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A review - Curbing Plastic pollution using microbes and electricity generation from wastes

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Abstract– **Plastic pollution is globally distributed and its properties of buoyancy, durability and the sorption of toxicants on to plastic has led some researchers to claim that synthetic polymers should be regarded highly hazardous. The most important characteristics of plastics that makes it threat is its non-biodegradable nature and emission of poisonous and oncogenic gases upon combustion. Meal worms are the larvae form of the darkling beetle. They can subsist on a diet of Styrofoam and other forms of polystyrene. This study aims to degrade the plastics using mealworms along with other organic wastes to maximize the production of biogas. A standard protocol was followed for biogas production. Biogas is a mixture containing predominantly methane (50-65% by volume) and carbon dioxide which makes it a valuable fuel. The current study is useful for the production of electricity from plastics to control plastic pollution and to bring reduction in green-house effect and global warming.**

Index Terms— **Plastic pollution, Meal worms, Biogas, Electricity, Global warming.**

I. INTRODUCTION

Plastic, long considered non-biodegradable [1], [2] and one of the biggest contributors to global pollution, might have met its match: The small, brownish, squirmy mealworm. Styrofoam is a plastic made of expandable polystyrene foam (EPS), the lightweight and buoyant plastic that can be used for a myriad of things from thermal insulation to disposable plates & cups, packing material etc. This study focuses on the production of biogas from the amalgamation of domestic wastes like cow-dung, vegetable wastes and biodegradable wastes produced by mealworms eating plastics'. The formidable methane concentration makes biogas a valuable fuel [3]. Methane is the valuable component under the aspect of using biogas fuel. The calorific value of biogas is about 6 kWh/m3. This corresponds to about half a litre of diesel oil which can be utilized directly as a heat source or to produce electricity. Chemical energy in the biogas is converted into mechanical energy, thermal energy and finally electricity [7], [8].

II. IMPACT OF PLASTICS TOWARDS ENVIRONMENT

"One of the most ubiquitous and long-lasting recent changes to the surface of our planet is the accumulation and fragmentation of plastics," wrote David Barnes, a lead author and researcher for the British Antarctic Survey. The report was published in the month July (2009) in a theme issue of Philosophical Transactions of The Royal Society B, a scientific journal [2].

Evidence is mounting that the chemical building blocks that make plastics so versatile are the same components that might harm people and the environment. And its production and disposal contribute to an array of environmental problems, too [2].

- Chemicals added to plastics are absorbed in a tiny quantity by human bodies. Some of these compounds have been found to alter hormones or have other potential human health effects.
- Plastic debris, laced with chemicals and often ingested by marine animals, can injure or poison-wildlife.
- Floating plastic waste, which can survive for thousands of years in water, serves as mini transportation devices for invasive species, disrupting habitats.
- Plastics buried deep in landfills can percolate harmful chemicals that spread into groundwater and contaminate them.
- Around 4 percent of world oil production is used as a feedstock to make plastics, and a similar amount is consumed as energy in the process.

III. CHARACTERISTICS OF MEAL WORMS

Mealworm, the tiny worm, which is the larvae form of the darkling beetle, can subsist on a diet of Styrofoam and other forms of polystyrene, according to Wei-Min Wu, a senior research engineer in the Department of Civil and Environmental Engineering at Stanford. Microorganisms in the mealworms' guts degrades the plastic.

Fig 1. Mealworms munching on Plastics [6]

The paper, published in *Environmental Science and Technology [10] is* the first to provide detailed evidence of bacterial degradation of plastic in an animal's gut. Understanding how bacteria within mealworms carry out this feat could potentially enable new options for safe management of plastic waste. In the lab, 100 mealworms ate between 34 and 39 milligrams of Styrofoam, about the weight of a small pill per day. The worms converted about half of the Styrofoam into carbon dioxide, as they would with any food source. Within 24 hours, they excreted the bulk of the remaining plastic as biodegraded fragments that look similar to tiny rabbit droppings [6]. Mealworms fed a steady diet of Styrofoam were as healthy as those eating a normal diet, and their waste appeared to be safe to use as soil for crops, said Wei-Min Wu. The new research on mealworms is significant, however, because Styrofoam was thought to have been non-biodegradable and more problematic for the environment.

IV. CHARACTERISTICS OF BIOGAS

Biogas is a clean and renewable form of energy that can be used as a substitute for conventional sources of energy such as fossil fuels, oil, etc. which causes ecological–environmental problems and at the same time depleting at a faster rate [4]. Biogas is a mixture containing predominantly methane (50-65% by volume) and carbon dioxide. In a natural setting, high methane concentration is found in swamps and anaerobic sediments serving as a source pool. Wet (40-95%) organic materials with low lignin and cellulose content are generally suitable for anaerobic digestion [3]. Biogas has the potential to replace a substantial level of gaseous fossil fuel. The sludge can be used as a natural fertilizer for plants instead of chemical fertilizer which causes fertility loss to the soil. Production of biogas provides a versatile carrier of renewable energy, as methane can be used for replacement of fossil fuels in both heat and power generation and as a vehicle fuel [3].

V. BIOGAS PRODUCTION FROM COW-DUNG

17kg of cow dung was charged into the digester with 34kg of water in the ratio of 1:2 of waste to water and the slurry was properly stirred. The mixing ratio was determined by the moisture content of the different wastes [9]. The daily ambient and slurry temperatures were measured using thermometer (-10 to 110°C). The pH values were monitored on 3 days' interval to determine the action of methanogens, which utilize the acids, carbon dioxide and hydrogen produced by non-methane producing bacterial using a digital pH meter. The volume of biogas produced was measured by a downward displacement method using a transparent 13L calibrated plastic bucket. The composition of the flammable biogas produced from cow-dung was determined through the use of Orsat apparatus. A locally fabricated biogas burner was used to check the flammability of the gas. Water and waste volumes were measured using a top loading balance (50kg capacity). The plant consists of a fermentation chamber, an inlet and outlet pipe, a gas pipe and a stirrer. The digester was charged and its performance was monitored for 30 days. The organic wastes were allowed to stabilise. Degradation of the wastes by the action of various microbes of different sizes and functions occurs. This leads to the production of biogas achieving anaerobic fermentation. Cow dung has 27.2% content of carbon dioxide and 67.9% content of methane. Cow dung generated total gas volume of 124.3 litres [9].

VI. BIOGAS PRODUCTION FROM COW DUNG AND ORGANIC WASTES

The materials used in this investigation as substrates were cow dung, waste residue from fruits such as: orange, pineapple and vegetables such: spinach, pumpkin, all of which were agricultural waste materials. The waste materials were collected fresh and were sun dried for twenty days and then oven dried at 110^{o}C for 10 hours before use [5]. The dried samples were grounded using wooden pestle and mortar. By using sieving machine in order to obtain powdered samples which were then stored in a separate black polyethylene bags. From the dried samples, slurry was prepared and used for the investigation. 200g of each substrate was taken and mixed with 1.5 litre of water and each transferred into a separate digester [5]. The biogas produced, from the digester was connected to a separate inverted 1000 cm^3 measuring cylinder. The volume of biogas produced from digester was recorded [5].

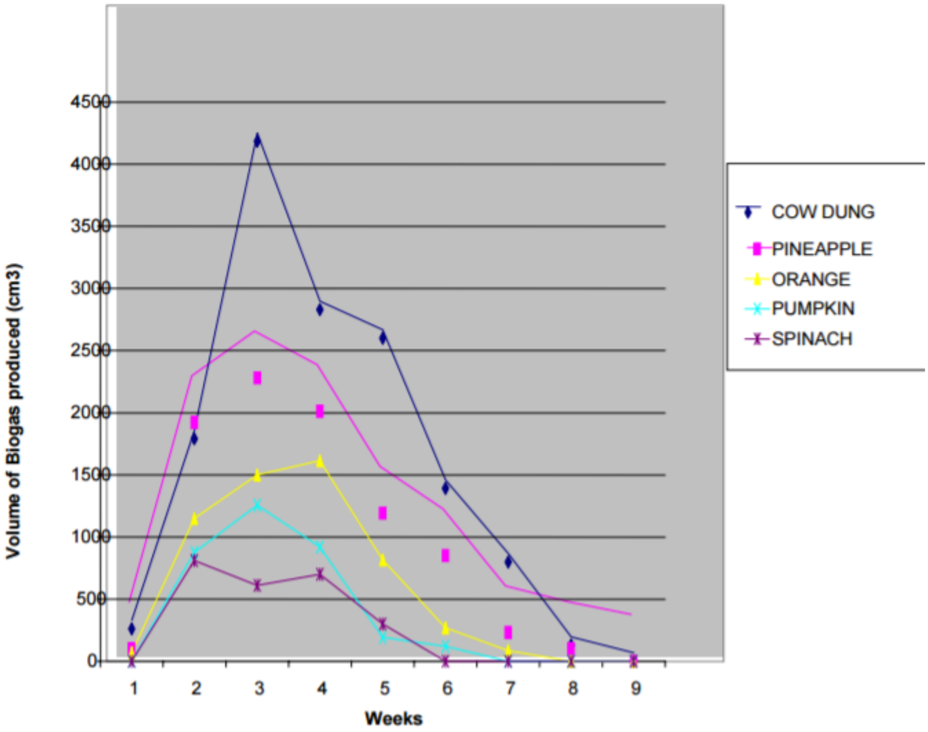

Fig 2. Biogas Production from Cow dung, fruit and vegetable wastes [5]

VII. BIOGAS PRODUCTION FROM ORGANIC WASTES ALONG WITH PLASTICS

From earlier studies it is known that organic wastes were used to produce biogas effectively [5][9]. Vermi-compost is the product of the composting process using various species of worms to create a heterogeneous mixture of decomposing vegetable or food waste. It is also called worm humus. Mealworms has the ability to digest plastics and excrete biodegradable waste [6]. Hence the protocol can be hypothesized by combining methodology from [5] [9]. The substrates used were cow-dung, orange, pineapple and spinach, pumpkin and excreta of the plastic eating mealworms. 200g of each substrate was taken and mixed with 1.5 litre of water and transferred into a digester. The biogas produced, from the digester was connected to an inverted 6000 cm^3 measuring cylinder. The volume of biogas produced from digester was recorded. The composition of the flammable biogas produced from cow-dung can be determined through the use of Orsat apparatus. A locally fabricated biogas burner can be used to check the flammability of the gas.

VIII. ELECTRICITY GENERATION USING BIOGAS IN SMALL SCALE

Biogas is used to generate electricity on a house-hold level. The chemical energy of the combustible gases is converted to mechanical energy in a controlled combustion system by a heat engine. This mechanical energy then activates a generator to produce electrical power [7]. For small-size heat engines, combustion engines are popular as they are more efficient and less expensive than small gas turbines. Gas turbines are found to be more efficient when operating in a cogeneration cycle (i.e. simultaneous production of heat and electricity). Biogas is burned for running a generator (e.g. micro turbine).

Fig 3. Combined heat and power (CHP) unit [7].

The installation is usually less than 5 KWe (Kilowatts-electrical, WRAPAI 2009). Instead of burning fuel to merely heat space or water, some of the energy is converted to electricity in addition to heat. Current Micro- and Mini CHP installations use five different technologies: micro turbines, internal combustion engines, external combustion engines, steam engines and fuel cells. The technology is easily adaptable and can be applied at household or community level. To minimize distribution losses, the reactors should be installed close to the CHP where the gas can be used. Micro cogeneration is a so-called distributed energy resource (DER) useful for a single house or small business because of the low power output [7].

IX. ELECTRICITY GENERATION USING BIOGAS IN LARGE SCALE

Generated electricity from biogas can be used in large scale. The chemical energy of the combustible gases is converted to mechanical energy in a controlled combustion system by a heat engine. This mechanical energy then activates a generator to produce electrical power [8]. Large-scale biogas conversion plants are almost always cogeneration plants (i.e. they produce heat and electricity simultaneously) based on gas turbines (internal combustion engines). The mechanical energy produced in such plants comes always from the pressure related to the change in temperature of a gas. The temperature gap required can lie either in a high temperature range or a low one. The heat from the combustion of the biogas activates a steam turbine, the exhausted steam is condensed and the low temperature heat released from this condensation is utilized for direct heating. Bottoming cycle plants produce high temperature heat for industrial processes. Cogeneration plants are commonly found in district heating systems of big towns, hospitals, prisons, oil refineries, paper mills, wastewater treatment plants and industrial plants with large heating needs. Typical large-scale biogas conversion CHP plants are: Gas turbine generating electricity and using the waste heat; Gas engines using a reciprocating engine; Combined cycle power plants (CCPP) adapted for CHP; Steam turbine CHP plants that use the heating system as the steam condenser for the steam turbine; Molten-carbonate fuel cells have a hot exhaust, very suitable for heating [8].

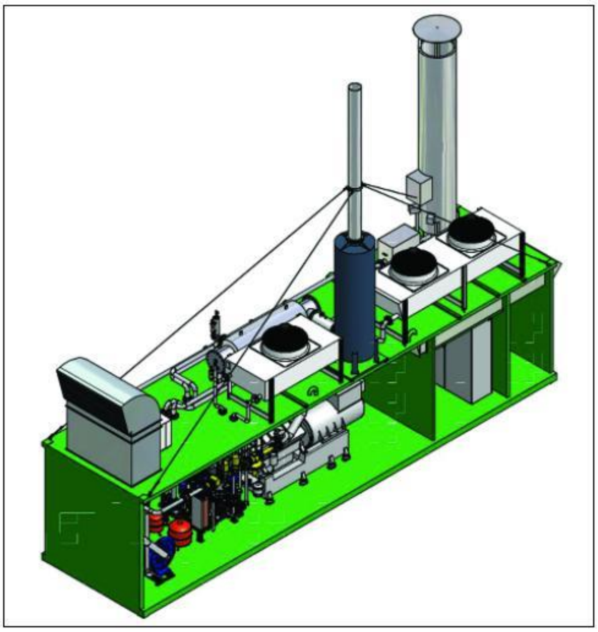

Fig 4. Design-model of a larger-scale biogas cogeneration unit [8].

This technology is easily adaptable and can be applied at community or city level. The electricity generation using biogas in landfills fulfils the electricity requirements of the plant and a surplus of energy can be delivered to the grid. In the agricultural sector, the biogas produced mainly from anaerobic digestion of manure can provide surplus energy depending on the quantity of manure obtained from animals and the technology used to treat their residues.

X. CONCLUSION

Meal worms are found to digest plastics [6] and thereby their excreta can be used along with other organic wastes for biogas production. This will help to reduce plastic pollution and biogas produced can serve as a source of energy which can be used for generating electricity. Biogas system is an environmental friendly way of energy production [7][8]. Biogas from meal worms can serve dual purpose of reducing plastic accumulation, thereby reducing the ill effects caused by plastic pollution to our environment and also serves as a source of generating electricity.

Biogas that has been produced by this method can be used

- ✓ To control plastic pollution.
- ✓ To prevent global warming.
- ✓ To produce electricity (for domestic and commercial purposes).
- ✓ To use as an alternate for fossil fuels.

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