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REVIEW ARTICLE

Review on Environmental Effect of Biogas Production

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Abstract

In the study of the environmental effect of biogas production, it is essential to identify the main constituents of the biogas with a special interest biogas process system. This paper reviews the formation processes of biogas production. In this paper, the roles of biogas application were discussed to make them more suitable to the environment and human activities. Furthermore, questions related to the disposal and management of wastes which leads to serious environmental and global concerns were addressed. Although these wastes offer abundant resources: large proportions of the wastes are biodegradable materials and can be efficiently used in producing biogas, which can serve as an answer to the greenhouse gas problem but also inappropriate controlling of the wastes will lead to the rise of greenhouse gas in the environment.

Keywords: Biogas, Environment, Waste, Greenhouse gas

Introduction

Biogas production from organic waste dates back to 3000 years ago. Facts have been developed, which shows the usage of biogas in both Assyria in the 10th century and Persia in the 16th century. Although, acceptance of organic waste as a basis of renewable energy was achieved in 1808 by Davy, who recorded the methane produced during the breakdown of live stocks manure. The first physical use of biogas for energy creation occur in 1896 in England when biogas formed from the digestion of sewage sludge was used to fuel street lights. Same as most other renewable energy, interests in anaerobic digestion suffered from the rise in reliance on petroleum. Nevertheless, some developing countries, mostly in Asia, adopted the technology for the small-scale generation of energy and sanitation services (Monnet et al., 2003). Since that time, there has been considerable interest in anaerobic digestion to achieve its waste removal and energy-generating abilities (Philip, 2008).

Biogas is formed in three main stages; hydrolysis, acidification and methanogenesis. The first stage of biogas formation is called hydrolysis which is known as the polymer breakdown stage. The second stage is known as the process of acidification where the acid-producing bacteria change the monomers formed in the first stage to different fermentation products, mostly acids. In the second step of this stage, called acetogenesis, the fermentation products will be converted to acetic acid, which is one of the substrates for the formation of methane. In the third stage, methane-producing bacteria utilize acetate, carbon dioxide and hydrogen to form methane and carbon dioxide. Biogas is becoming a solution to waste generated from the recycling, treatment and management of agriculture, domestic and municipal waste. The process involved in biogas production is anaerobic digestion and it allows organic waste including sewage sludge, manure, and landfill organics to be converted into usable products such as biogas, fertilizer and so on(Thomas et al., 1999). However, in utilizing these resources, there must be an understanding of the environmental concerns related to several anaerobic digestion technologies.

Anaerobic digestion refers to the degradation of organic matter in the absence of oxygen into a methane-rich gas through the complex and synergistic relations of various micro-organisms including hydrolysis, fermentation, acidogenesis, and methanogenesis bacteria (Philip, 2008 and Parawira 2004). The first set of microorganisms produces enzymes, which hydrolyses polysaccharides and proteins in the organic matter to monomers such as glucose and amino acids. The fermentative bacteria change the monomers produced during hydrolysis to organic acids, mostly acetic acid. The acidogenic bacteria change the acids to hydrogen, carbon dioxide, and acetate, which the methanogens utilize to produce methane and carbon dioxide (Philip, 2008 and Verma, 2002).

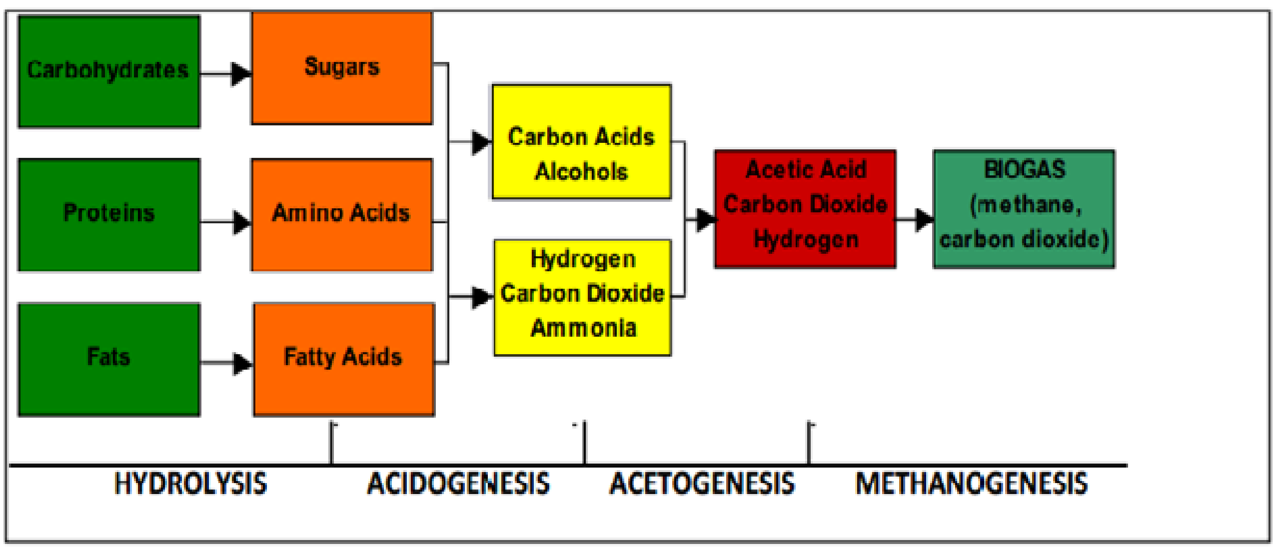

Figure 1: A typical anaerobic digestion process (Moriarty, 2013)

The role of renewable energy: Biogas technology (Anaerobic Digestion)

Improvement of renewable energy technologies, particularly biogas processing technology can help lessen reliance on non-renewable resources and curtail the social and environmental degradation problems related to fossil fuel (Amigun et al., 2008).

Renewable energy makes available the much desired sustainable rural regeneration in many countries that are still developing. It is a perfect substitute or alternative energy due to its less expensive option for low-income communities. An ideal renewable energy that is locally accessible, cheap and can be easily managed by local communities. Anaerobic digestion offers the practical option of producing modern energy resources utilizing readily available materials such as cow dung, domestic, municipal and agricultural wastes. Anaerobic digestion of huge amounts of municipal and agricultural waste in Africa can produce biogas that can be used for electricity generation and the digestate can be recycled as organic fertilizer. Anaerobic digestion processing systems are moderately simple and cost-effective (Von Blottnitz et al., 2007)

Materials and Methods

Composition of biogas

Biogas consists of a mix of methane (40-70 vol %), carbon dioxide (30-60 vol %) and trace components (1-5 vol %) like hydrogen (0-1 vol %) and hydrogen sulphide (0-3 vol %). The pressure, temperature, moisture content and composition of raw materials are determinants of the characteristic properties of biogas (Kossmann et al., 19990.

Methane

Methane (CH_4) gas contains one carbon and four hydrogen atoms and is the essential component of biogas. Methane is an odourless and colourless gas that is generated for thousands or millions of years ago. Putrefied plant and animal matter trapped deep underneath bedrock is changed into petroleum products by extreme pressure and heat. Without the presence of oxygen, methanogenic bacteria are accountable for converting organic materials into methane, which is similar to the processes that occur in anaerobic digestion. Anaerobic digestion process yields between 50-60% CH_4 for dairy manure wastes (Pellerin et al., 1987). The higher the content of methane in biogas, the higher the heat content.

Carbon Dioxide

Carbon dioxide is a gas comprising of one carbon and two oxygen atoms. Like methane, it is both odorless and colorless. Carbon dioxide is produced by the combustion of organic matter in the presence of oxygen or by microbial fermentation and plant respiration. In biogas, Carbon dioxide is produced when methanogenic bacteria degrade simple organic compounds through the fermentation process. The two main components of biogas are methane and Carbon dioxide. High amounts of Carbon dioxide suggest poor methane content and therefore a lower energy value.

Trace Components

The trace components make up about 2% or less of the biogas. The common trace components of anaerobically digested biogas include hydrogen, hydrogen sulfide (H_2S), and water vapour. Based on biogas use, it is important to ensure the removal of most trace components from the biogas. The presence of water vapor in biogas most is hazardous because it is highly corrosive when combined with acidic components such as hydrogen sulfide (H_2S) and to a lesser extent, when reacted with carbon dioxide (CO_2).

The major contaminant in biogas is H_2S, which is poisonous, pungent smell, corrosive and can cause damage such as corrosion to piping and equipment. In combustion, H_2S in the gas is also be released as sulphur dioxide, causing pollution to the atmosphere. During anaerobic digestion, biogas containing more than 6% H_2S can limit methanogenesis bacteria (Chynoweth et al., 1987) A wide range of applications are common for biogas, like other fuel gas for use in the household and industry. Some common applications include gas cookers, engines, incubators, and biogas lamps (Kossmann et al., 1999).

Green-house Gas and Effects

Greenhouse Gases refer to some particular gases present in the atmospheric layer which trap the heat that is attempting to escape back into space (Karl et al., 2003). The four main greenhouse gases, which cause adverse concern, are carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. Among these, carbon dioxide is the most vital greenhouse gas, ozone and sulphur dioxide also cause global warming. Hence, if there is an increase in the amount of these gases in the atmospheric layer, it is expected that large quantities of heat emitted by the surface of the earth will get trapped within the atmospheric layer. The greenhouse effect can therefore be defined as the continuous warming up of the earth's surface due to the blanketing effect of some gases (Supriya, 2005).

Generally, human beings are accountable for greenhouse gases released to the earth. Greenhouse gases production is basically due to fossil fuel burning such as petroleum, coal and so on and this has added up to the Green-house Effect process which occurs naturally and therefore is known as the Man-Made Greenhouse Effect. Also, fossil fuels burning elevate the level of carbon dioxide, causing about 76% of all the greenhouse gases in the atmosphere (Desideri et al., 2003). Methane gas is present in about 13% of the greenhouse gases in the atmosphere, ton of about 500 tons of methane annually is added to the air through the mining of coal, oil drilling and landfill emissions (Karl et al., 2003). Most greenhouse gases stay in the atmosphere for a very long time, however, methane stays for only 10 years and it traps heat 20 times more than carbon dioxide, methane is a strong greenhouse gas. Therefore, methane gas should be trapped/compressed and be used as an alternate source of energy.

Nitrous oxide concentration in the atmosphere is at an increase of 0.2 to 0.3% annually, causes of this increase include land-use conversion, biomass burning, combustion of fossil fuel and soil fertilization, likewise, using nitrates and ammonium fertilizers to enrich plant growth is another cause of nitrous oxide. Nitrous oxide makes up approximately 6% of the greenhouse gases in the atmosphere (Supriya, 2005). According to (Thomas et al., 1999), the increase of greenhouse gases causes a rise in the temperature of earth.

The most abundant greenhouse gas in earth's atmosphere includes Methane (CH_4), Carbon dioxide (CO_2), Nitrous oxide (N_20), Chlorofluorocarbons (CFCs) and Ozone (O_3).

Emission of Green House Gases

CH_4 emissions

Methane emission arises from the degradation of organic wastes in agriculture, municipal solid waste, landfills and the raising of livestock. Methane emissions from livestock keeping were evaluated concerning animal type, performance and feeding.

N_2O emission

N_2O emissions are assessed during agriculture and industrial activities, as well as during waste and fossil fuels burning. It was expected, although very simplified, that 1.25% nitrogen supplied to the soils by organic and mineral fertilization, N_2 fixation and N deposition is emitted in N_20–N form. Otherwise, a N_20–N emission factor of 2.53% of the overall N input as obtained in several measurements at the experimental farm was applied.

CO_2 emission

Carbon dioxide arises in the atmosphere through the burning of fossil fuels, solid waste, trees and wood products, and also as a result of some chemical reactions, for example, manufacture of cement. Removing carbon dioxide from the atmosphere is achieved when plants absorbed it as part of the biological carbon cycle.

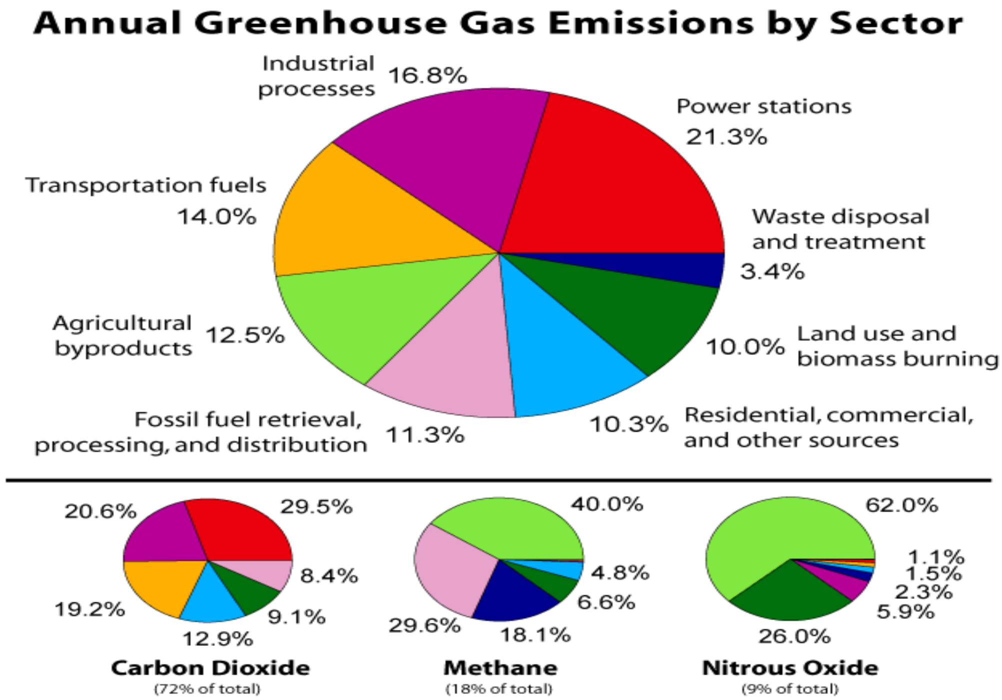

Figure 2. Emission of greenhouse gases (Pooja et al., 2015)

Causes of Green-House Effect

Deforestation

Deforestation is one of the man-made sources of the Greenhouse effect. It increases the extent of carbon dioxide in the atmosphere. Likewise, as a result of cutting down trees, photosynthesis cannot occur. Deforestation is widespread today due to the increase in the human population. There has been a rise in the levels of deforestation by about nine 9% in recent years. Similarly, wood-burning causes it to decay and this allows for the release of carbon dioxide into the atmosphere.

Industrial Emission

The burning of fossil fuels, coal and gas to run the factories has led to the hazardous rise of carbon dioxide and methane which has a radical impact on the global environment and also contributes to global warming. With this, industries can act as a main cause of the Greenhouse Effect. The manufacturing of goods also leads to a rise in the amount of greenhouse gases.

Electrical Emission

The emission of gases from electrical appliances is another man-made cause of the Greenhouse effect. Refrigerator in the house releases greenhouse gas which is known as chlorofluorocarbons (CFCs) and it contributes to the greenhouse effect.

Fuel Burning

Further man-made processes that contribute to the Greenhouse effect are the burning of gasoline, oil and coal. Apart from these, some farming practices also cause of Greenhouse effect. Likewise, Emissions from automobiles increase the amount of carbon dioxide in the environment similarly are other gases like carbon monoxide and sulphur dioxide emitted from vehicle exhaust pipes.

These gases contribute towards pollution of air, which causes the addition of greenhouse gases in the atmosphere.

Population

Population growth is an indirect contributor to the Greenhouse effect. As the population increases, the needs and wants of the people increases. Hence, this increases the manufacturing processes together with industrial processes, this result in the increase of the release of industrial gases which catalyzed the greenhouse effect. Also rise in agricultural practices is due to increased population.

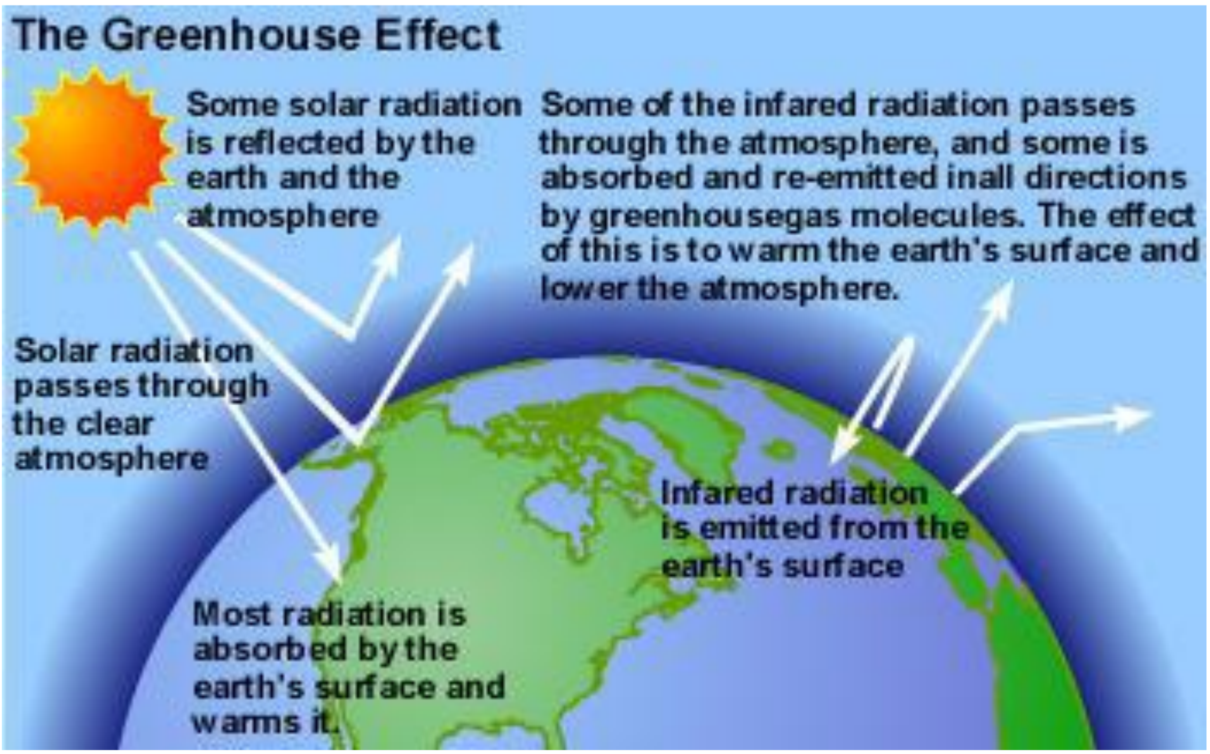

Figure 3: The Greenhouse Effect (Pooja et al., 2015)

Results and Discussion

Environmental Impacts Assessment of Biogas

Review on the environmental impact of biogas

The energy demand must be managed to cope with both energy and environmental problems as well. Energy production from renewable sources is one of the main issues to reduce environmental damage and greenhouse gas emissions (Karapidakis et al., 2010). The use of biogas as a source of fuel is eco-friendly because it contributes to a reduction of fossil fuel use and mitigates the greenhouse effect. In particular, the emissions of CH_4, one of the two greenhouse gases emitted, which is almost 21 times more dangerous than carbon dioxide for the greenhouse effect (Desideri et al., 2003).

With the use of biogas instead of fossil fuel, emissions of CO_2 and other greenhouse gases are declined, as a result, the greenhouse gas emission decreases 75% with the use of biogas in houses and cars (Cleugh, 2011). Methane is an important component of biogas and reducing the loss of methane from the biogas system will decrease greenhouse gas emissions. Eryasar, (Eryasar, 2007) reported that if organic matter are not used in the production of biogas, they become pathogenic and harmful to humans and the environment, biogas system provides a considerable reduction of environmental pollution that arises due to those waste. Biogas systems have two important impacts in terms of the greenhouse gas effect. First of all, biogas reduces methane emissions that occur during the storage of animal waste, Secondly, conversion of biogas reduces carbon dioxide emissions that will be caused by fossil fuels (Yilmaz, 2009). Analysis shows that if biogas is used for heating as a substitute for fossil fuel, emissions of greenhouse gas decrease around 75-90%, if it is used instead of combined heat and power, emissions of greenhouse gas decrease around 60-90%. If it is used as an alternative to gasoline and diesel for vehicles, emissions of greenhouse gas decrease around 50-85%.

Potential impacts of biogas on the environment

According to (Eryasar, 2007), potential impacts of biogas can be grouped under four categories as follows;

Fertilizer related impacts

Digestate of anaerobic digestion can be used as organic fertilizer. Nitrogen which is found in the digestate is mainly in ammonium form. And ammonium form is more appropriate for the development of plants, thus the use of commercial fertilizers is reduced.

Health-related impacts

People who live in rural areas use wood and plant waste for burning and this causes a variety of respiratory diseases, use of biogas anaerobic system eradicates these problems. In addition, flies that live on waste, and diseases threaten the health of people living in this area. Using anaerobic digestion, waste is disposed of most of the pathogens and parasites, with this, pathogen removal is around 90%, thus reduction occurs in health care expenses. (Stefan et al., 1999) enquired that biogas process technology does not attract flies or other insects, the vectors for contagious diseases for humans and animals are reduced. Likewise, eye infections and respiratory problems, attributed to soot and smoke from the burning of dried cow dung and firewood are mitigated.

Development related impact

Biogas system provides the improvement of rural living standards, as a result, rural to urban migration is reduced. Biogas for lighting can lead to changes in the way families integrate with the cultural and educational sectors. The use of biogas for lighting makes it possible to engage in activities at night such as reading or attending evening courses (Thomas et al., 1999).

Economic and Nutrition-related impacts

Biogas technology helps in increase savings and income; it reduces dependence on energy and expensive fertilizer. The accessibility of a well-functioning biogas plant in the household can have positive effects on the nutritious pattern. With easy access to energy, food like grain and beans can be cooked for long period, which aids digestion especially in children. Water may be boiled more regularly, thus reducing waterborne diseases (Stefan et al., 1999).

Furthermore, (Kossmann et al., 1999) also attribute the following as potential impacts of biogas on the environment,

Firewood consumption and soil erosion

An exceptional feature of biogas technology is that it simultaneously reduces the need for firewood and improves soil fertilization, thus substantially reducing the hazard of soil erosion. Consumption of firewood in rural areas is one of the major factors causing deforestation.

In years past, the consumption of firewood has steadily increased and will continue to do so as the population increases unless adequate alternative sources of energy are developed. In many developing countries such as India, the gathering of firewood is a form of wasteful exploitation. Soil erosion is due to increasing wood consumption caused by deforestation. This goes hand in hand with overgrazing which can cause severe damage to soils.

Soil protection and reforestation

The widespread production and application of biogas are expected to make an extensive contribution to soil protection and amelioration. Firstly, biogas replaces firewood as a source of energy, secondly, biogas technology yield more and improved fertilizer. As a result, more feed becomes obtainable for animals. This in turn, can minimize the danger of soil erosion attributable to overgrazing.

Effects of Green House Gas on Environment

The increased greenhouse gases have enhanced the natural greenhouse effect, contributing to global warming (Karl et al., 2003). Global warming happens to be the main effect of greenhouse gas emissions. Greenhouse gases help trap heat in the earth's atmosphere as a part of the greenhouse effect. However, human activities primarily the burning of fossil fuels and deforestation, have intensified the greenhouse effect, causing global warming (Le treut et al., 2007).

Global Warming

An increase in greenhouse gas concentration causes a reduction in outgoing infrared radiation, thus the earth's climate must change somehow to restore the balance between incoming and outgoing radiation. This climatic change will include global warming of the earth's surface and the lower atmosphere as warming up is the simplest way for the climate to get rid of the additional energy. Although, a small temperature rise will encourage many other changes, for instance, cloud cover and wind patterns. Some of these changes may act to improve the warming, others to counteract it.

Sea Level Rise

With the occurrence of global warming, the sea level will rise due to two different processes. Firstly, sea-level rise due to the thermal expansion of seawater caused by the warmer temperature. Secondly, the sea level will rise as a result of the addition of water from melting glaciers and the ice sheets of Greenland and Antarctica.

Ocean Acidification

Increases in carbon dioxide levels have made the world's oceans 30% more acidic since the Industrial Revolution (Bernstein et al., 2008). The ocean serves as a sink for this gas and absorbs about a quarter of human carbon dioxide emissions, which then goes on to react with seawater to form carbonic acid (Le Quéré, 2012). So rise in the level of carbon dioxide in the atmosphere will increase the acidification of the oceans.

Changes to plant growth and nutrition levels
Subsequently, carbon dioxide is needed for plants to grow, if high amounts of it are present in the air, it increases plant growth. Experiments show that where carbon dioxide concentrations were raised by around 50% increased crop growth by around 15% (Cleugh, 2011). Higher levels of carbon dioxide make carbon more available, but plants also need other nutrients like nitrogen, phosphorus, to grow and survive, less of these nutrients as well will cause the nutritional quality of many plants to decrease. In different experiments with elevated carbon dioxide levels, protein concentrations in wheat, rice, barley, and potato tubers, decreased by 5-14% (Taub et al., 2008).
Smog and ozone pollution
Over the last century, global background ozone concentrations have become 2 times larger due to increases in methane and nitrogen oxides caused by human emissions (West, 2006). At ground level, ozone is an air pollutant, which is a major component of smog that is unsafe to both humans and plants. Long-term exposure to ozone reduces life expectancy. Recent studies estimate that the global yields of staple crops, like soybean, maize, and wheat, are being reduced by 2-15% due to present-day ozone exposure (Avnery et al, 2013).

Ozone layer depletion
Nitrous oxide damages the ozone layer and is now the most important ozone-depleting substance and the largest cause of ozone layer depletion [28]. This is because many other gases that are harmful to the ozone layer including CFCs were banned by the Montreal Protocol (MP) and this has reduced their atmospheric concentration. However nitrous oxide was not restricted by the MP, thus as the levels of other ozone-depleting substances are decreasing, nitrous oxide levels continue to grow.

Potential effects on human life
Economic Effect
Almost half of the human population lives within 100 kilometers of the sea. Although most of this population lives in urban areas which serve as seaports, so, therefore, a measurable rise in sea level will have an economic effect on low-lying coastal areas and islands. For example, an increase in the beach erosion rates along coastlines, rising sea level displacing fresh groundwater.

Effects on Aquatic systems
The fish population most especially shellfish reduces due to the loss of coastal wetlands. Likewise, the increase of salinity in estuaries can decrease the abundance of freshwater species but could increase the presence of marine species.

Effects on Hydrological Cycle
Global precipitation is likely to increase. However, rainfall patterns will likely change. Some regions may experience more rainfall, while others may experience less. Furthermore, higher temperatures would probably increase evaporation.

Review On Greenhouse Gas Emissions from Manure Management Systems
This highlights what has been written about greenhouse gas emissions associated with manure management systems and biogas production plants in reducing manure-related emissions**.** In many countries, large livestock populations serve as an important source of greenhouse gas

emissions. Greenhouse gas emissions can result from livestock manure management (Jun, 2011). Manure management as related to livestock is defined as the collection, storage and disposal of livestock manure in an anaerobic digester. These manure management systems provide an anaerobic environment in which livestock manure decomposes and produces significant amounts of greenhouse gas, mainly methane (Petersen et al., 2005).

The important factors affecting the formation of methane from livestock manure is the amount of manure produced, manure composition, which in turn depends on the composition and digestibility of the livestock intake, the manure management system (Zeeman et al., 1999).

Biogas Plants in Reducing Manure Related GHG Emissions

There is a cost-effective and affordable technology that can reduce emissions from manure by recovering methane and using it as an energy source. This technology is referred to as anaerobic digester, decompose manure in a controlled environment and recover methane produced from the manure. Anaerobic digesters are designed to capture the methane produced from manure through anaerobic decomposition.

Reducing greenhouse gas emissions in a biogas plant system is achieved through capturing and burning of the biogas that is generated, preventing the release of the gas into the atmosphere (Bracmort, 2010). The methane burned can provide heat and other forms of energy. When the methane is burned to produce energy, the greenhouse gas emissions are reduced to only the carbon dioxide component in the biogas, which was already in the organic material at growth, and which has a global warming potential of 95% lower than that of Methane. According to U.N, the measure of how much a given mass of greenhouse gas is estimated to contribute to global warming is global warming potential. The dairy-waste management system at the farm incorporated an anaerobic digestion system that produced biogas, electricity and heat through the use of a combined heat and power unit. The analysis compared the greenhouse gas emissions and global warming potential associated with the anaerobic digestion system and a reference system without anaerobic digestion. This analysis indicates that by avoiding decomposition of the manure in open storage ponds, the anaerobic digestion system significantly reduces greenhouse gas emissions.

Conclusion

This study has shown biogas activities related to power generation, energy consumption and its associated emissions has the potential to influence greenhouse gas which is the main source of imminent global warming. Undoubtedly, biogas technology is the solution to reduce greenhouse gas emissions and improve the livelihoods, particularly of the rural communities, by addressing the energy challenges of the rural communities.

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