Montana Department of Transportation
Environmental Services

Memorandum

To: Dan Williams
Maintenance Division

From: Eric Stimson
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Date: Dec. 27, 2004

Subject: Chloride Levels in Streams Adjacent to Winter Maintenance Activities

Since part of the strategy to reduce the impacts of abrasives on rivers and streams adjacent to highways involves using chloride-based products (principally sodium chloride and magnesium chloride), MDT wants to make sure that these chlorides do not cause adverse environmental effects. This memorandum summarizes MDT's water quality sampling results and my investigation of U.S. and Canadian governmental studies, leading to the conclusion that MDT's present levels of chloride applications are having a negligible effect on aquatic plant and animal health.

Water Quality Sampling

Beginning in May 2003 and continuing to the present, MDT Environmental Services has collected monthly water quality samples from three creeks/rivers that are adjacent to streams that are the focus of the Total Maximum Daily Load (TMDL) program, administered by the Montana DEQ. Water samples were collected from several sample locations on Lolo Creek, Prospect Creek, and the St. Regis River adjacent to highways U.S. 12, MT 471, and I-90, respectively. Water samples were analyzed for chlorides, total dissolved solids (TDS), and total suspended solids (TSS). Background water samples were also collected for each stream from tributary streams not affected by highway maintenance activities. TSS and TDS values did not vary significantly from the background levels and are not discussed further in this memorandum. Appendix 1 summarizes the water quality data for Lolo Creek and the St. Regis River for the period from May 2003 to September 2004.

Range of Values Chloride levels in the waters of the three streams ranged from the background levels of 0-5 parts per million (ppm) in the tributary streams to a peak of 36 ppm detected in one sample from the St. Regis River in March 2004. The range of chloride levels in Prospect Creek (0-5 ppm) differed so little from the background levels (0-4 ppm) that water quality sampling on Prospect Creek was discontinued in September 2004 and the data are not included in this report.

Peak Levels Peak chloride levels in the St. Regis River ranged from 7 to 36 ppm at the nine sample locations. Peak chloride levels in Lolo Creek ranged from 6 to 17 ppm at the six sample locations. In general, chloride levels in these two streams reached their peak levels in March 2004 during the spring melting event.

Average Levels Average chloride levels in Lolo Creek ranged from 2.5 ppm to 5.6 ppm at the six sample locations during the period July 2003 to July 2004. Averaging the values at all six sample locations for the entire year gives an overall average for the waters of Lolo Creek of 4.2 ppm chloride.

Average chloride levels in the St. Regis River ranged from 3.3 ppm to 8.1 ppm for the nine sample locations same during the July 2003 - July 2004 time period. Averaging the values at all nine sample locations for the entire year gives an overall average for the waters of the St. Regis River of 5.8 ppm chloride.

In the six tributary (background) streams, the average chloride values ranged from less than one ppm to 1.7 ppm and averaged less than one ppm.

Summer Low Levels All sample locations reached their lowest chloride levels during the late summer months of July-August-September.

At Lolo Creek, the 2003 summer low levels ranged from 1.3 to 3.3 ppm and averaged 2.3 ppm. In 2004, the summer low levels ranged from 1.3 to 5.7 ppm and averaged 3.4 ppm.

At the St. Regis River, the 2003 summer low levels ranged from 1.5 to 2.5 ppm and averaged 2.1 ppm for the nine sample locations. In 2004, the summer low levels ranged from 1.3 to 4.0 ppm and averaged 3.1 ppm.

Chloride Toxicity Data: Canadian Information

In 2001, Environment Canada (the Canadian equivalent of the EPA) added road salts (chlorides) to Canada's List of Toxic Substances because of the potential for degradation to the environment as the result of winter road maintenance activities (Environment Canada, 2001). The summary report describes some of the higher levels of chloride applications in Canada (mainly in the eastern provinces where there are high road densities with heavy winter maintenance and heavy chloride applications) and points to various studies that have documented the toxic effects that these high chloride levels have on different plants and animals. For the most part, these studies deal with chloride concentrations in surface waters that are much higher than the chloride levels MDT has found in its water sampling so far.

Acute toxic effects, for example, were documented for the organism Ceriodaphnia dubia at 1,400 ppm (four-day median lethal concentration, or LC_{50}). Chloride levels this high and higher were documented in urban impoundment lakes and streams.

Chronic toxicity due to longer-term exposures occurs at lower chloride concentrations. Toxic effects were documented for three species (fathead minnow embryos, rainbow trout eggs and embryos, and water fleas) at concentrations between 870 and 1,070 ppm.

The "No Observed Effect Concentration" (NOEC) for the 33-day early-life-stage test for survival of the fathead minnow was 252 ppm chloride. The Environment Canada report estimates that 5% of aquatic species would be affected at chloride concentrations of about 210 ppm and 10% of species would be affected at chloride concentrations of about 240 ppm.

Chloride Toxicity Data: U.S. Information

In 1988, the EPA published Ambient Water Quality Criteria for Chloride (U.S. EPA, 1988), which summarized the available toxicity data for chlorides on freshwater plant and animal species. For aquatic animals, acute effects (short-term effects of high concentrations), and chronic effects (long-term effects of lower concentrations) were documented. For aquatic plants, only chronic effects were documented:

Acute Toxicity of Chloride to Aquatic Animals The acute effects (measured as LC_{50} values) of high concentrations of sodium, potassium, calcium and magnesium chlorides in 45 tests of various freshwater animal species were reported in U.S. EPA 1988, Table 1 (attached). For 33 of the 45 tests, the LC_{50} value is greater than 1,000 mg/l (ppm). For 43 of the 45 tests, the LC_{50} value is greater than 100 ppm. Only two of the tests (potassium chloride and calcium chloride effects on Daphnia magna) have LC_{50} values under 100 ppm (86 ppm and 92 ppm, respectively).

Chronic Toxicity of Chloride to Aquatic Animals The chronic effects of longer-term exposures of lower concentrations of sodium chloride on three species (rainbow trout, fathead minnow, and the water flea Daphnia pulex) were summarized in U.S. EPA 1988, Table 2 (attached). These three species suffered chronic effects from long-term chloride exposures of 923 ppm, 433 ppm, and 372 ppm, respectively.

Chronic Toxicity of Chloride to Aquatic Plants Chronic effects (3-day to 120-day exposures) of chloride concentrations to various species of algae, diatoms, and larger plants in 29 tests were documented in U.S. EPA 1988, Table 4 (attached). Negative effects were experienced at levels below 1,000 ppm in only 5 of the 29 tests, and in levels below 100 ppm in only one test (71 ppm chloride caused inhibited growth and chlorophyll fixation in the alga Spirogyra setiformis in a 10-day test).

Based on the tests described above, the EPA concluded, "…except possibly where a locally important species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of dissolved chloride, when associated with sodium, does not exceed 230 mg/l (ppm) more than once every three years on the average ("Criterion Continuous Concentration", or CCC), and if the one-hour concentration does not exceed 860 mg/l (ppm) more than once every three years on the average (Criteria Maximum Concentration", or CMC)." The EPA points out that these levels would be lower if the chloride is associated with potassium, calcium, or magnesium instead of sodium, but does not quantify that statement.

The EPA does not have a maximum contaminant level (MCL) for chloride, but assigns a "secondary MCL" level of 250 ppm chloride for drinking water (human consumption) based on unenforceable federal guidelines for taste, odor, and color.

Conclusions

Although there are presently no enforceable standards for chloride concentrations in Montana's rivers and streams, sufficiently high levels of chloride concentrations in other waters have been shown to have toxic effects on aquatic plants and animals. For most organisms, those concentrations are well in excess of 1,000 ppm. For a few organisms, the level at which negative effects are experienced are between 100 and 1,000 ppm. Only one organism of the dozens tested showed negative effects from chloride concentrations below 100 ppm.

The Criterion Continuous Concentration (CCC) level of 230 ppm is the most applicable guideline to the water quality testing data MDT has been acquiring. Since each monthly sampling event is a "snapshot" of chloride levels that may be representative of a period of time of up to a month, the 860 ppm (CMC) level for peak (one-hour) concentration is not an appropriate guideline. The 230 ppm level is also close to the EPA's Secondary MCL of 250 ppm for chloride in drinking water.

The levels that prompted the Canadian government to declare chlorides toxic substances are all in excess of 230 ppm, and are primarily above 1,000 ppm. High levels of chlorides (greater than 1,000 ppm) in Canadian surface waters were documented, primarily in the heavily populated eastern provinces with high road density and high snowfall, or in the vicinity of salt stockpile yards. MDT sand/salt stockpile sites are potential sources of high chlorides in adjacent surface waters and should be managed to minimize runoff. (The St. Regis River sample site located downstream from MDT's Taft road sand stockpile site had a peak level of 29 ppm chloride in March 2004.)

All of the chloride levels in the streams that MDT has sampled to date are considerably lower than the levels that caused concern in Canada. MDT's water quality testing data point to peak levels of 6-36 ppm chloride during a one-year period at 15 sample locations along Lolo Creek and the St. Regis River. These peak levels, which are indicative of short periods of time (up to around a one-month duration), are well below the CCC level of 230 ppm chloride.

As MDT continues to increase the salt concentrations in the traction sand being applied to the roadways, and continues to apply liquid magnesium chloride, it would be wise to continue water quality testing to ensure that the chloride levels in the adjacent surface waters continue to stay well below 230 ppm during the peak events. As long as sodium chloride remains the dominant chloride product used in winter highway maintenance, the CCC level of 230 ppm chloride is appropriate to use as a ceiling level. (During the 2003-2004 winter season in the Upper Lolo Creek TMDL area, MDT applied 62 tons of sodium chloride compared to 28 tons of (dry equivalent) magnesium chloride (MDT 2004). If MDT begins applying more magnesium chloride than sodium chloride, that ceiling level may need to be lowered.

REFERENCES

U.S. EPA (1988), Ambient Water Quality Criteria for Chloride, Office of Water Regulations and Standards, Publication 440588001

Environment Canada (2001), Report of the Assessment of the Substance Road Salts Specified on the Priority Substances List, Canada Gazette Vol.135, No. 48

MDT (2004), Progress Report: Winter Maintenance Activities in the Upper Lolo Creek TMDL Planning Area, Montana Department of Transportation Environmental Services Bureau