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Theoretical aspects of biological processes of anaerobic fermentation and the production of biogas as a renewable energy source

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Abstract- Urbanization, population growth industrialization and the development of consumption patterns produced accumulation of enormous quantities of waste with very high environment risk because, in the process of fermentation releases in atmosphere an impressive quantity of biogas (mean 500 m^3 N methane resulting from a tone of organic waste fermentation).Anaerobic digestion (AD) of organic waste provides the possibility of obtaining renewable energy, biogas, mainly composed of 65-70% CH_4 (a gas up to 8 times more pollutant than CO_2), 25 -30% CO_2, and small amounts of N_2, H_2, H_2S, water vapor and other gases. This gas stalled in waste, captured and used, can become a tremendous source of energy, being almost inexhaustible.

Keywords: anaerobic digestion (AD), biogas, renewable energy

1.INTRODUCTION

The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the build up of greenhouse gases. It is accepted that one of the most important environmental problems of the present century will be climate change. This will give rise to changes in weather patterns, and an increase in the frequency and severity of extreme events such as floods and droughts.

Environmental challenges that cities are facing today have significant consequences on human health, quality of urban life and economic performance of cities. Among the many environmental problems that threaten the cities of Europe, but also the entire planet, undoubtedly the biggest problem is the wastes. From all these wastes the most aggressive towards the environment are those of organic nature, because of their rapid fermentation with the release of biogas that creates a massive air and soil pollution.

The main components of biogas are methane and carbon dioxide. The methane from biogas allows the use of it as a fuel, a renewable energy source.

Also sewage water known as "wastewater" have evolved considerably in terms of quantity and quality nurturing day by day with more complex products (detergents, cleaning products, etc.). The need to protect the quality of natural waters (rivers, groundwater) requires operation of wastewater treatment plants.

The process of wastewater treatment is generating purified water that can be reintegrated into the environment in proportion 80% and inevitably a by-product known as sewage sludge at a rate less than 20%. Fresh sludge (raw) pose a threat (impact) for the environment because of its rapid fermentation, process by which it is released substantial amounts of methane.

For this reason, it is mandatory the application of mineralization techniques of processing sludge through a biogas station where it is decomposed and released methane is burned and transformed into energy.

2. BIOLOGICAL PROCESSES USED FOR MINERALIZATION

Sludge mineralization for further processing or storage can be achieved by anaerobic or aerobic fermentation processes - the first being the most frequently used. During the fermentation process the organic material is mineralized and colloidal structure of the sludge is change. Fermented sludge can be more easily dehydrated, with lower costs than for raw sludge.

1. Aerobic fermentation

Aerobic fermentation is carried out in practice through separate aeration of the sludge (primary, secondary or mixed) in open ponds, as stabilizing sludge (mud line) or in aeration tanks of water line that provides advanced sewage sludge. The aeration equipment is the same as for activated sludge tanks.

Aerobic fermentation sludge is recommended especially for working in excess activated sludge, where there is no primary decanting stage, or when primary sludge is not suitable for anaerobic fermentation.

Aerobically stabilized biological sludge is brown to dark brown and has a flocculent appearance.

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The smell of this kind of mud is not unpleasant, and resembles that of the

Sludge is considered aerobic fermented when organic composition was reduced by 20-25%, the amount of fat has reached maximum of 6.5% (vs. dry), and enzymatic activity is virtually null and the fermentation test is negative.

Plants for aerobic fermentation are sized, usually for the duration of retention of 8-15 days, depending on the sludge characteristics, which include a period of acclimatization to aerobic conditions (primary sludge).

Advantages of the process are: simple operation, no odor, sludge cleaning (reducing the number of pathogens) and reduce fat.

2. Anaerobic biological fermentation

Anaerobic biological fermentation is carried out in special facilities called digesters (methane tanks) whose work regime can be at temperatures of 30-35°C (mesophilic), 33-45°C (thermophilic) or at ambient temperature (cryophilic).

Photo 1. Digesters for anaerobic fermentation

Anaerobic fermentation is the most commonly used in wastewater treatment plants. The anaerobic fermentation results in a product called fermentation gas (biogas), recommended as a renewable energy sources.

Biological sludge treated anaerobic is dark brown to black and contains a large amount of biogas. When fermentation is complete, it is inert, with a faint smell of hot tar, or burnt rubber. Primary sludge anaerobic fermented produces about two times more methane than activated sludge. When passed through porous media in thin layers, solids are transported to the surface by the gas leaving a layer of clean water. Through dry solids, gases are released, forming a cracked surface with a smell like clay garden soil.

Fig 1 presents the scheme of an anaerobic digester in static condition.

Comparing the two systems of biological sludge stabilization the anaerobic stabilization process is better, especially in terms of energy.

In Table 1 are presented comparative data for the two processes.

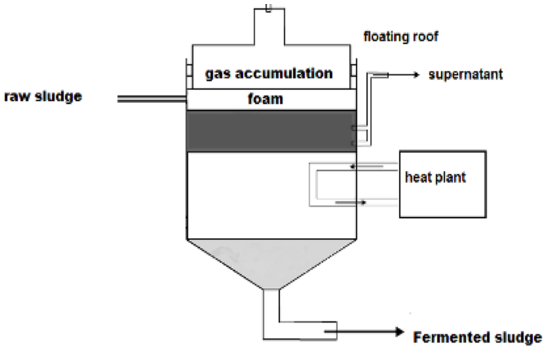


Fig.1. Technical scheme of anaerobic digester under static conditions

Table.1. Comparative data on anaerobic and aerobic digestion

Method	Retention period (days)	Energy consumption (KWh/m3 sludge)	Characteristic
Aerobic digestion	8 - 15	5 - 10	Simple, low-cost investment, high energy consumption.
Anaerobic digestion	15 - 20	0,2 - 0,6	High operating cost, high investment cost, low energy consumption, production of gas (power).

3. ANAEROBIC DIGESTION THEORY

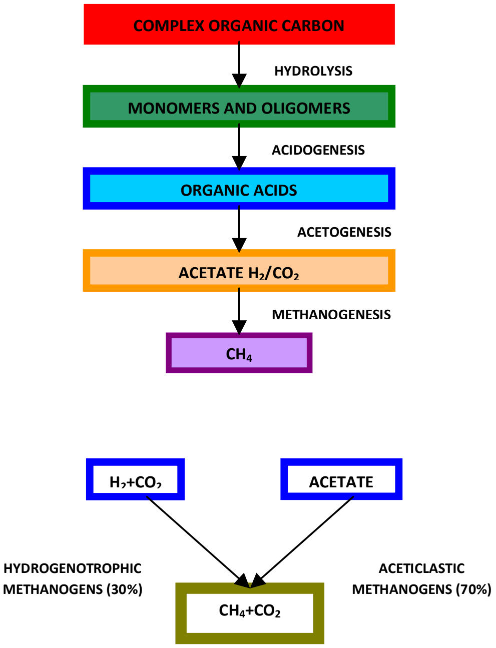
Anaerobic fermentation is a biological process of mineralization of sludge, resulting in the production and capture of biogas, and is a process driven by decomposition of moist organic matter, which takes place in closed chambers in controlled environmental conditions in the absence of molecular oxygen and light. Anaerobic fermentation occurs as a result of a complicated series of chemical and biochemical reactions in special facilities called fermentation tanks. Reactions taking place involving many types of bacteria, each type providing a unique and indispensable biotransformation.

Fermentation processes include the following steps:

- Hydrolysis,
- Acidogenesis,
- Acetogenesis,

- Methanogenesis.

Fig.2. Anaerobic digestion biochemical conversion pathways



In most cases biomass is made up of large organic polymers. In order for the bacteria in anaerobic digesters to access the energy potential of the material, these chains must first be broken down into their smaller constituent parts. These constituent parts or monomers such as sugars are readily available by other bacteria.

The process of breaking these chains and dissolving the smaller molecules into solution is called hydrolysis. Therefore hydrolysis of these high molecular weight polymeric components is the necessary first step in anaerobic digestion. Through hydrolysis the complex organic molecules are broken down into simple sugars, amino acids, and fatty acids.

Acetate and hydrogen produced in the first stages can be used directly by methanogens. Other molecules such as volatile fatty acids (VFA's) with a chain length that is greater than acetate must first be catabolised into compounds that can be directly utilized by methanogens.

The biological process of acidogenesis is where there is further breakdown of the remaining components by acidogenic (fermentative) bacteria. Here VFAs are created along with ammonia, carbon dioxide and hydrogen sulfide as well as other by-products. The process of acidogenesis is similar to the way that milk sours.

The third stage anaerobic digestion is acetogenesis. Here simple molecules created through the acidogenesis phase are further digested by acetogens to produce largely acetic acid as well as carbon dioxide and hydrogen.

The terminal stage of anaerobic digestion is the biological process of methanogenesis. Here methanogens utilize the intermediate products of the preceding stages and convert them into methane, carbon dioxide and water. It is these components that makes up the majority of the biogas emitted from the system.

Methanogenesis is sensitive to both high and low pHs and occurs between pH 6.5 and pH 8. The remaining, non-digestible material which the microbes cannot feed upon, along with any dead bacterial remains constitutes the digestate.

A simplified generic chemical equation for the overall processes outlined above is as follows:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

The factors influencing the fermentation process can be grouped into two categories:

-physical and chemical characteristics of sludge fermentation subject: solids concentration, the ratio of mineral / volatile organic component and the ratio of nutrients, presence of toxic or inhibitory substances;

- design facilities and operating conditions of fermentation temperature, supply and exhaust system, heater, recirculation, homogenizing, fermentation time, organic loading.

In general, anaerobic fermentation may be achieved in a wide range of temperature between 4-60°C, with acclimatization of the microorganisms in certain temperature areas. The speed of mineralization is influenced by temperature, to increase the duration of mineralization with decreasing temperature.

In terms of heat, anaerobic fermentation processes can be classified into three categories:

- cryophilic fermentation (without heating) at ambient temperature
- mesophilic fermentation (32-35° C)
- thermophilic fermentation (≈ 55°C).

In practice the mesophilic fermentation is most widely applied.

Thermophilic fermentation, while it has some advantages, like reducing the duration of fermentation and hence the volume of plants, however, rarely used, it implies additional consumption of heat (especially in winter) and form scabs and foam pools.

Microorganisms involved in fermentation and, in particular, the methane one are very sensitive to temperature variations even 2-3°C , so that maintaining temperature range in a steady process is one of the most important factors important factors. The heating of the fermentation tank is designed primarily with external heat exchangers, which provides a mixing of the sludge, and a preheating of raw sludge.

Recent researches on the mechanisms of degradation and conversion of organic matter from sludge have shown ways to stimulate the fermentation process by external factors. Thus, addition of nutrient medium for bacteria, added vitamins and other growth factors led to increasing gas production by fermentation with 10 to 15%. One of the advantages of anaerobic fermentation is the production of energy. Methane content in biogas produced can be used to heat sludge influent and recirculation of process temperature, and excess heat can be used for civil buildings and to produce electricity.

Through this process the negative effect on the environment is significantly reduced.

Carbon dioxide emitted from burning not from fossil energy carriers, has been stored many years ago but was recently removed from plants, thus being an organic flow. For this reason the production stations using biogas energy is considered neutral.

4. THE IMPORTANCE OF BIOGAS FROM AD

From environmental considerations the microbial production of biogas and other bio-fuels from organic waste is of great importance to unconventional energy resources as there is significant potential for considerable growth in production and in particular the potential contributions from livestock production (manure), sludge, waste and plants unsuitable for food and feed.

Biogas can be exploited in many useful applications, such as producing electricity, heating, cooling, and fueling vehicles.

Biogas is a vital energy resource, which contributes to sustainable economic development, agriculture, rural development, environmental protection and reducing energy dependence of the European Union.

Table.2. The multi purpose legislative value of biogas from AD in Europe (LIKEHURST, 2006)

Need	Legislation
Environmental	Climate change: • Reduce energy consumption • Cut emissions from: -Transport sector -Electricity production and distribution -Livestock production • Increase renewable energy production by 10% by 2010 Water quality: • Reduced risk of diffuse N pollution/ increased NH_4 available for take up (Nitrate Directive-91/676/EEC)
Agriculture	Nutrient management schemes: • Better control of ammonia emissions • Easier management of P_2O_5/ fiber separation • Reduced application of mineral fertilizer
Health and hygiene	• Improved bio-security from pathogen reduction (Animal by-product Directive 1774/2002 EC • Treatment of animal by products kitchen, catering or restaurant wastes and utilization for energy and bio-fertilizer production • Reduce sources for flies and rodents • Reduce odors from manure spreading
Waste reduction, recovery and recycling	• Waste disposal legislation and policy • Reducing amount disposed to landfill (The Landfill Directive 1999/31/EC) • Increase recycling and recovery (Pachaging Waste Directive 94/62/EC)

5. CONCLUSION

Energy component that calls for action of producing biogas is becoming more important under current energy crisis. Of course there are also other components: ecological, social, and pedological but the share of the first one tends to increase especially after the increasingly obvious crisis of fossil fuel and resources and the threat of global warming as a result of human activities. Biodegradable organic waste produces - in undirected way- large quantities of biogas with methane content that produces a greenhouse effect over 20 times bigger than carbon dioxide.

Ensuring appropriate environmental quality and protection - as a need for survival and progress - is a matter of current concern and social evolution. In this regard, it is necessary to maintain environmental quality and reduce the negative effects of human activity with its implications.

In this context the objective is not only rational use of resources, but also linking human activities with measures to protect natural factors by adopting cleaner technology to prevent and minimize the negative effects on the environment.

REFERENCES

[1] Al Saedi, T., 2002. Quality management of AD residues from biogas production.IEA.Bioenergy, Task 24 – Energy from Biological Conversion of Organic Waste, January 2002.

[2] Birkmose, T.,2007. Digested manure is a valuable fertizer. In: Proceedings of European Biogas Workshop- The future of biogas in

Europe III, University of Sothern Denmark 14-16, June, Intelligent Enegy- Europe programme, Probiogas project, pp 89-94.
[3]. M. Dima, Urban Waste Water Treatment, Ed Tehnopress, Iasi, 2005
[4]http://en.wikipedia.org/wiki/Anaerobic_digestion
[5] Renewable status report 2009 [Online]. Available:http://www.ren21.net/pdf/RE_GSR_2009_Update.pdf.