Due to the increasing amount of municipal wastes produced in the urban areas, waste disposal has become a major problem. Present disposal systems such as incineration and landfill, cannot be employed indefinitely. Moreover, incineration produces no useful byproducts and pollutes the air, and landfiling is becoming increasingly difficult and costlier as suitable land becomes scarce. Further leaching of filled areas may cause stream pollution. On the other hand, municipal wastes and sewage can provide a very good source for methane production by anaerobic fermentation. Anaerobic fermentation, also known as anaerobic ('bacterial') digestion is a much simpler and cheaper process than pyrolysis and hydrogasification process.

Biological methane production from organic material or fermentation is a two stage breakdown phenomenon [1]. The first stage consists of a bacterial degradation of complex organic materials into short-chain (volatile) organic acids such as acetic acid, along with alcohols and aldehydes. The second stage consists of bacteria utilizing these short-chain organic acids in their metabolic processes to form methane (CH₄), and carbon dioxide (CO₂).

The organic waste material is principally cellulose with some fats, proteins, and hydrocarbons, which form 60 percent of the municipal wastes. It has been found that the chemical composition and energy value of dry inert-free solid waste is relatively constant, and the organic portion of the solid waste can be represented by the empirical formula [2]:

\[
C_{30}H_{48}O_{19}N_0S_{0.05}.
\]

The bacteria, which are capable of producing methane aerobically as well as anaerobically, are found almost universal in nature. But the emphasis should be for the methane-bacteria which can be cultivated to a high degree of activity indefinitely provided a few simple rules concerning chemical and physical environment are followed for methane fermentation.

Control of Methane Fermentation — The high yield and uniformity of product depends upon the following four factors [3]:

a. Large Surface — When material of a fibrous or granular nature is fermented, this requirement is satisfied by grinding or shredding the substrate. But, when dissolved substrates are employed, some sort of inert surface (like asbestos) must be supplied.

b. Volatile Acids — The second condition is that the volatile acids -- the intermediate compounds in the decomposition of higher organic chemical compounds, must not exceed a predetermined value — usually from 2,000 to 3,000 ppm. Higher concentration value may result in cessation of all fermentation within 24 to 48 hours [4]. There is only one way to limit the accumulation of volatile acids, that is, to limit
the rate at which the substrate is added to the fermentation tanks. This way the acids can be fermented to CH₄ and CO₂ as rapidly as they are formed from the raw substrate.

If the volatile acids build up to a point where biological activity is inhibited, the mixture could be aerated to promote aerobic fermentation. But this would be a temporary situation used only to reduce acid concentration. During such period, heat would be produced and a higher rate of anaerobic fermentation should result afterwards.

Another remedy to reduce volatile acid concentration is dilution of the whole reaction-mix with water.

c. Scum — A third condition to be avoided is the formation of any considerable amount of scum, which is encountered while fermenting greasy material. The objection to scum is that it constitutes a zone of high substrate concentration in which a high amount of volatile acids is likely to develop.

Moistening the scum with liquid pumped from underneath, is an effective and inexpensive remedy for breaking the scum.

d. Fibrous Material — A fourth difficulty encountered is with fibrous material such as paper, plant stalks, etc. These substances form a tough mat at the top of the fermentation tanks. The objection to this mat is, as above, that it favors the accumulation of large amounts of acid. A mat can be broken up neither mechanically nor by circulation of liquid with any success; so shredding of the municipal waste prior to dumping it into fermentation tanks is required.

**Characteristics of Methane Formation**

i. Methane Bacteria — The formation of methane in the anaerobic decomposition of organic matter is the result of the action of a specialized physiological group of bacteria often referred to as the “methane-producing bacteria” or “methane bacteria.” These bacteria are found in preponderous numbers in decaying matter and sewage, but still care can be taken to supply mesophilic methane-producing bacteria additionally, by treating sewage-sludge or manure with a weak alkali like calcium-acetate or calcium butyrate.

The different methane bacteria are classified as family Methano-Bacteriaceae under which there are different genii or strains of methane bacteria [5]. The isolation of pure culture of individual species is a tough and time-consuming task but group cultures of “methane-bacteria” have been isolated and studied extensively as a whole group. So the essence is developing group cultures of methane bacteria and using them for the process.

Methane bacteria are extremely sensitive to oxygen and oxidizing agents viz. nitrate, so reducing agents like sodium-sulfide and sodium-hydrosulfite in small quantities can be used with care.

ii. Continuous Process — The mixed culture of methane bacteria makes possible the continuous operation of the anaerobic fermentation. It is possible to carry on this process in a system arranged to allow the organic matter to enter continuously at one point and the exhausted or inert residue to be discharged continuously at another, while the product gases - CH₄ and CO₂ are given off at a steady rate. There is apparently no limit to the size of apparatus which can be used; large tanks yielding several hundred thousand cubic feet of gas a day operate as smoothly as laboratory size flasks.

iii. Substrate type — A third characteristic of the process is that practically all sorts of organic matter can be used as a substrate. Nearly a hundred different pure substances and some 30-40 plant and animal products have been used successfully as fermentation material. But apparently there is no decomposition of mineral oils and lignin, so in the end residual sludge — lignin, plastic and some unreacted cellulose is obtained which may amount to as much as 25 percent of the original volume. This residual sludge can be filtered into a cake, which can serve as a fuel for industrial uses or may be disposed as landfill being undoubtedly more stable than untreated waste.

iv. Quantitative Yields — The approximate quantitative yields of two products — CH₄ and CO₂ are somewhat unique and can be calculated from the following equation, provided the composition of the substrate is known:

\[ C_n H_a O_b + (n - \frac{a}{4} - \frac{b}{2}) H_2 O \rightarrow (\frac{n}{2} - \frac{a}{8} + \frac{b}{4}) CH_4 + (\frac{n}{2} + \frac{a}{8} - \frac{b}{4}) CO_2 \]

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With a little care, it is possible to get 95-100 percent agreement with this equation. The actual gas-yields range from 12 scf per lb. or 700 cc/gm of decomposed refuse, for protein to about 20 scf per lb. or 1250 cc/gm decomposed for fats. From such yields it is seen that the ratio of the volume of gas-yield to the volume of fermentation-tanks should be from 2:1 to 4:1 in most cases, and about 80 percent of the total gas-yield is methane.

v. Wide Temperature Range — A fifth characteristic is the absence of any narrow range for optimum temperature. The rate of fermentation increases with increase in temperature from 0° to 55° C (or 30° to 130° F). Maxima have been reported at 26°, 37°, and 50° C (that is, the favorable range can be taken as 80° to 120° F) but these maxima are not very pronounced.

REFERENCES