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The Study on an Alternative Approach to Manage the Kitchen waste being discarded to Landfill

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Abstract: Developing countries generate a huge amount of waste which gets dumped in landfills directly. A major composition of this waste constitutes biodegradable waste. Portable Pyrolysis Plant is a method adopted to reduce the generation of waste right from the household, as it is the primary origin of the same. Biogas is an eco-friendly fuel produced by anaerobic digestion of organic waste, which generally comprises of 55-65 % methane, 35-45 % carbon dioxide, 0.5-1.0 % hydrogen sulphide and traces of water vapours. The objective behind present work is the generation of biogas and bio-oil from kitchen wastes (vegetables and leftover food) that can be used for our daily needs. Bio-oil is produced with kitchen waste comprising of biodegradable substances and discarded plastic covers involving the incineration of the same to recover the product under specific conditions.

Keyword: Kitchen waste; Landfill; Biogas; Biofuel; Pyrolysis; Leachate; Water Table; Waste disposal; Environmental Problem.

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I. INTRODUCTION

This compendium of technologies aims to present an overview of the technologies available for converting waste into a resource. It emphasizes the typical methods for converting kitchen waste into solid, liquid and gaseous fuels as well as the direct combustion of waste for specific applications. Biomass energy, or "Bioenergy", is energy produced from recently living organism's gasification, and biodiesel production. Kitchen waste is organic material having the high calorific value and nutritive value to microbes, that's why the efficiency of methane production can be increased by several orders of magnitude as said earlier. It means higher efficiency and size of the reactor and the cost of biogas production is reduced. Also in most of the cities and places, kitchen waste is disposed in a landfill or discarded which causes the public health hazards and disease like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences: It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease-bearing vectors. Also, it emits unpleasant odour& methane which is a major greenhouse gas contributing to global warming. Anaerobic digestion (AD) is a promising method to treat kitchen wastes. While anaerobic digestion for treatment of animal dung is common in rural parts of developing countries, information on technical and operational feasibilities of the treatment of organic solid waste is limited in those parts. There are many factors affecting the design and performance of anaerobic digestion. Some are related to feedstock characteristics, the design of reactors and operating conditions in real time. Physical and chemical characteristics of the organic wastes are important for designing and operating digesters because they affect the biogas production and process stability during anaerobic digestion. They include moisture content, volatile solids, nutrient contents, particle size, & biodegradability. The biodegradability of a feed is indicated by biogas production or methane yield and percentage of solids (total solids or total volatile solids) that are destroyed in the anaerobic digestion. The biogas or methane yield is measured by the amount of biogas or methane that can be produced per unit of volatile solids contained in the feedstock after subjecting it to anaerobic digestion for a sufficient amount of time under a given temperature which is taken to be laboratory temperature in our case. Anaerobic digestion (AD) is a microbial decomposition of organic matter into methane, carbon dioxide, inorganic nutrients and compost in absence of oxygen. This process is also known as bio-Methanogenesis. In the generalized scheme of the anaerobic digestion, the feedstock is collected, coarsely shredded and placed into a reactor with active inoculums of methanogenic microorganisms. Generally, three main reactions occur during the entire process of the anaerobic digestion to methane: hydrolysis, acid-forming, and methanogenesis. Although AD can be considered to take place in three stages all reactions occur simultaneously and are interdependent. Bioenergy, primarily in the form of heat, has been produced for thousands of years, providing a good precedent to build upon in planning for its use in agriculture. This burning of the biomass or products from it is known as direct combustion. Direct combustion is a comparatively efficient means of using Bioenergy, due to its minimal processing needs, the diversity of feedstock that can be used, relatively simple equipment needs, and a relatively high rate of energy recovery. For most operations, direct combustion is the only practical means of harnessing Bioenergy.

II. BIOGAS

Biogas is produced by bacteria through the biodegradation of organic material under anaerobic conditions. Natural generation of biogas is an important part of the biogeochemical carbon cycle. It can be used both in rural and urban areas.

***Composition of biogas*:** Biogas from sewage digesters usually contains from 55 to 65 % methane, 35 to 45 % carbon dioxide and < 1 % nitrogen, biogas from organic waste digesters usually contains from 60 to 70 % methane, 30 to 40 % carbon dioxide and < 1 % nitrogen, while in landfills methane content is usually from 45 to 55 %, carbon dioxide from 30 to 40 % and nitrogen from 5 to 15 % (Ras *et. al.*, 2007).

Microbiology of the biogas: Efficient production of biogas relies on a complex microbiological process. Controlling the biogas process in an efficient manner to ensure maximum yield requires some advanced knowledge of how microorganisms work and the microbiology underlying the biogas process. Many different organic materials can be decomposed to biogas in a digestion chamber (Gunaseelan 1997).

Characteristics of biogas: The composition of biogas depends upon feed material also. Biogas is about 20% lighter than air has an ignition temperature in the range of 650 to 750^0C. An odourless & colorless gas that burns with blue flame similar to LPG gas. It's caloric value is20 MegaJoules (MJ) /m3 and it usually burns with 60 % efficiency in a conventional biogas stove. This gas is useful as fuel to substitute firewood, cow-dung, petrol, LPG, diesel, & electricity, depending on the nature of the task, and local supply conditions and constraints. Biogas digester systems provide a residue organic waste, after its anaerobic digestion (AD) that has superior nutrient qualities over normal organic fertilizer, as it is in the form of ammonia and can be used as manure. Anaerobic biogas digesters also function as waste disposal systems, particularly for human wastes, and can, therefore, prevent potential sources of environmental contamination and the spread of pathogens and disease-causing bacteria. Biogas technology is particularly valuable in the agricultural residual treatment of animal excreta and kitchen refuse (residuals).

Table 1: The composition of Biogas

Component	Concentration (by volume)
Methane (CH4)	55-60 %
Carbon dioxide (CO2)	35-40 %
Water (H2O)	2-7 %
Hydrogen sulfide (H2S)	20-20,000 ppm (2%)
Ammonia (NH3)	0-0.05 %
Nitrogen (N)	0-2 %
Oxygen (0_2)	0-2%
Hydrogen (H)	0-1%

Properties of biogas:
1. Change in volume as a function of temperature and pressure.
2. Change in calorific value as a function of temperature, pressure and water vapor content.
3. Change in water vapor as a function of temperature and pressure.

III. BIO-OIL

Pyrolysis bio-oil is the liquid produced from the condensation of vapor of a pyrolysis reaction. It has the potential to be used as a fuel oil substitute.

Characteristics of Bio-oil: The bio-oils have heating values of 40%–50% of that of hydrocarbon fuels. The main advantages of pyrolysis liquid fuels are [9,10]:

- CO_2 balance is clearly positive in biofuel
- The possibility of utilization in small-scale power generation systems as well as use in a large power station
- Storability and transportability of liquid fuel
- High-energy density compared to biomass gasification fuel
- Potential of using pyrolysis liquid in existing power plants

Pyrolysis oils; usually referred to as bio-oil or bio-crude; are composed of a complex mixture of oxygenated compounds. Bio-oil contains various chemical functional groups such as carbonyls; carboxyls and phenolics that provide both potentials and challenges for utilization. However; numerous unknown factors are affecting the thermo-physical properties of pyrolysis bio-oil [11,12]. Pyrolysis bio-oils have limitations in fuel quality; phase separation; stability; fouling issues on thermal processing and economic viability of pyrolysis bio-oil. Pyrolysis oil consists of about 300 to 400 compounds [13]. During storage, the pyrolysis oil becomes more viscous due to chemical and physical changes as many reactions continue and volatiles are lost due to aging. Studies found that the reactions and aging effects occur faster at higher temperatures but the effects can be reduced if the pyrolysis oil is stored in a cool place [14,15]. However, the pyrolysis oil yields, quality, and stability can also be modified by process variables such as heating rate, pyrolysis temperature and residence times [16].

Table no 2: Properties of Bio-oil

Properties	Oil Characteristics	Reason
Appearance	Dark red-brown to dark green	Micro-carbon and chemical composition in oil
Odour	Distinctive odor—an acrid smoky smell	Lower molecular weight aldehydes and acids
Density	Very high compared to fossil fuel Pyrolysis bio-oil: 1.2 kg/liter Fossil oil: 0.85 kg/liter	High moisture and heavy molecule contamination
Viscosity	Can vary from as low as 25 centistokes (cSt) to as high as 1000 cSt	A wide range of feedstock, water content and the amount of light ends collected
Heating Value	Significantly lower than fossil oil	High oxygen content
Aging	Viscosity increase, volatility decrease, phase separation and deposition of gum occur with time	Complex structure and high pH value
Miscibility	Miscible with polar solvent but totally immiscible with petroleum fuel	Polar in nature

IV. LEACHATE

Leachate is a liquid which drains from a land region or stockpiled material that contains significantly higher concentrations of undesirable substances obtained from the media it passes through.

The following biological, physical and chemical events occur when solid waste is placed in a sanitary landfill:

- Biological decay of organic materials, either in aerobic or anaerobic with the evolution of gases and liquids.
- Chemical oxidation of waste materials
- Escape of gases from landfills
- Movement of liquid caused by differential heads
- Dissolving and leaching of organic and inorganic by water and leachate moving through the fills.
- Movement of dissolved material by concentration gradients and osmosis

Recycling of leachate water While the term “recycled water” is loosely defined in this paper it only refers to treated leachate wastewater. Water use in agriculture is a common phenomenon in developing countries where more than 80 percent is untreated. Their farmers face various health problems associated with close contact to wastewater and over time, the practice leads to a decrease in land productivity, due to increased soil salinity and loss of cropping options. However, in developed countries like Australia, all the wastewater generated is treated according to the Environment Protection Agency (EPA) standards before it is released into natural water bodies. In such countries like India, there is the potential to use treated wastewater in sectors other than agriculture.

Table 1: Chemical characteristics of the groundwater sample near the perungudi landfill site and their permissible limits as per IS10500 [6].

Characteristic	Units	Sample	Permissible Limit
pH	-	6.17	6.5-8.5
TDS	mg/l	471	500
Hardness	mg/l	699	300
Cadmium	mg/l	0.01	0.01
Chromium	mg/l	0.18	0.05
Copper	mg/l	0.15	0.05
Iron	mg/l	0.28	0.3

(The sample values are an average of 10 groundwater sample results)

From the above table, it clear that the concentration of the heavy metals Cr and Cu in the groundwater samples are beyond the permissible limit. But the survey shows that the leachate sample is percolating from the landfill site to the groundwater and hence affects other subsurface water sources. Due to this penetration of the leachate produced from the landfill site, existing landfill sites get contaminated. This finding indicates the contamination is severe in localities around the dumpsite. This in turn results in long term exposure to Copper and Cadmium which results in health effects like kidney damage and lung cancer.

V. PYROLYSIS TECHNOLOGY

Pyrolysis is the thermal decomposition of materials at elevated temperatures in an inert atmosphere [4]. It involves the change of chemical composition and is irreversible. The word is coined from the Greek-derived elements *pyro* "fire" and *lysis* "separating". Pyrolysis is most commonly used for the treatment of organic materials. It is one of the processes involved in charring wood [5]. In general, pyrolysis of organic substances produces volatile products and leaves a solid residue enriched in carbon, char. Extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization.

Pyrolysis of MSW collected from a waste treatment plant at 300–700°C with a residence time of 1–5 hr at a heating rate of 5°C/min in a Lab scale muffle furnace Char yields decreased from 65.6% to 27.8% as the temperature increased from 300°C to 700°C. The increasing temperature increased aromatization and stability. Low temperatures resulted in higher cation exchange capacity and available nutrients. Residence time influenced hydrophobicity and thermal stability [1].

Pyrolysis of MSW 450–800°C with a residence time of 15 min. CO2 and N2 were used as sweeping gas. In a Lab-scale tubular electrical furnace, Highest char surface area was obtained at 550–600°C. N_2 or CO_2 as inert gas gave comparable results. Moderate temperature favored the char porosity development [2].

Pyrolysis of Poultry litter 300–600°C with reaction time varies from 130 to 372 min in Lab-scale muffle furnace Char yields were 60%, 52%, and 47% at pyrolysis temperatures of 300°C, 400°C, and 500°C, respectively. Organic carbon content and cation exchange capacity of char products decreased with increased temperature, whereas surface area and organic carbon stabilities of char increased with increased temperature [3].

Advantages of pyrolysis process:

- Airlock raw material feeding system with nitrogen purging: to prevent oxygen from entering into the reactor.
- The lower reaction temperature of 350^0C to 475^0 C: Lower operating cost, increased safety, and reduced maintenance
- Step energy recovery system: to ensure energy efficiency of more than 80%.
- Energy self-sufficient machinery: ensures more profits to investor & no of oil, stable can be used to external fuel for heating required during normal operations
- Innovative catalyst combination: to ensure maximum yield reaction process
- Safe and automatic pyrolysis gas handling system: Excess gas run electricity generator or can be supplied to the furnace.
- Effective Scrubbing system: to ensure that emissions are well below limits prescribed by environmental authorities.
- Multiple layers of safety: to prevent machinery damage or health hazards.

VI. THE REVOLUTIONARY

The setup is primarily crafted to be portable so as to make it easier to handle. The setup consists of two chambers.

Chamber I – This is an airtight chamber where waste is fed in dried form and heated in an anaerobic condition with the help of heating coil wounded around it with a pitch equal to 3times the diameter of the coil. The coil heats the chamber at the rate of 12^0C/min. The capacity of the chamber is 7kg of waste with a density of 226kg/m^3 and volume of 0.031m^3 [7]. Chamber II – This chamber is the coolant (water) chamber through which the tube carrying the fumes from the combustion of waste is passed to reduce the temperature thereby producing bio-oil and biogas.

Figure no 1: Household Pyrolysis Unit for kitchen waste

The Catalyst – To speed up the conversion of the fumes to liquid, an external catalyst of Potassium Hydroxide (KOH) is used in the process.

1ST TRIAL:

Biodegradable waste – 5kg
Plastic (Kitchen Disposed) – 0kg
System Runtime – 2hours
Bio Oil – 10 % to 15% of wt
Bio Gas – less than 5% of wt
Calorific Value – 6KWh/m^3

2ND TRIAL:

Biodegradable waste – 4kg
Plastic (Kitchen Disposed) – 0.3kg
System Runtime – 1.5hours
Bio Oil – 15% to18% of wt
Bio Gas – 5% to 7% of wt
Calorific Value – 6KWh/m^3

The above trial helps in deciding the composition of waste that has to be fed into the chamber.

The Capacity of the biogas to replace other fuels listed below [8]:
1 Kg firewood =0.2 m^3 biogas
1 Kg dried cow dung =0.1 m^3 biogas
1 Kg Charcoal =0.5 m^3 biogas
1 Litre Kerosene =2.0 m^3 biogas

VII. CONCLUSION

By utilizing the waste generated from the kitchen, bio gas and the bio oil are collected and also the waste is directly treated which reduces the degradable waste getting discarded by a considerable amount which helps in better management of the waste. Also, the effect of leachate on water table is reduced.

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