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NOTE

THE MINERAL RIVER—A UNIQUE TRIBUTARY CHLORIDE LOAD TO LAKE SUPERIOR[1]

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ABSTRACT. The Mineral River contributes a significant amount of chloride to Lake Superior, more than one-third of the total U.S. tributary input. This unique discharge is attributed largely to the mine dewatering process of the White Pine Copper Company. Chloride concentrations as high as 2,000 mg/L have been recorded at the mouth of the Mineral River. The impact of this discharge on Lake Superior is not known; however, it is postulated that increased chloride concentrations may enhance the introduction and adaptation of marine organisms into the Great Lakes.
ADDITIONAL INDEX WORDS: Algae, marine algae, mine drainage.

INTRODUCTION

The Mineral River, located in Ontonagon County in Michigan's Upper Peninsula, is a tributary of Lake Superior and has a drainage basin area of approximately 100 km². It is a relatively small river in terms of flow, contributing less than 0.5% of the total flow to Lake Superior from U.S. tributaries (Quinn and Kelley 1983). However, the Mineral River has been estimated to contribute 35% to 40% of the total U.S. tributary load of chloride to Lake Superior (Sonzogni *et al.* 1978).

This extremely high chloride load can be attributed largely to discharges by the White Pine Copper Company, which operates a mine at the village of White Pine, Michigan, for mining and processing copper ore. According to Hartig (1980), a great deal of brine leaches into the mine works via cracks and fissures and is discharged, along with other process wastewater, to a settling pond for treatment. In addition, the village of White Pine discharges its secondary chlorinated effluent to the same pond. The settling pond decant is then released to Perch Creek, a tributary of the Mineral River.

The purpose of this note is to document the unique chloride discharge of the Mineral River. Chloride loads are calculated and presented for 1974–80. The impact of this discharge on Lake Superior, particularly its effects on biota, is also explored. Chloride is of special concern since it has been implicated as a factor influencing the assemblages of algae in the Great Lakes (Stoermer 1978, Sonzogni *et al.* 1983). The high chloride levels in the mouth of the Mineral River may make it an ideal site to investigate biological changes related to increased chlorinity.

METHOD

Mineral River chloride loads for Water Years 1974 and 1975 were calculated by the ratio estimator method as described in Dolan *et al.* (1981) and in a report of the Great Lakes Water Quality Board (1976). Concentration and flow data were used to calculate the average daily load at the mouth, and then that load was adjusted to account for the variability of flow over an annual cycle. The average daily load estimates were then used to calculate the annual load. Data used were from a sampling station maintained at the mouth of the Mineral River from 1971 to 1980 by the Michigan

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Department of Natural Resources. Chloride levels were regularly monitored throughout this period, but flow data were only recorded through 1975. These data were obtained through the U.S. Environmental Protection Agency's STORET system.

Chloride loads for Water Years 1976 through 1980 were calculated differently than those for previous years because flow data for the Mineral River were not available after 1975. For each of these years, an estimated mean annual flow was multiplied by the average chloride concentration to estimate an annual chloride load; the mean annual flows were estimated as the product of the 1975 mean annual flow and a flow factor derived from the flow behavior of two bordering rivers, the Presque Isle and the Ontonagon. The Mineral River flow pattern was assumed to be proportional to the flow patterns of the Presque isle and Ontonagon Rivers (i.e., if the Presque Isle and Ontonagon flows increased from 1975 to 1976, then it was assumed that the Mineral River flow would also increase). The Presque Isle and Ontonagon Rivers are gauged by the U.S. Geological Survey. The mean annual flows and chloride concentrations in the Mineral River that were used in the above calculations are presented in Table 1.

RESULTS

The Mineral River chloride discharges to Lake Superior during Water Years 1974 through 1980, as calculated by the above methods, are presented in Figure 1. These loads resemble previously reported loads of about 33,000 MT/yr from earlier tributary load studies based on more limited data (Sonzogni *et al.* 1978, Sullivan *et al.* 1980).

Figure 1 also compares the total tributary chloride inputs to Lake Superior from all Michigan tributaries and from U.S. Lake Superior tributaries in general (adapted from Sonzogni *et al.* 1978 and

TABLE 1. Mean annual flows and chloride concentrations in the Mineral River for water years 1974–80.

Water year	Mean annual flow (ft^3/sec)	Mean annual chloride concentration (mg/L)
1974	89.3	249.0
1975	49.1	426.5
1976	50.3	602.9
1977	32.8	694.3
1978	54.4	1,017.3
1979	52.3	752.3
1980	49.8	738.5

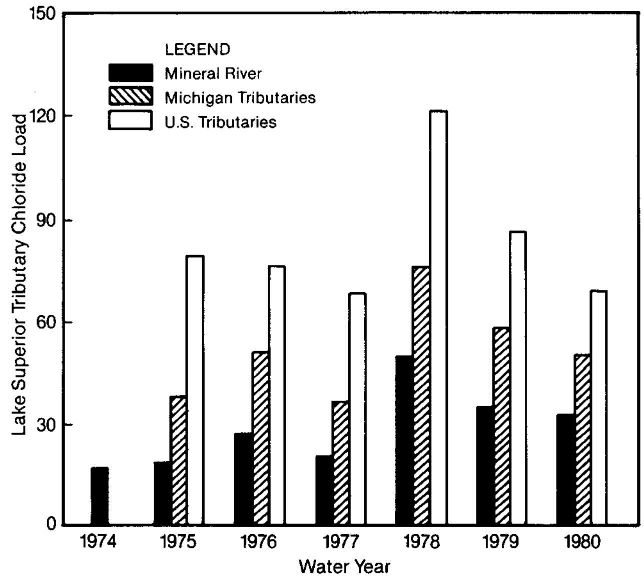

FIG. 1. Chloride to Lake Superior from U.S. tributaries (10^3 MT/yr), 1974–80. Black bar denotes Mineral River input, hatched bar denotes input from all Michigan tributaries, and white bar denotes input from all U.S. tributaries.

Sullivan *et al.* 1980 using the Mineral River chloride loads presented here). The Mineral River accounted for an average of 58% of the Michigan tributary chloride load and 37% of the total U.S. tributary chloride load to Lake Superior during Water Years 1975 to 1980. The portion contributed by the Mineral River generally increased during this time period to a high in Water Year 1980 of 65% and 49% of the total tributary chloride load from all Michigan and U.S. Lake Superior tributaries, respectively. Thus, despite its small size, the Mineral River is a major contributor of chloride to Lake Superior.

The 1979 Compliance Inspection Report for the White Pine Copper Company (Williams 1979) reported that the chloride concentration in the effluent of the White Pine Copper Company averaged 965 mg/L (with a high of 1,340 mg/L) in 1979. Selected samples along the Mineral River were also analyzed for chloride on 29 July 1979 (Hartig 1980). Chloride concentrations at the river mouth were close to 2,000 mg/L, while the concentration above the mine discharge was only about 13 mg/L. Thus, the chloride concentration of the Mineral River below the mine discharge is similar to sea water. By comparison, the chloride concentration of Lake Superior is only about 1 mg/L (Sonzogni *et al.* 1983).

Importantly, Michigan water quality standards are not being violated in the Mineral River because the Michigan Water Resources Commission has designated the Mineral River as a mixing zone for the White Pine Copper Company discharge (Hartig 1980). In addition, two wastewater monitoring surveys (Polasek and Long 1977, Ostlund and Hamilton 1981) showed that the White Pine Copper Company is in compliance with its National Pollution Discharge Elimination System (NPDES) permit.

DISCUSSION

The extent of harm, if any, that the Mineral River chloride load has had on Lake Superior is not known. Nor is quantitative evidence available to assess the effects of increased open water chloride concentrations on the Great Lakes system in general. But there is reason for concern, particularly about the effect of chloride on Great Lakes biota.

There is much speculation about the effects of chloride on the type and distribution of Great Lakes biota. Chloride concentrations in the Great Lakes have increased significantly since the early 1900s (Sonzogni *et al.* 1983), and it has been postulated that increased levels of chemical elements, namely chloride and other conservative ions, may enhance the introduction and adaptation of marine organisms into the Great Lakes (Stoermer 1978, Tuchman 1982).

The invasion of halophilic species of phytoplankton into the Great Lakes has already been documented (Stoermer and Yang 1970, Pringle *et al.* 1981, Lin and Blum 1977). Many of these species can tolerate, and some actually require, high levels of chloride. In addition, several species of saline-tolerant zooplankton have been observed in the Great Lakes (Pringle *et al.* 1981, Evans and Stewart 1977). However, the existence of marine-like plankton in the Lakes cannot be directly linked to increased chloride levels. Chloride is most likely just one of many factors influencing the assemblages of Great Lakes biota.

A chloride plume survey performed in a 0.04 mi^2 grid in Lake Superior near the mouth of the Mineral River indicated that chloride concentrations ranged from 1,900 mg/L at the river mouth to less than 5 mg/L at the outer edge of the grid (Hartig 1980). Thus, dilution of the Mineral River chloride input was very rapid, and if any environmental hazards have been caused by the Mineral River chloride load, they would be most acute in the waters just off the mouth of the river.

It is evident that more work needs to be done to better understand the effects of increased chlorinity on the physical and biological aspects of the Great Lakes system. The high chloride levels in the mouth of the Mineral River may make it an ideal site at which to investigate some of these effects.

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