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A Review paper on Comparative Study for Management of Landfill By-Products

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***Abstract**:*

Sanitary landfills are the most popular method of ultimate disposal of solid waste throughout the world. It is a land disposal site employing an engineered method of disposing of solid waste on land by minimizing volume and applying compaction cover material at the end of each day. Most of the global municipal solid waste is dumped in non regulated landfills which generate by-products like methane and leachate. The generated methane has high global warming potential while leachate is the most polluted liquid generated in a landfill which can pollute ground water. This paper focuses on comparative study of characteristics, generation process and various controlling techniques for reducing the concentration of methane and leachate. Both of which can also be used for generation of clean and renewable energy. An alternate eco-friendly energy fuel source "Microbial Fuel Cell (M.F.C)" which converts organic matter into electricity with the help of bacteria present in waste water while simultaneously treating the waste water will also be overviewed in this paper.

Keywords
Landfill, Solid waste, Methane, Leachate, eco-friendly energy sources, Microbial Fuel Cell (M.F.C).

1. Introduction

With the passage of time, municipal landfill becomes mature and difficult to deal with using conventional ways of treatment owing to presence of recalcitrant compounds. Looking to the future, we see that as a society we will need to continuously improve the way that we manage our wastes. Source reduction and recycling efforts will take on increasingly important roles, each year, the world's population generates more than 2 billion tons of waste; if society continues to move toward the current waste generation patterns of the wealthiest cities in high-income countries today, then by 2025, as much as 7 billion tons of waste could be generated each year. Rapid population growth and high rates of urbanization, coupled with increasing prosperity in developing countries, require a serious examination of the waste management process We believe there are significant environmental and economic benefits to be gained by making small changes in the way that we operate landfills. Methane, CO2, and leachate are the major By- products. This paper provides basic information about landfill gas-what it is composed of, how it is produced, and the conditions that affect its production. It also provides information about how landfill gas Moves and travels away from the landfill site. Finally, the paper presents an overview of the types of landfills that might be present in the community and the regulatory requirements that apply to each. Landfill Gas (LFG) is the product of microbiological decomposition of land-filled garbage. The bugs turn complex organic compounds in garbage into methane, carbon dioxide, and trace amounts of other compounds. The remaining compounds in the gas could be just present in negligible amount, depending on the climate and the garbage. Another major By-product is leachate. Landfill leachate is a liquid that is mainly produced by the precipitation which falls on the solid waste. The leachate usually contains high amount of ammonium, organic matter, toxic compounds and heavy metals. This master thesis introduces briefly facts of landfills, leachate formation and leachate characteristics. The rainwater infiltrates into the garbage based on compaction and soil properties and generates physical mixing and chemical reactions with the components existing in the waste. The primary objective of the present work was to study the ability of the microbial fuel cell technology to remove pollutants from landfill leachate. Recently, the scope of MFC technology has been extended. Microbial fuel cells (MFCs) are a promising technology for electricity production from a variety of materials. Which targets for the long term goals of renewable energy production and waste treatment.

1.1 Landfill Gas compounds:- Landfill gas is made up of combination of different compounds including:

Methane - Methane gas is naturally created as garbage decomposes in landfill. Methane is nonreactive and not harmful for human health, apart from this if there is so much methane in a room that it displaces the oxygen, one could die from suffocation. Methane is flammable gas. When present in very high amount it can be potentially explosive.

Carbon Dioxide- is present everywhere. The human lung transforms the oxygen inhaled in each breath into carbon dioxide (CO2) which is exhaled. Plants "inhale" CO2 and "exhale" oxygen. If methane and CO2 are odorless, then which compounds contribute to odour. Since the odorless gases carbon dioxide and methane are produced in large quantities, these gases carry the other landfill gases in negligible amount. Landfill gas is composed of a mixture of hundreds of different gases. By volume, landfill gas typically contains 45% to 60% methane and 40% to 60% carbon dioxide.

1.2 Where does LFG come from: Garbage contains many organic (carbon-based) compounds. Micro-organisms (bugs), which are found everywhere (air, water, soil, etc.), feed on organic compounds. Using water from precipitation or artificial sources, and nutrients found in the soil or garbage.

1.3 How is landfill gas: Produce Bacterial decomposition- Most landfill gas is produced by bacterial decomposition, which occurs when organic waste is broken down by bacteria naturally present in the waste and in the soil used to cover the landfill. Organic wastes include food, garden waste, street sweepings, textiles, and wood and paper products. Bacteria decompose organic waste in four phases, and the composition of the gas changes during each phase. The below on this provides detailed information about the four phases of bacterial decomposition and the gases produced during each phase.

2. The Four Phases Of Bacterial Decomposition Of Landfill Waste

Bacteria decompose landfill waste in four phases. The composition of the gas produced changes with each of the four phases of decomposition. Landfills often accept waste over a 20- to 30-year period, so waste in a landfill may be undergoing several phases of decomposition at various condition. This means that older waste in one area might be in a different phase of decomposition than more recently buried waste in another area.

Phase I

During the first phase of decomposition, aerobic bacteria, that live only in the presence of oxygen-consume oxygen while breaking down the long molecular chains of complex carbohydrates, proteins. and lipids that comprise organic waste. The primary by-product of this process is carbon dioxide. Nitrogen content is high at the starting of phase, but declines as the landfill moves through the four phases. Phase I continues until available oxygen is no long sufficient Phase I Decomposition can last for days or months, depending on how much oxygen is present when the waste is disposed in the landfill. Oxygen levels will vary according to factors such as how loose or compressed the waste was when it was buried.

Phase II

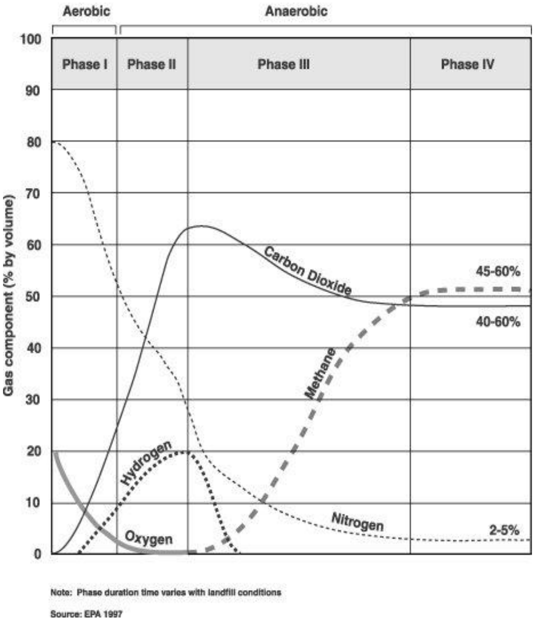
Phase II decomposition starts after the oxygen in the landfill has been used up. Using an anaerobic process (a process that does not require oxygen), bacteria convert compounds created by aerobic bacteria into acetic, lactic, and formic acids and alcohols such as methanol and ethanol. The landfill becomes highly acidic. As the acids mix with the moisture present in the landfill, they create certain nutrients to dissolve, making nitrogen and phosphorus available to the increasingly diverse species of bacteria in the landfill. The gaseous By-products of these processes are carbon dioxide and hydrogen. If the landfill is disturbed or if oxygen is somehow introduced into the landfill, microbial processes will return to Phase I.

Phase III

Phase III decomposition starts when certain kinds of anaerobic bacteria consume the organic acids produced in Phase II and form acetate, an organic acid. This process causes the landfill to become a more neutral environment in which methane producing bacteria begin to establish themselves. Methane- and acid-producing bacteria have a symbiotic, or mutually beneficial, relationship. acid-producing bacteria create compounds for the Methanogenic bacteria to consume the carbon dioxide and acetate, too much of which would be toxic to the acid-producing bacteria.

Phase IV

Phase IV decomposition begins when both the composition and production rates of landfill gas remain relatively constant. Phase IV landfill gas usually contains approximately 45% to 60% methane by volume, 40% to 60% carbon dioxide, and 2% to 9% other gases, such as sulfides. Gas is produced at a stable rate in Phase IV, typically for about 20 years; however, gas will continue to be emitted for 50 or more years after the waste is placed in the landfill. Gas production might last longer, for example, if greater amounts of organics are present in the waste, such as at a landfill receiving higher than average amounts of domestic animal waste .



2.1 Conditions affect landfill gas production

The rate and volume of landfill gas produced at a specific site depend on the characteristics of the waste (e.g., composition and age of the refuse) and a number of environmental factors affects (e.g., the presence of oxygen in the landfill, moisture content, and temperature).

Waste composition- The more organic waste present in a landfill, the more landfill gas (e.g., carbon dioxide, methane, nitrogen, and hydrogen sulfide) is produced by the bacteria during decomposition.

Presence of oxygen in the landfill- Methane will be produced only when oxygen is no longer period in the landfill.

Moisture content- The presence of moisture (unsaturated conditions) in a landfill increases gas production because it encourages bacterial decomposition. Moisture may also promote further chemical reactions that produce gases.

Temperature- As the landfill's temperature rises, bacterial activity also increases, resulting in increased gas production. Increased temperature may also increase rates of volatilization and chemical reaction in landfill.

2.2 How does landfill gas shift

Once gases are produced under the landfill surface, they generally try to move away from the landfill. Gases tend to expand and fill the available space, so that they move, or "migrate," through the limited pore spaces within the refuse and soils covering of the landfill. The natural tendency of landfill gases that are lighter than air, such as methane, is to move upward, usually through the landfill surface. Upward movement of landfill gas can be inhibited by densely compacted waste or landfill cover material (e.g., by daily soil cover and caps). When upward movement is inhibited, the gas tends to migrate horizontally or other areas within the landfill or to areas outside the landfill, where it can resume its upward path. Basically, the gases follow the path of least resistance. Some gases, such as carbon dioxide, are denser than air and will collect in subsurface areas, such as utility corridors. Three main factors influence the migration of landfill gases: diffusion (concentration), pressure, and permeability. It is difficult to predict the distance that landfill gas will travel because so many factors affect its ability to migrate underground; however, landfill gas can travel distances greater than 1,500 feet have been observed.

2.3 LFG Collection and Flaring

Usually LFG is collected using a system of wells or trenches. These wells or trenches are connected, through piping Collection systems can be configured as vertical wells. Most landfills with energy recovery systems include a flare for the combustion of excess gas and for use during equipment downtimes.

Gas Collection Wells- The most common method of LFG collection involves drilling vertical wells in the waste and connecting those wellheads to lateral piping that transports the gas to a collection header using a blower or vacuum induction system. Some collection systems involve a combination of vertical wells and horizontal collectors. Well-designed systems of either type are effective in collecting LFG. The design chosen depends on site-specific conditions and the timing of LFG collection system installation. Figure. illustrates the design of a typical vertical LFG extraction well.

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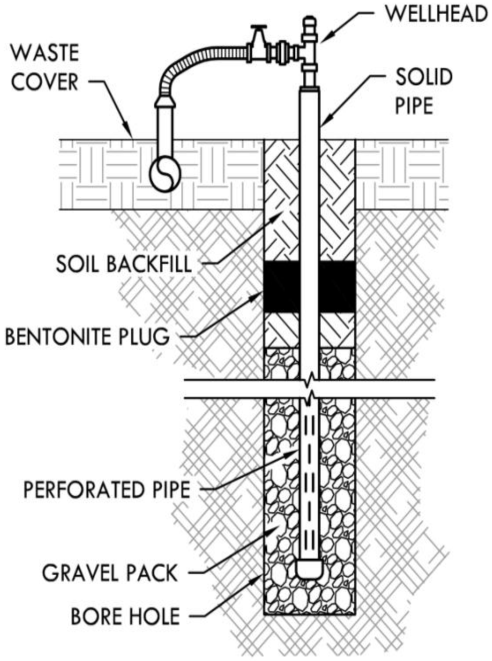

Vertical Extraction Well

2.4 LFG Treatment

Using LFG in an energy recovery system usually requires some treatment of the LFG to remove excess moisture, particulates and other impurities. The type and extent of treatment depend on site-specific LFG characteristics and the type of energy recovery system employed. Once the LFG is collected using the wells, Trenches, and fans, it is usually channeled to some sort of control device, typically a combustion device. Methane, although the simplest organic compound, is still a source of energy. One molecule of methane does not release as much heat and energy as one molecule of an NMOC, but it is still useful. Therefore, LFG (usually 40-60% methane) is often channeled to a turbine or other unit for the production of electricity or heat or power. The combustion of Methane (or other organic compounds) results in carbon dioxide, carbon monoxide, and water as the primary products. Many other compounds in LFG (complex sulfur compounds and NMOCs) are also destroyed in the combustion process-eliminating many of the odors associated with LFG. If the use of the methane energy in LFG is not feasible for whatever reasons, the LFG is often combusted in an open flare. Flare combustion of LFG has the same resulting products, however, the energy resulting from the combustion is not recovered for use.

2.5 Environmental and Economic Benefits of LFG Energy Recovery

Developing LFG energy projects is an effective way to reduce GHG emissions, improve local air quality and control odors. This section highlights the numerous environmental and economic benefits that LFG energy projects provide to the community, the landfill and the energy end user.

3. Landfill Leachate

Landfill leachate is a liquid that is mainly produced by the rain which falls on the top of the landfill. The rainwater infiltrates into the garbage and generates physical mixing and chemical reactions with the components existing in the waste. The leachate usually contains high concentrations of ammonium, organic matter, toxic compounds and heavy metals. According to the landfill age, leachate can be classified into three types: young leachate, intermediate leachate and stabilized leachate. Sometimes, young leachate and intermediate leachate are merged as one category young leachate below 5 years. To secure long term dewatering of landfills and reduce increasing of treatment costs it is necessary to control leachate quantity and quality. That when heavy rain occurs, the precipitation that drops on the waste is much faster than the bulk permeability and the expected absorptive capacity cannot be used immediately. It is a beneficial method to pump the young leachate back into a methanogenic part of a landfill. The young leachate has high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). After pumping the leachate back and keeping it in a methanogenic environment, the oxygen demand needed for the treatment of leachate is reduced. The cost of satisfying the oxygen demand is high, so this method decreases the cost and gives a sustainable economic achievement.

3.1 Composition standards

Leachate composition

Leachate is a complex material which contains e.g. water, organic materials, inorganic materials, bacteria and other microorganisms. Leachate varies from site to site, and its characteristics may change over time due to the degradation in the landfills. The composition of solid waste in landfill is dominated by biodegradable waste with naturally present bacteria. pH Hardness, Total dissolved solids (TDS),Chemical oxygen demand (COD),Biochemical oxygen demand (BOD) Ammonium, Nitrate, Nitrite, Sulphate (SO4), Phosphate (PO4),Aluminum, Arsenic, Barium, Beryllium, Boron, Bromide, Cadmium, Calcium, Chloride, Cobalt, Copper, Chromium, Fluoride, Iron, Lead, Magnesium, Manganese, Nickel, Potassium, Selenium, Sodium and Zinc are the various parameters.

3.2 Leachate treatment methods

Leachate treatment is done either biological or physical/chemical. Because of the multiple

characteristics of leachate, one single method could not be sufficient to produce the ideal result. To have a better treatment performance, an integrated system is used which combines the two methods. This paper is mainly focus on introduce some biological treatment methods of landfill leachate and physical/chemical treatment methods will only be introduced briefly. Nowadays, many leachate treatment methods have been used in the world, physical, chemical, biological and combined processes. Coagulation, precipitation, adsorption, membrane processes and some new methods have been added into the leachate treatment procedures in order to remove organic compounds, ammoniacal nitrogen, heavy mental, entrained oil and colloidal material.

3.2.1 Physical/Chemical treatment methods

For stabilized landfill leachate that contains high concentration of bio-toxicity and lack of degradable organic matters are hard to degrade. In this situation, an alternative and low cost efficient method should be introduced to the leachate treatment. The methods are used alongside biological processes in order to achieve the standards. Physical/chemical treatment method is a non-biological method used in leachate treatment as a pre-treatment and a post treatment method. It is necessary to establish on-site facilities when discharge leachate to wastewater treatment plant is not feasible. The treatment facilities are located beside the dump site and leachate is pumped into a treatment pond nearby. Leachate mixes with chemical compounds and settles with the solid contaminants in the tank before it goes to the second process. Below, some physical-chemical methods will be introduced, e.g. on-site leachate treatment.

Coagulation-Flocculation- Coagulation-Flocculation is a process of removing non-biodegradable organic compounds and heavy metals from leachate by adding coagulants Most of the colloidal particles have negative charge. To maximize the neutralization, the coagulants reduce the electric repulsion effects between particles in order to unite for precipitation. The coagulants.

Flotation- Flotation is a separation process which utilizes gas bubbles to attach to solid particles in suspension in order to make them float on the surface of the liquid. The main application of flotation process is wastewater treatment and focus on the removal of solids, ions, macromolecules and fibers in the waste.

Activated carbon adsorption-Adsorption is a method where dissolved compounds are adsorbed to the surface of an adsorbing medium which have a very big internal surface. This process happens when the attractive forces of the carbon surface overcome the attractive forces of the liquid.

Ammonia stripping-Ammonia stripping is a process which aims to reduce the concentration of ammonium in wastewater. In this method, pH plays an important role. When the pH is 7 or below, all the ammonia will turn to soluble ammonium. When pH is reaching 11, only dissolved ammonia gas is present which could be released from wastewater.

$NH4+ + OH- \rightarrow NH3 \uparrow + H2O$

Ion exchange

Ion exchange is a process that swaps ions between solid and liquid status where there is no permanent change in the structure of the solid. The equilibrium reaction can be displayed as:

nRSO3 - - H+ + Mn+ ↔ nRSO3

- Mn+ + nH+

Resin Solution Resin Solution

Electrochemical treatment- The electro-chemical treatment is mainly used in France and Brazil. The suggested explanation of the process is to break down the recalcitrant compounds in the leachate by electronic degradation. There are four electrochemical methods: electrode position, electro coagulation (EC), electro flotation (EF) and electro oxidation.

Chemical oxidation and AOP advanced oxidation process- When leachate contains soluble organic compounds, non-biodegradable or toxic substances which could not be treated by physical and biological methods, chemical oxidation can be used.

Membrane filtration- Membrane filtration is a technique which is used for removal of microorganisms, particulates and natural organic materials from liquid. It provides a physical barrier that can remove solid, viruses, bacteria and other molecules efficiently. The physical barriers are called membrane filters, they are microporous plastic films with specific pore size ratings. There are four types of membrane filtration: reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF). The most worldwide used methods for leachate treatment is biological treatment method. The basic principles for biological removal of nitrogen are nitrification and denitrification. In nitrification process, ammonium turns into nitrite and nitrate in an aerobic environment. And then nitrite and nitrate turns to nitrogen gas in an anaerobic environment. Comparing to artificial technologies, natural systems seem more economic and environmentally friendly for the treatment of landfill leachate. The natural systems mostly use renewable energy and are less polluting to the environment. The natural systems will be introduced are constructed wetlands and leachate recirculation.

Activated sludge- Activated sludge (AS) is common used in landfill leachate treatment. The bacteria in the tank with oxygen added from an active microbial floc called activated sludge. The proper pH for activated sludge is 6.0 – 7.5. leachate is leaded to a basin where it can mix with the activated sludge, after a while, the organic matters in the wastewater is transferred into new microbial biomass, carbon dioxide and water. After that, the mixture passes into a settling tank where sludge will separate from the leachate. A portion of the settled solids is recycled back to the aeration tank and others will run off as surplus sludge.

Trickling filters- The trickling filters have been used for biological nitrogen reduction from landfill leachate.This method has an economic advantage due to the low cost of filter media made by bed rock, slag, or plastic. Trickling filters have an encouraged performance on removing suspended solids, turbidity, biochemical oxygen demand.

Anaerobic filter- Anaerobic filter is a rock-filled bed similar to an aerobic trickling filter. There are upflow anaerobic filters and downflow anaerobic filters. When the leachate influent is charged from the bottom of the anaerobic filters and the flow is upward through the bed rocks, it is called upflow anaerobic filters.

3.3 Bioreactor Landfill Technology

Bioreactor technology accelerates the biological decomposition of food, greenwaste, paper and other organic wastes in a landfill by promoting conditions necessary for the microorganisms that degrade the waste. The single most important factor in promoting waste decomposition is the moisture content of the waste. Liquids must be added to the waste mass to obtain optimal moisture content, which ranges from 35 to 45 percent water by weight. Liquids that are added include: landfill leachate, gas condensate, water, storm water runoff, and wastewater treatment sludges.

4. MFC

A Technology using microbial fuel cell (MFC) that convert the energy stored in chemical bonds in organic compounds to electrical energy achieved through the catalytic reactions by microorganisms has generated considerable interests among academic researchers in Microbial fuel cells (MFCs) are a promising technology for electricity production from a variety of materials Bacteria can be used in MFCs to generate electricity while accomplishing the biodegradation of organic matters. It consists of anode and cathode chambers partitioned by a proton exchange membrane (PEM). Based on the electrode reaction pair above, an MFC bioreactor can generate electricity from the electron flow from the anode to cathode in the external circuit. Theoretically, most microbes can potentially be used as a biocatalyst in MFC.

5. Conclusion

LFG energy projects reduce global methane emissions and local air pollution, and create jobs, revenues, and cost savings. It was concluded that the project is not feasible for energy recovery as methane generation rate is very low. That's why flaring is only the option.from the biogas plant of higher capacity, sufficient amount of electricity can be generated which can be used for various small domestic needs. With modification in the electrode Sdesign. This study compares young and old landfill leachate at various operating modes in terms of power output and pollutants removal. bring together all aspects of gas management considered during the risk assessment and proposed operational controls

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