higher-than-usual salt concentrations in water supplies due to highway runoff, although such concentrations are seldom as high as those associated with improper salt storage.

The discovery of higher salt concentrations in drinking water due to road salt has raised concerns about possible adverse effects on public health. Salt is a source of sodium in the diet. Excess dietary sodium has been negatively associated with health primarily because of concerns related to hypertension, or high blood pressure. Typically, drinking water and all other beverages combined (which tend to have much higher concentrations of sodium than drinking water) account for less than 5 percent of daily sodium intake. Because of the normally minor contribution of drinking water to sodium intake, no federal standards have been established for salt (i.e., sodium or chloride) concentrations in water supplies.

Efforts to mitigate salt impacts on drinking water vary from state to state and by community. Common measures include modification of highway drainage, relocation of private wells, upgrading of salt storage facilities, and reduced salting activity in the vicinity of public water supplies. Nationally, about \$10 million is spent on mitigation each year by state and local governments, mostly in the Northeast and Midwest. Potential costs due to road salt in drinking water other than government spending on mitigation are largely unknown, prin-

cipally because of the uncertain effects of salt on health. As a result, no attempt was made in this study to estimate other costs of salting, if any, that might be related to public health.

REFERENCES

ABBREVIATIONS

AHA	American Heart Association
DHHS	Department of Health and Human Services
EPA	Environmental Protection Agency
HRB	Highway Research Board
NRC	National Research Council
TRB	Transportation Research Board

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