Restoration Of Water Quality In Lake Weston, Orlando, Florida

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ABSTRACT

Lake Weston, an 11.3-ha, 15-m deep eutrophic lake in Orlando, Florida, was polluted primarily by effluent from a waste treatment plant. It was treated by Clean-Flo Laboratories, Inc., with aeration equipment and a non-toxic, soluble calcium compound[1] to make phosphorus unavailable for plant assimilation. Results were compared to Lake Lovely, a control lake in which sewage was upgraded but no treatment given, and Lake Lawne, which received alum treatment, dredging, and draw-down.

INTRODUCTION

Water quality parameters were monitored by the Orange County Pollution Control Department on a monthly basis for 1 year before and 18 months after initiation of the aeration equipment on Lake Weston. All lakes had been slowly recovering prior to treatment after the waste treatment plant effluent was diverted to another facility. Water quality in Lake Weston rapidly improved following initiation of the aeration equipment, and again after adding calcium.

Initially, submergent aquatic macrophytes were not abundant, but the lake had a heavy green planktonic algae growth (coccoid). As chlorophyll-a decreased, the green coccoidal algae were replaced by diatoms. At this point, electric power interruptions to the aeration equipment occurred, and the lake reverted back to green algae. During the power interruptions, chlorophyll-a and bacterial plate count digressed, but not severely, compared to initial values.

By the end of the 18-month period, predetermined 3-year water quality goals for dissolved oxygen, total nitrogen (TKN), ammonia nitrogen, ortho phosphate, and BOD were exceeded, with the remaining goals for chlorophyll-a and total phosphate closely approached.

METHODS AND MATERIALS

Studies conducted on Lake Weston during 1972-75 showed a high level of nutrient content and poor water water quality.

It was determined that the cause of the eutrophication problem was stratification resulting in an inadequate supply of oxygen on the bottom, inability of the lake to rid itself of noxious gasses, and an accumulation of anaerobic acids. This caused phosphorus precipitate to redissolve on the bottom (6), and the low oxygen caused an apparent decline of fish health.

Four 0.5-Hp aeration systems were initiated on 5 June 1975. Each system consists of a 0.5-Hp oilless piston air compressor enclosed in a metal cabinet on shore. Polyethylene tubing connects each compressor to a microporous ceramic diffuser which sets on the lake bottom at four evenly spaced points in the lake. The tubing is weighted to lay on the lake bottom. Previous tests indicated that each system moves approximately 7660 liters per minute of bottom water up to the surface in a 0.7 to 1.2 m diameter column. As air bubbles emerge from the ceramic

[1]Clean-Flo Aeration/Circulation System™, and Clean-Flo Lake Cleanser™ (EPA Reg. No. 33436-1), manufactured by Clean-Flo Laboratories, Inc., Hopkins, Minnesota. Patents pending.

diffuser, some of the air dissolves directly into the water, increasing its bouyancy and causing it to rise to the surface. Bubbles which do not dissolve drag water to the surface due to surface tension. Thus, a current is developed along the bottom toward the diffuser, and then up in a column to the surface, where it spreads out and flows along toward the shore in a 0.25 cm thick sheet. As measured in tests on other lakes[2] four systems in Lake Weston would cause complete rollover of the lake approximately once every 12 days.

As the water flows along the surface, oxygen is absorbed while ammonia, hydrogen sulfide, methane, and carbon dioxile are diffused into the atmosphere. Acid-producing anaerobic bacteria are destroyed by exposure to ultraviolet light on the surface film, and by oxygen toxicity when the bottom water becomes oxygenated (3,9).[3]

Phosphate is continuously combining with natural calcium in the water, but redissolves when it reaches the anoxic bottom water. Upon the removal of the acid environment and the carbon dioxide and manganese from the bottom water, phosphate is then able to combine with natural calcium in the water and precipitate out of solution (1,4). Since natural calcium is in the carbonate form, and therefore slow to combine with phosphorus, 6136 kg of soluble calcium compound was added 3, 8, and 11 months after start up to accelerate the phosphorus removal (10 mg • liter^{-1} each time). Results in the figures expressed as mg/l represent mg•liter^{-1}.

RESULTS AND DISCUSSION

Immediately following initiation of the aeration equipment, all of the monitored water quality parameters improved except chlorophyll-a (Figure 1).

[2]Laing, R. L. and S. R. Adams. 1975. Oxygen transfer constant (K_La) for Clean-Flo Aeration/Circulation Systems. In-house publication, Clean-Flo Laboratories, Inc., Hopkins, Minnesota. 15 p.

[3]Laing, R. L. 1976. The effect of Aeration/Circulation of lakes upon pathogenic bacteria. In-house publication, Clean-Flo Laboratories, Inc., Hopkins, Minnesota. 2 p.

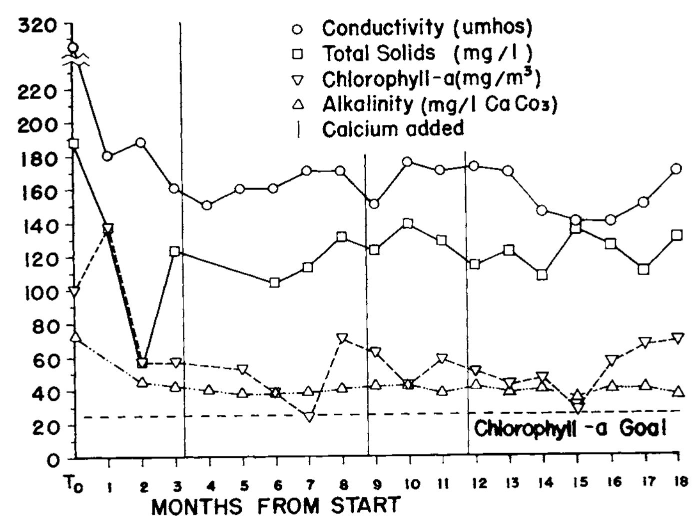

Figure 1. Conductivity, total solids, chlorophyll-a, and alkalinity in Lake Weston, following treatment. T_0 is the initial yearly average value. Chlorophyll-a reading for the seventh month is trichromatic. All readings are composite values.

In the 2nd month, (August) chlorophyll-a decreased to 56% of its initial value, while conductivity (Figure 1), ammonia nitrogen (Figure 2), and bacteria plate count, (Figure 3) increased. All other parameters continued to improve.

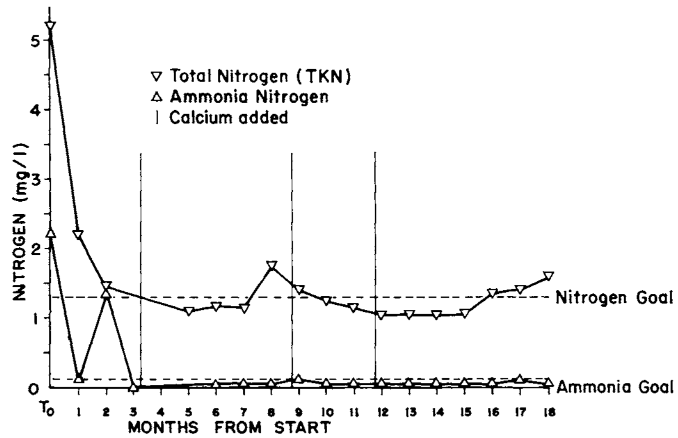

Figure 2. Composite values of total nitrogen (TKN) and ammonia nitrogen

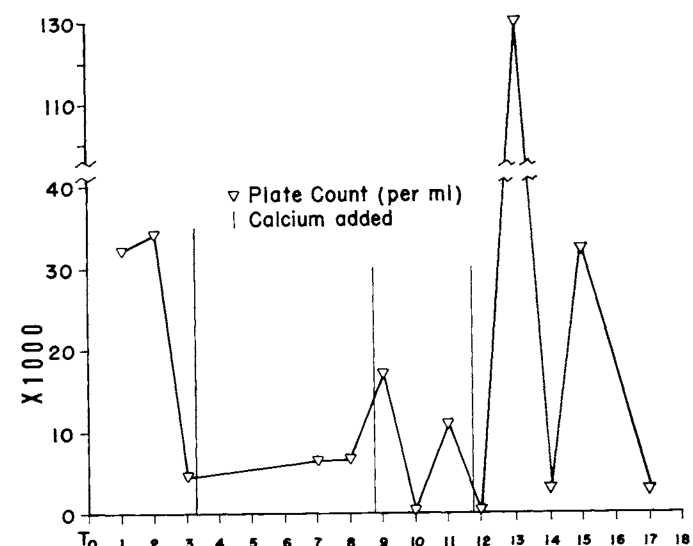

Figure 3. Composite values of bacterial plate count for Lake Weston. No readings were taken prior to 1 month after initiation of the aeration equipment.

In the 3rd month, (September) conductivity, ammonia nitrogen, and bacteria count all improved dramatically, while the other parameters continued to improve, except for total solids (Figure 1). Plate count decreased from 34,000 per ml down to 4,300, an 87% decrease. By this time the 3-year goal for bottom dissolved oxygen (Figure 4), total nitrogen, and ammonia had already been exceeded, while the 3-year goals for phosphorus, BOD (Figure 4), and chlorophyll-a were being closely approached.

During the 4th month, (October) the first application soluble calcium compound was added, and all parameters continued to improve. About 3 weeks later, as algae began to die, BOD increased, and a corresponding drop in dissolved oxygen and pH occurred. While the decline of algae followed the application of precipitant, it is possible

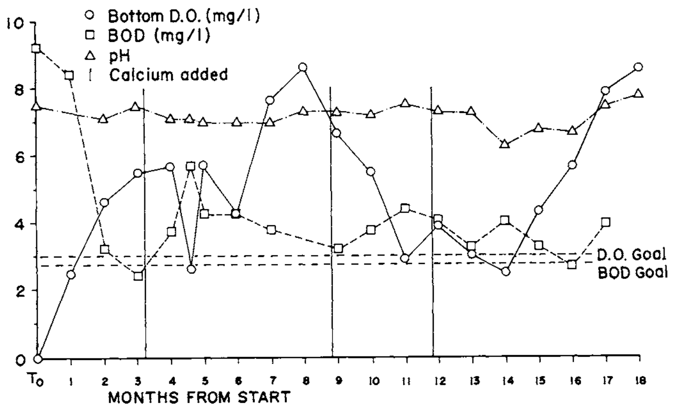

Figure 4. Bottom dissolved oxygen (D.O.), and composite values of biochemical oxygen demand and pH in Lake Weston following treatment.

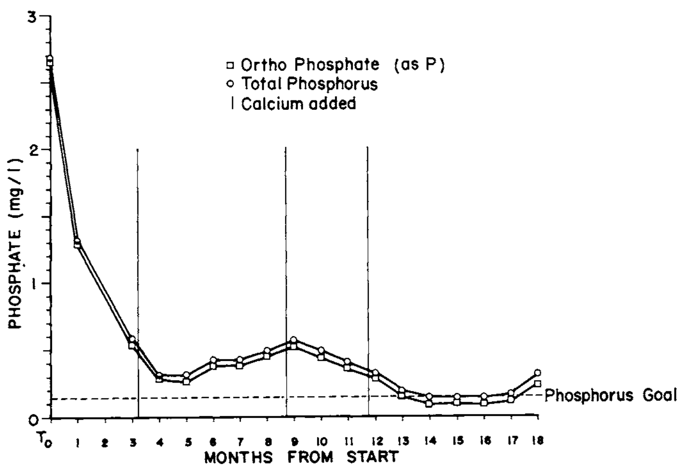

Figure 5. Composite values of ortho phosphate (as P) and total phosphorus in Lake Weston.

that this was seasonal decline. During the 7th month the green algae died out, and diatoms bloomed in their place for a few weeks (Figure 1). At this time, the 3-year goal for chlorophyll-a was temporarily exceeded.

After this time, several electric power failures occurred between the months of February and May 1976. The frequency and duration of interruptions are not precisely known. This caused a rather severe drop in bottom dissolved oxygen, but water quality remained better than the initial values.

By the 12th month (June, 1976), all of the 3-year goals except chlorophyll-a, total phosphorus, ortho phosphate, and BOD were exceeded. During this 1-year period, the alkaline earth metals sodium, magnesium, potassium, and calcium (Figure 6) declined, except for increases in calcium, due primarily to the addition of precipitant to the water. Many schools of bass 23 to 25 cm long are now seen along the shoreline, and fishing has been reported by residents to be greatly improved.

At this point it would have been difficult to determine whether the results were caused by the treatment, or were simply seasonal variations. However, over an 18-month period all of the water quality values, except plate count either continued to improve, or held approximately at their new improved values.

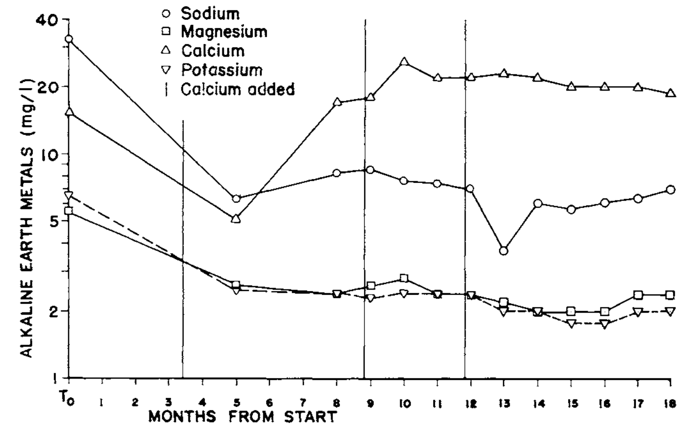

Figure 6. Semi-logarithmic graph of alkaline earth metals following initiation of the Lake Weston restoration program. Values are composite.

While phosphorus continued to decline from the beginning, in November, the 5th month, Lake Weston reached the generally accepted limiting values for sodium and nitrogen. At this time, the green algae disappeared and diatoms had taken their place by January. This was accompanied by an increase in water clarity, as monitored by Secchi disk and turbidity (Figure 7). The shift from green algae to diatoms could be a seasonal phenomenon, although it had not been noted in the past.

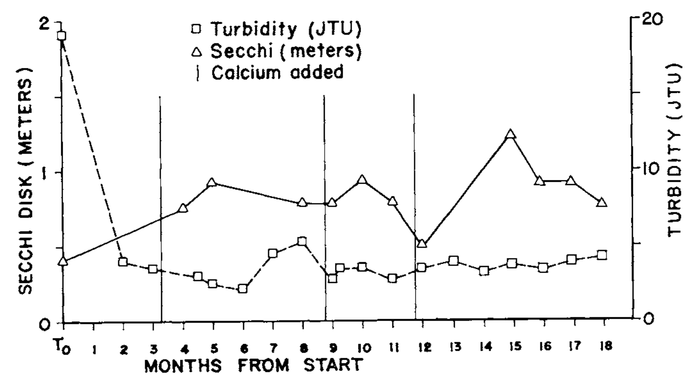

Figure 7. Water clarity following treatment of Lake Weston. Turbidity values are composite.

The increase in chlorophyll-a the 1st month was probably caused by bringing the highly eutrophic bottom water up to the surface, enabling subsurface algae to be nourished by the surface layer (5).[4] This increase was not serious, however, and the large drop in chlorophyll-a the 2nd month more than compensated for any deleterious effect.

Although phosphorus decreased following treatment with calcium, the observed value is misleading. As the algae died and decomposed, they released organically bound phosphorus back into the water. Although submerged macrophytes were not abundant, any aquatic plants present would have declined during the 3-month period following treat-

[4]Shapiro, J. and H. Pfannkuch. 1973. The Minneapolis chain of lakes—a study of urban drainage and its effects. Interim Report No. 9, Limnological Research Center, University of Minnesota, Minneapolis. pp. 116-118.

ment with the calcium compound.[5] A corresponding release of phosphorus would occur, not previously measured in total phosphorus readings. Corresponding to this action, a decline in chlorophyll-a and turbidity, and an increase in Secchi disk readings occurred during this 3-month period. After the above period, results deviated because of temporary regressions due to power failures and influent during rainstorms, and improvements following two more applications of calcium. During the 7th and 8th months construction work for a beach area took place and a corresponding increase in turbidity, plate count, nitrogen, phosphorus, and chlorophyll-a occurred.

The increase in bacteria count and ammonia nitrogen the 2nd month was probably caused by water flowing over the benthos, increasing anaerobic bacterial activity by agitation prior to their decrease during the 3rd month from oxygen toxicity. Again, these results were not serious. The increase in bacteria was only 11% and ammonia increased to only 59% of its initial value. Of far greater significance was the total elimination of ammonia and 87% reduction in bacteria count during the 3rd month. Cause of the temporary increases in bacteria during the 13th and 15th months is not known.

Although bottom organic muck was not monitored, it was observed by field personnel to decline in several places, particularly at the diffusers. This is because benthic organisms can feed on organic detritus once oxygen is present and toxic gases are removed (2,7,8).[6]

Lake Weston is not yet totally restored, and would deteriorate if the aerators were turned off at the present time. This fact is demonstrated by the temporary regressions following power interruptions. It is anticipated that after the desired goals are realized and found to be stable, the aeration equipment can be turned off, or operated intermittently at a reduced level, as needed.

About 0.6 km from Lake Weston is Lake Lovely, which was also polluted by 0.07 MGD (million gallons per day or 3.78×10^6 liters per day), sewage effluent. In January, 1976 the effluent was upgraded by improvements in a trickling filter and increased chlorination. The effluent was then sent to a retention pond and then 1.5 blocks to Lake Lovely. After the changes, the lake began to improve at a certain rate.

Another lake, Lake Lawne, in the same area had similar initial conditions to Lake Weston, having received 1 to 2 MGD 0.1 MGD, and 0.0525 MGD effluent from three waste treatment plants. Lake Lawne was not aerated, but was partially dredged from March, 1973 to March, 1974 following cessation of the 1 to 2 MGD influent in 1972. Aluminum sulfate was applied in May, 1974 to reduce turbidity following cessation of the 0.1 MGD influent in March. The lake was then drawn down in February, 1975 to expose approximately 75% of the bottom sediment. This was allowed to bake in the sun for one month, and then allowed to refill with natural watershed runoff. The influent from the 0.0525-MGD plant was diverted in April, 1976, but this effluent had to travel 1.6 km through an open ditch to reach the lake.

The program greatly reduced turbidity and firmed and hardened the bottom sediment. Water quality, while greatly improved, did not improve to the degree experienced in Lake Weston. Lake Weston influent was diverted in February, 1975, and was a flow rate of 0.525 MGD.

To test the effectiveness of the Lake Weston treatment, Lake Lovely was used as a control, and the improvements in Lakes Weston and Lawne were compared to the natural recovery of the control lake.

Water quality parameters were grouped into what was assumed to be five independent groups. The recovery of one group was assumed to not influence the recovery of another group of parameters. The reduction in ammonia nitrogen from 2.2 to 0.05 mg·liter^{-1} in Lake Weston could not be compared because ammonia was initially zero in the control lake. Data was not taken for chlorophyll-a, sodium, potassium, or magnesium in Lake Lawne.

Initial values of each lake were averaged over a 1 year period prior to treatment of Lake Weston. These values were normalized to those of Lake Lovely. The improvement in each lake was assigned a value from 0 to 10 by dividing the greatest improvement for all lakes into eleven classes. For example, if the greatest improvement in phosphorus in one lake was a reduction from 2.0 to 1.0 mg·liter^{-1}, while another lake improved from 2.0 to 1.5 mg·liter^{-1}, the improvement in the first lake would be assigned a class rating of 10, while the improvement in the other lake would be assigned a class rating of 5.

The average class into which the improvement in each of the five groups falls for Lake Lovely after 1 year is taken as the mean, $\bar{x}$.

The variance of $\bar{x}$ in the other two lakes at the end of one year, is taken as

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}}$$

where:

- s = the variance or improvement above the improvement in the control lake, if positive value, or the degree of less improvement than the control lake, if negative, based on a class scale ranging from 0 to 10
- x_i = the class rating of the improvement in the treated lake
- n = number of parameters in the group being tested

and the sign of s is determined by $x_i - \bar{x}$. The improvement ratings are given in Table 1 for Lake Lawne, and Table 2 for Lake Weston.

It should be noted that the information set forth herein is from preliminary data, and should not be construed to be conclusive. It appears that aeration of the lake properly prepared the water for phosphorus removal using a calcium based precipitant. In this process, it was necessary to raise bottom dissolved oxygen to at least 3 mg·liter^{-1}, bottom

[5]Laing, R. L. and A. M. Adams 1975. A study of the efficacy of Clean-Flo Lake Cleanser in controlling aquatic plants in three aerated Minnesota Lakes. In-house publication. 67 p.

[6]Laing, R. L. and A. M. Adams, 1975. Organic muck removal through aeration/circulation. In-house publication. 9 p.

TABLE 1. MEAN IMPROVEMENT RATING $\bar{x}$ AFTER 12 MONTHS, BASED ON A CLASS SCALE FROM 0 TO 10 FOR THE CONTROL LAKE, COMPARED TO VARIANCE ABOVE $\bar{x}$ (POSITIVE s VALUE) OR BELOW $\bar{x}$ (NEGATIVE s VALUE) FOR LAKE LAWNE.

Group[1]	n	$\bar{x}$	x_i	s
I	2	2.0	2,-10	-8.5
II	3	3.0	6,7,5	3.1
III	3	0.0	3,-6,7	2.7
IV	2	6.0	10,10	4
Average Mean Improvement		2.8	Average Variance	0.3

[1]
I = Dissolved oxygen and BOD.
II = Ortho phosphate, total phosphate, total Kjeldahl nitrogen.
III = Total alkalinity, pH, and conductivity.
IV = Turbidity and Secchi disk.

TABLE 2. MEAN IMPROVEMENT RATING $\bar{x}$ AFTER 12 MONTHS, BASED ON A CLASS SCALE FROM 0 TO 10 FOR THE CONTROL LAKE, COMPARED TO VARIANCE ABOVE $\bar{x}$ (POSITIVE s VALUE) OR BELOW $\bar{x}$ (NEGATIVE s VALUE) FOR LAKE WESTON.

Group[1]	n	$\bar{x}$	x_i	s
I	2	2.0	10,2	5.6
II	4	3.5	10,10,10,10	6.5
III	3	0.0	10,-4,10	7.8
IV	2	6.0	9,4	0.5
V	3	7.3	10,10,10	2.7
Average Mean Improvement		3.8	Average Variance	4.6

[1]
I = Dissolved oxygen and BOD.
II = Ortho phosphate, total phosphate, total Kjeldahl nitrogen, and chlorophyll-a.
III = Total alkalinity, pH, and conductivity.
IV = Turbidity and Secchi disk.
V = Sodium, potassium and magnesium.

ammonia to less than 0.11 mg·liter^{-1}, and pH greater than 6.5.

Aeration alone brought about many improvements in the lake ranging from improved environment for fish, a decrease in aquatic plant nutrient levels, and an apparent decrease in bottom muck. In addition to reduction in nitrogen and phosphorus, the reduction in alkaline earth metals probably helped control phytoplankton growth.

It is anticipated that the lake will continue to improve, reaching the desired goals within 2 years as the aeration continues, and two more applications of calcium are made during the next year. Preliminary data indicates that with an improvement rating ranging from 0 to 10, a lake with upgraded sewage influent improved a mean factor of 2.8 to 3.8 in 1 year. A lake which was dredged, clarified with alum, and drawn down improved by an average variance of 0.3 more than the control lake. Comparing the same control lake to Lake Weston, which underwent aeration and phosphorus precipitant, Lake Weston improved by a variance of 4.6 more than the control lake, or a total average improvement rating of 8.4.

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