WASTE CONVERSION BY ANEROBIC THERMOPHILIC METHODS

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INTRODUCTION

In order to extend man's journeys away from Earth he must either carry more supplies or manufacture his own. Our work in the Life Sciences Section of the Aerospace Division of the Martin-Marietta Corporation has been based on the premise that trips into space will soon be of such length as to necessitate the reutilization of original materials for the maintenance of the crew. Since the disposal of human wastes has presented a number of problems even before extended space trips were envisioned, it seems that this is a large obstacle standing in the way of perfected regenerative life support system. In such a system, however, the object is not to dispose of so-called waste materials, but to convert them to reutilizable substances. Because of the high organic content of human wastes, they cannot be utilized by oxygen-producing algae. Therefore some methods of degeneration to simpler inorganic ions must be devised. This resulting matter can then be used as nutrients for algae cultures and for the growth of higher food plants, if desired (Table 1.). As there are weight, space and energy restrictions to be considered, the most efficient procedure of waste conversion must be followed. Investigations of this problem have been carried out in this laboratory for several years. This paper will describe an anaerobic thermophilic method for the conversion of wastes.

It might be well to state several reasons for choosing this type of processing system before describing the equipment itself. There have been a number of methods suggested for the treatment of waste material other than biological. However, we do not believe that the use of living organisms presents too great a problem. The bacteria responsible for this process are adaptive to differing amounts and compositions or raw material and have been subjected to varying temperatures without losing their capabilities. Further investigation of the specific organisms involved may lead to even more efficient cultures being developed.

Anaerobic bacteria were chosen for this task because it was thought that a simpler system would be possible. The gas produced is a mixture of methane and carbon dioxide. This mixture can be burned to provide carbon dioxide for the algae cultures. The heat may well be used to incinerate the residue resulting from the digestive process further reducing the amount of solids. Again carbon dioxide plus other gases are obtained. The use of an anaerobic method does not, of course, decrease the amount of oxygen needed to bring the waste to the same state as with an aerobic system. The same amount will be needed with any method.

The operation of a digester at elevated or thermophilic temperatures increases the activity of the bacteria thus decreasing the time necessary

TABLE 1
(Milligrams per liter)

ELEMENT	PLANT NUTRIENT SOLUTION		HUMAN WASTE (Feces + 1200 ml urine) PER MAN PER DAY
	Food Plants	Algae	
N	168	65	10,720
P	63	31	1,450
K	390	230	2,370
Ca	200	8	603
Mg	96	44	250
Fe	1	3.3	7.1
Mn	0.3	1	5.8
B	0.5	1	* --
Cu	0.02	0.04	1.7
Zn	0.05	0.2	6.1
Mo	0.05	0.02	* --

*Presence not proved, but probably occurs in trace amounts.

for digestion of the waste material. If the digestion time is shortened, the digester unit can be reduced in size. It should also be noted that the raw feed used in this digester was broken down into very fine particles affording a greater surface area for bacterial action. This, too, lessens the detention time of the material in the processor.

OPERATIONAL PROCEDURES

The digester itself consists of two seven-liter Wolff bottles immersed in a warm water bath. (Fig. 1). Material moves from the first bottle into the second through an overflow tube. *Each bottle is fitted with a cold-water condenser to decrease evaporation and lessen the possibility of water-clogged lines and pumps. Gas produced is recirculated through both bottles to more rapidly mix the incoming raw feed with the digesting material, to decrease the formation of scum on the liquid surface and to equalize the temperature throughout the digester. The production of gas is a good criteria for the rate of digestion, therefore it is measured in a wet-test gas meter before being released to the outside. A plenum holds a supply of gas for analysis. Raw feed is kept in a bottle fitted with tubing for recirculation through a refrigeration unit, thus preventing digestion until released through a small gear pump controlled by a timing device. In this manner, measured amounts can be fed at intervals throughout a 24-hour day. By adjusting the time clock, the amount fed and the frequency of feeding can be varied.

This unit was started by completely filling the bottles with 14 liters of liquid drawn from the domestic sewage digester in the plant area. This liquid was taken just above the sludge blanket which was several weeks old thereby assuring a good population of digestive organisms. Homogenized, diluted fecal matter containing about six percent solids was added at the rate of 100 ml per day until gas was steadily being evolved. The rate of feeding was increased until a steady rise in volatile acid concentration was noted. At this time the temperature of the water bath was gradually increased a few degrees per day from the initial 85°F to 120°F. No problems were encountered in changing the mesophilic environment to thermophilic conditions. Experiments were conducted at these elevated temperatures to determine the overload point, the effect of changes in temperature, and changing composition of feed. Analysis of these operations was assisted by regular measurements of gas evolved and its composition, determination of pH and volatile acids produced, percent total and volatile solids, and percent alkalinity. The composition of effluent and incinerated sludge was determined occasionally.

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*A two-stage design was chosen so that if overloading, temperature drop, or other unfavorable conditions occur, liquor from the second bottle can be back-circulated. This would dilute the contents of the first bottle and reinoculate it with suitable organisms.

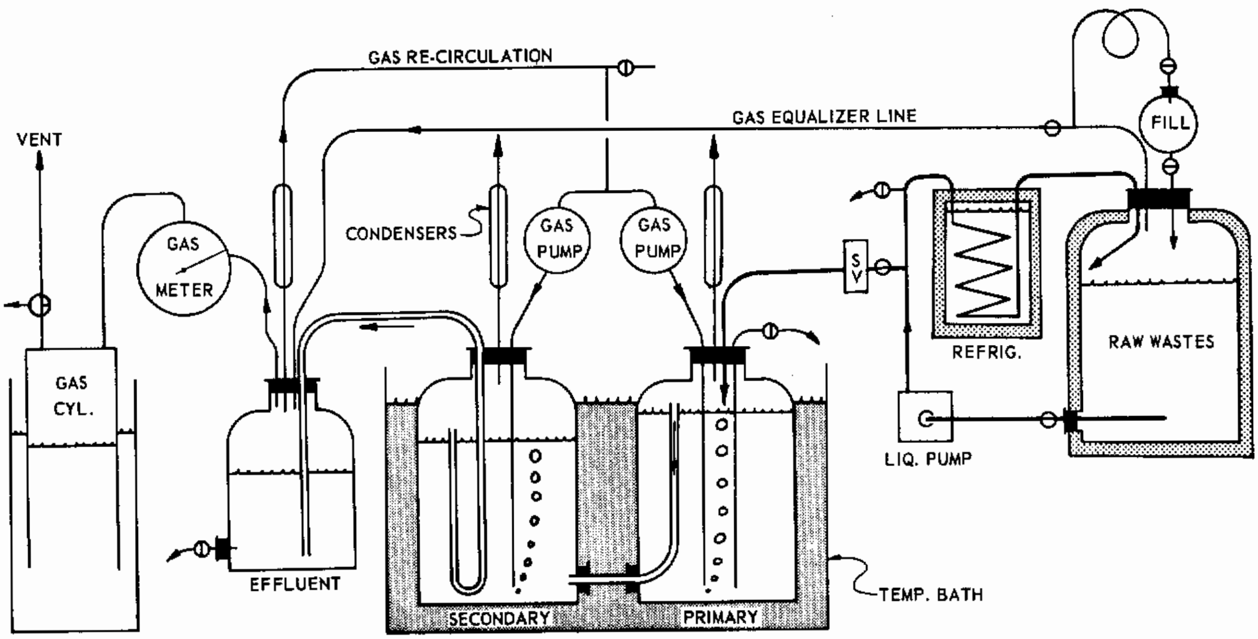

Figure 1. Anaerobic Thermophilic Digester System

EXPERIMENTAL RESULTS

To illustrate the efficiency of this system two experimental runs will be described in detail. In the first run of ten days duration a feed was used consisting of 1 part vegetable material (kitchen scraps from the plant cafeteria - mostly lettuce and carrot) to 6 parts feces, both on a dry weight basis. This was homogenized and diluted to 5.4 percent total solids of which 85% were volatile. A feeding rate of 456 ml per day was continued throughout this test period. The average volatile acid concentration was 605 p.p.m. as acetic acid. The average gas flow per day was 1616 liters. This gas consisted of 70 percent methane and 30 percent carbon dioxide. The calculated gas production was 12.8 cubic feet per pound of volatile solids. The average reduction in volatile solids was 67 percent.

In a second test run of 30 days a mixture of homogenized feces and lettuce leaves was fed the digesters. This was diluted to 4.9 percent total solids containing 83 percent volatile solids and was fed at a rate of 396 ml per day. The average volatile acid concentration was 430 p.p.m. as acetic acid. The average gas flow per day was 15.9 liters and was about 70 percent methane and 30 percent carbon dioxide. The calculated gas production was 19.7 cubic feet per pound of volatile solids. The average reduction in volatile solids was 49 percent. In both of these test runs the pH varied from about 7.8 to 8.2. Urine was not added to the digesters since urea is a good nitrogen source for algae and can be disposed of in that manner. It will be nearly impossible to digest concentrated mixtures of feces and urine without the addition of carbon dioxide-producing cellulosic materials since the carbonate formed by decomposition increases the pH to a level toxic to the bacteria. In an elaborate regenerative system there will be no lack of such vegetative matter, but even with more basic design, excess algae can be added to counteract this pH rise.

This method of processing waste materials produced an effluent which was very dark brown. This would, of course, greatly decrease light penetration into the algae cultures. Therefore, methods of bleaching this color were investigated. Treatment with a number of chemical reagents showed that 30 percent hydrogen peroxide would oxidize the liquid to a straw yellow. Experiments using ozone as an oxidizer are planned. The color is also destroyed by heating the effluent to dryness and ashing the residue. This ash is then brought up to the original volume with distilled water giving a colorless solution. In this form the solution was used to grow certain thermophilic strains of algae. This was especially effective when mixed with urine. Further work with algae and higher plants must be done to prove its worth as a nutrient source. Analysis of the effluent and the ash obtained from the incineration of sludge showed that favorable amount of the major nutrient elements were present. It has yet to be determined whether the entire amounts of all elements are in available form for use in plant growth.

FUTURE EXPERIMENTAL RESEARCH

Construction of a 30 liter two-stage digester is nearly complete. Digester units consist of six-inch lid, pyrex pipes fitted with bottom drains and the necessary tubing for continuous feeding of homogenized raw waste. Accompanying the digester will be a two-inch colloid mill which will produce even finer particles promoting more rapid digestion. On the exit side of the processing unit a small commercial-sized centrifuge will separate effluent and sludge. The digester tubes will be heated with electric tapes. Also planned are better facilities for collection and storage of fecal matter. This equipment will be connected and maintained in such a way as to effect a more automatic system.

This new digester will be operated with a greater variety of raw materials in more varied concentrations. Furthermore, meat products and algae will be added to check their effect on the digestive process. Waste plant materials in the same ratio as will actually be present in the operating life support system will be added to the human wastes.

Investigations have been begun on greater automation of the incineration of sludge materials and closer checks on the amount of oxygen required for this process. Various combinations of oxygen and evolved digester gas will be used at different pressures to determine the optimum conditions for sludge incineration.

SUMMARY

The efficiency of an anaerobic thermophilic biological waste digester has been shown to be significant enough to warrant further experimentation. A number of engineering problems still remain to be solved so that this segment of the regenerative system will require less attention. The possibilities of producing an innocuous nutrient solution for plant growth are quite promising and further efforts in this direction are definitely indicated.