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Review Article

Electricity Production from Waste and Solid Waste Management

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Abstract

Reclaimable energy generated from waste is a major source of environmentally sustainable energy that has not been much explored in India. Excessive waste generation and poor solid waste management has led to accumulation of waste in water, on land polluting environment and causing various public health crisis. On the other hand, conventional fuels required for production of electricity is decreasing day by day and it is very essential to find out alternative sources of raw material which can be used as fuel for the production of electricity especially for developing countries with high population like India. Energy recovery from waste constitute to an excellent system of energy which could be replenished as more waste is generated in time. Combustion is one such modern waste-to-electricity generation method technically called as Incineration. It is a high-quality controlled treatment of Municipal Solid Waste (MSW) which is very useful in populated countries like India, because it reduces the amount of waste to be dumped and in return offers wealth in form of energy. However, some drawbacks follows the advantages which include high economic investment along with special attention on the following issues like: volume/quantity of waste produced, heat of combustion of waste, site location, dimensions of the facility, operation and maintenance costs and investment. Disregarding the drawbacks of combustion this paper draws attention toward making sustainable environment and production of electricity for human welfare.

Keywords: *Combustion, Municipal solid waste, Electricity, Public Health crisis*

1. Introduction

Expeditious industrialization and population outburst in India has led to the migration of people from rural area like villages to urban areas like cities and towns, which leads to the generation of thousand tons of MSW daily. The MSW amount is expected to increase significantly in the near future as the country strives to attain an industrialized nation status by the year 2020.

In developing countries like India waste generation is increasing day by day due to boom in industrialization, urbanization and population. This also causes greater amounts of socio-economic and environmental issues due to which both energy systems and waste management systems has to undergo change. These changes are largely in context to environmental considerations posing a threat of global climate change. Fossil fuels are the best natural resources used as the raw materials for electrical energy

generation and the day to day life activities of the people all around the world is solely dependent on the electrical energy, The lifestyle of people in India, is changing gradually which is the cause of huge amount of waste generation. Also, there is almost no segregation of MSW, plastic wastes, commercial wastes, industrial refuses and e-wastes.

Municipal Solid Waste (MSW) contains major fraction of organic matter and minor fraction of inorganic matter. Organic matter possess latent energy suitable for Waste Processing and Treatment technologies. Besides energy production from solid wastes it also provides few additional benefits such as; up to 90% reduction in the solid waste, cost of transportation of waste gets reduced, landfill is reduced providing more land for other purposes and reduction in environmental pollution. However, energy resource viability, utilization and management from waste sources require detailed and adequate waste characterisation.

2. What is Municipal Solid Waste?

Municipal Solid Waste refers to all non-liquid waste, at national level it is defined as the waste consisting of everyday items such as products, packaging, grass, furniture, bottles, food etc. It creates significant health problems and a very unpleasant living condition mainly in urban areas if not disposed safely and appropriately. Along with land it also pollute water sources and the environment open burning of waste may also pollute air.

Figure portraying MUNICIPAL SOLID WASTE

1.1 ***Types of solid waste***

The type and quantity of waste produced in any situation varies greatly. As per survey each person produces 0.5 -1.0 litres of refuse per day [5]. Solid waste can be classified into different types depending on their sources:

a) **Household waste**

Household waste is generally classified as municipal solid waste. This garbage is generally collected from residential and commercial complexes. More than 40% of the waste is not collected at all, 70% of the Indian cities lack adequate capacity to transport it and there is no sanitary landfill to dispose of waste eventually leading to contamination of soil and groundwater.

b) Hazardous waste

Industrial and hospital waste are generally considered hazardous as they may contain toxic substances. Hazardous waste could be highly toxic to humans, animals and plants, they are corrosive, highly inflammable or explosive. India generates around 10 million tonnes of hazardous waste every year example chemicals, pesticides, dye, refining and rubber goods etc.

c) Hospital waste

Hospital waste is generated during the diagnosis, treatment, or immunization of human activities or in research activities. It may include waste like sharps, disposables, anatomical waste, cultures, discarded medicines, syringes, body fluids, human excreta. This waste is highly infectious and can be serious threat to human health.

Some of the factors affecting waste production are;

- The geographical region
- Socio-cultural practices and material levels among affected population
- The stage of emergency
- The packaging of food rations

2.2 Different categories of solid waste include

- Organic waste includes waste from food, animal excreta, which are biodegradable
- Combustible waste includes paper, wood, dried leaves, packaging for relief items etc (domestic waste)
- Non- combustibles includes tins cans, plastic bottles, stones etc(street waste)
- Residue from fires used for cooking (ashes)
- Hazardous waste include oils, battery acids, medical waste
- Bulky waste includes tree branches, tyres etc.
- Carcasses of domestic animals and livestock

3. Various techniques for electricity production from waste

“The waste is Gold if it is properly held.” There are several waste to energy technologies accessible based on the type, quantity and characteristics of waste used as raw material. The required method for energy production demand specific economic conditions, environmental standards distinct temperature range and a precise methodology. For the fulfilment of energy demands most commonly used waste to energy technologies are thermal,

bio-chemical and biological, electrochemical technologies.

3.1. BIOLOGICAL CONVERSION

Biological treatment of waste to energy is much more safe, economical and eco-friendly technologies as compared to the previous thermal technologies.

3.1.1 Composting

Composting method comprises decomposition of organic municipal solid waste by microorganisms under controlled aerobic conditions i.e. in the presence of air under humid and warm environment in a closed compost pit. Composting can be achieved by two different processes namely aerobic and anaerobic composting. The end product of composting is rich in excessive nutrients and humus called compost. This compost semi-solid product is used as a bio-fertilizers in crops and combustible gas consisting a mixture of carbon dioxide and methane called biogas, is used to produce heat and electric energy. 30% villages in India now have electricity and gas stoves for cooking in their house consuming biogas.

3.1.2 Anaerobic digestion

Anaerobic digestion of waste is also signified as a bio-methanation process. In this process biodegradable material is broken down in the anaerobic environment by micro-organism into carbon dioxide and methane (biogas) and few digestion co-products. Pre-treatment of waste includes sorting, moisture content adjusting and size reduction. Anaerobic digestion by micro-organisms include the hydrolysis of polysaccharides, proteins, and lipids into sugars, amino acids and fatty acids. The reaction may be carried out in either batch system or continuous systems, at temperature range of (20 – 40 ϖC) or (50 – 65 ϖC). Biogas can be cleaned and upgraded according to the use to remove hydrogen sulphide , water, CO_2 and particles .

3.2.THERMOCHEMICAL CONVERSION

3.2.1 Gasification OR Pyrolysis

Gasification is a process that converts waste into char, tar and syngas (mixture of hydrogen, carbon monoxide, carbon dioxide, hydrocarbons and methane) via partial combustion process in limited amount of air. Syngas is energy rich content and pass through gas turbine or engine to produce energy and heat. This process reduces about 70% mass of waste . This process needs high temperatures between 750 – 1600ϖC to decompose organic matter and produce either heat or fuel oil or gas, depending on process design and operating parameters. Equipment that are applied in waste gasification are : fixed-bed gasifiers, entrained-flow gasifiers, and fluidized-bed gasifiers. This process is suitable for waste containing high percentage of organic non-biodegradable matter and low moisture content.

3.3 THERMAL CONVERSION

3.3.1 Combustion or Incineration

Incineration of waste is a mass burn technology, using an enclosed device to thermally breakdown combustible solid waste performed at high temperature of around 700-1000ϖC (controlled combustion). The whole process is carried out in three phases i.e. incineration, energy

recovery and control of air pollution. Waste is placed on a grate of the combustor supplied with excess air to combust up to 1,100 metric tonne a day. The supply of air is controlled between the low levels and the high levels. Combustion results in transfer of 65% - 80% of heat content of the organic matter to hot air, steam, hot water, fuel gas and ash. The steam generated is in turn used in steam turbines to generate power.

3.4 CONVERSION

Electro decomposition of organics in the presence of microbes as a charge conducting medium is called as **Microbial fuel cells**. Electrochemical conversion is based on the oxidation–reduction machinery of immobilized microbial cells for generating electricity and bio-hydrogen. Although this technology has not yet much explored worldwide.

4. COMBUSTION: technique to convert waste to wealth

Combustion is the process of direct controlled burning of municipal solid waste in aerobic conditions at temperatures ranging between 700-1000ϖC, producing heat energy, generating light energy, gases and ash. Incineration is suitable for high calorific value wastes.

Waste Characterization	Calorific Value
Paper and cardboard	14.6
Plastic food pack	38.0
Plastic bottles	22.0
Food waste	6.7
Polythene bags	27.3
Polystyrene food pack	38.0
Others	17.6

Table showing waste and their calorific value

Experimentally, about 65 to 75% energy of the organic matter may be restored as heat energy, which can be later utilised for producing power with the help of steam turbine-generators or directly as thermal energy. Net energy yield depends upon the density, composition of the waste, relative percentage of moisture and inert materials which causes to the heat loss. The combustion temperature of traditional incinerators fuelled only by municipal solid wastes are about 760ϖC in the primary furnace and in exceeds of 870ϖC in the secondary combustion chamber. To avoid odour due to incomplete combustion such high temperature is needed but prove to be insufficient to even melt substances such as glass. To overcome the drawbacks of conventional incinerators, some modern incinerators exploit higher temperature up to 1650ϖC using auxiliary fuel, which reduces waste volume by nearly 95% and also converts inorganic metal and glass to inert ash. Incineration plant requires a large setup and huge initial investment.

The combustion plant has various sections performing specific functions.

- Firstly raw MSW burns with the fuel in incinerator leaving behind ashes the

hot steam is carried forward to next chamber of the plant.

- Second chamber is the flue gas cleanser. Here flue gas is often treated with a series of chemical processes and scrubbers which removes pollutants.
- Third chamber is a boiler. It is a piece of equipment which acts as a closed vessel to convert the water into steam .
- Finally this energy of steam is utilized for electricity generation.

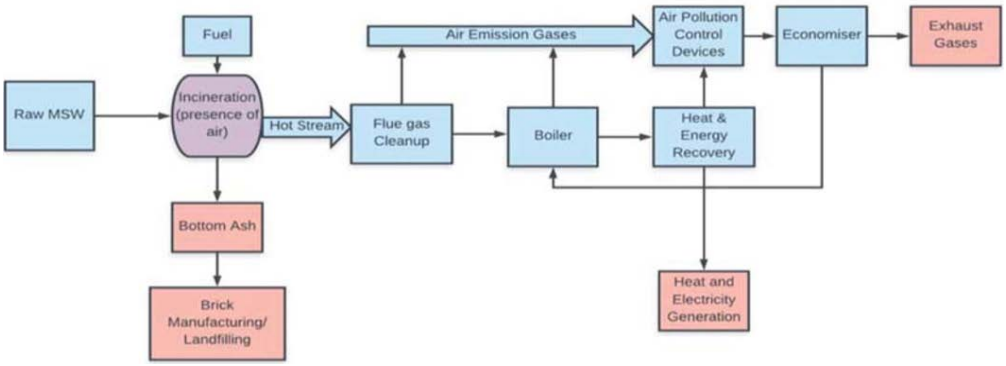

Figure showing procedure of combustion [2]

5. Precedence of Combustion

A considerable advantage of modern solid waste incineration technology is the controlled conversion process and the low dust emissions in the gases, which undoubtedly affects the reduction of the catalytic processes of hazardous substances being produced during the flue gas cooling process and resulting in smaller quantities of flue gas treatment residue.

5.1 Reduction in pollution

Studies have shown that solid waste combustors produces less pollution than landfills. Waste accumulated on land released higher amounts of green house gases, hydrocarbons, non-methane organic compounds, hazardous air pollutants, dioxin than incinerator. Landfills further leach dangerous chemical into the underlying groundwater, which can contaminate underground water system.

5.2 Filters Trap pollution

The flue gas treatment includes the removal of dust particles, nitric oxides, acid gasses, potentially present in organic substances and heavy metals along with reduction of nitric oxides, selective non catalytic removal with ammonia water injection into combustion chamber at temperatures around 900 °C, reduction of acid gases, reduction of particles with fabric or ceramic filters, reduction of heavy metals and organic matter.

5.3 Reduces volume of solid waste

During combustion of MSV in combustion plant input waste is reduced for about 90%. The remains of combustion are mostly bottom ash. Therefore, while incinerators does not eliminate the need for dumping ground completely, it certainly reduces the amount of land needed.

5.4 Power and Heat generation

As the energy demands are growing higher and higher, numerous countries sought to incorporate the energy and heat generated from garbage incinerators for the production of electricity through steam

turbines. This technique will produce energy along with decrease in waste accumulation.

6. Limitations Of Combustion

In European legislation thermal treatment i.e. combustion is regarded as technique that needs to fulfill integrated pollution prevention control demands. General image of the thermal treatment technologies is low and the spatial planning for these Plants is extremely problematic along with bad environmental impact.

The most common environmental impacts of combustion plants are:

- ash and slag,
- flue gas treatment residue,
- emissions to air, water and ground
- electromagnetic radiation,
- heat emissions to air and water,
- noise and odour,
- utilization of space is large

In general emission to air is most considered and regarded as most harmful environmental impact.

7. Sustainable Waste Management

India is the second fastest growing economy and one of the most polluted country in the world. Therefore combustion and other techniques are secondary, in the first place efforts must be made to minimise waste production and to recycle and reuse waste product to its maximum extent.

Some changes that are crucial in near future for the disposal of MSW includes more extensive integration of informal waste sector into the formal systems, increment in composting facilities and sanitary Landfill facilities with proper capping of landfills. The SWM sector in India has started to progressed in the last few years, after the introduction of Jawaharlal Nehru National Urban Renewal Mission (JnNURM) by the Government of India (GOI), Kolkata SWM Improvement Project, Navi Mumbai MWS management project, Uttar Pradesh : 6-MW Biomass Cogeneration Power Plant, Himachal Pradesh waste treatment plant are some of the ongoing projects building sustainable environment in India .

Different versions of the hierarchy of waste management exist but in most of the cases this current order is followed:

1. Reduce the quantity of waste
2. Reuse
3. Recycle the materials
4. Incinerate with heat recovery

8. Landfill of inert ash

Source reduction can be initiated at individual level by reducing the amount of waste generated and reusing materials to prohibit them from entering environment. Technical and economic limitations of recycling; different design product , insufficient separation of generated waste and inadequate markets that can use all sorted materials has lead to generation of landfills, water pollution, public health crisis in India. Each and every individual should start working with their partners, friends and families to promote source separation, efforts should be taken to handle the non-recyclable wastes that are also generated in huge amount and aim at achieving of sustainable environment.

9. Public Health Crises

The existing level of waste management services in various sectors of India is a potential threat to environment as well as

public health. Inhalation of flue gas, ash dust, smoke and fumes produced by open burning of waste causes precarious health problems. Also, the open landfills are the breeding ground of soil-borne bacteria like *Bacillus anthracis, Clostridium botulinium, Clostridium tetani,* causing infectious diseases like Anthrax, Botulism, Tetanus and many more. Toxic chemicals present in solid waste are determinants for respiratory and dermatological problems, abortions, eye infections and eventually decreases the life span of living beings. The fine particle range is dominated by carbonaceous fractions and toxic inorganic elements like Pb, Cr, Zn etc . Chiefly observed side effect of improper solid waste management in India is the introduction of heavy inorganic metals into the food chain. Due to bio magnification and bioaccumulation high amount of metals are found in fishes, birds, animals and human beings respectively.

Compost from mixed waste composting plants is highly contaminated with heavy metals which further result in contamination of the agricultural soil. Common heavy metals found in mixed waste composts are Zinc (Zn), Copper (Cu), Cadmium (Cd), Lead (Pb), Nickel (Ni) and Chromium (Cr). Hazardous diseases like cholera and dengue fever are caused due to stray animals, pests and insects attracted to open landfills of waste, sewers and drains clogged by solid waste are breeding grounds for mosquitoes pose a major threat to public health too. Improper SWM in the city Surat, caused city-wide bubonic plague epidemic in 1994, which later transformed Surat into one of the cleanliest cities in India.

Conclusion

Different varieties of waste materials are generated in the Indian cities as in other countries. However, due to lack of a well-planned waste management system from the very beginning i.e. waste segregation at source, ineffective regulation and defective control of rag-picking, indiscriminate waste burning and inadequate waste recycling activity, the left-over waste at the dumping yards is leading to landfills causing soil and groundwater contamination. It is common practice of adding the road sweepings and household waste to sewage or drains contaminating water and formation of breeding grounds causing hazardous diseases. Self-sustaining combustion cannot be obtained for waste such as plastic, tins, glass, metals and auxiliary fuel will be required for their complete combustion, hence, it has not been much preferred in India so far. Recent environmental regulations and social concern throughout the world have stimulated renewed efforts in industry to produce products which are compatible for environment. Therefore, with the expanding problems of Solid waste management in the urban areas and the increasing awareness about the harmful effects of the subsisting waste management practices on the public health. The imperative need for improving the Solid waste management system and acquisition of advanced and scientific methods of waste disposal along with incineration is paramount.

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