CHAPTER - VI

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WHY TOTAL OXIDATION IS IMPOSSIBLE IN HIGH-RATE OXIDATION PONDS:

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Why "total oxidation" is impossible in High - Rate Aerobic Ponds:

Before discussing Why "total oxidation" is impossible in a high-rate aerobic ponds, it is considered essential to understand (a) how a high-rate pond has been worked. An account of the same is furnished below, the details of which having been taken largely from the two important papers of Oswald et al (1959) and Oswald (1960).

(a) An account of the working of a high-rate aerobic ponds:

Their pilot pond measured 17x140 ft. of polyethylene sheet was then laid in such a manner as to extend over the entire area and totap over the top of the side walls consisting of planks. The depth and detention periods were varied for the several experiments from 5" to 12" and the detention period from 2 to 4 days. The recir--culation ratio was set at 8:1 continuous feeding could not be done throughout the day. Instead, the pond was fed once each day by pumping sewage to the inlet end and simultaneously displacing an equivalent amount at the effluent end, until a volume of sewage had been added which was equal to that required to maintain the desired detention period. The volume of displacement was controlled by manual operation of the feed pump.

Hydraulic and Organic loadings:

(i) Hydraulic load (inches) = 2-3

(ii) Organic load (lbs/acre/day) 100-200

(iii) Pond influent BOD5 at 20°C 200 ppm

(iv) Pond effluent BOD5 at 20°C = 20 to 30 ppm.

(v) % BOD removal = 80-95.

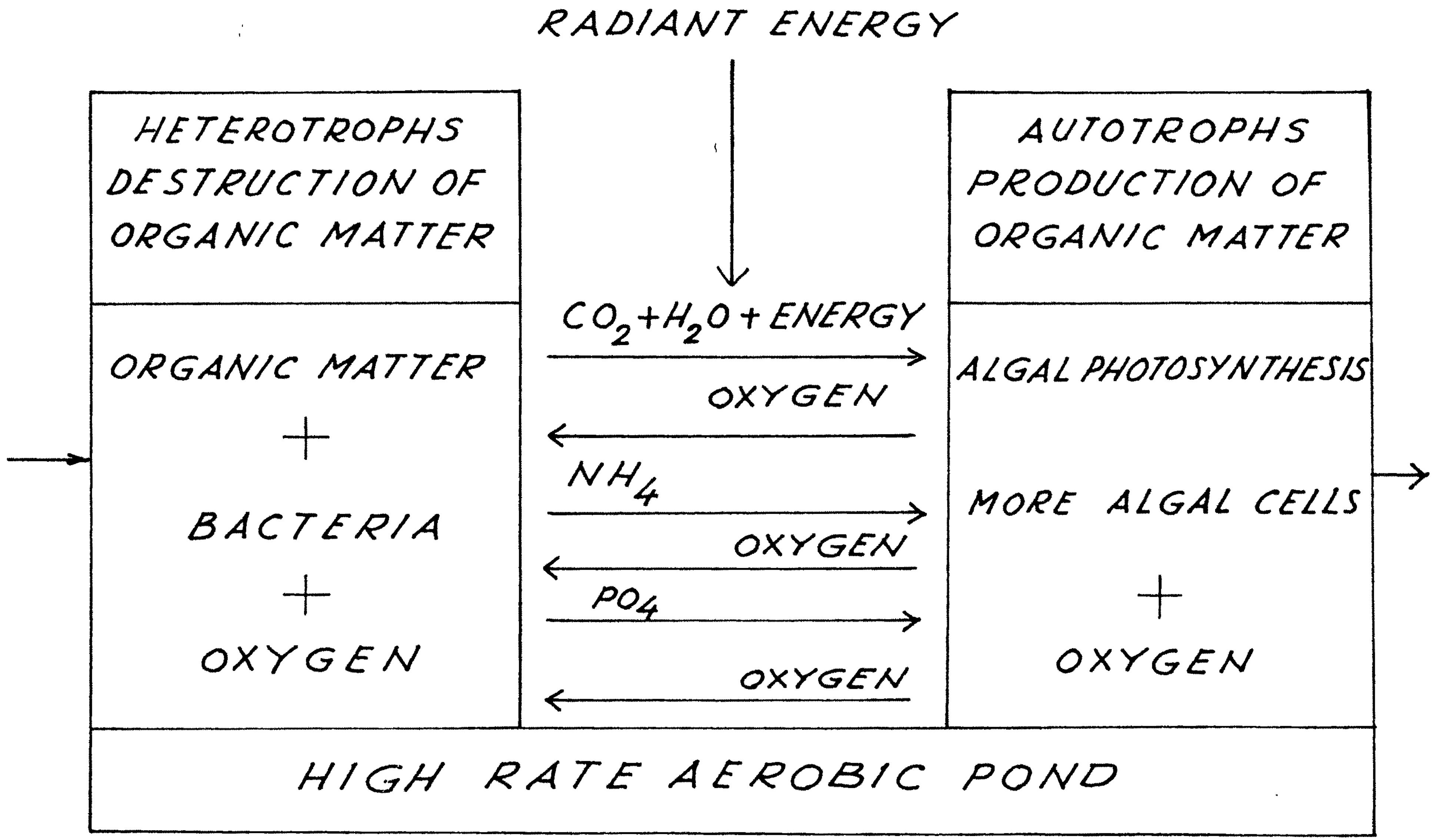
Sampling was done at hour intervals during a 4 hours period following the introduction of sewage and at 2 hours intervals during the remainder of the 24 hours period are detailed below.

" A 24 hour study was conducted with a plastic lined high-rate experimental pond, the contents of which were mixed at the beginning of the study and then dosed with sewage within two hours. Transient change in the pond BOD, dissolved oxygen concentration, and rate of deposition of settleable solids, were studied. About 90% of the BOD in the pond at the start of the experiment was in the bottom sludge. After mixing, about 12% of the bottom BOD remained in the supernatant and the remaining 88% quickly settled at the bottom."

"Upon adding a single dosage of sewage, a large protion of the added BOD also settled to the bottom of the pond as a sludge layer. At the end of the 24 hours period, the BOD of the pond super--natant had returned to its level at the start of the study, showing that all of the dissolved BOD was treated within the period. Thus a state of equilibrium existed in the pond in which the daily increments of BOD were disposed of by a complete aerobic process."

"After mixing, the BOD of the pond liquid did not return to its previous level, because some of the oxidizable organic matter in the disturbed layer had become dissolved and was re-distributed throughout the pond by mixing. The material giving rise to this fraction of the BOD probably represents the break down products of bacterial decomposition, which is constantly taking place in the sludge layer. Mixing serves the essential function of dispersing aerating these break down products."

"The limited increase in BOD of the pond liquid directly after adding sewage probably was due to the fact that some time was required before recirculation brought about complete mixing. Moreover,


RADIANT ENERGY
HETEROTROPHS DESTRUCTION OF ORGANIC MATTER
ORGANIC MATTER + BACTERIA + OXYGEN
CO2+H2O+ENERGY
OXYGEN
NH4
OXYGEN
PO4
OXYGEN
AUTOTROPHS PRODUCTION OF ORGANIC MATTER
ALGAL PHOTOSYNTHESIS
MORE ALGAL CELLS + OXYGEN
HIGH RATE AEROBIC POND

throughout this period portions of the newly added sewage were undergoing oxidation and bio-flocculation, so that the fraction in the supernatant decreased rapidly. That organic matter was being stored in the bottom sludge is indicated by the fact that the total BOD of bottom sludge plus pond liquid was almost four times that of the pond liquid, after recovering the sewage loading. The slow decline in BOD during the 2 to 6 hours interval after adding sewage probably was a function of both oxidation and settling. Apparently the relatively slow process of oxidation was accompanied by a build-up of floc particles through bacterial activity. As the floc particles increased in size, they began to settle rapidly; hence the rapid decline in BOD during the interval between the 6th and 8th hours."

The slow rate of decline in BOD from the 8th to 17th hours after adding sewage represents the slow oxidation and setting of organic matter resistant to rapid bacterial action. The rate of decline in BOD during this interval was low because the over-all concentration of organic matter in the liquid phase was low."

"About 90% of the suspended settlemble solids were on the bottom of the pond within 15 minutes after completion of the mixing operation. This was about the time required for the dissolved oxygen concentration to reach its level prior to mixing."

"The steady decline in dissolved oxygen concentration from the 3rd to 11th hours after mixing probably was caused by the increased utilization of oxygen by bacteria when stimulated by the added BOD load, and during the evening by the cessation of oxygen production by algae."

"The gradual rise in dissolved oxygen concentration which began at 11 p.m. was a result of diffusion of oxygen into the pond from the atmosphere. The relation of oxygen saturation to rate of diffusion from the atmosphere continued to be such that oxygen could diffuse into the pond until dawn, at which time the amount of oxygen required for bacterial activity was less than the amount of oxygen entering the pond. Had the pond been more than 5 inches in depth, or the BOD of the sewage greater than 60 ppm, the effect of the atmospheric reaeration would have been less noticeable."

"In as much as the primary settled sewage added to the pond contained a negligible amount of settleable solids, the accumu--lation of settleable solids on the bottom of the pond was probably due to the bio-flocculation. As the particles reached a "settleable" size, they sank to the bottom of the pond where they decomposed at a rate dependent upon the availability of oxygen. The small amount of settleable solids remaining suspended in the pond liquid at the end of the study represented the incipient floc particles or particles about to settle. These were generally discharged with the effluent and probably contributed significantly to the effluent BOD". They concluded from these experiments thus:

"A high-rate pond must be shallow enough to permit the entry of light almost to the bottom of the pond and it must be mixed to maintain the deposited, sludge in an aerobic condition, It must be lined to permit economical mixing to prevent undue turbidety and to control the growth of emergent vegetation."

"Mixing is accomplished through the use of high-rate volume, low-head pumps, which are automatically turned on periodically to create a flow velocity in the pond of about 1.5 ft. per second. This velocity sup-plies sufficient tractive force to suspend both deposited algae and deposited sludge, and to permit its contact with the oxygen rich supernatant at the pond. Experience has shown that a healthy aerobic sludge compared to activated sludge is main-

-tained in the pond, provided mixing is carried out for about 3 hours per day. Following an initial accumulation, the volume of the aerobic sludge does not increase but rather remains constant, indicating essentially that total oxidation is taking place. During mixing the sludge is suspended throughout the pond volume, but within 15 minutes after mixing ceases, more than 80% of the sludge settles and is again distributed over the pond bottom so that sunlight entering the surface is not obscured. The algae do not adhere to the sludge nor do they become incorporated in it. Rather they remain suspended to continue their synthesis in sunlight,unless an extremely high pH brings about autoflocculation. From the data presented in Table it is evident that high rate of entirely odour free BOD removal may be attained in high-rate ponds."

Oswald (1960) has further added:

"Although reports which list the specific organisms involved in aerobic oxidation in stabilization ponds are not availa--ble, it is extremely likely that the aerobic bacteria of ponds which are mainly contained in a yellow-bmown flocculent sludge (the substance created during bio-flocculation)differ but little from these found in activated sludge or in trickling filter slime (22)". Oswald (1960, p 384) has continued thus: "A healthy sludge compara-ble to activated sludge is maintained in the pond, provided mixing is carried out for about three hours a day. Following an initial accumulation, the volume of aerobic sludge does not increase but rather remains constant indicating essentially that total oxidation is taking place."

(iii) Again Golueke (1960) Professor Oswald's Colleague has observed as follows:-

"An extensive knowledge of the ecology of the organisms involved in the process for the treatment of waste in high rate oxidation pond is required. This is true because effective biological control requires an optimum relationship between the environment and the biotic community concerned; and this can be accomplished only by providing proper environmental conditions. To establish a relation--ship it is necessary to know the nature and extent of the fnfluence of the principal enviromental factors to which an algal bacterial community is subject in an oxidation pond".

"There is paucity of information in the literature on the effect of these enviromental factors either individually or colle--ctively on such organisms when living as members of a biotic commu--nity."

From the foregoing three feferences, it will be found that (i) so far no attempt has been made to identify the specific micro -organisms which are responsible for purification in the high-rate oxidation method (ii) how a healthy sludge comparable to activated sludge is maintained in the pond; (iii) how that the volume of the sludge does not increase but remains constant indicating (iv) that total bacterial oxidation is taking place. In short, the originators of the high-rate oxidation pond seem to think that metabolic processes similar to an activated sludge process are taking place but that they differ from the activated sludge process in two impor--tant respects; (i) in that the volume of the sludge does not increase quite unlike as in an activated sludge process; and (ii) that the total oxidation is taking place which is also not the case in the classical activated sludge process.

So to understand the mechanism of purification in the high-rate oxidation pond, it is necessary to trace briefly the basic facts known to date about the purification since 1914 and it is done below:

(b) Microbes in action in high-rate aerobic ponds:

A striking feature of microbial metabolism in waste treat--ment systems generally is the relatively enormous amount of new bacterial solids, which are normally produced during the oxidation of organic substrates. One should therefore, expect to find a heavy accumulation of bacterial sludge in the high-rate aerobic pond system. But Oswald (1960, P.384) has stated that a healthy sludge comparable to activated sludge is maintained in the pond and that, following an initial accumulation the volume of aerobic sludge does not increase but rather remains constant indicating that "total oxidation" is taking place. In our three laboratory batch culture experiments with Chlorella ~~nine different types of green and blue green algae~~, there was no accumulation of sludge as in the classicial activated sludge process but only comparatively less brownish deposits were seen intermixed with algae when viewed under a microscope. Also, the formation of a"constant" volume of bacterial sludge as in Oswald's field ponds and very little sludge in our laboratory experiments is possible only if the system is operated on endogenous metabolism resulting in "total oxidation" of bacterial sludge. It would appear therefore that the high-rate aerobic pond system also is operated on endogenous metabolism resulting in "total oxidation" and naturally one would expect to find entirely different types of microorganisms during the assimi--lation and endogenous phases. Infact jasewics and Porges (1956) and Porges (1960) have made a complete survey of the bacteria in action in a dairy waste activated sludge they found presence of *Psendomonas* and *Achromo bacteriaceae* when the sludge was in its endogenous phase and of *Bacillus* and *Bacterium* in its assimilation phase. However, these results were not confirmed by Admse(1968) in his systematic and equally thorough investigation of the bacterial flora of a similar dairy waste activated sludge. He found no signi--ficant difference, in composition of the activated sludge bacterial flora before and after feeding. In our case the results are confili--cting through conditions, favouring endogenous metabolism existed.

(c) "Complete" and "Constant" sludge volume in activated sludge and in high-rate aerobic pond.

Mekinney (1962, P.231) has stated that one of the most novel processes, was found in research on dairy wastes by Hoover Jasewics) and Porges (1951, 1952). They found that activated sludge rapidly removed the organic matter from solution and converted much of it into protoplasm which was degraded when all the organic matter was removed. This fundamental concept which was well known in the field of bacteri--ology had never been applied to practical problem, in waste treatment. They had applied it to dairy waste treatment. Porges (1960) has concluded that it should be theoretically possible to arrange conditions so as to maintain a balanced system in which sludge or cells do not accumu--late. All that would be required is sufficient nutrients to produce enough cells to replace those being oxidized by endogenous respiration. This ideal state has been approached but not attained". Oswald and his associates seem to have attained that "ideal State" in their high-rate aerobic ponds indicated at the beginning.

(d) Is total oxidation possible?

Rupert Kuntz and Firney (1959) at Pennsylvania State University were assigned the Job of converting the concept of "Complete oxidation" from the laboratory to full scale plants. It was found that it was im-possible "to burn up" the activated sludge completely by aeration.

In the Ideal case the reduction ~~is~~ in mass of activated sludge by aerobic digestion balances the growth of new sludge so that no surplus sludge is left for disposal.. From the experience in U.S.A. it is known that "total oxidation" of sludge cannot be achieved since there is always a fraction which is inert and which cannot be broken down by aeration. Kountz and Forney (1959) and Washington and Symons (1962) found that, the non degradable portion remaining to be approximately 20% of the maximum mass of microorganisms formed or 11 to 15% of the ultimate BOD_5 removed. Mc Whorter and Heukele--kian (1964) reported that the inert organic matter to be 12% of the initial COD, and Washington and Hetting (1965) to be about 10% of COD consumed.

(e) "A constant volume" of sludge in high-rate aerobic ponds:

So from the statement of Oswald (1960, p.384) "A healthy sludge comparable to activated sludge is maintained in the pond, provided mixing is carried out for about 3 hours a day; following an initial accumulation the volume of aerobic sludge does not increase, but rather remains constant indicating essentially that total oxidation is taking place, " it would appear that "the constant volume of aerobic sludge remaining in the high rate pond" may consist essentially of the inert matter and active bacterial mass. Further work is therefore necessary to examine the nature of its biochemical constituents.

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ADVANTAGES OF USING HIGH-RATE AEROBIC
OXIDATION PONDS

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