http://ijopaar.com; 2016 Vol. 3(1); pp. 11-17

Role of Plasma in Disposing the Plastic

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Date of revised paper submission: 19th July 2016; Date of acceptance: 31st July 2016
Date of publication: 14th August 2016; Impact Factor: 3.598; Quality Factor: 4.39
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Abstract

These days we are facing many problems related to pollution especially increase of pollutants in the atmosphere. Disposal of waste material without harming environmental conditions is the main objective of today. The rapid rate of urbanization in India has led to increase plastic waste. Bio-medical waste contains large amount of plastic waste, particularly plastic bags and PET bottles, metallic/ plastic syringes etc. being littered on the landscape of India. The use of plastic in India is going to be doubled in the next coming years as it is replacing conventional materials like metals, glass, cotton, wood and paper. Most of the plastic materials in India are being used in packaging in the form of films, pouches, carry bags, and containers, etc. Plastics do not degrade and decompose naturally so for that different technique can be used in which the most important is plasma pyrolysis and gasicification. Plasma pyrolysis is the disintegration of organic compounds into gases and non-leachable solid residues in an oxygen-starved environment. This technology offer unique solutions to meet the increasing demands of dematerialization and to develop ecological sensible industrial practices like high temperatures, high chemical reactivity, high energy density and ability to process solids, liquids and gases. It is fast quenching and consumes small quantity of gas. This study shows that high ultraviolet radiation flux destroys pathogens and waste to be treated, could be dry or wet and to recover energy in the form of carbon monoxide and hydrogen.

Keywords: Plastic waste, Plasma pyrolysis, Syngas, Energy.

1. Introduction

We are facing many problems due to population explosion and changes in living conditions had a cumulative effect in generation of large amount of waste. Improper disposal of waste creates pollution like land, water, air pollution. Nowadays we are using many ways to reduce pollution basically generated by the disposal of polymers and biomedical waste. In all the processes we found that plasma pyrolysis is the technology which could be found for safe disposal of wastes. It can easily reduce the generation of gases that are directly or indirectly responsible for global warming and other problems related to environment. Plasma is the "Fourth State of Matter," the other three being solid, liquid and gas. This is a distinct state of matter containing a significant number of electrically charged particles, a number sufficient to affect its electrical properties and behavior [1].

2. Different state of matter

The content material for plasma waste treatment is generally municipal solid waste, organic matter or we can include both of them. It also includes biomedical waste and other metallic waste materials. The content of the waste directly effect on the performance of a plasma capacity. Pre-sorting and recycling of useful material before this process required. Large amount of inorganic material like metal and construction waste increases the production of slag. Due to the formation of slag production of syngas (fuel gas mixture consisting of carbon dioxide can be split into carbon

monoxide then combined with hydrogen) decreases. The slag is chemically inert and safe to use.

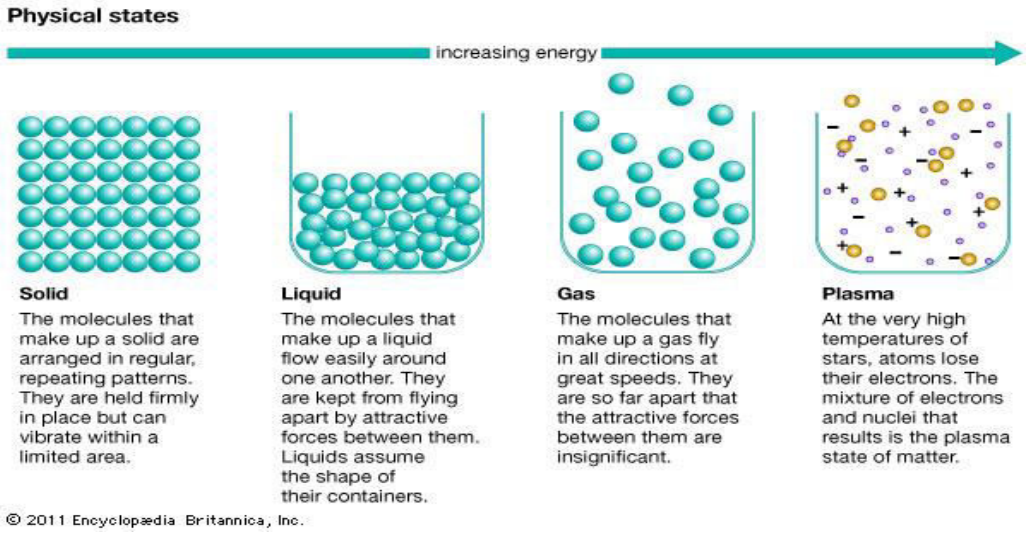

Figure- 1: Different states of matter.

Pyrolysis is basically a thermo chemical decomposition of organic material at high temperatures in the absence of oxygen. It involves the simultaneous change of chemical composition and physical phase, and is irreversible. The word is coined from the Greek word *pyro* "fire" and *lysis* "separating". It is a type of thermolysis and is commonly observed in organic materials exposed to high temperatures. This process is involved in charring wood which start at 200–300 °C (390–570 °F) [2]. It also occurs in fires where solid fuels are burning or when vegetation comes into contact with lava in volcanic eruptions. In general pyrolysis of organic substances produces carbonization gas, liquid products and leaves a solid residue richer in carbon content called char.

The process is used heavily in the chemical industry to produce charcoal, activated carbon, methanol and other chemicals from wood to convert ethylene dichloride into vinyl chloride to make poly vinyl chloride, to produce coke from coal, to convert biomass into syngas and bio-charred, to turn waste plastics back into usable oil [3] or waste into safely disposable substances and for transforming medium-weight hydrocarbons from oil into lighter ones like gasoline. These specialized uses of pyrolysis may be called various names such as dry distillation, destructive distillation or cracking. Pyrolysis is also used in the creation of nanoparticles [4], zirconia [5] and oxides [6]. Therefore we have to reduce such gases which are responsible for global warming.

3. Functioning of Plasma Pyrolysis

Plasma pyrolysis integrates the thermo-chemical properties of plasma with the pyrolysis process. Hot plasmas are particularly appropriate for treatment of solid waste and can also be employed for destruction of toxic molecules by thermal decomposition. Unlike incinerators, segregation of chlorinated waste is not essential in plasma pyrolysis and reduces the volume of organic matter more than 99%.

In an ordinary gas each contains an equal number of positive and negative charges. The positive charges in the nucleus are surrounded by an equal number of negatively charged electrons and each atom is electrically "neutral." A gas becomes plasma when the addition of heat or other energy causes a significant number of atoms to release some or all of their electrons [7]. The remaining parts of

atoms are left with a positive charge and negative electrons are free to move about. Those atoms and the resulting electrically charged gas are said to be "ionized." When enough atoms are ionized to

Figure-2: Hot plasma state

significantly affect the electrical characteristics of the gas, it is plasma. In many cases interactions between the charged particles and the neutral particles are important in determining the behavior and usefulness of the plasma [3]. The type of atoms in plasma, the ratio of ionized to neutral particles and the particle energies all result in a broad spectrum of plasma types, characteristics and behaviors. These unique behaviors cause plasmas to be useful in a large and growing number of applications important to our lives and to the world around us. This shows that plasma is the state of matter obtained by breaking down atoms into ions and electrons by the process of ionization.

4. Role of Plasma

Plasmas can quite easily reach temperatures of 10,000 ^{o}C. Plasma is a form of matter in which many of the electrons wanders around freely among the nuclei of the atom [8]. Plasma has been called the fourth state of matter, the other three being solid, liquid and gas . The electrons in a solid, liquid or gaseous sample of matter stay with same atomic nucleus. Some electrons can move from atom to atom if an electrical current flows in a solid or liquid, but the motion occurs as short jumps by individual electrons between adjacent nuclei. In plasma, a significant number of electrons have such high energy levels that no nucleus can hold them. Plasma pyrolysis technology is the disintegration of organic compounds into gases and non- leachable solid residues in an oxygen-starved environment plasma pyrolysis utilizes large fraction of electrons, ions and excited molecules together with the high energy radiation to decomposing chemicals. Plasma technologies offer unique solutions to meet the increasing demands of dematerialization to develop ecologically sensible industrial practices like high temperatures, high chemical reactivity, high energy density and ability to process solids, liquids and gases.

The increasing volumes of generated waste are a problem and the types of waste being generated further complicate the challenge of disposal. Waste-to-energy is an obvious replacement for medical waste incinerators whose numbers are likely to decline due to more stringent emission standards. The high plastic content of medical waste is looked at as a potential feedstock for a novel pyrolytic reactor [9]. Hence, various technologies and processes are evolved to utilize the waste resource efficiently. Pyrolysis is one of the latest technologies which have the potential to provide valuable liquid and gaseous fuels from these medical waste sources. In this work, thermal pyrolysis of plastic medical waste (plastic syringes) will be performed in a semi batch reactor at a temperature of 450°C for the production of pyrolytic oil. Plasma technologies offer unique solutions to meet the increasing demands of dematerialization to develop ecologically sensible industrial practices like high temperatures, high chemical reactivity, high energy density and ability to process

solids, liquids and gases. In plasma pyrolysis, generation of heat is independent of chemistry of material used. It is fast heating – 5000 ^{o}C can be achieved in milliseconds. It is fast quenching and consumes small quantity of gas. The high ultraviolet radiation flux destroys pathogens and waste to be treated, could be dry or wet. It is possible to recover energy in the form of carbon monoxide and hydrogen.

Plasma pyrolysis is an innovative technology for transforming high calorific plastic waste into a valuable synthesis gas (syngas) by means of thermal plasma. The process developed is a drastic non-incineration thermal process which uses extremely high temperature in an oxygen-starved environment to completely decompose input plastic waste into syngas, composed of very simple molecules: CO, H_2 and small amount of higher hydrocarbons. After pyrolysis of plastic waste in the plasma arc reactor, generated hot gases (syngas) are quenched through water scrubbing to avoid recombination reactions of gaseous molecules; this inhibits the formation of toxic gases. The formation of Syngas has been characterized by Gas chromatograph; residue/ash collected at the bottom of the pyrolyser has been analyzed on Neutron Activation Analyzer [10]. Research results indicated that the developed plasma pyrolyser might be a useful way of plastic waste treatment for energy recovery.

Plasma pyrolysis provides solutions for complete pyrolysis of typical hospital waste such as cellulose polymer dressings, polyvinyl chloride blood bags, polyurethane and silicon rubber gloves & catheters and other disposables made of polyethylene, polymethyl methacrylate, rubber, glass etc. The system provides high temperatures combined with high UV radiation flux which destroys pathogens completely.

5. Instrumentation

For the safe disposal of medical waste, FCIPT of the Institute for Plasma Research has developed a Plasma Pyrolyser which incinerates waste using plasma technology.

Figure-3: Plasma Pyrolyser

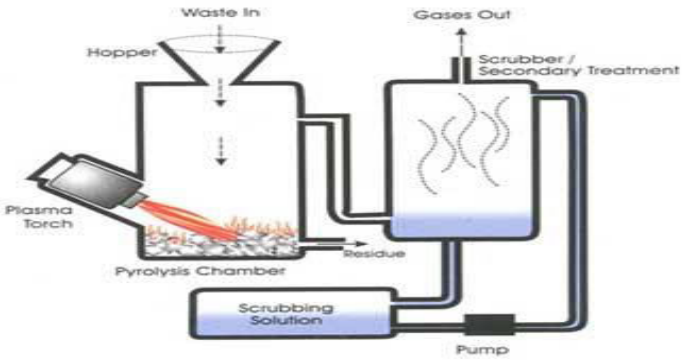

Figure-4: Commercial Plasma Pyrolysis System

6. Technical Brief of Plasma Pyrolyser

Plasma Pyrolysis System incorporates "CASS" (Complete Automated Safety System) that ensures an operating environment, which exceeds any safety norms. The cost of installing, operating and maintaining the Plasma Pyrolysis System is on par with conventional incineration facilities of similar capacity. The inherent simplicity, lack of moving parts, system redundancy, automation, and proven stability of the Plasma Pyrolysis System ensure very high reliability with minimal downtime and maintenance requirements.

Electricity requirement is very low. It is less than 1 kW per kg of charge (approx.). With the exception of start up and shut down, the plasma field is normally sufficient to maintain operating temperatures. With the additions of oxygen generators and co-generation, operating cost are well below and conventional waste processing or energy production systems in the market today.

The Bio-Medical Waste Disposal System is under actual field trials at the Gujarat Cancer Research Institute, Ahmedabad since August 2001. It has been operated for disposal of infected bio-medical waste including plastics, cotton, pathological waste and tissues [11]. The waste is treated for disposal as collected from the hospital without any segregation or pre-treatment. The system was run on a continuous basis for 4 to 5 hours per day. The rate of disposal was 18 - 20 kg/h. In December 2001, the system was tested for more than 100 hours for various combinations of waste material and operating conditions. More than 500 kg.of infected bio-medical waste was treated. The system was run exclusively for treated human tissues and pathological waste. During trials 100 kg of tissues were treated.

The System is microprocessor controlled, allowing one individual to operate one processing reactor systems, including loading and temperature controls. There are many advantages and disadvantages of this method. The main advantages of plasma technologies for waste treatment are:

7. Advantages

- ✓ Clean destruction of hazardous waste [12]
- ✓ Preventing hazardous waste from reaching landfills [13]
- ✓ No harmful emissions of toxic waste [14]
- ✓ Production of clean alloyed slag which could be used as construction material [15]
- ✓ Processing of organic waste into combustible syngas for electric power and thermal energy [16]
- ✓ Production of value-added products (metals) from slag.[17]

8. Disadvantages

Main disadvantages of plasma technologies for waste treatment are:

- Large initial investment costs relative to landfill [18]
- The plasma flame reduces the diameter of the sampler orifice over time, necessitating occasional maintenance [19], [20]

9. Conclusion

Therefore we can say that our motive is that to reduce waste without harming the environment so we can use plasma technique as plasma gasification. With the help of this we can recover gaseous and solid forms. The development of process for disposal of plastic waste using plasma pyrolysis technology and it is a better option for energy recovery. Plasma processing of waste is ecologically good. The lack of oxygen gas stopped the formation of many toxic substances or materials. That is our observation that plastic Waste generated by common man is creating lot of environmental problems and inviting criticism from environmentalists all over the country. To

minimise this problem so many companies and research institute doing there work with their innovative ideas and trying to develop new machines. For degradation of such waste material like polymer, we required the reutilisation of plastic waste.

Therefore through this process we can minimize the pollution generated by the disposal of biomedical waste and try to convert into maximum amount of hydrogen gas.

References

[1]. Tonks, L., 1967; The birth of plasma, Amer. J. Phys: 857-858.

[2]. Burning of wood, InnoFireWood's website. Accessed on 2010-02-06.

[3]. http://www.alternativesjournal.ca/science-and-solutions/plastic-oil

[4]. Pingali, Kalyana C., Rockstraw, David A., Deng, Shuguang, 2005; Silver Nanoparticles from Ultrasonic Spray Pyrolysis of Aqueous Silver Nitrate, Aerosol Science and Technology: 1010–1014.

[5]. Song, Y. L., Tsai, S. C., Chen, C. Y., Tseng, T. K., Tsai, C. S., Chen, J. W., Yao, Y. D., 2004; Ultrasonic Spray Pyrolysis for Synthesis of Spherical Zirconia Particles, Journal of the American Ceramic Society: 1864–1871.

[6]. Hoda Amani Hamedani, 2008; Investigation of Deposition Parameters in Ultrasonic Spray Pyrolysis for Fabrication of Solid Oxide Fuel Cell Cathode, Georgia Institute of Technology.

[7]. Letter from H. M. Mott-Smith to A. M. Bueche, Apr. 20, 1967 (on file at Communications Operation, General Electric R&D Center, Schenectady, NY).

[8]. S. C. Brown, "A short history of gaseous electronics," in Gaseous Electronics, vol. 1, M. N. Hirsh and H. J. Oskam, Eds. New York: Academic, 1978, pp. 1-18.

[9]. J.M. Burton, 1998; Sustainable waste management-a case study from the UK water industry, Water Sci Technol: 38, 51–58.

[10]. C.A. Boyle, 2000; Solid waste management in New Zealand Waste Manage: 20, 517–526.

[11]. H. Huang, L. Tang, 2007; Treatment of organic waste using thermal plasma pyrolysis technology Energy Conv Manage: 48, 1331–1337.

[12]. Tendler, Michael, Philip Rutberg, Guido van Oost, 2005; Plasma Based Waste Treatment and Energy Production, Plasma Physics and Controlled Fusion: 47 (5A) A219. doi:10.1088/0741-3335/47/5A/016. Retrieved 2013-03-19.

[13]. Tendler,Michael, PhilipRutberg, Guido van Oost, 2005; Plasma based waste treatment and Energy Production, 47, 219-220.

[14]. Lemmens, Bert, Helmut Elslander, Ive Vanderreydt, Kurt Peys, et al 2007; Assessment of Plasma Gasification of High Caloric Waste Streams, Waste Management, 27 (11), doi: 10.1016/ j.wasman. 2006. 07. 027. Retrieved 2013-03-20. 1562-1569.

[15]. Mountouris, A., E. Voutsas, D. Tassios, 2008; Plasma Gasification of Sewage Sludge: Process Development and Energy Optimization, Energy Conversion and Management, 49 (8), doi: 10.1016/ j.enconman. 2008.01.025. Retrieved 2013-03-20: 2264–2271.

[16]. Leal-Quirós, Edbertho, 2004; Plasma Processing of Municipal Solid Waste, Brazilian Journal of Physics, 34 (4B) Bibcode: 2004 BrJPh. 34.1587L. doi:10.1590/S0103-97332004000800015. Retrieved 2013-03-20: 1587–1593.

[17]. National Cheng Kung University - Tainan, Taiwan. PEAT International. Retrieved 2009-04-09.

[18]. Williams, R.B., Jenkins, B.M., Nguyen, D., 2003; Solid Waste Conversion: A review and database of current and emerging technologies (PDF) (Report). University of

California, Davis, Department of Biological and Agricultural Engineering. p. 23. Archived from the original (PDF) on 2007-04-15.

[19]. Czekaj, Laura, 2008; Mechanical problems plague Plasco. Ottawa Sun.

[20]. AFSOC makes 'green' history while investing in future. US Air Force Special Operations Command. Retrieved 2011-04-28.

[21]. Khare, Richa 2011; Determination of atmospheric conc. of PAH's, International. J, Chemical Sciences: 432-442.

[22]. Tyata, R. B. et al., 2016; Electrical Characterization of Dielectric Barrier Discharge, International Journal of Pure and Applied Researches, 2016 Vol.1(1), pp. 01-08.

[23]. http://ijopaar.com/files/CurrentIssue/A16101.pdf