INCINERATION PROCESS FOR SOLID WASTE MANAGEMENT AND EFFECTIVE UTILIZATION OF BY PRODUCTS

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Abstract - *Municipal solid waste remains one of the major problems in modern societies, even though the significant efforts to prevent, reduce, reuse and recycle. At present, municipal solid waste incineration (MSWI) in waste-to-energy (WtE) plants is one of the main management options in most of the developed countries. The waste material collection is piling up every day in almost all the cities of India and creating hazardous situation in terms of pollution. Due to this the average life span of living beings has deteriorated to a great extent. Our main aim is to utilize these waste materials in an effective way to help mankind by the process of incineration. Incineration is the best process of combustion of Organic materials present in the waste and giving useful byproducts. The by-products of incineration are heat, flue gases and ash. This paper has made an attempt in highlighting the proper use of those products. The effective use of these by products can be generation of electricity, growth in the production of crops. The attempt as an assessment has been made to bring in awareness about the effective utilization of low cost incineration and Air pollution control devices used for cleaning.*

***Keywords*: Incineration, wastemanagement,residues, Incinerators, Air pollution control etc**

1. INTRODUCTION

Incineration is the treatment of waste material by combustion of organic substances present in the waste materials. It converts the waste material into heat, flue gas and ash which are released into the atmosphere without any further treatment for usage. In this context, the paper studies the types of waste products produced which can be further used in an effective way by proper treatment reaction and analysis. Heat which is in major percentage can be used to generate electric power. Flue gases contain traces of nitrogen, carbon dioxide and sulfur dioxide, each of which has better utilization when used optimally. Nitrogen produced can be used as fertilizers to increase the productivity of crops, carbon dioxide can be used as fire extinguishers and sulfur once extracted from sulfur dioxide can be used in dental treatment. Ash is obtained in the form of solid lumps which can be used for construction purposes. The benefit of incineration is that it reduces the solid mass of organic wastes by 80-85% and volume by 95-96% which is commendable. The paper further explores on the various processes practiced in major countries like Japan, Germany, Europe and France and highlights on the methodologies adopted by these countries. A bottom ash is the most significant by-product from MSWI, which accounts for about 80%-87% (in weight) of the solid residues. The amount of bottom ash is 20%-30% of the initial weight of wastes incinerated. Due to its origin, MSWI bottom ash is mainly composed of high-temperature solids, which is rapidly cooled down when the material is quenched after exiting the combustion chamber. It is mainly composed of Si, Fe, Ca, Al, Na and K, in the form of oxides, and thus, presents a similar composition to that of geological materials. From the constitutional phases of MSWI bottom ash, it is therefore similar to the geological materials.

A typical scheme for an incineration plant operating on real waste and with energy recovery is given in Fig. 1

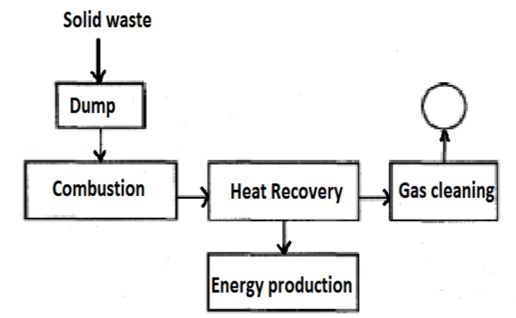
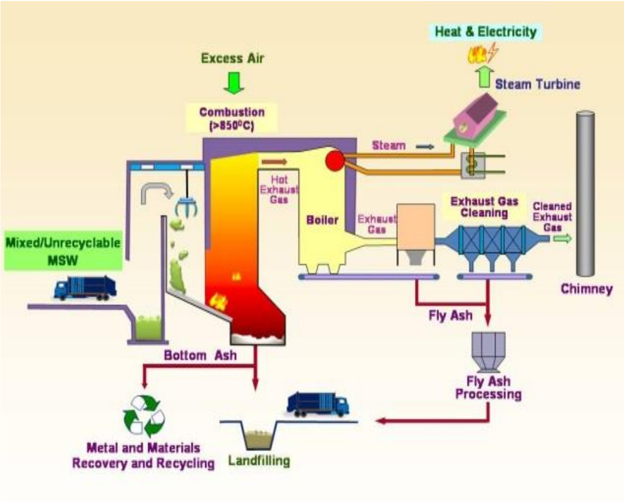


Fig-1. Flow chart of incineration process

The collected material is located in a land site and from here taken to be sent to the incineration process, normally performed in grid or rotating kilns. The gas coming from the combustion process at a temperature around 900° C to 1000° C is sent to a heat exchanger for steam production to be then used in a thermal cycle for energy production. Out of the exchanger, at a temperature around 200° to 250°C, the gas is then sent to the gas cleaning line to abate the polluting substances (dust, acid gas, etc.), and is discharged from the chimney into the atmosphere. As already noted, energy recovery is performed in a thermal cycle, usually with turbine and condenser to maximize the production of electric energy.

2. INCINERATION PROCESS:



Combustion: Waste is continuously fed into the furnace by an overhead crane. The waste is combusted in the specially designed furnace at high temperature of > 850ºC for more than 2 second with sufficient supply of air so as to ensure complete burning of the waste and to prevent the formation of dioxins and carbon monoxide.

Boiler/ steam turbine: The heat from the combustion is used to generate steam in the boiler. The steam then drives the turbine which is coupled to the electricity generator. The excess heat generated can also be used for other purposes, e.g. heat for swimming pool.

Exhaust gas cleaning: The exhaust gas from the boiler is typically cleaned by the following advanced pollution control systems to ensure compliance with the stringent environmental standards.

Dry or Wet scrubbers: To spray lime powder or fine atomized slurry into the hot exhaust gas to neutralize and remove the polluted acidic gases (sulphur oxides, hydrogen chloride).

Activated Carbon Injection: To adsorb and remove any heavy metal and organic pollutants (e.g. dioxins) in the exhaust gas.

Bag house filter: To filter and remove dust and fine particulates.

Selective Non-Catalytic Reduction: To remove a nitrogen oxide (which is a cause of urban smog) by reacting them with ammonia or urea.

2.1 Input materials:

The quality and quantity of the MSWI input and output are influenced by several factors:

- Waste generators are households and industrial or commercial sites.
- Waste generation both in households and industry is (theoretically) influenced by waste prevention.
- Separate collection exerts a strong influence on the quantities and quality of waste for incineration. For example, the separate collection of small electrical appliances could reduce the Cu content in MSWI bottom ash by up to 80%. Through source separation of recyclables and biogenic waste, the quantity of waste for treatment is significantly reduced.
- Residues from waste processing technologies (e.g. sorting of plastics after separate collection) and other materials can also be part of the input to MSWI.

2.2 MSWI residue

As a result of the incineration process, different solid and liquid residual materials as well as gaseous effluents are generated. Approximately one-fourth of the waste mass on a wet basis remains as solids. The volume of residues corresponds to one-tenth of the initial waste volume. Typical residues of MSWI by grate combustion are:

- Bottom ash, which consists primarily of coarse non-combustible materials and unburned organic matter collected at the outlet of the combustion chamber in a quenching/cooling tank.
- Grate siftings, including relatively fine materials passing through the grate and collected at the bottom of the combustion chamber. Grate siftings are usually combined with bottom ash, so that in most cases it is not possible to separate the two waste streams. Together bottom ash and grate siftings typically represent 20–30% by mass of the original waste on a wet basis.
- Boiler and economizer ash, which represent the coarse fraction of the particulate carried over by the flue gases from the combustion chamber and collected at the heat recovery section. This stream may constitute up to 10% by mass of the original waste on a wet basis.
- Fly ash, the fine particulate matter still in the flue gases downstream of the heat recovery units, is removed before any further treatment of the gaseous effluents. The amount of fly ash produced by an MSW incinerator is in the order of 1–3% of the waste input mass on a wet basis.
- Air pollution control (APC) residues, including the particulate material captured after reagent injection in the acid gas treatment units prior to effluent gas discharge into the atmosphere. This residue may be in a solid, liquid or sludge form, depending on whether dry, semi-dry or wet processes are adopted for air pollution control. APC residues are usually in the range of 2% to 5% of the original waste on a wet basis.

3. TYPES OF INCINERATORS

There are three main types of combustion technologies in commercial practice:

1. Rotary Kiln,
2. Moving Grate
3. Fluidized Bed.

1. Rotary kilns:

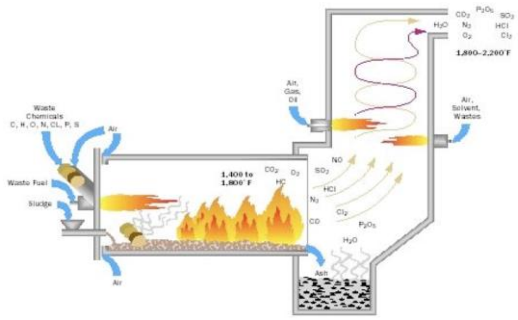


Fig-2 Rotary kilns

A rotary kiln are commonly used for combusting industrial and hazardous wastes, but is also used in some municipal solid waste incinerators. The principle design consists of two thermal treatment chambers: a slightly inclined primary chamber where waste is fed in (together with inlet of hot exhaust air with oxygen), rotated and thermally decomposed by the heat radiation from the secondary chamber: the re-combustion chamber positioned at the rear of the kiln where the decomposition air and the rest waste is completely burnt with the supply of secondary air. Rotary kiln have the advantage of producing a low level of NOx and thermal destruction of hazardous chemicals.

2. Moving Grate:

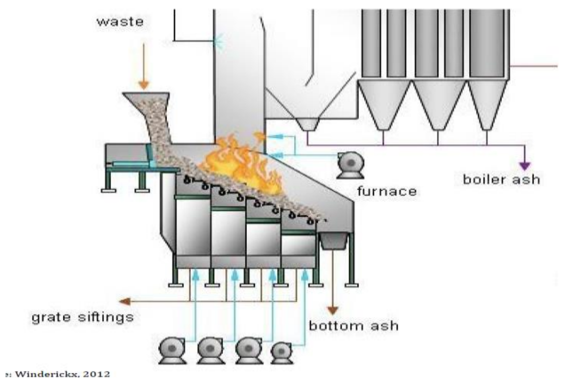


Fig-3 Moving Grate

A moving grate is a typical combustion design of a municipal solid waste incinerator. Waste is dropped by a crane on to the descending grate, which moves into the combustion chamber and eventually moves down to drop the burnt residuals into an ash pit at the other end of the grate .The moving grate is a metallic porous bed, allowing primary combustion air to flow through from the bottom. Secondary combustion air is supplied by nozzles from above the grate, facilitating a complete combustion by the introduction of turbulence.

3. Fluidized Bed:

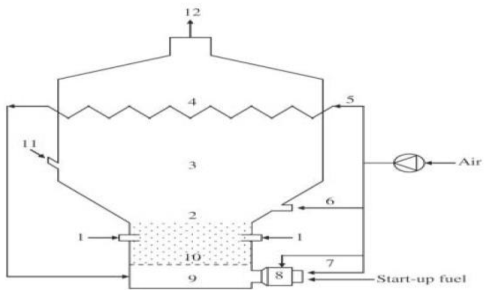


Fig-4 Fluidized Bed

Fluidized bed combustion has recently increased in application in municipal solid waste incinerators, although it is still mainly used for the combustion of hazardous waste. There are different types of fluidized bed combustors (bubbling, rotating and circulating fluidized bed), but the principle of the design remains the same: waste particles are suspended by the upward flow of combustion air injected from beneath so that it seems like a fluid, by which the turbulence created enhances uniform mixing and heat transfer hence an increased combustion efficiency. The advantage of fluidized bed technology is the enhanced combustion efficiency, however the pre-condition of that is the homogenization of waste inputs in size as well as in heat value, which requires extensive pre-treatment of waste including typically size reduction and mixing.

4. PLANT LOCATION

An incineration plant for municipal solid waste is a public service facility. The location of plant should always be determined with respect to both economic and environmental issues.

An MSW incineration plant will generate surplus energy, which may be made available in the form of heat or power depending on the demand of the local energy market. In that respect, an incarnation plant is comparable to a fossil fuel power plant. It is further comparable to a coal-fueled power plant in respect to flue gas emissions and solid residues from the combustion process and flue gas cleaning. Therefore waste incineration plant should be situated near to an existing fossil fuel power plant for the two plants to enjoy mutual benefits from the service facilities needed or it could be adjacent to or part of a new power plant.

❖ A controlled and well-operated landfill must be available for disposing residues.

- MSW incineration plants should be located in land-use zones dedicated to medium or heavy industry.
- MSW incineration plants should be located in industrial areas close to power plants.
- The travelling should take no longer than one hour to drive a truck from the waste generation area to the plant.
- MSW incineration plants should be located near suitable energy consumers.

5. EFFECTIVE UTILIZATION OF BY PRODUCTS DURING INCINERATION

The waste materials are collected all together and they undergo incineration process for the combustion of organic components. The output of this incineration process is released into the atmosphere causing acid rain, infectious diseases and wastage of heat energy. This paper highlights the usage of the heat energy, flue gases and ash content in an effective way for the benefit of living beings including human beings and animals as inhaling harmful air causes side effects.

Ash:

The waste material is loaded from top and after undergoing incineration process the ash content is withdrawn from the ash door. The ash is in the form of solid lumps which can be effectively used for construction of both commercial and residential purposes. It can also be used in the construction of roads.

Flue gases:

Flue gas which are a mixture of many gases are obtained as the byproduct of the incineration process. These gases are released into the an atmosphere which are the root cause of many diseases such as asthma, lung cancer, heart attacks which indirectly leads to early death of living beings.

This paper takes a step to understand the effective use of the gases evolved during incineration

The gases evolved during incineration mainly are Nitrogen dioxide, Carbon dioxide, Sulfur dioxide, water vapor and traces of oxygen.

Sulfur can be extracted from sulfur dioxide by Claus process as sulfur dioxide is a strong oxidizing agent. So sulfur dioxide is reduced by hydrogen sulfide to give elementary sulfur.

$$SO_2 + 2\ H_2S \longrightarrow 3\ S + 2\ H_2O$$

The elementary sulfur can undergo chemical reactions to get sulfur compounds such as sodium thiosulfate which can be used in dental treatment. Nitrogen dioxide, oxygen and water are also by products of incineration process. By using Ostwald's process, approx. 98% of nitric acid can be obtained when NO_2, oxygen and water react under a pressure of 4 to 10 atm and 217 degrees.

$$4\ NO_2\ (g) + O_2\ (g) + 2\ H_2O\ (l) \longrightarrow 4\ HNO_3\ (aq)$$

This nitric acid is used in the production of crops. This will improve the production and help the farmers to grow better quality crops.

Heat:

Waste heat can be utilized by converting it into electricity. Thermoelectric generators are used to convert heat to energy by seebeck effect. Thermoelectric materials use a phenomenon of converting the temperature difference into an electric potential. A commonly used thermoelectric material is bismuth telluride. These days there is lot of power cut in every city of India, this power generation method will utilize the waste material and produce electricity and thus reducing electricity problem in India.

6. AIR POLLUTION CONTROL

Incinerating MSW generates large volumes of flue gases. The flue gases carry residues from incomplete combustion and a wide range of harmful pollutants. The pollutants and their concentration depend on the composition of the waste incinerated and the combustion conditions. However, these gases consist of ash, heavy metals, and a variety of organic and inorganic compounds.

The pollutants are present as particles (dust) and gases such as HCl, HF, and SO_2. Some harmful compounds such as mercury, dioxins, and NOx can be fully removed only through advanced and costly chemical treatment technologies. Primary measures which are initiatives that actually hinder the formation of pollutants, especially NOx and organic compositions such as dioxins must be applied as much as possible.

The air pollution control (APC) system comprises electrostatic precipitators; bag house filters; dry, semi-dry, and wet acid gas removal systems; catalysts; and the like. Some characteristics of the secondary measures are that they precipitate, adsorb, absorb, or transform the pollutants. The selection of the APC system depends primarily on the actual emission limits or standards, if any, and the desired emission level. In this context, the different APC systems can be grouped as basic, medium, or advanced emission control.

6.1 AIR POLLUTION CONTROL TECHNOLOGY

Following are the equipment for the control of air pollution:

1. Mechanical collectors (cyclones and multi-cyclones)
2. Wet scrubbers (such as Venturi scrubbers)

3. Fabric filters (bag house filters)
4. Electrostatic precipitators (ESPs)

Mechanical collectors (cyclones and multi- cyclones) :

Mechanical collectors (such as the cyclone) do not effectively reduce the dust content of the flue gas to 150 mg/Nm^3 or below. Consequently, they are of interest only as a component of a more advanced flue gas treatment system or as a secondary dust arrestor at hoppers and similar installations. Wet scrubbers (Venturi scrubbers) and electric precipitators) can be designed to fulfill a specified emission limit value for example,100 mg/Nm^3.Scrubbers are not practical as the first or only air pollution control device, however, as the water applied will also remove most of the HCl present in the flue gas. Consequently, it will produce a dust laden corrosive waste water stream with a pH value around 0. Fabric filters inherently have a high cleaning efficiency, and whether required or not they will remove the particles to about 10 mg/Nm^3. However, fabric filters working directly on the gases from the boiler are vulnerable to varying temperature, humidity, and carryover of sparks from the combustion. Moreover they must be bypassed during plant start-up and shutdown.

Cyclone:

Application • Dust collector
Emission level • 500 mg/Nm^3
Working principle: The dust-laden gas enters tangentially and is brought to rotate. Centrifugal forces cause the dust particles to impinge on the wall and fall into the conical bottom, where they are removed. The treated flue gas leaves through the central outlet.

Venturi scrubber:

Application • Dust collector
Emission level • About 100 mg/Nm^3
Working principle: The dust-laden gas accelerates through a throat (a Venturi), atomizing the water injected. The water droplets collect the dust particles, and the droplets are subsequently precipitated in something like a cyclonic settling chamber.

Electrostatic precipitators:

Application • Dust collector
Emission level • 20-150 mg/Nm^3,
Working principle: The dust-laden gas is led into a box in which a number of grounded collecting plates are suspended. Discharge electrodes negatively charged by rectified high- voltage DC—are located between each row of plates. This generates an electric field, charging the particles and causing them to migrate to the plates, forming a dust layer. The plates are shaken from time to time, and the dust falls into the bottom hopper.

Fabric filter:

Application • Dust collector
Emission level • 10 mg/Nm^3
Working principle: The dust-laden gas passes into a box, then is sucked or pressed through cylindrical bags .A dust layer forms on the surface (most often, the outer surface, in which case the bags are supported by cages). This layer is removed by various shaking mechanisms.

7. CONCLUSION

Incineration is the volume reduction process, now a days, it has a lot of scope for waste management. A low cost incinerator can be constructed and to utilize the byproducts obtained effectively. The byproducts evolved are released into the atmosphere which causes acid rain, infectious diseases and wastage of heat energy. The attempt is made to utilize these byproducts effectively for the welfare of living beings. An optimization control system of waste incinerator for power generation is proposed. The process control procedure is divided into different parts effectively in terms of the demands of municipal solid waste incineration process control unit, and each part can work independently without other parts to be affected.

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