Transactions of the Illinois State Academy of Science
(1983), Volume 76, 1 and 2, pp. 277-280

A Digest of Water Quality of Three Central Illinois Impoundments

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ABSTRACT

Samples from Lakes Canton, Decatur, and Eureka were collected weekly for over 2 years and were analyzed for 22 parameters. These parameters are transparency, water temperature, dissolved oxygen (DO), turbidity, pH, alkalinity, hardness, ammonia and nitrate nitrogen, dissolved and total phosphorus, iron, manganese, sulfate, chlorine demand, chemical oxygen demand (COD), total organic carbon (TOC), silica, threshold odor number (TON), algae, standard plate count (SPC), and actinomycetes. Presented are summaries of the comparisons of water quality characteristics, 1) with different depths, 2) with different lakes, and 3) with Illinois Pollution Control Board's standards.

INTRODUCTION

The three man-made impoundments serve principally as sources of public water supplies and as public recreation areas. Lake Decatur has a large surface area (1170 ha) and a maximum depth of 5 m. Lake Eureka is a small body (15 ha) of water with a maximum depth of 7 m. Lake Canton has a mid-size surface area (88 ha) and a maximum depth of about 11 m.

Over a 2-year period, mid-September 1976 to mid-October 1978, water samples from these three impoundments were collected weekly at the deepest locations. Sample collections were made at the surface, mid-depth, and near bottom at each location and were analyzed for 22 physical, chemical, and microbiological constituents.

This paper is a summary of the findings of the study. Taste and odor portions have been reported elsewhere (Lin and Evans, 1981a, 1981b). The observed data are available from computer storage at Illinois State Water Survey.

RESULTS AND DISCUSSION

Table 1 shows average values and geometric means of the observed data depending on distribution. The transparency in Lake Canton was generally greater than that in Lakes Eureka and Decatur. Low transparency occurred in mid-spring and late summer.

The water temperature exhibited seasonal changes throughout the water column. The water of L. Canton and L. Eureka was thermally stratified for about six months every year from mid-April to mid-October. The temperature stratification barrier for L. Canton and L. Eureka occurred at 12 to 14 feet (3.7 to 4.3 m) and 4 to 10 feet (1.2 to 3.0 m), respectively.

During the winter and between the spring and fall, lake turnovers, stratification in terms of dissolved oxygen occurred in all three lakes. The lower strata of water in L. Canton and L. Eureka were void of dissolved oxygen during the summer stagnation period. There was never a void of dissolved oxygen in Lake Decatur. During the summer stagnation period (June to mid-October 1978) for about 70 percent of the time the anaerobic zone in L. Canton and L. Eureka extended into the overlying water 14 to 20 feet (4.3 to 6.1 m) and 6 to 8 feet (1.8 to 2.4 m), respectively, from the lake bottom. The thermal stratification of the lakes was not a barrier to the anerobic zone penetrating the overlying waters.

In general, except during the summer stagnation periods, hardness, COD, and TOC in all lakes did not change in water column. In L. Decatur concentrations of pH, alkalinity, nitrate, sulfate, chlorine demand, and silica did not change on the vertical.

At the surface and mid-depth of L. Canton and L. Eureka, the turbidity, alkalinity, nitrate nitrogen, and sulfate concentrations were not significantly different. There was no difference in dissolved and total phosphorus concentration at the surface and mid-depth in each of the three lakes. For the upper layes (surface through mid-depth) the stable constituents were: ammonia-nitrogen in Lake Decatur, manganese in L. Decatur and L. Eureka, and chlorine demand in Lake Canton. The concentrations of these parameters at the deep waters were significantly greater than that at the upper half stratum in each lake.

Concentrations increasing with water depth were as follows: iron, standard plate count, and actinomycete densities in all three lakes; ammonia nitrogen, manganese, and silica in Lake Canton; ammonia nitrogen, chlorine demand, and silica in Lake Eureka; and turbidity in Lake Decatur. In contrast, algal densities in each lake decreased significantly with water depth.

In Lake Decatur, there were no trends for temporal variations of all water quality characteristics except algae, alkalinity, and turbidity. Turbidity in Lakes Decatur and Eureka were higher in the summer. However, no seasonal pattern of turbidity was observed in the deeper portion of Lake Canton. Alkalinity values in Lake Decatur were higher in the winter. Hardness, pH, COD, TOC, silica, and actinomycete in Lakes Canton and Eureka exhibited no temporal variations. The water in Lake Canton can be classified as moderate-hard. Lakes Decatur and Eureka are hard waters.

During the summer stagnation period in L. Canton and L. Eureka the hypolimnion became anaerobic. The phenomena at the lower strata of water in L. Canton and L. Eureka were the increases of turbidity, alkalinity, hardness, ammonia-nitrogen, dissolved and total phosphorus, iron, manganese, chlorine demand, silica, and SPC, and the decreases of pH, nitrate-nitrogen, and sulfate. These phenomena were due to bacterial fermentation and decomposition. At the surface waters, in contrast, alkalinity and silica decreased; and pH and algae increased due to active algal growths. *Aphanizomenon flos-aquae* and *Ceratium hirundinella* were the predominant algae in Lakes Canton and Eureka; respectively. *A. flos-aquae* dominated in Lake Decatur during the summer.

Vertical migration of silica in Lakes Canton and Eureka was much less than that of phosphorus and iron. The vertical limit of ammonia-nitrogen concentrations was consistent with the limit of the anaerobic zones. The releases of phosphorus and iron at the bottom of Lake Decatur were sporadic and unpredictable. Turbidity contents at the deep waters in Lake Decatur were higher in the summer due to sedimentation.

The magnitude of taste and odor in the three lakes was found to be a seasonal function. High TONs generally occurred during the period from May through October, the period of anoxic conditions in bottom waters of impoundments. Regardless of the magnitude of TONs for the raw waters, the TONs for the three water treatment plants finished waters ranged from 3 to 10 about 95 percent of the time.

Water temperature and sulfate concentrations in the three lakes were well within the IPCB limits. Ten surface water samples collected from Lakes Canton and Eureka exceeded the stipulated pH limit of 9.0. Nitrate nitrogen values in Lake Decatur exceeded the IPCB standard of 10 mg/1, only during mid-May to mid-June 1977 (about 3 percent of the total samples). Some samples taken from the mid-depth and deep stations of L. Canton and L. Eureka did not meet the ammonia nitrogen limits.

The concentrations of total phosphorus in the upper strata of L. Canton and L. Eureka exceeded the limit of 0.05 mg/1 for about 50 and 75 percent of the time, respectively. For the remaining stations, total phosphorus concentrations exceeded the limit more than 90 percent of the time. The iron concentrations of the upper stratum of Lake Canton violated the limit of 0.3 mg/1 about one-third of the time. At all other locations iron concentrations violated the limits 54 to 90 percent of the time. Manganese contents in the three lakes met the limit of 1.0 mg/1 most of the time except at the deep waters in L. Canton and L. Eureka. About one-third of samples from each lake exceeded 500 counts/ml of SPC limit.

Most of the water quality parameters exhibited no seasonal or yearly variation. There was no correlation between parameters except for TON vs. nitrate, sulfate, manganese, and chlorine demand. Parameter concentrations are the results of a very complex inter-reaction. Much of these inter-reactions are still unknown. Thus, modeling a complicated natural system should be discouraged until the nature and rates of interactions are better defined.

ACKNOWLEDGMENTS

The writers thank the personnel of the Water Quality Section of Illinois State Water Survey for collection and analyses of samples. They are Randy Rohman, Robert Grabel, Dave Hullinger, Gary Benker, Melbern Jannett, Wuncheng Wang, Dana Shackleford, Dave Beuscher, Tom Hill, Scott Bell, and Donald Schnepper. Robert Sinclair assisted in statistical analyses. Donald Schnepper reviewed the manuscript. The personnel of the water works at Canton, Decatur, and Eureka were most helpful in providing access to the lakes.

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Table 1. Averages or geometric means of observed data.

Parameter	Lake Canton			Lake Decatur			Lake Eureka		
	Surface	Mid-depth	Deep	Surface	Mid-depth	Deep	Surface	Mid-depth	Deep
Transparency, cm		113			80			83	
Temperature, °C	15.2	12.0	9.0	13.7	13.4	13.1	16.1	13.3	11.7
Dissolved oxygen, mg/l	9.5	6.0	2.9	9.9	9.1	8.0	9.6	6.4	4.1
Turbidity, NTU	2.8	2.6	7.3	4.5	6.5	9.8	2.3	3.5	7.4
pH, median	8.3	8.1	7.8	8.3	8.3	8.2	8.4	8.2	8.0
Alkalinity, mg/l as $CaCO_3$	135	145	190	195	196	197	233	242	263
Hardness, mg/l as $CaCO_3$	220	232	250	298	301	300	278	296	300
Nitrate-N, mg/l	0.79	0.83	0.61	3.58	3.58	3.58	2.71	2.78	2.73
Ammonia-N, mg/l	0.16	0.35	1.30	0.05	0.05	0.06	0.11	0.15	0.52
Phosphorus, mg/l									
Dissolved*	0.018	0.020	0.060	0.040	0.044	0.052	0.018	0.016	0.023
Total*	0.050	0.055	0.150	0.11	0.11	0.13	0.080	0.088	0.141
Iron*, mg/l	0.17	0.23	0.72	0.42	0.51	0.99	0.31	0.38	0.99
Manganese, mg/l	0.08	0.16	0.85	0.08	0.08	0.11	0.09	0.08	0.34
Sulfate, mg/l	52.0	51.0	44.6				40.3	40.0	34.6
Sulfate*, mg/l				48.5	48.0	47.0			
Chlorine demand, mg/l	5.2	6.0	9.6						
Cl_2 demand, mg/l				2.2	2.0	2.1	3.6	4.3	7.8
COD, mg/l	10.4			6.8			16.1		
COD*, mg/l		12.0	13.5		11.5	12.8		19.2	21.0
TOC*, mg/l	8.0	7.4	8.2	6.8	6.6	7.0	10.9	9.1	11.2
Silica, mg/l				5.7	5.0	5.4	5.3	6.3	7.8
Silica*, mg/l	2.7	3.4	6.1						
TON*	43	49	130	45	52	67	59	68	100
Algae*, organisms/ml	340	200	96	230	140	63	230	120	72
SPC*, organisms/ml	260	420	630	400	470	560	310	410	510
Actinomycetes*, organisms/ml	44	81	210	100	150	210	59	79	140

*Geometric mean