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Review on Portable Garbage Incinerator

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Abstract: Municipal solid waste and its accumulation is a critical problem around the globe, due to rapid growth in the world population. Recently, an Indian city "Bengaluru" is planning to construct a plant that will burn garbage to produce energy. Garbage from homes, schools and business parks around the globe amounts to 2 billion metric tons (approx.) a year. Incineration is a treatment involving destruction of solid waste by controlled burning at high temperatures. The heat liberated can be used to either generate energy or to boil water or for room heating in northern parts of country during winters. the following below mentioned governing parameters of the portable incinerator for household operation are discussed in our paper which are: volume/quantity of waste, cost, dimension of the incinerator, operations and controlled emission.

Keyword: Waste management, Incinerator, Sustainability, Combustion, Pollution

I. INTRODUCTION

Design is generally regarded as a process by which new effective methods, devices and technology are developed to solve new or existing problems. The basic approach is to review the governing factors involved in a garbage incinerator. This device can be utilized in places like homes, school, business tasks, etc. for room heating, water heating and power generation purposes. This research or review will deal with various practical and theoretical data obtained from the research done by different scientists and include the following parameters: cost, volume of waste, heat generation per kg of waste, emission from waste, oxygen consumption, insulator material, types of waste. This is a non-traditional design methodology based on experience, informal approach, information on existing systems and current practice, etc.

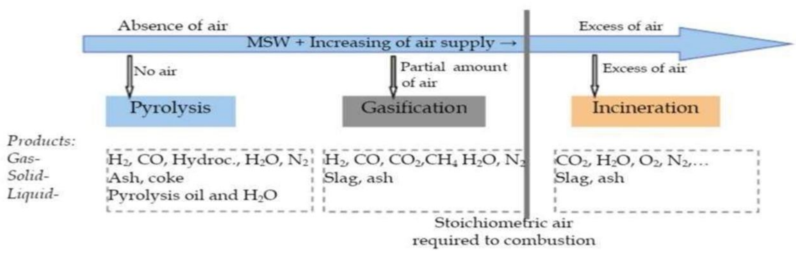

Fig.1. Classification of the thermal technologies for treating MSW.
(Source: Air Pollution Control in Municipal Solid Waste Incinerators)

The irrational dumping of waste has adverse consequences on the environment, health and aesthetic hazards including blockage of drainage channels, spreading of disease, etc. In developing countries like India with a tremendous population which accounts to millions of tons of municipal solid waste from house, school, business parks, textile waste, which are generally dumped or burned in open air without being utilized to its full potential. Incineration process can be the key to solve the ongoing dumping problem and energy need along with lowering the dependence of fossil fuels. MSW combustion or incineration is a controlled burning process which can curb the on growing air pollution that results from open air burning and utilizing the flue gases to possible required need. The heat energy requirement for the incinerator process completely depends on the combustion method. Combustion is a chemical process in which reactants are treated thereby generating heat and by product, commonly called burning. The design of the incinerator will have air passage for easy and optimum supply of oxygen to the combustion chamber.

$$C_6H_{10}O_5 + 6O_2 \longrightarrow 6CO_2 + 5H_2O + \text{Heat.}$$

The main emissions are CO2 (carbon dioxide), NO_x (oxide of nitrogen), NH (ammonia), HCL, Sulphur dioxide and organic compounds. To control pollution emission from incinerators, the use of air pollution control (APCs) and scrubbers are inculcated into the design of incinerators, which can limit the emission to a great extent.

Some of previous works in management of MSW by different researcher or authors are:

1) As this paper suggest, that main problem associates with this process is large volume of gaseous emission. However, it very important to note that pollution induced by MSWI can be easily controlled by our up to date sophisticate air pollution control equipment. So this paper helps us in building knowledge regarding air pollution control. [Marganda J. Quima, et all 2014].
2) As this paper suggest, that portable incinerator can helps in reducing the mass of the solid waste, which is major problem nowadays. And residue flue gages can also further use for the generation of energy. [Jude C. Akpe, et all 2016].
3) As this paper contends, each country must change its waste disposal system. As the waste is increasing rapidly, we have to switch to new technology like incineration which not only helps in reducing the waste also by the residue gases of the waste can help in energy generation. [Ola Eriksson, et al 2017].

II. METHODOLOGY

Every incinerator is unique, but the most common technique is called "mass burn". The general process followed in a mass burn incinerator includes the following steps:

1) *Waste Preparation:* Oversized items and metals are removed. The remaining waste is often shredded before it enters the incinerator.
2) *Combustion:* Waste is burned in an oxygenated primary chamber (combustion chamber). Materials are burned at extremely high temperatures of 1000-1200°C. At those temperatures, waste should be completely combusted, leaving nothing but gases and ash.
3) *Environmental Control:* The cooled gas is treated by scrubbers, precipitators, and filters to remove pollutants. The ash that forms during treatment, is disposed of in a landfill.
4) *Environmental Release:* The treated gas is released to the atmosphere. There should be minimal visible smoke from the chimney.

III. COMPONENTS

A. Base / Stand

The material must have high compressive strength, temperature resistance, thermal conductivity and wear resistance. Cast iron along with a nylon coating can be a most economical material for the designing of the base of an incinerator.

Cast iron - 800°C

Nylon - 1300°C

Generally, alloys of CO – Cr offer the best above properties as they are used for aircraft engine design.

B. Body

The main body will consist of two chambers primary and secondary. Both the chambers will have a refractory lining/ fine /clay/ brick. Inner lining to accumulate the heat and to pause temperature, the outer covering will consist of stainless steel casing to provide wear resistance and rigidity.

C. Burner

The waste is first thermally treated up to a temperature of 800-900°C, providing solid ashes and gases. The fuel (LPG, Petrol, Diesel, Coal, etc.) fired burner can be used to pre ignite the waste. The post combustion chamber uses air supply passages to minimize the smoke and odors burn the gases produced to a higher temperature of 900-1200°C which can be utilized for our needs.

D. Grinder

A device which is used to shred the MSW into small or powder like form. Since in this way surface area will increase which will cause faster rapid burning, the rate of burning will increase and the pre heating time will be reduced.

E. Fuel Channel

A diffuse outlet through which flue gases at high pressure and temperature can be obtained in order to utilize them at will.

F. Pollution Control / Air Pollution Control

As per the WHO guidelines for India the incinerator temperature to achieve an efficiency of 90 -99% pollution control.
The primary chamber temperature – 540 to 980°C.
And secondary chamber temperature – 1000 or 1100°C.
Furthermore, to achieve the best results an electric precipitator can be used.

G. Temperature Sensor

They are used to display the current temperature of the primary and secondary chamber.

IV. DESIGN

The prototype of portable incinerator is designed with the help of the Solid Works software for the proper and efficient analysis of the respective module design. This gives an option of analysing the problems related to the design and provides us the solutions to overcome them and come up with Thebes's efficient module design possible.

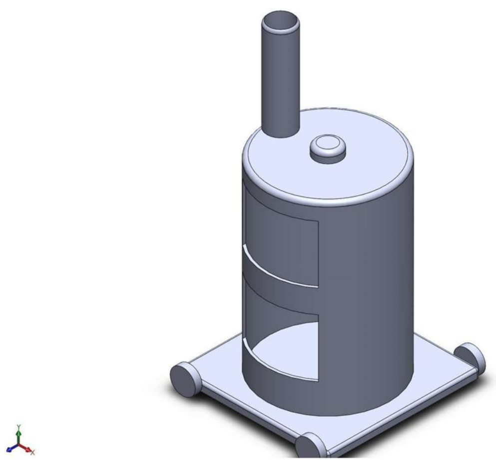

Fig.2.SolidWorks Design of Portable Incinerator Fig.3.Working Model of Portable Incinerator (Source: Industry Search)

The incinerator is designed to be charged manually with the MSW (municipal solid waste). The waste is ignited in the primary chamber with the aid of a burner, followed by post heating in the secondary chamber to re-burn products. Also the primary chamber will have a de-ash door to manually remove the ash.

A. Primary Chamber

$v = \pi r^2 l$

v = volume of the primary chamber of the incinerator.
l = length of the primary chamber.
r = radius of primary chamber.
It will be used to preheat/ignite the waste or charge.

B. Secondary Chamber

It is designed to facilitate a gas residence time of 1.5 -2.5 seconds(approx.) to obtain the property of dry air and to remove all the toxic effluents from the flue gases.

C. Thickness of Insulator (Inner Wall)

To minimize the heat loss a refractory brick is used. The rate of heat transfer can be calculated by using Fourier law.

$$Q = -KA\frac{dt}{dx}$$

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Q = rate of heat transfers through the wall.
K = thermal conductivity.
A = perpendicular area along the direction of heat flow.
dt = temperature difference along the direction of heat transfer.
dx = effective length of insulation lining.

V. CALCULATIONS

Theoretical calculation achieved by data obtained through previous research and works.

1) *Step.1.* Waste composition.

S. No.	Components	Composition (% by weight)	Moisture Contents	Energy Contents	Dry weight (approx.)	Energy Source (approx.)
1	Food waste	9	70	4,645	2.7	41,802
2	Paper	34	6	16,701	32	5,68,513
3	Card waste	6	5	16,256	6.7	97,539
4	Plastics	7	2	32,513	6.9	2,27,591
5	Textiles	2	10	17,418	1.8	34,835

Note: All the results are in approximate units.

2) *Step.2.* Determine holes of oxygen required to combust the sample completely.

$$C + O_2 \longrightarrow CO_2$$

$$4H + O_2 \longrightarrow 2H_2O$$

$$2O \longrightarrow O_2$$

$$2N \longrightarrow N_2$$

$$S + O_2 \longrightarrow SO_2$$

Note: Oxygen in the waste mass is released during combustion and decrease in oxygen is required for stoichiometric combustion.

S. No.	Components	Weight (gram)	Molecular Weight (gram)	Moles Required (g/mole)	Moles of O_2
1	Carbon	22.813	12	1.9025	1.901
2	Hydrogen	3.04	1	3.04	0.76
3	Oxygen	19.795	16	1.237	-0.6185
4	Nitrogen	0.266	14	0.019	0
5	Sulphur	0.089	32.1	2.77×10^{-3}	2.77×10^{-3}
6	Ash	3.069	n/a	---	0

Oxygen for combustion of 100g of MSW is 2.045g/mole.

3) *Step.3.* Composition of flue gases.

S. No.	Components	Moles (g/mole)	Combustion Pathway	Combustion Product	Combustion (g/moles)	
1	Carbon	1.9025	$C + O_2$	CO_2	CO_2 =	2.045
2	Hydrogen	3.04	$4H + O_2 \longrightarrow 2H_2O$		H_2O =	14.09
3	Oxygen	1.237	--		--	--
4	Nitrogen	0.19	$2N \longrightarrow N_2$		N_2 =	0.022
	Total					6.157

4) *Step. 4.* To calculate flue gas enthalpy.
Joules /g/ mole is function of temperature is directly proportional to compound, this function is complex and non-linear.
Total joules/ g/ mole is a weighted average of all gages present.

Temperature	CO2	H_2O	O2	N2	Average Enthalpy of Flue Gas
810K	23335	62529	16196	15606	29416.5
1100K	37655	73719	25565	24515	40363.5
1350K	52762	85702	35279	33721	51866
1650K	68600	98480	45325	43217	63905.5

5) *Step.5.* To determine enthalpy in terms of joules/g waste.

$$Joules\ /\ g\ waste\ = \frac{[(Enthalpy\ in\ joules\ /\ g\ /\ mole) \times (moles\ of\ flue\ gas)]}{100\ g\ waste}$$

Temperature	Flue Gases (J/g/ waste)
810K	1817.17
1100K	2485.180
1350K	3193.38
1650K	3934.66

VI. OBSERVATIONS

A. Cost

It is the most crucial factor to determine the feasibility of the project. Our team aimed to build the portable incinerator at the best possible price. The main cost controlling factor include the following: -

1) Consumption cost of fuel to ignite the charge.
2) Air pollution control devices.
3) Repair and maintenance cost.

According to the Indian markets the approximate cost of following major components are listed below: -

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Table. 1

Components	Cost
Air filter (catalytic convertor)	Rs.5000
LPG burner and cylinder	Rs.1000
Solid waste grinder	Rs.9000-15000
Nylon insulation	Rs.40/kg

B. Material

The base material will be cast iron as it has great compressive strength and absorbs vibration. The inner lining must be made of refractory brick. The thickness of the insulator must be at least "50mm" for adequate insulation. Nylon coating will provide further insulation and will help in achieving high temperature zones in the secondary chamber. The outer casting can be done by using standard stainless steel as it will offer corrosion resistance, thermal conductivity and strength to the brick lining.

C. Waste Material/Charge Input

The municipal solid waste generally has a composition of the following food waste, PVC, polythene, textile and paper, etc. The research/review through various existing data from some available papers, practical and theoretical experiences show following results.

Table. 2

	Constituent	Percentage	Mass (Kg)	Higher Heating Value (KJ/kg)	Total heat (MQ) (KJ)
1	Food	53.39	32.03	19,228	615,876.84
2	PVC	7.45	4.47	22,630	101,156.1
3	Polythene	13.15	7.88	46,304	364,875.52
4	textile	3.03	1.8	9,270	16,686
5	Paper	22.89	13.73	18,119	24,877.39
	Total	**100**	**60**		**1,101,471.85**

Source: (Ministry of Environment, Ontario, 1986)

(Source: AIJST)

Table. 3

Waste Parameters	Desirable Range
Moisture content	<45%
Organic or volatile matter	>40%
Fixed carbon	<15%
Total inert	<35%
Net calorific value	>120kcal/kg

D. Fuel

The charge can be ignited via LPG is an optimum fuel to ignite the charge as they offer low ignition temperature and high calorific value and Their cost is economical also.

E. Exhaust

It is quite difficult to meet the exact emission standards for low cost small scale incinerators. The name of general gases and their approximate quantity is listed in the below table.

Table. 4

Waste	Gas
High in paper & polythene	NO_2, NO_x
High in PVC & polythene	NO_x
High in PVC & textile	HCL

Table.5. The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources.

Substance	Non-Continuous samples	Half-hour mean value	Daily mean value	Notes
Dust		1-20	1-5	Lower levels achieved with fabric filters as hose bags filters
HCl		1-50	1-8	Use of wet processes preferred
SO_2		1-150	1-40	Use of wet processes preferred
NOx with SCR		40-300	40-100	Additional energy demand and costs
NOx with SCR		30-250	120-180	At high raw gas NOx levels, NH_3 slip to be taken into account, preferred method in conjunction with wet processes
TOC		1-20	1-10	Optimum combustion conditions are required
CO		5-100	5-30	Optimum combustion conditions
Hg	<0.05	0.001-0.03	0.001-0.02	Input control, carbon-based adsorption processes
PCDD/PCDF (ng ITEQ/Nm³)	0.01-0.1			Optimum combustion conditions, temperatures controls to reduce synthesis, carbon-based adsorption processes.

(Source: Attainable emission levels for waste incineration facilities (excerpt from Table 5.2 of BREF (2006) "Operational emission levels associated with the use of BAT" for air pollutants expressed in mg/Nm3).)

These possible devices can be utilized at garbage incinerator to meet the desired pollution control norms

1) Air pollution control equipment
2) Optimum combustion process temperature
3) Process control parameters

In addition to above devices the optimum combustion temperature generally brings the emission level within the desired range. Which further facilitates cost cutting.

VII. SCOPE OF WORK

The aim of work is to address the various controlling factors required to design an optimum portable garbage incinerator. In our country open burning is quite frequent in empty places or space available. Despite the merits or demerits of an incinerator. A portable incinerator specified for household, schools, society and business parks is one of the possible ways of managing MSW. And to utilize the available flue gases in our advantages such as for heating, boiling of water, room heating purposes, etc. In continuation, the ash available can also be utilized as binding and strengthening material of concrete blocks.

However, the limiting factor for the effectiveness and efficiency of incinerator is governed by availability of the charge in adequate quantity that is directly dependent on the population of the place. Hence a garbage incinerator offers a wider range of usefulness in an urban/metropolitan than in a rural part of the country.

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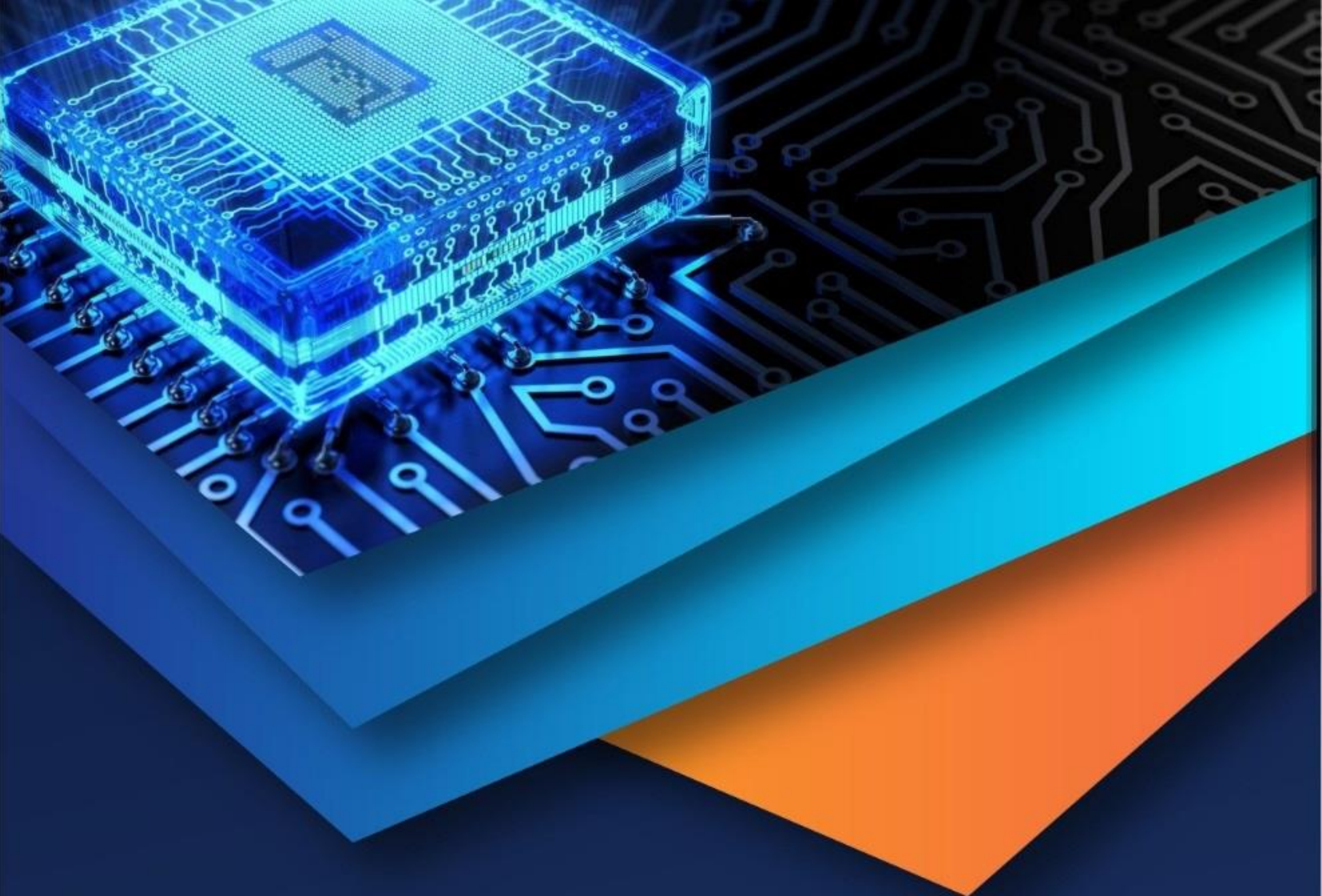

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