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IMPACTS OF CHLORIDE ON THE NATURAL AND BUILT ENVIRONMENT

Chapter 5

IMPACTS OF CHLORIDES ON HUMANS AND HUMAN ACTIVITIES

5.1 INTRODUCTION

Elevated concentrations of chloride salts in the environment can affect human activities. High concentrations of chloride salts affect the suitability of water for human consumption both because of the effects of the salts on the taste of water and the direct and indirect effects of the salts on human health. Contamination with chloride salts can also reduce the suitability of soil and irrigation water for agricultural use. Mobilization of chloride salts into the atmosphere can contribute to particulate pollution in the air, which can affect human health. Finally, the use of chloride salts can affect other activities including recreation, cleaning of the interiors of buildings during the winter, and roadside aesthetics.

As noted in previous Chapters of this Report, concentrations of chloride salts, associated salinity and specific conductance have been increasing in surface waters, both in the Southeastern Wisconsin Region and much of the nation.[1]. As discussed in previous Chapters of this Report, increases of chloride salts in the

[1] *See for example, Richard C. Lathrop, "Chloride and Sodium Trends in the Yahara Lakes,* Research Management Findings, *No.12, Wisconsin Department of Natural Resources, June 1998; S.R. Corsi, L.A. De Cicco, M.A. Lutz, and R.M. Hirsch, "River Chloride Trends in Snow-Affected Urban Watersheds: Increasing Concentrations Outpace Urban Growth Rate and Are Common Among All Seasons,"* Science of the Total Environment,*508:488-497, 2015; and J.A. Thornton, T.M. Slawski, and H. Lin, "Salinization: The Ultimate Threat to Temperate Lakes, with Particular Reference to Southeastern Wisconsin (USA),"* Chinese Journal of Oceanology and Limnology, *33:1-15, 2015.*

environment have the potential to impact and alter ecological systems and contribute to the deterioration of vehicles and transportation and water supply infrastructure.

This Chapter presents the findings of a literature review of the impacts of chloride salts on human health and human activities. Health effects of elevated concentrations of chloride salts include direct effects on human cardiovascular and respiratory systems, as well as indirect effects that can occur through the promotion of the release of heavy metals by these salts. Health effects also include those related to the contributions of chloride salts to aerial particulates. The chapter also discusses the impact of chloride salts on agricultural systems and the potential effects of elevated concentrations of chloride salts on recreational opportunities and aesthetics.

5.2 IMPACTS OF CHLORIDE SALTS ON HUMAN HEALTH

Elevated concentrations of chlorides can affect human health. Some health effects are related to the consumption of drinking water with elevated concentrations of chloride salts. While drinking water is not the primary source of these salts, it can contribute to the salt dose people receive. Other health effects are related to direct contact with chloride salts or the presence of particles or aerosols containing chloride salts in the atmosphere. Some health impacts are directly caused by chloride salts, especially the cation sodium. Other health impacts occur indirectly through chloride salts participating in chemical reactions that release other substances that can affect human health. This section describes health impacts caused by chloride salts.

Effects on Blood Pressure and Cardiovascular Health

Hypertension or high blood pressure is defined as systolic blood pressure greater than 130 millimeters of mercury (mm Hg)[2] or a diastolic blood pressure greater than 80 mm Hg.[3] About 116 million adults in the United States either have or are taking medication to treat hypertension.[4]

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[2] *Acronyms and abbreviations used in this report are defined in Appendix A.*

[3] *Systolic blood pressure is the maximum blood pressure during a heartbeat. Diastolic blood pressure is the minimum blood pressure between two heartbeats.*

[4] *U.S. Centers for Disease Control and Prevention,* Hypertension Cascade: Hypertension Prevalence, Treatment and Control Estimates Among U.S. Adults 18 Years and Older Applying the Criteria from the American College of Cardiology and American Heart Association's 2017 Hypertension Guideline—NHANES 2015-2018, *U.S. Department of Health and Human Services, 2021.*

Role of Salt and Sodium in Hypertension

The role of dietary consumption of salt as a cause of hypertension has been recognized for over a century.[5] The incidence of hypertension in members of cultures that have low salt intake is low.[6] In addition, blood pressure does not generally rise as members of these cultures age.[7] This is unlike the pattern seen in cultures in which higher dietary intake of salt is the norm. Also, the incidence of hypertension and blood pressure rising with age in low dietary salt cultures increases as salt use increases, especially in conjunction with migration.[8] Finally, epidemiological and other data have shown that higher salt diets can lead to increased blood pressure.[9]

<u>Evidence Relating Sodium Intake to Hypertension</u>

The effect of salt ingestion on blood pressure has been linked to the intake of sodium. At least three lines of evidence support the idea that long-term ingestion of high levels of sodium leads to an increase in blood pressure. First, epidemiological comparisons of neighboring communities show that a greater incidence of high blood pressure is associated with higher concentrations of sodium in drinking water. For example, a study of two communities with drinking water concentrations of sodium of 8 mg/l and 108 mg/l found a significantly higher incidence of high blood pressure in the community with the higher sodium level after controlling for 18 other factors.[10]

Second, experimental reductions of sodium intake have been shown to lead to lower blood pressure. For example, a meta-analysis of 31 studies in which sodium intake was reduced for more than four weeks found a median reduction in dietary sodium of about 1,810 milligrams per day (mg per day) led to reductions of

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[5] *For example: L. Ambard and E. Beaujard, "Causes de l'Hypertension Arterielle,"* Archives of General Medicine*, 1:520, 1904, cited in: E.M. Freis, "Salt, Volume and the Prevention of Hypertension,* Circulation*, 53:589-595, 1976.*

[6] *B. Kaminer and W.P.W. Lutz, "Blood Pressure in Bushmen of the Kalahari," Circulation, 22:289-295, 1960; C.J. Burns-Cox and J.D. McLean, "Splenomegaly and Blood Pressure in an Orang Asli Community in West Malaysia,"* American Heart Journal*, 80:718-719, 1970.*

[7] *F.W. Lowenstein, "Blood Pressure in Relation to Age and Sex in the Tropics and Subtropics: A Review of the Literature and an Investigation in Two Tribes of Brazil Indians,"* The Lancet*, 277:389-392, 1961.*

[8] *R. Cruz-Coke, R. Etcheverry, and R. Nagel, "Influence of Migration on Blood Pressure of Easter Islanders,"* The Lancet*, 283:697-699, 1964.*

[9] *Freis 1976,* op. cit.

[10] *E.J. Calabrese and R.W. Tuthill, "Sources of Elevated Sodium Levels in Drinking Water and Recommendations for Reduction,"* Journal of Environmental Health*, 41:151-155, 1978.*

2.03 millimeters of mercury (mm Hg) of systolic blood pressure and 0.99 mm Hg diastolic blood pressure.[11] This sodium reduction is equivalent to a salt reduction of 4,600 mg per day. This study also found that the greater the reduction in salt intake, the greater reduction in blood pressure. The study concluded that in people with elevated blood pressure, a reduction of sodium intake of 2,360 mg per day or a reduction of about 6,000 mg salt per day would lead to reductions of 7.2 mm Hg systolic blood pressure and 3.8 mm Hg diastolic blood pressure. Smaller reductions were predicted to occur in people with normal blood pressure. In people with elevated blood pressure, reductions of this magnitude would be expected to reduce deaths from stroke and ischemic heart disease by 14 percent and nine percent, respectively.[12] The authors of the meta-analysis noted that since the median duration of the studies examined was five weeks, longer-term reductions in sodium intake could potentially lead to greater reductions in blood pressure than found in their analysis.

Third, studies have found relationships between increases in salinity in drinking water and increases in blood pressure. For instance, a study in Bangladesh found that an increase of 1,000 mg/l in drinking water salinity led to a 2.2 mm Hg rise in systolic blood pressure.[13] Studies have also documented seasonal increases in hypertension, heart attack, and stroke during winter months that might be related to elevated levels of sodium in drinking water.[14]

Excess sodium affects blood pressure through its impact on extracellular fluids.[15] As sodium accumulates in tissue, the body retains water to dilute the sodium. This increases the amount of fluid surrounding cells and the volume of the blood. This fluid increase can lead to stiffening and structural narrowing of arteries and

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[11] *F.J. He and G.A. MacGregor, "Effect of Longer-Term Modest Salt Reduction on Blood Pressure (Review),"* The Cochrane Library, *Issue 3, 2006.*

[12] *S. MacMahon, R. Petro, J. Cutler, J. Collins, et al., "Blood Pressure, Stroke, and Coronary Heart Disease. Part I, Prolonged Differences in Blood Pressure: Prospective Observational Studies Corrected for Regression Dilution Bias,"* The Lancet, *335:765-774, 1990.*

[13] *M.R.R. Talukder, S. Rutherford, C. Huang, D. Phung, et al., "The Effect of Drinking Water Salinity on Blood Pressure in Young Adults of Coastal Bangladesh,"* Environmental Pollution*, 214:248-254, 2016.*

[14] *T. Takenaka, E. Kojima, K. Sueyoshi, T. Sato, et al., "Seasonal Variations of Daily Changes in Blood Pressure among Hypertensive Patients with End-Stage Renal Diseases,"* Clinical and Experimental Hypertension*, 32:221-233, 2010; A. Fares, "Winter Cardiovascular Diseases Phenomenon,"* North American Journal of Medical Sciences*, 5:266, 2013.*

[15] *Harvard T.H. Chan School of Public Health,* Salt and Sodium*, www.hsph.harvard.edu/nutritionsource/salt-and-sodium/, accessed April 28, 2023.*

arterioles.[16] This change in blood vessels causes increased resistance to blood flow which results in higher blood pressure.

Human Sodium Requirements

Sodium is a required nutrient for humans for numerous biological processes. It has an important role in the transmission of nerve impulses. When a nerve cell transmits an impulse, sodium ions flow into the cell from the extracellular fluid.[17] Sodium plays a similar role in the initiation of contraction and relaxation of muscles. Finally, sodium ions are necessary for maintaining the proper balance of water and minerals in bodily fluids.[18]

Several agencies have recommended levels of human sodium intake based on different physiological thresholds and medical conditions. The minimum amount of sodium that adults need to maintain physiological functions is about 500 mg per day.[19] The U.S. Institute of Medicine of the National Academies of Sciences, Medicine, and Engineering has issued a guideline for the adequate sodium intake for adults. This guideline of for sodium of 1,200 to 1,500 mg per day represents the lowest level at which nutritional deficiencies were not observed.[20] This institute has also established a tolerable upper limit for sodium intake for adults of 2,300 mg per day.[21] The Blood and Lung Institute of the National Institutes of Health recommends that adults on a low sodium diet ingest no more than 1,500 mg of sodium per day.[22] By way of comparison, the average sodium intake of American adults is about 3,400 mg per day.

Although intake through food is the main source of sodium to humans, higher levels of sodium in drinking water can contribute to health problems. The U.S. Environmental Protection Agency (USEPA) has issued a

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[16] *B. Folkow, "Physiological Aspects of Primary Hypertension,"* Physiological Reviews*, 62:347-504, 1982.*

[17] *M.W. Barnett and P.M. Larkman, "The Action Potential,"* Practical Neurology*, 7:192-197, 2007.*

[18] *Harvard T.H. Chan School of Public Health,* op. cit.

[19] *National Research Council Subcommittee on the Tenth Edition of the Recommended Dietary Allowances,* Recommended Dietary Allowances*, National Academies Press, Washington, D.C., 1989.*

[20] *U.S. Institute of Medicine,* Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate, *National Academies Press, Washington, D.C., 2005.*

[21] Ibid.

[22] *National Institutes of Health,* Your Guide to Lowering Your Blood Pressure with DASH (No. 6), *2006.*

health advisory that recommends that concentrations of sodium in drinking water not exceed 20 mg/l.[23] This advisory was based on the risks posed by sodium to individuals with salt restricted diets. Water utilities are required to report exceedances of this 20 mg/l level to public health officials so that physicians can advise high-risk patients.

Consequences of Hypertension

Hypertension is an important precursor to other medical conditions. In 2021, hypertension was a primary or contributing cause of over 691,000 deaths in the United States.[24] High blood pressure is a potential cause of several other heart and vascular diseases. It is a major risk factor for coronary heart disease which involves the reduction of blood flow to the heart due to the buildup of atherosclerotic plaque in arteries of the heart.[25] About half of all heart attacks can be attributed to high blood pressure.[26] Hypertension is also a major factor leading to strokes,[27] accounting for about two-thirds of all strokes.[28] High blood pressure is a risk factor for atrial fibrillation which consists of an abnormal heart rhythm consisting of rapid, irregular beating of the atrial chambers of the heart.[29] Congestive heart failure and aortic aneurysms can also be

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[23] *U.S. Environmental Protection Agency,* Drinking Water Advisory: Consumer Acceptability and Health Effects Analysis on Sodium*, EPA 822-R-03-006, 2003.*

[24] *National Center for Health Statistics,* Multiple Cause of Death 2018-2021 on CDC WONDER Database*, Accessed May 30, 2023.*

[25] *S. Lewington, R. Clarke, Qizilbash, R. Peto, and R. Collins, "Age-Specific Relevance of Usual Blood Pressure to Vascular Mortality: A Meta-Analysis of Individual Data for One Million Adults in 61 Prospective Studies,"* The Lancet*, 360:1,903-1,913, 2002.*

[26] *F.J. He and G.A. MacGregor, "A Comprehensive Review on Salt and Health and Current Experience of Worldwide Salt Reduction Programs,"* Journal of Human Hypertension*, 23:363-384, 2009.*

[27] *M.A. Weber and D.T. Lackland, "Global Burden of Cardiovascular Disease and Stroke: Hypertension and the Core,"* Canadian Journal of Cardiology*, 31:569-571, 2015.*

[28] *He and MacGregor 2009,* op. cit.

[29] *D.H. Lau, S. Nattel, J.M. Kalman, and P. Sanders, "Modifiable Risk Factors and Atrial Fibrillation,"* Circulation*, 136:583-596, 2017.*

attributed to high blood pressure. Hypertension is also a major risk factor for other medical conditions including vision loss, chronic kidney disease, and dementia.[30]

Effects on Air Quality

Air pollution presents a major health risk that contributes to several acute and chronic medical conditions including respiratory infections and diseases, heart disease, and cancer.[31] While several pollutants contribute to the health impacts of polluted air, respirable particulate matter, especially particulate matter with an aerodynamic diameter of 2.5 micrometers or smaller ($PM_{2.5}$), has a greater impact on human health outcomes than other ambient air pollutants.[32] Prolonged exposure to $PM_{2.5}$ has been associated with several health conditions. It is considered a cause of asthma and respiratory inflammation and can promote development of cancers, including lung cancer.[33] Reductions in ambient concentrations of $PM_{2.5}$ have been associated with longer life expectancies; however, the benefits of such reductions are generally greater in urban areas than in rural areas.[34] The authors of a study showing this suggested three possible explanations for this difference.[35] First, the chemical composition of $PM_{2.5}$ differs between urban and rural areas.[36] These differences may cause $PM_{2.5}$ to have larger health impacts in urban areas. Because the health impacts of $PM_{2.5}$ are greater in urban areas, reductions of $PM_{2.5}$ would lead to greater improvements in life span in those areas than in rural areas. Second, mortality rates are higher in rural areas than in urban areas. Several

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[30] *D.T. Lackland and M.A. Weber, "Global Burden of Cardiovascular Disease and Stroke: Hypertension at the Core,"* Canadian Journal of Cardiology, *31:569-571, 2015; I. Hernandorena, E. Duron, J.S. Vidal, and O. Hanon, "Treatment Options and Considerations for Hypertensive Patients to Prevent Dementia,"* Expert Opinion on Pharmacotherapy, *18:989-1,000, 2017.*

[31] *W.S. Beckett, "Current Concepts: Occupational Respiratory Diseases,"* New England Journal of Medicine, *342:406-413, 2000; S. Karnae and K. John, "Source Apportionment of Fine Particulate Matter Measured in an Industrialized Coastal Urban Area of South Texas,"* Atmospheric Environment, *45:3,769-3,776, 2011.*

[32] *D.W. Dockery et al., "An Association Between Air Pollution and Mortality in Six United States Cities,"* New England Journal of Medicine, *329:1,753-1,759, 1993.*

[33] *See Y.-F. Xing, Y.-H. Xu, M.-H Shi, and Y.-X. Lian, "The Impact of PM2.5 on the Human Respiratory System,"* Journal of Thoracic Diseases, *8:E69-E74, 2016 and the references therein.*

[34] *A.W. Correia et al., "Effect of Air Pollution Control on Life Expectancy in the United States: An Analysis of 545 U.S. Counties for the Period from 2000 to 2007,"* Epidemiology, *24:23-31, 2013.*

[35] Ibid.

[36] *See, for example, Louie, P.K. et al., "$PM_{2.5}$ Chemical Composition in Hong Kong: Urban and Rural Variations,"* Science of the Total Environment, *338:267-281, 2005.*

factors have been suggested to contribute to this geographical difference in death rates including physician shortages in rural areas, the relative lack of health insurance in rural areas, and the greater prevalence of poverty in rural areas.[37] Third, the geographical difference in death rate could potentially be an artifact resulting from misclassification of the exposure to $PM_{2.5}$ during data analysis. Since urban areas are more densely populated than rural areas, it is more likely that two persons in the same urban area would be exposed to the same levels of $PM_{2.5}$. Because of this, misclassification of exposure may be more likely in rural areas than urban areas. The USEPA has set a primary ambient air quality standard for $PM_{2.5}$ of 12 micrograms per cubic meter ($\mu g/m^3$) on an average annual basis.

Studies examining the sources and chemical composition of $PM_{2.5}$ have found that deicing salts constitute a measurable portion of ambient concentrations of these fine particulates. One study that monitored air quality over the Lake Champlain basin in Vermont found that road salt comprised about 4.6 percent of the ambient $PM_{2.5}$.[38] Other constituents of $PM_{2.5}$ included nitrates, wood smoke, soil, oil combustion products, automobile exhaust, sulfate-rich aerosols, and emissions from metal working. A second study investigated the composition and sources of $PM_{2.5}$ at rural and urban locations in Iowa between April 2009 and December 2012.[39] Concentrations of $PM_{2.5}$ tended to be higher and more variable at rural sites. Overall deicing salt represented about two to six percent of ambient $PM_{2.5}$, with it constituting two to three percent of $PM_{2.5}$ at urban sites and four to six percent of $PM_{2.5}$ at rural sites. The highest contributions of deicing salt to $PM_{2.5}$ were observed during winter months when deicing occurs. The percentages of $PM_{2.5}$ consisting of deicing salt in these two studies are consistent with those found in a third study which examined air quality in Detroit, Michigan.[40] This study found that deicing salt represented about five to eight percent of $PM_{2.5}$.

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[37] *G. Gong et al., "Higher US Rural Mortality Rates Linked to Socioeconomic Status, Physician Shortages, and Lack of Health Insurance,"* Rural Health*, 38:201900722, 2019.*

[38] *N. Gao et al., "Sources of Fine Particulate Species in Ambient Air Over Lake Champlain Basin, VT,"* Journal of the Air and Waste Management Association*, 56:1,607-1,620, 2006.*

[39] *S. Kundu and E.A. Stone, "Composition and Sources of Fine Particulate Matter Across Urban and Rural Sites in the Midwestern United States,"* Environmental Science: Processes and Impacts*, 16:1,360-1,374, 2014.*

[40] *A.E. Gildenmeister, P.K. Hopke, and E. Kim, "Sources of Fine Urban Particulate Matter in Detroit, MI,"* Chemosphere*, 69:1,064-1,074, 2007.*

$PM_{2.5}$ is thought to be responsible for about 15 percent of lung cancer deaths.[41] Based on the fraction of $PM_{2.5}$ consisting of road salt, road salt applications may be associated with about one percent of all lung cancer deaths due to $PM_{2.5}$ levels in the United States.[42] Given that about 127,000 people die from lung cancer each year in the United States,[43] this suggests that road salt applications could be associated with about 190 deaths from lung cancer per year nationally.

Release of Heavy Metals from Water Sources and Drinking Water Infrastructure

Elevated concentrations of chloride salts can lead to the mobilization of heavy metals and metalloids from rock, sediment, and drinking water infrastructure into surface, groundwater, and potable water supplies. The mechanisms through which the release of metals occurs are discussed in Chapters 2 and 4 of this Report. When these metals and metalloids are released into water used for human consumption, they pose risks to human health through toxicity and other effects.

There are health concerns regarding approximately 23 different heavy metals. The most common of these substances include arsenic, cadmium, chromium, lead, and mercury. Other heavy metals of concern include copper, nickel, radium, silver, and zinc. While each of these metals can produce different health effects, general effects include reduced energy levels and damage to the functioning of the brain, nervous system, liver, lungs, blood, and other organs.[44] Long-term exposure to some of these metals can lead to progressive degenerative processes that mimic conditions such as Parkinson's disease, Alzheimer disease, and muscular dystrophy. Some heavy metals are also carcinogenic.

Some heavy metals in drinking water can assume more than one chemical form, with some chemical forms being more toxic than others. Chromium, for example, can form two different ions, chromium (III) which has a positive charge of 3 and chromium (VI) which has a positive charge of 6. While both forms can produce adverse effects on the respiratory tract, chromium (VI) is much more toxic than chromium (III) and produces

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[41] *International Agency for Research of Cancer (IARC),* Outdoor Air Pollution: IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 109, Lyon, France, 2013.*

[42] *M.H. Nazari et al., "Toxicological Impacts of Roadway Deicers on Aquatic Resources and Human Health: A Review,"* Water Environment Research*, doi: 10.1002/wer.1581, 2021.*

[43] *American Cancer Society,* Cancer Facts and Figures 2023*, American Cancer Society, Atlanta, Georgia, 2023.*

[44] *M. Jaishankar et al., "Toxicity, Mechanism and Health Effects of Some Heavy Metals,"* Interdisciplinary Toxicology,*" 7:60-72, 2014.*

a wider range of adverse effects in humans.[45] This difference in toxicity between the two forms of chromium occurs with both acute and chronic exposures.

Some heavy metals are essential nutrients for humans. Trace amounts are required for certain biological processes. For example, humans require small amounts of zinc for the functioning of certain enzymes. Similarly, small amounts of copper are needed as a cofactor for the functioning of cytochrome oxidase C, a membrane protein that is important in cellular respiration. While humans and other organisms need small amounts of these elements, exposure to greater amounts can produce adverse effects.

Release of Heavy Metals into Source Water

Elevated concentrations of chloride salts can lead to heavy metal contamination of drinking water supply sources. For instance, sodium chloride or calcium chloride in deicing salts can mobilize mercury ions from sediment into water. One study found that such mobilization increased the amount of mercury ions in water by two to five orders of magnitude.[46] This effect increased as the concentration of chloride salts in the water and/or the concentration of mercury in sediment increased. At least two mechanisms contributed to the mobilization of mercury from the sediment. First, sodium and calcium ions from deicing salts compete with mercury ions for exchange sites on clay and humus particles. Second, chloride ions can form strong chemical complexes with mercury ions, making them more soluble in water. The mechanisms leading to mobilization of metals from soil and sediment are discussed in Chapter 2 of this Report.

Release of Metals from Drinking Water Infrastructure and Plumbing

Elevated levels of chloride in drinking water can lead to dezincification and galvanic corrosion of plumbing resulting in the leaching of metals from pipes and plumbing fixtures.[47] The mechanisms causing these processes were discussed in Chapter 4 of this Report. Another metal that can be released from plumbing is lead. In buildings with lead service lines or plumbing fixtures such corrosion can lead to the release of lead into the drinking water. This was likely a factor in the lead contamination of drinking water in Flint, Michigan, as chloride concentrations in the City's drinking water increased from 11 mg/l to 94 mg/l following the switch of their water source to the Flint River. Similarly, a study in New York that examined deicing salt

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[45] *Agency for Toxic Substances and Disease Registry,* Toxicological Profile for Chromium*, U.S. Public Health Service, 1998.*

[46] *G. Feick, R.A. Horne, and D. Yeaple, "Release of Mercury from Contaminated Freshwater Sediment by the Runoff of Road Deicing Salt,"* Science*, 175:1,142-1,143, 1972.*

[47] *K.J. Pieper et al., "Impact of Road Salt on Drinking Water Quality and Infrastructure Corrosion in Private Wells,"* Environmental Science and Technology*, 52:14,078-14,087, 2018.*

contamination in private wells found that about 24 percent of the homes studied had detectable lead levels in their drinking water after one minute of flushing.[48] The concentration of lead in the water was highly correlated with the concentrations of zinc and copper, suggesting that the source of the lead was corrosion of brass plumbing fixtures and fittings.

Service lines that transport drinking water from utility mains into buildings can be a source of lead. Historically, these pipes were often made from lead or galvanized iron which can also leach lead as it corrodes. In Wisconsin, responsibility for the service line is shared between the property owner and the municipal utility. Typically, the property owner is responsible for the portion of the service line that extends from the curb stop, where there is a control valve, into the building. The utility is responsible for the portion of the service line that extends from the water main to the curb stop. There are a substantial number of water service lines in the Southeastern Wisconsin Region that are made of lead or galvanized iron or that may contain lead. Table 5.1 shows the number of these lead-containing service lines in the Region at the end of 2022 as reported by the utilities in their annual reports to the Wisconsin Public Service Commission. As of 2022, there were more than 115,000 portions of service lines owned by utilities and more than 119,000 portions of service lines owned by property owners that were known to contain or suspected of containing lead or galvanized iron. This represents about 24 percent of portions of service lines owned by utilities and 27 percent of service lines owned by property owners in the Southeastern Wisconsin Region.[49] Out of 70 water utilities in the Region, 32 reported the presence of service lines known to contain or suspected of containing lead. The highest numbers were reported by the utilities serving the Cities of Kenosha, Milwaukee, Racine, Wauwatosa, and West Allis and the Villages of Shorewood and Whitefish Bay.

Exposure to lead can cause several adverse health effects. The most sensitive tissues are the nervous system, blood and cardiovascular system, and the kidneys. Developing nervous systems in children are especially susceptible to lead toxicity because exposure to lead during development can interfere with the formation, maintenance, and regulation of connections between nerve cells in the brain.

Relatively low levels of lead exposure can affect neurobehavioral development in children. This can result in cognitive deficits that may also be associated with distractibility, inability to inhibit inappropriate responses, and preservation of behaviors that are no longer appropriate. Somewhat higher levels of exposure can cause anemia due to the inhibitory effect of lead on the synthesis of heme, a component of hemoglobin,

[48] Ibid.

[49] *As of 2023. many utilities in the Region were still conducting inventories of service lines.*

and shortening of the lifespan of red blood cells. These levels of lead exposure can also result in peripheral nerve dysfunction, resulting in weakness and loss of coordination in wrists, hands, feet, and ankles. Even higher levels of lead exposure can cause colic, kidney damage, muscle weakness, brain damage, paralysis, and death.

Prior to 2021, a lead blood concentration of 5 micrograms per deciliter (µg/dl) or more was considered indicative of lead poisoning. Based on data from local health departments, the Wisconsin Department of Health Services reported that from 2016 through 2020, an annual average of 2,600 children under six years of age out of an annual average of 42,702 tested in the seven-county Southeastern Wisconsin Region were found to have blood stream lead concentrations greater than 5 µg/dl. It should be noted that an unusually low number of children were tested in 2020, probably due to the Covid-19 pandemic. In addition, in late 2021, the U.S. Centers for Disease Control and Prevention lowered their reference level for identifying children with high blood levels of lead from 5 µg/dl to 3.5 µg/dl.[50] Thus, the average for 2016 through 2020 may underestimate the incidence of children suffering from lead poisoning in the Southeastern Wisconsin Region. More information on lead in drinking water can be found in a white paper issued by Commission staff.[51]

Other Health Effects

Intake of dietary sodium and salt have been linked to at least two other health conditions. Sodium intake may be a factor affecting the severity of osteoporosis. Increases in 24-hour urinary excretion of sodium, a surrogate for sodium intake, have been shown to indicate increases in the amount of calcium lost in urine and to the loss of hip bone density in post-menopausal women.[52] In addition, sodium intake greater than 4,600 mg per day was associated with the progression of chronic kidney disease.[53]

A study conducted in British Columbia noted that chloride-based deicing products can be irritating to skin and eyes on contact, depending on the duration, concentration, and frequency of exposure and individual

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[50] *As of June 7, 2023, Wisconsin Statute 254.11(9) defines the blood level indicating lead poisoning as 5 µg/dl.*

[51] *SEWRPC Staff Memorandum,* Lead in Drinking Water in Southeastern Wisconsin*, April 19, 2019.*

[52] *A. Devine, R.A. Criddle, I.M. Dick, D.A. Kerr et al.," A Longitudinal Study of the Effect of Sodium and Calcium Intakes on Regional Bone Density in Postmenopausal Women,"* American Journal of Clinical Nutrition*, 62:740-745, 1995.*

[53] *A. Smyth, M.J. O'Donnell, S. Yusuf, C.M. Clase, et al, "Sodium Intake and Renal Outcomes: A Systematic Review,"* American Journal of Hypertension*, 10: 1,277-1,284, 2014.*

sensitivities to the chemicals.[54] Calcium chloride was irritating to skin and eyes on contact. It can also produce toxic effects if inhaled. By contrast, sodium chloride and magnesium chloride were slight eye irritants. It should be noted that some non-chloride-based deicers, such as calcium magnesium acetate, were also found to be irritating to skin and eyes.

Contamination of groundwater by sodium chloride can lead to mobilization of radium into groundwater. This can lead to increased flux of radon gas and the accumulation of radon in buildings, leading to greater radon exposure to occupants.[55] The mechanisms through which radon exposure happens are discussed in Chapter 2 of this Report. Exposure to radon has been shown to cause lung cancer.[56] Radon exposure is the leading cause of death from lung cancer in nonsmokers. The USEPA estimates that radon is responsible for about 21,000 lung cancer deaths per year.[57] The lifetime risk in developing lung cancer from exposure to 4.0 picocuries of radon per liter air (pCi per l) is estimated as seven in 1,000 for nonsmokers and 62 in 1,000 for current smokers. Data from indoor air tests conducted between 1995 and 2016 indicate that this concentration often occurs in buildings in the Southeastern Wisconsin Region.[58] Across the Region, about 55 percent of over 32,000 tests reported concentrations of radon in buildings equal to or above this level. The percentage of radon tests equal to or greater than 4.0 pCi per l varied by zip code, ranging from 0 percent to 90 percent.

5.3 IMPACTS OF CHLORIDE SALTS ON DRINKING WATER

High concentrations of chloride salts can reduce the suitability of water for human consumption. In addition to producing the health effects discussed previously in this Chapter, additions of salts can reduce the aesthetic quality of drinking water. Water has a salty taste when the concentration of chloride exceeds about

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[54] *P.D. Warrington,* Roadsalt and Winter Maintenance for British Columbia Municipalities: Best Management Practices to Protect Water Quality, *British Columbia Ministry of Water, Land and Air Protection, 1998.*

[55] *L.A. McNaboe, G.A. Robbins, and M.E. Dietz, "Mobilization of Radium and Radon by Deicing Salt Contamination of Groundwater."* Water, Air, and Soil Pollution*, 228:94, 2017.*

[56] *R.W. Field et al., "Residential Radon Gas Exposure and Lung Cancer: The Iowa Lung Cancer Study,"* American Journal of Epidemiology*, 151:1,091-1,102, 2000.*

[57] *U.S. Environmental Protection Agency,* EPA Assessment of Risks from Radon in Homes*, EPA-402-R-03-003, June 2003.*

[58] *Wisconsin Department of Health Services,* Wisconsin Indoor Radon Test Results*, wi-dhs.maps.arcgis.com/apps/webappviewer/index.html?id=68f3a3e068854810b626d002ce47aff4, accessed June 7, 2023.*

250 mg/l or the concentration of sodium exceeds about 200 mg/l.[59] These thresholds can vary among individual people.

The USEPA and the State of Wisconsin have issued guidelines regarding the appropriate levels of chloride and sodium in drinking water.[60] Both the Agency and the State have set a secondary drinking water standard for chloride of 250 mg/l. In addition, an advisory from the USEPA recommends that sodium concentrations in drinking water not exceed 30 to 60 mg/l, based on taste.

Several studies have reported chloride contamination of drinking water. A study in New York found that 24 percent of the private wells sampled in the study area were contaminated with deicing salt and 21 percent of the wells sampled in the study area had chloride concentrations in excess of 250 mg/l.[61] The highest concentrations of chloride were observed in wells down gradient of a road salt storage barn. The median chloride concentration in these wells was 228 mg/l with a maximum concentration of 1,401 mg/l. Elevated chloride concentrations were also observed in samples from wells within about 100 feet of a major highway. The median chloride concentration in these wells was 116 mg/l, with a maximum concentration in excess of 500 mg/l. The median chloride concentration in wells near minor roads was 70 mg/l; however, concentrations of chloride in some of these wells were still quite high with the maximum concentration reported being in excess of 400 mg/l. About 70 percent of the participants in the study reported that they had stopped drinking their well water due to aesthetic and safety concerns.

The New York study also conducted a spatial analysis to estimate the likely number of private wells in the State that might potentially be impacted by deicing salt contamination. Based on the results of this analysis, the study concluded that about 35,000 wells, or two percent of the private wells in the State, could potentially be impacted by salt contamination from salt storage facilities. Similarly, the study concluded that about 460,000 wells, or 24 percent of the private wells in the State, could potentially be impacted by contamination from road salt applications. This deicing contamination of private wells may not be unique to New York. A study in Minnesota showed that about 30 percent of the wells tested in the Twin Cities metropolitan area exceeded the State standard for chloride.[62]

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[59] *Health Canada,* Guidelines for Canadian Drinking Water Quality (6th Edition)*, 1996.*

[60] Ibid.

[61] *Pieper et al. 2018,* op. cit.

[62] *S. Kroening and M. Ferry,* The Condition of Minnesota's Groundwater, 2007-2011*, Minnesota Pollution Control Agency wq-am1-06, 2013.*

Similar chloride contamination of private wells has been reported in Wisconsin. One study monitored the impact of construction of a subdivision on groundwater in Dane County, about 15 miles northeast of Madison.[63] Monitoring wells were installed at the site in 2001, prior to the construction of the subdivision. Following construction of 18 homes in 2003, some domestic wells were also monitored through 2014. Concentrations of chloride increased over time in the 12 most frequently monitored domestic drinking water wells. Peak chloride concentrations in four of these wells exceeded 200 mg/l. In two of the wells, peak chloride concentration exceeded 400 mg/l. The Dane County study concluded that the increases in chloride concentrations in the wells was likely due to the increased use of deicing salts in and near the subdivision as well as effluent from onsite wastewater treatment systems. The effluent was assumed to include elevated concentrations of chloride due to the use of water softeners.

A 2016 search of the WDNR Public Water System database found 46 wells statewide that had reported concentrations of chloride over 100 mg/l and concentrations of sodium over 20 mg/l.[64] The areas in which these public water supply wells were located aligned well with areas experiencing heavy applications of road salt. This search found that two wells in Waukesha County were shut down in 2016 when drinking water chloride concentrations exceeded 400 mg/l. The search also found that most of the public drinking water system wells in the State had not been sampled for chloride over the previous 10 to 20 years.

Some municipal wells in the Southeastern Wisconsin Region may be impacted by contamination with chloride salts. Commission staff reviewed recent Consumer Confidence Reports for 69 municipal water utilities in the Region. These reports contain information on the quality and safety of the water provided by the utilities and are required to be provided annually to their customers. One utility in the Region reported that the chloride concentration in the water it provides was greater than 250 mg/l. Six more utilities reported chloride concentrations between 200 mg/l and 250 mg/l. These numbers may be underestimates as only 46 utilities reported the concentration of chloride in their water. In addition, 34 utilities reported providing water with sodium concentrations in excess of 20 mg/l, including one that reported sodium concentration greater than 200 mg/l. It should also be noted that since conventional water softeners work by exchanging calcium and magnesium ions in water for sodium on the ion exchange resin, residents in the Region who

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[63] *K.R. Bradbury, T.W. Rayne, and J.J. Krause,* Impacts of a Rural Subdivision on Groundwater: Results of a Decade of Monitoring*, Wisconsin Geological and Natural History final report to the Wisconsin Department of Natural Resources, October 2015.*

[64] *J. Jansen,* Chlorides in Groundwater: A Rising Concern*, Presentation at the Fox River Summit, Burlington, Wisconsin, March 17, 2022.*

soften their water are likely exposed to higher concentrations of sodium than those in the public water supply.

Wells in at least two types of locations appear to be sensitive to contamination from deicing salts. First, high concentrations of deicing salts often occur in wells located downgradient from salt storage facilities. For instance, a study in New York found concentrations of chloride as high as 1,800 mg/l and concentrations of sodium as high as 860 mg/l in such wells.[65] Second, wells near roads, especially those near roads at lower elevations or downgradient of road networks often have relatively high chloride concentrations. For example, a study of 4,319 domestic wells in Vermont found that wells within about 330 feet of roads had significantly higher chloride concentrations than those that were farther away.[66] This study found that chloride contamination of wells near roads was especially common in urban and densely populated areas.

As mentioned in the previous section on the release of metals from drinking water infrastructure and plumbing, elevated concentrations of chloride salts in drinking water can lead to corrosion of water supply infrastructure and plumbing. This impact was discussed in Chapter 4 of this Report. The fact that many water systems are not regularly sampling for chlorides in the water they provide to the public may make it more difficult to identify other potential health issues. Corrosion can cause the release of lead from water mains, water supply service lines, interior plumbing, fittings, and solder that are not lead-free. While utilities are required to inventory water mains and water service lines that contain lead and to conduct monitoring at the taps of customers with lead service lines, no monitoring is required based on the possibility older buildings may have lead-containing interior plumbing. Regular monitoring of chloride and chloride-sulfate mass ratios in water systems at the tap could provide a preliminary way to evaluate the potential for lead release in buildings with older plumbing.

While it is technically feasible to remove chloride and associated cations from drinking water at a water treatment plant or wellhead using membrane filtration methods such as reverse osmosis, such treatment can drastically increase costs. Table 5.2 shows estimated capital and annual operation and maintenance costs for adding membrane filtration to water treatment plants with three different capacities. It should also be noted that membrane filtration produces a waste brine that requires disposal. Depending on the method

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[65] *V.R. Kelly et al., "The Distribution of Road Salt in Private Drinking Water Wells in a Southeastern New York Suburban Township,"* Journal of Environmental Quality, *47:445-451, 2018.*

[66] *J.P. Levitt and S.L. Larsen,* Groundwater Chloride Concentrations in Domestic Wells and Proximity to Roadways in Vermont, *U.S. Geological Survey Open-File Report No. 2019-1148, 2020.*

used, such disposal may return the chloride salts to the environment. Disposal of this brine can also impact plant operating costs. In general, producing a higher-concentration brine reduces disposal costs; however, producing such a brine increases the energy costs associated with membrane filtration. More information on water treatment techniques for removing chlorides from water can be found in the Chloride Study State-of-the-Art technical report.[67]

5.4 IMPACTS OF CHLORIDE SALTS ON AGRICULTURE

As described in Chapter 2 of this report, introduction of chloride salts into the environment can increase the salinity of soil and water. This salinity increase can impact agriculture, reducing the yields of many crops. At high enough salinity, chloride salts can make soils unsuitable for agricultural activities.

Stress from salinity in soil can reduce crop growth and yields. Electrical conductivity is an indicator of soil salinity and can be measured as the specific conductance of water samples extracted from saturated soil during the maximum period of plant growth. Table 5.3 shows the soil specific conductance at which several crops experience 10, 25, and 50 percent reductions in yields. The specific conductance at which a particular level of yield reduction occurs varies among crops. Vegetable crops are generally more sensitive to soil salinity than field crops and forage crops. For most vegetables, the threshold of specific conductance in soil at which damage occurs to the crop is less than 2,500 microSiemens per cm (μS/cm).[68]

Salinity in irrigation water can also reduce crop yields. Yield impacts occur at relatively low levels of salinity and tend to rise at a near linear rate with water salinity.[69] Table 5.4 shows the thresholds of specific conductance in irrigation water above which crop yields of several vegetables are reduced. These thresholds tend to be lower than the thresholds for specific conductance in soil at which the same vegetables experience yield reductions of about 10 percent (compare Tables 5.3 and 5.4). The impact of crop reductions due to salinity in irrigation water can be substantial. One study that used a predictive model estimated that water salinity annually reduces global agricultural production by enough to feed about 170 million people.[70]

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[67] *SEWRPC Technical Report No. 66,* State of the Art of Chloride Management*, in preparation.*

[68] *R.M. Almeida Machado and R.P. Serralheiro, "Soil Salinity: Vegetable Crop Growth. Management Practices to Prevent and Mitigate Soil Salinization,"* Horticulturae*, 3:30, 2017.*

[69] *D. Russ et al.,* Salt of the Earth: Quantifying the Impact of Water Salinity on Global Agricultural Productivity, *The World Bank, Washington, D.C. 2019.*

[70] Ibid.

Direct salt contact on the above ground portions of plants can also reduce crop yields. Examples of this include reduced yields in blueberries and peaches and reduced number of flowers and flower buds on trees. These examples are discussed in the section on the impacts of chloride salts on terrestrial plants in Chapter 3 of this Report.

In addition to reducing the size of crop yields, stress from chloride salts can increase the fraction of crop yields that are unmarketable due to damage. For example, irrigation with salt contaminated water enhances blossom-end rot in plants like tomatoes, peppers, and eggplants.[71]

There are several ways through which elevated concentrations of chloride salts in soil and water and physical contact with chloride salts can interfere with crop growth. These are discussed in detail in Chapter 2 and 3 of this report. Briefly, these mechanisms include:

- Degradation of soil structure
- Displacement of other nutrients
- Salt withdrawing water from surrounding soil
- Salt increasing plant energy requirements for extracting water and nutrients from soil
- Interference with chlorophyll production and photosynthesis
- Toxicity effects of chloride salts
- Physical damage to plants

5.5 AESTHETIC, RECREATIONAL, AND OTHER IMPACTS OF CHLORIDE SALTS

Elevated levels of chloride in the environment can potentially affect other human activities. These effects include impacts on aesthetic attributes and recreational potential of both natural and built environments. Unfortunately, few data are available to assess these chloride impacts.

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[71] *Almeida Machado and Serralheiro 2017,* op. cit.

Impacts on Fishing

Increases in salinity can potentially compromise the recreation and aesthetic values of freshwater aquatic systems.[72] As discussed in Chapter 3 of this Report, fishing is an important outdoor recreation activity in Wisconsin. The Wisconsin Department of Natural Resources (WDNR) estimates that fishing generates almost $2.3 billion in economic activity annually. Reductions in habitat quality and biodiversity due to elevated concentrations of chloride salts in streams, rivers, and lakes could potentially reduce the quality of fisheries and reduce the recreational experience of residents and tourists. This could occur directly through the effects of chloride salts on the fish and indirectly through impacts to organisms that serve as food resources to fish or provide important habitat structure. Examples of these effects are discussed in Chapter 3 of this Report.

Aesthetic Impacts to the Environment

Applications of chloride salts can also cause aesthetic damage in terrestrial environments. One study estimated the cost of aesthetic damage to roadside trees in the Adirondack Forest Preserve in New York State as being about $157 per ton of road salt applied (2022 dollars).[73,74] In a second study, the New York State Department of Transportation estimated a cost of about $13,700 per mile (2022 dollars) to replant and re-establish natural vegetation along a two-mile section of highway in the Adirondack Mountains that had been damaged by applications of road salt.[75]

Another study used a simulation model of impacts on surface waters and forests to estimate the annual reduction of environmental value due to application of road salts.[76] This study concluded that these environmental value reductions were on the order of $3,140 per lane mile per year (2022 dollars). Using this

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[72] *M. Cañedo-Argüelles Iglesias, "A Review of Recent Advances and Future Challenges in Freshwater Salinization,"* Limnetica*, 39:185-211, 2020.*

[73] *D.F. Vitaliano, "An Economic Assessment of the Social Costs of Highway Salting and the Efficiency of Substituting a New Deicing Material,"* Journal of Policy Analysis and Management*, 11:397-418, 1992.*

[74] *This cost estimates in this section were adjusted to 2022 dollars using the U.S. Bureau of Labor Statistics Consumer Price Index.*

[75] *T. Lindberg, S. Lorey, and B. Houseal,* Low Sodium Diet: Curbing New York's Appetite for Damaging Road Salt*, Adirondack Council, 2009.*

[76] *D.L. Kelting and C.L. Laxson,* Review of Effects and Costs of Road De-icing with Recommendations for Winter Road Management in the Adirondack Park*, Adirondack Watershed Institute Report No. AWI2010-01, Paul Smith's College, February 2010.*

estimate and salt application and other data from the Twin Cities Metropolitan Area (TCMA), a second study estimated that this environmental value reduction was equivalent to about $230 to $310 per ton of salt applied.[77] The calculation for the lower cost in this range includes estimates of all salt applied within the TCMA, while the higher cost in this range excludes bulk and packaged salt applied by private companies.

The cost estimates given in the previous two paragraphs should be interpreted with caution. They are based on limited data from a few examples in a single part of the country. It is not certain how representative they may be of similar costs in Wisconsin. Still, they give a rough sense of the order of magnitude of aesthetic damage to roadside vegetation and reductions of environmental value that may occur due to application of deicing salt.

Impacts on Building Cleaning

Applications of road salt can also affect the aesthetics inside buildings. This can result in additional costs for maintenance and cleaning to remove salt deposited inside buildings during winter months. One study estimated these costs for a large urban university.[78] Dalhousie University is located on about 60 acres in Halifax, Nova Scotia, Canada. In 2022, about 21,000 students were enrolled on this campus. In addition, this school employed about 2,000 full-time and part-time staff. Based on interviews with maintenance staff, the study estimated that the costs in 2004 of cleaning and maintenance to address damage from salt to floors and baseboards were about 15,000 Canadian dollars (Can$). These costs included those associated with cleaning floors, baseboards, walls, mats, and carpets. University staff also reported annually spending an additional Can$1,000 to Can$2,000 during the winter on waxes and sealants for floors. Converting these estimates to U.S. dollars and adjusting for inflation suggests that annual cost for a similar facility in the U.S. would be about $19,200 to $20,400.[79] This annual cost for building maintenance estimate should be interpreted with caution as it is based on estimated costs from one facility. In addition, conversions of costs from one currency to another based on exchange rates ignore the fact that wage rates and prices of individual goods may vary greatly among countries. In addition, cleaning and maintenance costs are likely to be partially dependent on factors such as the rate of salt application, the amount of foot traffic through individual buildings, and the number of winter storms occurring at individual sites.

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[77] *C. Dindorf, C. Fortin, B. Asleson, and J. Erdmann,* The Real Cost of Salt Use for Winter Maintenance in the Twin Cities Metropolitan Area, *Minnesota Pollution Control Agency, wq-iw11-06bb, October 2014.*

[78] *A. Campbell et al.,* Feasibility Analysis of the Deicing Methods at Dalhousie University*, Dalhousie University, April 2004.*

[79] *The average exchange rate between U.S. and Canadian dollars in 2004 was $1.00 = Can$1.30. This was adjusted to 2022 dollars using a multiplier of 1.5596 based on the U.S. Bureau of Labor Statistics Consumer Price Index.*

Impacts on Pets

Deicing salts can pose hazards to pets that are exposed to them. Cats and dogs walking on roads, sidewalks, and driveways that have been treated with deicers can collect these salts on their paws and fur. Casual exposures to salt can cause irritation to animal paws. Depending on the deicer used and the amount of exposure, this irritation may consist of dryness, cracking, or chemical burns.

Pets may experience other hazards if they lick deicing salts off their paws and fur or drink salt-contaminated water. While ingestion of small amounts of chloride-based deicers may not be harmful, ingestion of larger amounts can lead to high blood concentrations of sodium that result in thirst, salivation, vomiting, diarrhea, and lethargy. Ingestion of larger amounts of deicing salts can lead to more severe consequences such as convulsions and kidney damage. A lethal dose of sodium chloride for dogs is about two grams per pound.[80] This is the equivalent of a tablespoon of salt for a seven-pound dog. The American Society for the Prevention of Cruelty to Animals noted that in 1998 more than 50 cases of poisoning to animals by deicing salts were reported to their animal poison control center.[81] The toxicity of chloride salts for vertebrate animals is discussed in Chapter 3 of this report.

Impacts on Industrial Use of Water

The introduction of chloride salts into the environment can increase the salinity of water. Water with increased salinity may not be suitable for some industrial uses. Salt in water can also damage some equipment. In addition, salt may interfere with chemical reactions that occur during the production of some types of products.

The concentration at which water becomes unsuitable for industrial uses varies among industries. Table 5.5 shows critical concentrations thresholds above which saline water is not suitable for several industries. For some industries, such as in the textile industry, water becomes unsuitable at relatively low salinity. Other industries, such as in the petroleum industry, are able to use water until it reaches a higher salinity.

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[80] *Bryan Ray,* Be Salt Wise and Pet Smart, *Wisconsin Salt Wise, https://www.youtube.com/watch?v=QI8s-i5BniY, January 12, 2021.*

[81] *L.A. Hautekeete,* Ice Melts Are Health Hazards, *American Society for the Prevention of Cruelty to Animals, www.aspcapro.org/sites/default/files/u-toxbrief_2000.pdf, accessed June 15, 2023.*

5.6 SUMMARY

Chloride salts are associated with several impacts on human activities. The effects of chloride salts on human health include:

- Ingestion of excess sodium can cause high blood pressure, which is a major factor causing strokes, heart failure, kidney disease, and other ailments
- Ingestion of excess sodium can contribute to osteoporosis in post-menopausal women
- Elevated concentrations of chloride salts in water can result in release of heavy metals, which are toxic substances, from sediment, rock, and drinking water infrastructure
- Deicing salts are a constituent of fine particulate matter in the atmosphere ($PM_{2.5}$) which contributes to lung cancer and other respiratory ailments
- Upon contact, chloride salts can cause irritation to skin and eyes

Chloride salts can also degrade the aesthetics of the natural and built environment. Examples of this include:

- Chloride imparts a salty taste to water at a concentration of about 250 mg/l
- Sodium imparts a salty taste to water at a concentration of about 200 mg/l
- Chloride salts can degrade roadside aesthetics by damaging adjacent vegetation
- Use of deicing salts can increase costs of cleaning and maintenance of building interiors during winter months

Other effects of chloride salts on human activities include:

- Elevated concentrations of chloride salts in soil and irrigation water can reduce crop yields

- Through their effects on organisms, elevated concentrations of chloride salts in lakes, streams, and rivers can reduce the quality of fisheries, thereby reducing recreational opportunities

- Deicing salts can cause medical issues for pets

- Increased salinity can make water unsuitable for some industrial uses

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IMPACTS OF CHLORIDE ON THE NATURAL AND BUILT ENVIRONMENT

Chapter 5

IMPACTS OF CHLORIDES ON HUMANS AND HUMAN ACTIVITIES

TABLES

#268677 – TR-62 (Chloride Study Impacts) Table 5.1
200-1100
LKH/JEB/mid
6/14/23, 6/26/23, 10/19/23, 12/11/23

Table 5.1
Water Service Lines Containing Lead or Galvanized Iron in Areas Served by Water Utilities in Southeastern Wisconsin: 2022

Water Service Line Material	Utility-Owned Service Lines	Customer-Owned Service Lines
Lead	112,629	108,498
Galvanized Iron	737	4,195
Unknown—May Contain Lead	2,276	6,366
Total	115,642	119,059

Source: Wisconsin Public Service Commission and SEWRPC

Table 5.2
Estimated Capital and Annual Operation and Maintenance Costs for Implementing Membrane Filtration at Drinking Water Treatment Plants

Plant Capacity (million gallons per day)	Capital Cost (dollars)	Annual Operations and Maintenance Cost Operating at 35 Percent of Capacity (dollars)
1	6,470,000	124,000
5	20,000,000	244,000
10	36,100,000	455,000

Note: Cost estimates were developed using the cost curve in Appendix A of SEWRPC Technical Report No. 43, *State-of-the-Art Water Supply Practices*, July 2007 and were updated from 2007 to 2022 dollars using Engineering News Record Construction Cost Index of 9,986.58 for 2007 and 16,171.31 for 2022.

Source: SEWRPC

Table 5.3
Soil Specific Conductance in MicroSiemens per Centimeter at Which Reduced Crop Yields Can Be Expected[a]

	Percent Yield Reduction		
Crop	10	25	50
	Field Crops		
Barley	11,900	15,800	17,500
Sugar beets	10,000	13,000	16,000
Safflower	7,000	11,000	14,000
Wheat	7,100	10,000	14,000
Sorghum	5,900	9,000	11,900
Soybean	5,200	6,900	9,000
Rice	5,100	5,900	8,000
Corn	5,100	5,900	7,000
Broad bean	3,100	4,200	6,200
Beans	1,100	2,100	3,000
	Vegetable Crops		
Beets	8,000	9,700	11,700
Spinach	5,700	6,900	8,000
Tomato	4,000	6,600	8,000
Broccoli	4,000	5,900	8,000
Cabbage	2,500	4,000	7,000
Potato	2,500	4,000	6,000
Corn	2,500	4,000	6,000
Sweet potato	2,500	3,700	6,000
Lettuce	2,000	3,000	4,800
Bell pepper	2,000	3,000	4,800
Onion	2,000	3,400	4,000
Carrot	1,300	2,500	4,200
Bean	1,300	2,000	3,200
	Forage Crops		
Tall wheatgrass	10,900	15,100	18,100
Crested wheatgrass	5,900	11,000	18,100
Tall fescue	6,800	10,400	14,700
Barley hay	8,200	11,000	13,500
Perennial rye	7,900	10,000	13,000
Beardless wild rye	3,900	7,000	10,800
Alfalfa	3,000	4,900	8,200
Clovers	2,100	2,500	4,200

[a] *Values represent the specific conductance of saturated soil extracts during the period of maximum plant growth.*

Source: L. Bernstein, Salt Tolerance of Plants, *U.S. Department of Agriculture Information Bulletin 283, 1964.*

Table 5.4
Specific Conductance Thresholds for Irrigation Water Causing Reduced Vegetable Yields

Vegetable	Threshold (µS/cm)
Asparagus	2,700
Red beet	2,700
Broccoli	1,900
Cauliflower	1,900
Tomato	1,700
Spinach	1,300
Celery	1,200
Pepper	1,000
Potato	1,100
Onion	800
Bean	700
Carrot	700
Eggplant	700
Strawberry	700

Source: P.M Almeida Machado and R.P Serralheira, "Soil Salinity: Effect on Vegetable Crop Growth. Management Practices to Prevent and Mitigate Soil Salinization," Horticulturae, *3:30, 2017.*

Table 5.5
Critical Levels of Salinity for Certain Industries[a]

Industry	Salinity (mg/l)
Textiles	100
Pulp and paper	200-500
Food (general)	850
Canning	850
Brewing, distilling	500-1,000
Chemical	2,500
Petroleum	3,500

[a] *These industrial uses are generally affected by salinity and not chloride per se; however, contamination of water with chloride salts increases salinity which can lead to the water being unsuitable for industrial uses.*

Source: W.D. Williams, "Salinization of Rivers and Streams: An Important Environmental Hazard," Ambio, *16:180-185, 1987.*