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Plasma Gasification: A Sustainable Solution for the Municipal Solid Waste Management in the State of Madhya Pradesh, India

Patel Munna Lal[1], Chauhan Janardan Singh[2]

1- Executive Engineer, M. P. Pollution Control Board, E-5, Arera Colony, Bhopal

2- Professor and Head of the Department (Civil), Samrat Ashoka Technological Institutes (Engineering College) Vidisha (M. P) India

mlp_pcb@rediffmail.com

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ABSTRACT

The Municipal Solid Waste Management is a challenge to the Environmental Engineers, City Planners and Local Administration. Day to day increase in its quantity, complex in composition and scarcity in land availability for the landfill is making it more difficult. A disposal process, that can get rid of almost any kind of waste at a fraction of the cost of today's disposal techniques, eliminate existing landfills, and produce an excess of clean energy is called Plasma Gasification Process (PGP). Almost any material can be broken down with this technology, eliminating the time-consuming, tedious and costly process of waste sorting. (Nuclear waste is an exception due to its indestructible isotopes.) Utilization of plasma gasification (Pourali, M. 2010) in waste to energy is one of the novel applications that were introduced several decades ago. In plasma arc gasifies the organic waste materials are gasified to generate a syngas which can be used to produce energy through reciprocating engine generators, gas turbines and boilers. The in-organic waste materials (Blees Tom, 2008) are vitrified which is reusable metal. The goal of this study is to describe the basics of this technology, review the challenges and to create opportunities for its implementation in waste to energy applications and provide a roadmap to eliminate current roadblocks for developing such projects. The PGP holds a very good prospect of adoption for Municipal Solid Waste Management, as it is a process which is very efficient (Evans Steve D, 2009), at diverting waste away from landfill, and thus scores highly among waste disposal engineers who are constantly seeking to comply with regulations to reduce the amount of organic waste sent to landfill. This might be proven as Environmentally Safe and Sustainable Solution for Municipal Solid Waste Management in the State of Madhya Pradesh, India.

Keywords: Disposal techniques, Plasma gasification, waste to energy, syngas, Municipal Solid Waste, landfill, environmentally safe and sustainable.

1. Introduction

The concept of treating MSW using plasma arc technology was first introduced by Dr. S. L. Camacho in December 1973 and got its first patent in this field (Pourali, M. 2010). 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 vitrified rock-like byproduct to use as aggregate (Camacho, S. L. 1996) for construction. The gaseous emission to atmosphere (Camacho, S. L. 1996) were limited and very much under control. The waste materials are processed without any ashes that would require to be sent to a landfill. The environmental regulations are becoming more stringent which in turn causing to increase the cost of opening, maintaining, and operating

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landfills. The harmful attributes of landfills to environment are also revealed through in-depth studies. Consequently, all of the issues related to landfills, created an atmosphere for academia and industry to extend their research for new solutions. In 1992, Dr Camacho was granted (Pourali, M. 2010) another patents for his invention in this field in 1992 and 1996.

Georgia Institute of Technology (Georgia Tech) started a plasma arc research technology program and established Plasma Applications Research Facility (PARF) laboratory in 1991 which was the largest university based research facility for plasma technology. Through the years, the lab ran several experiments under the supervision of Dr. L. J. Circeo. Numerous papers were published and contributed many project developments in the United States and worldwide on the basis of this research. Resorption Canada Limited (now renamed to Plasco Energy Group) introduced their prototype plasma gasification for treatment of MSW in 1988. Their system used a 150 kW plasma torch in a furnace to generate plasma from approximately 500 pounds of MSW per hour.

In Plasma Gasification Process (PGP) (http://www.recoveredenergy.com/ d_plasma.html) the matter 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. Electricity is fed to a torch, which has two electrodes, creating an arc. A constant flow of electricity through the plasma maintains a field of extremely intense energy powerful enough to disintegrate the garbage into its component elements. The byproducts are a glass-like substance used as raw materials for high-strength asphalt or household tiles and "syngas". Syngas is a mixture (Blees, Tom 2008) of hydrogen and carbon monoxide and it can be converted into fuels such as hydrogen, natural gas or ethanol. The Syngas so generated is fed into a cooling system which generates steam. This steam is used to drive turbines which produce 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. The metals become molten and in-organics such as silica, soil, concrete, glass, gravel, etc. are vitrified and flow out the bottom of the reactor. There are no tars, furans or ashes to go back to landfills.

Municipal solid waste (MSW) is considered as a source of renewable energy, and plasma gasification technology is one of the leading-edge technologies (Pourali, M. 2010) available to harness this energy. The MSW is a never lasting source and increasing day by day in a developing States like Madhya Pradesh, India and hence; Plasma Gasification may be proven as a sustainable source of energy and environmentally safe solution for MSW disposal in the State.

1.1 Methodology

The information regarding the Municipal Solid Waste generation is collected from the local bodies and analyzed for assessment of the status of its management. The following methodology adopted for the data collection

1. The list of the local bodies made available by the State Urban Administration & Development department on its official website and the population details from the census records (2001).
2 Survey has been conducted for the assessment of Municipal Solid Waste (MSW) generation in the State, through its Local Bodies. The local bodies provided information based on collection and transportation. Quantification of waste based on

survey of waste collection vehicles. The number of trips of the transporting vehicle was basic criteria for the quantity assessment.

3. The data regarding the waste generation and the facilities available collected from the local bodies and 15% data verified through personal discussion.
4. The data provided by the Local Bodies analyzed and necessary correction made on the average basis of the nature and size of the Local Body.
5. The MSW analysed for its composition and calorific value. The sampling of the Municipal Solid waste was done from the dump sites as per the guidelines issued by the International Environmental Technology Centre, United Nations Environment Program (UNEP). The samples were mixed and divided to get average sample by discarding diagonally opposite waste. Manual and hand sorting of the waste was applied to categorize it in different waste streams. The waste composition decided as a percentage fraction of the sample. The waste analysed for moisture content for the average mixed waste and sorted waste streams on the basis of loss of weight on drying at $85^{o}C$ for 48 hours and cooling for 48 hours. The moisture content in plastic waste stream is determined by the method of difference.

1.2 Status of Municipal Solid Waste generation in Madhya Pradesh

Studies regarding the generation of Municipal Solid Waste in the State is done on the basis of the information supplied by the local bodies. The quantity is given by the local bodies on the basis of the actual collection and the facilities available with them. It is estimated that around 4500 MT/day Municipal Solid Waste is generated (Patel et al., 2010) from 342 local bodies of the State. The Status of the implementation of MSW, Rules in the State is not very satisfactory. The collection of the waste is around 60% -70%. The status of Municipal Solid Waste generation in the State is depicted in Table-1 and its composition is depicted in Table-2.

Table 1: Municipal Solid Waste Generation in the State and its composition

S. No.	Type of Local Bodies	No of local bodies	Population covered	Per capita waste generation (Kg/d)
1.	Municipal Corporations	14	7109503	0.364
2.	Municipal Committees	86	4785940	0.240
3.	Nagar Panchyats	237	3367948	0.202
4.	Cantonment Boards	5	232205	0.195
	Total	**342**	**15495596**	**0.287**

Table 2: Municipal Solid Waste composition

S. No.	Type of Local Bodies	Quantity of MSW (MT/d)			Range of plastic waste (%)
		Organic	In-Organic	Total	
1.	Municipal Corporations	1256 (48.5%)	1330.01 (51.5%)	2586.01	4 -8 (6)
2.	Municipal Committees	613.14 (53.4%)	535.538 (46.6%)	1148.678	2.5-5 (3.75)

3.	Nagar Panchyats	395.61 (58%)	285.582 (42%)	681.192	1 -3 (2)
4.	Cantonment Boards	23.86 (52.8%)	21.34 (47.2%)	45.2	3-6 (4.5)
	Total	**2288.61 (51.3%)**	**2172.47 (48.7%)**	**4461.08**	**4.5**

There are 14 major cities in the State having Municipal Corporations as governing bodies, responsible for the management of the Municipal Solid Waste. Theses cities contribute about 57% of the total MSW generated in the State (Patel & Jain, 2010). The percentage of plastic waste (Patel et al., 2011) present in municipal solid waste varies from 1% to 8%. The waste from smaller localities contains lower quantities of plastic components. The average rate of plastic waste generation throughout the state does not exceed 5%, but its presence contributes towards creating environmental problems. The plastic waste generally contains chlorinated compounds like PVC and is a major concern to the Environmentalist regarding the dioxin & furans emission. The unintentionally produced Persistent Organic Pollutants (POPs) may also be generated due to presence of other chlorinated compounds and plastic in MSW due to burning at low temperatures.

2. Plasma Gasification: The literature review

Plasma is a fourth state of matter similar to gas in which a certain portion of the particles are ionized. After sufficient heating a gas dissociates its molecular bonds, rendering it into constituent atoms. However, further heating may also lead to ionization (a loss or gain of electrons) of the molecules or atoms of the gas, thus turning it into plasma, containing charged particles: positive ions and negative electrons. The Plasma was described (Crookes Sir William,1879) 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 (Langmuir I., 1928) perhaps because the glowing discharge molds itself to the shape of the Crooks tube (Gr. πλάσμα - "to mold"). The observation was described as:

“Except near the electrodes, where there are sheaths containing very few electrons, the ionized gas contains ions and electrons in about equal numbers ((Langmuir, I. 1928)) so that the resultant space charge is very small. We shall use the name plasma to describe this region containing balanced charges of ions and electrons.”

The presence of a non-negligible number of charge carriers makes the plasma electrically conductive so that it responds strongly to electromagnetic fields. Plasma is often called the fourth state of matter. Plasma, therefore, has properties quite unlike those of solids, liquids, or gases and is considered a distinct state of matter. Like gas, plasma does not have a definite shape or a definite volume unless enclosed in a container; unlike gas, under the influence of a magnetic field, it may form structures such as filaments, beams and double layers. Although it is closely related to the gas phase in that it also has no definite form or volume, it differs in a number of ways, depicted in table-3.

2.1 Generation of artificial plasma

There are several means for the generation of Plasma, however, one principle is common to all of them (Hippler et al., 2008), that there must be energy input to produce and sustain it. Plasma is generated when an electrical current is applied across a dielectric gas or fluid. The potential difference and subsequent electric field causes ionization of material and electrons are pulled toward the anode while the nucleus (Chen, Francis F. 1984) pulled towards cathode. The current stresses the material by electric polarization beyond its dielectric strength into a stage of electrical breakdown. As the voltage increases, it forms an electric spark, where the material transforms from insulator to a conductor (as it becomes increasingly ionized). This is a stage of a massive ionization, where collisions between electrons and gas atoms create more ions and electrons. The first impact of an electron on an atom results in one ion and two electrons. Therefore, the number of charged particles increases rapidly (in the millions) only "after about 20 successive sets of collisions" (Edbertho Leal-Quirós, 2004) mainly due to a small mean free path (average distance traveled between collisions). The figure-1 describes the Cascade process of ionization.

Table 3: Difference between Gas and Plasma

Property	Gas	Plasma
Electrical Conductivity	**Very low** Air is an excellent insulator until it breaks down into plasma at electric field strengths above 30 kilovolts per centimeter.	**Usually very high** For many purposes, the conductivity of plasma may be treated as infinite.
Independently acting species	**One** All gas particles behave in a similar way, influenced by gravity and by collisions with one another.	**Two or three** Electrons, ions, protons and neutrons can be distinguished by the sign and value of their charge so that they behave independently in many circumstances, with different bulk velocities and temperatures, allowing phenomena such as new types of waves and instabilities.
Velocity distribution	**Maxwellian** Collisions usually lead to a Maxwellian velocity distribution of all gas particles, with very few relatively fast particles.	**Often non-Maxwellian** Collisional interactions are often weak in hot plasmas and external forcing can drive the plasma far from local equilibrium and lead to a significant population of unusually fast particles.
Interactions	**Binary** Two-particle collisions are the rule, three-body collisions extremely rare.	**Collective** Waves, or organized motion of plasma, are very important because the particles can interact at long ranges through the electric and magnetic forces.

2.2 Examples of industrial/commercial plasma

Plasmas find applications in many fields of research, technology and industry due to its sizable temperature and density ranges. It is being used in industrial and extractive metallurgy, (Gomez et al., 2009) surface treatments such as thermal spraying (coating), etching in microelectronics, metal cutting and welding etc.

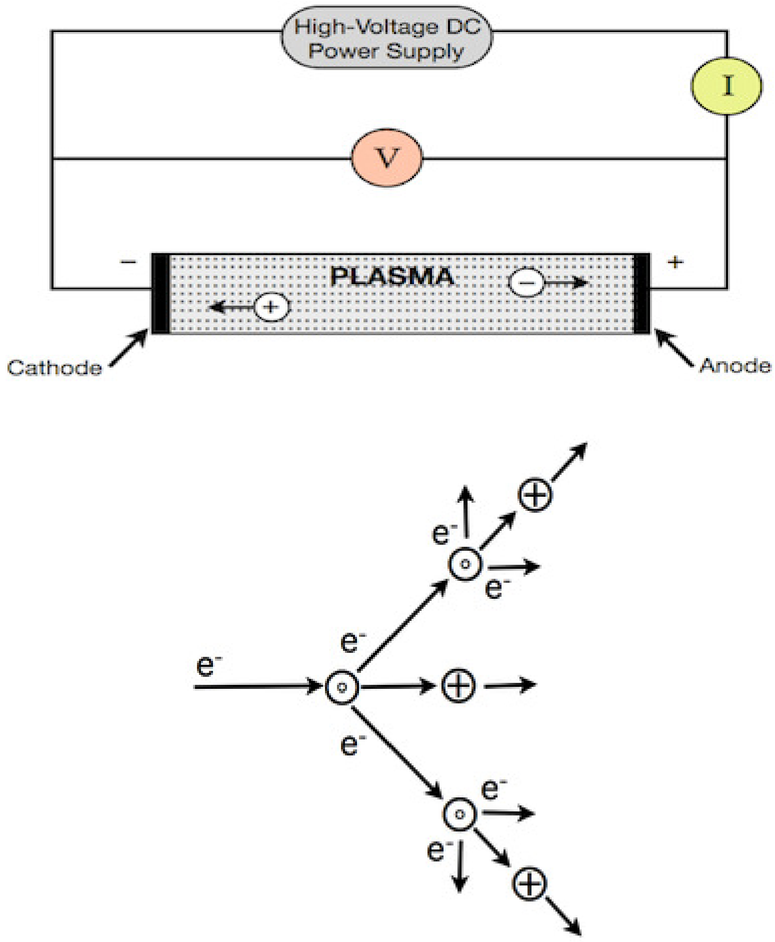

Figure 1: Cascade process of ionization. Electrons are ‘e–’, neutral atoms ‘o’, and cations ‘+’

The plasma torches and plasma arc technology have been (Pourali, M. 2010) used in a variety of industrial, military, space and other applications such as:

1) **Space Programs:** Over forty years ago, as one of the first applications of plasma arc, NASA developed this technology to simulate the re-entry temperature and tested the space shuttles heat shield capability.
2) **Waste Disposal:** United States Navy shipboards and a few of the cruise liners use plasma torches for destruction of their daily solid waste. In addition, several wastes to energy plants are operational in Japan.
3) **Remediation of Radioactive Waste:** Highly radioactive waste is mixed with glass particles and exposed to plasma torches and heated to produce a molten glass. After the mixture cools, it forms a stable glass and traps the radioactive elements and prevents them from moving through the air and leaching to ground water.

Other applications of plasma arc technology include medical waste destruction, asbestos destruction, PCB destruction, melting incinerator ash, heavy metals cutting and melting scrap metals.

2.3 Plasma Gasification of wastes

Plasma gasification is an efficient and environmentally responsible form of thermal treatment (Dighe Shyam V., 2008) of wastes which occurs in oxygen starved environment so the waste is gasified, not incinerated. Predominantly, the metals and non-combustible inorganic components are melted and captured in an environmentally benign slag, which can be used as construction aggregate. Westinghouse Plasma Corporation (WPC) has developed a plasma gasification system which uses plasma heat in a vertical shaft cupola adopted from the foundry industry. The power of plasma gasification makes it environmentally clean technique. Plasma Gasification Plant (PGP) projects (Evans Steve D, 2009) 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.

The gasification takes place in a closed plasma chamber called the plasma reactor which is a sealed, stainless steel vessel filled with or ordinary air. A 650-volt electrical current is passed between two electrodes; this rips electrons from the air and creates plasma. The plasma reactor does not discriminate between any types of wastes. The only variable is the amount of energy that it takes to destroy the waste. Consequently, no sorting of waste is necessary and any type of waste, other than nuclear waste, can be processed.

The gas from the reactor has a low to medium calorific value, and is therefore suitable as fuel for a gas fired power generation unit. However, after leaving the reactor, the gas is still contaminated with a number of undesirable compounds, such as hydrogen chloride and metal particulates, that can cause damage to machinery and the environment. The gas is therefore cleaned through various process equipments. The cleaned gas, similar in quality to natural gas, is then fed to a compressor and storage facility ready for use. The most typical use of the gas is as fuel for power generation, although it can also be used as a feedstock for chemical processes i.e. the production of methanol. When used as a fuel for power generation, more power is usually produced than is consumed by the gasifier.

2.4 Technological Developments

The Plasma Gasification Process is not primarily an Energy from Waste (EfW) or Waste to Energy technology. There are other more efficient, and potentially cheaper ways to produce Energy from Waste. PGPs suffer a high sacrificial load from the use of power at the electrodes to generate the plasma, and energy is also expended before the MSW reaches the plasma zone in the gasifier in chopping up and ensuring that the particle size of the waste is quite small. For this reason they do expend a large proportion of the power generated just in maintaining their own internal power demand. A plasma electrode-type plasma spray gun, which can generate a high temperature and clean plasma jet (Osaki et al., 2002) by injecting various materials into the center of the arc column, has been developed. It was clarified by the studies of the application feasibility of plasma spray gun that the effects of powder loading on the plasma jet was very stable and not contaminated by electrode materials, i.e. clean, and the extent of the jet temperature decrease was a little, i.e. about 1000 K. World wide studies are in progress to use Plasma Gasification Process for the waste disposal with energy generation.

3. Environmental Sustainability of Plasma Gasification of Municipal Solid Waste

The Georgia Tech PARF lab conducted several tests (Pourali, M. 2010) 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. Following sections present summary of some of the Georgia Tech PARF lab experiment results (courtesy: Dr. L. J Circeo) are as follows:

1) MSW Weight Loss from Plasma Processing: Table-4 shows the percentage weight loss of the MSW after plasma processing, where in experiment 3, significant amount of soil was added to the mix and as expected, weight loss was significantly less than the other two experiments.

Table 4: MSW weight loss from Plasma Processing

Experiment No	Initial Weight (lbs)	Final Weight (lbs)	Weight Loss (%)
1	36.1	5.9	84
2	28.5	5.5	81
3	103.8	42.1	59

2) MSW Volume Reduction through Plasma GasificationProcess: Table-5 shows the percentage volume reduction (Pourali, M. 2010) of the MSW after plasma processing. Significant amount of soil was added to the mix in experiment 3, and consequently the volume reduction was reasonably different comparing experiment 1 & 2.

3)

Table 5: MSW volume reduction through Plasma Processing

Experiment No	Initial Volume (in3)	Final Volume (in3)	Volume Loss (%)
1.	1,621	67.9	95.8
2.	1,801	63.3	96.5
3.	4,233	483.8	88.6

4) Toxicity Leaching Tests Results: Table-6 show the results of standard toxicity characteristics leaching of vitrified glass for experiment with out soil and experiment with soil respectively

Table 6: toxicity leaching results of vitrified glass

Heavy Metal	Permissible Concentration (mg/l)	Measured Concentration without Soil (mg/l)	Measured Concentration with Soil (mg/l)
Arsenic	5.0	BDL (0.1)	BDL (0.1)
Barium	100.0	0.47	BDL (0.1)
Cadmium	1.0	BDL (0.1)	BDL (0.1)
Chromium	5.0	BDL (0.1)	BDL (0.1)

Lead	5.0	BDL (0.1)	BDL (0.1)
Mercury	0.2	BDL (0.01)	BDL (0.01)
Selenium	1.0	BDL (0.2)	BDL (0.2)
Silver	5.0	BDL (0.1)	BDL (0.1)

5) Output Gas Composition: Table-7 shows the output syngas compositions for experiment without soil and with soil respectively

Table 7: Output syngas composition

Output Gas	**Experiment without Soil (PPM)**	**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

6) Flue gas emission from Mihama Mikata, Japan, PGP plant for MSW: Table-8 shows the flue gas emission results (Hitachi Metals) at Mihama Mikata Japan PGP Plant

Table 8: the flue gas emission results at Mihama Mikata Japan PGP Plant

Item	Unit	Regulation value	Measured value 1	Measured value 2
Dust	g/ Nm3	0.15	< 0.003	< 0.002
HCL	ppm	430	39	22
NOx	Ppm	250	62	82
Sox	ppm	--	<1	<2
CO	ppm	--	29	27
Dioxins	ng-TEQ/ Nm3	0.5	0.00059	0.00067

3.1 Environmental sensitivity of electricity generation from different processes

The rate of Carbon dioxide emission (Circeo et al., 1997) per MWH of electricity produced from different processes is depicted in table 9

Table 9: CO_2 emission per MWH of power generation

S. No.	**Power Generation Process**	**Ponds of CO2 Emission/MWH**
1.	MSW Incineration	2,988
2.	MSW Plasma	1,419
3.	Coal	2,249
4.	Natural Gas	1,135
5.	Oil	1,672

3.2 Plasma Gasification a sustainable solution for Municipal Solid Waste Management in Madhya Pradesh, India

The local bodies are the authorities for the proper management of the Municipal Solid Waste in the State of Madhya Pradesh, India. Almost all the local bodies are practicing the open dumping of the MSW in the outskirt of the township. Open dumping creates Environmental Problems & huge land is required for its disposal through engineered trenching. The quantity and composition of the waste contributed a lot for the selection of the management solution. In fact, selection of a method of management of waste management facility is very ticklish and multi-disciplinary issue and involves various environmental, economical and community aspects. Hence, the logical algorithm as perceived to be followed before earmarking a full-fledged solution.

3.3 Waste management criteria

There is an emerging global (Rathi Sarika, 2007) consensus to develop local level solutions and community participation for better MSW management. Emphasizes has been given to citizens' awareness and involvement for better (Beukering et al.,1999) 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 (Maimone, M., 1985) concluded that composting was the best option of waste management. Study for the United Kingdom concluded that refused derived fuel (Powell, J.C., 1996) 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 integrate the best feasible method of waste management in State of Madhya Pradesh, India 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 (Varma, Dr. R. Ajayakumar, 2009) and geophysical background of the location. The Plasma Gasification (Lisa Zyga, 2012,) Process (PGP) seems to be a realistic solution for the MSW disposal in the State. It is a disposal process, that can get rid of almost any kind of waste by eliminate existing landfills, and produce a clean energy.

3.4 Land requirement criteria

The land and transportation facilities are basic requirement for MSW management. As per the provisions of Municipal Solid Waste (Management & Handling) Rules, 2000, the landfill site shall be large enough to last for 20-25 years. 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. Table-10 shows the assessment of the land requirement for the landfill site and the land requirement for the PGP.

3.5 Sustainability criteria

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 hence reducing the payback period. Typical plasma gasification for waste to energy plant with a feedstock of 3,000 MT of MSW per day is estimated that the installation cost over $400 million (Rs 1800 Crores) that will generate about 120 MW (Rs 15 Crores per MW) of electricity (Circeo et al., 1997). Estimation for a 2,000 MT of MSW per day (Blees,Tom 2008) 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 (Circeo et al., 1997) 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 both. This implies that similar to any other new technology, the cost will decrease significantly after the commencement of mass production. Table-11 shows the assessment of power generation from un-segregated MSW in the State of Madhya Pradesh through PGP.

Table 10: Assessment of the land requirement for the landfill site and for the installation of PGP in the State of Madhya Pradesh

S. No.	**Type of Local Bodies**	**Quantity of MSW (MT/d)**	**Land required for disposal in the landfills (ha) (as per the provisions of MSW rules, 2000 for 20 years)**	**Land required for installation of PGP (ha)**
1.	Municipal Corporations	2586.01	517.202	78
2.	Municipal Committees	1148.678	269.542	41
3.	Nagar Panchyats	681.192	474	71
4.	Cantonment Boards	45.2	12	2
	Total	**4461.08**	**1212.744**	**202**

Table 11: Assessment of net power generation through PGP in the State of Madhya Pradesh

S. No	**Type of Local Bodies**	**MSW generation MT/hour**	**Electricity generation from PGP (Kwh)**	**Electricity consumption for PGP (Kwh)**	**Net power saving (Kwh)**
1.	Municipal Corporations	108	88128	12960	75168
2.	Municipal Committees	48	39168	5760	33408
3.	Nagar Panchyats	28	22848	3360	19488
4.	Cantonment Boards	1.8	1468	216	1252
	Total	**185.8**	**151612**	**19272**	**132340**

4. Results and discussion

Municipal Solid Waste Management is a great challenge to the Town Planners, Waste Managers and Civil Engineers. The quantity of Municipal Solid Waste generation is increasing and availability of land for the landfills in decreasing year by year 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;

1. The average Municipal Solid Waste generation from 342 local bodies of the State of Madhya Pradesh, India is around 4500MT/day (Table-1).
2. The percentage of plastic waste (Patel et al., 2011) present in municipal solid waste varies from 1% to 8%. The waste from smaller localities contains lower quantities of plastic components (Table-2). The average rate of plastic waste generation throughout the State does not exceed 5%, but its presence contributes towards creating environmental problems.
3. As depicted from Table-3, the plasma resembles with the gaseous state of matter but differs in many ways.
4. As depicted from Table-4 & 5, the Plasma Gasification Process of Municipal Solid Waste is a proven technology in which the weight reduced by more than 80% and the volume of organic matter reduced by more than 95%.
5. The vitrified glass generated as residue from Plasma Gasification Process is environmentally safe for toxicity leaching, Table-6. The vitrified glass contains mainly silica (sand, quartz), CaO, Fe_2O_3, and Al_2O_3 and can be used for the construction work.
6. The PGP out put gas is Environmentally (Dighe Shyam V., 2008) safe as depicted in Table-7, the flue gas emissions are also within prescribed limit, Table-8, the process is environmentally safe in terms of rate of Carbon dioxide emission (Circeo et al., 1997) per MWH of electricity produced in comparison to different processes as depicted in Table-9.
7. As depicted in Table-10, the land requirement for management of Municipal Solid Waste in the State through land fills is around 1213(ha), as per the provisions of MSW rules, 2000 for 20 years which will reduce to 202 (ha) for Plasma Gasification Process. The reduction in the space required for un-segregated MSW management by about 84%.
8. As estimated in Table – 11 The Plasma Gasification Processing plants will generate 151 MW of electricity from MSW out of which 19 MW will be utilized in the process and there will be a saving of around (132340x24) 3176160 units per day for the use by the local utility through national grid. At the price of Rs 3.9 per kWh, the revenue generation from energy generation would be Rs12.3 million (Rs 1.23crores) per day.
9. 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. Hence, there will be saving of 596250 liters of oil or 1125 MT of Coal per day. It has been estimated that one ton of MSW combusted rather than land filled reduces greenhouse gas emissions by 1.2 MT of carbon dioxide. Hence, there will be reduction of 5400 MT/day of land filled greenhouse gas emissions.

The Municipal Solid Waste management is a challenge for the Civil Engineers, Town Planners and the Local Bodies due to its increasing quantity and limited land resources. This is the reason that most of the latest efforts focus on "Zero Waste" and/or "Zero Landfilling" which is certainly expensive (Shekdar Ashok V., 2009) for weaker economies. Around 55% load on MSW landfills can be reduced by utilizing the Refuse Derived Fuel in the Cement Industries. It is a better option for the eco-friendly disposal and for recovering its energy potential, but it has area limitations. The comprehensive method of MSW management is out of reach (Kumar Sunil et.al. 2009) of the small local bodies due to financial constraints. Hence, developing countries, though poor should develop area-specific solutions to their problems (Henry et al., 2006) 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 (Tom Blees, 2008) of disposing MSW. Municipal solid waste is considered as 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. The solution is defined as “Prescription for the Planet” the painless remedy (Blees Tom, 2008) for our Energy & Environmental Crises. 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 (Blees Tom, 2008) 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 the oil companies. Plasma converters represent the ultimate in recycling; making virtually 100% of the waste (Blees Tom, 2008) a household normally produces into usable 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 crud oil, a mislabeling of plasma gasification technology as another type of incineration, the competing low cost of opening new landfills and a lack of government sponsored development and pilot projects, have contributed to the lack of progress in development and utilization of this technology.

The sustainability of any solid waste management system depends (Pradhan Upendra Mani, 2008) on numerous factors; however, the most important factor is the will of the people to change the existing system and develop something better. Adoption of latest technologies have to be taken into consideration while selection of a waste management system. However for any waste management to be successful, the government should step up and take the required initiatives. Even though financial constraints are a part of the system, the government can make a formal and sincere commitment for eliminating garbage from the planet.

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