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INTRODUCTION

General principles involved in the three treatment processes

The three well-known methods of aerobic biological treatment of sewage and other organic wastes at the present day are the activated sludge process, the trickling filter, and the oxidation pond. In all these treatment devices, the soluble organic matter is either removed essentially by the combined metabolic activity of a mixed population of aerobic heterotrophic bacteria resulting in the same final degradation products such as carbon dioxide, nitrites, nitrates, water and/or is converted into cellular material. It is, therefore, also stated that the fundamental biochemical principles involved in purification by these engineered biological treatment processes are basically the same though differing from each other in so far as plant and operation are concerned.

The basis for success in each method

In the first two systems, the success of the treatment depends upon (a) the formation of sludge-flocs containing microorganisms, (b) nutrients present in sewage or organic wastes, (c) a continuous source of oxygen supply, (d) the physical methods adopted to keep (a), (b) and (c) dispersed and in constant contact with each other, and (e) continuous or frequent removal or sloughing off of excess by-products in the form of activated sludge flocs or accumulations on filter stones. The mixing is brought about in the case of the activated sludge process by " agitation of the sludge - sewage mix with compressed air " and in the case of the trickling filter " the sludge mass is held dispersed on a framework of stones or other material while the sewage trickles over the surfaces of the sludge. " While the two processes are fundamentally similar it does not necessarily follow that the active bacterial agents are the same or even belonging to the same group of organisms " (Butterfield and Wattie 1941). But in the conventional oxidation pond method of sewage treatment, there is neither the formation of visible suspended sludge flocs, nor continuous mixing and agitation, nor continuous withdrawal of excess sludge as in activated sludge process, nor periodic sloughing off of the accumulations on filter stones as in a trickling filter. So, it would seem that the exact mechanism of purification may not be the same as in the other two processes.

<u>Difference in purification time in each case</u>

The specialised treatment structures imposed by the mechanical aspects of these systems have been arrived at by " purely emperical procedures " (Phelps 1938) ; and are, perhaps, responsible for causing differences in the patterns of the degradation processes. So, the time taken for purification in each case is strikingly different. In the case of the activated sludge system " with its wide spectrum of modifications ", where huge quantity of floc is in constant motion sweeping through the liquid to be purified, the contact period between the organic wastes and the activated sludge when the stabilization is brought about is about 4-6 hours. If molecular oxygen replaces air in the above process, purification is effected in less than one hour (Water Pollution Research 1957). Trickling filter, on the other hand, does not remove as much organic matter as activated sludge or oxidation pond, as the purifying films on the filter media are stationary with the sewage flowing over them; and the contact period between the wastes passing through the trickling filter and the microbial surfaces on the filter stones is approximately thirty seconds according to the studies made at the Robert A. Taft Engineering Centre and at the Purdue University (Mckinney and Pfeffer, 1965). However in the case of the conventional oxidation pond neither of the above phenomenon occurs. Surface aeration with atmospheric oxygen takes place to begin with and is later followed by photo-synthetic oxygenation. The time required for organic wastes to be purified by this comparatively sluggish process, is 20-30 days, which is lessened to 2-5 days in the high rate oxidation pond

(McGauhey 1960). According to Lackey and Smith (1956) " The environment largely determines what species accomplish treatment." In other words, Darwin's theory of the survival of the fittest is the foundation of all the three processes.

Mechanism of purification in each case

The exact principles or pattern of purification may be expected to be different in each of these three cases. For example McNamee (1936) found that the soluble and colloidal matter in sewage is oxidised more rapidly in activated sludge process although the microorganisms in the trickling filter and activated sludge processes are reported to be similar (Butterfield and Wattie 1941; and Feldman 1955). Since the physical conditions in the two systems are entirely different there is no assurance that the rates of oxidation observed in one system will also be obtained in the other (Sorrels and Zeller 1953). Again, Hotchkiss (1924) found that not only proteolytic bacteria predominated but also those bacteria concerned with nitrogen transformations were abundant in trickling filters. James (1964) found 90% of his total counts in trickling filters to consist of Gram negative rod shaped bacteria belonging to the genera Achromobacter, Alcaligenes, Flavobacterium, Pseudomonas and Zoogloea.

Johnson (1941) found the slimy growths on the filter media in the upper half of the trickling filters to consist of Zoogloea ramigera. Allen (1940), on the other hand, found that the bacteria isolated from activated sludge to be non-proteolytic soon after the formation of sludge flocs but a proteolytic flora was established after the sludge had been built up for a period of four weeks. Investigations of the patterns or pathways of purification of all the three processes have not been made. Though a considerable amount of literature is available on the theory and mechanism of purification by the activated sludge process only, still unanimity of opinion has not yet been reached on this process as to the exact mechanics of purification. "Fundamental knowledge about the activated sludge floc is inadequate " (Van Zuilen 1964).

Algal-bacterial Symbiosis

While activated sludge tanks and trickling filters provide an extremely favourable environment for the growth and operation of biological flocs the conventional oxidation pond imposes definite environmental restrictions for the development of such biological flocs, thus seemingly restricting the usefulness of this method of sewage purification. According to Oswald, Gotaas, Ludwig and

Lynch, (1953 (a)), oxidation of soluble organic matter by bacterial action takes place during the first two weeks or so. This phase is soon succeeded by the algal phase when, as a result of photosynthesis molecular oxygen is produced in sufficient amounts permitting bacterial oxidation to proceed unhindered. These two phases, the bacterial phase I and the algal phase II are not necessarily sharply divided rather they may overlap to some extent. All the same, it is stated by Gotaas and Oswald (1955) and Oswald and Gotaas(1957) that this method of purification is as efficient as the other two systems, and that purification is effected by " algalbacterial symbiosis " or by the combined activity of heterotrophs and autotrophs. The types of bacteria concerned in the symbiosis and the pattern or the pathways of degradation of the soluble organic substrates are still unknown although enormous literature has been published on certain aspects of purification such as design-criteria, criteria for operation, physico-chemical changes, BOD and Coliform reductions, development of algal types etc.Parker (1962) has also stated that no detailed study of the dominant bacterial species occuring in different types of oxidation ponds has been made so far.

How oxidation pond is more economical and useful

Again, the two systems of treatment - the activated sludge process and the trickling filter - "have not been designed for direct recovery of any appreciable amount of the millions of tons of nutrient materials now being wasted. As a result, waste treatment generally represents almost a complete loss of energy and fertility values, in addition to requiring the expenditure of large sums for constructing and operating treatment plants. Thus, in the name of sanitation civilized nations are systematically financing a more rapid than necessary depletion of their natural resources " (Gotaas and Oswald 1955). The nitrogen discharged in sewage effluents from the first two systems in Britain alone has been estimated to be equivalent to about one-third of the country's requirements of nitrogenous fertilizer (Natural Resources - Technical - Committee 1954). But in culturing algae in oxidation ponds nitrogen is conserved as algae (vegetable protein) which can be used as food for man or animal. So it would appear that the oxidation pond method might be more useful in the interest of economy, prevention of health hazards, and of nuisance, in the under-developed and developing countries of the world.

In India, for example, which is a fast developing country, there are 558,089 villages and 3018 towns. How the urban population is distributed in the different towns of India where the disposal of sewage is an urgent problem, is shown below :

Description	No. of towns	No. of town dwellers in Lakhs	Urban Population %
Cities	73	235	38.0
Major towns	485	186	30.1
Minor towns	1848	178	28.6
Townships	612	20	3.3
Total	3018	619	100.0

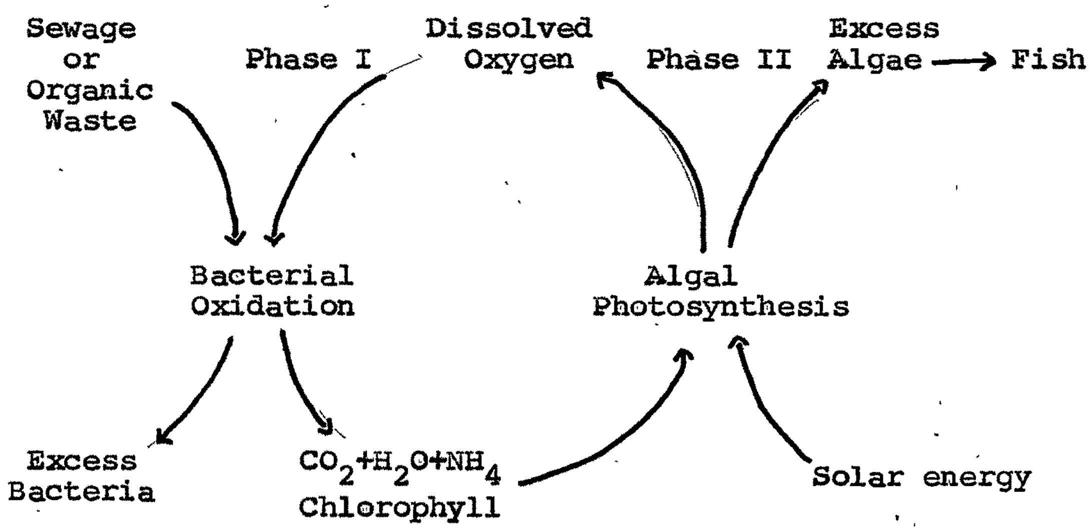
The need for low-cost treatment devices whose operational requirements are within the reach of the above rapidly growing urban communities with limited funds will thus be evident. Sewage treatment by oxidation ponds is considerably cheaper than other methods as long as a municipality is not too large (Frankel 1964). It is a form of secondary treatment of organic wastes where large quantities of cumbersome sludge are not formed; and therefore there is no need for disposal of sludge by separate sludge digestion process as in activated sludge process. Imhoff and Fair (1956) have stated that in the case of a 10 acre oxidation pond used for 1000 population, the net volume of digested sludge per year is 3212 Cft. thick. In other words 135 years will be required for building up one foot layer of sludge in the bottom only. This is not likely to produce an appreciable loss of capacity of the pond. Hence it is stated that the necessity of sludge removal will not arise for a very, very long time.

Also, " In a world that is poor in proteins, particularly in tropical areas which receive abundant sunlight with millions of under-nourished people and declining fixed energy sources, it appears that engineering photosynthesis utilising solar energy for waste reclamation has excellent future, permitting man's wastes to offset his wants " (Gotaas and Oswald,1955). For this reason oxidation ponds may be considered as combining the production of a useful food for man or animal with the effective disposal of organic wastes.

Land is comparatively very cheap and easily available in India. Sunshine which is essential for photosynthesis is found in optimum. Warmth which is necessary for speeding up biochemical activity is greater. So, the reaction speed of biochemical activity according to van't Hoff theory will be four to nine times greater than in the temperate regions; and consequently, the pattern of degradation of the soluble organic constituents may be expected to be different in the tropics. From the bacteriological point, the final effluents are comparatively better than those from other biological treatment systems (Klein, 1957).

Lack of information about the microbial and biochemical changes taking place in oxidation ponds

The basic overall reactions of bacterial oxidation and photosynthetic reduction taking place in the process has been shown thus by Oswald and Gotaas (1957) :



A thorough and detailed knowledge of the basic microbiological and biochemical aspects of any waste treatment system is desirable if the system has to be properly designed and operated in as much as microorganisms are responsible for stabilization (McKinney, 1956a).
" Considerable research has been done on the removal of pathogenic bacteria during stabilization but less attention has been devoted to the presence of indigenous bacterial flora " (Gloyna 1965). Again McKinney (1962) states : " Waste treatment plants which base their entire operations on the

microorganisms within them have been designed for the past fifty years with almost no consideration for the biochemical reactions brought about by the various microorganisms. The net result of ignoring the organisms has been retarded development of new biological waste treatment process."

Wachs, Rebhun, Meron, Kott and Sless (1961) in their study on sewage stabilization ponds in Israel, state that the pond at which considerable change occurs seems to correspond with a detention period of 8-10 days and that the changes taking place during this period should be more closely investigated.

In view of the lack of definitive information relating to the substrate interactions taking place and the relative distribution of the type of bacterial flora involved in stabilization in a conventional oxidation pond during a fairly long period of 20 to 30 days, studies were started for increasing our knowledge and understanding of the fundamental physico-chemical, biochemical, bacteriological and biological mechanisms involved in this secondary process of sewage treatment. This thesis is the first of a series of studies concerned with algal-bacterial symbiosis in oxidation ponds from this laboratory. The results of these researches are expected to unravel the mystery of the exact pattern of degradation of the soluble organic matter constituents so that the information thus obtained may be used by Public Health Engineers in further simplifying the design criteria and criteria for operation of this most unsophisticated method of sewage treatment.
