Runoff of Deicing Salt in Buffalo, New York

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ABSTRACT

The rising level of chloride concentration in Lakes Erie and Ontario has resulted in studies directed towards identification of salt sources, mathematical modelling of the material balance of salt in the Great Lakes Basin, predictions for the future, and consideration of salt management alternatives. The present study is concerned with deicing salt retention and flushing from the City of Buffalo, a major urban area located on the eastern shore of Lake Erie. Attempts have been made to account for the fate of all salt applied to the city streets. The data reveal that Buffalo is efficiently flushed of deicing salt by a combined sewer system. The salt load in the sewage flow is discharged directly into the Niagara River. The ultimate purpose of this study is to enable calibration of a material balance equation for salt build-up in the Great Lakes. The data also provide information on base salt loads in the sewage flow when deicing salt is not in use and the response of the collection system as a function of deicing salt applications and climatic conditions.

INTRODUCTION

The chloride concentration in Lake Erie and Lake Ontario has increased remarkably during the past sixty years. Beeton (1965) and Weiler and Chawla (1969) have documented this increased chloride concentration which has risen from 7 parts per million in 1910 to almost 30 parts per million at the present time. Although the present chloride concentration is still far below the U.S. Public Health Service (PHS) suggested allowable concentration of 250 parts per million for potable water supplies, the situation calls for studies aimed at explaining quantitatively the present trend and providing an operational model which can be used to predict future concentrations. The model would enable planners to examine the future consequences of alternative management decisions relative to salt use. Ownbey and Kee (1967) examined the salt buildup in Lake Erie and concluded that control measures were needed. Their projections included the possibility that the deicing salt contribution could become a major factor, second only to industrial salt-bearing wastes. O'Connor and Mueller (1970) developed a water quality model for chlorides in the Great Lakes. The relative strengths of various salt sources were estimated. They recommended that a more detailed analysis of salt sources be made so that a careful assessment could be made of alternative control strategies. Bubeck, et al. (1971) reported that the total consumption of salt in the United States increased by a factor of 5 during the period 1940 to 1970 while the salt used for road deicing increased by a factor of 38 over the same period. Their study of the chloride build-up in Irondequoit Bay near Rochester, New York revealed that significant limnological changes were occurring in this Bay because of the deicing salt drainage into it from the basin.

It is the purpose of the present investigation to extend the work of O'Connor and Mueller (1970) and, specifically, to relate the contribution of deicing salt to the total salt budget of the Great Lakes. It was decided to calibrate the deicing salt use in the city of Buffalo, a major urban area located at the eastern end of Lake Erie. The investigation began in January of 1972 and is continuing. This report covers the period January to July, 1972.

DATA COLLECTION AND ANALYSIS

The City of Buffalo has a population of approximately 460,000. The city is served by a combined sewer system and a central sewage treatment plant (design flow of 150 million gallons per day). The treatment plant discharges its effluent into the Niagara River which connects Lake Erie and Lake Ontario. In addition to the City of Buffalo, the treatment plant also receives a limited sewage flow from some community and county owned sewer districts. It is estimated that an additional 40,000 persons are served in this way.

The method of approach to data collection was to account for the daily use of deicing salt in the city and measure the salt flushed from the city via the combined sewer system and the sewage treatment plant. As is typical of combined sewer systems, direct discharge of sewage (overflows) to the receiving streams occurs periodically and these had to be estimated.

Sewage treatment plant effluent samples have been collected and analyzed for chloride concentration on a daily basis since January 15, 1972. The plant flow in million gallons per day was also measured and recorded. Precipitation and temperature records have been obtained from the National Weather Service Office in Buffalo. The quantity of deicing salt applied to the streets has been provided by the City of Buffalo, the Town of Lackawanna, the New York Thruway Authority, and the New York State Department of Transportation. Because the overflows were unknown, the study period of 201 days was divided into several sub-periods which were determined largely by considering the pattern of the precipitation and temperature records. A water budget balance was performed for each sub-period and overflows were estimated during each sub-period. The overflows of a given sub-period were proportionately distributed according to the difference between the actual plant flow and the design flow of 150 million gallons per day. The collected data were analyzed to determine the quantity of deicing salt that was returned to the receiving surface water system by the combined sewer system and to distinguish this deicing salt load from the normal salt discharge from the City of Buffalo.

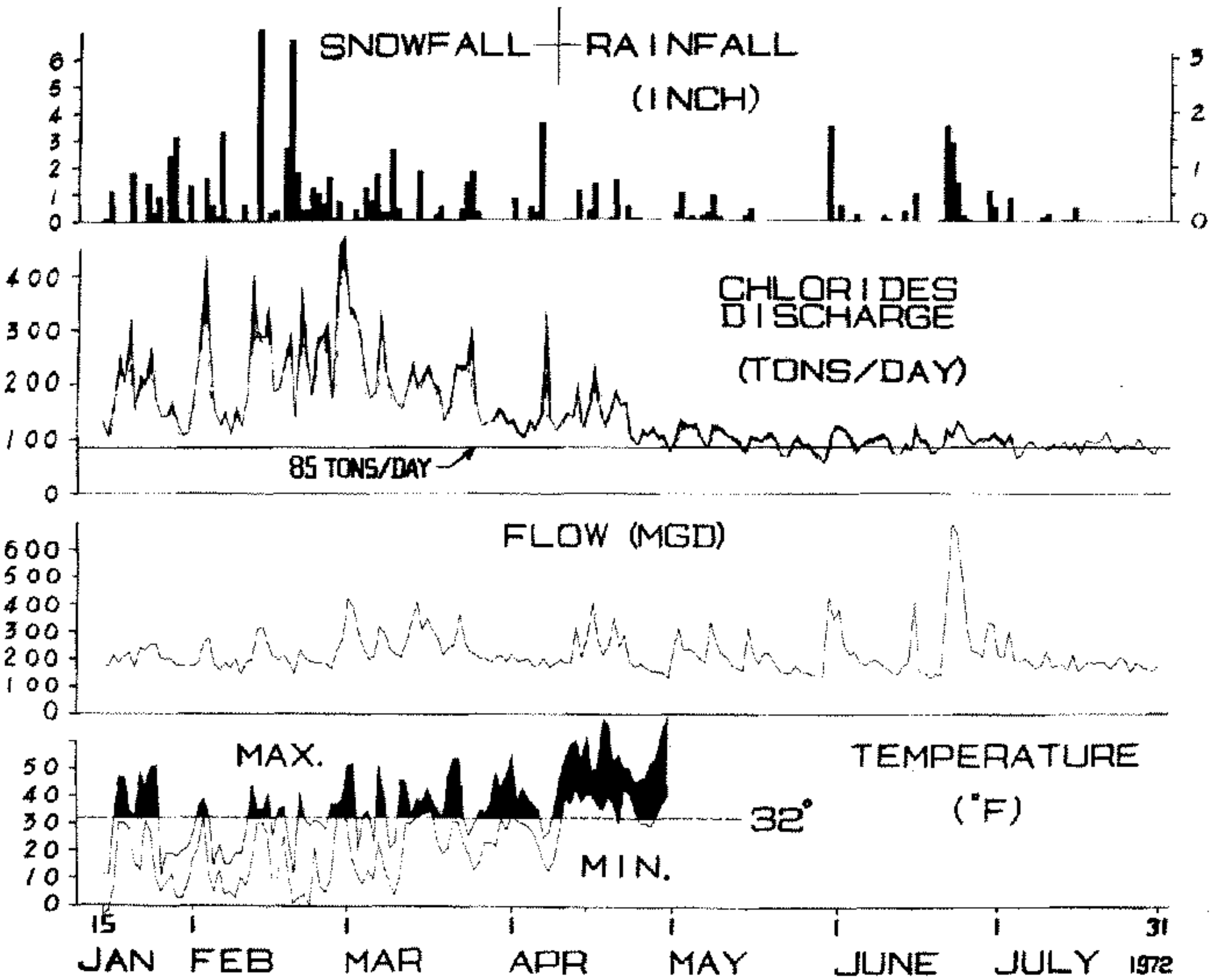

Figure 1. Display of Meteorological and Salt Runoff Data.

The data and results are graphically displayed in Figure 1. It can be seen that a chloride discharge of 85 tons per day can be considered as the normal chloride discharge of the system under study. Of this normal chloride discharge, approximately 10 tons per day is unavoidable since this amount was contained in the original potable water supply to the city. The water supply source is Lake Erie. In general, chloride discharge in excess of 85 tons per day can be considered as deicing salt runoff. The tabulated data can be found in Tables I, II, and III.

Based on the analysis of the data, it was found that the total chloride discharge during the study period of 201 days was 30,706 tons. The estimated base chloride discharge during the study period was 17,085 tons. Therefore, the chloride discharge attributed to deicing salt runoff during the study period amounted to 13,621 tons. The quantity of deicing salt applied during the study period was equal to 24,816 tons which converted to an equivalent weight of chlorides of 15,050 tons. Therefore, the ratio of the deicing salt discharged to that applied was found to be 13,621/15,050 or a recovery of 90.5%. Private and commercial use of deicing salt has been assumed to be small relative to the use of deicing road salt.

The base load of 85 tons of chloride per day is reduced to 75 tons of chloride when the original salt load of the drinking water is subtracted. Converting this latter figure to tons of salt (NaCl) it is found that the per capita contribution of salt is 0.5 pounds per day. This is thought to include a significant amount of salt waste from industry. By comparison, the average quantity of salt excreted by humans is 0.0154 pounds per day. Some of the difference can be accounted for by other uses of salt in the home.

TABLE I

Estimated Flow (10^6 gal.) = (Plent Flow + Estimated Overflow)

	Jan.	Feb.	Mar.	April	May	June	July
1		174.9	420.3	217.8	222.1	382.1	212.1
2		186.0	388.5	193.2	310.0	248.2	284.3
3		261.9	294.8	173.9	232.0	219.1	303.4
4		278.9	239.8	200.1	235.5	225.6	196.0
5		180.6	200.3	175.6	222.9	184.5	191.6
6		158.0	210.2	179.3	201.7	177.0	199.9
7		184.2	314.1	200.8	188.7	191.7	181.6
8		168.2	293.4	169.6	336.2	193.5	164.4
9		197.1	237.3	182.9	262.0	179.1	175.9
10		145.8	215.1	197.4	220.2	153.7	227.3
11		189.0	205.9	185.9	209.3	149.0	170.7
12		195.9	258.9	183.1	177.2	143.7	171.8
13		308.4	331.6	317.3	166.0	175.2	176.5
14		314.0	404.4	207.7	159.1	188.3	159.7
15	178.0	257.3	304.1	282.0	310.9	408.5	210.9
16	173.0	208.0	346.6	404.9	221.5	150.	153.6
17	212.1	196.3	301.5	277.4	185.8	148.4	172.5
18	186.7	211.9	273.1	216.3	217.9	131.2	189.1
19	209.5	185.7	216.0	247.6	217.9	144.4	181.8
20	224.2	145.2	239.6	351.4	187.2	143.8	183.3
21	171.3	233.2	251.8	244.7	154.6	419.5	186.1
22	240.0	200.0	311.0	286.5	148.3	691.2	163.1
23	232.0	189.8	275.9	186.7	150.7	646.8	180.4
24	250.0	186.0	227.6	170.8	174.7	484.7	206.3
25	253.8	185.4	214.5	180.6	150.7	306.8	190.0
26	199.6	178.9	199.9	166.9	148.3	228.1	149.8
27	198.7	165.8	201.9	154.3	141.7	222.6	181.2
28	196.9	230.2	189.0	154.5	137.7	207.3	169.6
29	176.9	271.7	204.8	147.7	129.2	329.6	160.2
30	175.9		208.7	132.1	425.4	325.2	154.4
31	174.4		191.0		343.6		169.8

TABLE II

Chloride Discharge* (includes overflow)

1972

	Jan.	Feb.	Mar.	April	May	June	July
1		170.7	344.2	135.6	102.1	120.3	102.3
2		251.2	332.4	113.0	136.2	116.2	95.6
3		446.2	295.1	105.8	127.5	102.4	111.3
4		286.9	226.0	137.5	125.7	81.1	65.9
5		149.7	174.9	121.2	129.3	91.6	70.9
6		127.5	185.4	143.8	102.5	99.8	93.5
7		151.0	337.9	383.4	86.1	99.9	95.2
8		109.9	222.0	136.7	125.6	105.7	82.3
9		159.5	191.6	116.2	124.7	108.9	86.6
10		123.1	165.5	132.4	117.5	98.7	78.7
11		183.8	155.5	147.8	105.2	71.3	91.4
12		400.9	194.9	138.5	104.0	71.7	83.0
13		294.5	239.8	201.3	96.1	93.8	96.3
14		284.7	196.0	121.3	78.4	80.5	80.5
15	132.1	343.7	218.3	163.4	105.3	128.7	95.1
16	105.9	186.0	225.4	235.2	103.4	98.6	70.5
17	165.3	192.9	199.8	166.7	97.1	99.4	97.2
18	253.9	239.3	195.7	126.9	106.0	75.3	95.6
19	203.0	294.0	134.0	152.4	113.0	80.5	92.6
20	319.8	139.2	164.0	188.5	96.2	86.7	98.3
21	155.4	377.5	237.0	162.9	69.7	121.8	114.0
22	214.9	266.6	232.7	166.6	67.3	105.7	86.5
23	203.1	182.1	234.3	105.1	95.1	133.4	76.0
24	269.7	284.9	305.6	89.4	107.1	123.7	88.7
25	170.5	287.7	164.9	117.6	88.2	99.5	90.2
26	140.7	315.7	124.4	109.0	91.3	91.4	82.9
27	143.0	175.8	130.5	123.4	76.6	101.2	103.1
28	169.2	461.4	133.0	104.6	69.9	101.1	87.2
29	129.0	470.7	155.8	106.3	56.8	103.0	82.1
30	107.4		150.3	76.9	103.6	113.0	72.1
31	113.2		131.3		123.8		87.9

*Quantities are in tons per day

TABLE III

Summary of Data

Period (1972)	No. of Days	Total Plant Flow 10^6 Gal.	Total[1] Precip. (in)	Est. Storm[2] Water 10^6 Gal.	Est. Over-flow 10^6 Gal.	Calculated By-passed cl (tons)
1/13-1/25	13	2564.1	.94	478	689.1	37
1/26-2/ 4	10	1879.2	.64	325	378.0	139
2/ 5-2/15	11	1986.3	.84	427	340.5	348
2/16-2/22	7	1295.5	1.89	960	250.9	772
2/23-3/23	30	7298.2	4.13	2098	2798.2	
3/24-4/ 7	15	2917.0	0.84	427	667.9	44
4/ 8-4/14	7	1310.9	0.50	254	260.9	91
4/15-4/30	16	3004.3	1.74	884	624.5	347
5/ 1-5/14	14	2605.9	1.50	762	505.9	85
5/15-5/29	15	2347.2	0.27	137	132.0	52
5/30-6/12	14	2468.9	2.17	1102	376.2	77
6/13-6/20	8	1236.8	0.57	290	69.0	40
6/21-6/28	8	1885.9	3.95	2007	685.9	82
6/29-7/14	16	3045.9	1.32	671	645.9	47
7/15-7/31	17	2847.0	0.22	112	297.2	25

[1] Effective precipitation = Actual precipitation—.05" (each episode) (snow depths have been converted to equivalent water depths)

[2] Volume of storm water precipitated onto the basin.

Sibley and Stewart (1969) reported a maximum difference of chloride concentration of 2 to 3 parts per million between the source and the mouth of the Niagara River. In the present study, it has been found that during the winter period, the deicing salt discharge can cause an increase of chloride concentration in the Niagara River by as much as 1 part per million. It would appear that during the snow season, the runoff of deicing salt could account for a major part of the differences observed by Sibley and Stewart.

The annual salt discharge from the City of Buffalo is calculated to be 73,820 tons of which 22,820 tons can be attributed to deicing salt runoff. Thus, 31% of the total annual salt discharge from the City of Buffalo can be attributed to deicing salt.

SUMMARY

The analysis of the collected data reveals that deicing salt runoff is a significant contributor to the total salt discharge from the City of Buffalo. The analysis provides data that can be used to calibrate a more comprehensive mathematical model for salt balance in the Lake Erie basin (and then, logically, to each of the other Great Lakes). This data collection program has been extended to include three other municipalities in the western New York. These include a town with a rapidly developing suburban residential area, a town with a separated sewer system, and another town serviced by a combined sewer system.

The study reveals that the City of Buffalo is efficiently flushed of deicing salt by a combined sewer system. Bubeck et al (1971) have found that for the rural watershed draining into Irondequoit Bay, the recovery of deicing salt is much less efficient (on the order of 50%).

It is clear that the chloride concentrations of the Great Lakes can not be permitted to increase forever. It is important to calibrate the various sources of salt in the Great Lakes Basin and use this information in the application of a salt balance model that will enable accurate predictions for the future and also the appraisal of alternative salt management strategies. It is hoped that a rational basis for salt management will evolve from this study and others similar to it.

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