PHOSPHORUS REDUCTION
BY ALGAL CULTURES

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By

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INTRODUCTION

Because of the relatively low carbon/phosphorus ratio of algae, much interest has been given to the *use* of algal cultures as a means of stripping phosphorus from municipal sewage treatment plant effluents. This process has been studied rather extensively because of its possible economic advantage since algae so produced may have a potential market as a protein source in animal and human foods.

Most of the algae studied for phosphate removal has been grown in waste stabilization ponds although several laboratory studies have also been conducted. An attempt will be made, in this paper, to summarize the results of several of these studies and to outline the results of field and laboratory studies and observations carried out by the Division of Research, Ontario Water Resources Commission.

ROLE OF ALGAE IN PHOSPHORUS REMOVAL

Phosphorus enters a tertiary pond mainly in the soluble orthophosphate state with the complex forms comprising generally less than 10% of the total phosphorus in sewage treatment plant effluents. Within the, pond, phosphorus may be removed from solution by the action of the algae or through precipitation as calcium phosphate. Precipitation of calcium phosphate occurs when the pH of the pond contents is raised due to carbon dioxide utilization by the algal culture.

Phosphorus is removed from solution by algae, both by metabolic uptake and by chemical coagulation and adsorption. Adsorption and coagulation appear to play the major role in rapid removal of large concentrations of phosphorus.

Precipitation

The use of algae to raise the pH in a sewage treatment plant effluent and so reduce phosphate concentrations by calcium phosphate precipitation was investigated by Bogan (4) and Fitzgerald and Rohlich (7). Bogan (4) found that the rate of photosynthetic pH adjustment was principally controlled by light intensity. Judged solely on the basis of pH adjustment for phosphate precipitation, minimum light intensity requirements appear to lie in the vicinity of 100 to 200 foot-candles (f.c.).

Fitzgerald and Rohlich (7) reported that in laboratory culture flasks, illuminated at 175 f.c. at the flask surface and incubated, at 24°C, soluble phosphorus concentrations in secondary effluent could be reduced from 6.0 to 0.3 mg P/L in 14 days. Much of this removal was attributed to the increased pH brought about by the algae.

Owing to a high rate of light attenuation, it is exceedingly difficult to maintain adequate illumination in large scale cultures. Theoretical considerations indicate that it ordinarily would not be possible to maintain light intensities above 100 f.c. by natural or artificial means at depths much greater than one foot.

Because of area limitations tertiary oxidation ponds are generally constructed at depths of not less than 3 ft. Thus, although light intensities may be such during the summer season to raise the pH of the pond contents to such a value to allow calcium phosphate precipitation, winter conditions are inadequate to maintain a high pH and the calcium phosphate previously precipitated is re-dissolved.

Fitzgerald (6) showed that this dissolution of previously precipitated phosphate occurs at a drop in pH to 8.0. In ponds with 9 to 10 days detention time and depths of 2 to 3.5 ft, he found a direct correlation between pH and phosphorus removal. Removal was high in summer but in winter the effluent phosphorus often exceeded that of the influent. Similar effects were observed by Loehr and Stephenson (8) , Neos (10) and Mackenthum and McNabb (9).

This dissolution is especially evident in the Ontario climate where ice cover greatly reduces algal activity. Observations of this effect were made by this Division at the Brampton (3) and Don West (1) effluent polishing installations and at the Sandwich West Industrial lagoon system (2).

This dissolution problem could be partly solved through intermittent mixing of the pond (requiring lined ponds) and continuous treatment of the lagoon effluent to remove the precipitated phosphorus. It is doubtful, however, that much can be done to produce effective phosphorus removal by this method in northern climates where ponds are ice covered in winter.

Biological Uptake

The relative significance of biological uptake of phosphorus by algal cultures depends upon algal growth rate, environmental conditions and upon the time available for growth.

Bush *et al* (5) treated activated sludge effluent in a lagoon in which carbon dioxide was added to provide carbon and to control the pH at 7.5 to 8.5. Lagoon influent phosphorus concentrations varied from 1.6 to 4.8 mg P/L. As detention time in the lagoon was decreased from 29 to 2.5 hrs, phosphorus removal increased from 19 to 68%. The higher flow rates, giving the shorter detention times, promoted greater growth and thus higher phosphorus removals.

Laboratory studies by Fitzgerald (6) indicated that the growth of an algae, such as *Chlorella*, in domestic sewage effluents, could efficiently remove algal nutrients from solution during that portion of the year when the temperature and light intensity is conducive to the growth of algae. In contrast to the results of controlled laboratory experiments, however, data from the operation of a test pond indicated that there were considerable periods of time, during what might be considered the optimum algae growing period of the year, when there was very little algae growth or changes in nutrient levels.

OWRC STUDIES

Laboratory and field studies conducted by the Division of Research, Ontario Water Resources Commission bear out the fact that removal of phosphorus from sewage effluents by algal cultures is inconsistent. Results from a field study of the Bradford lagoon treating raw sewage and from a laboratory study where high concentrations of phosphorus were fed to a light and temperature controlled tank are presented in Tables 1 and 2. Light intensity at the surface of the laboratory culture was maintained at 200 f.c.

Temperatures were maintained at 19 ± 1°C. Soluble phosphate concentrations were determined from filtered samples using a millipore filter unit.

From Table 1 it may be seen that phosphate uptake by algae in the Bradford lagoon averaged 28% but ranged from 6 to 46%. In the controlled laboratory study (Table 2) phosphate uptake by algae ranged from 1 to 57% and averaged 20.5%.

Studies of algae harvesting are presently being conducted by the Division of Research but preliminary findings indicate this to be a very difficult and costly undertaking.

TABLE 1: Bradford Lagoon Phosphate Uptake By Algae.

Total PO_4 (ppm)	Soluble PO_4 (ppm)	Algae Bound PO_4 (ppm)	% Bound PO_4
11.0	6.5	4.5	41
8.5	8.0	0.5	6
9.0	8.5	0.5	6
11.0	7.5	3.5	32
10.5	6.5	4.0	38
11.5	8.5	3.0	26
18.5	10.0	8.5	46
14.5	11.8	2.7	19
11.0	6.5	4.5	41
		Average	28%

TABLE 2: Laboratory Lagoon Phosphate Uptake By Algae.

Total PO_4 (ppm)	Soluble PO_4 (ppm)	Algae Bound PO_4 (ppm)	% Bound PO_4
21	17	4	24
160	117	43	37
170	150	20	13
235	210	25	12
290	245	45	18
400	254	146	57
430	290	140	31
650	512	138	27
800	780	20	2.7
840	620	220	36
1000	427	573	57
1090	1020	70	7.0
1170	1160	10	0.9
1375	1100	275	25
1440	1400	40	2.9
1450	1300	150	12
1500	1350	150	11
1725	1625	100	6.2
		Average	20.5%

CONCLUSIONS

From a review of available literature and as a result of studies conducted by the Division of Research, Ontario Water Resources Commission, it may be concluded that under Ontario's climatic conditions, the use of tertiary detention ponds is not an effective method for controlling the amount of phosphorus discharged from waste water treatment facilities.

Specially designed systems could conceivably be constructed for removing phosphorus by algal cultures. Such a system would involve a pond 1 ft deep with a detention time of 8 - 12 days. Supplemental illumination would be provided to maintain at least 200 foot candles at the entire pond surface, operating approximately 60% of the time. This system would require algal harvesting.

A study conducted by the Pennsylvania State University (11) concluded that the cost of such a system treating 10 MGD would be $1,172 per MG of waste treated. This cost may be compared to a chemical precipitation method employing ferric sulphate at a total cost of $36 per MG of waste treated.

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