CALCULATION OF THE ELECTRIC POWER POTENTIAL OF HUMAN WASTE USING SOAK-AWAY PITS IN STUDENT HOUSING

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Abstract:-Nigeria's expanding need for electricity has necessitated a review of all available electricity producing methods, particularly renewable ones. It is well known that a significant byproduct of anaerobic digestion of human waste is methane gas, which can be burned to produce power**.** This study gives a clearly stated approach to the process of estimating the amount of power that can be generated from a specific volume of human waste**.** This essay offers a clearly thought-out method for calculating how much electricity may be produced from a given volume of human feces. The Federal University of Technology, Owerri's analysis of data from a student residence pit toilet reveals that the case study area's daily biomass waste availability is 3.66 tonnes, and the bimonthly biogas accruable is 154.76 kg, enough to power a 5 KW biogas generator for six (6) days.

Keywords: Solid Waste, Human Waste, Bio-Gas and Electric Power

INTRODUCTION

Robert Boyle and Stephen Hale, who discovered that combustible gas was released by disturbing the sediment of streams and lakes, first noted the scientific interest in the manufacture of gas created by the natural decomposition of organic materials in the 17th century[Ferguson, 2006]. Sir Humphrey Davy discovered methane in the vapors created by cow manure in 1808 [Cruazon, 2007]. Leper colony in Bombay, India, constructed the first anaerobic digester in 1859. In Exeter, England, a septic tank was utilized to produce gas for the sewage gas destructor lamp, a sort of gas illumination, in 1895. The first dual-purpose tank for both sedimentation and sludge treatment was set up in Hampton, England, in 1904 as well. An early type of digester known as the Imhoff tank received a patent in Germany in 1907.

In the 1930s, anaerobic digestion received academic acceptance as a result of scientific research. The microorganisms that aid in the process, anaerobic bacteria, were discovered as a result of this research Additional study was done to look into the circumstances that whereby methanogenic bacteria could develop and proliferate [Humanic, 2007]. During World War II, there was a rise in the use of anaerobic digestion for the treatment of manure in both Germany and France, which led to the development of this study.

1.0 Biogas production methods

Anaerobic digestion is broken down into four main biological and chemical phases:

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis

Large organic polymers make up the majority of biomass. These chains must be disassembled into their smaller component pieces before the bacteria in anaerobic digesters can access the material's energy potential. Other bacteria can easily access these component elements, or monomers, such as sugars. Hydrolysis is the process of rupturing these chains and putting the smaller molecules in solution. In order to begin anaerobic digestion, it is necessary to hydrolyze these high-molecular-weight polymeric components. Simple sugars, amino acids, and fatty acids are produced from the breakdown of complex chemical compounds. Methanogens can immediately utilize the acetate and hydrogen generated in the early phases.

It is necessary to first catabolize other molecules, such as volatile fatty acids (VFAs) with a chain length longer than that of acetate, into substances that can be utilized directly by methanogens [Boone, Mah, 2006]. Acidogenic (fermentative) bacteria continue to break down the remaining components as a result of the biological process of acidogenesis. VFAs are produced here along with other byproducts such ammonia, carbon dioxide, and hydrogen sulfide. Acidogenesis is a process that resembles how milk spoilsAcetogenesis is the third stage of anaerobic digestion. Here, acetogens continue to break down the simple molecules produced during the acidogenesis phase to primarily produce acetic acid as well as carbon dioxide and hydrogen. Methanogenesis is a natural process that occurs at the end of anaerobic digestion. The intermediate byproducts from the stages before are used by methanogens to produce methane, carbon dioxide, and water in this stage. Most of the biogas released from the system is composed of these elements. According to Martin (2007), methanogenesis takes place between pH 6.5 and pH 8 and is sensitive to both high and low pH. The digestate is made up of the leftover, indigestible material that the microorganisms are unable to utilize and any dead bacterial remnants.

Equation 2.14.$C_6H_{12}O_6 3CO_2+3CH_4$ (1.0) is a generalized, simplified chemical equation for the broad operations described above

1.1 Biomass Energy Production

There is a significant volume of wastewater produced every day by people who live in countries with flush toilets and running water. Organic substances abound in this, and they have chemical bonds that can store useful energy. Engineers can harvest it using a variety of techniques. For instance, they can use microbial fuel cells to generate energy or anaerobic (oxygen-free) digestion to obtain methane. Typically, agricultural waste and animal manure are plentiful in rural regions and may theoretically be converted into a useful energy source. Anaerobic fermentation looks to have the greatest immediate promise for using these materials as fuel sources. Complex organic matter is converted to methane and other gases during this procedure, also known as anaerobic digestion. It has benefits that urge serious attention, including:

1. 1. To reduce the risk to the public health posed by the management and disposal of human and animal wastes, it is the most straightforward and practical treatment approach currently available.; and
2. All the necessary nutrients present in the raw materials are contained in the residue that remains after the gas has been removed, making it a great fertilizer.

Since ancient times, people have been aware that organic material that is rotting in an environment without air will produce a combustible gas. This is especially true of the phenomena known as

gas from the marsh. The "will-o'-the-wisp," or fool's fire, legends are based on the sporadic dancing flames of this gas that occasionally appear at night (perhaps sparked by stray sparks from a nearby fire). We know that in 1895, Exeter, England, used the gas from a "carefully designed" septic tank for street lighting, even though it is unclear when the idea that manure, if left to decay in a sealed pit, would also produce a flammable gas was originally identified [McCabe, Eckenfelder, 1957]. The experience must have been successful enough to encourage others, for, in the 1920s, several devices were built and used in England, specifically for the purpose of generating this gas,' which is primarily methane, the simplest organic compound of carbon and hydrogen. The process has also been utilized where energy supplies have been reduced, as in France, Algeria, and Germany during and after World War II, when methane thus produced was used to run automobiles.

Methane-generating technology has frequently been modified to accommodate rural needs in nations that struggle with low natural abundance or insufficient dispersion of energy resources. In a variety of climates and civilizations, family-sized methane-generating systems have been deployed. Because cow dung was once used as fuel in India, early attempts to create a mechanism to deliver fuel without destroying the dried dung were motivated by worries about the loss of cow dung for fertilizer. At New Delhi's Agricultural Research Institute, these studies were started in 1939. The studies led to the design of a straightforward and user-friendly gas plant where dung is fermented to produce a combustible gas that can be used as fuel and the dung residue may be used as manure, according to an account of this experience. The Khadi and Village Industries Commission encouraged the continuation and expansion of the work in India. The Gobar Gas Research Station was established in Ajitmal, Etawah (Uttar Pradesh), in 1961, and it released a number of gas plant designs in 1971. Many thousands of these plants have been constructed in India over the years since the country's trials initially started, the most of them in rural areas and serving one to several families. With the possible exception of Taiwan, interest in this anaerobic digestion procedure is not as easily documented for other emerging nations as it is for India. There, research in producing working fuel from pig excrement started around 1955 and turned into a government-backed program [Ju-tung, 1965]. According to sources, only half of the 7,500 such devices that have been developed in Taiwan as permanent add-ons to pig-raising operations on small and medium-sized farms are really in use [Chan, 1983]. There are scattered reports of the use of methane generation from waste materials in other countries. Installations have been reported in Uganda [Jefferies, 1964], and Bangladesh [Chan,1983].

A trial project was built on a small farm in Fiji, and a successful demonstration project was run in Port Moresby, Papua New Guinea, as part of studies that have been conducted on South Pacific islands since 1971.

Last but not least, interest in using anaerobic digestion to produce fuel and risk-free "natural" fertilizer for small-scale use in the United States and Western Europe has been rising steadily for a number of years, and numerous pamphlets have appeared that provide more-or-less comprehensive instructions for building digesters [Garg, 2009].

Anaerobic digestion is a well-known process that has been used for many years to recover energy from garbage. But it hasn't just been used on a limited basis. Municipal sewage sludge is treated in large-scale digesters, with the generated gases helping to meet some of the energy requirements of the municipal treatment facility. Commonly referred to as "waste" materials, these include agriculture residues, animal wastes, and urban wastes such night soil. Some of these elements are currently utilized as fuels and/or fertilizers in developing nations. Utilizing these materials to produce methane, as shown in Fig. 1.0, will increase their value while maintaining their prior advantages.

Fig.1.0: Utilization of Biomass as a Fuel.

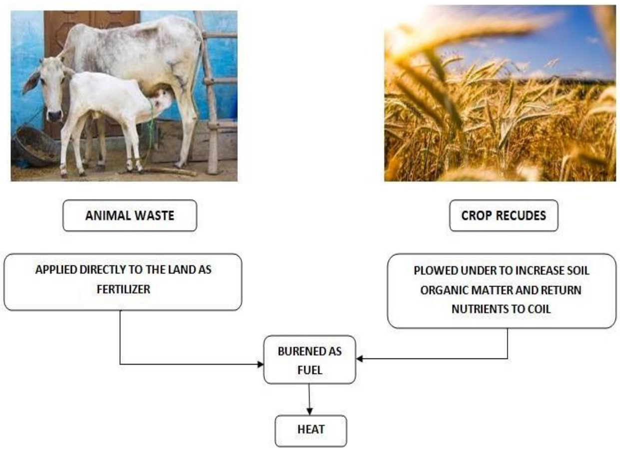

***Fig.2.0: Process of Methane Generation*.**

Since harnessing sewage power could enable water treatment facilities to generate enough electricity to meet all of their own consumption as well as act as a fuel source in developing nations where supplies are currently unreliable, more research has recently been devoted to developing and improving these techniques. The amount of useful energy contained in raw sewage must be known. This was the inquiry put out by the researchers of a study that was printed in the journal Environmental Science & Technology [Mukhopadhyay, 2004]. The lead author of the new study, Elizabeth Heidrich, a PhD candidate at Newcastle University in England, studied microbial fuel cells, which produce electrical current by capturing the electrons released as bacteria break down organic matter in wastewater. Their conclusion was that wastewater likely holds a lot more than was previously believed. To find out how much energy engineers might rely on wastewater to provide, she made the decision as she was drafting her doctoral research project. Heidrich was able to locate just one study that had attempted to address the query; it was published in 2004. The internal chemical energy of the sample was determined by the authors to be 6.3 kilojoules per liter after testing a sample of untreated municipal sewage taken from a Toronto treatment facility using calorimetry (the measurement of heat absorption and emission). Additionally, they examined the sample's Chemical Oxygen Demand (COD), a widely used indirect indicator of dissolved organic molecules. They found a correlation between the sample's COD and the amount of energy it contained. Based on this link, they hypothesized that the 6.8 billion people living in the world in 2004 generated wastewater that contained a steady supply of energy between 70 and 140 gigawatts. Around 1 gigawatt is generated by one sizable nuclear power facility. However, Heidrich points out that the study's findings, which have been extensively referenced in the literature on microbial fuel cells, are questionable. A sample must be dry before it can be analyzed in a calorimeter, and in this case, the authors' sample was dried by putting it in an oven set to 103 degrees Celsius for a whole night. Additionally, losses are anticipated since several organic substances contained in sewage, such as methanol, ethanol, and formic acid, have boiling temperatures lower than 103 degrees. These losses would indicate that not all of the energy present in the sample had been taken into consideration by the authors. Therefore, in a related investigation, the researchers obtained their own samples from two facilities: one that treats domestic, residential wastewater, and the other that treats "mixed" wastewater that also contains chemicals discarded by industrial operations. They tested the samples in a calorimeter after freeze-drying them as opposed to using an oven. The household sample included 7.6 - 20 percent more energy than the last study's domestic sample, according to their findings, while the industrial sample contained roughly 16.8 kilojoules per liter. The fact that the energy content of wastewater samples does not truly correspond with the commonly used COD measurement, making it an unreliable metric, may be even more significant given the considerable variability of wastewater samples. They would have discovered only around half the energy stored in each of their samples if they had relied on the same computation techniques used in the prior study. Therefore, the earlier estimate is probably "substantially underestimated."

Heidrich's approach has several drawbacks of its own. Weeks are required for the freeze-drying process, hence it cannot be used as a regular testing technique. Additionally, some energy molecules are lost despite the technique preserving more organic content than oven drying. Heidrich observes that the findings of the study have direct, practical relevance. Domestic municipal wastewater was formerly thought to be ineffective in producing energy and was not thought to be worth the effort. That idea has since evolved. Many locations have begun using bio wastes due to the escalating global power crisis and rising expense of fuels. Human waste is used to produce electricity in San Antonio, pet waste is used in San Francisco, and pig litter is used on numerous sizable US farms. Because of its success, Suffolk in the UK is now intending to build a human waste factory in Northamptonshire. Suffolk's power plant produces 12.7 MW of energy and uses 125,000 tonnes of poultry litter annually. Additionally, the UN is supporting a project in Bangladesh to generate electricity from poultry waste [Sujata, 2010].

Although all farm wastes can be used efficiently, power from human wastes will be especially important in metropolitan settings. Each day, the 7 billion people in the globe produce over 14 million tonnes of waste, and 25% of this waste has the potential to generate about 40,000 MW of energy. India, which has one-seventh of the world's population, could thereby increase her slowly expanding electricity capacity by about 6,000 MW. Additionally, much of this potential may be swiftly made available because the technology is quite straightforward and affordable. At several of its large prisons, where many thousands of people convicted of genocide are being held, Rwanda has constructed 20 human waste power generating plants, each with a capacity of 500 kW. These now meet nearly half of their electrical needs. Rwanda received the $50,000 cash Ashden Award for Sustainable Energy for this endeavor. It is obvious that more research in this area needs to be done globally if Rwanda is able to do this. The process of producing gas, using that gas, and using the sludge that is left over once fermentation is finished are all included in the biogas system.

Biogas Production and Use

The production of methane during the anaerobic digestion of biologically degradable organic matter depends on the amount and kind of material added to the system. The efficiencyof production of methane depends, to some extent, on the continuous operation of thesystem. As much as 1000m^3 of gas (containing 50-

70 percent methane) can be produced from 1000m^3 of volatile solids added to the digester when the organic matter is highly biodegradable (e.g., night soil or poultry, pig, or beef-cattle faecal matter) for a period of 30 days [Sujata, 2010]. Combustion of about 30litres (1 ft^3) of gas will release an amount of energy equivalent to lighting a 25-watt bulb for about 6 hours [Sujata, 2010].

When the wastes are less biodegradable, the gas production rates often decrease. An crucial factor to take into account in underdeveloped countries be the variations in the volume and quality of waste material generated from diverse sources; for instance, the amount and quality of animal manure are impacted by the nutrition and general health of the animals. The elimination of non-combustible (like carbon dioxide) and corrosive (like hydrogen sulfide) components affects the usage that the gas is put to. Hot-water heating, building heating, room lighting, and domestic cooking are just a few of the numerous potential applications for digester gas. Gas-burning equipment that have been adjusted for its use can utilise gas from a digester. Internal combustion engine conversion to operate on digester gas may be rather straightforward; Consequently, the gas might be utilized to pump water for irrigation. History has revealed that methane is mostly used for lighting and cooking in rural parts of emerging nations where it is produced in significant amounts.

Colorless, combustible, and primarily composed of methane, which makes up 60% of the gas created by the digestion of organic waste, carbon dioxide makes up 40%, and other gases like hydrogen, nitrogen, and hydrogen sulfide make up very minor amounts of the gas. With more than 500 Btu/ft3 (18,676kJ/m3) in calorific value, it is very calorific. Methane is a non-toxic gas that doesn't smell bad by itself; however, the gas will smell bad if the conditions of digestion result in substantial amounts of hydrogen sulfide.

Biogas Resource Assessment:

The quantity and type of material fed to the system affects the system's ability to break down biologically degradable organic materials without producing methane. Methane production efficiency depends on the system running continuously. When highly biodegradable organic matter (such as night soil, animal waste, pig, chicken, or beef feces, or human municipal waste) is introduced to the digester, as much as 1000l of gas (containing 50–70% methane) can be produced from 1000l of volatile solids (1000kg/m3).

Biomass Sources in FUTO

Municipal solid waste (MSW), green leaves, and cow manure all make up the biomass in FUTO. Due to the quantity of students residing in the dormitory, some garbage from people may be produced.

The director of the Estate and Works Department told us that septic tanks are often dug up every two months. The Physical Planning and Development (PP and D) Unit in the Senate building provided the measurements of the septic tanks utilized at the various hostels. This made it possible to determine the waste's volume every two months. The Dean of Student Affairs determined that each pit would cost 50,000 naira to remove. The software needs this value in order to implement the cost analysis cost effectively.

Biogas Resource Calculations

The analysis produced the following findings, which were producing methane through the anaerobic digestion of biomass wastes utilizing human wastes:

A basic gas turbine's fuel consumption is 3415/0.34 = 1000 Btu/kWh, where 0.34 is the plant factor, since 1 kWh equals 3415 Btu.

Methane's net heating value is 21433 Btu per pound. In a simple gas turbine, the methane consumption would be as follows: 10000/21433=0.47pounds/kWh = 0.21kg/kWh 1 mol = 22.4 l/1000 = 1 m3

Methane has a molecular mass of 16g. In light of this, 16/1mol = 714g/m3 and 1000l/m3 1/22.4l

43.2 m3 is the amount of human waste from hostel A.

43.2 m3 is the amount of human waste from hostel B. 43.2 m3 is the amount of human waste from hostel C. 43.2 m3 is the amount of human waste from hostel D.

Human waste volume from hostel E = 43.2 m3 3.75 m3 is the amount of human excrement from the PG hostel.

Total volume = 43.2% x (5) + 3.75 = 219.75 m3

219.75 m3 × 0.714=154.76kg.

Since 70% of biogas may be created from any given quantity of human waste, if 1000 liters of human waste yield 700 liters of biogas, then 219.75 m3 will yield 153.83 m3 of biogas [Martin, 2007]. The amount of energy generated from 154.76 kg of biogas is 154.76 kg / 0.21 kg/kWh = 736,95 kWh. The 5 kW biogas generator that is suggested can run for 736.95/5 = 147.39, 147.39/24h = 6.14, or almost six days.

Human waste weighs 1000 kg per square meter, which is roughly equivalent to the density of water.Human waste weight equals 1000 x 219.75 = 219750kg

The septic tanks in the dormitories are removed every two months, thus the mass each month is 109875kg. The daily mass is 3662.5kg.

The daily amount of available biomass waste, which is reported as 3662.5/1000 or 3.66 tonnes, will fluctuate depending on the number of students present at school.

CONCLUSION

The findings of this study provide strong evidence that human feces can serve as a source of biogas that can be used to generate a useful quantity of electricity. This kind of energy is environmentally favorable because it is a renewable resource. Sludge, which is typically the byproduct of anaerobic digestion, can also be an extremely beneficial source of natural manure. The results of this study offer convincing proof that biogas produced from human waste can be used to produce a significant amount of electricity. Because it comes from a renewable resource, this type of energy is good for the environment. A very useful source of natural manure is sludge, which is often a result of anaerobic digestion.

REFERENCES

[1] Boone, D., Mah, R. (2006) Transitional bacteria in anaerobic digestion of biomass, New York: Mc-Graw Hill, Pp 35.

[2] Chan, L.G. (1983) Waste Utilization in Rural Industrialization, Papua Guinea: University of Papua Guinea.

[3] Chaniotakis, E. (2001), M.Sc. Thesis on Energy Systems and the Environment, Department of Mechanical Engineering University of Strathclyde.

[4] Cruazon, B., History of anaerobic digestion, web.pdx.edu. 2007.

[5] Energy from Human Waste. Retrieved from www.pubs.acs.org/stoken/presspac/presspac/full/10.1021/es103058w

[6] Fergusen, T., Mah, R. (2006) Methanogenic bacteria in anaerobic digestion of Biomass, New York: Mc-Graw, , Pp49.

[7] Garg, A.C., M. A. Idani, T. P. Abraham (2009), Organic Manures, Bulletin No.32, New Delhi: Indian Council of Agricultural Research.

[8] Humanik, F. et al. Anaerobic digestion of animal manure, epa.gov. 2007 Hybrid

Renewable Energy System; Wikipedia, the free encyclopedia.Hydro power, micro hydro power, small hydro turbine. Retrieved from http//www.micro-hydro-power.com

[9] Jefferies, C. et al. (1964). A review of Colonial Research, New York: McGraw, Pp 44- 67.

[10] Jedlicka, D.A., Comments on the Introduction of Methane Generation in Mexico with Emphasis on Diffusion of Back-yard Generators for use by Peasant Farmers, U.S.A.: University of Northern Iowa, 1974.

[11] Ju-tung, Y (1965) Notes on RaisingPigs to gain Wealth, Taipei: Feng Nien She. Kaldellis, J.K. Kondili E, E. and Filios, A. (2006), Sizing a Hybrid Wind Diesel Stand- alone system on the Basis of Minimum LongTerm Electricity Production Cost, Applied Energy, Vol. 83,. Pp. 1384-1403.

[12] Ma, S., H. Yin, D. M. Kline, (2006) Efficient System Design and Sustainable Finance for China's Village Electrification Program, Conference Paper NREL/CP-710 - 39588.

[13] Martin, A.D. (2007) "Understanding Anaerobic Digestion," Presentation to the Environmental Services Association

[14] McCabe, J. Eckenfelder. (1957) Biological Treatment of Sewage and Industrial Wastes, Anaerobic Digestion and Solids-Liquids Seperation, Papers presented at the Conference on Anaerobic Digestion and Solids Handling, Sponsored by Manhattan College, New York:Reinhold Publishing Company.

[15] Mukhopadhyay, K. (2004), Anassessment of a biomass gasification basedPower plant in Sunderbans. Biomass and bioenergy 27(3), pages 253-264.

[16] Sujata, G. (2010) Biogas comes in from the cold, New Scientist Conference, London: Sunita Harrington, Pp14.

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