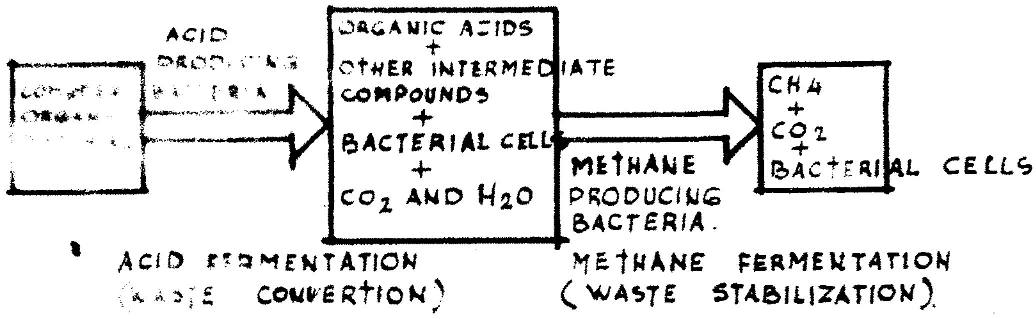
Chapter III

THEORETICAL CONCEPTS OF ANAEROBIC DIGESTION

The anaerobic digestion follows in two stages, viz. acid fermentation and methane fermentation. In order to bring these two stages, two major groups of bacetria play a key role viz. acid fermenters and methane fermenters. In anaerobic treatment the dissimilation of substrate is achieved with the chemically bound oxygen and not the molecular oxygen as hydrogen acceptor. Some of the compounds which release this chemically bound oxygen are in the form of carbondioxide, nitrates, sulphates or organic molecule itself. It is expected that the strict anaerobic conditions are required to obtain a well stabilisation of organic matter. The traces of molecular oxygen that are likely to enter through the substrates is taken up by faculatative bacteria and thus creating an environment favourable to methame fermenters.

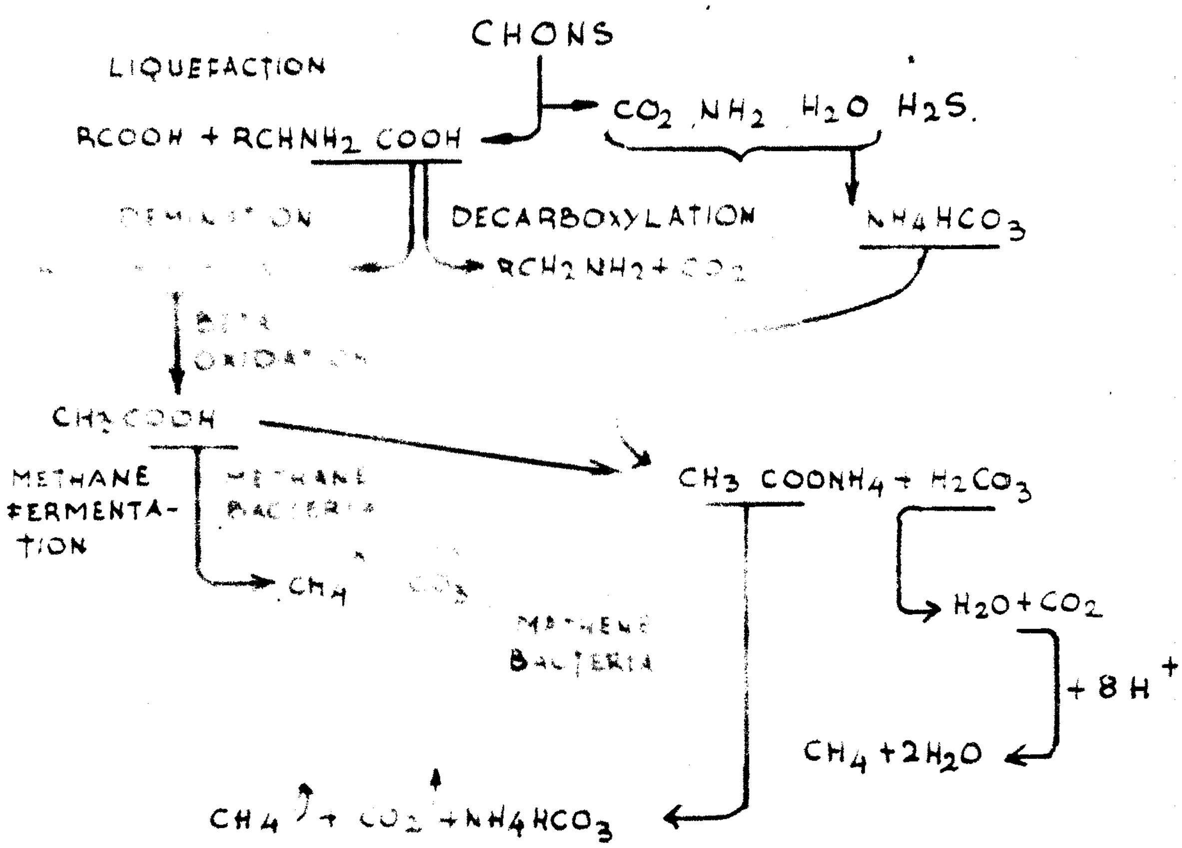
This condition is more severe in open anaerobic lagoons where the liquid comes in contact with atmosphere continuously. It may be, therefore, concluded that facultative bacteria would also play a major role to help methane fermenters to achieve strict anaerobic conditions. In such circumstances a competition between acid fermenters and methane fermenters are so crucial that unless a proper balance is maintained between these two groups of bacteria the stabilisation of organic matter is not achieved properly.

The microbial population which converts complex organic matter into simpler compounds in the first stage are generally



...ENTIAL MECHANISM OF ANAEROBIC WASTE TREATMENT.

COMPLEX ORGANIC SUBSTANCES. CARBOHYDRATES
LIPIDS AND PROTEINS.



ANAEROBIC DEGRADATI.N COMPLEX.
ORGANIC SUBSTANCES

FIG. 1.

facultative, eventhough some of them are strict anaerobes. The common genera are : Aerobacter, Alcaligenes Clostridium, Escherichia, Flavobacterium, Lactobacillus, Micrococcus, Pseudomonas and Streptococcus.

It was expected since the acid fermenters function is only to hydrolyse complex organic compounds into simpler compounds there would not be any reduction of COD or BOD in the first stage. However, the methane fermenters utilise carbondioxide. It is, therefore, that in the second stage, the stabilisation of organic matter takes place.

A schematic diagram of the stabilisation of the two stages are given in Fig. I. The methane bacteria are very specific in sub-strate utilisation. For example, the valeric acid is oxidised by Methano-bacterium suboxydans to acetic and propionic acids. However, it can not further decompose these acids any more. The propionate is converted by Methanobacterium propionicum to acetate, carbon dioxide and methane, however, since Methanobacterium Propionicum cannot utilise the acetate, a third species Methanosarcina methanica would be necessary to ferment the acetate to methane and carbon dioxide.

* The methane bacteria utilizes acetic acid readily, however, the other acids are also utilised by specific group of bacteria. The decomposition of acetic acid is shown below :

$$CH_3\,COOH \rightarrow CH_4 + CO_2 \text{ and}$$

$$CO_2 + 8H \rightarrow CH_4 + 2\,H_2O\,.$$

Propionic acid on the other hand requires a two step degradation, namely :

Step I $4\ CH_3\ CH_2\ COOH + 2\ H_2O \rightarrow 4\ CH_3\ COOH + CO_2 + 3\ CH_4$

Step II $4\ CH_3\ COOH \rightarrow 4\ CH_4 + 4\ CO_2$

Overall $4\ CH_3\ CH_2\ COOH + 2\ H_2O \rightarrow 5\ CO_2 + 7\ CH_4$

Butyric acid is similarly decomposed in a stepwise manner.

Step I $2\ CH_3\ CH_2\ CH_2\ CH_2\ COOH + 2\ H_2O + CO_2 \rightarrow 4\ CH_3\ COOH + CH_4$

Step II $4\ CH_3\ COOH \rightarrow 4\ CH_4 + 4\ CO_2$

Overall $2\ CH_3\ CH_2\ CH_2\ COOH + 2\ H_2O \rightarrow 5\ CH_4 + 3\ CO_2$

The methane fermentation of propionic and acetic acids resulting from the anaerobic decomposition of a complex waste accounts for approximately 85 percent of methane produced. The remainder of methane produced results from the fermentation of formic acid, from reduction of carbon dioxide by hydrogen and from methane fermentation of long-chained fatty acids which undergo "beta-oxidation".

The advantages of separating the two stages of digestion, namely acid fermentation of methane fermentation is recognised by HÄUSLER[88]. It was stated that if the acid fermentation is brought in separate digesters the antagonistic effects caused by different species can be eliminated and found to give better performance especially when the wastes contain considerable amount of carbohydrates. The major draw back of this method is the neutralisation of waste after acid fermentation which may need huge quantities of lime. However, if the buffering system of the waste is high the neutralisation can be eliminated. If the theory of separation of various physiological stages of bacteria is true, this method can be applied readily to lagoon treatment. This can be done economically by designing the lagoons in such a way to encourage acid fermentation in the first units and carry out the methane fermentation in subsequent units by designing the lagoons in series. The advantages of the system are explained by Häusler as to totally eliminate the antagonistic effects caused by different volatile acids and obtain a better performance of the digester.

B. Design Considerations

The anaerobic lagoon is a modification of septic tank to obtain improved performance of waste stabilisation. In septic tanks, the sedimentation of the suspended particles is given a major consideration. The loading in properly designed septic tanks may be taken as 0.2 Kg.Vs/cum/day, based on a daily contribution of solids of 70 gms per capita. It is observed that many of the septic tanks are not designed properly and as such give foul odours. In controlled digestion, the loadings are as high as 0.5 to 0.65 Kg.Vs/cum/day for conventional type and 1.6 to 3.0 Kg.Vs/cum/day for high rate digesters. The BOD loadings of anaerobic lagoons treating domestic sewage in tropical countries like India were reported to be 0.062 - 0.109 Kg/cum/day[24]. The loading of a septic tank based on BOD loading can be calculated as 0.08 to 0.1 Kg/cum/day.

The detention time in a properly designed septic tank can be taken as 4 days. While treating domestic sewage in anaerobic lagoons Parker[6] reported the detention time as 1.57 - 4 days and the studies in India confirmed this observation[24]. It is therefore seen that the design considerations are same both for septic tank and anaerobic lagoons. The only difference between these units are that septic tanks are covered and anaerobic lagoons are open to atmosphere.

It appears that in both designs the important aspect of solids retention time is forgotton. It is observed for methane bacteria, the regeneration time required is 2-11 days depending on the species. Since septic tanks and anaerobic lagoons are conventional type, the hydraulic retention time is equal to the solids retention time. The poor performance recorded in both the above treatment methods can be partly attributed to the fact that not much attention is given to the solids retention time. If methane bacteria are to do their function, a minimum solids retention time is to be maintained in the system. It is therefore essential to find out the solids retention time under the conditions of operation for septic tanks and anaerobic lagoons and maintain the SRTc, in the system to obtain the maximum possible efficiency of stabilisation.

The other consideration is whether the solid retention time is same for concentrated and dilute wastes. If the concentrated waste is treated the population of methane bacteria required will be more, however, if the same waste is diluted the population of methane fermenters required would be less.

Theoretically the solids retention time should be same for both wastes, however, it may be possible that solids retention time required may be more in case of concentrated wastes as the organic matter concentration to be xkxkkix stabilised is more. It is therefore necessary to investigate whether the stabilisation is also a function of the concentration of organic matter.

The anaerobic lagoons have been used to treat a number of industrial wastes at varying temperatures and organic matter concentrations. It was reported that lagoons can take wide variations in temperatures and organic matter concentrations. The methane bacteria would operate at three distinct temperature ranges and any variation in these temperature ranges would need acclamatisation for this group of bacteria and also to the organic loading. It is therefore necessary to obtain the design criteria for lagoons which are operated at uncontrolled conditions of temperature ranges and varying organic matter concentrations. It was reported by some investigators(37), that temperature variations do not effect the efficiency of anaerobic digestion provided the solids retention time is maintained in the system.

C. Operational Efficiency

The concentrations of cations and sulphates that are considered to be harmful in a controlled digester may be also true in lagoons. The stimulating agents such as iron that are added to digestion process must also act in a similar manner in lagoon operation. This aspect also need to be studied as some of

Industrial Wastes contain considerable amount of cations, which may deteriorate the process efficiency.

The operational depth of lagoons is also questionable. It is thought that deeper tanks provide more conservation of heat and thus provide better efficiency of stabilisation of organic wastes. However, it may not be economical to provide greater depths in certain cases where the Ground strata may not permit to increase the depth beyond a certain strata and as also the maintenance of side slopes is difficult. Yet the Ground water pollution is another consideration to have deep lagoons. It is thought to study the effect of depth on the performance of lagoons and fix the limits if there are any.

The sludge accumulated in controlled digesters are removed continuously whereas in lagoons the amount of sludge accumulated need to be calculated and the periodicity of cleaning lagoons will have to be established. The concentration of seed sludge needed in anaerobic digestion has been established as 25 percent of the volume of the tank[23]. It is rather difficult to obtain such an amount of seed sludge in lagoons. In such a case it is worth while to build up the seed sludge in lagoons and start the process of stabilisation. The mixing in the controlled digesters improved the performance considerably. However, it may not be economical to provide mixing arrangements in lagoons. The object of mixing is primarily to bring the in-coming waste in contact with the stabilised sludge and also to break the scum layer formed. In open anaerobic lagoons the scum layer formation may do more good to conserve heat.