Appendix A

UK Without Incineration

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AD and Biogas

The Chemical Process

There are many descriptions of AD available on the internet both relatively simple and technically advanced, and many with pictures and charts. Here are two:

http://www.anaerobic-digestion.com/html/anaerobic_flow_diagram.html

Andigestion's Holsworthy process:

http://www.andigestion.co.uk/content/the-holsworthy-process

An explanation of optimised AD processes and plant to meet the requirements of specific feedstocks requires specialist expertise and is beyond the scope of this brief.

The following summary makes use of

http://www.daviddarling.info/encyclopedia/A/AE_anaerobic_digestion.html

Methane and anaerobic bacteria

AD is the process by which organic matter is decomposed by anaerobic bacteria. The process produces a gaseous by-product called biogas, which consists primarily of methane and carbon dioxide. AD occurs in nature and can be harnessed to produce biogas from biomass in an anaerobic digester.

Methane is the major component of natural gas. It is odourless, colourless, and yields about 11 Kwh of heat energy per cubic metre of gas when burned. Natural gas is a fossil fuel that was created many millions of years ago by the anaerobic decomposition of organic materials. It is often found in association with oil and coal.

The same types of anaerobic bacteria that produce natural gas also produce methane today. Anaerobic microbes (anaerobes) are some of the oldest forms of life on earth and comprise two major types, bacteria and archaea. They dominated the world before photosynthesis developed in green plants and released large quantities of oxygen into the atmosphere. Anaerobes break down or "digest" organic material in the absence of oxygen and produce biogas as a waste product. (Aerobic decomposition, or composting, involves other types of microbes that use oxygen and produce carbon dioxide with some heat.)

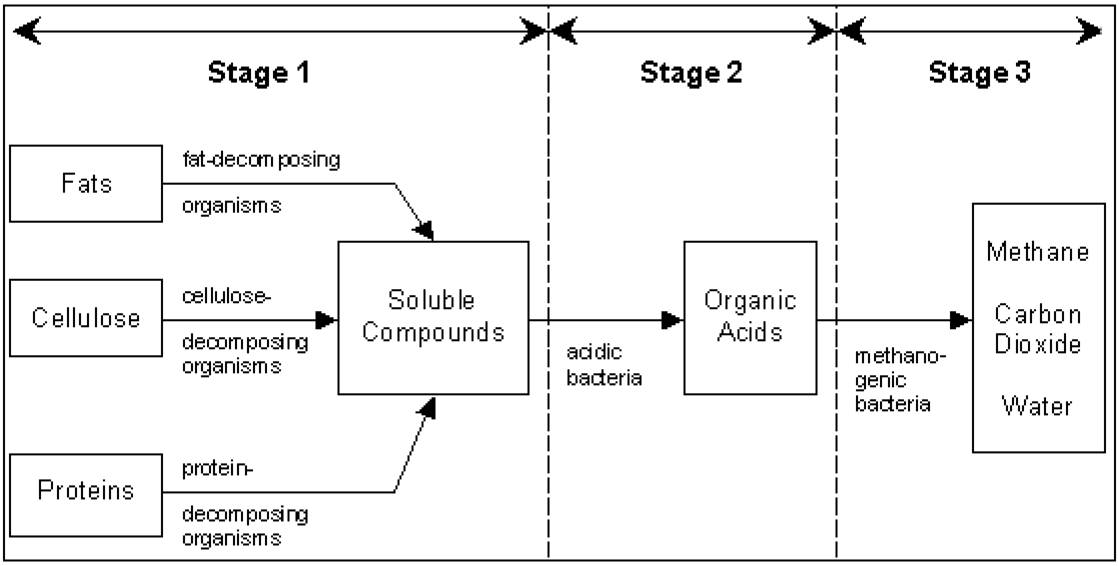
Anaerobic decomposition occurs naturally in swamps, water-logged soils and rice fields, deep bodies of water, and in the digestive systems of termites and ruminant animals. Anaerobic processes can be managed in a digester (consisting of one or more airtight vessels) or a covered lagoon (eg a pond used to store manure) for waste treatment**.**

Biogas produced in anaerobic digesters consists of methane (about 60%) carbon dioxide (about 40%) and trace levels of other gases such as hydrogen, carbon monoxide, nitrogen, oxygen, and hydrogen sulphide.

The relative percentages of these gases in biogas depend on the feed material and management of the process. When burned, biogas composed of 60% methane yields 5,400 kcal/cubic metre, equivalent to about 6.55 kWh, although only a proportion of this energy can be achieved if the gas is used to generate electricity. .

Anaerobic digestion

Anaerobic decomposition is a complex process. It occurs in three basic stages as the result of the activity of a variety of microorganisms. Initially, a group of microorganisms converts organic material to a form that a second group of organisms utilizes to form organic acids. Methane-producing (methanogenic) anaerobic bacteria utilize these acids and complete the decomposition process.



A variety of factors affect the rate of digestion and biogas production. The most important is temperature. Anaerobic bacteria communities can endure temperatures ranging from below freezing to above 135℉ (57.2℃) , but they thrive best at temperatures of about 98℉ (36.7℃) (mesophilic) and 130℉ (54.4℃) (thermophilic). Bacterial activity, and thus biogas production, falls off significantly between about 103° and 125℉ (39.4° and 51.7℃) and gradually from 95° to 32℉ (35° to 0℃).

In the thermophilic range, decomposition and biogas production occur more rapidly than in the mesophilic range. However, the process is sensitive to disturbances, such as changes in feed materials or temperature. While all anaerobic digesters reduce the viability of weed seeds and disease-producing (pathogenic) organisms, the higher temperatures of thermophilic digestion result in near sterilisation. Although digesters operated in the mesophilic range must be larger (to accommodate a longer period of decomposition within the tank [residence time]), the process is less sensitive to upset or change in operating regimen.

To optimize the digestion process, the biodigester must be kept at a consistent temperature, as rapid changes will upset bacterial activity. Digestion vessels require some level of insulation and/or heating. Some installations circulate the coolant from their biogas-powered engines in or around the digester to keep it warm, while others burn part of the biogas to heat the digester. In a properly designed system, heating generally results in an increase in biogas production during colder periods.

The trade-offs in maintaining optimum digester temperatures to maximize gas production while minimizing expenses are somewhat complex. Studies on digesters in the USA indicate that maximum net biogas production can occur in digesters maintained at temperatures as low as (22℃) but the process is then very slow taking weeks.

Factors other than temperature affect the rate and amount of biogas output. These include pH, water/solids ratio, carbon/nitrogen ratio, mixing of the digesting material, the particle size of the material being digested, mix of microorganisms supplied in seeding material and retention time. Pre-sizing and mixing of the feed material for a uniform consistency allow the bacteria to work more quickly.

The pH is self-regulating in most cases. Bicarbonate of soda can be added to maintain a consistent pH; for example, when too much "green" or material high in nitrogen content is added. It may be necessary to add water to the feed material if it is too dry or if the nitrogen content is very high. A carbon/nitrogen ratio of 20/1 to 30/1 is best. Agitation of the digesting material aids the digestion process.

In addition to uncontrolled temperature changes, contaminated feedstock (eg animal feed additives containing metals or antibiotics) can harm the bacteria. Household toxic materials may likewise inhibit bacterial action and this is one reason for source segregation of waste feedstocks.

The non gaseous material drawn from the anaerobic digester is called sludge, or digestate. It is rich in nutrients (ammonia, phosphorus, potassium, and more than a dozen trace elements) and is an excellent fertiliser.

Advanced AD plants (an example of recent technical progress) include a special first stage pre digestion process that significantly enhances the breakdown of organic materials by, for example, breaking down cell walls. With thermal hydrolysis, this is achieved by an initial high temperature of 165℃ co mbined with high pressure (6 Bar) for less than one hour, or with enzyme hydrolysis, which is achieved by phasing an increased temperature from 42℃ to 55℃ over severa l days.

See also

http://www.energysavers.gov/your_workplace/farms_ranches/index.cfm/mytopic=30003

http://www.anaerobic-digestion.com/html/anaerobic_flow_diagram.html

http://www.foe.co.uk/resource/briefings/anaerobic_digestion.pdf

http://www.biogas-info.co.uk/index.php/regulations-qa

http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,17509&_dad=portal&_schema=PORTAL

For Advanced AD see the summary detail in

http://www.renewableenergyworld.com/rea/news/article/2009/04/advanced-anaerobic-digestion-more-gas-from-sewage-sludge