wjert, 2017, Vol. 3, Issue 5, 449-459. Review Article ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 4.326

SUSTAINABLE TREATMENT OF MUNICIPAL SOLID WASTE WITH PLASMA GASIFICATION AS AN OPTION IN GHANA

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Article Received on 28/07/2017 **Article Revised on 18/08/2017** **Article Accepted on 08/09/2017**

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ABSTRACT

Everybody generates waste and some attempt to manage what they generated. However, the local authorities have the most responsibility to manage the generated waste within its community. Most authorities somehow utilises some available technologies in their attempt to manage the municipal solid waste. Most of these methods in Ghana, including open burning, land filling, incineration, composting and recycling, are either not sustainable or employed unsustainably. With The current methods, management of these solid wastes is also increasingly becoming a problem. One of the sustainable methods of waste treatment that can result in sustainable waste management is the plasma gasification technology. The technology takes electrical energy as an input source. This is, however, recoverable if coupled with marching generation system. Plasma Gasification is advantageous since it allows for the disintegration of waste with energy recovery and without the air pollution that is characteristic of other thermal methods. The technology when apply in Ghana will produce a net energy of 35.88 MW and 27.60 MW respectively in Accra and Kumasi. Sorting is also unnecessary since the technology does not discriminate between materials.

KEYWORDS: Sustainable waste treatment; Plasma gasification; Municipal Solid Waste; waste-to-energy.

INTRODUCTION

Waste is considered generally as a material or matter that is no longer useful and should be put away. These wastes are generated out of the activities of humans in all spheres of life. As such waste generation is part of human alive and posed a lot of challenge managing such. Waste could be in any state of matter; solid, liquid or gas. Most generated wastes within residential community are solid and liquid waste which are generated by each individual on daily basis. Each individual is naturally conscious of removing his or her generated waste around his or her immediate environment. However, within a community, it is difficult for individual to handle, as such community authorities take responsibility in waste management. Within each community, the management of solid and liquid waste pose different challenges. This paper presents a method of sustainable treatment of municipal solid waste that can lead to total waste management in Ghana.

A solid waste management (SWM) system includes the generation of waste, storage, collection, transportation, processing and final disposal. Waste collection in most parts of the world is centralized and all kinds of waste generated by a household or institution are collected together as mixed wastes or are sorted at source. Solid waste management starts with the collection of solid wastes and ends with their disposal and/or beneficial use. Managing municipal solid waste sustainably is always a challenge to municipal authorities around the globe. In most developed nations, systems have been developed over the years that led to a better system of waste management. In developing nations, among which is Ghana, waste management is still a big challenge to the authorities. A number of waste collection companies are usually engaged by municipal authorities of large cities in Ghana. These companies seems to be doing well but most time waste are seen in the cities making the environment unkept. Apparently, it turns out that collection companies all have common issue at hand. One of the major components of waste management is the final disposal or treatment of the waste. This stage has been a big challenge to most if not all municipalities in Ghana and it is the common issue that all the collection companies face.

Waste Generation in Ghana

In Ghana, about 3 million tonnes of solid waste is generated annually with an average of 0.45 kg per capita. Accra, the capital city and Kumasi the second largest city, combine to generate about 3,000 tonnes of solid waste daily. Boateng and Nkrumah (2006) have further indicated that, solid waste generated daily in Accra was between 1500-1800 tonnes. Also, according to

Anomanyo (2004) about 1800 tonnes of municipal solid wastes were generated per day in the Accra Metropolis and the average waste generated per capita per day was estimated at 0.5 tonnes while Miezah et al (2015) gave the per capita per day generation as 0.47. He attributed this to the rate of population growth in the Metropolis which stood at 3.5 percent.Waste from domestic sources include, food waste, garden waste, sweepings, ash, packaging materials, textiles and electric and electronic waste with organic waste being the major component (about 65 to 70 per cent). According to Anomanyo (2004), the high proportion of food and plant waste was due to the fact that Ghana's economy largely depended on agricultural products for export and domestic consumption. According to Miezah et al (2015) Waste composition was 61% organics, 14% plastics, 6% inert, 5% miscellaneous, 5% paper, 3% metals, 3% glass, 1% leather and rubber, and 1% textiles. From the second largest city, Kumasi, the Kumasi Metropolitan Authority report indicated that the current domestic waste generation in Kumasi rate was approximately between 1000-1500 tonnes a day (KMA, 2009). This was based on the projected population of 1,610,867. According to Ketibuah et al (2010), in Kumasi the bulk of household waste is found to be organic waste which includes food waste and putrescible waste.

Properties of municipal solid waste generated are mostly dependent on the kind of generating community. In Ghana, MSW composition varied with kind of locality. Moisture content of MSW within Accra is estimated by Carboo and Fobil (2006) as ranges between 39.8 to 62.2% depending on the locality. According to Fobil et al (2005), MSW in a typical low-income community is wet with calorific values between 14 MJ/kg and 20 MJ/kg and an average energy recovery efficiency of about 40%.

Sustainable Waste Management

Doing things in a sustainable manner is highly appreciated in most sectors. As such, in waste management it is prudent to pursue sustainability. 'Sustainable' can be said as being capable and of being continued with minimal long-term effect on the environment with any activity or action. The environment is paramount in the issues of sustainability. By definition sustainable waste management is *"Using material resources efficiently to cut down on the amount of waste produced. And, where waste is generated, dealing with it in a way that actively contributes to the economic, social and environmental goals of sustainable development"* (ISWA, 2013). Sustainability implies responsible and proactive decision-making and innovation that minimizes negative impact and maintains balance between ecological

resilience, economic prosperity, political justice and cultural vibrancy to ensure a desirable planet for all species now and in the future.

Morelli, John (2011) defines environmental sustainability as meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them. This implies that any activity or action that is being implemented within an environment should be such that it better the condition of the environment or at woes remain as it was. Any action that turns to degrade the environment can be said to be environmentally unsustainable.

The possibility of a sustainable solid waste management is an idea commonly used by scientific authors. Focus is however sometimes limited to the choice of treatment processes, such as recycling and energy recovery (Troschinetz & Mihelcic, 2009; Daskalopoulos, et al., 1998). Such a limitation has a tendency to omit important social aspects. The general requisite of a development that meets the present needs without compromising the future needs, therefore apply. Furthermore sustainable solid waste management should meet the necessary demands of social development, economic development and the environmental protection.

In effect, waste management is expected to minimise any negative effect on the environment. The desire of any community is to have a clean or waste free environment as long as the community exist. However, this desire has eluded most, if not all communities in developing countries like Ghana.

Current practises of waste treatment in Ghana

Waste management involve a number of processes. The process starts with collection and end with disposal or treatment. The Solid waste management has actually over the years been an albatross around the neck of city authorities in Ghana. And it is more so in larger cities, particularly Accra and Kumasi, where over 3,000 tons of solid waste is generated daily.

Consequently, heaps of solid wastes are not uncommon sights in the cities mostly near market centres and low income areas. This situation presents a host of problems as these huge piles of waste pose grave risks to human life and the environment as well. Apparently, it is not that authorities have no plan at all in handling the waste situation. The authorities are really employing various methods in the waste management process but the methods seem to

be unsustainable. Over the years, there were some periods when effective waste management is seen to be on going at various places but mostly for short time. The problem appears to be at the final treatment or disposal point. The major final disposal method is landfill sight.

Apparently when a sight get filled-up, locating a new one become a problem as nearby communities almost always opposed to it. Major common issue is that most collection companies are not always sure of where to and how to dispose the waste eventually.

The methods currently employed include land fill, incineration, composting and open burning. The predominant method is the landfill which is mostly not engineered.

Landfill Disposal

A landfill site is a site for the disposal of waste materials by burial and is the oldest form of waste disposal. The method has some advantages that include: a specific location for disposal that can be monitored; the space can be reclaimed, built on or used as parks or farming land; well-engineered landfills can capture the natural gas (methane) produced by the decomposing material underground and properly managed landfills can minimize and or capture the leachate produced by the decomposing material underground. The method has some disadvantages as well including: the surrounding areas are often heavily polluted; the system can pollute water, air, and also the soil in and around the sight; It is difficult to keep dangerous chemicals from leaching out into the surrounding land; Dangerous chemicals can spread into the water table or into waterways; the landfill can attract animals and insects such as raccoons, rats, mosquitoes, cockroaches, and seagulls; it can also be the cause of sicknesses, illnesses, and diseases which might spread in communities; globally, landfill can increase the chances of global warming by releasing methane, a dangerous greenhouse gas. With these many and dangerous disadvantage, the method can be said to be unsustainable. In some communities, there have been outcry and demonstration against some disposal sites.

Incineration Treatment Method

Incineration of waste is also carried on in Ghana but it is limited to institutions and small communities. It is not employed in large scale. Incineration is a thermal treatment of waste materials. The system converts the waste material into ash and flue gas. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas. The method has some advantages including: use of small space, and the heat produced by burning solid waste can be used to generate electricity. The

disadvantages of the process include: a number of outputs such as the ash and the emission to the atmosphere as flue gas; the flue gases may contain significant amounts of particulate matter, heavy metals, dioxins, furans, sulfur dioxide, methane, and hydrochloric acid. If plants have inadequate controls, these outputs may add a significant pollution component to stack emissions. Some waste still remains after incineration. Considering the input into the environment, the incineration technique can be considered as unsustainable.

Recycling Method

In Ghana, a number recycling processes are going on particularly for plastics and metals. Recycling is the process of reclaiming raw materials and reusing them to create new products. Recycling reduces the volume of solid waste by enabling people to use the materials in the waste again. Advantages of recycling include reduction in landfill waste and the generation of new materials for manufacturing. However, the process's disadvantages include posing health risks for sanitation workers. Disposal of mercury-containing products such as compact fluorescent bulbs can expose workers to unsafe levels of mercury. Mercury exposure can cause neurological damage in developing foetuses. Other health risks include fumes from hazardous waste products such as solvents and petroleum products. The longer a worker is exposed to these toxins, the greater the health risk. Some waste management services may not accept certain hazardous materials in order to protect their staff. In effect the recycling process is a selective waste treatment process and cannot be said to be a sustainable waste management process.

Composting Method

In Ghana, the composing method of solid waste treatment is used but with a single plant in Accra. Composting can be said to be nature's way of recycling. Composting biodegrades organic waste. i. e. food waste, manure, leaves, grass trimmings, paper, wood, feathers, crop residue etc., and turns it into a valuable organic fertilizer. Composting is a natural biological process, carried out under controlled aerobic conditions. In the process, various microorganisms, including bacteria and fungi, break down organic matter into simpler substances. The effectiveness of the composting process is dependent upon the environmental conditions present within the composting system. The conditions are dependent on oxygen, temperature, moisture, material disturbance, organic matter and the size and activity of microbial populations.

Composting is relatively simple to manage and can be carried out on a wide range of scales in almost any indoor or outdoor environment and in almost any geographic location. It has the potential to manage most of the organic material in the waste stream. Since approximately 45 - 55% of the waste stream is organic matter, composting can play a significant role in diverting waste from landfills thereby conserving landfill space and reducing the production of leachate and methane gas. In addition, an effective composting program can produce a high quality soil amendment with a variety of end uses. Despite the effective nature of composting, there is still almost 45% of the waste available for alternative disposal method. As such, the composting method cannot be used for total waste disposal.

All the stated methods are currently being used in Ghana by various municipal authorities for the disposal of municipal solid waste. The question that may be asked is if these method are in operation, why then should there be a problem? It is clear then that these method are not sustainable and or not enough to deal with the waste disposal issues. The waste disposal in Ghana can be said to be very challenging possibly due to the current methods being employed. It will therefore be prudent to seek for alternate technology.

The Plasma Gasification Technology

In Physics, plasma is an electrically conducting medium in which there are roughly equal numbers of positively and negatively charged particles, produced when the atoms in a gas become ionized. It is sometimes referred to as the fourth state of matter, distinct from the solid, liquid, and gaseous states. Lightning is an example of natural form of plasma. In industry, plasma is generated through plasma torches. It is by heating a gas to an extremely high temperature causing the gas to ionize and create the plasma. The temperature of the environment of the plasma torch can reach 2,000 ^{o}C and higher.

Historically, the concept of treating MSW using plasma arc technology was first introduced by Dr. S. L. Camacho in his December 1973 patent. He proposed a furnace with multiple plasma torches to continuously pyrolyze household and industrial wastes. He showed that the process would produce useful gas that could be used for producing energy, and rock-like by-product to use as aggregate for construction. He also demonstrated that gaseous emission to atmosphere were limited and very much under control. Additionally, he showed that using his methodology, all kinds of waste material would be processed without any ashes that would require to be sent to a landfill.

Use of Plasma in gasification is a non-incineration thermal process that gasifiers matter in an oxygen-starved environment to decompose waste material into its basic molecular structure. Plasma gasification does not combust the waste as incinerators do. It converts the organic waste into a fuel gas that still contains all the chemical and heat energy from the waste. It converts the inorganic waste into an inert vitrified glass. It can, therefore, be said that the technology result in producing fuel gas or syngas and vitrified glass all of which are useful.
When using these high temperatures the waste is completely destroyed and broken down into its basic elemental components. There are no tars or furans at these high temperatures, all metals become molten and Inorganic matter such as silica, soil, concrete, glass, gravel, etc. are vitrified into glass and flow out the bottom of the reactor. There is no ash remaining to go back to a landfill. Consequently, since both organic and inorganic components of the waste are utilised, no sorting of waste is necessary and any type of waste, other than nuclear waste, can be processed. The consistently low environmental emission characteristics exhibited by plasma gasification indicate that it can be used as a waste treatment alternative to other technologies with substantial environmental emission level improvements for both air emissions and slag leachate toxicity.

According to research conducted by Caroline Ducharme (2010), the energy produced per ton of feedstock is higher in plasma assisted-gasification than in grate combustion. The base scenario for the plasma-assisted plant resulted in a net energy generation of 533 kWh per ton of MSW processed, while the average generation for conventional U.S.WTE plants is 500 kWh/ton. However, due to process differences, there is potential to generate more than 617 kWh/ton of MSW, which is enough to make the process economically feasible. It is interesting to underline that the sensible heat in the process gas is not recovered but is lost to quenching. If it were, the energy generation plasma-assisted processes would be higher.
In Ghana/Africa, MSW are relatively mixture of all components of waste stream since waste sorting is not a practise. This situation with the municipal solid waste in Ghana can be easily treated by the plasma technology.

Potentials for use in Ghana

Conversion ratio (CR) is a measure of efficiency of the plasma gasification process and it is the ratio of energy in the product gas compared to the total electrical energy input into the plasma arc generator. For most waste processing applications, the energy in the product gas stream is more than four times the electrical energy require to operate the system (CR>4:1). If

the energy in the product gas stream is recovered and converted to electricity with efficiency factor of at least 25%, the facility can be self sufficient in terms of electrical energy. In case where the relative proportion of energy out to energy in can be improved for a given application, the system can be a net supplier of electrical energy.

The consideration of using plasma gasification technology in Ghana will lead to waste removal within the communities in a sustainable manner and energy generation as an essential by-product of the waste treatment. Typical results are estimated as in table 1.

Estimating for the use of 2MW torch capacity unit, there will be 5.0 tonnes/hr waste treatment with minimum power output of 4.76 MW (the least MSW calorific value is used as a conversation value). This is producing an excess power of 2.76 MW which can be made available for industrial as well as residential use from each plasma gasification unit (table 1). But for average waste generation of 1650 tonnes/day in Accra, 13 units will be install and minimum net power output will be 35.88 MW. In the case of Kumasi, 10 units of 2MW plasma gasification system can be installed with minimum net power output of 27.60 MW.

Table 1: Power estimation from MSW by Plasma gasification system.

Item	Value
Unit throughput for one unit of system	5000 kg/hr
Organic Waste component available (70%)	3500 kg/hr
Conversion rate of organic component into syngas	0.972 kg/s
Total power of Plasma Torch system	2 MW
Calorific value of Municipal Solid Waste	14 – 20 MJ/kg
Power available in waste using lower value (14MJ/kg x 0.972 kg/s)	13.608 MW
Overall efficiency of electrical generation system (33 – 39.5%)	35%
Electrical power Generation (0.35 x 13.608)	4.76 MW
Net Power output (4.76 – 2.0 MW)	2.76 MW
Average waste generation in Accra	1650 tonnes/day
	68.75 tonnes/hr
Minimum Number of unit in Accra	13 unit
Total net power in Accra	35.88 MW
Average waste generation in Kumasi	1250 tonnes/day
	52.08 tonnes/hr
Minimum Number of unit in Kumasi	10 unit
Total net power in Kumasi	27.60 MW

CONCLUSION

Municipal solid waste treatment is a great problem in Ghana as the technologies being used currently are all either not sustainable or being used unsustainably. The results of these are

the available seen of hips of waste most times left attended to at various places in and around public places. The better option is the plasma gasification technology being introduced. The plasma gasification technology will destroy the waste in the first place, then produce syngas and vitrified glass which are useful by products of the technology. The syngas can be used in power generation whist the vitrified glass could be used in construction sector. In the two largest cities, Accra and Kumasi, 35.88 MW and 27.60 MW power can be generated respectively as a net output after utilising generated power to power the system. It is, therefore a better option to invest in for sustainable waste treatment in Ghana.

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