Rochester Committee for Scientific Information
Rochester, NY

RCSI Bulletin 28
Sewage Phosphates and Algae in Lake Ontario I

By: J. Roger Christensen, Neal Dunkleberg, Herman Forest, & David J. Wilson
June 1967

THE ROCHESTER COMMITTEE FOR SCIENTIFIC INFORMATION

Post Office Box 5236
River Campus Station
Rochester, New York 14627

#28(w)

SEWAGE PHOSPHATES AND ALGAE IN LAKE ONTARIO

I. Summary

In recent years, massive growths of algae in Lakes Erie and Ontario have become more frequent; they now constitute one of the most serious problems arising from pollution. Not only do immense slimy deposits of rotting algae wash up on lake shores, where they foul beaches and lakefront property, but the algae also interfere with industrial and municipal water supplies by clogging water intakes, filters, and pipes. They may seriously taint drinking water.

It is well established that massive algal growths occur in waters over-fertilized with nitrates and phosphates. In clear lakes and streams phosphate concentrations are usually lower than about 0.04 parts per million (ppm PO_4^{-3}) -- too low for heavy growth to take place. Massive growth, or blooms, characterized by a "pea-soup" appearance of the water and by thick scums of algae, require about five to ten-fold larger phosphate concentrations, or 0.20 to 0.40 ppm. A common source of phosphate in lakes and streams is raw sewage and effluents from sewage treatment plants. It has been estimated that 80% of all phosphate discharged into Lakes Erie and Ontario enters in sewage.

Heavy algal deposits on the beaches of Monroe County (such as the one which was a major factor in the closing of Webster Beach last August) and in Irondequoit Bay led the RCSI to determine phosphate concentrations in samples of some Monroe County waters during April and May. Altogether more than 70 samples from 23 locations have been assayed. Representative findings are as follows:

Location	Soluble ortho-phosphate (ppm)
Canadice Lake	0.10
Honeoye Creek south of U.S. 20	0.10
Irondequoit Creek downstream from sewage treatment plants (STP)	2.0 - 4.0
Allen's Creek below STP	5.0 - 10.0
Slater Creek below STP	6.0
Irondequoit Bay, mouth	1.0 - 3.0
Ontario and Durand-Eastman Beaches	0.2 - 0.5
Barge Canal, vicinity of Pittsford STP	2.0
Genesee River, mouth	0.3

The phosphate concentrations found in all of the locations listed above except for Canadice Lake and Honeoye Creek are ample to produce algal blooms, and greatly exceed the concentrations commonly found in unpolluted freshwater lakes. The especially high values in Irondequoit Bay and the Barge Canal account for the very heavy algal growths seen in these locations. The values for Lake Ontario beaches are remarkably high considering the dilution of river and stream waters in the lake, and are unquestionably large enough to explain the algal deposits seen during the summer; these are in part responsible for the state's decision to close our beaches this coming summer.

We have estimated from the quantity of sewage discharged by Monroe County into Lake Ontario each year, that about 4 million tons of algal growth could be supported by the phosphate contained in the sewage. If only 1% of this growth washed up on shore there would be slightly less than one ton of algae for every 10 feet of shoreline extending for 100 miles.

Our analyses prove that Lake Ontario and Irondequoit Bay, as well as several creeks which discharge into them, contain high phosphate concentrations. It can be reasonably concluded that sewage effluents are the primary source of the phosphate, and, furthermore, that the massive algal growths observed in the lake and the bay are a result of the phosphate discharged.

Up to now, state and county plans to fight pollution have been primarily concerned with eliminating disease-causing bacteria from sewage effluents. We believe that steps to eliminate phosphate must also be given immediate attention if the esthetic recreational and industrial values of the lake are to be restored.

II. Background Information

Last summer members of the Committee frequently noted massive wash-ins of the branching green attached alga Cladophora glomerata (L.) Kuetz. on our Lake Ontario beaches, and in recent years tremendous summer growths of algae in Irondequoit Bay have become the rule. Such crops of algae interfere very seriously with the uses of a lake. They produce bad odors and tastes in drinking water, clog the filters of the treatment plants, interfere with proper chlorination and coagulation, and produce growths on the pipes of the distribution system.[1] They interfere with the proper operation of industrial water treatment plants, ruin the bathing beaches (the closing of Webster Beach last summer was due in part to algae), and play havoc with the value of lake-front property.[2] Living algae do not cause diseases, but the foul odors, "pea soup" water, and the slimy piles of decaying refuse which they create are about as effective as the threat of disease in ruining the recreational values of a lake. Furthermore, algae can easily become consumers of oxygen, causing the suffocation of themselves and other aquatic life. Dead algae is, of course, oxygen demand, and may result in the removal of most of the dissolved oxygen from water, thereby making it uninhabitable for fish and other normal aquatic life.

This is not an isolated problem peculiar to the Rochester area. Lake Mendota and the Madison Lakes in Wisconsin have yielded "excessive and obnoxious growths" of algae,[3] and Lake Washington in Seattle has exhibited the same thing.[4] The problem occurs in the southern United States,[5] in England,[6] and in Europe.[7] The effects of these prodigious growths of algae in Lake Erie have been disastrous.[8] A recent government report describes the problem in great detail, and remarks that the growth of algae is by far the most serious threat to water quality in Lake Erie.[9]

Neil and Owen, of the Ontario Water Resources Commission, published an elegant study of the conditions required for the production of the heavy growths of Cladophora algae observed along certain sections of the shoreline of the Great Lakes, particularly Lake Erie and Lake Ontario.[10] They noted that health agencies have received complaints of accumulations of rotting, foul-smelling algae on the shores of Lake Erie and Lake Ontario since the early 1930's, pointed out the tastes and odors produced in drinking water by the decomposing algae, and indicated that the drifting algae materially reduced the capacity of city and industrial water supply facilities. On July 17, 1963, these authors surveyed a 50-mile stretch of Lake Erie shoreline west of Fort Erie, and one can readily calculate from their description that somewhere between one and two hundred thousand tons of Cladophora algae had accumulated during this one wash-in.

Casper reported an algae "bloom" (a dense growth of floating and suspended algae) in Lake Erie in September 1964, north of Sandusky, Ohio. Over an area greater than 800 square miles there was a surface "pea soup" scum about two feet thick. The total mass of algae (wet weight) produced in this single bloom can readily be calculated; it must have been of the order of 40 million tons.[11]

Beeton notes that the mean plankton (suspended organisms, mainly algae) production in Lake Erie has tripled in recent years, and that in Lake Ontario it has doubled. He points out that the areas of shoreline in both lakes on which extensive growths of Cladophora (attached) algae occur have markedly increased.[12]

These massive growths of algae are due to the overfertilization of the water with nitrates and phosphates, both of which are important plant foods. As a rule, phosphate is the limiting factor in algal growth, occurring in concentrations of the order of 0.07 parts per million PO_4^{-3} (ppm) in unpolluted rivers and 0.01 to 0.04 ppm in fresh-water lakes.[6] The massive algal blooms in Lake Mendota, Wisconsin, have been traced to the loading of the lake with nitrates and phosphates from sewage.[3] Experiments on the Nussensee in Austria demonstrated that fertilization of this water with phosphate yields "mass development of algal vegetations."[7] Lake Erie, most plagued of the Great Lakes by algae, contains an average phosphate concentration nearly 12 times that of Lake Superior and 6 times that of Lake Huron,[13] nearly 0.2 ppm, roughly ten times the level found in normal, unpolluted lakes. Neil and Owen demonstrated that application of phosphate to unpolluted Lake Huron waters which had been seeded with Cladophora (no Cladophora occurred native to the site) resulted in the establishment of a sizable area of growth. These studies indicate that in all probability phosphate is the limiting factor in the growth of Cladophora.[10]

The report of the federal government's scientists at the congressional hearings on water pollution here last summer included a large amount of data taken locally by Mr. Lee Townsend and his co-workers here in the Federal Water Pollution Control Administration. This report stressed the importance of the pollution of Lake Ontario and Irondequoit Bay with phosphates and nitrates, and indicated that this pollution was responsible for the massive growths of algae which were occurring. In the hue and cry over bacterial pollution from undisinfected sewage, however, sight was lost of this aspect of the federal report.

The RCSI has begun an investigation of the problem of phosphate pollution; where does it come from, how much of it is there, where does it go, and what does it do? This report presents (1) background material; (2) data on phosphate levels in the river, at the mouth of the Bay, in the lake and in three area streams; and (3) rough estimates on the phosphate burden discharged by the Durand-Eastman plant and by the county as a whole, together with approximate information on the total amount of algae this burden would produce in the lake when a steady state is reached.

The approximate concentrations of phosphate in various types of municipal sewage are as follows:[14]

	No treatment	Primary	Secondary	Tertiary (liming)
PO_4^{-3} concentration (ppm)	35	32	25	1-2

The average phosphate loading per person per year is approximately 4.1 kilograms (9 lb.) per capita per year.[14]

III. Phosphate Levels in Some Waters of Monroe County. Data.

Ortho-phosphate and total phosphate analyses were carried out by the molybdenum blue-stannous chloride method as described in a manual published by the Federal Water Pollution Administration,[15] or by the procedure given in the Hach Company's Field Laboratory Kit Manual.

Location	Date	PO_4^{-3} (ppm) (ortho unless otherwise marked)	
Red Creek, seven sites along the lower mile and a half	16 Apr.	.4, .4, .4, .4, .4, .3, .2	
Irondequoit Creek, just south of Highway 96	18 Apr.	.2	
" " ¼ mile " " " "	18 Apr.	.2	
" " at Washington Street	15 Apr.	1.8	1.8 (total)
	23 Apr.	1.6	
	1 May	3.1	
" " at Penfield Road	15 Apr.	2.8	3.3 (total)
	23 Apr.	2.6	
	1 May	4.8	
" " at Browncroft Boulevard	15 Apr.	2.2	2.2 (total)
	23 Apr.	2.3	
	1 May	3.7	
" " at Thompson Creek	15 Apr.	2.0	2.1 (total)
	23 Apr.	2.4	
" " at Empire Boulevard	15 Apr.	2.2	2.4 (total)
	23 Apr.	2.4	
	1 May	3.5	
Mouth of Irondequoit Bay	22 Apr.	2.3	
	29 Apr.	3.5	
	4 May	0.4	
Allen's Creek at Nalge plant, below Brighton's Allen's Creek STP	15 Apr.	5.8	6.2 (total)
	23 Apr.	5.1	
	1 May	10.5	
Thompson Cr., 50 yds from Irondequoit Cr.	15 Apr.	1.0	1.8 (total)
Barge Canal, vicinity of the outfall of Pittsford's STP on Highway 96	18 Apr.	2.0, 2.4, 2.0	
Slater Cr. At Ling Rd., below Greece's Latta Rd. STP	22 Apr.	6.0	
Outlet of Slater Cr. at Little Pond, creek flow greatly augmented by cooling water from Russell Station	22 Apr.	0.6	
	29 Apr.	0.7	
	4 May	1.0	
Ontario Beach	22 Apr.	0.2	
	29 Apr.	0.35	
	2 May	0.55	
	4 May	0.15	

Location	Date	PO_4^{-3} (ppm) (ortho unless otherwise marked)
Durand-Eastman Beach	22 Apr.	0.30
	29 Apr.	0.22
	2 May	0.50
	4 May	0.30
	5 May	0.40
Irondequoit Bay, north end	29 Apr.	2.9, 2.5
Lake Ontario, vicinity of Durand-Eastman STP outfall, and SE toward the Beach	29 Apr.	0.40, 0.25, 0.20, 0.55 0.40, 0.20, 0.25
Mouth of Genesee River	29 Apr.	0.24
	4 May	0.30
Summerville Beach	4 May	0.30
Webster Beach, 50 ft W. of creek outlet	5 May	0.40
Creek at Webster Beach	5 May	0.75
Canadice Lake	7 May	0.10, 0.10
Upper Honeoye Cr. S. of U.S. 20 at Richmond Mills Rd.	29 Apr.	0.10

The following data on the Genesee River and Lake Ontario are taken from the State Health Department's Periodic Report of the Water Quality Surveillance Network 1960 through 1964:[18]

			PO_4^{-3} (ppm)
Lake Ontario - Rochester	1963		
		Maximum	.63
		Minimum	.45
		Mean	.55
		Entries	11
	1964		
		Maximum	.5
		Minimum	.1
		Entries	2
Genesee River - Chili	1963		.19
	1964		
		Maximum	.2
		Minimum	.12
		Entries	2

The following data on Lake Ontario were obtained on lake cruises carried out by the Federal Water Pollution Control Administration, and reported at the Congressional hearing here last summer. This group found phosphate concentrations in Irondequoit Bay of 1 to 3 ppm.

	Western Section	Central	Eastern
Total Phosphate	.03 - .10	.03-.08	.02-.06
Average Total Phosphate	.05	.04	.04

IV. Interpretation

The results on Canadice Lake, upper Honeoye Creek, upper Irondequoit Creek, and the Genesee River at Chili establish that the phosphate levels in area waters due to natural sources, agricultural run-off, etc., are in the range from 0.1 to 0.2 ppm. The results on lower Irondequoit Creek, Slater Creek, the Barge Canal, and Allen's Creek all demonstrate the occurrence of phosphate levels roughly 10 times greater downstream from our sewage treatment plants than are found upstream from them. The high concentration of phosphate at the mouth of Irondequoit Bay is ascribed to the sewage carried by streams tributary to the Bay and by sewage discharged directly into the Bay itself. According to the federal report presented at the congressional hearings last summer, the Bay receives the sewage from a population of over 100,000.

V. Phosphate Burden from Rochester and Monroe County.

Monroe County recieves approximately 2.5 billion tons of rainfall each year. If we use a figure of 0.1 ppm (the Honeoye Creek and Canadice Lake figures) as the concentration of phosphate due to natural sources, this leads us to a figure of about 250 tons of phosphate per year which would come off of Monroe County in the absence of man. In fact, this figure should be somewhat lower, due to water losses from evaporation and transpiration. Even so, this maximum natural loading, as we shall see, is only about 5 to 10% of the phosphate loading which comes from the sewage plants of Monroe County.

Rochester discharges roughly 100 million gallons of primary-treated sewage per day into Lake Ontario. This corresponds to an annual phosphate load of 4,600 tons, if we assume that this is typical primary effluent.[14]

$$10^8 \text{ gal/day} \times 365 \text{ days/year} \times 8 \text{ lb/gal} \times 32 \times 10^{-6} \text{ ppm } PO_4^{-3} \times \frac{1}{2000} \text{ ton/lb}$$

$$= 4{,}600 \text{ tons phosphate}$$

An alternative method of doing the calculation, assuming a sewered population of 300,000 and an annual per capita phosphate load of 9 lb yields an annual total phosphate burden of about 1,400 tons.

If we assume an additional sewered population of 200,000 in the county, and assume (optimistically) that their sewage all receives secondary treatment, this gives an additional 2,400 tons as an upper limit, or 730 tons as a lower limit. We note that neither primary treatment nor secondary treatment remove very much phosphate from sewage. The total phosphate burden from the county's sewage plants lies somewhere between 2,100 and 7,000 tons/year. Let us more or less arbitrarily choose 3,500 tons as a figure for further calculation.

These data establish that by far the largest source of phosphate pollution of Lake Ontario in Monroe County is municipal sewage. The results obtained on our local lake waters, of the order of 0.4 ppm, are far in excess of the levels found for the lake as a whole (0.05 approximately), and are also much larger than the levels of 0.01 to 0.04 ppm commonly found in unpolluted freshwater lakes. The concentration of phosphate in the Rochester Embayment is double the average phosphate concentration in Lake Erie, which routinely suffers from massive algal growth.

The per cent of phosphorus as phosphate in dry algae and higher aquatic plants is approximately 0.75%, although the figure varies from species to species, and a single species may show considerable variability.[16] The wet weight of algae is generally 8 to 10 times the dry weight.[16] Therefore the roughly 3,500 tons of phosphate we discharge into the lake per year would, if completely utilized, raise about 4.2 million tons of algae. (Actually the situation is even worse than these figures indicate, for the phosphate is not used only once, but is recycled through several crops of algae before it is finally washed down the St. Lawrence River. Phosphate is not destroyed, although some of it is precipitated on the lake bottom; a rough estimate of the mean lifetime of water in the lake is 8 years; this is computed from data given by Beeton and Chandler.[13]

Lake Ontario	Mean discharge	233,900 ft^3/sec
	Mean depth	283 ft
	Water surface	7,520 sq mi

If we take 4.2 million tons of algae per year as the crop for which Monroe County is responsible, and assume that roughly 1% of this algae is washed up on 100 miles of lake shoreline, this would result in approximately 1,600 lb of algae (wet weight) for every 10 feet of shoreline. (We note that Cladophora grows only near the shoreline, and hence is particularly prone to wash in.) Wash-ins of this magnitude will not occur until the phosphate concentration in the lake has had more time to build up; this should require of the order of 5 years or so.

We note that some of the blue-green algae which occur in over-fertilized waters have been demonstrated to be toxic to animals drinking this water.[17] (Microcystis aeruginosa and Anabaena flos-aquae, particularly.)

VI. Conclusions and Future Work

This background paper and first report of phosphate data obtained by the RCSI demonstrates the great seriousness of the pollution of Lake Ontario with phosphate. It shows that the major factor in this type of pollution here is municipal sewage, rather than natural or agricultural sources. Because the water of the Rochester Embayment does not immediately mix with all of the lake waters, the local condition can be (and has been) far worse than that in the lake as a whole. Our conclusions are entirely consistent with the earlier findings of the Federal Water Pollution Control Administration group here under Lee Townsend. It should be remarked, of course, that the phosphate problem is a Great Lakes water shed problem, not just a Monroe County problem. If New York and Ontario do not take vigorous corrective measures in the immediate future, Lake Ontario as we now know it will be destroyed, turned into pea soup rimmed with stinking mounds of rotting algae, and unfit for drinking, industrial use, or recreation. The economic impact of such a disaster would be major. We remark that the probability of such a disaster was forecast by one of us in testimony at the congressional hearing on water pollution here last summer, and that his conclusions were in agreement with those reached in the extensive survey carried out by the FWPCA group.

Further reports on the phosphate problem will be concerned with data on the lake, especially in the vicinity of the Durand-Eastman plant; the lower Genesee; with seasonal variations during the next few months; and with the technology and economics of phosphate removal.

We are indebted to Ray Huther, of the Monroe County Conservation Council and the Committee, for assistance in sampling, and to Martha Wertlieb for the publication of the report.

J. Roger Christensen
Neal Dunkleberg
Herman Forest
David J. Wilson

June 1967

BIBLIOGRAPHY

1. C.M. Tarzwell, in Limnology in North America, D.G. Frey, ed., University of Wisconsin Press, 1963, p. 653. This book will henceforth be referred to as LNA.
2. A.F. Bartch and W.M. Ingram, Pub. Works 90, No. 7, pp. 104-110 (1959).
3. A.D. Hasler, LNA, p. 87.
4. W.T. Edmondson, LNA, p. 371.
5. J.L. Yount, LNA, p. 269.
6. G.E. Hutchinson, A Treatise on Limnology, John Wiley and Sons, 1957.
7. F. Ruttner, Fundamentals of Limnology, University of Toronto Press, 1953.
8. A.M. Beeton, Trans. Amer. Fish. Soc. 90, 153 (1961).
9. Report of the Lake Erie Enforcement Conference Technical Committee, March, 1967. This reference gives a particularly clear picture of the state of the lake.
10. J.H. Neil and G.E. Owen, Pub. No. 11, Great Lakes Research Division, the University of Michigan (1964), p. 113. These publications will hence forth be referred to by publication number, GLRD.
11. V.L. Casper, Pub. No. 13, GLRD (1965), p. 29.
12. A.M. Beeton, Pub. No. 15, GLRD (1966), p. 1.
13. A.M. Beeton and D.C. Chandler, LNA, p. 540.
14. L.W. Weinberger, D.G. Stephan and F.M. Middleton, Ann. N.Y. Acad. Sci. 136, 131 (1966).
15. R.J. Lishka, in Chemical Analyses for Water Quality, FWPCA, (1967).
16. P.S. Welch, Limnology, McGraw-Hill, 1952.
17. K.D. Carlander, R.S. Campbell and W.H. Erwin, LNA, pp. 329,331.
18. Periodic Report of the Water Quality Surveillance Network 1960 Thru 1964, New York State Department of Health.