International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 7 ǁ July. 2013 ǁ PP.42-50

Environmentally Friendly and Sustainable Municipal Solid waste Management in Abuja

Anyaegbunam F.N.C.
Department of Physics/Geology/Geophysics, Federal University Alike Ikwo.Abakaliki Nigeria

ABSTRACT:*Municipal Solid Waste (MSW) Management is a challenge to the Engineers, Scientists, City Planners and Local Administrators. Landfill sites and incineration continue to be the primary methods used to dispose wastes with significant negative impact on the environment. Landfill releases methane which is 21 times more dangerous as a greenhouse gas than carbon dioxide. Incineration is often pushed as an alternative to land filling. However, it is a known fact that incinerator ashes are contaminated with heavy metals, unburned chemicals and new chemicals formed during the burning process. These ashes are then buried in landfill or dumped in the environment. Sustainable and successful treatment of MSW should be safe, effective, and environmentally friendly. Application of plasma gasification in waste to energy is one of the novel applications that were introduced several decades ago. In plasma arc gasifying vessel, the organic waste materials are gasified to generate a syngas which can be used to produce energy. This study tries to describe the basics of this technology, reviews the challenges andbenefits of its implementation in waste to energy generation. It might prove to be an Environmentally Safe and Sustainable Solution for Municipal Solid Waste Management in Abuja, Nigeria.*

KEYWORDS:*Plasma arc gasification, waste to energy, syngas, Municipal Solid Waste, Power.*

I. INTRODUCTION

Although plasma technology is used in various applications since 1950s, it was Camacho that first used this technology to transform waste to energy in early 1970s. He showed that the process would produce useful gas that could be used for producing various forms of energy, and vitrified rock-like byproduct that could be used as construction aggregate [1]. Thegaseous emission to the atmospherewere limited and very much under control[1]. Waste materials are processed without any fly ashes that would require to be sent to a landfill. The environmental regulations are becoming more stringent andthis leads to increase in the cost of opening, maintaining, and operating landfills. The harmful attributes of landfills to environment are also revealed [2]. They suggested that Sustainable and successful treatment of MSW should be safe, effective, and environmentally friendly. Consequently, the issues related to landfills, created an atmosphere for academia and industry to extend their research frontiers for new solutions that would be environmentally friendly.

Plasma arc technology is not new.However, adaptation of this approach to large-scale solid waste disposal, including gasification of waste and recovery of energy from the gas generated is new.Plasma gasification ofmunicipal solid waste (MSW) is a fairly new application that combines well-established sub-systems into one new system. In Plasma Arc

Gasification(PAG)(http://www.recoveredenergy.com/d_plasma.html),the MSW is gasified in an oxygen-starved environment to decompose waste material into its basic molecular structure. It does not combust the waste as in the incinerators. Plasma may be created in a variety of ways, including passing a gas between objects with large differences in electrical potential, as in the case of lightning, or by exposing gases to high temperatures, as in the case of arc welding or graphite electrode torches. Plasma arc torches (Fig.1) utilize a combination of these techniques[3]. A relatively small quantity of ionized gas is produced by an "arc igniter" and introduced between the electrodes contained in the body of the torch. The presence of this ionized gas allows the formation of an electric arc between the electrodes, and the arc serves as a resistive heating element with the electric current creating heat which creates additional plasma that allows the arc to be sustained. Interaction between the arc and process gas introduced into the torch causes the temperature of the gas to reach very high temperatures, often nearly as hot as the sun's surface. The ability to increase the temperature of the process gas to temperatures two to ten times higher than those attainable by conventional combustion makes plasma arc technology ideally suited for high temperature process applications such as gasification of MSW.The extremely intense energy produced by the torch is powerful enough to disintegrate the MSW into its component elements. The subsequent reaction produces syngas and by-productsconsisting of a glass-like substance used as raw materials for high-strength asphalt or household tiles, and also re-useable metals. Syngas is a mixture of hydrogen and carbon monoxide[4]and it can be converted into fuels such as hydrogen, natural gas or ethanol.

The Syngas so generated is fed into a heat recovery steam generator (HRSG) which generates steam. This steam is used to drive steam turbinewhich in turn produces electricity – part of which is used to power the converter, while the rest can be used for the plant's heating or electrical needs, or sold back to the utility grid. Essentially the inorganic materials such as silica, soil, concrete, glass, gravel, including metals in the waste are vitrified and flow out the bottom of the reactor. There are no tars, furans or ashes enough topollute the environment.

Municipal solid waste (MSW) is believed to be a source of renewable energy, and plasma arc gasification technology is one of the leading-edge technologies available to harness this energy[5]. The MSW is a sustainablefuel source and increasing day by day in Abuja which is one of the fastest growing cities in the world. Therefore Plasma Arc Gasification may be proven as a sustainable source of energy and environmentally safe solution for MSW disposal in the City.

1.1Abuja Environmental Protection Board (AEPB) Waste Management

Solid waste management in Nigeria[6]is characterized by improper collection methods, insufficient coverage of the collection system and improper disposal of solid waste. Abuja Environmental Protection Board was founded in 1989 by the government to, among other things, ensure that municipal solid waste is collected and disposed regularly, manage hospital and other hazardous wastes, manage landfill sites as well as sweeping the markets and streets to make the city clean. They achieve this [7] by placing refuse bins in public places such as markets and residential areas so that garbage can be collected and taken to the dumpsites by compacting trucks, side loaders and tippers.

There are two types of waste that can be found in the city. One is garbage from various houses and industries. Secondly, there are alsowastes from the hospitals and clinics, referred to as the clinical garbage [7](abujaenvironmentalprotectionboard.gnbo.com.ng).The local administration, AEPB, has entered into a Public-Private Partnership (PPP) arrangement with some contractors for the collection and disposal of solid wastes in landfill and other dumpsites located in the city. Abuja city is divided into 20 district lots for this purpose, each district lot being manned by a cleaning contractor on a renewable concession agreement for three years. Under the agreement, the AEPB contributed 20 per cent of the funds used in procuring 50 compacting trucks and 12 street sweepers, while the technical partners were to contribute the remaining 80 per cent. The vehicles have been shared out to the cleaning contractors in charge of the 20 lots and the size of each district determines the number of vehicles allocated to each cleaner. This arrangement was not sustained as the technical partners failed to fulfill their own obligations. Today millions of tons of MSW have been accumulated over the years in landfill and dumpsites at Gosa and Mpape localitiesof Abuja despite irregular collection method andpoor management. This is causing serious environmental problems. It is estimated that over 5000MT per day of MSW[8] is collectible in Abuja if collection mechanism is properly organized due to fast growing population caused by the influx of people from other parts of Nigeria. This value of MSW can produce up to 320MW of Electricity[3].Less than 60% of MSW generated is collected in developing countries [6]. Solid waste generation exceeds collection capacity. [9]describes that one to two thirds of the solid waste generation in developing countries is not collected. In developing countries, waste stream is over 50% organic material [10]. The density of solid waste in Nigeria ranged from 280 kg/m3 to 370 kg/m3 higher than solid waste densities found in developed countries. 60% of wastes collected in Nigeria are organic waste [6].

II. METHODOLOGY

Information on waste collection and handling is supplied by Abuja environmental protection board (AEPB) and also from various municipal area councils in the Federal Capital Territory. Some workers at AEPB were interviewed to gather relevant information on the status of MSW collection and disposal. Various open dumpsites were visited and waste samples collected and analyzed. Useful information is also gathered from AEPB website: (www.environmentalprotectionboard.gnbo.com.ng). Data collection and analysis are based on the information about the six municipal area councils of Abuja on 2006 population census. A survey is conducted on the status of solid waste generation in each of the municipal area councils. The area councils provided information based on collection and transportation.

The data collected from the area councils and those obtained on their websites were analyzed and corrections made on average basis of the size of the area council. The sampling was done at the dumpsites and analysis done for the composition of MSW in each area council as per established guidelines issued by the United Nations Environment Program (UNEP).

2.1Municipal Solid WasteGeneration and Characterization

Solid waste generation studies are based on the information supplied by the local area councils. It is shown that 1918MT/day of MSW is collected. There are no regulations or standards to guide the collection and monitoring of the MSW. The waste collection is not properly organized. Less than 50% of the waste generated is collected. The MSW generation in Abuja is shown in Table 1. The rate of MSW generation in Abuja is about 0.67 kg/cap/day. Other results show that this rate is 0.66kg/cap/day[6].

Table 1. Municipal Solid Waste Generation in Abuja

MUNICIPAL AREA COUNCILS	POPULATION	MSW /MT/d	Per capita waste Generation/kg/d
ABUJA	2,245,000	1527	0.68
ABAJI	58,444	38	0.65
BWARI	227,216	150	0.66
GWAGALADA	157,770	104	0.66
KWALI	85,837	55	0.64
KUJE	97,367	44	0.67
TOTAL	2871634	1918	0.668

Table 2. Waste Stream Composition

	ABUJA	ABAJI	BWARI	GWAGALADA	KWALI	KUJE
Putreserible	53.2	52..5	50.8	51.9	54.5	55.0
Plastics	7.2	8.2	8.1	7.8	6.8	7.6
Paper	14.0	12.4	14.3	13.5	12.1	13.8
Textile	4.1	3.5	2.6	4.0	4.6	2.7
Metal	5.0	4,5	5.1	5.2	4.9	3,9
Glass	3.5.	3.9	4.0	4.2	4.3	4.1
Others	13.0	15.0	15.1	13.4	12.8	12.9

The food consumption of residents of Abuja and the municipal area councils is essentially carbohydrate and vegetables just as in most part of Nigeria. This partly gives rise to higher percentage of organic component of the MSW. Because of non-properly organized collection methods, the AEPB does not provide separate solid waste management for the seven classifications of solid waste. The majority of substances composing municipal solid waste include paper, vegetable matter, plastics, metals, textile, rubber and glass. Table 2 shows a comparative analysis of municipal solid waste composition in the six Municipal area councils of Abuja. It can be seen that great majority of the total solid waste generated in Abuja is organic.

2.2Waste Handling and Treatment

In Abuja like most developing countries, wastes are commonly dumped in open dumpsuncontrolled landfills where a waste collection service is organized. Open dumping of waste cannot be considered as a long-term environmental method of disposal. The dangers of open dumping are many; health hazard to scavengers at the dump site, pollution of ground water, spread of infectious diseases, highly toxic smoke from continuously smoldering fires and foul odors from decomposing refuse. However, the presentcontrolleddumpsite in Abuja is at GOSA, near the Airport road. There is no defined method of waste handling and treatment in Abuja today but several million tons of MSW have been deposited in open dumpsites over the years.A new technology such as Plasma Arc Gasification Technology may prove to be an environmentally friendly solution for the treatment of wastes in the city of Abuja.

III. PLASMA GASIFICATION

Plasma, often referred to as the “fourth state of matter”, is the term given to a gas that has become ionized. An ionized gas is one where the atoms of the gas have lost one or more electrons and have become electrically charged. The sun and lightning are examples of plasma in nature. Important properties of plasma include the ability to conduct an electric current and to respond to electromagnetic fields. Plasma was described [11] as "radiant matter" The nature of the Crookes tube "cathode ray" matter was subsequently identified by British physicist Sir J.J. Thomson in 1897. The term "plasma" was coined[12] perhaps, because the glowing discharge molds itself to the shape of the Crooks tube. The presence of a non-negligible number of charge carriers makes the plasma electrically conductive so that it responds strongly to electromagnetic fields,[13].

Artificial Plasma may be created in a variety of ways, including passing a process gas,which serves as a dielectric, between objects with large electrical potential differences, or by exposing gases to high temperatures, as in the case of arc welding or graphite electrode torches. The potential difference and subsequent electric field causes ionization of the gas and electrons are pulled toward the anode while the nucleus[13] pulled towards cathode. The current stresses the gas by electric polarization beyond its dielectric strength into a stage of electrical breakdown. The presence of this ionized gas allows the formation of an electric arc between the two electrodes, and the arc serves as a resistive heating element with the electric current creating heat which creates additional plasma that allows the arc to be sustained. A major advantage of the plasma arc as a resistive heating element is that it is formed in a gas and cannot melt or fail as can solid heating elements. Interaction between the arc and process gas introduced into the torch causes the temperature of the gas to be very high and the hot gas can exit the plasma torch (Fig. 1) at about 10,000°C.The ability to increase the temperature of the process gas to temperatures up to ten times higher than those attainable by conventional combustion makes plasma arc technology ideally suited for high temperature process applications such as gasification.

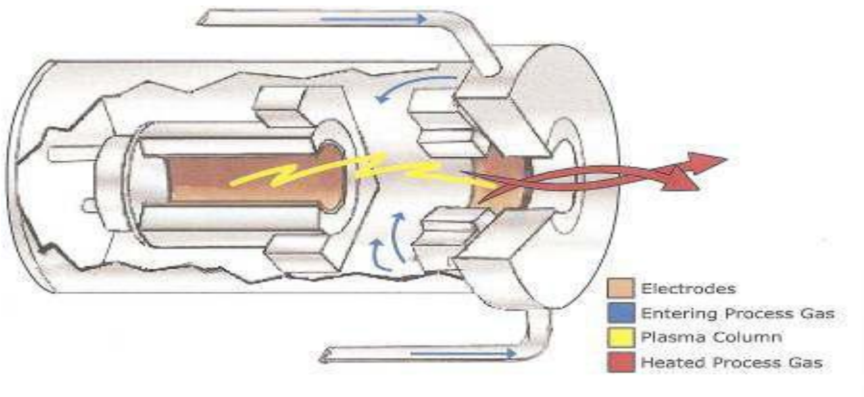

Fig.1 Plasma Tourch

3.1.Gasification Process

Gasification is a process that converts carbon-containing materials, such as municipal solid waste (MSW), coal, petroleum coke, or biomass, into a synthesis gas (syngas) composed primarily of carbon monoxide and hydrogen. Gasification occurs[3] when a carbon-containing feedstock is exposed to elevated temperatures and/or pressures in the presence of controlled amounts of oxygen which may be supplied by air, oxygen enriched air (essentially pure oxygen), or steam. Gasification accomplished through the use of controlled amounts of air or oxygen ("starved air gasification") produces a product gas composed primarily of carbon monoxide plus smaller amounts of hydrogen produced by reaction between carbon and moisture in the feedstock.The global gasification reaction is written as follows; waste material is described by its global analysis, CHxOy),[2]:

$$CH_xO_y + wH_2O + mO_2 + 3.76mN_2 \rightarrow aH_2 + bCO + cCO_2 + dH_2O + eCH_4 + fN_2 + gC$$

Where w is the amount of water per mole of waste material, m is the amount of O_2 per mole of waste, a, b, c, d, e, f and g are the coefficients of the gaseous products and soot (all stoichiometric coefficients in moles). This overall equation has also been used for the calculation of chemical equilibrium occurring in the thermal plasma gasification with input electrical energy. The concentrations of each gas have been decided depending on the amount of injected O_2, H_2O, and input thermal plasma enthalpy.The detailed main reactions are as follows:

$CH4 + H2O \rightarrow CO + 3H2$ (CH4 decomposition-endothermic)
$CO + H2O \rightarrow CO2 + H2$ (water gas shift reaction-exothermic)
$C + H2O \rightarrow CO + H2$ (Heterogeneous water gas shift reaction-endothermic)
$C+CO2 \rightarrow 2CO$ (Boudouard equilibrium-endothermic)
$2C + O2 \rightarrow CO$

The H2 and CO generated during the gasification process can be a fuel source. Therefore, plasma gasification process has been combined with many other technologies to recover energy from the syngas.

3.2Plasma Gasification of Municipal Solid Waste (MSW)

Plasma gasification is an efficient and environmentally responsible form of thermal treatment [14] of wastes which occurs in oxygen starved environment so that waste is gasified, not incinerated. Westinghouse Plasma Corporation (WPC) has developed a plasma gasification system[15]; [3] which uses plasma heat in a vertical shaft cupola adopted from the foundry industry. The WPC plasma gasification process is illustrated in Fig. 2 below,[3]. The heart of the process is the "Plasma Gasifier"; a vertical refractory lined vessel into which the feed material is introduced near the top along with metallurgical coke and limestone. Plasma torches are located near the bottom of the vessel and direct the high temperature process gas into a bed of coke at the bottom of the vessel. Air or oxygen is introduced through tuyres located above the torches. The high temperature process gas introduced through the torch raises the temperature of the coke bed to a very high level to provide a heat reservoir and the process gas moves upward through the gasifying vessel to gasify the waste. The power of plasma gasification makes it environmentally clean technique. Plasma Gasification Plant (PGP) projects[16] are being developed by many gas plasma technology companies, and there are real benefits to be obtained from this technology for the Municipal Solid Waste (MSW) disposal.

Additional heat is introduced from the reaction of the carbon in the waste with the oxygen introduced through the tuyres to produce carbon monoxide in the gasification process. The hot product gas, passing upward though the waste breaks down organic compounds and dries the waste at the top of the “gasifier”. This is pyrolysis process. As the waste moves downward through the “gasifier” vessel, inorganic materials such as metal, glass and soil are melted and produce a two phase liquid stream consisting of metals and a glass-like (vitrified) residue that flows to the bottom of the vessel. Discharge of the molten material into water results in the formation of metal nodules and a coarse sand-like material very similar to the black sand beaches produced in Hawaii when lava flows into the sea.

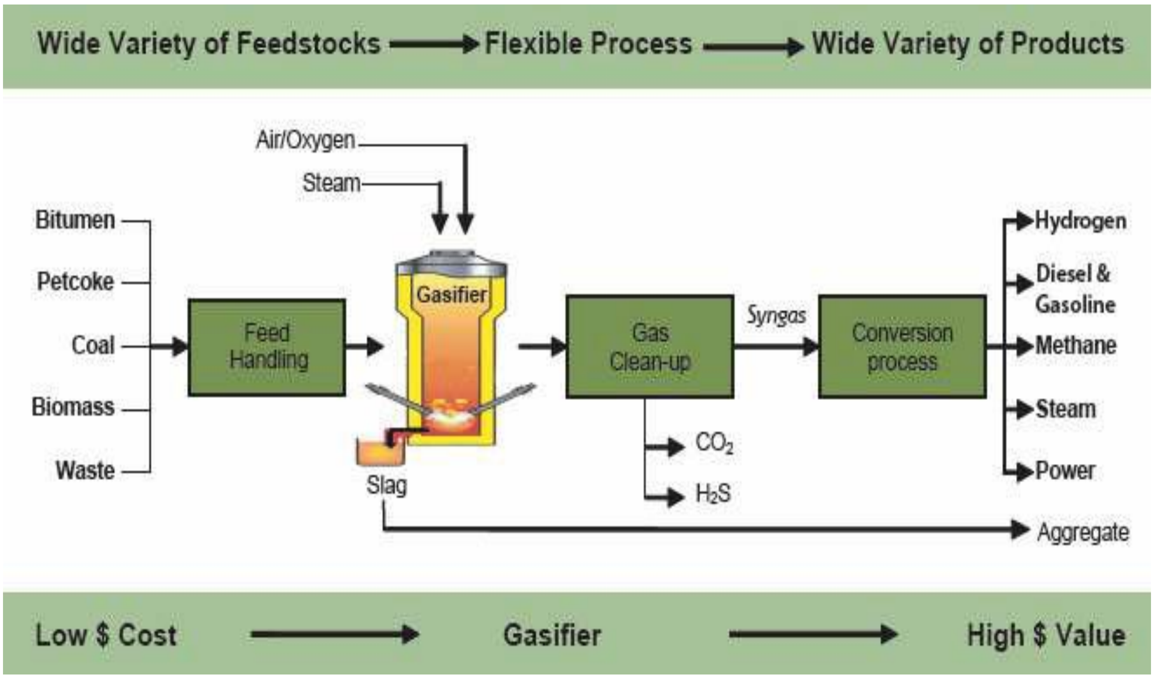

Fig. 2 WPC Plasma gasification process

IV. ENVIRONMENTAL FRIENDLINESS AND SUSTAINABILITY OF PLASMA GASIFICATION OF MSW.

Plasma gasification represents a clean and efficient option to convert various feed stocks into energy in an environmentally responsible manner [3]. In the plasma gasification process, heat nearly as hot as the sun’s surface is used to break down the molecular structure of any carbon-containing materials – such as municipal solid waste (MSW), tires, hazardous waste, biomass, river sediment, coal and petroleum coke – and convert them into synthesis gas (product gas) that can be used to generate power, liquid fuels or other sustainable sources of energy.

The Georgia Tech PARF lab conducted several tests [5] using their prototype plasma gasification units. One of the units contained a 100 kW and the other a 240 kW plasma heating system. The plasma gas was mainly air; however, Argon and Hydrogen were tested too. The main supplies of the furnaces were artificial combination of materials to simulate typical average constituents of MSW based on US EPA. For the Ex-Situ experiments the MSW constituents were used and for In Situ experiments, soil was added to the MSW constituents to simulate a real landfill. The summary of the PARF lab experiment results are as follows:

1. The percentage weight loss of the MSW after plasmaprocessing is 84% for ex-situ experiment where the MSW constituents alone wereused,and 59% for in-situ experiment where soil was added to MSW to simulate a real landfill or dumpsite.And weight loss wassignificantly less than for ex-situ experiments, [5].

2. The percentage volume reduction of the MSW after plasma processing was 95.8% for ex-situ experiments and 88.6% for in-situ experiment. Again, given that significant amount of soil was added to the mix in in-situ experiment, obviously, the soil was melted (vitrified) but did not gasify (pyrolyze) and consequently the volume reduction was reasonably different comparing with ex-situ experiment, [5].
3. Toxicity Leaching text results for heavy metals (Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium and Silver) present after plasma gasification process are below detectable levels (BDL) in both experiments, and also far below the permissible standards established by US EPA.[5].
4. Output Gas Composition: [5] Table-3 shows the output syngas compositions for experiment without soil and with soil respectively in parts per million:

Table 3 Output Gas Composition

Output Gas	Ex-Situ Experiment without soil (PPM)	In-Situ Experiment with soil (PPM)
Hydrogen (H2)	>20,000	>20,000
Carbon Monoxide (CO)	100,000	>100,000
Carbon Dioxide (CO2)	100,000	90,000
Nitrogen Oxides (NOx)	<50	100
Hydrogen Sulfide (H2S)	100	80
Hydrogen Chloride (HCL)	<20	225
Hydrocarbons	>5,000	>4,500

PPM = parts per million.

The rate of Carbon dioxide emission [17]per MWH of electricity produced from different processes is shown in Fig.3

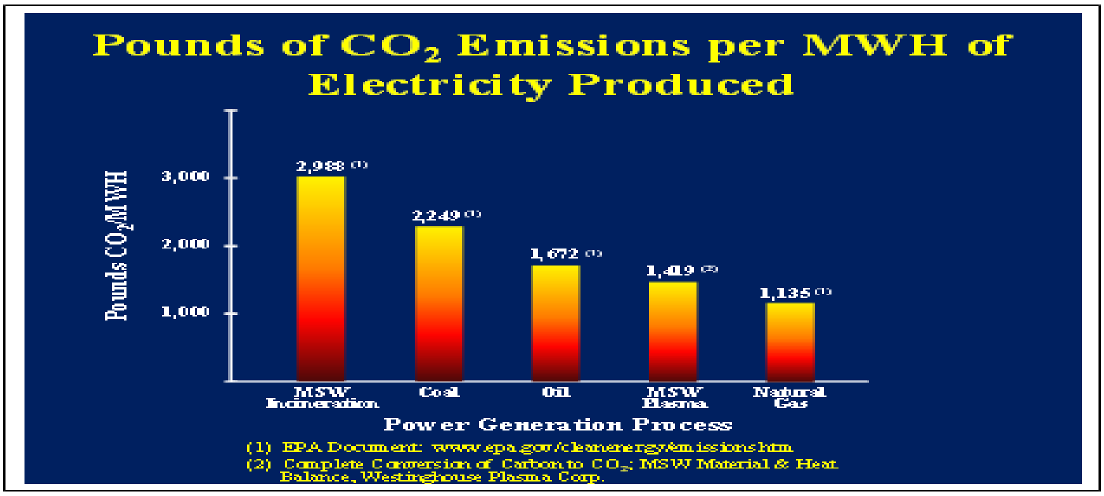

Fig. 3: Pounds of CO2 Emissions per MWH of Electricity Produced

Each plasma gasification application will have a differing environmental profile, [3]but in general terms a plasma gasification facility will have very low emissions of NOx, SOx, dioxins and furans. In summary, when compared to conventional incineration or traditional gasification technologies, the WPC Plasma Gasification technology and its plasma torch systems offer the following benefits listed in table 4:

Table 4. Plasma Gasification Compered to Incineration and Other Gasification Processes

Feedstock Flexible	Ease of Operation	Environmental Benefits	Flexible Product Delivery
A wide range of opportunity fuels can be accepted with limited pre-processing requirements	The Gasification Reactor Operates at ambient pressures allowing for simple feed system and online maintenance of the plasma torches	Operation is environmentally responsible creating a product gas with very low quantities of NOx, SOx, dioxins and furans	Syngas composition (H2 to CO ratio, N2) can be matched to downstream Process equipment by selection of oxidant and torch power consumption
Multiple Feed Stocks can be combined	Plasma Torches have no moving parts resulting in high reliability. Torch consumables are quickly replaced offline by plant maintenance personnel	Inorganic components get converted to glassy slag safe for use as a construction aggregate	Multiple gasification reactors are used for larger projects increasing availability of the gasification system

4.1Plasma Gasification an environmentally friendly sustainable solution for Municipal Solid Waste Management in Abuja

Abuja is made up of six municipal area councils for effective administration. The AEPB is the local authority responsible for the proper management of the Municipal Solid Waste inAbuja.As at today, AEPB still practice dumping of the MSW in the outskirt of the township. Open dumping creates huge Environmental Problems. The quantity and composition of the waste contribute much for the selection of the management solution. In fact, waste management is multi-disciplinary issue and involves various environmental, economic and community aspects. Hence, certain criteria should be satisfied for any waste management method desired.

4.2Waste management criteria

There is an emerging global [18], [15]consensus to develop local level solutions and community participation for better MSW management. Emphasis has been given to citizens' awareness and involvement for better [19]waste management. A number of studies were carried out in the past to compare different methods of waste disposal and processing for different places. Study for the Netherlands[20]concluded that composting was the best option of waste management. Study for the United Kingdom concluded that refused derived fuel [21]was the best option. It can be inferred from the literature that no one method in isolation can solve the problem of waste management. The present study is an attempt to establish the best feasible method of waste management in Abuja by taking various factors in consideration.

The suitability of a particular technology for the treatment of MSW depends on a number of factors which includes techno-economic viability, environmental factors, sustainability [22] and geophysical background of the location. The Plasma Gasification [23] Process (PGP) seems to be a realistic solution for the MSW disposal in the Abuja. It is a disposal process that can get rid of almost any kind of waste by eliminating existing landfills, open dumps, and produce a clean energy for the city.

4.3Land requirement

The land and transportation facilities are basic requirement for MSW management. As per the provisions of Municipal Solid Waste (Management and Handling) Rules, 2000, the landfill site shallbe large enough to last for 20-25 years[15]. It is the general experience that the land requirement for development of the MSW landfill site is around 0.2 ha/MT of MSW generation per day with minimum requirement of 2.0 ha land area. The projected minimum land requirement for Plasma Gasification Process (PGP), [3]is dependent on the processing capacity of the plant and ancillary processes that maybe included in the overall plant design. However, a standard IGCC configured plant having a capacity of 1000 MT per day would require about 2.02 Hectares (5Acres) of land. Increasing the capacityof the plant to 3000 M.T. per day would increase land requirement to about 4.04 Hectares (10 Acres).

4.4Sustainability

The sustainability of any project depends up on the capital cost, running & maintenance cost, availability of raw materials and payback cost. Capital costs for a plasma gasification plant are similar to those for a municipal solid waste incineration power plant, but plasma gasification plants are more economical because the plant's inorganic byproduct can be sold to the market as bricks and concrete aggregate. Plasma gasification plants also produce up to 50% more electricity than other gasification technologies,[17]) hence, reducing the payback period.Nedcorp group plasma gasification system using Westinghouse Plasma Corporation plasma touches [3] uses 2 to 5% of energy input to produce 80% of energy output. Typical plasma gasification for waste to energy plant with a feedstock of 3,000 MT of MSWper dayis estimatedto cost over

$400 million for installation and will generate about 120 MW of electricity [5]. Estimation for a 2,000 MT of MSW per day [4] is about $250 million. Most of the Plasma Gasification Plants require 120 Kwh of energy for un-segregated per ton of MSW and 816 kwh electricity is generated from the process. It is also projected [5]that each ton of MSW has the potential to produce 900 kWh. The same plant can produce 1,200 kWh for each ton of MSW if it is equipped with cogeneration auxiliaries i.e. steam turbine and gas turbine in an integrated gasification combine circle (IGCC). This implies that similar to any other new technology, the cost will decrease significantly after the commencement of mass production.

V. RESULTS AND DISCUSSION

Municipal Solid Waste Management is a great challenge to the Town Planners, Waste Managers, Scientists and Engineers. The quantity of Municipal Solid Waste generation is increasing and availability of land for the landfills or open dump disposal in Abuja and elsewhere is decreasing day by day and hence most of the latest efforts focus on "Zero Waste" and/or "Zero Land filling" disposal methods. It is depicted from the data interpretation that;The average Municipal Solid Waste generation from the six municipal area councils of Abujais about 1918MT/day (Table-1), due to lack of proper method of waste collection. When it is properlyorganized,waste collection will exceed 5000MT/day for the fast growing city[8].The percentage of plastic wastepresent in municipal solid waste is about 8% on average. The Plasma Gasification Process of Municipal Solid Waste is a proven technology in which the weight is reduced by more than 88% and the volume of organic matter reduced by more than 95%[17]. The vitrified glass generated as residue from Plasma Gasification Process is alsoenvironmentally safe for toxicity leaching. The vitrified glass contains mainly silica (sand, quartz), CaO, Fe2O3, and Al2O3 and can be used for the construction work. The reaction processes inPGP produce mainly syngas (Hydrogen and Carbon monoxide). The PGP out-put gas is environmentally safe. WPC Plasma Gasification technology and its plasma torch systems when compared to incineration or traditional gasification offer unique environmental benefits.Operation is environmentally responsible creating a product gas with very low quantities of NOx, SOx, dioxins and furans. Inorganic components get converted to glassy slag safe for use as a construction aggregate.The fuel gas emissions are also within prescribed limit, the process is environmentally safe in terms of rate of Carbon dioxide emission [17]per MWH of electricity produced in comparison to different processes as depicted in Fig.3. The land requirement for management of Municipal Solid Waste in the City through landfillswould be around 384ha for 1918MT/day. However, processing of 3000MT/day by plasma gasification process will require only 4.02ha of land, [3]. The reduction in the space required for un-segregated MSW management by PGP is very significant. This is positive for the fast growing City ofAbuja where land space is diminishing by the day.The Plasma Gasification Processing (PGP) plants will generate 320MW of electricity when 5000MT/day is processed[3]; [24]and this will be used by the local utility through national grid. The PGP plants conserve fossil fuels by generating electricity.One ton of MSW will reduce oil consumption of 132.50 liters or will save 0.25 MT of coal, [15]. It has been estimated that one ton of MSW decomposed in a PGP rather than land filled reduces greenhouse gas emissions by 1.2 MT of carbon dioxide [15]. Hence, there will be reduction of over 2300MT/day of land filled greenhouse gas emissions with the technology proposed.

The Municipal Solid Waste management is a challenge due to its increasing quantity and limited land resources. This is the reason that most ofthe latest efforts focus on "Zero Waste" and/or "Zero Landfilling" which is certainly expensive [25] for weaker economies. Developing countries, though poor should develop area-specific solutions to their problems [26]in the MSW management. Application of Plasma Gasification Process (PGP) in waste to energy, relieves the pressure on distressed landfills, and offers an environmentally benign method [4] of disposing MSW. Municipal solid waste is considered as a source of renewable energy, and plasma gasification technology is one of the leading-edge technologies available to harness this energy. In recent years, the US government officially declared the MSW as a renewable source of energy, and power generated through the use of MSW is considered green power and qualified for all eligible incentives. Plasma technology purports to be an economic and abundant source of energy, and a reliable source of power. Looking ahead to many applications of Plasma Gasification Process, the profit potential of plasma conversion [4] is tremendous. Private companies could build facilities in developing countries and it would naturally be in their financial best interest to develop the garbage collection infrastructure to support their business, indirectly the collection system will be improved.

This is a perfect niche for theoil companies. Plasma converters represent the ultimate in recycling; making virtually 100% of the waste a household normally produces into usable [4] and even valuable end products. There would be no need to have two garbage pickups every week, one for trash and one for recyclables that people have perhaps been conscientious enough to separate. The plasma gasification process of MSW has all the merits of adoption, even though there are many disagreements among scientists and policy makers on these matters, there is, however, consensus that alternative sources of energy that are sustainable, environmental friendly and regionally available must be the best choice. However, skepticism about the technology, lack of historical data, volatile price of crude oil, a mislabeling of plasma gasification technology as another type of incineration and a lack of government sponsored development and projects, have contributed to the lack of progress in development and utilization of this technology, [15].

The sustainability of any solid waste management system depends [27] on numerous factors; however, the most important factor is the will of the people to change the existing system and develop something better. For any waste management to be successful, the government should take the required initiatives. Even though financial constraints arepart of the system, the government can make a formal and sincere commitment for eliminating garbage from the City through a sustainable and environmentally responsible manner.

VI. ACKNOWLEDGEMENT

I am grateful to the staff of Abuja Environmental Protection Board (AEPB), and of the six municipal area councils of Abuja who provided me with relevant information, without of which this study might not be possible.

REFERENCES

[1] **Camacho S. L., 1996)**, Plasma Pyrolysis and Vitrification of Municipal Waste, U.S. Patent No. 5,544,597, Aug. 1996.

[2] **YoungchulByun, Moohyun Cho, Soon-Mo Hwang and Jaewoo Chung, (2012)** Thermal Plasma Gasification of Municipal Solid Waste (MSW). (www.intechopen.com/thermal_plasma_gasification_of_municipal_solid_waste)

[3] **Nedcorp Group (2009)** Environmentally Friendly Waste Destruction and Sustainable Renewable Energy. A feasibility document of Nedcorp group, July 2009.

[4] **Blees Tom, (2008**), Prescription for the Planet, The Painless Remedy for our Energy & Environmental Crises, ISBN: 1-4196-5582-5, ISBN-13: 9781419655821 Library of Congress Control Number: 2008905155.

[5] **Pourali, M., (2010),** Application of Plasma Gasification Technology in Waste to Energy—Challenges and Opportunities, The IEEE Xplore digital library (Institute of Electrical and Electronics Engineers), 1(3), pp 125-130,

[6] **Ogwuneleka, T. C, (2009),** Municipal Solid Waste Characterization and Management In Nigeria. Iran. J. Environ. Health. Sci. Eng., 2009, Vol. 6, No. 3, pp. 173-180

[7] **Abuja Environmental Protection Board (AEPB) website**: abujaenvironmentalprotectionboard.gnbo.com.ng

[8] **Ayaegbunam F.N.C, (2012**), Feasibility Study for Plasma Power Project in Abuja. BPP publiccations, Jan; 2012.

[9] **Zurbrugg, C., (2003).** Urban solid waste management in low-income countries of Asia, How to cope with the Garbage crisis, Available in the website: http;//www.sandec.ch.

[10] **Hoornweg, D., Thomas, L., and Otten, L., (1999).**Composting and its applicability in developing countries.Urban waste management working paper series 8.Washington, DC; World Bank.

[11] **Crookes Sir William, (1879)**, presented a lecture to the British Association for the Advancement of Science, in Sheffield, on Friday, 22 August 1879.

[12] **Langmuir I. (1928),** Oscillations in ionized gases, Proceeding of National academy of science, U.S. 14(8), pp 628.

[13] **Chen, Francis F. (1984)**, Plasma Physics and Controlled Fusion. Plenum Press. ISBN 0306413329

[14] **Evans Steve D, (2009)**, Plasma Gasification Plant Benefits for Municipal Waste Management, EzineArticles.com, available at http://www.articlesbase.com/literaturearticles/plasma-gasification-plant-benefits-for-municipal-waste-management-850915 . html, accessed during December 2011.

[15] **Patel MunnaLal, ChauhanJanardan Singh (2012)**, Plasma Gasification: A Sustainable Solution for the Municipal Solid Waste Management in the State of Madhya Pradesh, India. INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCES Volume 3, No 1, 2012

[16] **Dighe, Shyam V. (2008)**, Westinghouse Plasma Corporation, Madison, Pennsylvania, USA, Plasma Gassification : a proven technology, Proceedings of NAWTEC16, 16th Annual North American Waste-to-Energy Conference, May 19-21, 2008, Philadelphia, Pennsylvania, USA.

[17] **Circeo L. J, (2012),** Plasma Arc Gasification of Municipal Solid Waste. Georgia Tech Research Institute, Environmental Science and Technology Program, Electro-Optical Systems laboratory.

[18] **RathiSarika, (2007)**, Optimization model for integrated municipal solid waste management in Mumbai, India, Environment and Development Economics 12, pp 105-121.

[19] **Beukering, (1999)**, Waste recovery in Bombay: a socio-economic and environmental assessment of different waste management options, Third World Planning Review 19(2),pp 163–187.

[20] **Maimone, M., (1985)**, An application of multi-criteria evaluation in assessing MSW treatment and disposal systems, Waste Management and Research, 3, pp 217–231.

[21] **Powell, J.C., (1996)**, The evaluation of waste management options, Waste Management and Research 14, pp 515–526, reprinted in Powell et al. 2001.

[22] **Varma, R. Ajayakumar, (2009),**Technoligical Options for Treatment of Municipal Solid Waste with special reference to Kerala, Workshop on Public Office Sanitation at State Municipal House on 25th Sept 2009, available at sanitation.kerala.gov.in/pdf/workshop/techno_2.pdf, accessed during December 2011.

[23] **Lisa Zyga, (2012)**, Plasma Gasification Transforms Garbage into Clean Energy, Science Blogger, InventorSpot.com, via: Popular Science.

[24] **Anyaegbunam F.N.C, JVL Capital (2012)**, Plasma Power Project Feasibility Report, prepared for Brain-Fintek Plasma Power Limited. BPP publications, July 2012.

[25] **Shekder Ashok V., (2009)**, Sustainable solid waste management: An integrated approach for Asian countries Waste Management, 29(4), pp1438-1448.

[26] **enry, (2006),** Country report, Municipal solid waste management challenges in developing countries – Kenyan case study, Waste Management, 26, 92–100.

[27] **PradhanUpendra Mani, (2008),** Sustainable Solid Waste Management in a Mountain Ecosystem: Darjeeling, WestBengal, India, A Thesis Submitted to the Faculty of Graduate Studies In Partial Fulfillment of the Requirements For the Degree of Master of Natural Resources Management, Faculty of Environment Earth and Resources Natural Resources Institute University of Manitoba, November, 2008.