CHAPTER - VIII

SUMMARY AND CONCLUSIONS

SUMMARY:

The results of investigations carried out with three normal types of photosynthetic algae under constant incident intensity of light during day and night requiring only inorganic nutrients, with heterotrophic sewage bacteria in laboratory models simulating high-rate aerobic ponds and using Baroda raw, settled, and strained sewage and are furnished and discussed in detail. The algal cultures used are Scenedesmus obliqus, Microcystis aeruginosa and Mixed algae. The two growth cultures (Scenedesmus and Microcystis) were examined for their physico-chemical and biological conditions. Scenedesmus obliqus alone was examined for bacteriological conditions and the mixed algae for their biochemical aspects on 0, 2, 4 and 6 days of detention period. Great improvement in quality of the final effluent was effected on the 6th day in all aspects in the case of the algal cultures as will be evident from the following data:-

1. The brown colour of the sewage gradually turned into green and clear in the case of *Scenedesmus obliqus* and blue green and clear in the case of *Microcystis aeruginosa* after six days.

2. The pH was found to reach the maximum of 9.2 to 9.8 in both the algal treated samples mainly due to algal activities.

3. Phenolphthalein alkalinity also was found to increase (15 to 84 mg/l) in both the algal treated samples.

4. 89% and 86% reductions were found in ammonia nitrogen within six days in *Scenedesmus* and *Microcystis* treated samples respectively.

5. Phosphate reduction after 6 days of detention period was found to be 83% in *Scenedesmus* and 62% in *Microcystis*.

6. 90 to 91% reduction of BOD_5 was brought about by the two algae. and bacteria

7. 85% and 91% reduction of COD was found in *Scenedesmus* and *Microcystis* treated samples respectively.

8. Percentage of reduction in bio-chemical tests like amino-acid nitrogen, protein, total sugar, free sugar and organic acids for the mixed algae alone were found to be 100%, 90%, 82.8%, 84% and 91% respectively.

9. The production of algal biomass (dry weight) in six days were found to be 282 and 236 mg/l in Scenedesmus and Microcystis treated samples respectively.

10. Occurrence of dark to light brown filaments resembling Leptothrix ochracea in large number were seen in both the control and algal flasks. Their significance is not known.

    Minute quantities of organic debris were seen intermixed with algae in algal cultures when viewed under a microscope.

    Rotifers (Lucane Sp.) were found in the algal treated samples alone.

11. From the sanitary aspect there was 99.9% reduction in Coliforms.

12. The 200 bacterial isolates have been classified according to certain important biochemical tests and studied for their dominancy on different detention periods. The most dominant bacteria found on different days are <u>Achromobacter</u>, <u>Aerobacter</u>, <u>Aeromonas</u>, <u>Alcaligens</u>, <u>Bacillus</u>, <u>Comamonas</u>, <u>Proteus</u>, <u>Pseudomonas</u> and <u>Zoogloea</u>. Significant difference in composition of the bacterial flora was found in the assimilatory and endogenous phases (Table - 8).

13. Most of the physico-chemical variables such as ammonia nitrogen, phosphate, BOD_5 and COD were used up and algal biomass was formed to a very great extent during first two days of the assimilatory phase and much less quantities were used during the last four days of the endogenous phase.

14. Dissection of the mechanism of algal-bacterial symbiosis into its two component parts; (a) bacterial oxidation and (b) algal photosynthesis has been made with a view to evaluate quantitatively how one process has helped the other, in our two experiments by means of simple equations and certain assumptions based on well known facts.

This is an important contribution to our knowledge on the subject of high-rate oxidation ponds.

Calculations of total bacterial mass according to Sawyer (1956) and McKinney (1952) and their correlation have been worked out. It is found that Sawyer's formula which is based on BOD gives values which corresponds to nearly two thirds of McKinney's formula which is based on COD.

Using Porge's (1960) factor (1.2) for conversion of COD values into organic matter values, and with the help of Oswald _et al_'s (1958) experimentally found equation for the oxidation of sewage organic matter, two factors have been found for estimating CO_2 production as a result of "total oxidation" of organic matter and for O_2 requirement. It is 1.56 mg of O_2 required for each mg of organic matter oxidised and 1.69 mg of CO_2 is released during total oxidation of 1 mg of organic matter.

For calculating the quantity of CO_2 required for algal biomass production, Myer's (1962) value of 1.8 mg per mg of algal dry mass has been used.

For calculating photosynthetic O_2 production, Gotaas and Oswald's (1955) factor of 1.6 mg per mg of algal mass has been used.

15. With the help of these factors it is possible to evaluate quantitatively how much CO_2 was liberated by organic matter and used by algal biomass; and how much O_2 was required for bioxidation and liberated by algae in the experiment. It was always found that organic CO_2 from organic matter was not sufficient for algal biomass production and that a certain quantity originated from the atmosphere and that photosynthetic O_2 production was always in excess.

During the bacterial oxidation phase, 263 and 255 mg/l of sewage organic matter were oxidized in 6 days using 410 and 398 mg/l of O_2 and liberating 445 and 431 mg/l of CO_2 for use by the algae in photosynthesis in *Scenedesmus* and *Microcystis* treated samples respectively.

During algal photosynthesis phase, there was the formation of 282 and 236 mg/l of algal biomass, which used up 508 and 425 mg/l of CO_2 and released

451 and 508 mg/l of photosynthetic O_2 in the two experiments.

16. A quantitative correlation between total bacterial biomass according to McKinney's formula and the determined algal biomass values has been established and the former is found to be about one-half of the latter.

17. Direct correlation between algal bio-mass formed and COD used up has also been found, the correlation coefficient was found +0.71 and +0.997 in *Scenedesmus* and *Microcystis* treated samples respectively.

18. The percentage efficiency of light utilization by *Scenedesmus obliqus* was 2.53% and in the case of *Microcystis aeruginosa* 2.12%.

19. These bio-chemical reactions are rendered possible on account of the penetration of radiant energy into the shallow depth of the culture flasks throughout day and night.

20. Solid surfaces are provided by the algae which, besides furnishing photosynthetic O_2 for bacterial

oxidation, also seem to act as resting places for bacteria and where nutrients also concentrate on their solid surfaces. So, that bacterial oxidation is taking place at different depths in the high-rate oxidation pond.

21. Mixing for a few hours everyday helps in distributing oxygen throughout the liquid medium and in maintaining the bacterial sludge in an aerobic condition so that bio-stimulatory nutrients are released into the medium for algal synthesis. Also, it is another way of increasing the photosynthetic efficiency of the algal cells.

22. During the phase of bacterial oxidation of organic matter, complete oxidation of organic matter, cellular synthesis, and bacterial sludge formation do take place along with endogenous respiration of the bacterial sludge thus formed, in the presence of excessive amount of photosynthetic nascent oxygen and newly formed algal cells.

All these processes are taking place almost simultaneously with the result that an abundance of algal cells alone is visible, of course intermixed with the skeletons of bacterial sludge and newly formed algal cells. These reactions are continuous so that it is not possible to say which of the biochemical reactions is taking place first and which next.

23. The entire biochemical processes resemble those taking place in the euphotic zone of a shallow pond in the tropics.

24. The "constancy" in sludge volume in high-rate aerobic ponds has been explained and it would seem to consist of non-bio-degradable organic matter and active bacterial mass. Further field work is necessary to determine the nature and composition of the "constant sludge volume" in high-rate aerobic ponds.

CONCLUSION

1. This form of treatment is far superior to an activated sludge process or trickling filter as (a) it purifies the sewage to a very high degree

(b) removes both organic and inorganic nutrients, (c) to reclaim nutrients as algae, whose separation now appears to be within the realms of practical economics, (d) harvested algae is a valuable by product, which can be used as poultry or animal feed in the form of algal protein and also could effect a significant part of the cost of sewage treatment, and (e) the effluent does not cause eutrophication in receiving waters.

2. A method for quantitative evaluation of algal bacterial symbiosis taking place in high-rate aerobic pond has been devised for the first time making use of COD and algal bio-mass data.

3. COD and algal bio-mass are the two indispensable factors from which a number of interesting predictions can be made : (a) it is possible to predict the quantity of algae that can be produced from a waste water with a known COD value and (b) the concomitant photosynthetic oxygen production for bio-oxidation of organic matter in organic waste.

4. In India, ponds resembling high-rate aerobic pond system, have been in existance for the past several centuries with permanent blooms of blue-green algae, the like of which exist no where else in the world. They are temple tanks attached to each of the hundreds of ancient temples in India. They are highly organically contaminated (of course not with sewage); and it will be of great scientific interest and practical value if the biochemistry of a few of them are thoroughly studied.