REVIEW ON THE SIGNIFICANCE OF BACTERIA IN LANDFILL GAS PRODUCTION

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ABSTRACT

This review paper describes systems used to manage Municipal solid waste for landfill gas production. It addresses the general considerations pertaining landfill design and operation to growth requirements mechanisms for bacteria i.e. neutral pH, moderate temperature, moisture, oxygen (optional) and nutrients and once the growth conditions are known, bacteria (methanogens) can possibly be cultured to catalyzed degradation depending on need for methane. Though sanitary landfill is the most considerable option, they provide sufficient gas with control of nearly all gas collecting system and bacterial growth conditions. In contrast, an unengineered landfill or open dump offer substantial control, but few feature the likelihood for levels of productivity that offset their low cost and control. One of the greatest challenges of landfill with gas collecting system is its design and how to increase awareness in developing countries in order to benefit from economy of scale and produce meaningful quantities of landfill gas (biogas).

Keywords: Municipal solid waste (MSW), Landfill, Landfill gas, Methane, Bacteria, Growth

INTRODUCTION

The management of urban solid waste is one of the most immediate and serious environmental problems facing governments in African cities. The conventional municipal solid waste management approach (based on collection and disposal) has failed to provide effective services to all urban residents. The environment steadily degrades due to waste which is not managed effectively. The overall goal of solid waste management is to collect and dispose of solid wastes generated by population groups in an environmentally and satisfactory manner. As cities grow economically, business activity and consumption patterns drive up solid waste quantities (Oyelola and others, 2011)

Most developed countries have advance from an ethos of removing waste from point of depositing in the most expedient and economic alternative location, to control waste production, provision of appropriate treatment options and the engineering of final land disposal so as to minimise resource recovery(Alexander, 2003). Recognizing that our world is finite and that the continued pollution of our environment will, if uncontrolled, be difficult to rectify in the future, the subject of characterisation study of solid waste is both timely and important. Traditionally, disposal of waste to someone else and marking it a problem is most commonly deployed for many businesses. It remained a problem until the disposal of waste became linked with ecological degradation (Pitt etal, 2002). There are three primary purposes for solid waste characterisation. First, the data became basis for planning economic analysis, design and subsequent management and operation of a disposal system or material – energy resource recovery facilities. Second, solid waste characterisations for rehabilitation or retrofit of facilities redefine the quantity and type of waste for disposal (Salami and others, 2011).

The composition of solid waste must be known for local authorities to select the most economical collection means, to design and operate an efficient central incineration plant, to plan ahead for suitable sanitary landfill sites or design a compositing plant or a central grinding plant to forecast future demand which they are likely to meet and to forecast accurately the cost and efficiency of operation when choosing a particular method of disposal

Because municipal solid waste (MSW) landfills emit significant amounts of methane, a potent greenhouse gas, there is considerable interest in quantifying surficial methane emissions from landfills (Veronica and others, 2009). Global climate change is due in large part to the emissions of human-generated greenhouse gases, mainly CO_2, CH_4, nitrous oxide, and chlorofluorocarbons (CFCs).

Methanogenesis or biomethanation is the formation of methane by microbes known as methanogens. Organisms capable of producing methane have been identified only from the domain Archaea, a group phylogenetically distinct from both eukaryotes and bacteria, although many live in close association with anaerobic bacteria. The production of methane is an important and widespread form of microbial metabolism. In most environments, it is the final step in the decomposition of biomass (Wikipedia, 2015).

Biogas contains both CH_4 and CO_2; however, CH_4 is more of a concern. CH_4 has a global warming potential of 25 times that of CO2 over 100-yr time horizon (Forster and others, 2007) Because CH_4 is a key greenhouse gas and landfills produce a significant amount of CH_4, there is considerable interest in quantifying surficial CH_4 emissions from landfills (Veronica and others, 2009).

Table 1: Typical Component Values and Composition of Solid Wastes

Component	Moisture % Typical	Density kg/m^3 Typical	C	H	O	N	S	Ash
Organic matter	25	240	48.50	6.50	37.50	2.20	0.30	5.0
Plastics	2	65	60	7.20	22.80	-	-	10
Paper	6	85	43.50	6.0	44.0	0.3	0.2	6.0
Glass	2	195	-	-	-	-	-	-
Silts	20	130	-	-	-	-	-	-
Ash	8	480	26.30	3.0	2.0	0.5	0.2	68.0

Basis: 100kg of solid waste sample

Source: Tchobanologlou and others,(1972)

Table 2: Physical Waste Composition in Developed and Developing Countries

Composition (% by mass)	Developed countries			Thailand	Cities in developing countries				
	USA.	Holland	UK.	**Bangkok**	India (Delhi)	China (Wuhan)	S.Africa (Soweto)	Peru (Lima)	Mexico (Mexico city)
DOC									
Garden and food waste	25	48	25	**13.9**	47	16	9	56	56
Paper	35	24	30	**15.7**	6	2	9	14	17
Textile	3	3	3	**4.4**	-	0.6	1	4	6
Non-DOC									
Metals	10	3	8	**3**	1	0.5	3	4	6
Glass	9	9	12	**9.9**	0.6	0.6	12	3	4
Plastic	8	7	5	*	0.9	0.5	3	7	6
Wood	4	1	-	**2.9**	-	1.8	63	12	5
Dust, ash, others	6	2	17	**40.8**	44.5	78	-	-	-
Refuse density	-	-	145	-	420	600	400	350	-
Refuse generation rate ton/person/yr.	0.61	0.61	0.5	**0.32**	0.14	0.2	0.15	0.3	0.55
(Kg/person/day)	(1.7)	(1.7)	(1.4)	**0.89**	(0.38)	(0.54)	(0.41)	(0.9)	(1.5)

* Classified in dust, ash and others.
Source: Blight (1996)

Definitions of Disposal Sites

Disposal sites in are typically classified into three groups: open dump site, non-engineered landfilling site and sanitary landfill.

Sanitary Landfill *:* Sanitary Landfill is defined by American Society of Civil Engineering
(1970) as: A method of disposing of refuse on land without creating nuisances of hazards to public health or safety, by utilizing a principle of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at a conclusion of each day's operation, or at such more frequent intervals as may be necessary. It consists of four basic operations:

1) the solid wastes are deposited in a controlled manner in a prepared portion of the site;
2) solid wastes are spread and compacted in thin layers;
3) the solid wastes are converted daily or more frequently, if necessary, with a layer of earth;
4) the cover material is compacted daily.

Today, sanitary landfill refers to as engineered facility for disposal of municipal solid waste designed and operated to minimize public health and environmental impacts. Landfilling is the process by which residual solid waste is placed in a landfill (including monitoring of incoming waste stream, placement and compaction of waste, and installation of landfill environmental monitoring and control facilities).

Non-Engineered Landfill

Non-engineered landfill is defined as a disposal site either has been excavated or non-excavated, with daily cover soil or when the site is full. The site is managed without an engineering design, operation and monitoring. Therefore, public health and environmental impact from water, air and soil contamination are not minimized.

Open-Dump Site

An open-dump site is a solid disposal site without waste compaction during placement, neither compact nor cover with soil. The land is used without preparation of engineering planning. The uncontrollable wastes are placed as mountain of waste. It is normally a source of infection, odor pollution, and environmental contamination.

Table 3 : U.S. CH_4 emissions by source (Tg CO_2 equivalents)

Source Category	1990	2000	2001	2002	2003
Landfills	172.2	130.7	126.2	126.8	131.2
Natural gas systems	128.3	132.1	131.8	130.6	125.9
Enteric fermentation	117.9	115.6	114.5	114.6	115
Coal mining	81.9	56.2	55.6	52.4	53.8
Manure management	31.2	38.1	38.9	39.3	39.1
Wastewater treatment	24.8	34.3	34.7	35.8	36.8
Other	45.8	43.5	41.7	39.6	39.8
Total for United States	605.3	554.2	546.7	542.3	544.9

Notes: [a]Tg = 10^{12} g.
Source: Veronica and other (2009)

Table 4: Principle Properties of Major Landfill Gases (in Isolation State)

GAS	CHARACTERISTICS
Methane	Colorless odorless Soluble in water
	Lighter than air (specific gravity 0.55)
	Explosive (concentration from 5% - 15% by vol. of air *)
	Non toxic to plant but cause oxygen depletion in root zone

Carbon dioxide	
	Non combustible odorless Colorless
	Soluble in water
	1.5 times heavier than air (specific gravity 1.53)
	Risk as asphyxiation
	Toxic to plant (more than 5-10% by vol. in the root zone)
	occupational limits of maximum
	acceptable 0.5 and 1.5% by volume for occupational longterm
	(8 h.) and short-term (10 min.) exposure respectively.**
Oxygen	odorless Colorless
	Slightly soluble in water
	Heavier than air (specific gravity 1.11) Highly toxic by inhalation less than 18% by vol.
	Explosive limit 15-26.6% by vol
Ammonia.	Specific gravity of 0.07
	Found during the anaerobic non-methanogenic stage
	Explosive limit 4.0-74.2% by vol
.	
Hydrogen	odorless Non toxic colorless
	Specific gravity of 0.07
	Found during the anaerobic non-methanogenic stage
	Explosive limit 4.0-74.2% by vol.
Hydrogen sulfide	Colorless, Distinctive odor of “rotten egg”
	Soluble in water
	Specific gravity of 1.19
	Highly flammable (explosive in the range 4.4-45% by vol.)
	Occupational limits of 10 ppm and 15 ppm for 8 h and 10 min. respectively.
Carbon monoxide	Colorless, odorless
	Slightly soluble (specific gravity 0.97)
	Produced by incomplete combustion of organic materials(in this case underground combustion)
	Explosive in the range 1.25-74.2% by vol
.	Highly toxic by inhalation

	occupational limits of 50 ppm and300 ppm for 8 h and 10 min. respectively.

* the lower and upper explosive limits, LEL and UEL, respectively.
** Health and Safety Executive (EH40/91)
Source: adapted from Cairney (1993) and Lagrega (1994)

LANDFILL GAS GENERATION, PRINCIPAL GASES AND THEIR PROPERTIES

Solid waste landfill contains mostly organic waste and water which promote the biochemical reactions. Their major products are landfill gases and leachate (liquid that has percolated through solid waste and has extracted dissolved or suspended materials, mostly, the liquid has entered landfill from external sources such as rainfall, surface drainage). Gases found in landfill include ammonia (NH_3), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen (H_2), hydrogen sulfide (H_2S), methane (CH_4), nitrogen (N_2), and oxygen (O_2),

Methane and carbon dioxide are the major principal gases produced from the anaerobic decomposition of the biodegradable organic waste components in municipal solid waste.

Typically, landfill gas is composed of 45 - 60% methane and 40 - 50% carbon dioxide. In addition, gas from older landfills which accepted hazardous wastes that contained volatile organic compounds (VOC's) may contain significant amounts of VOC's.

The landfill gas generation rate varies with time. Normally, the generation is separated into five phases.

I Initial adjustment phase:

The biological decomposition occurs under aerobic conditions, because it still has certain amount of air in a landfill.

II Transition phase

Oxygen depletes and anaerobic condition begins to develop. The measurement of oxidation/reduction potential at -150 to -300 millivolts shows the occurrence of methane
production.

III Acid phase

In acid phase, hydrolysis of high molecular mass compound takes place and its products are compounds suitable for microorganism to use as energy or carbon sources. In addition, acidogenesis process (utilization of compounds from former steps) produces carbon dioxide as major gas in the third phase.

IV Methane fermentation phase

Methanogenic bacteria converts acetic acid and hydrogen formed in acid phase to CH_4 and CO2.

V Final phase

The final phase is maturation. It occurs when available biodegradable waste has already convert to CH_4 and CO_2. The rate of gas generation diminished because most of nutrients have been removed with leachate during the previous phases and substrates that remain in landfill are slowly biodegradable. Figure 1 illustrates a typical landfill gas production pattern.

During anaerobic condition, the generalized chemical reaction for anaerobic decomposition of solid waste can be written as:

$$\text{organic matter} + H_2O \xrightarrow{\text{Bacteria}} \text{biodegraded} + CH_4 + CO_2 + \text{other gases}$$

(solid waste) organic matter (1)

(Reaction is under the presence of water)

There are a lot of methods for theoretical maximum methane yield (Emcon Associates, 1980; Tchobanoglous and others, 1994). However, the methane generation rate is mostly calculated from biodegradable portion of waste. If the individual organic constituents found in MSW (with exception of plastic) are represented with the general formula of the term CaHbOcNd, then the total volume of gas can be estimated using Eq. 2, assuming the complete conversion of biodegradable organic waste to CO_2 and CH_4.

$$CaHbOcNd + \left(\frac{4a - b - 2c + 3d}{4}\right) H2O \rightarrow \left(\frac{4a + b - 2c - 3d}{8}\right) CH4 + \left(\frac{4a - b + 2c + 3d}{8}\right) CO2 + dNH4 \qquad (2)$$

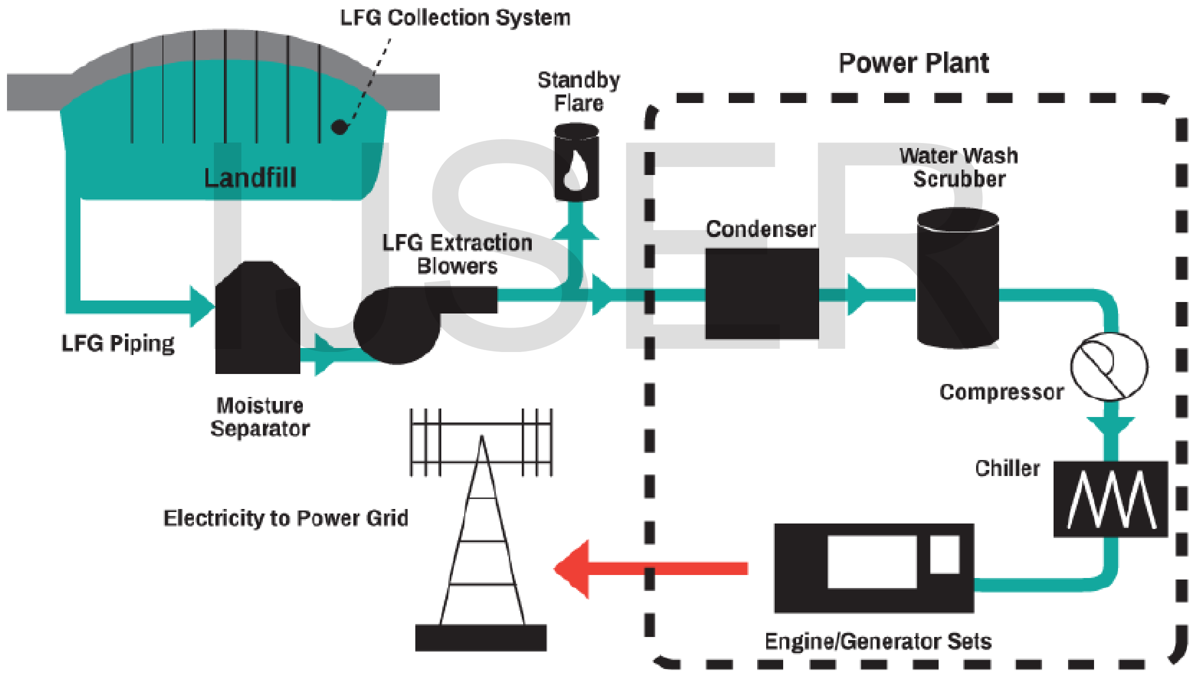

Figure 1: landfill gas collection and utilization system

Source: http://www.wt-energy.com/wte-solutions/landfill-biogas-captation/

Landfill with Energy Recovery

Landfill is a method, where solid waste is buried between the layers of dirt to fill in or reclaim low-lying ground. " A disposal site where solid waste, such as paper, glass, and metal, is buried between layers of dirt and other materials in such a way as to reduce contamination of the surrounding land. Modern landfills are often lined with layers of absorbent material and sheets of plastic to keep pollutants from leaking into the soil and water. Also called sanitary landfill" (dictionary.com, 2013).

Landfill waste management method requires big piece of land and it is suitable for the countries, which have geographically plain land available away from residential areas. It is most common method has been used by even great industrialized countries of the world. Over 70% of municipal wastes in North America and Western Europe are land filled with little or no treatment. "According to a study released by scientists at Columbia University, landfills across the country contain enough plastic waste to provide power for 5.2 million American homes, fuel six million cars for a year, and potentially much more" (Hall, 2011) Landfill gas (LFG) recovered from municipal solid waste landfills as a source of renewable energy. As solid waste decomposes in landfills, a gas is emitted that is approximately 50 percent methane (CH_4) and 50 percent carbon dioxide (CO_2), both of which are GHGs (U.S. EPA, 2011)20. LFG energy technologies capture CH_4 to prevent it from being emitted to the atmosphere, and can reduce landfill CH_4 emissions by between 60 and 90 percent (depending on project design and effective- ness) (U.S. EPA, 2011).

Production rate of landfill gas

LGF production varies considerably from one plant to another, depending on the situation in the individual country and landfill. The production rate depends on the following parameters:

1. Waste age:

LFG production reaches its maximum capacity after 3-8 years and normally decreases after 15-30 years, when it is no longer profitable to extract the gas for energy purposes.

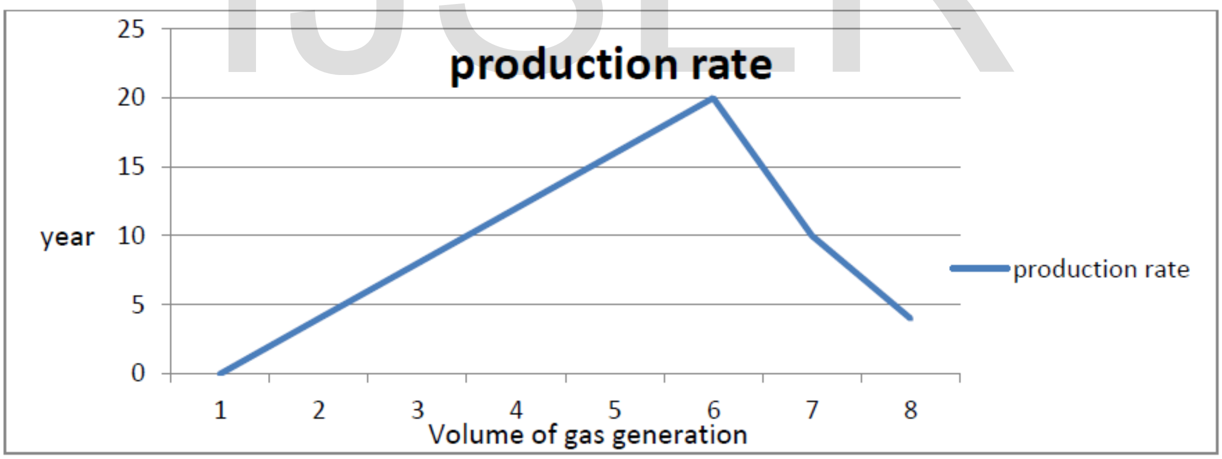

Figure 2: production start after 6 months and increase till 20 than decrease

Source:

2. Waste structure:

Because degrading microorganisms are active in the water film around the waste particles, smaller particles of organic materials produce more LFG.

3. Moisture content of the waste:

Methane generation bacteria live in the water film around the waste particles. Sufficient water is needed to cover the organic particles. Moisture can accelerate bacterial activity or smother it completely if the waste is completely saturated.

4. Temperature in the landfill:

Methane bacteria find optimum mesophyll conditions at 350 C. this temperature is found in deep landfills. In shallower landfills (10-15 meters deep) the temperature is normally as low as 200C.

5. Landfill cover:

Landfills must be covered to keep out atmospheric air, which will disturb the anaerobic conditions. The cover material should allow penetration of rainwater to maintain adequate humidity in the waste.

EXISTING CH_4 EMISSION ESTIMATION TECHNIQUES

Numerous techniques exist for the estimation of CH_4 emissions from landfills. The most popular methods are the chamber techniques, either static or dynamic (Perera and others, 2002). Both techniques have their own advantages and disadvantages. For example, the dynamic or open flux chamber simulates field conditions better than the static or closed flux chamber; however, the open chamber may indicate artificially high fluxes because of pressure changes inside of the chamber (Perera and others, 2002). In contrast, the closed flux chamber is much easier to use and cheaper to operate than the open chamber; however, the closed chamber tends to underestimate the gas fluxes because of pressure buildup with time that distorts the gas flow pathways in the soil and decreases the flow into the chamber (Perera and others, 2002). Other drawbacks to the flux chamber method include labor and time required and getting only point measurements that often give highly variable results between measurements even just a few meters apart.

CH_4 production rates can be estimated by any of several biogas production models. The U.S. Environmental Protection Agency (EPA) Landfill Gas Emissions Model (LandGEM) is such an estimation tool; another is MICROGEN- MGM (Senevirathna and others, 2007). Gas generation models rely on assumptions of waste decomposition rates and microbial growth kinetics.

A major drawback is the need for precise data on landfill data (waste composition, emplacement history, rainfall history, etc.). Also, the models do not account for how much of the CH4 is being captured versus being emitted (although one can always assume a collection system efficiency and make a simple estimate).

The CH_4 emissions from an entire area source can be calculated using a ground-based optical remote sensing (ORS) method. The ORS method uses open-path Fourier transform infrared (OP-FTIR) spectroscopy to obtain path integrated pollution concentration information along multiple plane-configured optical paths (Thoma and others, 2005). The source emissions can be determined after processing the pollutant concentration information and wind vector information with a plane-integrating computer algorithm. Problems with ORS methods are that they are expensive, time and labor intensive, depend on good measurement of meteorological parameters, and produce only one integrated emission rate for the whole landfill. This last disadvantage may make this method questionable for use in dispersion modeling studies (such as with odors) of a LFG collection system to determine compliance. Readings above 500 parts per million (ppm) require remedial action and may imply that something is wrong in the gas collection system (Veronica and others, 2009).

BIODEGRADATION OF WASTE

In landfills, the natural process of anaerobic decomposition of biodegradable waste creates biogas. Biogas is roughly composed of 45–60% methane (CH_4), 40–60% carbon dioxide (CO_2), and trace species.(USEPA, 1990; Hurst and others , 2005; Tchobanoglos and others, 1993) The trace gases often are highly odorous. The amount of biogas produced in landfills is a function of the waste (quantity, type, and age), landfill moisture content, temperature, and management practices at the site.

Archaeological investigations of landfills have revealed that biodegradable wastes can be found — virtually intact — 25 years after burial. We know that landfills contain bacteria with the metabolic capability to degrade many of the materials that are common components of municipal refuse. The persistence for decades of degradable materials in the presence of such organisms appears somewhat paradoxical.

Biodegradation of cellulose, hemicellulose, and lignin

Cellulose and hemicellulose are the principal biodegradable constituents of refuse accounting for 91% of the total methane potential. Cellulose forms the structural fiber of many plants. Mammals, including humans, lack the enzymes to degrade cellulose. However, bacteria that can break cellulose down into its subunits are widely distributed in natural systems, and ruminants, such as cows, have these microorganisms in their digestive tract. Cellulose is a polysaccharide that is composed of glucose subunits (see Figure 3).

Another component of the walls of plants is hemicellulose, which sounds similar to cellulose but is unrelated other that that it is another type of polysaccharide. Hemicelluloses made up of five carbon sugars (primarily xylose) are the most abundant in nature.

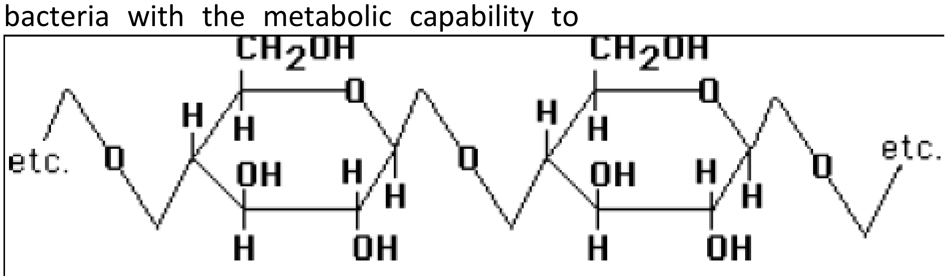

Figure 3: Cellulose (two glucose subunits)

Lignin is an important structural component in plant materials and constitutes roughly 30% of wood. Significant components of lignin include coniferyl alcohol and syringyl alcohol subunits (Figure 4).

The exact chemical structure of lignin is not known but its reactivity, breakdown products, and the results of spectroscopic studies reveal it to be a polymeric material containing aromatic rings with methoxy groups (-OCH3) (Tchobanoglous, Theisen et al. 1993). One of the many proposed structures for lignin is shown in Figure 5-3.
Degradation of lignin requires the presence of moisture and oxygen and is carried out by filamentous fungi (Prescot, Harley et al. 1993).

The biodegradability of lignocellulosic materials can be increased by an array of physical/chemical processes including pretreatment to increase surface area (size reduction), heat treatment, and treatment with acids or bases. Such treatments are useful when wood and plant materials are to be anaerobically degraded to produce methane. Research on this topic has been performed by Cornell Prof. James Gossett (Gossett and McCarty 1976; Chandler, Jewell et al. 1980; Gossett, Stuckey et al. 1982; Pavlostathis and Gossett 1985a; Pavlostathis and Gossett 1985b).

Three major groups of bacteria are involved in the conversion of cellulosic material to methane (Zehnder 1978):
(1) The hydrolytic and fermentative bacteria that break down biological polymers such as cellulose and hemicellulose to sugars that are then fermented to carboxylic acids, alcohols, carbon dioxide and hydrogen gas,
(2) The obligate hydrogen reducing acetogenic bacteria that convert carboxylic acids and alcohols to acetate and hydrogen, and
(3) The methanogenic bacteria that convert primarily acetate and hydrogen plus carbon dioxide to methane. Sulfate reducing bacteria (SRB) may also play a role in the anaerobic mineralization of cellulosic material. In the presence of sulfate, the degradation process may be directed towards sulfate reduction by SRB with the production of hydrogen sulfide and carbon dioxide (Barlaz, Ham et al. 1992).

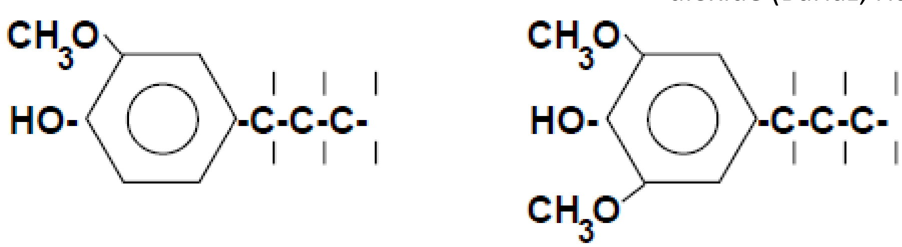

Figure 4: Coniferyl (left) and syringyl (right) subunits of lignin

BACTERIAL LIFE CYCLE AND GROWTH

Bacterial life cycle

The bacteria life cycle consists of the lag phase, the log or exponential phase, the stationary phase and the death phase. Factors that influence bacterial growth bear heavily on this cycle.

Lag Phase

- Bacteria do not grow during the lag phase. However, they do adjust to their environment and metabolize, that is, produce vitamins and amino acids needed for division. They begin making copies of their DNA, and if the environment supplies plenty of nutrients, the lag phase may be very short. Then the bacteria will proceed to the next phase of their life.

Log or Exponential Phase

- During the log or exponential phase, bacteria multiply rapidly, even exponentially. The time it takes for a culture to double is called "generation time," and under the best conditions, the fastest bacteria can double in about 15 minutes. Other bacteria take days.

Within a bacterium, the DNA copy drifts to the opposite side of the membrane. The bacterium then pulls apart, creating two identical "daughter cells," which begin dividing anew. This process is called binary fission.

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Stationary Phase

- During the stationary phase, bacteria growth dwindles. Due to accumulating waste and a lack of space, bacteria cannot maintain the clip of the log or exponential phase. If the bacteria moves to another culture, however, rapid growth may resume.

Death Phase

- During the death phase, bacteria lose all ability to reproduce, which becomes their death knell. Like the log or exponential phase, bacterial death may occur as rapidly as their growth.

Factors that Influence Growth

- Temperature, acidity, energy sources and the presence of oxygen, nitrogen, minerals and water all affect bacterial growth, thus affecting the bacteria life cycle. Optimal growing conditions depend on the bacteria. Psychrophiles, for example, thrive in arctic conditions while hyperthermophiles grow best in hot environments, such as ocean vents. Allaliphiles require highly acidic environments while neutrophiles prefer places that are neither acidic nor basic. Of course, these are only two of many possible examples.

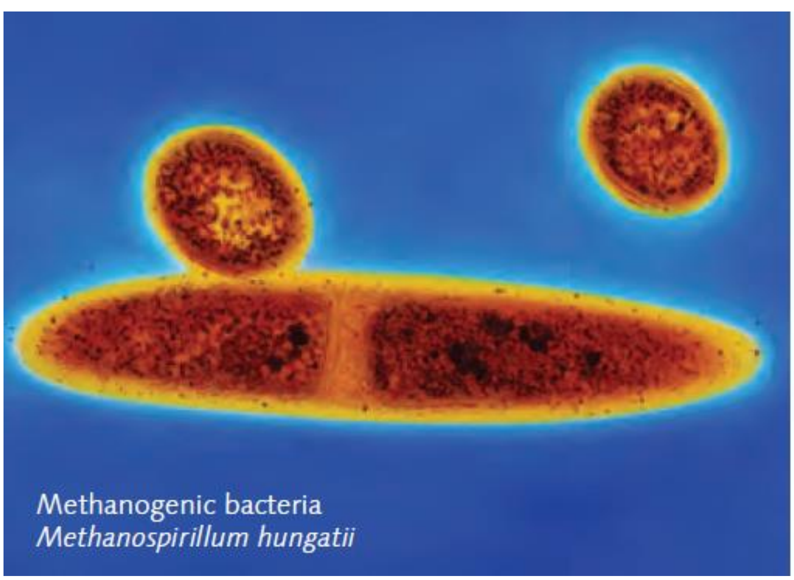

Figure 6: Methanogens bacteria

Source:

Cellular requirements for growth

Oxygen

The availability of oxygen is a prime determinant in the type of microbial metabolism that will occur. Microbial respiration of organic carbon is a combustion process, in which the carbon is oxidized (i.e., is the electron donor) in tandem with the reduction of an electron acceptor. The energy available to microorganisms is greatest when oxygen is used as the electron acceptor and therefore aerobic metabolic processes will dominate when oxygen is available. Some microorganisms require oxygen to obtain their energy and are termed "obligate aerobes." In the absence of oxygen, other electron acceptors such as nitrate (NO_3^-), sulfate (SO_4^{-2}) and carbon dioxide (CO_2) can be used. Organisms that can only exist in an environment that contains no oxygen are termed "obligate anaerobes." Organisms that have the ability to grow in both the presence and the absence of oxygen are said to be "facultative."

Nutrient

The availability of nutrients can limit the ability of cells to grow and consequently the extent of biodegradation. Nitrogen and/or phosphorous constitute important nutrients required for cell synthesis. Inorganic bacterial nutritional requirements also include sulfur, potassium, magnesium, calcium, iron, sodium and chloride. In addition, inorganic nutrients needed in small amounts (minor or trace nutrients) include zinc, manganese, molybdenum, selenium, cobalt, copper, nickel, vanadium and tungsten. Organic nutrients (termed "growth factors") are also sometimes needed (depending on the microorganism) and include certain amino acids, and vitamins (Metcalf & Eddy 1991).

pH,Temperature,Moisture and Salt concentration

Environmental conditions such as pH, temperature, moisture content, and salt concentration can have a great influence on the ability of bacteria to grow and survive. Most bacteria grow in the pH range from 4.0 to 9.5 (although some organisms can tolerate more extreme pH values), and typically grow best in the relatively narrow range from 6.5 to 7.5 (Metcalf & Eddy, 1991). Microorganisms have a temperature range over which they function best, and are loosely characterized as phychrophilic (ability to grow at 0°C), mesophilic (optimal growth at 25-40°C) or thermophilic (optimal growth above 45-50°C) (Brock 1970). Many common methanogens are mesophilic. Elevated temperatures also favor faster reaction rates.

While some microorganisms are very tolerant of low moisture conditions, active microbial growth and degradation of organic matter necessitates that water not be a scarce resource. Cells take water in through their semi-permeable membrane surface by osmosis. This uptake mechanism requires that the solute concentration inside the cell be higher than that of the outside media. Organisms that grow in dilute solutions can not tolerate high salt concentrations because their normal osmotic gradient is reversed and they can not take in water. Some cell strains, termed "halophiles" are adapted for growth at very high salt concentrations.

The above factors suggest that bacterial degradation of MSW to produce methane will occur optimally at circumneutral pH, low ionic strength, in the absence of oxygen, nitrate and sulfate, in the presence of moisture and nutrients, and under mesophilic conditions.

Potential methane production from municipal solid waste

Under anaerobic conditions microorganisms can produce both CO_2 and CH_4 (methane) without consuming any oxygen. Other significant end products include odorous gases such as ammonia (NH_3), and hydrogen sulfide (H_2S) (see Figure 5-4). Because anaerobic biodegradation produces gas it is possible to monitor the extent and rate of anaerobic biodegradation by measuring gas production (Suflita and Concannon 1995).

Gas production

Because anaerobes get relatively little energy from the organic matter their conversion of carbon to cell material (synthesis) is much lower than for aerobes. Typically 10% of the organic matter may be converted to anaerobe cell mass. Thus the majority of the biodegraded organic matter is converted to gas and the gas production can be used as a measure of biodegradation. The ideal gas law is used to determine the moles of gas produced from the pressure, volume, and temperature.

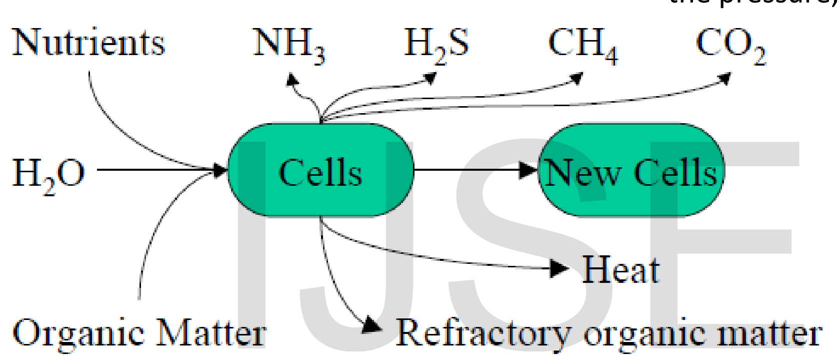

Figure 7: Reactants and products for anaerobic degradation of organic matter

CONCLUSION

Landfill (sanitary) energy recovery technology is the most socially acceptable, environmentally friendly and the cheapest among all other available worldwide waste-to-energy technology for biogas recovery. Methane as a product from methanogenesis and a source of energy can be trapped in either open dump, unengineered landfill or sanitary landfill depending on the need, for efficient use. Since the methanogens, which are the bacterial for waste degradation needs nutrient and other conditions for growth, it can be as well cultured like other microorganism for faster degradation of organic waste.

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