
Algal Succession and Bacterial Reduction in Bio-Oxidation Ponds

ERNST M. DAVIS, MAXWELL J. WILCOMB and GEORGE W. REID

University of Oklahoma, Norman

The School of Civil Engineering and Environmental Science at the University has been engaged for two years in a research project supported by a Demonstration Project Grant from the Division of Water Supply and Pollution Control, Public Health Service. The primary purpose of the project is to determine the ability of the bio-oxidation ponds to remove nitrogen and phosphorus through action of bacteria and algae(2,8). This has rendered necessary the accumulation of data relating to algal and bacterial population, a part of which is presented in this paper. Other parameters measured were BOD; ammonia and Kjeldahl nitrogen; ortho, meta, and total phosphate; pH, alkalinity, and temperature.

Bio-oxidation ponds, also called waste stabilization lagoons, have become popular in recent years for disposal of raw sewage or primary effluents, particularly among smaller municipalities or subdivisions where low construction and maintenance costs are a significant advantage and land is not a primary problem.(5) Probably there are now more than two hundred of these ponds in the state.

The relationship between heterotrophic and phototrophic metabolism in bio-oxidation ponds is essentially that of any pond in nature, the principal difference lying in the comparatively large amount of dissolved nutrients available from the sewage, and the comparatively large bacterial and algal population resulting. The bacteria metabolize the organic matter usually aerobically with the production of bacterial protoplasm, carbon dioxide and water. The algae utilize the carbon dioxide, water, phosphorus, nitrogen, and other inorganics and convert them into algal protoplasm. There is a release of oxygen in proportion to the carbon dioxide reduced; thus the basic elements for a symbiotic relationship exist, and an additional source of oxygen is available to satisfy the bacterial oxygen demand, and help to maintain the pond in an aerobic state.

PROCEDURES

Rather than develop a single experimental unit that could be loaded at will to select and study ten existing ponds, representative of various loadings and physical characteristics and located within a 50-mile radius of the University of Oklahoma. Samples for bacterial determination were taken bi-monthly at the influent and final effluent. Algal samples were taken from the final effluent of each bio-oxidation pond. This report covers the samples taken between September 1963 and September 1964.

Algal samples were preserved with 1% formaldehyde, if not counted immediately, and concentrated by filtration or diluted as necessary for accurate counting. Counts were made under a compound microscope with the aid of a Whipple eyepiece and Sedgewick-Rafter counting chamber and the results reported in areal standard units (ASU). Bacterial samples were diluted in buffered dilution water, filtered out on Millipore HA (0.45 micron) filter membranes, and cultured in Millipore disposable petri dishes at 37 C for 20 hours.(4) Duplicate samples of each were run, one in Difco M-HD Endo broth for determination of the coliform group, and one in Difco M-Enrichment Broth for total counts. The latter medium, containing extra peptones and phosphate, was found to develop about twice as many colonies as the nutrient broth ordinarily used.

RESULTS AND CONCLUSIONS

The bacteriological findings are summarized in Figure 1. Reduction of population of all species of bacteria in the ponds are always less than the reductions in the coliform group. McKinney(1) points out that this is usually the case. The predominant bacteria in aerobic ponds are mostly *Pseudononas, Flavobacterium,* and *Alcaligenes,* heterotrophs able to compete in widely varied substrates. Probably, of the coliforms remaining, most are of soil rather than enteric origin. Oddly enough, reductions at one installation, Rhapsody Heights, a four-pond system mechanically augmented with two Yeowave aerators, are less than that at another installation at Cullens, a simple series four-pond system without mechanical augmentation. The Unit Parts pond receives principally industrial waste, whereas the other ponds do not. It is a single pond, but well designed and with no evidence of short circuiting. The remaining ponds shown in Figure 1 all show good reduction.

Figures 2 and 9, which present the algal populations for each pond, are self-explanatory. There are several principal points of significance, the first being that there are no coincidental peaks between the three Divisions of algae shown (Chrysophyta never exceeded 180 ASU's, hence are not shown in the graphs).

The green algae (Chlorophyta) predominate during the winter months, whereas the bluegreens (Cyanophyta) are most prevalent during the summer and early fall. Apparently this condition would prevail also in a noneutrophic natural pond also. The flagellates (Euglenophyta) appear to occur intermittently throughout the year, usually when the other Divisions are not numerous. Apparently the nature of the waste does not influence the cyclic nature of the algal populations, because Unit Parts shows distinct cyclic changes and is not appreciably different from other lagoons in this respect. For a week-long period in February, Washington's lagoon was devoid of all algae. Populations recovered rapidly. This may have been due to predation by *Culicoides* larvae which were overwhelmingly abundant in this short period. No more than twenty genera appeared during the period of study. The principal bluegreen genera were *Anacystis, Oscillatoria, Phormidium,* and *Spirulina.* The greens were mostly *Chlorella, Ankistrodesmus, Scenedesmus,* and *Chlorococcum.* Euglenophyta were Euglena and Phacus. Notice that Division peaks do not necessarily occur at exactly the same time in all ponds, due to immediate local environmental differences. Figure 10 is an attempt to establish single expectable peaks by using means of each Division from Figures 2 through 9. As expected, the bluegreens showed definite summer-to-early-fall peaking, and the flagellates exhibit annual cyclic variation. What might be expected from a typical southwestern United States bio-oxidation pond is not a single peak in the green algae, but (as shown) a trimodal peak; the highest peak is in midwinter.

ACKNOWLEDGEMENTS

The work represented herein was made possible by a grant from the United States Public Health Service—Demonstration Project Grant Number WPD - 7 - 01 - 62.

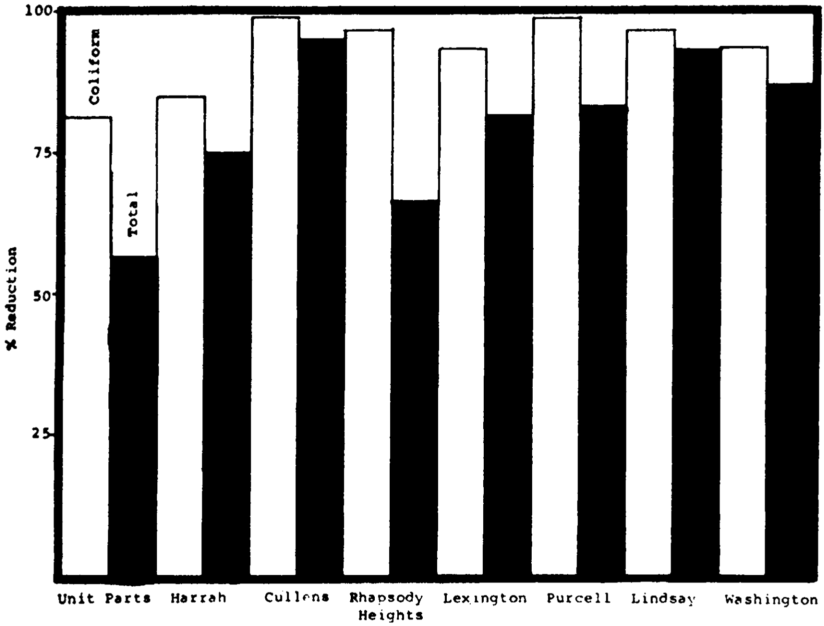

Figure 1. Percent reductions of coliform and total bacteria from raw influent to final effluent.

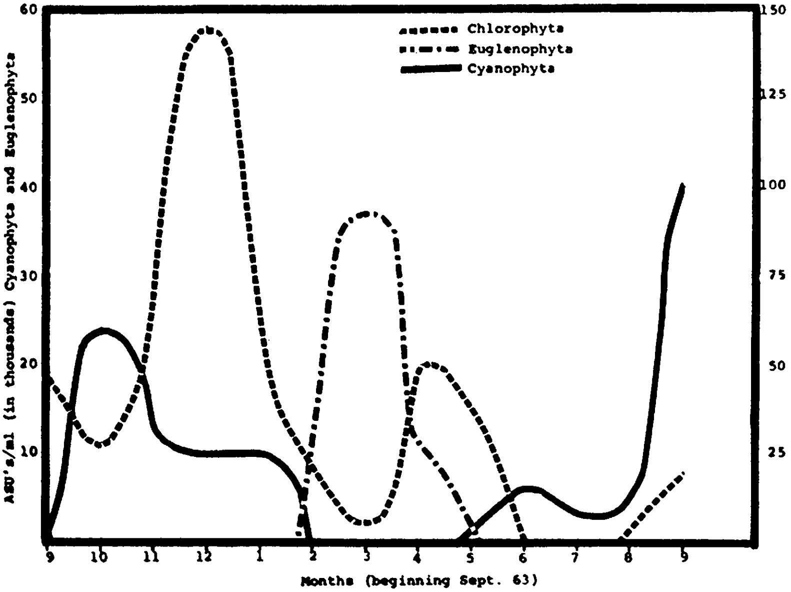

Figure 2. Seasonal prevalence of algae in Unit Parts final effluent.

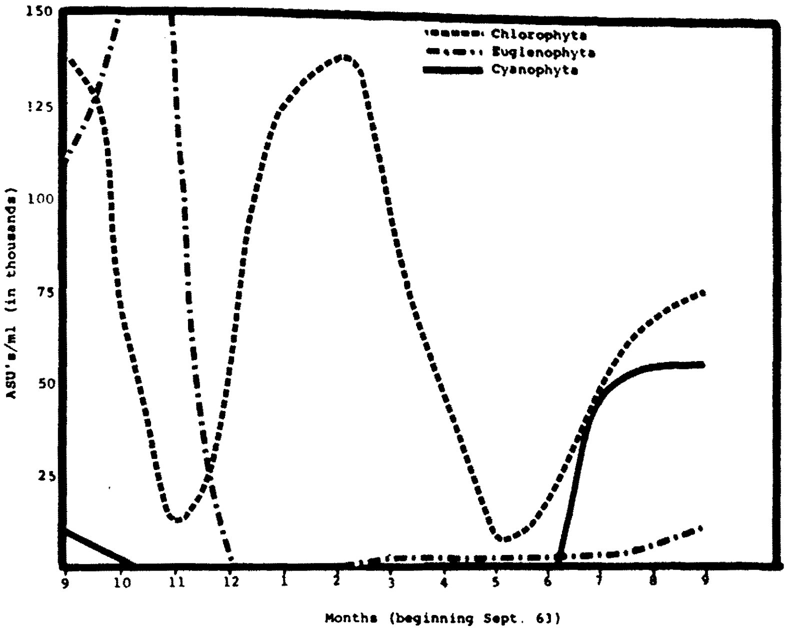

Figure 3. Seasonal prevalence of algae in Cullens final effluent.

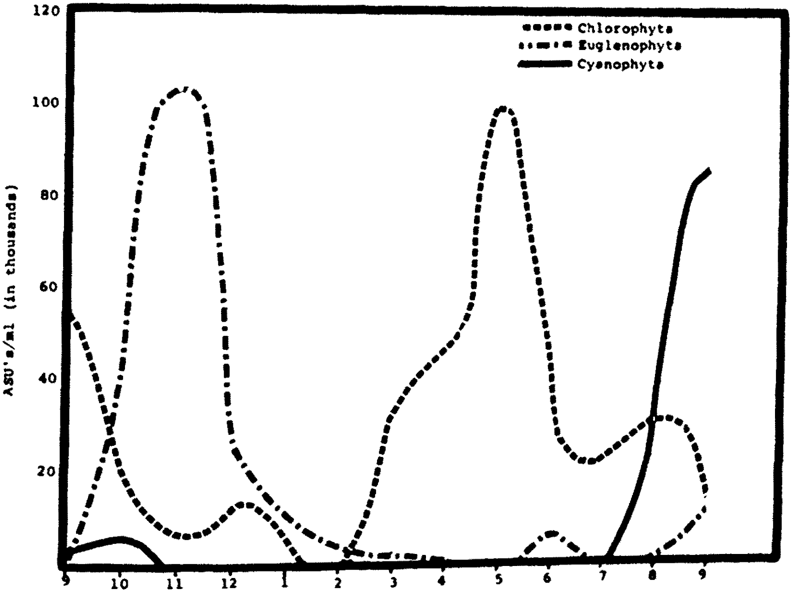

Figure 4. Seasonal prevalence of algae in Washington final effluent

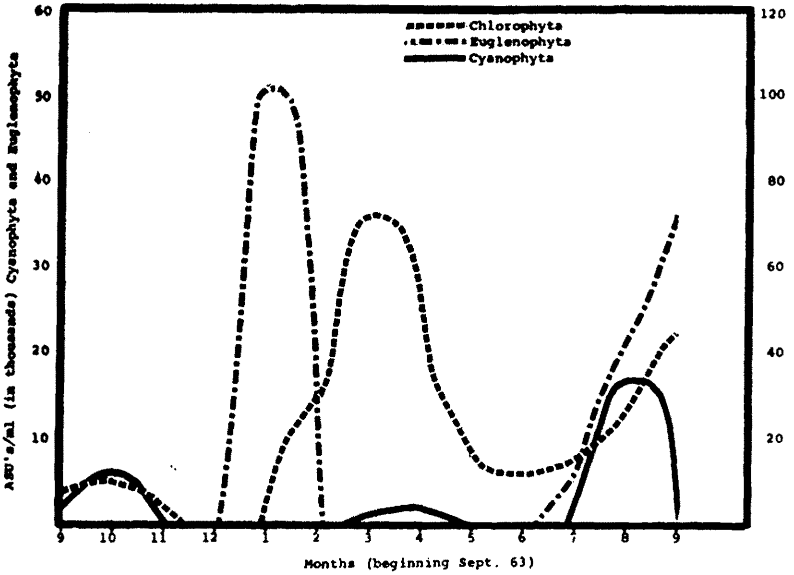

Figure 5. Seasonal prevalence of algae in Rhapsody Heights final effluent.

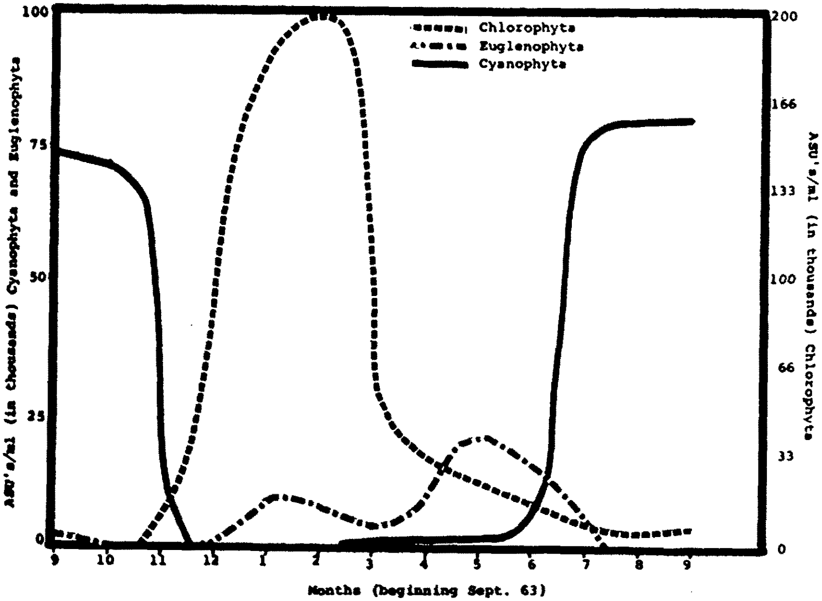

Figure 6. Seasonal prevalence of algae in Harrah final effluent.

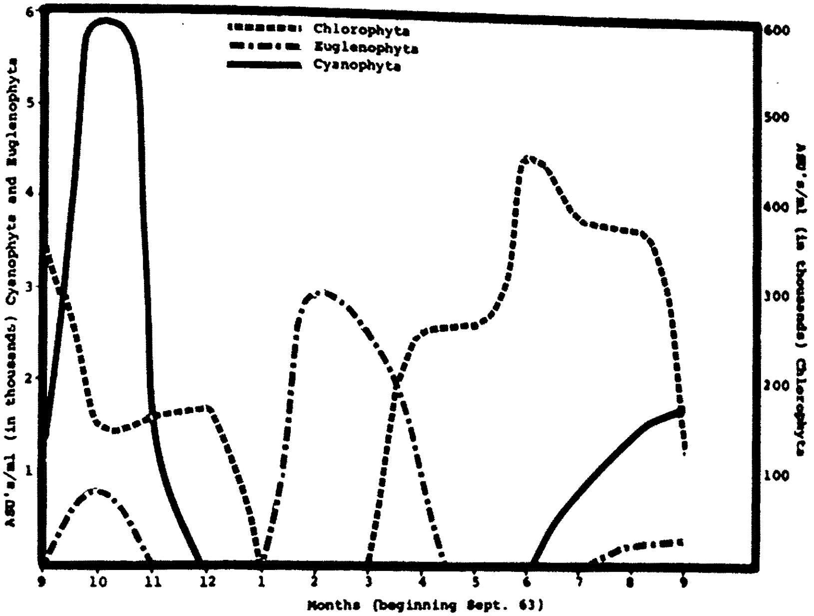

Figure 7. Seasonal prevalence of algae in Lindsay final effluent.

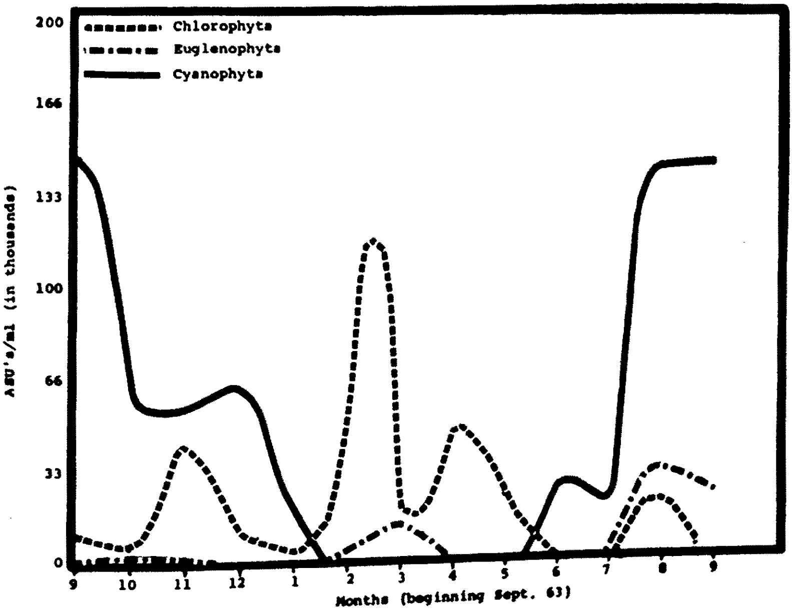

Figure 8. Seasonal prevalence of algae in Purcell final effluent.

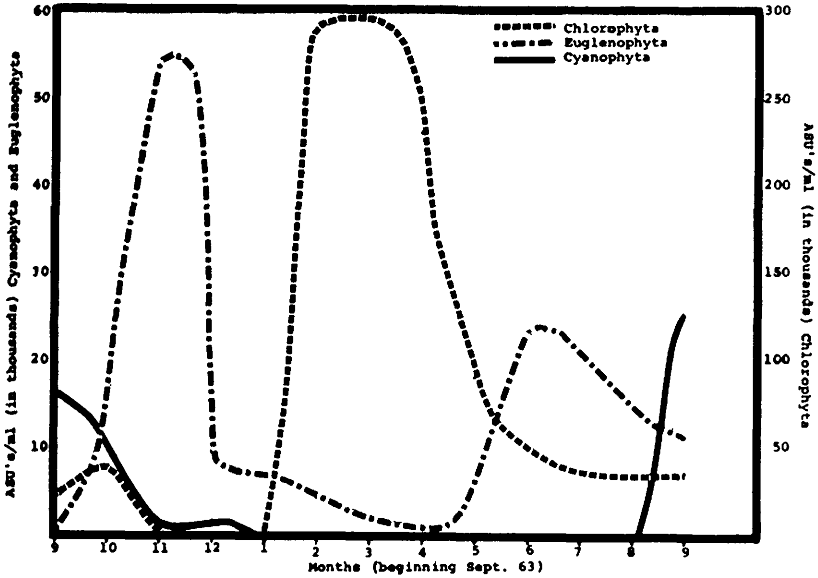

Figure 9. Seasonal prevalence of algae in Lexington final effluent.

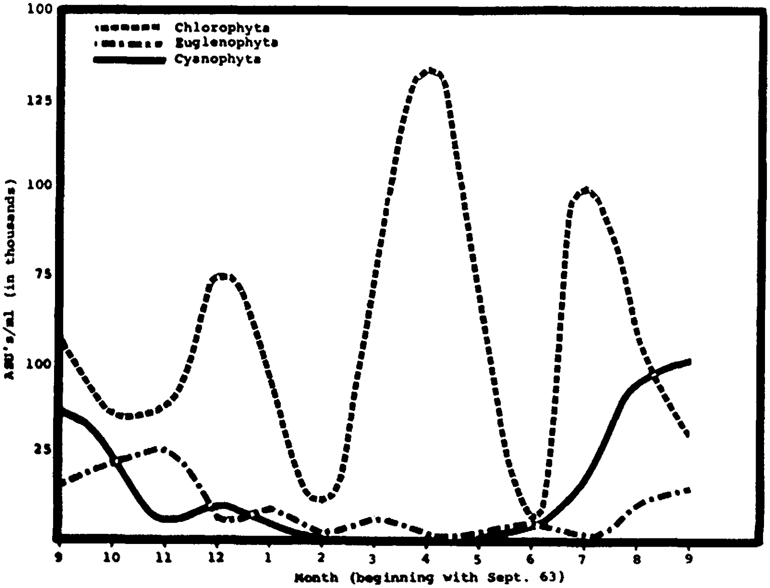

Figure 10. Mean ASU of plankton (by Division) of Purcell, Lindsay, Lexington, Rhapsody Heights, Washington, Cullens, Harrah, and Unit Parts lagoon final effluent.

LITERATURE CITED

1. McKinney, Ross E. 1962. *Microbiology for Sanitary Engineers*, McGraw-Hill Book Company, Inc., New York.

2. Reid, G. W., M. J. Wilcomb, J. R. Assenzo and E. M. Davis. 1964. *Removal of Nitrogen and Phosphorus by Bio-Oxidation Ponds*, Progress Report, University of Oklahoma Research Institute, July 25.

3. Reid, G. W., M. J. Wilcomb and J. R. Assenzo. 1964. *Design Criteria for Nitrogen and Phosphorus Removals by Bio-Oxidation Ponds*, Proceedings of 14th Industrial Waste Conference, Oklahoma.

4. *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association, Inc., 1790 Broadway, New York 19, New York, 11th Edition, 1962.

5. Van Heuvelen, Willis, J. K. Smith and G. J. Hopkins. 1960. Waste Stabilization Lagoons—Design Construction, and Operation Practices Among Missouri Basin States, J. Water Pollution Control Fed. 32: 904-918.