NUTRIENTS AND ALGAL REMOVAL FROM OXIDATION PONDS EFFLUENTS

by

Adnan Shindala
Associate Professor of Sanitary Engineering
Mississippi State University

INTRODUCTION

Waste stabilization ponds have been used effectively to treat domestic and many types of industrial wastewaters throughout the United States. The low cost of construction and operation has resulted in their wide adoption by municipalities and industries as a means of wastewater treatment.

It is generally recognized that, when properly designed, stabilization ponds will eventually become populated with suitable bacteria and algae. Bacteria will oxidize the organic matter while algae, through the process of photosynthesis, supply the oxygen needed for the aerobic bacterial action. A cyclic process is therefore, established in which unstable organic matter is converted to stable cell material.

Until recently, waste stabilization ponds have been accepted to satisfy essential waste treatment requirements. However, due to the growing awareness of the pollutional aspects of wastewater and in order to preserve the natural values of streams for fish, wildlife, recreation, water supply and for general aesthetic considerations, higher degrees of wastewater treatment must be provided. Unfortunately, the currently used waste stabilization ponds do not provide such high degree of treatment. The low degree of treatment during the winter months and the heavily algae laden effluents in the long hot summer days are two of the main characteristics of waste stabilization ponds. Algae in the pond effluent will eventually die away in the receiving streams and will be available for bacterial degradation which, besides odor and aesthetic conditions, add an additional BOD to the stream. Consequently, post treatment of oxidation pond effluents would become essential if ponds are to continue to be used as an acceptable means of wastewater treatment.

Information concerning post treatment methods for waste stabilization pond effluents are scarce. Some of the methods reported in the literature include settling, flotation, microstraining, centrifugation, filteration, bioflocculation, sonic vibration and chemical coagulation. Of all the methods reported, chemical coagulation looked the most promising. The marked reductions in BOD, COD, nitrogen, and phosphorus, along with the effective removal of algae offered by chemical coagulation make this method most attractive as a post treatment process.

In the study reported herein, chemical coagulation was investigated as a post treatment process to remove the algae and to improve the quality of the effluent of a stabilization pond. Several different coagulants were tested. The degree of effectiveness was measured on the basis of reductions in BOD, COD, total phosphates, total nitrogen, coliform bacteria, and algal concentrations. A mathematical model relating the degree of effectiveness of phosphate removal to coagulant dosage was developed.

Procedures and Equipment

To widen the application of the results of the laboratory investigation, several ponds receiving different types of wastes and operating under different conditions were sampled. Grab samples were collected from the effluent of the Starkville, Mississippi, Columbus, Mississippi, West Point, Mississippi, and Mississippi State University (MSU) stabilization ponds. The samples were collected at various times of the day ranging from 7:30 A.M. to 7:00 P.M. Samples were collected in polyethylene jugs and transported to the MSU Sanitary Engineering Research Laboratory where jar tests were run immediately on each sample. The optimum pH for coagulation and the optimum coagulant dosage were determined following the procedure outlined by Eckenfelder (1). Reductions in COD and phosphate concentrations were used as criteria for selecting the optimum values of pH and coagulant dosage.

The effectiveness of the chemical coagulation process was measured in terms of reductions in BOD_5, COD, total phosphate, total nitrogen, coliforms and algal concentrations. All tests were run immediately following sample collection. The samples were refrigerated at 4°C in polyethelene bottles during the period of testing. All analytical tests were performed by following the general procedures outlined in the 12th edition of Standard Methods for the Examination of Water and Wastewater (2).

Results and Discussion

Three different coagulants, aluminum sulfate (alum), ferric chloride, and ferric sulfate, were tested. Using a minimum of 90 percent removal of phosphate and 70 percent removal of COD as criteria, the optimum coagulants dosages were found to be 85 mg/1 for alum, 85 mg/1 for ferric chloride, and 125 mg/1 for ferric sulfate. Optimum pH varied from 5.5 for alum to 4.8 for ferric sulfate. Due to the cost of the ferric coagulants and the iron color noticed in the supernatant, alum was chosen as the favorite coagulant and was used in the entire investigation that followed. Therefore, the results and discussion to be presented in the following paragraphs will only be related to alum as the coagulant.

To facilitate interpretation of the data the results are reported in terms of frequency of occurrence of any particular characteristic at varying coagulant dosages and are summarized in Table 1. The alum dosage was varied between 0 - 200 mg/1. As shown in Table 1, the removal efficiencies of the characteristics measured increased rapidly with the increase in the alum dosage up to a dosage of 100 mg/1 and then leveled off. No appreciable increase in efficiencies was observed at dosages greater than 100 mg/l. The clarity of the supernatant was also observed to increase with the increase in coagulant dosage. At a dosage of 100 mg/l alum the clarity of supernatant was observed to be that of tap water.

Examination of the different characteristics of the supernatant, as reported in Table 1, clearly demonstrate the effectiveness of chemical coagulation as a post treatment method of oxidation ponds effluents. At an alum dosage of 100 mg/l, for example, the coagulation process resulted in an effluent as clear as tap water and with BOD_5, COD, total phosphate, and total nitrogen content equal to or less than 2.3, 32, 1.2, and 6.6 mg/l respectively, 90 percent of the time. These values compare favorably with those to be expected from tertiary treatment of biologically treated effluents. In addition chemical coagulation resulted in a marked reduction in the coliform content of the ponds effluents with an average value of 5000 coliform/100 ml remaining in the coagulated supernatant.

In most cases, the flocs formed were observed to settle rapidly. The size of the flocs was noticed to decrease with the increase in dosage although this seemed to have no effect on the settling characteristics. The problem of algae floating was only observed twice. This seemed to be attributed to the release of dissolved oxygen from the super-saturated effluents. An additional rapid-mix time of one to two minutes was found to remedy this situation. Typical settling curves are shown in Figure 1.

To estimate the algae contribution to BOD, COD, total phosphates, and total nitrogen, tests were conducted on filtered and unfiltered samples of pond effluents. Results indicate that, on the average, algae contributed quite heavily (greater than 50 percent) to the BOD_5, COD, and nitrogen, while contributing less than 25 percent to phosphates.

Relationship Between Phosphate Removal and Alum Dosage

To facilitate future continuous studies the following mathematical model relating influent phosphate concentration, effluent phosphate concentration, and alum dosage within a certain boundries was developed following the procedure by Emery and Malina (3).

$$C = \frac{(PO_4)_i}{0.06\,(PO_4)_e + 0.132} - 8.0$$

Boundary conditions used in the derivation of the model include influent phosphate concentration ranging from 20.5 to 6.8 mg/l, and the effluent phosphate concentrations was selected to range between 1.0 to 5.0 mg/l.

Symbols used in the derivation of this model are as follows:

C = concentration of the alum required (mg/l)

$(PO_4)_i$ = influent total phosphate concentration (mg/l)

$(PO_4)_e$ = effluent total phosphate concentration after treatment with alum (mg/l)

Conclusions

From the data collected in this investigation, the following conclusions can be made:

1. Chemical coagulation proved to be an effective post treatment process for algal removal and for improving the quality of effluents from stabilization ponds.

2. Of the coagulants tested, alum was found to be the most favorable coagulant.

3. The optimum dosage for best removal of the parameters studied was found to be in the range of 75 to 100 mg/l. Using this dosage, the supernatant from the chemical coagulation process was found to contain 2.5 mg/l BOD_5, 22.0 mg/l COD, 1.5 mg/l total phosphates, 3.5 mg/l total nitrogen, 500 to 1000 algal cells/ml and approximately 5,000 coliforms/100 ml.

4. A mathematical model,

$$C = \frac{(PO_4)_i}{0.06(PO_4)_e + 0.132} - 8.0$$

   can be used to predict the required dosage, C, of alum in mg/l to produce effluent phosphate concentration $(PO_4)_e$ in the range of 1 to 5 mg/l.

5. The algae in the pond effluents was found to contribute heavily to the BOD_5, COD, and nitrogen in the effluent, while the contribution to the phosphates concentration was not found to be as significant as that of the other parameters.

While the flocculation-sedimentation technique has been found to efficiently remove algae from stabilization pond effluent, no study was made of sludge disposal. It is anticipated that a pilot plant study involving this method of treatment would be made at the Mississippi State University campus with provisions for recycling the sludge to the stabilization pond.

BIBLIOGRAPHY

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3. Emery, M.M., and J.F. Malina, Jr., "Phosphate Removal Characteristics of Lime Softening Sludge," Technical Report to the U. S. Public Health Service, EHE-11-6801, University of Texas, (November, 1968).

TABLE 1

Frequency of Occurence of Characteristics Measured

(Parameters Evaluated for Unfiltered Samples)

Alum Dosage mg/1	BOD_5 mg/1 % Occur.* 50	90	BOD_5 % Remain. % Occur.* 50	90	Total Phosphates mg/1 % Occur.* 50	90	Total Phosphates % Remain. % Occur. * 50	90	COD mg/1 % Occur. * 50	90	COD % Remain. % Occur. * 50	90	Total Nitrogen mg/1 % Occur.* 50	90	Total Nitrogen % Remain. % Occur.* 50	90
0	43.0	51.0	100	100	14.0	19.0	100	100	142.0	250.0	100	100	12.0	16.0	100	100
25	6.0	9.8	15.0	25.0	5.6	11.8	34.0	57.0	42.0	64.0	32.0	47.0	5.0	8.5	43.0	76.0
50	2.3	3.6	7.0	13.5	1.7	3.0	12.0	19.5	27.5	43.0	21.0	29.0	3.7	6.9	32.0	64.0
75	1.6	2.6	4.5	8.0	1.0	1.6	6.4	8.6	23.5	37.0	18.0	29.0	3.5	6.7	30.0	60.0
100	1.5	2.3	3.5	6.0	0.8	1.2	5.0	6.1	21.5	32.0	16.7	26.5	3.4	6.6	29.5	59.0
125	1.4	2.2	3.5	6.0	0.7	1.0	4.5	5.4	20.5	32.0	16.0	26.0	3.4	6.6	29.5	59.0
150	1.4	2.2	3.0	6.0	0.6	0.8	4.0	4.6	20.0	31.0	14.5	24.0	3.4	6.6	29.5	59.0
175	1.2	2.1	3.0	5.5	0.6	0.8	4.0	4.6	20.0	20.0	14.5	24.0	3.4	6.6	29.5	59.0
200	1.2	2.1	3.0	5.5	0.5	0.8	3.5	4.6	20.0	30.0	14.5	23.5	3.4	6.6	29.5	59.0

* Percent of time value is equal to or less than shown.

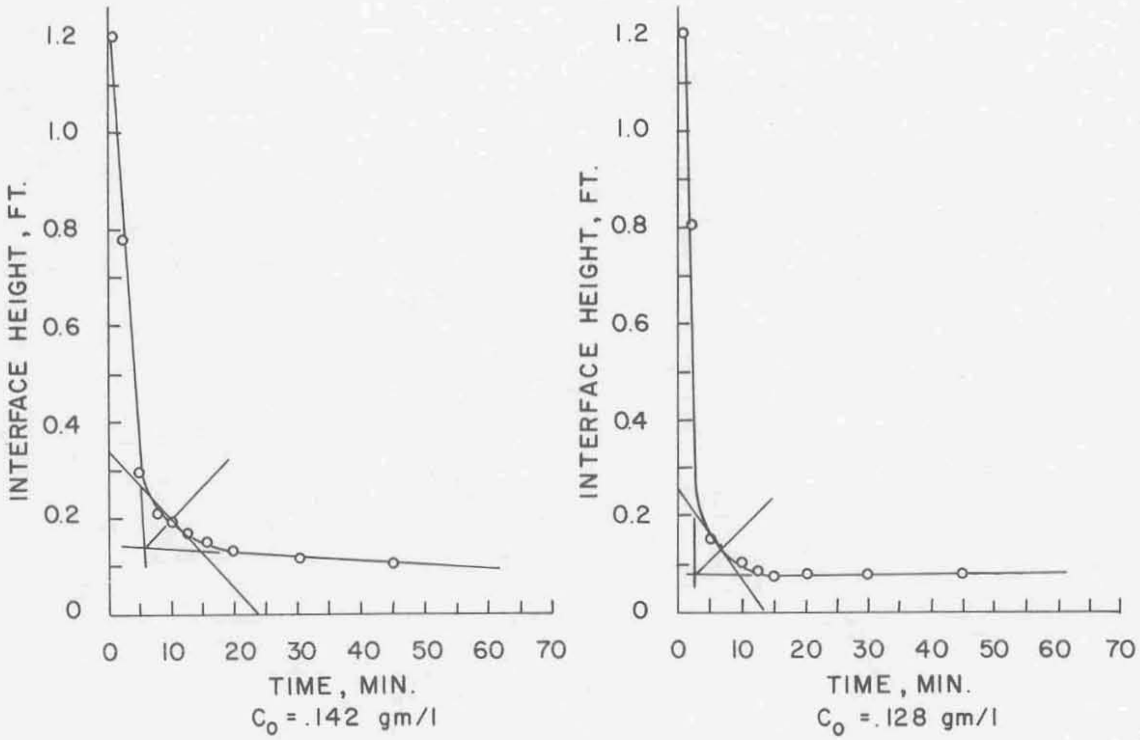

FIGURE 1. Typical Setting Curves