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CHLORIDE AND SODIUM TRENDS IN THE YAHARA LAKES

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The Yahara River flows through 4 lakes (Mendota, Monona, Waubesa, and Kegonsa) as it passes through the city of Madison and surrounding communities (Fig. 1). These lakes, collectively called the Yahara lakes, are among the most important water resources of southern Wisconsin. Chloride and sodium concentrations in the lakes have been affected over the years by both sewage effluent discharges and road salt use. Because of the urban setting of the Yahara lakes, the concentration of these ions is a continuing concern.

Most of the historic data on chloride concentrations, the majority obtained by the Madison City Health Department, have been summarized from 1940 through the 1970s (Beach et al. 1975). However, data collected in more recent years by the Bureau of Research as part of our long-term research study on the Yahara lakes have not been reported. Sodium was not routinely tested in earlier years, and data have not previously been summarized.

My objective in this report is to bring together information on chloride and sodium concentrations in the Yahara lakes to provide a picture of long-term trends. Data sources are as follows: Mendota 1907 (Birge and Juday 1911), Yahara lakes 1940-49 and 1962-87 (Madison City Health Dept. 1988), Yahara lakes 1962-64 (Poff 1967), and Mendota 1965-67 (UW Water Chemistry Program student data including 1967 MS thesis by J. Hawley). The DNR Bureau of Research began sampling Monona in 1967, Waubesa and Kegonsa in 1973, and Mendota in 1975. Sampling has continued on all 4 lakes until the present. Bureau of Research samples were analyzed at the DNR

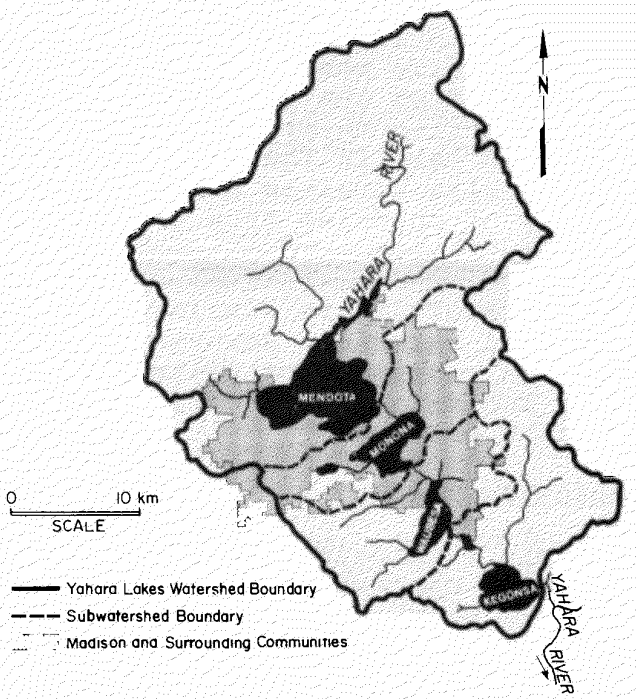

FIGURE 1. Yahara lakes watershed.

Fish Management Lab in 1967-69, State Lab of Hygiene (SLOH) in the winter of 1970, Delafield Research Lab in 1970-79, and SLOH beginning in 1980. Sodium was not analyzed in 1980-86.

Sources of Chloride and Sodium Ions

Locating the major sources of chloride to Lake Mendota is difficult because of its complex hydrology and long flushing rate (about every 6 years). Chloride enters the lake in runoff from streets and roads where de-icing salts have been applied. Prior to 1960, road salt use in Madison was low. Use increased dramatically during the 1960s, then moderated after the mid 1970s. Chloride also enters Mendota from ground water discharging directly to the lake or to the baseflow of inflowing streams.

The lower 3 lakes, particularly Waubesa and Kegonsa, received chloride from the Madison Metropolitan Sewerage District (MMSD) effluent until it was diverted in 1958. Today, the lower lakes receive most of their chloride from the Yahara River, which carries chloride from each upstream lake in the chain. Lake Monona also receives a heavy influx of chloride from urban runoff.

Sodium sources are similar to those of chloride. However, road salt is comprised of salts other than sodium chloride, principally calcium chloride.

Chloride Trends

Mendota's chloride was low prior to 1950; concentrations were about 3 mg/L, which probably represents unpolluted background levels (Fig. 2). Monona's chloride was only slightly higher in the 1940s, except from 1947-49 when Monona received sewage effluent discharge while MMSD's eastside interceptor was being built. Chloride concentrations in Waubesa and Kegonsa prior to 1950 reflect the high loading of chloride from the MMSD effluent. Concentrations decreased after the effluent was diverted in 1958. Beginning in the early 1960s, chloride has been steadily increasing at about the same rate in all 4 lakes. Because Waubesa and Kegonsa are flushed almost 3 times per year due to their shallowness, chloride concentrations have been similar to concentrations in upstream Lake Monona. Mendota's chloride concentrations have lagged behind Monona's, which reflects greater urban runoff inputs to Monona. (Monona flushes about once per year.) This urban contribution also has been evident in Lake Wingra, where chloride concentrations in the 1970s and 1980s were about twice as great as in Monona (Madison City Health Dept. 1988). Wingra discharges to Monona.

Sodium Trends

Sodium concentrations in Lake Mendota increased from 3 mg/L in the early 1900s to 5-6 mg/L in the 1960s and 8-9 mg/L in the 1970s (Table 1). Concentrations averaged

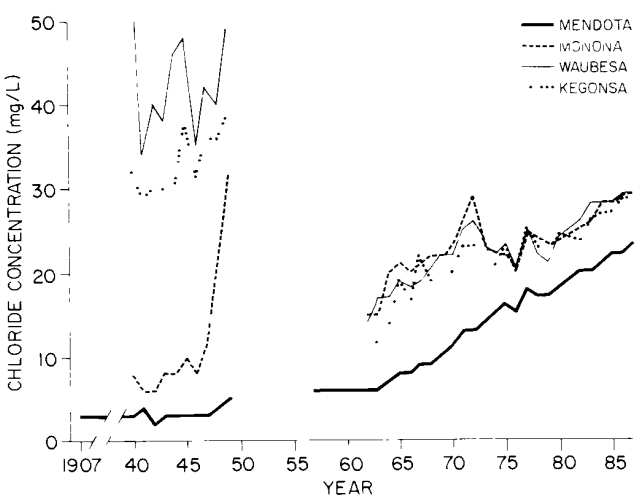

FIGURE 2. Chloride concentrations in Lake Mendota, 1907-1987.

10 mg/L in the 1980s. Since the 1960s, concentrations have been similar for the 3 lower lakes and slightly higher than in Mendota. The 9 mg/L measurement for Waubesa and Kegonsa in 1964 is relatively low, indicating that the levels had decreased since the 1958 sewage diversion. However, no sodium data were found for the lower lakes for the period of sewage effluent discharge. Madison's urban contribution of sodium also has been evident in Lake Wingra, where sodium has been about 75% higher than in Monona during 1977-87 (Madison City Health Dept. 1988).

TABLE 1. Sodium concentrations in the Yahara lakes, 1907-1987. Ranges of data represent averages from different sources.

	Sodium (mg/L)			
Year	Men	Mon	Wau	Keg
1907	3	-	-	-
1962-64	5	9	9	9
1965-69	6	11	-	-
1970-72	9	15	15	13
1973-75	9	-	12	13
1977-79	8-9	12-13	12	11-12
1980-82	9	14	13	12
1983-85	10	15	15	13
1986-87	10-11	14	14	14

Other Major Ions

Information on the major cations and anions in the Yahara lakes for 1987 is given in Table 2. Magnesium (from dolomite) and calcium are the major cations. They occur naturally in high concentrations in the Yahara lakes because of the region's calcareous geology. Bicarbonate is the major anion. Sodium and chloride represent a much smaller part of the total ionic balance expressed as milliequivalents per liter (meq/L).

Significance of Chloride and Sodium Trends

Sodium concentrations have increased since the early 1960s but have not mirrored the steady

TABLE 2. Concentrations of major cations and anions in the Yahara lakes in 1987, based on quarterly sampling by the Bureau of Research.

	Ion Concentrations in mg/L (meq/L in parentheses)			
Ion	Mendota	Monona	Waubesa	Kegonsa
Cations				
Calcium	31 (1.6)	30 (1.5)	32 (1.6)	33 (1.7)
Magnesium	32 (2.6)	31 (2.6)	34 (2.8)	34 (2.8)
Sodium	10 (0.44)	14 (0.61)	14 (0.61)	14 (0.61)
Potassium	3 (0.08)	3 (0.08)	3 (0.08)	3 (0.08)
Anions				
Total Alkalinity*	181 (3.6)	171 (3.4)	170 (3.4)	175 (3.5)
Chloride	23 (0.65)	29 (0.81)	29 (0.81)	29 (0.81)
Sulfate (as SO_4)	22 (0.46)	23 (0.48)	22 (0.46)	23 (0.48)
Sum Cations (meq/L)	(4.7)	(4.7)	(5.1)	(5.1)
Sum Anions (meq/L)	(4.7)	(4.7)	(4.7)	(4.8)

* Total alkalinity as mg/L $CaCO_3$ and meq/L bicarbonate.

increase in chloride. The use of calcium chloride as a road salt may be partly responsible for higher loadings of chloride compared with sodium. Also, sodium may be tied to soil particles via ion exchange reactions as the salt percolates into the shallow ground water system. The mobility of chloride ion should be much greater.

Levels of chloride and sodium considered toxic to fresh-water aquatic life are more than 10 times greater than present concentrations in the Yahara lakes. Therefore, increases at current rates should not be a concern for aquatic life in the foreseeable future.

However, chloride and sodium trends in the lakes may reflect changes in ground water concentrations. The Madison City Health Department recently found much higher concentrations of sodium and chloride in Madison's deep-aquifer wells than in the Yahara lakes. (The deep aquifer presumably is receiving salt from the shallow aquifer, which is part of the lakes' ground water hydrology.) Sodium is of particular concern because of the 20 mg/L warning level for people on restricted salt diets.

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