INTERESTING — 6
INFORMATIVE — 5
PRACTICAL — 8
REALISTIC
WILITY

Anaerobic Digestion and Use of Its Residues in Agriculture

Sikandar Ali Arbani*, Farzana Hussain Panhwar and Mohammad Hussain Panhwar*****

ABSTRACT

Anaerobic digestion is a natural process in which all materials of organic origion are digested to various kinds of gases water soluble and insoluble organic compounds. The residue or sludge of anaerobic digestion is used as fertilizer and can have many other uses. The process consists of formation of enzymes, which produces organic acid and the material ultimately is converted in to acetic acid. This acetic acid partially breaks down to methane CH_4, CO_2 and sludge. Of the gases formed CH_4 is about 60%, CO_2 40%, and the other gases about 1%. Solid residue, or sludge, having the proteineous part is about 12 to 20%, is used as fertilizer. In the paper the advantages of residues as fertilizer are also discussed.

INTRODUCTION

In anaerobic processes different types of bacteria attacks substrate and produces complex compounds, CO_2 and methane gas [1]. The gas production is a fermentation process in which degradable organic matter is anaerobically digested producing gases rich in methane. The bio-degradiable materials suitable for digestion are given in Table (1). The anaerobic reaction or fermentation takes, place in absence of oxygen and needs substrate, which in turn contains about 60% or more water. The substrate is to have hemicellulose, cellulose, lipids, proteins and micronutrients which are soluble and insoluble compounds. The substrate has to be maintained at a temperature of 30-42°C, as at lower temperatures, the gas production reduces considerably falling to less than 50% at 15°C. The process of gas production can be increased by heating the digester at 55 to 60°C at which temperatures a different type of bacteria named as thermophilic, becomes active and rate of gas production is enhanced. The anaerobic digestion reactions are given in Fig. (1-2).

The organic matter usually contain various kind of diseases or organism as discussed in Table (2). These organisms are destroyed in the anaerobic digestion process. The raw material consists of human and cattle wastes and excreta and also decaying organic material, usually is attacked by bacteria and virus organisms. Their handling need careful management to avoid risk to human, cattle and environments.

About 25-33% of the solid material is digested in the anaerobic process. The undigested materials or residue have all other ingredients like N.P.K., and micronutrients increased by 33-50% per unit weight of residue, as compared to unit weight of raw materials fed to the digester. The residue can best be used as plant nutrient. Residue or sludge when applied to soil has the same effect as applying any organic matter. The humus material formed improves the physical properties of soil by increasing moisture, aeration, water infiltration, availability of micronutrients, nitrogen, potash, phosphates etc. Thus as a fertilizer the residue has more nutrients and the micronutrients are in chelated form, readily absorable by soil and plants.

Anaerobic digestion system is an economical method to dispose off organic wastes, human and animal fectal matter [2]. The advantages and disadvantages of anaerobic digestion and the uses of digested residue in agriculture is also discussed in the paper.

BIOLOGICAL BACTERIAL ACTIVITY

Biological bacterial activity takes place in 3 stages, and environments in the digester have to be optimum in all these stages [3].

Stage No. 1

The substrate contains a large fraction of organic matter in form of cellulose, which may account for 4-40% in most agricultural wastes. The range of various ingredients in manures, sewage sludge and agricultural wastes is given in Table below:

TABLE COMPOSITION OF SUBTRATE

Ingredient	Percent Dry Weight
Hemicellulose	4 - 8%
Cellulose	30 - 40%
Lipids	12 - 20%
Proteins	15 - 25%
Ash	30 - 40%

In the first stage at least 3 types of bacteria decompose substrate. These bacteria are:

- Fat decomposing bacteria.
- Cellulose decomposing bacteria
- Protein decomposing bacteria

By Enzymic hydrolysis, bacteria converts these three ingredients to soluble compounds or monomers

* Associate Professor, Department of Petroleum and Gas Enggi. Mehran University of Engineering and Technology, Jamshoro.

** General Manager, Soil Testing Laboratories. 57-C, Unit No. 2. Latifabad, Hyerabad.

*** Managing Director, Research and Development Engineers. 54-D. Clifton, Karachi.

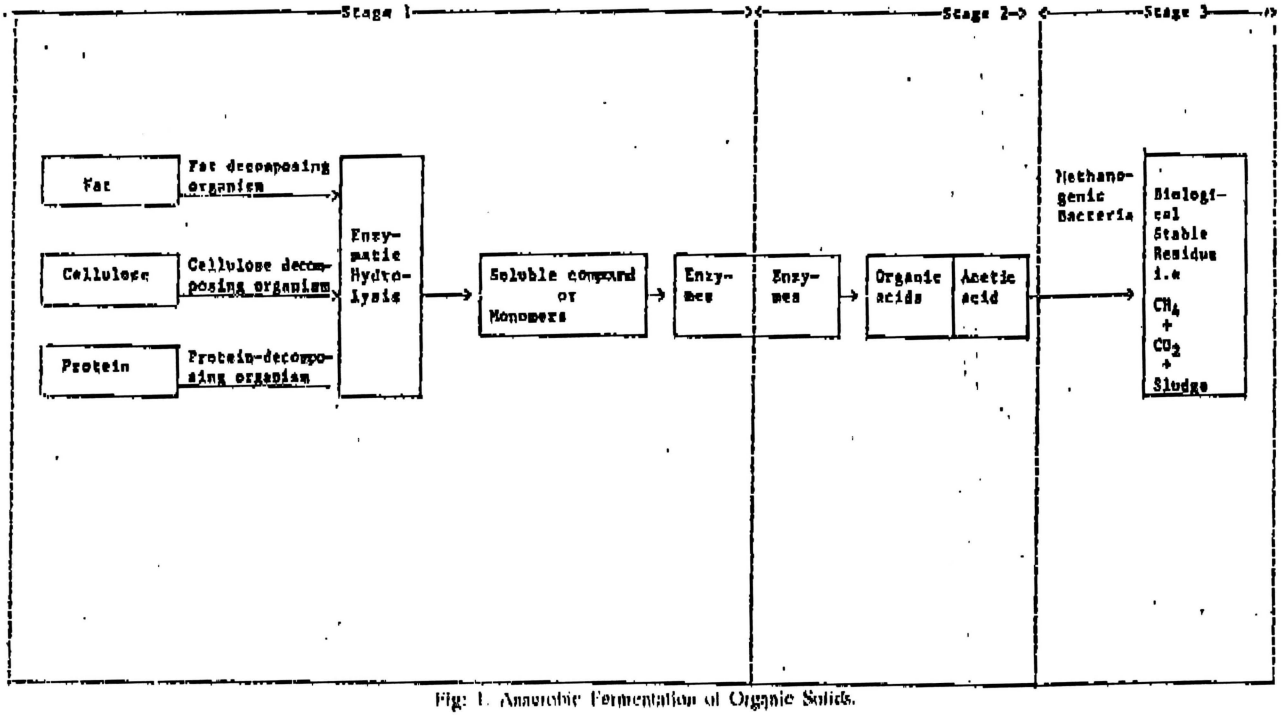

Fig: 1. Anaerobic Fermentation of Organic Solids.

Stage No. 2

In this stage acid forming bacteria attack soluble compounds or monomers and produce acetic acid. These bacteria can be two types; mesophilic, which operate in the range of 30 - 42°C and thermophilic which operate between 50 - 60°C. Both have pH requirement of about 7.0 ± 0.5 i.e 6.5 to 7.5. At pH 7.0 they are most efficient. These anaerobic digestion porcesses are given in Figures (1,2).

Stage No. 3

In this stage methane forming or methanogenic bacteria, convert acetic acids into biologically stable residues CH_4, CO_2 and undigestible residues. The production of biogas from different agricultural waste is given in Table (3).

Temperatures

Two types of bacteria mesophilic and thermophilic work at 30 - 42°C and 50 - 60°C respectively. However, bacteria are most active between the temperature ranges of 33 - 38°C and 55 - 58°C. Thermophilic bacteria produce 30 - 50% more methane than mesophilic with in the same time. To take the best advantage thermophilic reactions retaining time is reduced from 30 days for mesophilic, to 15 days for thermophilic, during which time same amount of gas is produced, as in 30 days, in mesophilic reaction.

Composition of Residue

It is the cellulose which is digested in fermentation which comes out of out-let pipe. About 25-33% of material can be digested and therefore residue will have all other ingredients like N,P. and K and micronutrients increased by 33-50% per unit weight of residue, as compared to unit weight of raw materials fed to the digester. Thus as a fertilizer. for the same weight of organic material applied to crops, residue has more nutrients.

Use of Residues as Fertilizer

The residues as fertilizer, has following uses :

* It has higher N,P,K and micronutrients by 33 to 50%.
* Micronutrients like iron, copper, zinc, manganese and molybedenum in residue, turn into chelated forms and therefore are readily available to the plants, without being fixed in to soil.
* In the raw materials N,P, and K are available to crops, slowly over 3 years and only 50% of them become ultimately available, whereas in sludge, they are available immediately.
* Residues have no offensive smell, seeds, insects and bacteria harmful to plants and humans.
* Residues do not attract flies, rodents, insects etc.
* Residues as dry matter contain about 80% of nitrogen of original organic matter. About 18% more is available in residue liquids as ammonia and this can get lost, unless liquid in slurry is immediately

* Fungi in the raw materials carry diseases to the plants, when applied to the field, but after anaerobic digestion all fungi are totally destroyed.
* Residue improves the physical properties of soil, by increasing moisture holding capacity, aeration and infiltration.
* Availability of micronutrients (copper, zinc manganese, iron, boron and molybedonum) contained in sludge is available to the plant easily and readily as these compounds are in chelated form, as a consequence of anaerobic digestion.
* Availability of nitrogen and potash to the plants is immediate, unlike manure which release them slowly. Manure release only upto 50% of total nitrogen, that also over a period of 3 years whereas in sludge 100% is made available readily and utilized in 3-4 months.
* Ready availability of phosphates to plants rather than fixing them to soil.
* Residue or digested slurry is not toxic to plants, unless these are applied in heavy dozes, when they can become toxic.

HAZARDS TO HUMAN HEALTH

Hazards of Handling Raw Materials

Handling of wastes of diseased animals can entail some danger, but human feces and excrement may impart viral, bacterial, protozoan and helminthic origin diseases [4].

Table below gives the details of such diseases and organisms involved:

Survival of Disease Producing Organism in the Digester

Anaerobic digestion can kill mostly 99.9% of all pathogens, dangerous to human health, within 15 days of digestion.

Biogas as Hazard

Biogas when mixed with 15-25% air forms a highly explosive mixture and it can blow up the plant as well as damage adjoining property and kill persons and animals passing by or set adjoining property to fire.

Residue or Slurry as Hazard

Almost 99.9% of micro-organism of public health significance are killed by digestion process, and those which survive, get killed within a few days of storage of slurry due to in-hospitable environments.

Advantages and Dis-Advantages of Digestion System

The advantages of the system are:

* Production of methane, which can be used or stored nominal cost.
* Production of sludge which is odourless and not disagreeable to handle as manure.
* Residue has good fertilizer value and in some cases can be mixed with animal feed.
* Sludge has micro-nutrients in chelated from and can increase production if applied to crops.
* Reduce organic matter volume of manure by 30-50% and could be kept for long time before applying to the crop.
* Anaerobic digestion destroys weed seeds.
* It does not attract mosquitos, flies, rodents, birds as happens with manure.
* Animal and human fecial matter can be disposed of hygienically.
* It produces energy and there by saves on cost of wood, gas and oil as fuel, for kitchen or engines.

Disadvantages of the system are:

* Hazard of explosion.
* High capital cost per unit of fuel or energy produced.
* Liquid sludge handling and drying needs more labour than manure.
* Needs maintenance and service.
* Needs periodic cleaning and painting of drum.
* Handling manure sludge is messy.
* Needs, training to operate the system.
* Needs facilities for removal of hydrogen sulphide and carbondioxide for use in modern internal combustion engines.

CONCLUSION

In the paper the biological reactions in anaerobic digestion are discussed. It is the most economical method of disposal of organic waste, animal and human fecial matter by anaerobic digestion. It produces methane which can be used as a fuel and can be stored at nominal costs, thus producing energy and saving the cost of wood, gas and oil as a fuel for kitchens and engines. The residues or sludge can be used as fertilizer. It has micronutrients in chelated form and can increase the production, if applied to crops.

The anaerobic digestion being highly economical is not without hazards. It does need proper design, and handling of raw material, without workers, catching diseases. Properly handled system would be most economical for developing countries.

TABLE 1. BIO-DEGRABLE ORGANIC MATERIALS

Crop wastes.	Sugarcane tops, sugarcane trash, weeds, corn and crop stubble, straw, spoiled fodder.
Wastes of animal origin	Cattle-shed wastes (dung, urine, litter), poultry litter, sheep and goat droppings slaughterhouse wastes (blood, bone, meal), fishery wastes, leather, wool and cotton waste.
Wastes of human origin	Faces, urine refuse.
By-products and wastes of Agro-Industries.	Oil cakes, bagasse, rice and wheat bran, tobacco wastes and seeds, wastes from fruit and vegetable processing, press-mud from sugar factories, cotton dust from textile industries.
Forest litter	Twigs, bark, branches, leaves.
Wastes from aquatic growth	Marine algae, seaweeds, water hyacinths.

TABLE 2. SOME DISEASES AND CAUSATIVE ORGANISMS OF CONCERN IN HANDLING OF HUMAN EXCREMENT

Category	Disease	Organisms
Viral	Infectious helpatitis	
	Gastroenteritis	Adenovirus
	Respiratory illness	Reovirus
	Poiomyelitis	Enterovirus (poliovirus)
Bacterial	Typhoid fever	Salmonellosis typhosa
	Salmonellosis	Salmonella spp.
	Bacillary dysentery	
	(Shigellosis)	Vibrio chlocrae
	Cholera Tuberculosis	Mycobacterium Luberculosis
rotozoan	Amebiasis (Amebic dysentery)	Entamoeba histolytica
elminthic	(Roundworm)	Ascaris Lumbricoides
	(Prinworm)	Oxyaris vermicularis
	(Whipworm)	Trihurus trichiurs
	(Tapeworm)	Taenia saginate
	(Hookworm)	Ancylostoma duodenable
		Necator americanus

TABLE 3. BIOGAS PRODUCTION FROM VARIOUS AGRICULTURAL WASTE MATERIAL

Raw Material	Biogas Production Per Unit Weight of Dry Solids		Temperature	CH_4 Content in Gas (%)	Fermentation Time (Days)
	ft^3/lb	m^3/kg	°C		
Cattle manure	3.5-8.0	0.23-0.50	11.1 - 13.1	56	75
Chiken manure	5.0	0.31	37.3	60	30
Poultry manure	7.3 - 8.6	0.46 - 0.54	32.6	58	10-15
Goat & sheep manure	5.9-9.7	0.37-061	-	64	20
Sugar beet leaves	8	0.5	-	55	14
Algae	5.1	0.32	45-50	62	11-20
Night soil	6	0.38	20-26.2	64	21

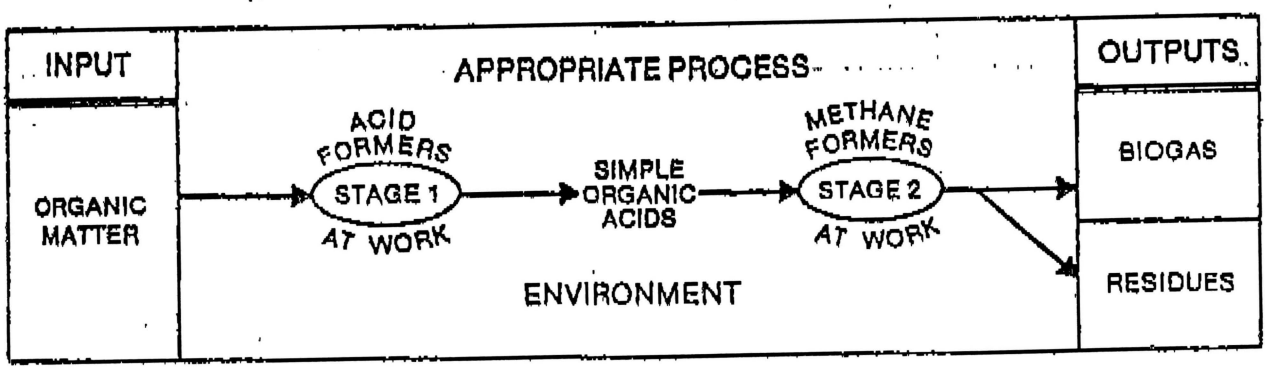

Fig: 2. Schematic Diagram Showing Anaerobic Digestion

REFERENCES

[1] Jewell William J., Anaerobic digestion publications, National Technical Information Service, U.K. Dept. of Commerce, 1984.

[2] Fischer J.R., Osburn D.D., Meador N.F. and Fulhage C.D., Economic of a manure anaerobic digester, American Society of Agricultural Engineers, 1981.

[3] Dodson C.E. and Maynall P.J., Anaerobic treatment of organic waste, anaerobic digestion and Biomass Advancement Company Ltd, U.K, 1984.

[4] Iannotti, E.L. Fisher, J.R. and Sievers D.M., Characterization of bacteria from a manure digester, University of Missouri-Columbia, 1981.