I N T R O D U C T I O N

CHAPTER - I

INTRODUCTION

1. HISTORICAL:

The conventional oxidation pond method of sewage purifica--tion and its various modifications as we know them today, did not develop from a well planned research programme but was evolved out of the time-honoured emperical practice of lagooning organic liquid wastes in basins or depressions or ditches used chiefly for seepage, settling or holding. Soon after, such accidental or designed use of ponds was reported as a means of treating municipal wastes. The earliest records of the existence since 1924 of one such oxidation pond is in Santa Rosa in the U.S.A. and the first scientific paper giving real importance to oxidation pond as a distinct method of sewage treatment is by coldwell (1946). Since then, numerous publications have appeared, all of which deal with either design, operation and performance or all the three. This treatment system depends on the effective use of bacteria for degradation of the soluble organic constituents and ordinarily of green algae for oxygenation. Aerobic conditions are maintained near the surface in facultative ponds and throughout the depth in aerobic ponds.

Fitzgerald and Rohlich (1958) have evaluated the existing literature on the subject under several heads such as the history of the use of oxidation ponds, their effectiveness in lowering BOD, relationship between algae and standard BOD measurements and its removal, organic loading and purification, their effectiveness in lowering coliforms, pathogenic bacteria and nutrients and algae, their yield, seasonal variations and limiting factors, their economic etc. Recently Gloyna (1965,1971) has furnished an account of the experience and concepts pertaining to all the three main types of waste stabilization ponds.

2. Rational Design Criteria:

Fundamental quantitative data for their economical and efficient engineering design have been furnished first by the California university Engineering Research Group led by Gotaas and Oswald. Gotaas and Oswald (1955) and Oswald and Gotaas (1957) have developed design criteria for oxidation ponds taking into account both controllable and uncontrollable factors. Suwannakaran and Gloyna (1963) have evaluated later, under laboratory conditions, the effects of temperature and organic loading on the performance with a view to establish better design criteria. They found that within limits, the BOD removal increased with the increase in temperature; changes in biological activity due to temperature fluctuations influenced the pH, MPN of coliforms, suspended solids, light transmission, predominant algal species etc. They claimed that it was possible to formulate a design equation taking into account both temperature and pond loading. Van R.Marais (1963) has also presented a rational theory for designing oxidation ponds in tropical and subtropical areas of Africa based on the correlations of the kinetics of BOD and faecal bacterial reductions in a series system of oxidation ponds, Wachs, Bebhum, Meron, Kutt and Siess (1961) have studied the oxidation ponds in Israel and stressed the need for investigations regarding the chemical and biological processes involved in them. Neel,Dermott and Monday (Jr.) (1961) studied five identically sized oxidation ponds loaded at 40,50,60,80 and 100 lbs/acre/day and showed that oxidatiom ponds were very efficient in reducing BOD, phosphate, and nitrogen compounds. Parker (1962) has furnished data on eight oxidation ponds working in series in Australia. The BOD reduction was reported to be excellent throughout the ponds. Only the eighth pond showed a definite reduction in nitrogen content. ~~Bogan, Albertson and Pluntze (1960) studied the removal of phosphates by algae and found that these were removed better by chemical purification rather than by algal metabolism.~~ Bush, Ishwarhood and Rodgi (1961) attem--pted to remove the nutrient substances from an activated sludge effluent by treating it with a continuous supply of carbon dioxide for increased algal gfowth, and to maintain a pH between 7.0 and 8.5 76% of the phosphates and 100% of the nitrogen were thus removed. Ganapati, Prasadrao, Godbole, Kothandaraman and Koshy (1965) have studied the bio-ecology of solar serwage drying beds (which are nothing but small-sized high rate aerobic oxidation ponds) in the Pirana Sewage farm at Ahmedabad, India. Gann, Collier and Lowrence (1968) state that the bacteriology of stabilization ponds is conspi--cuous by its absence from literature.

From the foregoing brief review of the literature, it will be seen that most of the studies deal either with engineering design data or with the non-pathogenic coliforms which are indicators of sewage pollution or with pathogenic bacteria of the Salmonella and Shigella groups and practically none about the relative distribution of the natural microbial populations involved in the so called "algal-bacterial symbiosis" as they undergo environmental stress as a result of long storage or retention period of 20-30 days in conventional oxidation ponds.

3. Role of algae in the purification of sewage:

In the two older conventional methods of sewage purification, the activated sludge process and the trickling filter, oxygen which is essential for oxidation of the putrid and decomposing organic matter is obtained by mechanical means. But in the oxidation pond method, oxygen is releasek into the water medium by fresh algal cells which split water molecules as a part of their photosynthetic activity. Thus natural light energy is used to produce oxygen, when two basic types of reactions are taking place together: Oxygenation by algal photosynthesis and bacterial oxidation of the decomposing organic matter. The rates of these reactions are governed by the rate of growth of algal cells, which is believed to depend primarily upon the availability of Co_2 and the amount of light. So sun's energy is trapped through algal photosynthesis as the principal synthetic force for purifying sewage in oxidation ponds.

Algae may release twenty times as much oxygen in photosynthesis as they utilise in metabolism (Palmer 1956). The significance of this in the biological aerobic purification of organic wastes is obvious, since rapid decomposition of wastes depends primarily on aerobic bacteria. So intensive cultivation of algae in fresh sewage is a highly effective means both for supplying oxygen for aerobic decomposition of organic matter and for reclaiming nutrients from the wastes in the form of algal cells.

4. Aerobic Ponds:

Oswald and Gotaas (1957) have divided aerobic oxidation ponds into two rather artificial classiciations. Type I ponds are those which by the authors definition, obtain the oxygen necessary for waste stabilization through surface aeration and have detention periods of from atleast three weeks to six months. Type II ponds on the other hand, are those which have detention periods of less than one week and are called high rate aerobic ponds and which are soley dependent on photosynthesis for oxygen supply.

Gloyna (1971 83) on the other hand classifies aerobic ponds on three concepts (a) minimum depth and maximum, algal production, (b) equalisation of BOD removal and pathogen control and (c) induced mechanical mixing or aeration which may support aerobic bacterial activity without involving photosynthetic process. That sewage treatment by complete photosynthetic oxygenation using minimum depth and maximum algal production in shallow ponds called high rate oxida--tion ponds is feasible was first demonstrated by Gotaas and Oswald (1955), Golueke et al (1959). Oswald et al (1959 a, b) and Oswald (1960). The designs of such ponds are being based on large surface area to volume ratios, when large amounts of algae are found to de--velop with comparatively little bacterial sludge. Field studies on high rate aerobic ponds carried out with waste waters (demestic, industrial and agricultural) for stripping them of their nutrients and/or for mass culture of algas (Oswald et al 1964, Hemens andMason 1958, Oswald and Golueke, 1968) have amply demonstrated the practi-cability of the concept on a large scale,(Beek at al 1969).

In recent years a fourth concept known as "activated algae" process has been developed by Mckinney and his associates, and it is based on the classical activated sludge and oxidation pond models. Initial laboratory experiments have shown the soundness of the concept (Mc Griffand Mckinney, 1971, McGriff, 1970; Mckinney and Waheb, 1968; Goodman and weiss 1968; and Humenik and Hannah (1969). A secondary tertiary activated algae system with flocculating proper--ties similar to an activated sludge system is being established with excellent BOD and solids reduction." Initially nutrient removal was the objective, but fundamentals indicated that the algal-bacte--rial symbiosis of the oxidation pond could be applied to an activated sludge that was capable of removing both the organic and the nutri--ent elements. The key was applying the basic concepts of microbial flocculation that had been developed from the research on conventional activated sludge. The initial effort to take activated algae to the field failed, but repeated laboratory studies have demonstrated the soundness of the concept. In time, a field unit will be possible to fully evaluate the potential of activated algae process for solving some of our waste water treatment problems." Thus Mckinney has summarised the lavdable efforts of his five young men who had worked so very hard to make "activated algae" work in the laboratory.

There are several points of similarity and difference between the two types reported above. Emperical methods were adopted in improving both. The net result is that the high rate aerobic pond is a success while the "activated algae" process is a failure at the moment. In spite of the voluminous literature now available on stabilisation of wastewater by the oxidation pond method, our knowled--ge about the technical operation of the process is still "much emperical" (Oswald, 1960, P.384). Only quite a few references are concerned with the nature of the purification process and till today only a few basic facts have been found. Little is known about the principles underlying the absence of huge bacterial flocs as in the conventional activated sludge process. This demonstrates the need for a detailed probe into the fundamental principles of bacterial oxidation and photosynthetic reduction in the high rate aerobic pond system. Without understanding why and how it works, it will be impossible to obtain full benefit, from it. Also, for proper opera--tion and design of any biological waste treatment, a thorough knowledge of the basic principles of biochemistry and microbilogy in the system is a desideration because stabilization of organic matter is brought about chiefly by microorganisms. These facts are sufficienetly convincing to justify detailed bio-chemical studies on algal-bacterial symbiosis in high-rate aerobic ponds with varying detention periods and algae. An attempt is made in this thesis to study the bio-chemistry of algal-bacterial symbiosis in high rate oxidation ponds using Chlorella vulgaris, Euglena Gracilis and Microcystis aeruginosa which are technically classed as autotrophic photolotho trophos and Baroda settled raw sewage. Although in the title only the name of one alga is given, I have experimented with two more algae later on at the time. I registered for my Ph.D. I was doing only with Chlorella and hence the name of one alga is mentioned.

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