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THE SUITABILITY OF THE INNOVATIVE TECHNOLOGY OF PLASMA PYROLYSIS FOR DISPOSAL OF BIOMEDICAL WASTE IN THE CITY OF AGRA (INDIA)

Engineering

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ABSTRACT

The plasma pyrolysis technology has emerged as the latest alternative to incineration technology for disposal of biomedical waste. The incineration technology has always been opposed by the people who live in the nearby area of the installation of the system. It is because of the pollutions emerging from the emissions. Though many manufactures of incinerator plants have claimed that their systems are capable to achieve all emission standards prescribed by CPCB (India), yet the fear of being contaminated is so deeply rooted in their minds that the general answers from the people is that the incineration system should not to be installed in their own area. There is stiff opposition from the general people. Now in such a situation the system of plasma pyrolysis has emerged as a ray of hope which provides a great solace to the people. Plasma pyrolysis is the safest technology for disposal of biomedical waste. The peculiarity of the system is that the plasma produces very high temperature which kills the bacterial spores which are generally very hard to kill and the hot gases are cooled down so quickly that the recombination reaction is avoided and thus the creation of POPs such as dioxins and furans is restricted.

KEYWORDS

Biomedical Waste, Plasma, Pyrolysis, Incineration, Disposal

INTRODUCTION

The City of Agra has been fortunate enough to have been selected for the development under the smart City Programme. A major problem of Agra City is the poor management of biomedical waste. Now Agra Municipal Corporation is planning to use high tech project for up gradation of biomedical waste management and put check on irregularities in the garbage collection, transportation and disposal of waste in the city. [1]. Agra Municipal Corporation has always adopted the path of innovation for offering good quality public life to the citizens of Agra. There is only one biomedical waste disposal plant in Agra which has issued several notices to the concerned authorities for shutting down the plant [2] .In this situation it is convenient for Agra Municipal Corporation to install the system of plasma pyrolysis technology for disposal of biomedical waste. The technology of plasma pyrolysis for disposal of biomedical waste has been included by the MOEF&CC in the category of an accepted process of incineration. A gazette has been brought out with the notification accepting this new innovative process in the incineration category in the year 2016.

PLASMA STATE

Generally the common people have been aware only about the three Forms of matter e.g. (I) the matter in firm and stable shape (Solid) (II) The matter that flows freely (Liquid) (III) The matter that is air-like and expands to fill any space available (Gas). The fourth form is plasma which is the ionized state of matter. It is well known that the matter consists of atoms. Two or three atoms combined together make molecules. The atom is made of electrons which move around its center which is known as the nucleus. The nucleus consists of neutrons and protons. The process of ionization removes the electrons from the bondage. When the bondage is broken then the resultant mixture of electrons with neutrons and protons come into existence which is called the plasma. Plasma is the fourth state of matter because the properties of plasma are different from the properties of solids liquids and gases. The plasma exists in the universe in abundance. The sun, stars and other interstellar matter are the manifestation of plasma. It is well known that when any matter e.g. Solid liquid or gas is exposed to plasma, the physical, chemical or metallurgical change occurs in the materials.

Historical Background (In Global Perspective)

According to Neema et.al (2002) the historical reference of plasma arc heaters may be traced back to the period during the early 1900s when in chemical industries acetylene was manufactured from the natural gas by using plasma heaters. Later in 1960, the plasma arc heaters drew the attention of scientists of the United States NASA when they selected plasma arc heating technology for simulating and recreating intense temperature which the spacecraft had to encounter during their reentry into the atmosphere of the earth. After that many small scale plasma heater processes were built in 1970s. During 1970s many small scale plasma heaters processes were built. During 1980s the technology further developed and many large-scale industrial plants were built.
Ganesh Prasad et.al have enumerated the names of several large scale companies which are contributing to the development of plasma arc technologies these are:

(i) Westinghouse Environmental Service at USA. This company built a prototype unit of DC arc incinerator in 1987.
(ii) Plasma Energy applied technology Inc. USA.
(iii) Plasma Pole, France.
(iv) Siemens, Germany
(v) Pyrolysis Systems Inc. Canada
(vi) Electrical Industry research Institute in Hungary
(vii) Reteach Incorporation in California

Historical Background (In Indian Perspective)

In India the whole plasma technology is directly related with the Department of Atomic Energy. Other institutions in this field are the FCIPT, institute of Plasma Research and Centre for Plasma Physics etc.

Dr. Shashank Chaturvedi, (2017) Director, Institute for Plasma Research, in his message under the caption “message from Director” has enumerated the names of various sectors for which their institute has developed plasma technologies e.g. (1) Textile (2) Heat Treatment (3) Waste Management (4) Nano particle production and (5) Plasma medicines. Mr. Vishal Jain the scientist of FCIPT has discussed the researches for developing 1 KW Microwave plasma Arc, which is going on in FCIPT (Published in plasma processing update, A news letter from the FCIPT, IPR issue 69 (Jan-June 2014) FCIPT has successfully established and operating plasma pyrolysis waste disposal systems at eleven different locations in the country which are: (i)Goa(ii)Sikkim(iii)Andaman & Nikobar,(iv) Himachal Pradesh (v)Hyderabad (vi) Gujarat (vii)Jammu &Kashmir(viii) Uttarakhand (ix)Kerala (x) Haryana(xi) Tripura. FCIPT has also transferred Plasma Pyrolysis Technology to M/s. G.P. Green Energy Systems Pvt Ltd, Kolkata. As the system of plasma is new and innovative, the literature in this field is not sufficiently available. However some important research papers can be found. Joachin Heberlien et al. (2008) have described that plasma waste treatment over the past decades has become a more prominent technology because of the increasing problems with the disposal and because of the realization of

opportunities to generate valuable ex-products. Plasma vitrification of hazardous slags has become a commercial technology for several years [3]. Gomez E, Amutha Rani et al.(2009) have observed that there have been continued advantages in the application of plasma technology for waste treatment and this is now a viable alternative to other potential treatment / disposal options[4]. Puncochar MB.Ruj et.al (2012) have described that plasma pyrolysis has a number of unique advantages over the conventional pyrolysis. It provides high temperature and high energy for reaction. Some reactions occur that do not appear in conventional pyrolysis [5]. S.K Neema et.al,(2002) first of all presented a comprehensive description of the design and the full process of operation including the schematic diagram and proved by calculations that the process is economically viable[8]. In the year 2017 the CPCB (India) issued the guidelines for the plasma pyrolysis process and also suggested some modifications in the design of the system[9]. C Madhavipadma et.al. (2018) has observed that the system of plasma pyrolysis is a ray of hope which provide a complete solution to destroy hospital waste safely [10].

The description of the plasma pyrolysis system:

The plasma pyrolysis process can conveniently be divided into eight subsections, e.g.
(I) Plasma torch (ii) Power supply (iii) Gas Injection System (iv) Feeder (v) The primary chamber (vi) secondary chamber (vii) scrubbers (viii) Pump and ID Fan.

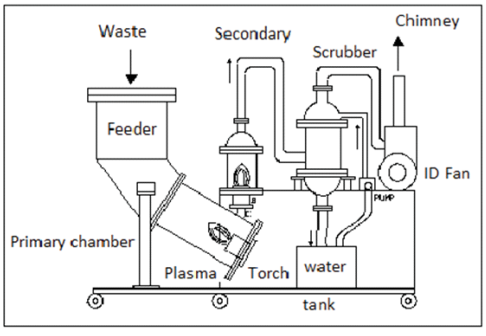

Figure 1: Plasma –Pyrolysis-Reactor (source: CPCB, Plasma Pyrolysis Technology October 2016 page 5)

(1) The Plasma Torch:
(i) The most popular torch is the graphite plasma torch for biomedical waste disposal.
(ii) The plasma torch consists of one anode and two cathodes.
(iii) The shape of the anode is tube-like and the shape of the cathode is rod-like.
(iv) The electrodes are placed on the appropriate support.
(v) The anode moves around the cathode in a circular but with sharp Cornered deviations.
(vi) The electrodes are positioned at 90^0 angles.

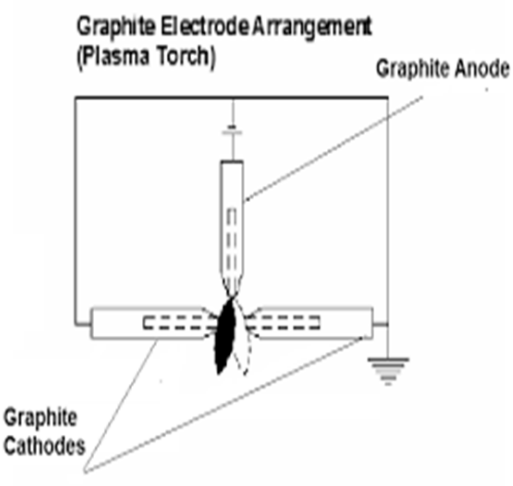

Figure 2: Plasma Torch (source: CPCB, Plasma Pyrolysis Technology October 2016 page 6)

Advantages of Graphite Plasma Torch are as follows:-
The notable advantages are:
(i) The cooling of the electrode is not required.

(ii) There is no loss of energy in the form of heat which would have been lost in case of cooling requirements.

(iii) The peculiar aspect of this process is that the gas flow is not required for striking and maintaining the plasma.

(iv) The other important benefit is that the graphite plasma torch generate non-transfer arc.

(2) The Power Supply:
(I) In order to produce plasma arc among these electrodes, the DC power is supplied.

(ii) With this process, the electrical energy is converted into the form of thermal energy.

(iii) The thermal energy is utilized for raising temperature of the reaction zone inside the primary chamber where process of pyrolysis starts.

(iv) A very good but sophisticated power supply device has been designed and developed by the scientists of FCIPT, Institute of Plasma Research (Indigenously). This is fabricated for 200 ampere and 125 volt power supply.

(3) Gas Injection System:
(i) Through the torch, nitrogen gas is introduced forcefully into the system provided in the first chamber.

(ii) With the device provided in the torch, compressed air (may be dry air or in steam form) also is pushed forcefully into the primary chamber pointing towards the reaction Zone).

(iii) The facility of Rota meter is provided for controlling the gas flow.

(4) Feeder:
The feeder has the following features:
(I) The feeder is kept inclined, so that the waste may slip down smoothly.

(ii) The feeder is unique in the sense that the door for feeding is opened and closed hydraulically. At the time of feeding the door is opened and immediately after the feeding is completed the door is closed automatically.

(iii) A most appropriate sealing is fitted in the door so that there may not be any possibility of leakage of gas outside.

(5) The Primary Chamber:
(I) One plasma torch is provided in the primary chamber.

(ii) In the primary chamber the waste is decomposed due to high temperature and the absence of oxygen inside the chamber.

(iii) The wastes are pyrolysed in this chamber at very high degree of heat ($>1000^0$C)

(iv) In the reaction due to high temperature in oxygen starved zone the syn gases are created.

(v) The syn gases contain carbon monoxide, Hydrogen and methane.

(6) The Reaction in the Secondary Chamber:
The features and reactions in the secondary chamber are as follows:
(i) A separate plasma torch is provided in the secondary chamber.

(ii) The syn gases that come out from the primary chamber are combusted in the secondary chamber at high degree of heat.

(iii) The temperature in the secondary chamber is maintained at $>1100^0$C.

(iv) Some amount of controlled air is also supplied into the chamber.

(v) The gases formed after combustion reactions is primarily Carbon dioxide and water vapor.

(vi) During this process the following chemical reaction take place.

(Cellulose) $C_6H_{10}O5 + Heat =$
$CH_4+C_2H_6+CO_2+H_2+CO$— (i)
$CH_4 + H_2O = CO + 3H_2$ -------- (ii)
$C + H_2O = CO_2 + H_2$ ------ (iii)

(7) Scrubber:
(i) With provision of a fountain device, the PH 12 NaOH solution is circulated for cooling.

(ii) This makes the temperature cooled which is in turn prevents the recombination reaction.

(iii) The design of scrubber is made in such a way that it enables to maintain enough residence of the gas to be cooled down up to the ambient temperature.

(iv) The HCl is also removed from the residual gas by the use of NaOH.

(8) The Pump and the ID Fan:
The ID Fan pushes up the residual gas up to the height of the chimney from where the residual gases are thrown out and mix in outside air.

The CPCB India has issued suggestions for further modification in design of the system for plasma pyrolysis. The notification issued in March 2017 which is as follows:

(1) The primary and secondary chamber:
(i) The primary chamber of the plasma pyrolysis shall have the oxygen starved condition and it should be free from leakages and the secondary chamber shall have the controlled combustion processing atmosphere so that the complete combustion of the synthetic gases emanating from the primary chamber may take place.

(ii) All corners of the primary any secondary chamber shall be rounded so that there may not be any possibility of the formation of dead zones/black pockets.

(2) The Provision of the Torches:
(i) Separate graphite plasma torch, one for the primary chamber and the other for the secondary chamber should be provided.

(ii) There should be automatic switching off/on control so that the temperature fluctuation may be controlled.

(iii) The facility of the view port should be provided for observing the flame of the torch.

(iv) The torch provided in the primary chamber shall be pointing towards the centre of the feed.

(3) The provision of programmable logical control:
(I) There shall be provision of suitable PLC based automatic recording for the parameters e.g., date, time, batch no and other parameters such as temperature in primary and secondary chamber, amount of excess air supplied in the secondary chamber, air flow rate, residing time for saturated gases, scrubber and water temperature etc.

(4) The provision of feeder Cycle:
(i) The feeder cycle should only be started when the adequate preheating temperature has been attained in the primary chamber.

(ii) There should be arrangement of tangential loading so that the material may move down easily.

(iii) A suction arrangement should be provided in feeder section to avoid fugitive emissions during loading process.

(5) The provision of Insulation:
The provision of adequate insulation as a safe guard of the work zone area. Full precautions shall be taken to provide adequate insulation in the system externally to avoid thermal radiation in the area of the work zone.

(6) The provision of stack monitoring System:
The stack monitoring system should be provided for detection of Dioxins and Furans etc.

(7) The need of adequately qualified Operator:
The operator must be skilled and have the required capability of handling the plasma pyrolysis system.

The authorized manufacturer of Plasma pyrolysis equipment must be instructed to modify the design strictly in compliance with the suggestions issued by CPCB (India), which has been described in the above section.

RESULT AND DISCUSSION

If the process of plasma pyrolysis is compared with the process of incineration, it may conveniently be said that the plasma pyrolysis process is a better technology in comparison to incineration. The distinguishable features are:

(i) In plasma pyrolysis the process in the first chamber is performed in absence of oxygen while in incineration the first chamber requires the amount of stoichiometric oxygen which is called the starved air.

(ii) In plasma pyrolysis the process in the secondary chamber is performed with a very little amount of air while in incineration process 150% of excess air is necessarily required.

(ii) In plasma pyrolysis the reside is an inert slag which looks like glass while in incineration process the residue is ash which is thought to be contaminated. The ash is considered to be in the category of hazardous waste.

(iv) In plasma pyrolysis the quantity of the residue is drastically reduced. It amounts to about 6% to 15% of the volume of the untreated waste while in incineration process the residue may be reduced up to 15% to 30% of the volume of the untreated waste.

(v) In plasma pyrolysis, the emissions level fully meet the national or the international standards of emission while in incineration process a very few manufacturing companies have claimed that their incinerators are capable to achieve the prescribed standards.

The comparative advantages of Plasma Pyrolysis as per FCIPT
Dr. SB Gupta, of FCIPT, Institute of plasma research Gandhinagar (Gujarat) has presented the following table for showing the superior standard of emission of plasma pyrolysis in comparison to the accepted standard of CPCB (India). The table for comparison is presented as follows:

Pollutants	CPCB Standards	Emission from Plasma System
CO	< 100 mg/Nm^3	40-85 mg/Nm^3
NOx	< 400 mg/Nm^3	7-25 mg/Nm^3
Particulate Matter	< 150 mg/Nm^3	31-105 mg/Nm^3
Dioxins & Furans	< 0.1 ng/Nm^3TEQ	< 0.1 ng/Nm^3TEQ

On the basis of the above data it may be said that the process of plasma pyrolysis is a superior technology; rather it is an innovative technology.

CONCLUSION

(i) Now it may be concluded that the world will now enter into a new age of the cleanest technology for disposal of the infected waste.

(ii) The general people in India and in so many other countries have been showing their resentment against installation of the incinerators. Now there will be no resentment in the public against installation of the plasma pyrolysis system.

(iii) The temperature of the plasma pyrolysis is very high due to which the bacterial spores which are otherwise very difficult to kill are fully destroyed, the ultraviolet radiation present in the plasma kill all pathogens completely.

(iv) By calculating the energy recovery benefits (as has been done by S.K Neema et.al (2002) it can be concluded that the process of plasma pyrolysis is economically viable.

(v) Thus it may safely be concluded that the process of plasma pyrolysis technology is the most suitable technology for the city of Agra where most of the dignitaries of the World come every year to visit the Tajmahal.

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