

A WATERSHED RESTORATION PLAN FOR THE ROOT RIVER WATERSHED

Appendix E

**ACUTE TOXICITY OF SODIUM CHLORIDE  
TO FRESHWATER AQUATIC ORGANISMS**

Few data regarding instream concentrations of chloride and values of specific conductance are available for streams of the Root River watershed for the winter deicing seasons. A recent examination of specific conductance and chloride in the Menomonee River watershed may shed light on what these conditions in some parts of the Root River stream system may be like during winter months.

In 2012, during review of the second part of the draft SEWRPC Staff Memorandum, “Development of a Framework for a Watershed-Based Municipal Stormwater Permit for the Menomonee River Watershed,” by the Menomonee River Watershed-Based Permit (WBP) Framework Group, a question arose as to what effects concentration spikes of chloride occurring during cold weather are likely to have upon aquatic biota within the Menomonee River watershed. This appendix presents the results of a literature review to address this question. Specifically, this appendix presents the results of a review of the literature regarding the acute toxicity of sodium chloride to freshwater aquatic organisms, compares the results of this review to estimates of chloride concentrations during the winter deicing season at locations within the Menomonee River watershed, and discusses whether aquatic organisms are likely to experience toxic effects in streams in the watershed.

Table E-1 presents data on the acute toxicity of sodium chloride to freshwater aquatic organisms. These results are taken from the toxicological and ecological literature. With two exceptions the tests use the LC50, the concentration at which 50 percent of the organisms die over the duration of the test, as the measure of acute toxicity.<sup>1</sup> A higher LC50 indicates lower toxicity to the organism, while a lower LC50 indicates greater sensitivity to the toxin. The table presents results for several exposure times; however, the majority of results listed come from 96-hour (four-day) acute toxicity tests. This is in keeping with standard toxicological procedures. The results are presented in terms of both the concentration of sodium chloride and an equivalent concentration of chloride. This was done to facilitate comparison of the toxicological data to estimates of chloride concentrations in streams and to the State’s acute toxicity criterion for fish and aquatic life. In the discussion that follows, the LC50s will be expressed in terms of chloride concentrations.

Some patterns are apparent in the LC50 values presented in Table E-1. There is considerable variation in LC50 values. For 96-hour tests, they range from 425 milligrams of chloride per liter (mg Cl/l) for the mayfly, *Callibaetis coloradensis*, to 13,085 mg Cl/l for the American eel, *Anguilla rostrata*. With the exception of the

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<sup>1</sup>The two exceptions occur in six-hour toxicity tests and use LC40 and LC47 endpoints. These reflect the concentrations at which 40 percent and 47 percent, respectively, of organisms die during the course of the test. LC50 values for these organisms in six-hour acute toxicity tests would be higher than the values shown.

LC50 value for *C. coloradensis*, these values are all higher than the State's acute toxicity criterion for chloride of 757 milligrams per liter. LC50 values for fish species tend to be higher than those for many invertebrate species, suggesting that they are less sensitive to acute chloride toxicity. LC50 values also vary among tests for the same species. This may be due to several factors, including differences in test conditions, genetic variation within species, and differences among statistical techniques used to calculate the LC50 value from the raw toxicological data.

While it may be hypothesized that sodium chloride would be more toxic under warmer conditions, few data are available on the effects of temperature upon the acute toxicity of this salt. The one study that examined this found that the mayfly *Hexigenia limbata* was more sensitive to chloride at a higher water temperature than at a lower temperature. It is important to note that the temperatures used in this study, 28°C and 18°C, were both higher than what would be expected to be observed in streams of the Root River watershed during the winter deicing season.

With one exception, the most sensitive organisms listed in Table E-1 have LC50 values in 96-hour toxicity tests starting at about 1,400 mg Cl/l.<sup>2</sup> Based on this, it was decided to use 1,400 mg Cl/l as a threshold for acute toxicity effects in further analysis and discussion. It should be noted that this threshold is considerably higher than the State of Wisconsin's acute toxicity criterion for fish and aquatic life for chloride of 757 mg/l and represents a threshold at which substantial acute toxic effects would be expected to occur. This threshold does not represent a value that would be protective of fish and aquatic life.

The LC50 values listed in Table E-1 are for toxicity associated with sodium chloride. The toxicity of chloride can vary depending upon the cations with which it is associated. Sodium chloride-based deicers were shown to have lower toxicity to rainbow trout, the water flea *Ceriodaphnia dubia*, and the alga *Selenastrum capricornatum* than other chloride-based deicers such as calcium chloride and magnesium chloride and acetate-based deicers.<sup>3</sup> For example, the LC50 for sodium chloride for *C. dubia* was 6,583 mg/l. Lower LC50s were seen in tests with other chloride-based deicers for this organism with an LC50 for calcium chloride of 3,828 mg/l and LC50's for magnesium chloride ranging between 660 mg/l and 4,950 mg/l, depending on the particular deicer formulation. By comparison, LC50s for *C. dubia* for acetate-based deicers range between 660 mg/l and 4,670 mg/l.<sup>4</sup>

It is important to note that the LC50 values listed in Table E-1 reflect the toxicity of sodium chloride. Commercial deicers also contain trace amounts of metals and other substances. For example, one study found that sodium chloride-based deicers contained trace amounts of copper, zinc, cyanide, and sulfate.<sup>5</sup> Some of these substances can cause acute toxicity in aquatic organisms at low concentrations. Toxic effects related to the presence of these substances in deicers are not reflected in the LC50 values in Table E-1.

LC50 values represent a substantial toxic effect to organism populations. While the LC50 values are useful measures of acute toxicity, they do not represent thresholds below which concentrations are safe or harmless in aquatic habitats. It should be kept in mind that appreciable acute toxic effects can be expected to occur at chloride

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<sup>2</sup>The LC50 of the one exception, the mayfly *Callibaetis coloradensis*, is below the range of chloride concentrations that can be calculated from specific conductance using the regression relationship described in the next section.

<sup>3</sup>B. Mussato and T. Guthrie, "Anti-icers: Chemical Analysis and Toxicity Test Results," Prepared for Insurance Corporation of British Columbia, 2000, cited in Colorado Department of Transportation, "Evaluation of Selected Deicers Based Upon a Review of the Literature," Report No. CDOT-DTD-R-2001-15, October 30, 2001.

<sup>4</sup>An important caution in interpreting these comparisons is that they do not take into account any differences in how they are used. It is possible that a more toxic deicer may produce fewer toxic effects in nature due to less of the deicer being required to remove ice from roads.

<sup>5</sup>Mussato and Guthrie, op. cit.

concentrations that are lower than the LC50s. In addition, appreciable acute toxic effects can be expected to occur over shorter periods of time than the test period associated with a particular LC50. Because of this, it is important to recognize that evaluations of toxicity that utilize LC50s as an indicator of toxicity refer to concentrations at which substantial incidences of toxic effects are likely to be occurring, as opposed to concentrations at which toxic effects begin to appear.

## **AMBIENT CHLORIDE CONCENTRATIONS IN STREAMS OF THE MENOMONEE RIVER WATERSHED DURING THE WINTER DEICING SEASON**

Whether toxicity resulting from road salt constitutes a water quality problem within the Menomonee River watershed depends, in part, on whether concentrations of chloride in streams of the watershed reach the toxic levels identified in Table E-1 for appreciable periods of time during the winter deicing season. A reasonable hypothesis is that much of the chloride loading to these streams consists of pulses that occur either while deicing operations are conducted during winter storms or when ice melt and snowmelt during thaws carries accumulated salt into streams. Under this sort of scenario, it might be expected that chloride concentrations would spike fairly rapidly, followed by a rapid decrease to a relatively nontoxic level. If chloride loading during winter follows this sort of pattern, aquatic organisms might be exposed to high concentrations of chloride for relatively brief periods.

Unfortunately, chloride concentrations in streams of the Menomonee River watershed are rarely directly measured during the winter deicing season. Few data exist and those that do are not collected with enough frequency to allow characterization of the sort of spikes hypothesized in the previous paragraph. Because of this, measurements of specific conductance were chosen as a surrogate for chloride concentration.

Continuously collected specific conductance data are available from six monitoring stations in the Menomonee River watershed which were established as part of a joint Milwaukee Metropolitan Sewerage District (MMSD)-U.S. Geological Survey (USGS) real-time water quality monitoring program. Under this program, real-time sensors measure specific conductance, dissolved oxygen concentration, turbidity, water temperature, flow, and river level at five-minute intervals under all weather conditions. The data are transmitted to MMSD and USGS offices. While the five-minute interval data are retained for only 120 days, summary data consisting of daily minimum, maximum, and mean values are archived and available from the USGS's NWIS database. Table E-2 lists the monitoring stations from this program that are located in the Menomonee River watershed and lists the periods of record for specific conductance monitoring at these stations. The table also identifies the extent of gaps in the records during the winter deicing season in which specific conductance data were not collected.

A regression model is available that relates specific conductance to chloride concentration in Wisconsin streams<sup>6</sup>. The model was developed using simultaneously collected measurements of specific conductance and chloride concentration from 17 Wisconsin streams, including several in the Milwaukee area. The equation developed in this model is:

$$Cl = 0.363 \times Sc - 271.$$

In this equation, Cl indicates chloride concentration in milligrams per liter (mg/l) and Sc indicates specific conductance in microSiemens per centimeter ( $\mu\text{S}/\text{cm}$ ). Based on graphical examination of the data, it was determined that the relationship is valid for chloride concentrations greater than 230 mg/l, which is equivalent to a specific conductance of 1,380  $\mu\text{S}/\text{cm}$ . The regression has an  $R^2$  value of 0.997, indicating that this relationship accounts for over 99 percent of the variation in the data within the valid range.

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<sup>6</sup>Corsi, S.R., D.J. Graczyk, S.W. Geis, N.L. Booth, and K. D. Richards, "A Fresh Look at Road Salt: Aquatic Toxicity and Water-Quality Impacts on Local, Regional, and National Scales," Environmental Science & Technology, Volume 44, 2010.

This regression model was used to estimate minimum, maximum, and mean daily chloride concentrations at monitoring stations in the Menomonee River watershed using the daily summary values of specific conductance collected as part of the MMSD-USGS real-time monitoring program. For all values of minimum, maximum, and mean daily specific conductance that were equal to or greater than 1,380  $\mu\text{S}/\text{cm}$ , the concentration of chloride was estimated using the regression equation. For each monitoring station, the record of estimated chloride concentrations was examined to identify periods in which the daily minimum chloride concentration was equal to or greater than 1,400 mg Cl/l for four or more days. This value was chosen as the screening value because it both exceeds the State's acute toxicity criterion for fish and aquatic life for chloride and reflects the low end of the LC50 values identified for freshwater organisms in the 96-hour acute toxicity studies summarized in Table E-1.

There were two stations, one along Honey Creek and one in Underwood Creek, at which periods were detected when the daily minimum concentration of chloride exceeded 1,400 mg Cl/l for four or more days. These periods are summarized in Table E-3. At the monitoring station along Honey Creek, there were nine periods between November 2008 and March 2011 during which the daily minimum concentration of chloride exceeded 1,400 mg/l for four or more days. The lengths of these periods ranged from four to 19 days. These periods often occurred in rapid succession. For example, four periods occurred during the time between December 22, 2010 and February 28, 2011, accounting for 42 out of 69 days. The summary statistics presented in Table E-3 suggest that chloride concentrations in Honey Creek were quite variable during these periods. For example, during the period December 22-25, 2010 the daily minimum chloride concentrations at the Honey Creek monitoring station ranged between 1,566 mg/l and 5,718 mg/l. Maximum daily chloride concentrations at this station during the same period ranged between 2,226 mg/l and 7,933 mg/l. The average chloride concentrations detected in these streams during these periods ranged between 1,917 mg/l and 3,742 mg/l. At the monitoring station along Underwood Creek, one period during which the daily minimum concentration of chloride exceeded 1,400 mg/l for four or more days occurred between February 2010 and July 2011. Chloride concentrations at that station were above 1,400 mg/l for nine consecutive days.

Daily minimum chloride concentrations at three other monitoring stations—the Little Menomonee River near Freistadt, the Menomonee River at Pilgrim Road, and the Menomonee River at N. 70th Street—did not exceed 1,400 mg/l for periods of four or more days during the period of record.

Two conclusions emerge from this examination of winter deicing season chloride concentrations calculated from specific conductance. First, concentrations of chloride during the winter in Honey and Underwood Creeks, as calculated from specific conductance, achieve levels that are well within the range of chloride concentrations that were found to result in the deaths of 50 percent of test organism in 96-hour toxicity tests. In both streams, chloride concentrations during the winter deicing season appear to remain at levels that are associated with acute toxic effects for extended periods of time. Thus, for these streams, the rapid-spike model previously hypothesized does not appear to give a good description of chloride concentrations during the winter.

Second, the results suggest that chloride concentrations probably reach higher levels in smaller streams that are located in highly urbanized areas than they do in larger streams and streams located in less urbanized areas. Comparisons of discharge at streamflow monitoring gauges in the Menomonee River watershed show that on average discharge at the monitoring stations along Honey and Underwood Creek account for 6 and 14 percent, respectively, of the discharge at the gauge along the Menomonee River at N. 70th Street.<sup>7</sup> In addition, the subwatersheds drained by these streams are highly urbanized. By contrast, discharge at the gauge along the Menomonee River at Pilgrim Road—one of the sites where calculated chloride concentrations did not exceed 1,400 mg/l for periods of four or more days during the period of record—accounts for 29 percent of the discharge at the gauge along Menomonee River at N. 70th Street. The higher volume of discharge at this station may result in greater dilution of chloride. In addition, rural land uses comprise a greater percentage of the areas upstream of this site than they do for the Honey Creek and Underwood Creek stations.

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<sup>7</sup>See Map 32 in *SEWRPC Technical Report No. 39, Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds, November 2007*.

## LIKELY EFFECTS OF POTENTIALLY TOXIC CONCENTRATIONS OF CHLORIDE TO ORGANISMS IN THE MENOMONEE RIVER

As described above, chloride concentrations in some streams of the Menomonee River watershed reach toxic levels during the winter deicing season for extended periods of time. The likelihood that toxic effects are occurring in these streams also depends upon what organisms are present in the streams during the winter deicing season. It should be noted that, to some extent, the organisms listed in Table E-1 for which the acute toxicity of sodium chloride has been characterized reflect species that are suitable for toxicity testing. These are organisms that are readily available, that can be maintained under laboratory conditions, and that have well-understood physiological and nutritional requirements. How much they reveal about potential toxic effects in streams of the Menomonee River watershed depends on at least two factors: 1) how representative these species are of the biota found in streams of the watershed, and 2) whether sensitive life history stages of these species are present in streams during the winter deicing season.

The species for which sodium chloride toxicity has been characterized, as listed in Table E-1, were compared to the species records reviewed as part of the analyses made for the recent update of the regional water quality management plan for the Greater Milwaukee watersheds.<sup>8</sup> Four fish species listed in Table E-1—bluegill, brook trout, fathead minnow, and goldfish—have been detected in fisheries surveys of the watershed. In species other than fish, one frog species—wood frog—and two macroinvertebrate species—the scud *Gammarus pseudolimnaeus*, and the caddisfly *Hydropsyche betteni*—have also been reported as being present. In addition, organisms belonging to five additional macroinvertebrate genera—caddisflies in the genera *Hydroptila* and *Pycnopsyche*, mayflies of the genus *Callibaetis*, midges of the genus *Chironomus*, and snails of the genus *Physa*—have been collected from streams in the Menomonee River watershed. It is important to note that organisms were identified only to the level of genus in many of the macroinvertebrate surveys, so it is possible but not certain that these particular test species are also present in the watershed. At least seven to 12 of the species listed on Table E-1 have been reported as being present in streams of the Menomonee River watershed. Given this, Table E-1 can be held as including a reasonable representation of aquatic organism species typical of the Menomonee River watershed.

A brief review of available literature regarding the life histories of the species listed in Table E-1 indicates that many of the species listed would be expected to be present in streams during the winter deicing season. Three of the fish species that are listed in the table and present in streams of the watershed—bluegill, brook trout, and goldfish—have life spans that last several years.<sup>9</sup> While fathead minnows typically live for only one to two years, spawning occurs in the spring and eggs hatch within about a week of spawning.<sup>10</sup> Thus, all four of these species may be present in streams as adults during the winter deicing season. The remaining vertebrate listed in the table—the wood frog—typically would not be present in streams during the winter deicing season. These animals normally hibernate in terrestrial and wetland forest habitats.<sup>11</sup>

Life history information was available for some of the invertebrates listed in Table E-1. Two groups of caddisflies listed in the table, the species *Hydropsyche betteni* and members of the genus *Pycnopsyche*, overwinter in

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<sup>8</sup>SEWRPC Technical Report No. 39, Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds, November 2007.

<sup>9</sup>George Becker, *Fishes of Wisconsin*, University of Wisconsin Press, 1983.

<sup>10</sup>Ibid.

<sup>11</sup>A.H. Wright and A.A. Wright, *Handbook of Frogs and Toads of the United States and Canada*, 3rd edition, Cornell University Press, 1949.

waterbodies as late-instar larvae.<sup>12</sup> In northern areas like Wisconsin, the mayfly *Hexagenia limbata* typically completes its life cycle over two years. While some populations may overwinter as eggs during the first winter, they are typically present in waterbodies as larvae during the second.<sup>13</sup> The scud *Gammarus lacustris* has a 15-month lifespan with reproduction occurring in or around the month of February.<sup>14</sup> Thus, this species is present in streams as adults for much of the winter. The isopod *Lirceus fontinalis* overwinters as adults or large juveniles.<sup>15</sup> The water flea *Daphnia pulex* overwinters both as resting eggs and as adults in the water column.<sup>16</sup>

Some of the invertebrate species that are present in waterbodies during the winter may experience less exposure to dissolved chloride than would be indicated based on ambient concentrations either because they remove themselves from the water column or enter a diapause, or resting, stage during winter. Nymphs of mayflies in the genus *Callibaetis* are thought move to areas of deeper water and overwinter in mats of vegetation.<sup>17</sup> Larvae of midges of the genus *Chironomus* often overwinter in diapause.<sup>18</sup>

Based on the available life history information, it is likely that organisms are present in streams of the Menomonee River watershed during the winter deicing season. Given that concentrations of chloride in some streams of watershed appear to reach levels associated with substantial incidences of toxic effects as measured by LC50 concentrations for extended periods of time, it is likely that inputs of chlorides from deicers are causing some toxic effects to aquatic organisms in streams of the watershed.

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<sup>12</sup>S. Alexander and L.A. Smock, "Life Histories and Production of *Cheumatopsyche analis* and *Hydropsyche betteni*, (Trichoptera: Hydropsychidae) in an Urban Virginia Stream, *Northeastern Naturalist*, Volume 12, 2005; R. J. Mackay, The Life Cycle and Ecology of *Pycnopsyche gentilis* (McLachlan), *P. luculenta* (Betten), and *P. scabripennis* (Rambur), (Trichoptera: Limnephilidae) in West Creek, Mont. St. Hilaire, Quebec, *Ph.D. Dissertation*, McGill University, Montreal, Quebec, April 1992.

<sup>13</sup>B.P. Hunt, "The Life History and Economic Importance of a Burrowing Mayfly, *Hexagenia limbata* in Southern Michigan Lakes," Michigan Conservation Department Bulletin of the Institute of Fisheries Research, No.4, 1953.

<sup>14</sup>H.B.N. Hynes and F. Harper, "The Life Histories of *Gammarus lacustris* and *Gammarus pseudolimnaeus* in Southern Ontario, *Crustaceana*, Supplement No. 3: *Studies on Peracarida*, 1972.

<sup>15</sup>X. Zhao, M.G. Fox, D.C. Lasenby, A.C. Armit, and D.N Kuthamale, "Substrate Selection and Seasonal Variation in Abundance and Size Composition of Isopod *Lirceus fontinalis* in Ontario Streams, Canada," *Chinese Journal of Oceanography and Limnology*, Volume 25, 2007.

<sup>16</sup>W. Lampert, K.P. Lampert, and P. Larsson, "Coexisting Overwintering Strategies in *Daphnia pulex*: A Test of Genetic Differences and Growth Responses," *Limnology and Oceanography*, Volume 55, 2010.

<sup>17</sup>K. E. Gibbs, "Ovoviviparity and Nymphal Seasonal Movements of *Callibaetis* spp. (Ephemeroptera: Baetidae) in a Pond in Southwestern Canada," *Canadian Entomologist*, Volume 111, 1979.

<sup>18</sup>B.R. Goddeeris, A.C. Vermeulen, E. DeGeest, H. Jacobs, B. Baert, and F. Ollevier, "Diapause Induction in the Third and Fourth Instar of *Chironomus riparius* (Diptera) from Belgian Lowland Brooks," *Archiv fur Hydrobiologie*, Volume 150, 2001.

## REFERENCES FOR TABLE E-1

- Adelman, I.R., L.L.J. Smith, and G.D. Siesennop, "Acute Toxicity of Sodium Chloride, Pentachlorophenol, Guthion, and Hexavalent Chromium to Fathead Minnows (*Pimephales promelas*) and Goldfish (*Carassius auratus*)," *Journal of the Fisheries Research Board of Canada*, Volume 33, 1976.
- Anderson, B.G., "The Apparent Thresholds of Toxicity to *Daphnia magna* for Chlorides of Various Metals When Added to Lake Erie Water," *Transactions of the American Fisheries Society*, Volume 98, 1948.
- Arambasic, M.B., S. Bjelic, and G. Subakov, "Acute Toxicity of Heavy Metals (copper, lead, zinc), phenol and sodium on *Allium cepa* L., *Lepidium sativum* L. and *Daphnia magna* St.: Comparative Investigations and Practical Applications," *Water Research*, Volume 29, 1995.
- Birge, W.J., J.A. Black, A.G. Westerman, T.M. Short, S.B. Taylor, D.M. Bruser, and E.D. Wallingford, *Recommendations on Numerical Values for Regulating Iron and Chloride Concentrations for the Purpose of Protecting Warmwater Species of Aquatic Life in the Commonwealth of Kentucky*, Kentucky Natural Resources and Environmental Protection Cabinet, Lexington, Kentucky (Memorandum of Agreement No. 5429).
- Blasius, B.J. and R.W. Merritt, "Field and Laboratory Investigations on the Effects of Road Salt (NaCl) on Stream Macroinvertebrate Communities," *Environmental Pollution*, Volume 120, 2002.
- Chadwick, M.A.J., *Influences of Seasonal Salinity and Temperature on Hexagenia limbata (Serville) (Ephemeroptera: Ephemeridae) in the Mobile River*, Master's Thesis, Auburn University, Alabama.
- Cowgill, U.M. and D.P. Milazzo, "The Sensitivity of Two Cladocerans to Water Quality Variables: Salinity and Hardness," *Archiv fur Hydrobiologie*, Volume 120, 1990.
- Doudoroff, P. and M. Katz, "Critical Review of Literature on the Toxicity of Industrial Wastes and Their Components to Fish," *Sewage and Industrial Wastes*, Volume 25, 1953
- Dowden, B.F. and H.J. Bennett, "Toxicity of Selected Chemicals to Certain Animals," *Journal of the Water Pollution Control Federation*, Volume 37, 1965.
- Gardner, K.M. and T.V. Royer, "Effect of Road Salt Application on Seasonal Chloride Concentrations and Toxicity in South-Central Indiana Streams," *Journal of Environmental Quality*, Volume 39, 2010.
- Gosh, A.K. and R.N. Pal, "Toxicity of Four Therapeutic Compounds to Fry of Indian Major Carps," *Fisheries Technology*, Volume 6, 1969.
- Hamilton, R.W., J.K. Buttner, and R.G. Brunetti, "Lethal Levels of Sodium Chloride and Potassium Chloride for an Oligochaete, a Chironomid Midge, and a Caddisfly of Lake Michigan," *Environmental Entomology*, Volume 4, 1975.
- Hinton, M.J. and A.G. Eversole, "Toxicity of Ten Commonly Used Chemicals to American Eels," Agricultural Experiment Station, U.S. Department of Agriculture (Technical Contribution 1595), 1978.
- Kundman, J.M., *The Effects of Road Salt Run-Off (NaCl) on Caddisfly (Hydropsyche betteni) Drift in Mill Run, Meadville, Pennsylvania*, Unpublished Senior Thesis, Department of Environmental Science, Allegheny College, Meadville Pennsylvania.
- Phillips, A.M.J., "The Physiological Effect of Sodium Chloride upon Brook Trout," *Transactions of the American Fisheries Society*, Volume 75, 1944.
- Sanzo, D. and S.J. Hecnar, "Effects of Road De-Icing Salt (NaCl) on Larval Wood Frogs (*Rana sylvatica*)," *Environmental Pollution*, Volume 140, 2006.

Spehar, R.L., Memorandum to C. Stephan, U.S. Environmental Protection Agency, June 24, 1987 [cited in U.S. Environmental Protection Agency, *Ambient Water Quality Criteria for Chloride*, 1988.]

Sutcliffe, D.W., "Studies on Salt and Water Balance in Caddis Larvae (Trichoptera): II. Osmotic and Ionic Regulation of Body Fluids in *Limnephilus stigma* Curtis and *Anabolia nervosa* Leach," *Journal of Experimental Biology*, Volume 38, 1961.

Thornton, K.W. and J.R. Sauer, "Physiological Effects of NaCl on *Chironomus attenuates* (Diptera: Chironomidae)," *Annals of the Entomological Society of America*, Volume 65, 1972.

Trama, F.B. "The Acute Toxicity of Some Common Salts of Sodium, Potassium, and Calcium to the Common Bluegill (*Lepomis macrochirus*)," *Proceedings of the Academy of Natural Sciences Philadelphia*, Volume 196, 1954.

Wallen, I.E., W.C. Greer, and R. Lasater, "Toxicity to *Gambusia affinis* of Certain Pure Chemicals in Turbid Waters," *Environmental Future*, Volume 29, 1957.

Waller, D.L., S.W. Fisher, and H. Dabrowska, "Prevention of Zebra Mussel Infestation and Dispersal During Aquaculture Activities," *The Progressive Fish-Culturist*, Volume 58, 1996.

Wichard, W., "Osmoregulatory Adaptations of Aquatic Insects in the Lake District 'Neusiedlersee,'" *Nachrichtenblatt der Bayerischen Entomologen*, Volume 24, 1975.

Williams, D.D., N.E. Williams, and Y. Cao, "Road Salt Contamination of Groundwater in a Major Metropolitan Area and Development of a Biological Index to Monitor Its Impact," *Water Research*, Volume 34, 2000.

Wisconsin State Laboratory of Hygiene, Unpublished Data on Chloride Toxicity of Aquatic Species. From A. Letts (Technical Manager, Morton International, Inc., Chicago, Illinois) to M.S. Evans (National Hydrology Research Institute, Environment Canada), August 11, 1998 [cited in Environment Canada, *Priority Substances List Assessment Report: Road Salts*, 2001].

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**SEWRPC Community Assistance Planning Report No. 316**

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**Appendix E**

**ACUTE TOXICITY OF SODIUM CHLORIDE  
TO FRESHWATER AQUATIC ORGANISMS**

**TABLES FOR MAY 1, 2013, MEETING**

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Table E-1

## ACUTE TOXICITY OF SALT (SODIUM CHLORIDE) TO FRESHWATER AQUATIC ORGANISMS

Species	Common Name	NaCl Concentration (mg/l)	Chloride Concentration (mg/l)	Exposure Time (hours)	Response <sup>a</sup>	Reference
<i>Salvelinus fontinalis</i>	Brook trout	50,000	30,330	0.25	LC50	Phillips, 1944
<i>Lepomis macrochirus</i>	Bluegill	20,000	12,132	6.00	LC47	Waller, <i>et al.</i> , 1996
<i>Oncorhynchus mykiss</i>	Rainbow trout	20,000	12,132	6.00	LC40	Waller, <i>et al.</i> , 1996
<i>Chironomus attenuatus</i>	Midge	9,995	6,063	6.00	LC50	Thornton and Sauer, 1972
<i>Lepomis macrochirus</i>	Bluegill	14,100	8,553	24.00	LC50	Doudoroff and Katz, 1953
<i>Daphnia magna</i>	Water flea	7,754	4,704	24.00	LC50	Cowgill and Milazzo, 1990
<i>Cirrhinus mrigalo</i>	Indian carp fry	7,500	4,550	24.00	LC50	Gosh and Pal, 1969
<i>Labeo rohoto</i>	Indian carp fry	7,500	4,550	24.00	LC50	Gosh and Pal, 1969
<i>Catla catla</i>	Indian carp fry	7,500	4,550	24.00	LC50	Gosh and Pal, 1969
<i>Daphnia pulex</i>	Water flea	2,724	1,652	24.00	LC50	Cowgill and Milazzo, 1990
<i>Ceriodaphnia dubia</i>	Water flea	2,724	1,652	24.00	LC50	Cowgill and Milazzo, 1990
<i>Daphnia pulex</i>	Water flea	2,042	1,239	48.00	LC50	Gardner and Royer, 2010
<i>Daphnia pulex</i>	Water flea	1,812	1,099	48.00	LC50	Gardner and Royer, 2010
<i>Anguilla rostrata</i>	American eel, (black eel stage)	21,571	13,085	96.00	LC50	Hinton and Eversole, 1978
<i>Anguilla rostrata</i>	American eel, (black eel stage)	17,969	10,900	96.00	LC50	Hinton and Eversole, 1978
<i>Gambusia affinis</i>	Mosquito fish	17,500	10,616	96.00	LC50	Wallen, <i>et al.</i> , 1957
<i>Hydropsyche betteni</i>	Caddisfly	13,308	8,073	96.00	LC50	Kundman, 1998
<i>Lepomis macrochirus</i>	Bluegill	12,964	7,864	96.00	LC50	Trama, 1954
<i>Oncorhynchus mykiss</i>	Rainbow trout	11,112	6,743	96.00	LC50	Spehar, 1987
<i>Pimephales promelas</i>	Fathead minnow	10,831	6,570	96.00	LC50	Birge, <i>et al.</i> 1985
<i>Culex</i> sp.	Mosquito	10,254	6,222	96.00	LC50	Dowden and Bennett, 1965
<i>Lepomis macrochirus</i>	Bluegill	9,627	5,840	96.00	LC50	Birge, <i>et al.</i> 1985
<i>Gammarus pseudolimnaeus</i>	Scud	7,700	4,670	96.00	LC50	Blasius and Merritt, 2002
<i>Pimephales promelas</i>	Fathead minnow	7,681	4,659	96.00	LC50	Wisconsin State Laboratory of Health, 1995
<i>Pimephales promelas</i>	Fathead minnow	7,650	4,640	96.00	LC50	Adelman, <i>et al.</i> , 1976
<i>Carassius auratus</i>	Goldfish	7,341	4,453	96.00	LC50	Adelman, <i>et al.</i> , 1976
<i>Anaobolia nervosa</i>	Caddisfly	7,014	4,255	96.00	LC50	Sutcliffe, 1961
<i>Limnephilus stigma</i>	Caddisfly	7,014	4,255	96.00	LC50	Sutcliffe, 1961
<i>Daphnia magna</i>	Water flea	6,709	4,071	96.00	LC50	Wisconsin State Laboratory of Health, 1995
<i>Chironomus attenuatus</i>	Midge	6,637	4,026	96.00	LC50	Thornton and Sauer, 1972
<i>Hexagenia limbata</i>	Mayfly	6,300	3,822	96.00	LC50 at 18°C	Chadwick, 1997
<i>Daphnia magna</i>	Water flea	6,031	3,658	96.00	LC50	Cowgill and Milazzo, 1990
<i>Lepidostoma</i> sp.	Caddisfly	6,000	3,640	96.00	LC50	Williams, <i>et al.</i> , 2000
<i>Hydroptila angusta</i>	Caddisfly	5,526	3,352	96.00	LC50	Hamilton <i>et al.</i> , 1975

PRELIMINARY DRAFT

Table E-1 (continued)

Species	Common Name	NaCl Concentration (mg/l)	Chloride Concentration (mg/l)	Exposure Time (hours)	Response <sup>a</sup>	Reference
<i>Cricotopus trifascia</i>	Midge	5,192	3,149	96.00	LC50	Hamilton <i>et al.</i> , 1975
<i>Rana sylvatica</i>	Wood frog (tadpoles)	5,109	3,099	96.00	LC50	Sanzo and Hecnar, 2006
<i>Cirrhinius mrigalo</i>	Indian carp fry	4,980	3,021	96.00	LC50	Gosh and Pal, 1969
<i>Labeo rohoto</i>	Indian carp fry	4,980	3,021	96.00	LC50	Gosh and Pal, 1969
<i>Catla catla</i>	Indian carp fry	4,980	3,021	96.00	LC50	Gosh and Pal, 1969
<i>Lirceus fontinalis</i>	Isopod	4,896	2,970	96.00	LC50	Birge, <i>et al.</i> , 1985
<i>Physa gyrina</i>	Snail	4,088	2,480	96.00	LC50	Birge, <i>et al.</i> , 1985
<i>Daphnia magna</i>	Water flea	3,939	2,390	96.00	LC50	Arambasic, <i>et al.</i> , 1995
<i>Pycnopsyche guttifer</i>	Caddisfly	3,526	2,140	96.00	LC50	Blasius and Merritt, 2002
<i>Pycnopsyche lepida</i>	Caddisfly	3,526	2,140	96.00	LC50	Blasius and Merritt, 2002
<i>Daphnia magna</i>	Water flea	3,054	1,853	96.00	LC50	Anderson, 1948
<i>Rana sylvatica</i>	Wood frog (tadpoles)	2,636	1,599	96.00	LC50	Sanzo and Hecnar, 2006
<i>Ceriodaphnia dubia</i>	Water flea	2,630	1,596	96.00	LC50	Wisconsin State Laboratory of Health, 1995
<i>Daphnia pulex</i>	Water flea	2,422	1,470	96.00	LC50	Birge, <i>et al.</i> , 1985
<i>Hexagenia limbata</i>	Mayfly	2,400	1,456	96.00	LC50 at 28°C	Chadwick, 1997
<i>Ceriodaphnia dubia</i>	Water flea	2,308	1,400	96.00	LC50	Cowgill and Milazzo, 1990
<i>Callibaetis coloradensis</i>	Mayfly	700	425	96.00	LC50	Wichard, 1975

<sup>a</sup>LC50 is the concentration that is lethal to 50 percent of the test organisms. A higher LC50 value means lower toxicity of the chemical to the organism.

Source: SEWRPC.

**Table E-2****CONTINUOUS SPECIFIC CONDUCTANCE DATA RECORDS AVAILABLE IN THE MENOMONEE RIVER WATERSHED**

Location	Period of Record	Comments
Honey Creek at Wauwatosa (Honey Creek Parkway)	12/6/2008 to 8/26/2011	Six data gaps during winter deicing seasons totaling to 37 days without data
Little Menomonee River near Friestadt (downstream of W. Donges Bay Road)	11/8/2008 to 7/26/2011	One data gap during winter deicing season totaling four days without data
Little Menomonee River at USH 41	5/7/2010 to 9/28/2010, 5/5/2011 to 7/18/2011	No data collected during the winter deicing season
Menomonee River at N. 70th Street	11/5/2008 to 9/13/2010	Three data gaps during winter deicing seasons totaling nine days without data
Menomonee River at Pilgrim Road	11/8/2008 to 7/26/2011	- -
Underwood Creek at Wauwatosa (Gravel Sholes Park downstream of Mayfair Road)	2/12/2010 to 7/26/2011	One data gap during winter deicing season totaling two days without data

Source: Milwaukee Metropolitan Sewerage District, U.S. Geological Survey, and SEWRPC.

Table E-3

**PERIODS WHEN CALCULATED CHLORIDE CONCENTRATION IN STREAMS OF THE MENOMONEE RIVER  
WATERSHED EXCEEDED 1,400 MILLIGRAMS PER LITER FOR FOUR DAYS OR MORE: NOVEMBER 2008 TO JULY 2011**

Stream	Length (days)	Calculated Chloride Concentrations (milligrams per liter)						
		Lowest Daily Minimum	Highest Daily Minimum	Lowest Daily Maximum	Highest Daily Maximum	Lowest Daily Mean	Highest Daily Mean	Average over the Period
Honey Creek at Wauwatosa								
December 6, 2008-December 13, 2008 .....	8	1,715	3,348	2,724	6,589	1,998	4,630	3,448
January 8, 2009-January 12, 2009.....	5	1,417	3,087	2,223	4,230	1,882	3,577	2,613
January 18, 2009-January 22, 2009.....	5	1,420	1,613	1,969	2,727	1,733	2,179	1,917
February 9, 2010-February 14, 2010 .....	6	1,504	2,266	1,972	4,775	1,734	3,021	2,519
February 17, 2010-March 2, 2010.....	14	1,410	3,326	1,751	6,227	1,577	4,266	2,421
December 22, 2010-December 25, 2010 .....	4	1,566	5,718	2,226	7,933	1,842	6,590	3,742
January 11, 2011-January 21, 2011.....	11	1,613	3,904	2,383	7,679	2,092	6,227	3,522
January 28, 2011-February 15, 2011 .....	19	1,456	3,504	2,001	5,573	1,725	3,904	2,542
February 21, 2011-February 28, 2011 .....	8	1,929	2,680	2,963	4,448	2,426	3,831	3,024
Underwood Creek at Wauwatosa <sup>b</sup>								
February 21, 2011-March 1, 2011 .....	9	1,413	1,940	1,649	2,869	1,507	2,383	1,833

<sup>a</sup>Chloride concentrations were calculated from specific conductance using the regression equation from Corsi et al. (2010). The regression equation is based on data from 17 Wisconsin streams. The regression equation is  $Cl = 0.363 \times Sc - 271$ , where  $Cl$  is the concentration of chloride in milligrams per liter and  $Sc$  is the specific conductance in microSiemens per centimeter. This equation is considered valid for chloride concentrations greater than 230 milligrams per liter, which is equivalent to a specific conductance of 1,380 in microSiemens per centimeter.

<sup>b</sup>Period of record at this site was February 12, 2010 through July 26, 2011.

Source: SEWRPC.