A Study of Waste Disposal Using a Portable Single-Chambered Incinerator

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Abstract: *In order to cope up with the worldwide demand of more efficient waste management systems, incineration remains among the most effective in volume reduction of the solid waste, thereby reducing the burden on landfills. Globally these issues hit third-world developing countries worse than others. Cities spend about 20% to 50% of their budgets dealing with waste management, a hardship for cash-strapped nation. The major problems affecting solid waste management in countries like India are improper collection of waste, unscientific treatment, and ethical ignorance. This in turn leads to hazards like environmental degradation, air pollution, soil pollution, and water pollution.*

Keywords: Incinerator, Waste disposal, Solid waste, Flue gas.

1. INTRODUCTION

Solid waste disposal by combustion (incineration) is now and will continue to be an important part of the global solid waste management programme. Treatment of solid wastes (municipal, medical, industrial etc.) has become one of the main concerns of many urban and rural communities. Adequate management of the wastes through reduction of the waste production from households by recycling and reuse should be given the highest priority. However, some portions of these wastes are buried underground, i.e. landfill. Incineration of solid wastes is sometimes considered to be the foremost effective in volume reduction of the solid waste, thereby reducing the burden of landfill. The requirement for a fast, reliable, and environmentally friendly method of waste disposal generated from households, hospitals, markets, industries etc., has brought attention to the mainstream designing and construction of a specialty incinerator to suit both rural and urban purposes. Incineration is the method of waste destruction in a furnace by controlled combustion at high temperatures. Incineration of waste materials converts the waste into ash, flue gases and heat energy. The ash is generally formed by inorganic constituents of the waste, and will take the shape of solid lumps or particulates carried by the flue gas. Incineration has frequently been preferred to other waste treatment or disposal alternatives due to advantages such as; the volume and mass of the solid waste is reduced to a fraction of its original size by 85-90% volume, the waste reduction is immediate and not dependent on long biological breakdown reaction times.

The public health impact related to emissions from solid wastes (municipal, hospital etc.) has become a significant subject of concern due to these points:

(i) Some materials aren't purported to be incinerated as they're more valuable if recycled, they're non-combustible or their by-product may produce to harmful emissions.
(ii) Poor operating practice and also the presence of chlorine within the waste may

cause emissions containing highly toxic dioxins and furans
(iii) The control of metal emissions is also difficult for inorganic wastes containing heavy metals, like arsenic, cadmium, chromium, copper, lead, mercury, nickel, etc.
(iv) Incinerators require high capital costs and trained operators resulting in moderately high operating costs.
(v) Supplementary fuels are sometimes required to attain the mandatory high temperatures.
(vi) Residual disposal (fly ash and bottom ash) presents a spread of aesthetic, pollution, and worker health related problems that need attention in system design and operation.
(vii) Process analysis of combustors is extremely difficult; changes in waste character are common thanks to differences due to the season in municipal waste or product changes in industrial waste.

Communities are faced with the challenge of developing waste-management approaches from options that include reduction of waste generated, incineration, landfilling, recycling, reuse and composting. In general, any incineration facility will incorporate the following processes: waste storage and handling, processing to rearrange waste, combustion, air-pollution control, and residue (ash) handling. There's an outsized type of waste starting from community waste, household waste, medical waste, etc. which is being disposed-off on open grounds on a routine.
To study the trend, the researchers observed the current scenario in USA, where the three varieties of waste to which incineration is applied extensively are:

1. Municipal Solid Waste- Municipal solid waste is defined as the solid portion of the waste (not classified as hazardous or toxic) generated by households, commercial establishments, public and private institutions, government agencies, and other sources. MSW waste stream includes food and yard wastes, durable and non-durable processes and packaging.

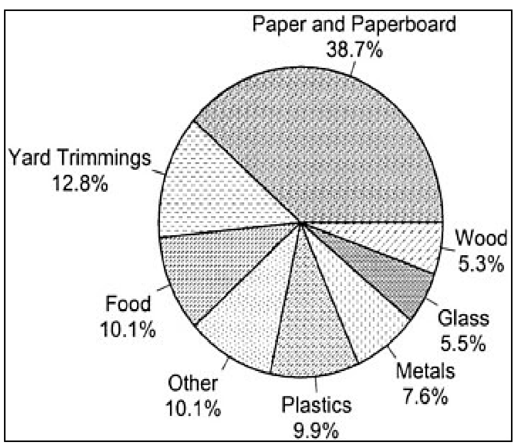

Figure 1. Municipal Solid-waste Weight Composition, 1997.
(Total weight = 217 million tons.) Source: Franklin Associates 1998.

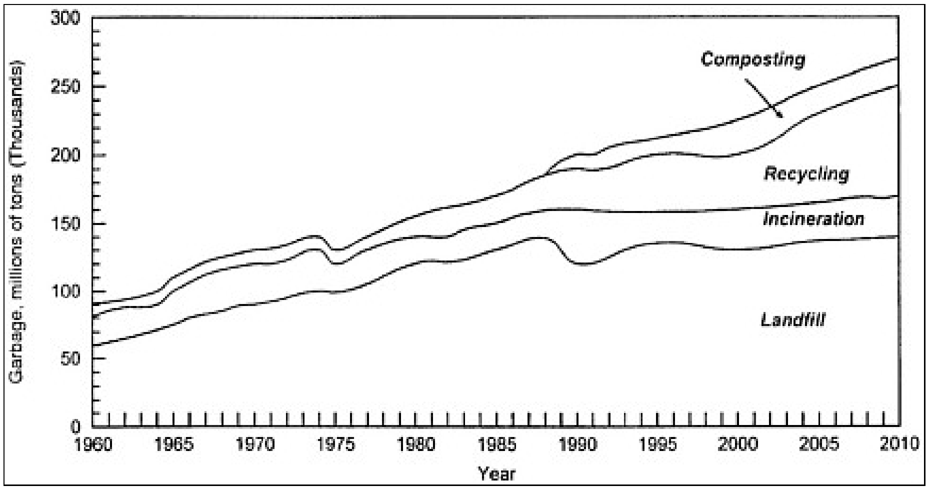

Figure 2. Municipal solid-waste generation management and trends in the United States, 1960-2010. Source: Franklin Associates 1997.

2. Hazardous Waste- Hazardous waste is defined by EPA under the Resource Conservation and Recovery Act (RCRA) as a stuff that may be classified as potentially dangerous to human health or the environment on the premise of any of the subsequent criteria. It'd ignite easily, posing a health hazard. It'd be corrosive, capable of damaging materials. It'd be reactive—likely to explode, catch fire, or give off dangerous gases when in-tuned with water or other materials. It'd be toxic, capable of causing illness or other health problems if handled incorrectly. It contains specific wastes or discarded compounds that EPA has classified as hazardous.

3. Medical Waste- Medical (biomedical) wastes can have infectious or toxic characteristics that, with improper disposal, pose public-health concerns. Medical waste is generated by a large array of activities. Essentially every aspect of the supplying system contributes, but hospitals are the biggest medical-waste producers.

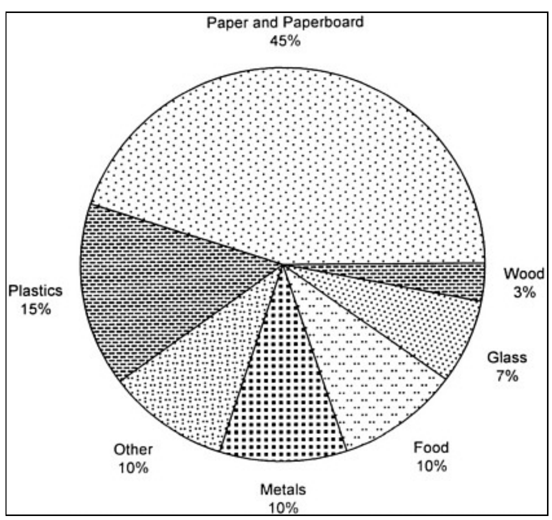

**Figure 3. Composition of medical waste.
Data from AHA 2013**

2. OBJECTIVE

The primary objective of the project was to explore the possibility of achieving engineering and technological innovation by designing and constructing a low-smoke and low-pollutant emitting incineration system for environmental sustainability through responsible waste management. Incineration has already proven to be a key process in the hazardous waste and clinical waste treatment. One of its largest current applications comes in the disposal of medical wastes which is often imperatively subjected to the high temperatures of incineration for the destruction of pathogens and toxic contaminants that it contains. The reason Incineration was chosen over conventional waste management techniques such as landfills, is explored in the comparison between the two also mentioned in this report.

The project has kept in consideration the various national, regional, state, or local regulations or guidelines that have been proposed and enforced in the regions of the USA and the European Union. These regions were chosen to lend perspective into the scale and sustainability of incineration as they have already undergone implementation in parts of these regions. The project intends to use these insights to provide factual evidence to support the implementation of Incinerator based waste disposal major emerging economies such as Brazil, Russia, India, China, and South Africa which are in dire need of effective waste disposal.

Although the device presented in our project works on a very small scale, it distinctly displays the various methodologies that may be crucial in the construction of a large-scale incineration waste disposal framework. The report further provides evidence to conclude (through its theoretical formulations and simulations) that incineration is doubtlessly better than other conventional means of waste disposal.

3. METHODOLOGY

- **Design Philosophy:**
  The design concept of the chamber is relatively straightforward. The shape isn't critical and may be supported by manufacturing considerations. The first stage must be a sealed, vertical, cylindrical steel shell lined with insulation and refractory. The waste is received by the chamber through a loading port, underfire air tubes receive the air and exhaust port receives the discharge smoke within the ceiling. The underfire air tubes have holes sized to produce the right amount of air at the design pressure. The concept for this design is for normal combustible waste. Additional fuel is used only as a pilot and as a supplement when the smoke isn't rich enough to sustain combustion. In previous experiments with a waste composed of 90% dry cardboard and therefore the remainder, a combination of polystyrene, polyethylene, and PVC, the ultimate observed temperature was 2450 degree F with 4.3% excess air. The research indicates that normal type waste will produce temperatures within the 1500 degree F to 2000 degree F range with a lower limit of combustion of about 1000 degree F.

- **Standards For Incineration:**
  All incinerators must meet the following operation and emissions standards:

1. **Operating Standards:**
   Combustion Efficiency (CE) has to be at least 99%.
   The CE is computed as follows:

$$CE = (\%CO_2 / (\%CO_2 + \%CO)) \times 100$$

2. **Stack Height:**
Minimum Stack Height must be 30m above the ground and shall be attached with the necessary monitoring facilities as per requirement of 'General Parameters' as notified in the Environmental (Protection) Act, 1986 and in accordance with the CPCB Guidelines of Emission Regulations, Part 3.

4. PROJECT REPORT

- **Components:**

1. Standard '55-gallon Barrel' (208L) with the following specifications: Inner Dimensions:
Internal Diameter - 22.5"
External Diameter - 23"
Internal Height - 33.5"
External Height - 34"
Weight - About 27Kgs
Thickness:
Shell Thickness - 0.82 mm
Head Thickness - 1.11 mm
Volume: 208L
2. Two steel panels similar to the shape of 'Donuts' with the dimensions:
Outer Diameter - 23.6"
Hole - 8.75"
3. 8" Schedule 40 Pipe - 8"-12" length
4. 6" Stainless Steel flat stock plate - 80" long (padded)
5. 3" Stainless Steel flat stock plate - 80" long (padded)
6. Flex Hose - 3" Diameter
7. Straight Pipe - 24" of 2.5" Outer Diameter
8. Enough Grating to cover the 8" pipe (Spark Arrestor)
9. Sufficient Metal for handles - 1/2" tube stock
10. 1' Spare Wood Panel - 2"x4"
11. One High CFM, Variable Speed Leaf Blower - Gas or Electric
12. One length of Dryer Hookup Tubing - 3" Diameter

- **Target Wastes:**

1. Paper
2. Wood
3. Food Wastes
4. Medical Wastes (Non-Hazardous)
5. Plastics
6. Newspapers
7. Non-recyclable plastic (Not large volume waste)
8. Cardboard not suited for recycling (waxy or coated with food waste)
9. Leaves, shoots and parts of vegetation.
10. Organic wastes

- **Waste Loading Pattern:**
The top and bottom layers should always be cardboard or something easy to burn (Layer 1 & 4). Next, a hard to burn layer of wastes like wood, etc. (Layer 2). The next layer from the bottom can be wastes harder to burn like plastic or kitchen waste (Layer 3).

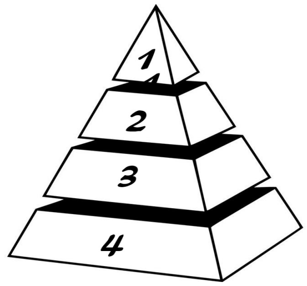

Figure 4. Loading Pattern for Proposed Incinerator

- **Working Procedure:**

1. Waste is placed in the drum chamber.
2. Ignition is caused in the drum.
3. The drum lid is closed.
4. The air blower is switched on, causing cyclonic flames in the combustion chamber.
5. The ash residue is collected from the bottom after the combustion of wastes.

- **Nomenclature:**

a = Ratio of W to H
A = Grate Area (m^2)
b = Ratio of L to H
B = Heating Value of Fuel (*J/kg*)
F = Firing Rate or Incinerator Capacity ($kg\ s^{-1}$)
F_A = Area Firing Rate ($kg\ m^{-2}s^{-1}$)
H = Combustion Chamber Height (*m*)
I = Combustion Intensity ($J\ m^{-3}s^{-1}(Pa)^{-1}$)
K = Waste Factor
K_L= Logarithmic Waste Factor
L = Length of Incinerator
P = Pressure in Combustion Chamber (*atm*)
R = Proportionality Factor
R_L= Average Reaction Rate ($J/s\ m^3$)
V_C = Combustion Chamber Volume (m^3)
W = Combustion Chamber Width (*ft*)

- **Calculations:**

To derive the burning rate equation that relates I, F and F_A it's assumed that the combustion chamber of any incinerator can be represented as equivalent to a rectangular box of height H, width W and length L. The width and length can then be represented as multiples of the height.

1. Combustion Chamber Model:

$$W = aH \quad (1)$$
$$L = bH \quad (2)$$

For the grate area A, and the combustion volume V_C,

$$(\text{Area})\ A = WL = [(ab)\ H^2] \quad (3)$$
$$(\text{Volume})\ V_C = HWL = [(ab)\ H^3] \quad (4)$$

The quantities 'a' and 'b' are ratios and their range of value are such that 'a' would be about ½ and the recommended ratio of length to width (b/a) to lie between one and two the quantity (ab) could, therefore, lie between 0.25 to 2. Now, Combustion Intensity (I) is given by,

$$I = [FB/ V_C P] \quad (J\ m^{-3} s^{-1} (Pa)^{-1}) \tag{5}$$

P is the Absolute Pressure in atmosphere (atm) and P = 1 for incinerators. Now, substituting P = 1 and the value of V_C in eq. (5) and eq. (4),

$$F = [(I / B)\ (ab)\ H^3] \tag{6}$$

Area Firing Rate (F_A) is given by,

$$F_A = [F / A] \tag{7}$$

Substituting the value of A from eq. (3),

$$F = [(ab)\ H^2 F_A] \tag{8}$$

2. **Burning Rate Equation:**
   The incinerator Height, H in eq. (6) and eq. (8) can be eliminated given the Burning Rate Equation:

$$F_A = [(I / B)^{2/3} (ab)^{-1/3}]\ F^{1/3} \tag{10}$$

This can be written in a more simplified form,

$$F_A = [K \cdot F^{1/3}] \tag{11}$$

Where 'K' is a 'waste factor' for a given incinerator. This factor depends primarily on the calorific value of the particular waste and the allowable Combustion Intensity that can be achieved with the waste.

5. RESULTS

The development of such portable incinerators can result in reduction of waste and sort of energy source. The incinerator has been built using steel for the fabricated parts like connector pipes, donut shape panels, stock plates. The chamber is formed from a 55 gallon barrel and it's modified in keeping with design. The materials are employed in an incinerator which might withstand very large temperatures above 800°C. It can replace dust bins on a small scale and therefore the cost is matched with energy produced. The pollution is a smaller amount compared to other energy sources. It may be shifted from one place to a different one or is stationed at one place.

One great advantage to be derived from the employment of this machine is that the price of running its minimal compared to what it takes to run a full plant. The simplicity of operation of this machine ensures that no excessive amount of technical skill is required to work it. Emissions from incineration facilities are reduced by modifying operating characteristics- such as furnace temperature, air-injection rate, flue-gas temperature, reagent type, and injection rate, and by selecting optimal combustor designs and emission-control technologies. Improving the combustion efficiency of an incineration process by optimizing combustor operations will reduce the amount of soot produced. However, one must take into consideration the potential to extend the heavy-metal content within the emissions because of volatilization resulting from the upper combustion temperatures needed to enhance combustion efficiency.

- **Comparison Between Incineration And Landfills:**

1. **Land Use:** Energy from waste plants (incinerators) takes up a substantial amount of space; generally a landfill site would take less. There are other significant factors to contemplate during placement like noise and pollution to nearby residents, traffic management. What's often not realised is that EFWs do produce residual ash that's disposed of in landfill – so there is still need for landfill sites. The land is getting harder to come back by and is therefore expensive; landfills don't decrease the amount of the waste they contain so they require more room. EFW sites can reduce 2000lbs of waste right down to 600lbs of ash so there are obvious space-saving advantages.
2. **Emissions:** Vehicles delivering household waste to both landfill sites and EFW plants have the same impact on carbon emissions subject to the full distance the waste is transported which may vary greatly. EFWs are significantly more efficient than they once were but still are on the average 40% less efficient at producing energy than burning gas in modern generator systems. EFW plants also generate 65% more carbonic acid gas (CO_2) than generator systems and more CO_2 per unit of electricity than coal burning plastics has also been proven to release dioxins, furans, styrene gases though if burnt at higher temperatures these health hazards are less likely. Of course, landfills generate methane –a more powerful greenhouse emission than CO_2– owing to biodegradable waste decomposition without oxygen. Parts of this will be extracted and burnt to come up with electricity but the amount has been falling steadily for the last 6 years. This is often thought to be as a result of reduced gas yields which increases the value of extraction and eventually makes it economically unviable. In 2011, landfilling was estimated to get most of the three of carbon emissions that waste management accounted for within the UK but emissions from the waste sector had actually decreased by 64% since 1990, mainly because of diversion of biodegradable waste removed from landfill.
3. **Long-Term Impacts:** The common perception is that burning waste is healthier than landfilling because it requires less space and will result in fewer emissions. It certainly obviates what's perceived as an issue – waste – very quickly. Yet, when staring at a long-term picture quick solutions aren't always the most effective. Waste is simply a derogatory term for resources, which are dwindling with the exception of renewable ones. Burning things like plastics means those fossil fuel-based materials are lost forever and definitely contribute to global climate change. Burying them in landfill will be seen as carbon sequestration rather than what some people term as "sky filling". The most important objection to Incineration/EFW is its disincentivizing impact on zero waste and circular economy efforts which must be the end goal to attain true sustainability. The plants require many finance and guaranteed high volumes of materials to repeatedly burn for twenty or more years. This greatly undermines both local and national efforts to cut back waste within the first place. So landfills cost more, than burning waste even after not including the price of sending toxic bottom ash to specialist landfill sites, though EFW sites take up less space, they are doing tend to simply accept waste from a bigger area leading to more vehicles making longer journeys. There's also more risks of about 6 toxic substances going in the air should the cleaning processes fail.
4. **Harnessing Heat and Power Potential:** Excluding all sorts of recycling, about 70% of solid waste is combustible. That features paper, cardboard, biodegradable waste, textiles, plastics and more. Additionally to households, many industries

produce waste whose value is often captured through incineration. There are many forms of industrial waste, including hydrocarbon residue, tar and used solvents. There are also various forms of agricultural waste, like straw from wheat, corn and rice, moreover as agro-industrial waste, which mostly comes from sugar and oil mills. Papermaking creates waste, too. After extracting cellulose from wood to form pulp, pulp mills burn the by-product called “black liquor.” By exploiting its potential to recover energy from waste, Europe could provide power to 17 million homes and heat to 24 million. Denmark is currently the European Union trendsetter in terms of per capita power and heat production.

5. How Energy Efficient is Incineration?

Two kinds of energy are produced in an incineration plant: heat and power. Each type has its own production process and level of energy efficiency:

A. Power Production: The heat exchanger has got to contain steam at the best possible pressure. This steam is distributed to a turbine that drives 7 an electrical generator. The ability produced is supplied to the grid all year round. The energy efficiency of this process is about 20 to 25% (300 to 400 kWh).

B. Heat Production: This involves simply heating water through waste combustion. This process is energy efficient, with 70 to 80% of the combustion heat recovered after incineration, or about 1,500 kWh of thermal energy per ton of refuse. Of course, the heat produced then is required to be used somewhere near the incineration plant.

- **Advantages Of Incineration Over Landfills:**

1. Decreases quantity of waste.
2. Production of heat and power.
3. Reduction of Pollution.
4. Incinerators have filters for trapping pollutants.
5. Saves on Transportation of Waste.
6. Provides better control over odour and noise.
7. Prevent the emission of methane gas.
8. Eliminates harmful germs and chemicals.
9. Incinerators operate in any weather.

- **Disadvantages Of Incineration Over Landfills:**

1. Adverse climate changes are experienced.
2. Smoke obscures visibility.
3. By burning garbage, mercury is often released and leaches into the soil, the air and in water.
4. The presence of oxide is activated and increased within the air.
5. Smoke causes irreparable harm to the environment.

- **Calorific Value of Different Target Wastes:**

The calorific value of the waste depends on the composition of the waste. Waste with lots of PVC has a higher calorific value then waste with less PVC and more paper. To estimate the calorific value of the waste mix an average of the composition must be taken.

A material can burn without supporting fuel when it has a calorific value of min. 14.4 MJ/kg; this is often approximately the same as dry wood. To understand the calorific value of the waste, you need to measure the calorific value or estimate by analysing the composition. If there's no chemical change by mixing the various materials together, a weighted average of the various calorific values are approximate values for the CV of the waste mix. If the quantity of waste is known, and also the calorific value of the waste is known, it's possible to design the scale of the incinerator and flue gas treatment system.

Table 1. Particulars of the target wastes

Sl. No.	Target Waste	Specific Heat (kJ/kg-k)	Calorific Value (MJ/kg)	Ignition Temp. (℃)
1.	Plastics (Non-recyclable)	1.108	38	435-557
2.	Paper	1.4	13.5	220-250
3.	Wood	1.67	14.4	250-300
4.	Food Waste	1.54	12	600
5.	Medical Waste	1.278	19-24	870-980
6.	Cardboard	1.7	16.9	427
7.	Newspaper	1.4	16.4	185

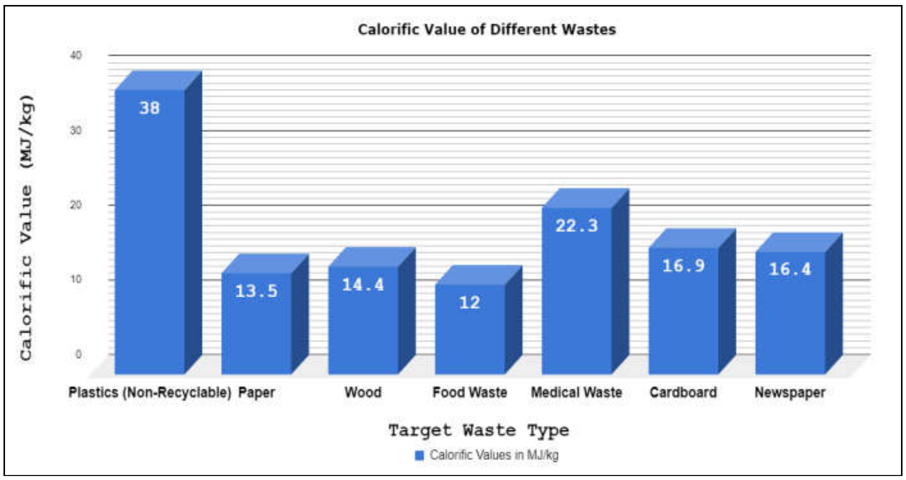

Figure 5. Target Waste Types

6. CONCLUSIONS

Although there exists no single recipe for effective waste management, there are some golden rules: start small, keep it simple and advance step by step. It's better to not apply the foremost advanced technologies. There are too many redundant waste plants worldwide. All stakeholders within the waste chain should be involved but it should be realised that PPPs might take a protracted time, up to five years. When assessing a waste project, the worth of the number of jobs created should be included; this might be important to demonstrate economic viability. Likewise, environmental costs should be taken into consideration.

- **Odour:**

  The combustion process destroys all odour-emitting substances within the waste. Furthermore, the slag and ash are also sterile and odourless after cooling.

MSW incinerator odour is thus emitted mainly from handling and storing waste before combustion. The main sources are the unloading activities and also the waste storage pit. The pit or hopper is a buffer to equalize the feeding of the furnaces, and can thus always contain a variable amount of waste. A large amount of the waste could also be within the pit for several days before being fed to the device. During this period, the putrescible waste will degrade under anaerobic conditions—especially at high ambient temperatures—and emit an unpleasant smell. The necessary handling of the waste in and around the pit will create odour—and will make bacteria and toxins airborne.

To avoid emitting foul air into the environment, the waste pit and therefore the feeding section of the plant hopper area must be enclosed with roof and walls. The air for the combustion process must be abstracted from the top of this more or less open room (that is, from the pit) to come up with an induced air flow into the area and keep foul-smelling substances from escaping into the environment. Besides this, the unavoidable spillage must be cleaned and the general area must be kept tidy. This must be specified to the person/people handling the device and even be present within the operation manuals.

- **Waste Generation and Access To Landfill:**

In the combustion process, the volume of the waste will be reduced by approximately 90% and therefore the weight by 70% - 75%. The output (residue) from the combustion process will mainly be bottom ash (slag), and the ash will account for a low percent of the waste incinerated.

In addition to the slag, odour and ash, the device may generate residues of the dry, semi-dry and wet flue gas type. The amount and its environmental characteristics will rely on the rate and also the amount of waste undergoing combustion. The slag from a well-operated waste incinerator will be burned-out, with only a little amount of organic material. The slag may therefore be used as building material, reducing the land-fill capacity requirement. The ash and other residues will, however, have to be disposed of in an exceedingly controlled landfill, as will the incombustible waste generated in the area. It is therefore absolutely necessary to own a well-engineered and operated landfill available for these varieties of waste.

- **Occupational Safety And Health:**

Solid waste handling exposes staff to dust, microorganisms including gram-negative bacteria, fungi, and endotoxins, and gases and odour from biological decomposition of the waste. Incineration further involves a risk of exposure to combustion products—for example, gases and particles at various stages of the method and applied chemicals. Combustion products are often inhaled or ingested. The incinerator must be designed, operated and maintained to attenuate human exposure. This requires application of a mix of permanent installations and private protection equipment. In situations where waste isn't recycled or can't be separated, it's true that they need evolved means of disposal. While facilities nowadays are much safer than those of previous times, there are still some serious potential risks & uncertainties that indicate that their general implementation on a mass scale isn't recommended. The incineration model isn't the ultimate answer to waste treatment. Incinerators should be reserved for treating waste that may now not be recycled or where separation costs are excessively high and, as a precaution, placed in unpopulated areas.

At the current global scenario, incinerators occupy the penultimate position in the waste management hierarchy. First, the priority should be in reducing waste. If that's impossible, then there should be an attempt to reuse it. And if it isn't possible to reuse it either, there should be initiative to recycle it, and if nothing else is found viable, send the waste for incineration. From the energy perspective this can be translated as: First, recover the maximum amount of reusable material as possible, internally- in eco parks. If this too is found to be a major challenge, the last resort is to recover the maximum amount of energy possible, to justify the means to the ends.

The use of various waste management strategies can substantially affect the dimensions and composition of the waste stream that's fed to an incineration facility. Waste reduction, reuse, recycling, and composting are all designed to cut back the number of material that has got to be incinerated and ultimately landfilled, and that they are likely to vary the characteristics of the wastes that are incinerated and landfilled.

A first step in controlling emissions is to attenuate their creation within the incinerator. Measures for pollution prevention include reductions of pollutant precursors within the waste stream (for example, metals, chlorine, sulphur, and nitrogen) by means of product and packaging redesign, the products and packaging that contain precursors or catalysts for production of trace toxics must be reused, and recycling products and packaging. Reduction of the number of toxic elements within the waste stream or reductions of elements that are transformed into, or catalyse production of, pollutants of concern upon incineration are often-overlooked components of source reduction.

7. RECOMMENDATIONS

This project has provided an in-depth analysis on Waste Disposal employing a Portable incinerator. To assist increased use of incinerators, the subsequent recommendations are proposed:

1. Emission and ash can be improved by improving designing and operating conditions. This information might be used to maximize the combustion efficiency. It should also indicate the categories and combinations of operating conditions that optimize the effectiveness of emission-control devices.
2. Emissions testing have been generally performed under relatively steady state and ideal conditions. However, the best emissions are expected to occur during starting, shutdown, and malfunctions. Such emissions have to be better characterized with reference to possible health effects. Therefore sufficient data are needed on the amount of emissions, any accidents and unusual performance, and also the reasons for such occurrences.
3. New combustor designs, emission monitors, technologies for emission control, operating practices, fuel cleaning and fuel preparation, demonstrated environmental performance records and effects on ash and emissions.
4. Better material information like measurements of source emissions to air and deposition rates to soil, water, and vegetation are needed to solve the contribution of waste incineration facilities to environmental concentrations of persistent chemicals. The variation of those emissions over time must be taken into consideration.

8. ACKNOWLEDGEMENT

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