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Waste Generation Perspective of Gorakhpur City and Related Waste Treatment Techniques

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Abstract

It will be every beautifull effort to exercise the waste to energy conversion for small cities like Gorakhpur. The present paper basically a small effort to familiarize some thermochemical processes for such cities. In a survey it was found that daily on an average per capita solid waste generation from the residential area of the Gorakhpur city is about 0.270 kg. though the municilple standard(0.375 grams) is quite higher. The present paper deals with all possible waste management technologies and this paper mainly focuses on plasma techniques. Plasma pyrolysis and plasma gasification are advanced processes and they transforms the waste in to useful gases which is a good source of energy. The extremely high temperatures generated by plasma torches have spurred development of their application to waste processing, as they are capable of significantly decreasing the waste volume to a non-leachable residue. Catalytic pyrolysis which overcomes the issues associated with thermal pyrolysis but cost of catalyst used condition the economy of the process. Microwave pyrolysis which is new not due to the fact that microwave energy is used. It is new because microwave energy is used for the destruction of waste materials in to fuels and chemical. It provides fast heating and better control over the temperature.

Keywords: thermochemical processes, , plasma, gasification, pyrolysis, catalyst, microwave.

Introduction

There is great demand of converting the different types of waste into some useful forms such as fuels and chemicals. However, the waste materials upon which the present paper is going to focuss is based on Gorakhpur city of uttar Pradesh state of india. Gorakhpur is the prime whole sale and retail commercial centre for the surrounding rural areas it is also the middle income group dominant city(50% habitate belong to MIG)[1]. In residential solid waste generation, the middle income group is at the top.

In Gorakhpur city the waste generation amounts to be 350 tons per day and will increase as the population grows and access to consumer good increases. There are 230 hospitals and nursing homes in the city. Many of these considered as waste generated as solid waste and not biodegradable waste[2]. However, modern situation of the worlds have enough techniques to convert these non-biodegradable waste into energy. There are different waste management techniques are existing such as landfillig, mechaniucal recycling, chemical(feedstock) recycling and incineration. It should be noted that landfilling is easiest one for handllig waste but space scarcity for disposal of waste are limited now a days. On the other hand landfilling produces leachets and reduce the quality of underground water. Incineration which is nothing but combustion produces heat but is a worst option from global warming point of view . mechanical recycling which is a process of converting the waste(such as plastics, e-waste etc) into virgin one. There is only chemical recycling or feedstock recycling which is the process of converting the waste material into some usefull form of energy in eco friendly manner. The present paper present a grasp on the main techniques such as pyrolysis(catalytic, plsma, microwave) and gasification. These techniqiues have been described in detail in the below hedings. As far as waste material is concerned it include e-waste, plastics, biomedical waste, industrial waste, MSW hazardous waste etc.

Waste generation in Gorakhpur city

Gorakhpur, a low lying and bowl shaped city of Eastern Uttar Pradesh, is rich in the cultural heritage and historical importance. At present the municipal corporation Gorakhpur(MCG) has no solid waste management system in place. The whole soild waste generated is being disposed either along the roads or are being used as landfilling material.

During the survey it was found that daily on an average per capita solid waste generation from the

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residential area of the city is about 0.270 kg. though the municilple standard(0.375 grams) is quite higher.

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Table. 1 Estimated solid waste generation per day in city

Category	Generation amount (in tons)	Percentage
Residential	168.13	57.86
Construction and other	41.4	14.24
Commercial	40.0	13.76
Industrial	40.0	13.76
Industrial	0.53	0.18
Clinical Waste	0.50	0.17
Total	290.56	100

he total quantity of waste generation in Gorakhpur is about 300 million tons per day out of which only 250 MTs per day is being addressed. Houseled and commercial waste compisese the maximum percentage of solid waste generated. The estimated solid waste generation per day in city is shown in table 1[1]. It was found that only 44.73% of total solid waste is of biodegradable nature. The recyclable waste(polyethylene, plastic, paper cartoon) which account 13.97% of total waste are often segregated manually by rag pickers. Whereas construction waste, street sweeping and rain silt are account for 13.8%, 22.49% and 5% recpectively. it is very necessary to know the future amount of solid waste genearation because of technological development which is required to handle these waste in an efficient manner. The following graph shows how the solid waste generation will be growing in Gorakhpur city in near future. It was projected that solid waste generation is countinus then by 2031, about 231 quintals of solid waste in the form of paper, rubber, synthetics, glass, metals, polythene bags, vegetable peels, animal remnants, construction materials, medical wastes and drain silt) will be generated every hour in the city.

Table 2 Future solid waste generation from Residential area

Years	Population	Waste generations in tons
Table 1 Estimated Solid Waste Generation per day in	city	
2011	769452	207.75
2021	944150	207.75
2031	1154044	3011.59

In Gorakhpur city both centralized and decentralized solid waste managfement are being practicised. The centralized waste management waste are not collected in efficient manner which results in overflowing garbage bins at the public collection site. One of the obvious advantages of a decentralized system is the improved aesthetic and hygiene condition in the locality. For the cities like gorakhpur decentralized solid waste management will be more useful. Directly proportional to population increase, the solid waste problem has become one of the prime concerns for the city Government. The efficient collection of waste reduce theoverflowing and sanitary conditions. In this regard a more efficient utilization of scientific invention for sustainable hadling of the waste is required. The present paper basically focesse on thermochemical utilization which is far from combustion technique, to convert these waste into energy.

Waste management techniques

Landfilling

As far as the waste management techniques are concerned landfilling is the simplest. After receiving the waste from centralized or decentralized capturing of the waste it can be successfully diposed. However, The present days situation does not permit the exrvise of landfilling because it occupies space as well as pollutes the under ground water Friends of earth have described earth as 'Dumping rubbish' in the ground or in the waste mountains, and have set out the drawbacks of land fill as :a) Release toxins, b) Threatens our quality or life.

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Incineration

Incineration refers to the combustion of waste materials, which results in formation of residues and gas emission. It is a controlled burning of solid waste at extremely high temperature-often as high as 2000°F.Waste to energy concept refers to an incinerator that incorporates technology to generate power from the heat produced during combustion process. Incineration produces dioxins and furans which are hazardous for health. The process of incineration is somewhat different; utilizing two combustion chambers; gases generated in the first chamber are more completely combusted in the second, providing the primary environmental pollution control. Negative environmental consequences of incineration mostly revolve around air borne mixture [3].

Biological recycling

Biological recycling is a process of recycling which involve degradation by means of bacteria, fungi or algae and is broken down into a biogas,(CO_2 for aerobic degradation and CH_4 for anaerobic degradation) and soggy biomass for plant fertilizer. The biodegradable by–products are then naturally recycled back into cycle of earth. Biological recycling or organic recycling transforms organic waste into a reusable resource through composting. Biological recycling of plastic waste can be divided into two methods, anaerobic digestion (AD) and aerobic composting (AC). Aerobic digestion is the bio-degradation of organic matter in absence of oxygen utilizing anaerobic micro-organisms. The AD process reduces green house gas, is a renewable source of energy and reduces soil and ground water contamination but the main problem associated with AD process is that bacteria are fluid and temperature dependent and have complicated mechanism etc. Aerobic composting uses natural process to increase the rate of biological decomposition of organic materials. Win draw-based and in-vessel technologies are two composting processes, reduces the land fill disposal and green house reduction and increase recycling rate but it is independent of renewable energy production and has continual operations.

Mechanical recycling

Mechanical recycling is a method by which waste materials are recycled into “new” (secondary) raw materials without changing the basic structure of the material. It is also known as material recycling or material recovery. For example for plastics waste mechanical recycling can convert it into new plastic products, often substituting virgin plastics. Feasibility of mechanical recycling depends upon quantity as well as the quality of materials to be recycled.

Chemical recycling/feedstock recycling

The basic idea of the tertiary recycling (Chemical recycling) process is to break up organic substance into smaller organic molecules. This recycling process provides not only a solution for plastic waste management but also develops transportation fuel or feedstock for the production of virgin (new) material [4, 5]. There are efficient thermochemical conversion techniques such as Gasification, pyrolysis (Thermal, Catalytic, Plasma and Microwave) which are used to convert these waste into value added product. It should be noted that thermochemical conversion techniques of waste materials are suitable for organic wastes such as plastics, e-waste, military and other types of waste which contains carbon. Because the thermal treatments are widely accepted for conversion of wastes into fuels(liquid and gaseous fuels) and chemicals.

Thermal treatment of organic materilas

Pyrolysis

Pyrolysis is endothermic, irreversible high temperature phenomenon which requires no oxgen for decomposition of organic waste in to liquid and gaseous fuels. Pyrolysis process produces gas and liquid products and also produces solid residues together with char. Other biproducts of this process are commonly reported, but the list and proportion of each differs depending upon reactor design, reaction conditions, and feed stock. There are various types of pyrolysis: thermal pyrolysis, catalytic pyrolysis, plasma pyrolysis and micro-wave pyrolysis. which have been discussed following.

Thermal pyrolysis

In this pyrolysis process feed stock is heated at high temperature (350-900°C) in absence of catalyst. Typically thermal cracking yields low octane liquid products and gases which re quire further refining for being a useable fuel products. Thermal pyrolysis is implemented under reduced atmosphere, yields liquids waxes, unconverted residues, char and gas[6]. Product yield is highly dependent on process condition employed and feed stock.

Catalytic pyrolysis

Thermal cracking provide high product distribution, polymers require high temperature to breakdown in low molecular weight products also it

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requires high reaction time. T hese are some problem because of that catakytic cracking comes into existence. Less temperature and less time consumption and narrower product distribution makes the catalytic process more economical and attractive. It also increases reaction rate necessitate smaller reactor volume.Catalytic cracking results in production of branched and cyclic molecules and aromatics [7]. Improved selectivity and quality of product are the main features of catalytic cracking[8,9,10]. These are the advantages associated with catalytic processes but some challenges are also present. Catalyst activity can be lost due to coke formation. The rate of reaction, distribution of products, type of upgrading reaction can be altered by the use of heterogeneous catalyst [11, 12].

Microwave pyrolysis

The quality of the end product depends mainly on the ability to control the temperature through the whole feedstock. Waste Organic materials are in general poor heat-conductors, so this is not easily achieved by conventional pyrolysis techniques. The poor quality of the end product prevents reasonable prices to make the process economical viable**.** Microwave pyrolysis is relatively newfield. It provide more even distribution of heat and better control over the heating process. In laboratory studies, it has been used successfully to treat aluminium/polymer laminates with 100%recovery of aluminium present. Microwave pyrolysis not only overcome the disadvantage of conventional pyrolysis such as slow heating and feedstock shredding but also improves quality of final pyrolysis product and same time the energy[18].

Plasma pyrolysis

Plasma pyrolysis integrates thermochemical properties of plasma with pyrolysis process,which takes place in absence or negligible amount of oxygen. It is an alternative ideal suited for toxic wastes and complex waste streams which have recoverable energy content. The high temperature plasma arc greatly reduces the potential for undesirable by products to be generated that are observed in incineration stack gas[13]. The intense heat generated by the plasma enables it to dispose all types of waste including municipal solid waste, biomedical waste and hazardous waste in a safe and reliable manner. Medical waste is pyrolyzed into CO, H_2, and hydrocarbons when it comes in contact with the plasma-arc. These gases are burned and produce a high temperature (around 1200°C). 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 this process. Another advantage of plasma pyrolysis is the reduction in volume of organic matter, which is more than 99%. Based on numerous advantages of plasma technology it is speculated that in the near future, plasma pyrolysis reactors will be widely accepted for toxic waste treatment[14]. By far the most important application of thermal plasma waste treatment is focused on the destruction of hazardous wastes rather than recycling because of economic issues.

Plasma pyrolysis vs conventional pyrolysis

Thermal plasma pyrolysis of organic waste gives only two product streams: a combustible gas and a solid residue. Where as conventional pyrolysis products are a gases, liquid and solid product. The liquid product is a tarry oil consisting of a variety of heavy hydrocarbon compounds; and separation and collection of the oil from other gas and solid products are difficult. Plasma pyrolysis not only destroy the complex waste in an efficient manner but also provides a gas which is known as syn gas can be further used in generator to produce electricity. The combustion heat value of the gas product is in the range of 4–9 MJ/Nm3, so it can be used directly as a fuel in various energy applications such as direct firing in boilers, gas turbines or gas engines. A easy achievement of high and effective processing temperatures in very compact, high throughput and fast response reactors is the characteristics of plasma pyrolysis. it provides Efficient delivery of heat energy for simultaneous rapid promotion of both physical and chemical changes in waste material.

Plasma generators (torches)

Thermal plasma generation can be achieved by direct current (DC) or an alternating current (AC) electrical discharge or using a radio frequency (RF) induction or a microwave (MW) discharge. Discharge produced by DC arc provides a high energy density and high temperature region between two electrodes and, in the presence of a sufficiently high gas flow, the plasma extends beyond one of the electrodes in the form of a plasma jet. DC arc plasma torches are commonly available at power levels up to 1.5 MW. Scale up is possible to 6 MW [15]. RF plasma torches utilize inductive or capacitive coupling to transfer electromagnetic energy from the RF power source to the plasma working gas. They are compact in nature and deliver very high input energy per unit volume. Unlike DC arc plasma torches, there are no locally high temperature arcs, no moving parts and no

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parts subject to wear. RF plasma generators are commonly available at power levels of 100 kW. Scale up has been demonstrated to the 1 MW range [15]. The characteristics of thermal plasma torches have been studied extensively [16,17]. A comparison of the main features of different plasma processes for waste treatment is given in Table 2.

Table 2: Comparison of different plasma processes for waste treatment

Item	DC arc plasma	RF plasma
temperature	5000-10000K	3000-8000K
Electrode erosion	Yes, (1000–3000 h lifetime in inert gas, 200–500 h lifetime in oxidative gas)	No
Cooling of plasma generator and reactor	Required	Required
Plasma ignition	Easy	Difficult
Plasma volume	Small medium	
Gas velocity	High	High
Solid feeding position	Downstream of plasma	Upstream of plasma
Influence of solid feeding on plasma stability	No	Yes
Efficiency of power supply devices	60-90%	40-70%

Plasma gasification

For sustaining the gasification process the fuel should be capable of sustaining their own gasifiction without some other fuel. however, a waste material like industrial waste, household etc. are not capable of holding their own gasification. Some other fuel source must be induced to start their gasification chemistry. For this reason, there is an increasing interest in plasma gasification, an innovative technology for converting waste streams into a valuable synthesis gas and a vitrified slag by means of a thermal plasma. The high temperature of plasma gasification helps to break down the waste material in to synthesis gas containing hydrogen and carbon monoxide. On the one hand, tar, char and dioxins are broken down, resulting in a synthesis gas that is cleaner compared to conventional gasification processes. The inorganic fraction (glass, metals, silicates, heavy metals) on the other hand, is melted and converted into a dense, inert, non-leaching vitrified slag. The synthesis gas can be used to produce electricity, heat and biofuels (*e.g.* Fischer Tropsch diesel)[19].

Conclusion

Thus, considering the graveness of the problem, community participation in waste management has now become imperative. For the Gorakhpur city the different waste management technique which have been discussed above should be practicised. There is no doubt that plasma technologies are very usefull from waste destruction point of view. For Gorakhpur city a plasma pyrolysis or plasma gasification setup should be developed. Cost analysis is required to forcast the expenditure involved. The researchers and scientist should focuss on new technology like plasma pyrolysis, plasma gasification, microwave pyrolysis.the above paper takes Gorakhpur city as a example for putting up the overview of the techniques.

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