GREEN ENERGY-ANAEROBIC DIGESTION

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Abstract:

The issue of waste management has moved a centre stage, both in the public perceptions and in terms of national regulations. 200 years ago when we first started to burn our waste as a means of disposal, there was not the understanding that we have today of the need to protect the environment from air-borne emissions. Until recently principal means of waste management has simply been deposit in landfill. This is now understood as unsustainable practice, creating potential environmental problems for future generations. Processed In the appropriate manner, waste can be seen as a valuable resource to recover useful energy for electricity generation.

This is happening in Amsterdam where 236 trams and 106 trains in Dutch capital have been run on electricity generated from city's garbage. Electricity is generated from high calorific content of Municipal solid waste (MSW) from process of Anaerobic digestion (AD) .AD has the opportunity to be an integral part of the solution to two of the most pressing environmental concerns of urban centers: waste management and renewable energy. Through AD, organics are decomposed by specialized bacteria in an oxygen-depleted environment to produce biogas and a stable solid. Each of these products can be used for beneficial purposes to close the loop in organic waste management. The biogas, which consists of up to 65% methane, can be combusted in a cogeneration unit and produce green energy. The solid digestate can be used as an organic soil amendment. As a waste management strategy employed in over 20 countries, AD has been successful in reducing the volume of waste going to landfill, decreasing emissions of greenhouse gases and creating organic fertilizer, all at a profit.

This paper introduces current AD practices used for electricity generation and describes the advantages over conventional technology in the spheres of local amenity, efficient usage of heat and lower environmental impact.

1.**R**enewable energy:

Bioenergy accounts for the largest renewable energy usage today. Biomass is solar energy stored in organic matter. Biomass is a renewable energy source because the growth of new plants and trees replenishes the supply. The use of biomass for energy does not increase carbon dioxide emissions and does not contribute to the risk of global climate change. In addition, using biomass to produce energy is often a way to dispose of waste materials that otherwise would create environmental risks. By comparison, fossil fuels such as natural gas and coal require millions of years of natural processes to be produced. Therefore, mining coal and natural gas depletes the Earth's resources for thousands of generations. Alternatively, biomass can easily be grown or collected, utilized and replaced.

2.Biomass:

Biogas consists of 60 to 80% methane, 20 to 40% carbon dioxide, and several trace compounds such as hydrogen sulfide and ammonia Biomass is generally made up of woody plant residue and complex starches. The largest percentage of biomass used to create energy is wood, but other bioproducts, such as fast-growing switchgrass, are being investigated as sources of energy. The three largest sources of biomass used for fuel are cellulose, hemicellulose, and lignin. Biomass processing results in the end-products biochemicals, biofuels, and bio power, all of which can be used as fuel sources. Biochemicals involve converting biomass into chemicals to produce electricity; biofuels are biomass converted into liquids for transportation; and biopower is made by either burning biomass directly (as with a wood-burning stove) or converting it into a gaseous fuel to generate electric power.

3.Technologies:

3.1Direct combustion:

Direct combustion involves the burning of biomass with excess air, producing hot flue gases that are used to produce steam in the heat exchange sections of boilers. The steam is used to produce electricity in steam turbine generators.

3.2Co-firing:

Co-firing refers to the practice of introducing biomass in high-efficiency coal fired boilers as a supplementary energy source. Co-firing has been evaluated for a variety of boiler technologies including pulverized coal, cyclone, fluidized bed and spreader stokers. For utilities and power generating companies with coal-fired capacity, co-firing with biomass may represent one of the least-cost renewable energy options.

3.3Gasification:

Biomass gasification for power production involves heating biomass in an oxygen-starved environment to produce a medium or low calorific gas. This "biogas" is then used as fuel in a combined cycle power generation plant that includes a gas turbine topping cycle and a steam turbine bottoming cycle.

3.4Pyrolysis:

Biomass pyrolysis refers to a process where biomass is exposed to high temperatures in the absence of air, causing the biomass to decompose. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide).

3.5Anaerobic Digestion:

Anaerobic digestion is a process by which organic matter is decomposed by bacteria in the absence of oxygen to produce methane and other byproducts. The primary energy product is a low to medium calorific gas, normally consisting of 50 to 60 percent methane. Comparing to the other processes anaerobic digestion solely for the purpose of electricity generation is about twice as productive as total landfill.

4.Anaerobic digestion:

The process of Anaerobic digestion (AD) makes use of anaerobic bacteria to break down organic waste, converting it into a stable solid and biogas, Which is a mixture of carbon dioxide and methane in an oxygen depleted environment. AD process requires relatively high water content, the heating value of Municipal solid waste (MSW) increases with decreasing moisture content.

If the wet stream of MSW could be separated and could be used for AD, the dry stream could be combusted more efficiently.

The process of AD is one of the oldest forms of digestion and occurs naturally in the absence of oxygen.

Efficiency and stability of AD can vary significantly with the type of digester used and with the parameters of operation.

Important factors are:

Waste (feed) type, digester design, digester temperature, retention time, pH, bacteria, material flow, organic loading rate and presence of toxicants.
MSW include waste from residential sources, commercial sources and institutional sources.

Stages of AD:

4.1**H**ydrolysis:

In the first stage, complex organic materials are broken down into their constituent parts in a process known as hydrolysis. The result is soluble monomers: Proteins are converted to amino acids; fats to fatty acids, glycerol and triglycerides; complex carbohydrates such as polysaccharides, cellulose, lignin, starch and fiber converted to simple sugars, such as glucose. Hydrolic or fermentive bacteria are responsible for the creation of monomers, which are then available to the next group of bacteria.
An approximate chemical formula for the mixture of organic waste is $C_6H_{10}O_4$. A hydrolysis reaction where organic waste is broken down into a simple sugar, in this case glucose, can be represented by the following:
$C_6H_{10}O_4 + 2H_2O \rightarrow C_6H_{12}O_6 + 2H_2$ (1)

4.2 **A**cidogenesis:

Hydrolysis is immediately followed by the acid-forming phase of acidogenesis. In this process, acidogenic bacteria turn the products of hydrolysis into simple organic compounds, mostly short chain (volatile) acids (e.g., propionic, formic, lactic, butyric, or succinic acids), ketones (e.g., ethanol, methanol, glycerol, acetone) and alcohols. The Specific concentrations of products formed in this stage vary with the type of bacteria as well as with culture conditions, such as temperature and pH (United Tech)[1].
Typical reactions in the acid-forming stages are shown below. In equation 2, glucose is converted to ethanol and equation 3 shows glucose is transformed to propionate.
$C_6H_{12}O_6 \leftrightarrow 2\ CH_3CH_2OH + 2CO_2$ (2)
$C_6H_{12}O_6 + 2H_2 \leftrightarrow 2CH_3CH_2COOH + 2\ H_2O$ (3)

4.3**A**cetagenesis:

The next stage of acetagenesis is often considered with acidogenesis to be part of a single acid forming stage. Biological oxygen demand (BOD) and chemical oxygen demand (COD) are reduced through these pathways. Acetagenesis occurs through carbohydrate fermentation, through which acetate is the main product, and other metabolic processes.
The result is a combination of acetate, CO_2, and H_2. The role of hydrogen as an intermediary is of critical importance to AD reactions. Long chain fatty acids, formed from the hydrolysis of lipids, are oxidized to acetate or propionate and hydrogen gas is formed. The reaction only proceeds if the hydrogen partial pressure is low enough to thermodynamically allow the conversion. The presence of hydrogen scavenging bacteria
(HMBs) that consume hydrogen, thus lowering the partial pressure, is necessary to ensure thermodynamic feasibility and thus the conversion of all the acids. As a result, the concentration of hydrogen, measured by partial pressure, is an indicator of the health of a digester
As an example, the free energy value of the reaction that converts propionate to acetate, shown in equation 4 below, is +76.1 kJ**,** so that this reaction is thermodynamically impractical. When bacteria, however, the free, consume acetate and hydrogen energy becomes negative. In general, for reactions producing H_2, it is necessary for hydrogen to have a low partial pressure for the reaction to proceed.
$CH_3CH_2COO^- + 3H_2O \leftrightarrow CH_3COO^- + H^+ + HCO_3^- + 3H_2$ (4)
Other important reactions in the acetogenic stage involve the conversion of glucose (5),
ethanol (6) and bicarbonate (7) to acetate.
$C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2\ CO_2 + 4H_2$ (5)
$CH_3CH_2OH + 2H_2O \leftrightarrow CH_3COO^- + 2H_2 + H^+$ (6)
$2HCO_3^- + 4H_2 + H^+ \leftrightarrow CH_3COO^- + 4H_2O$ (7)

1 United Tech ,Inc. "Anaerobic Digestion UTI Web design", 2003

4.4Methanogenesis:

The methanogenic anaerobic bacteria involved in the third stage, known as methanogenesis or methane fermentation, are the same fastidious bacteria that occur naturally in deep sediments or in the rumen of herbivores. This population converts the soluble matter into methane, about two thirds of which is derived from acetate conversion (equation 8 followed by 9), or the fermentation of an alcohol, such as methyl alcohol (10), and one third is the result of carbon dioxide reduction by hydrogen (11) (United Tech 2003)[1.]
$2\ CH_3CH_3OH + CO_2 \leftrightarrow 2\ CH_3\ COOH + CH_4$ (8)
$CH_3COOH \leftrightarrow CH_4 + CO_2$ (9)
$CH_3OH + H_2 \leftrightarrow CH_4 + H_2O$ (10)
$CO_2 + 4H_2 \leftrightarrow CH_4 + 2H_2O$ (11)
Methanogens are very sensitive to changes and prefer a neutral to slightly alkaline environment (Gas Technology)[2]. If the pH is allowed to fall below 6, Methanogenic bacteria cannot survive. Methanogenesis is the rate-controlling portion of the process because methanogens have a much slower

growth rate than acidogens. Therefore, the kinetics of the entire process can be described by the kinetics of methanogenesis (Davis and Cornwell)[3].

5.**P**arameters in Anaerobic Digestion:

The complete process of anaerobic digestion requires a complex interaction of several varieties of bacteria that must be in equilibrium in order for the digester to remain stable.

5.1**p**H

A primary gauge of digester health is the pH level, which changes in response to biological conversions during the different processes of AD. A stable pH indicates system equilibrium and digester stability. A falling pH can point toward acid accumulation and digester instability.

The range of acceptable pH for the bacteria participating in digestion is from 5.5 to 8.5, though the closer to neutral, the greater the chance that the Methanogenic bacteria will function. Most methanogens function in a pH range between 6.7 and 7.4, and optimally between 7.0 and 7.2.

5.2**T**emperature:

Due to the strong dependence of temperature on digestion rate, temperature is perhaps the most critical parameter to maintain in a desired range. As Figure shows, anaerobic bacteria can survive in a wide range of temperatures, from freezing to 70°C, but thrive within two ranges: from 25°C (77°F) -40°C(104°F), the mesophilic range, and from 50°C (122°F) to 65°C (149°F), thermophilic range.[1]

5.3 **C/N** Ratio:

The Carbon/Nitrogen Ratio is a measure of the relative amounts of organic carbon and nitrogen present in the feedstock. If a feedstock is high in carbon, manure can also be added to increase nitrogen. As with composting, the optimum C/N ratio is between 20-30, with most sources citing 25 as the ideal level. A low C/N ratio, or too much nitrogen, can cause ammonia to accumulate which would lead to pH values above 8.5. Additionally, the quality of the compost is lessened with high ammonia production.

5.4**R**etention Time:

The amount of time that feedstock stays in the digester is known as retention time or residence time. The retention time is determined by the average time it takes for organic material to digest, as measured by the COD and BOD of exiting effluent. The longer a substrate is kept under proper reaction conditions, the more complete its degradation will be.

The rate of the reaction, however, will decrease with increasing residence time.

5.4**O**rganic Loading Rate:

The final parameter to control is the organic loading rate (OLR), which determines how many volatile solids are input to the digester. A higher OLR will demand more of the bacteria, which may cause the system to crash if it is not prepared. One danger of increasing the OLR would be that the acidogenic bacteria, which act early in the digestion process and reproduce quickly given enough substrate, would multiply and produce acids rapidly. The Methanogenic bacteria, which take longer to increase their populations, would not be able to consume the acids at the same pace. The pH of the system would then fall, killing more of the Methanogenic bacteria and leading to a positive feedback loop, eventually halting digestion. An early indication of this is lowered biogas production and eventually a lower pH.

6.**D**igester Designs:

Anaerobic digesters are made out of concrete, steel, brick, or plastic. They are shaped like silos, troughs, basins or ponds, and may be placed underground or on the surface. All designs incorporate the same basic components: a pre-mixing area or tank, a digester vessel(s), a system for using the biogas, and a system for distributing or spreading the effluent (the remaining digested material).There are two basic types of digesters: batch and continuous.

Batch-type digesters, Their operation consists of loading the digester with organic materials and allowing it to digest. The retention time depends on temperature and other factors. Once the digestion is complete, the effluent is removed and the process is repeated. In a continuous digester, organic material is constantly or regularly fed into the digester. The material moves through the digester either mechanically or by the force of the new feed pushing out digested material. Unlike batch-type digesters, continuous digesters produce biogas without the interruption of loading material and unloading

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[1] United Tech ,Inc. "Anaerobic Digestion UTI Web design", 2003

[2] Gas Technology, Inc "HIMET- A Two Stage Anaerobic Digestion Process for converting waste to energy", 2003

[3] Davis, M and D.Cornwell , "Introduction to environmental Engineering" WCB/Mc Graw-Hill, New York,NY,1998

effluent.

Biogas has advantages over conventional technology:

Less impact on local amenity in the host location Better prospects for efficient use of heat Higher levels of employment with distributed plants and operations associated with materials recovery and processing

Far lower environmental impact due to the character of the technology and the better dispersion profiles of smaller distributed plant.

Environmental impact:

All the greenhouse gas generated is burnt for energy recovery rather than letting some of it escape to the atmosphere as would occur in landfill. CO2 is emitted but as it comes from organic material this has a short carbon cycle and so has no overall environmental impact.

This process suits Indian climate as the mesophilic temperature range is around 35 degrees so this process if utilized properly can turn out to be good profit.

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