

PHOSPHORUS REMOVAL IN OHIO WASTEWATER TREATMENT PLANTS WITHIN THE LAKE ERIE BASIN¹

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ABSTRACT. Eutrophication in the Great Lakes, especially Lake Erie, has caused the creation of regulations limiting the phosphorus that may be discharged by wastewater treatment plants to 1 mg P/L. Municipal plants in Ohio have made significant improvements in their ability to remove wastewater phosphorus during treatment. During 1980, the flow-weighted average concentration of phosphorus in wastewater discharges for the Ohio Great Lakes Basin was 1.57 mg P/L, based on data from the Ohio Environmental Protection Agency (OEPA). When 11 more plants reach the goal of the regulations, the average will drop to 1.0 mg P/L. Achievement of this goal will make wastewater discharges a minor contribution (about 6%) of the total phosphorus entering Lake Erie.

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INTRODUCTION

Awareness of the eutrophication of the Great Lakes was heightened during the 1960s when excessive algal production led to unsightly "blooms" and decreased recreational use of the Lakes. In addition, the decay of these algal blooms utilized oxygen from surrounding waters that was needed by fish and other aquatic life. Consequently, the control of algae was found to be essential in maintaining an aqueous environment that was both aesthetically pleasing and suitable for the other aquatic species.

Phosphorus has been identified as the key element in the control of excessive algal growth in Lake Erie and most surface waters (Lee et al. 1978). Inputs of phosphorus to the Great Lakes have generally been attributed to non-point sources such as runoff from agricultural and urban lands as well as the atmosphere, and to point sources such as industrial and municipal wastewater treatment plant effluents

(Phosphorus Management Strategies Task Force 1980). The non-point source discharges are considered much more difficult to control, therefore, the major effort has been directed toward controlling point source discharges.

In 1972, a "Water Quality Agreement" was signed between Canada and the United States (International Joint Commission 1972). Part of that agreement reads as follows: "The phosphorus concentrations in effluent from municipal waste treatment plants discharging in excess of 1 million gallons per day, and from smaller plants as required by regulatory agencies, shall not exceed a daily average of 1 mg/L into Lake Erie, Lake Ontario and the International Section of the St. Lawrence River."

The basic regulatory mechanism for controlling these discharges in the United States is the National Pollutant Discharge Elimination System (NPDES). Under this system, the states are given authority to issue permits which incorporate effluent limitations designed to meet established water quality standards. The water quality standards established by the states must be acceptable to the U.S. Environmental Pro-

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tection Agency. Dischargers are required to analyze their discharges and report the results to the states.

Ohio wastewater treatment plants that discharge one million gallons per day (MGD), or more, to the Lake Erie Basin have NPDES requirements that limit the phosphorus concentration in their effluent to 1.0 mg/L. This limit can generally be achieved by using chemicals which coagulate and precipitate phosphorus during treatment. The increasing use of chemical coagulants, along with the general upgrading of wastewater treatment during the 1970s, have caused a reduction in the concentration of phosphorus in treatment plant effluents. The purpose of this paper is to evaluate the progress being made in the State of Ohio toward reducing the phosphorus loading to Lake Erie via management of the NPDES system.

METHODS AND MATERIALS

Sixty-eight wastewater treatment plants in the Ohio Great Lakes Basin discharged one million gallons of wastewater per day or greater in calendar year 1979 or 1980. The Ohio EPA receives the mean daily concentration of effluent phosphorus and daily flow data from these plants. From these data, Ohio EPA calculates annual means for daily phosphorus loading, daily flow, and flow-weighted phosphorus concentration for each plant (S. Thompson, Technical Records Section, Ohio EPA, pers. comm.).

For this paper, an "excess" P load was calculated for each plant as the extent to which that load deviated from the load that would occur if the plant effluent were exactly 1.0 mg/L: Excess P load = (P load) - (P load at 1.0 mg/L). The excess P load will be greater than zero (i.e. a positive number) when the effluent concentration is greater than 1.0 mg P/L, and will be a negative number when the effluent concentration is less than 1.0 mg P/L. All data were tabulated in terms of elemental phosphorus.

The 68 plants were then ranked in order of excess P load. All plants with a negative excess P load were removing more phosphorus than required and were labeled a "credit" group. The plants with a positive excess P load were not removing as much phosphorus as required, and were split into 2 groups. Of these, the plants with the smallest excess P load were combined until their total excess P load was equal to that of the credit group. This second group was called the "offset" group because, when combined with the credit group, their net excess P load was zero. The remaining plants were placed in a third group labeled the "debit" group.

RESULTS

In 1980, 27 plants achieved a phosphorus concentration in their effluent of less than 1.0 mg/L and thus formed a "credit" group consisting of plants that removed more phosphorus than required. Table 1 lists these 27 plants with their annual average phosphorus concentrations, flows, and excess P loads, ranked by the magnitude of their excess P loads. For comparison, the 1979 excess P loads are also presented.

The excess removal of phosphorus by the credit group of -477.9 kg P/day was then applied against those plants which least exceeded the loading equivalent to 1.0 mg P/L. This second group of 31 plants formed an "offset" group and are listed in table 2. Their excess discharge of 444.9 kg of phosphorus per day approximately equals the "credit" in table 1. The 57 plants in the credit and offset groups, therefore, achieved an overall weighted average of 1.0 mg P/L in their effluent during 1980.

The remaining group of 11 plants discharged the highest excess loading of phosphorus and formed the "debit" group (table 3). These 11 plants had an excess phosphorus load of 1407 kg/day and consequently had a significant effect on the statewide weighted-average phosphorus concentration.

Within each group, a flow-weighted-average of the effluent phosphorus concentration was calculated from the total of the daily flows and total of the daily loads. These averages are given in table 4.

DISCUSSION

In the early 1970s, the concentration of phosphorus in influent wastewater averaged about 10 mg/L (Metcalf and Eddy, Inc. 1972). Phosphorus removal in wastewater treatment was generally limited to the amounts removed by sedimentation in primary treatment and by biological uptake in secondary treatment. Few plants practiced chemical removal of phosphorus. Gakstatter et al. (1978), reporting results

from the National Eutrophication Survey in 1972–1975, found that only about 4% of the plants in the survey practiced chemical removal of phosphorus. The plants that did not practice chemical removal of phosphorus (and were not in areas where laundry detergent phosphorus was banned) had a mean concentration of 7.0 mg P/L in their effluent.

Since the National Eutrophication Survey, the techniques of phosphorus removal during wastewater treatment have been developed and instituted at many plants, especially in the Great Lakes area. The weighted-average concentration of phosphorus in wastewater discharges for the

Ohio Great Lakes Basin was 1.57 mg P/L in 1980. This same analysis of 1979 data found a weighted-average concentration of 2.03 mg P/L. Both represent a significant decrease from the concentrations reported by Gakstatter et al. (1978).

The changes in excess load from one year to the next are useful to identify the plants that achieved the most progress. For example, by comparison of the 1979 and 1980 excess load tables, the reduced concentration in 1980 can be largely attributed to 7 plants. The Cleveland Easterly and Toledo plants increased the size of their credit by decreasing the concentration of phosphorus in their effluents between 1979

TABLE 1
"Credit" group of Ohio municipal wastewater treatment plants in Lake Erie Basin.

Plant	1980 Annual Average			1979
	Flow (MGD)	Effluent P (mg/liter)	Excess P Load* (kg/day)	Excess P Load (kg/day)
Cleveland Easterly	116.7	0.45	-242.9	-206.9
Toledo	87.9	0.61	-129.8	-33.8
Lorain	15.4	0.64	-21.0	+99.3
Sandusky	10.9	0.74	-10.7	-7.9
Lakewood	10.4	0.79	-8.3	-14.3
Fremont	5.6	0.64	-7.6	-8.1
Painesville	4.4	0.64	-6.0	-3.3
Lima	14.2	0.89	-5.9	-11.7
Avon Lake	4.4	0.68	-5.3	-2.1
Willoughby-Eastlake	7.2	0.81	-5.2	-1.6
Perrysburg	1.8	0.31	-4.7	-3.5
Van Wert	2.8	0.65	-3.7	-2.3
Archbold	1.5	0.36	-3.6	+4.4
Sheffield-French Creek	2.1	0.61	-3.1	-2.0
Medina 300	1.3	0.41	-2.9	-0.3
Geneva	1.2	0.40	-2.7	-2.0
Maumee River-Lucas Co.	6.0	0.89	-2.5	+3.6
Tiffin	2.9	0.79	-2.3	-3.3
Conneaut	1.6	0.67	-2.0	-1.7
Oberlin	1.6	0.70	-1.8	-0.1
Bryan	1.8	0.82	-1.2	+8.5
Napoleon	1.4	0.78	-1.2	+12.3
Ravenna	1.7	0.87	-0.8	-0.5
Bowling Green	4.4	0.95	-0.8	+3.7
Oregon	2.2	0.91	-0.8	-0.8
Port Clinton	1.5	0.89	-0.6	-1.4
Chagrin Falls	1.2	0.89	-0.5	-0.2
"Credit" Group Totals	314.1		-477.9	

*Excess Load (kg/day) = Flow (MGD) × [Effluent P (mg/L) - 1] × 3.785 (L/gal)

TABLE 2
 "Offset" group of Ohio municipal wastewater treatment plants in Lake Erie Basin.

Plant	1980 Annual Average			1979
	Flow (MGD)	Effluent P (mg/liter)	Excess P Load (kg/day)	Excess P Load (kg/day)
Lake Co.-Mentor	6.9	2.61	42.1	39.5
Medina 5	3.2	4.23	39.1	9.8
Bedford	2.9	4.28	36.0	5.5
Strongsville	1.9	5.82	34.7	35.5
Delphos	2.4	4.53	32.1	26.4
Middleburg Heights	1.9	5.00	28.8	-4.0
Brookpark	1.4	5.77	25.3	21.1
Findlay	7.4	1.87	24.4	43.1
Medina 100	1.5	5.06	23.1	27.3
Bucyrus	1.9	3.75	19.8	71.4
North Royalton	1.2	4.88	17.6	13.5
Lake Co.-Madison	1.5	3.72	15.4	16.8
Clyde	1.0	5.20	15.9	21.0
Vermillion	1.2	4.02	13.7	29.1
Montpelier	1.2	3.92	13.3	6.3
Kent	2.1	2.45	11.5	29.2
St. Mary's	1.0	3.74	10.4	41.4
Defiance	3.2	1.82	9.9	9.0
Fostoria	4.2	1.37	5.9	3.8
North Olmstead	5.5	1.26	5.4	5.8
Ottawa	1.0	2.25	4.7	4.6
Bellevue	0.9	1.92	3.1	11.2
Brecksville	1.5	1.45	2.6	-1.2
Amherst	1.3	1.51	2.5	4.5
Twinsburg	1.0	1.56	2.1	-0.3
Summit 15	1.8	1.29	2.0	18.8
Summit 6	1.5	1.20	1.1	4.7
Ashtabula	5.0	1.05	1.0	2.4
Bedford Heights	2.6	1.09	0.9	4.2
Upper Sandusky	1.3	1.11	0.5	5.7
"Offset" Group Totals	71.4		444.9	

and 1980. The Lorain plant moved from the debit group in 1979 to the credit group in 1980, and the first 4 plants in the debit group made sizeable reductions in their phosphorus loading between 1979 and 1980.

Although the Water Quality Agreement required each plant to achieve 1.0 mg P/L in their effluent, the calculation of an overall average (as if all plants discharged into a single pipe) is also a realistic way to review progress within a state. The division of the 68 Ohio plants into 3 groups by excess load is useful to identify those plants

that should receive the highest level of attention. The largest potential for further reductions in the phosphorus loading to the Lake Erie Basin from Ohio plants lies within the debit group since these plants discharge the highest excess load of phosphorus. A closer examination of several of the debit plants in the fall of 1981 revealed the following information:

1. Cleveland Southerly is in the middle of a major construction project to upgrade its operation by adding a second stage of aeration and final filtration for better solids removal. This project should be completed

TABLE 3
 "Debit" group of Ohio municipal wastewater treatment plants in Lake Erie Basin.

Plant	1980 Annual Average			1979
	Flow (MGD)	Effluent P (mg/liter)	Excess P Load (kg/day)	Excess P Load (kg/day)
Cleveland Southerly	96.1	1.95	345.6	692.0
Cleveland Westerly	29.8	2.75	197.4	538.6
Akron	77.8	1.66	194.4	303.4
Euclid	19.2	2.65	119.9	324.5
Berea	7.9	4.57	106.8	40.4
Wapakoneta	1.6	18.3	104.8	80.6
Elyria	8.1	4.14	96.3	128.6
Solon	2.2	10.98	83.1	94.1
Rocky River	10.2	2.49	57.5	64.4
Norwalk	2.2	7.18	51.5	44.1
Medina 200	1.7	8.72	49.7	50.1
"Debit" Group Totals	256.8		1407.0	

by early 1983. A separate project at this plant involves building the Southwest Interceptor and Cuyahoga Valley Interceptor. These interceptors will allow the plants at Berea, Brookpark, Brecksville, Maple Heights, Middleburg Heights, and Strongsville to be abandoned and to send their wastewater to the Southerly Plant; completion is expected in 1985.

2. Cleveland Westerly added new clarifiers in 1981 to improve solids removal. Because wastewater solids typically contain 2-3% phosphorus, this change will significantly improve overall phosphorus removal at this facility.

3. Akron has recently been adding a polymer to flocculate and remove suspended solids, and phosphorus removal has also improved substantially. Its effluent P concentration is now about 0.8 mg P/L.

4. Euclid is upgrading its microscreens to improve solids removal and thereby improve phosphorus removal. In addition, chemicals are being added to remove phosphorus, and the effluent P concentration is now about 1 mg P/L.

5. Solon is adding chemicals to remove phosphorus during wastewater treatment and, in recent months, has reduced its effluent P concentration to about 7 mg P/L.

TABLE 4
 Summary of phosphorus loading to Lake Erie from Ohio municipal wastewater treatment plants during 1980.

Plant Group	Total Flow (MGD)	Total Excess Phosphorus Load (kg/day)	Annual Mean of the Flow-Weighted Daily Concentration of Effluent Phosphorus (mg/L)
Credit Group	314.1	-477.9	0.60
Offset Group	71.4	444.9	2.65
Debit Group	256.8	1407.0	2.45
Entire Ohio Lake Erie Basin	642.3	1374.0	1.57

6. Medina 200, as well as Medina 100, have been diverted to Medina 500, a new plant that has phosphorus removal capability and is discharging considerably less phosphorus than previously.

The improvements that occurred in 1981 have reduced the excess phosphorus load at Akron from 194.4 kg/day in 1980 to -16 kg/day in 1981. At Euclid, the excess load decreased from 119.9 to 0 kg P/day and, at Solon, from 83.1 to 13 kg P/day. These reductions of 210.4, 119.9, and 70.1 kg P/day, respectively, mean a decrease in the excess load to Lake Erie of 400 kg P/day. This reduction decreased Ohio's 1980 excess load of 1374 kg P/day to about 974 kg P/day in 1981, a 30% reduction. The other construction plans mentioned above should also cause an additional and significant reduction in the phosphorus loading from these debit-group plants within a few years.

The phosphorus limit of 1.0 mg P/L for these 68 plants, which discharge about 640 MGD, will mean a total load of 2420 kg P/day or 884 metric tons P/year. For comparison, the total estimated phosphorus input to Lake Erie from all sources was 14,855 metric tons P/year for 1980 (excluding shoreline erosion and sediment redissolution) (Great Lakes Water Quality Board 1981).

The foregoing data demonstrate the progress that has been made by Ohio's wastewater treatment plants in the Lake Erie Basin toward achieving phosphorus reductions in their effluents. At the vast majority of the plants, the concentrations of phosphorus discharged during 1980 were considerably lower than the concen-

trations reported before chemical removal of phosphorus became commonly practiced. About 40% of the plants were below 1.0 mg P/L during 1980 while another 44% had excess phosphorus discharges which were small enough to be offset by the more efficient plants. The remaining plants will soon upgrade their facilities or will be abandoned with their flows diverted to better facilities. During 1983, Ohio's municipal wastewater treatment plants should, on average, be in compliance with their phosphorus limits. Achievement of this goal will decrease the effect of wastewater discharges on eutrophication of Lake Erie and will make such discharges a minor contribution (about 6%) to the overall phosphorus load.

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