THE DESIGN AND CONSTRUCTION OF A MOBILE WASTE INCINERATOR FOR AGRO COMBUSTIBLE WASTES

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ABSTRACT

This study presents the design and construction of an incinerator used for burning dried agricultural combustible waste materials and recovering the ashes for domestic and industrial uses. Burning of agro wastes in open air causes flies ash and environmental pollution. Ashes are stressful to collect except when materials are burnt in a closed chamber. It became difficult and more expensive to collect waste around the farm point. Effective, economical, and environmentally friendly waste management method was needed on the farm. These waste management challenges resulted in the design and fabrication of a mobile waste incinerator. The incinerator was fabricated using 2 mm thick sheet metal to fabricate the body and the ashtray. The tray has a handle for pulling it in and out. Other components included angle iron, metal mesh, chimney, metal handle, and thick pressure gas cylinder. The mobility of the incinerator was achieved through four trolley tyres at the base. The combustion chamber is made of a thick sheet of metal with high refraction properties. The incinerator has a waste charging point at the top. The incinerator fire is supplied by Liquified Petroleum Gas (LPG) to burn wastes quickly in the combustion chamber and prevent a long burning process reducing the releases of flue gas. Subsequently, the flue gas escaped through the chimney welded to the top of the incinerator. The ashes dropped into a collector tray of volume 0.0296 m^3 and dimension of 0.62 m x 0.596 m x 0.08 m. The incinerator was designed to treat a bulk waste of volume of 0.455 m^3. and dimensioned to be 0.62 m x 0.596 m x 1.23 m. The dimension of the incinerator is 0.62 m x 0.596 m x 1.456 m and a volume of 0.538 m^3 including the ash chamber. The design and fabrication of this waste green technology incinerator resulted in an effective method of waste management on the farm and converted waste into useful ashes. The efficiency of the mobile incinerator is 72.6%. The mobility concept of the incinerator reduced the stress and cost of transferring wastes to the disposal and burning point. Environmental pollution was reduced as fly ash was prevented by the fiber flue gas filter installed at the top of the chimney.

Keywords: Agrowaste, Ashes, Combustion, Construction, Design, Incinerator, Mobile

1. Introduction

Incineration is a waste treatment process that involves the combustion of organic substances [1].

The incinerator converts waste materials into ash, burnt waste, flue gas, and heat. The ashes are

mostly formed by the inorganic constituent of the wastes and may take the form of solid lumps

or particulates carried by the flue gas. The flue gases must be free of gaseous and particulate pollutants before they are dispersed into the atmosphere. [2] reported that in some cases, the heat generated by the incineration process can be used to generate electric power.

The incinerator reduces the solid mass of the original waste to about 20% and volume to 15% depending on the composition of the waste [3]. Incineration with energy recovery is one of the several Wastes to Energy (WTE) technologies such as gasification, pyrolysis, and anaerobic digestion. Incineration and gasification technologies are similar in principle. Heat energy produced from incineration is of higher temperature than gasification. However, combustible gas is often the main energy product from gasification. Incineration and gasification may be implemented without energy and materials recovery. Incineration has been used widely for waste disposal, including household, hazardous, and medical waste but there is increasing public concern over the benefits of combusting the waste versus the health risk from pollutants emitted during combustion [4].

[1] reported that waste combustion is particularly popular in a country like Japan, where land is a scarce resource. Denmark and Sweden are leading countries in energy generation from incineration, the localized combination of heat and power facilities, and supporting district heating schemes. In 2005, waste incineration produced 4.8% of the electricity generation and 13.7% of the total domestic heat generation in Denmark [5]. Some European countries rely heavily on incineration for handling municipal waste, in particular, Luxembourg, Netherlands, Germany, and France [6].

Studies on waste composition in some Nigerian cities indicate that about 25% of most urban wastes in Nigeria comprise paper and non-toxic materials, which can be burnt in suitably

designed incinerators to generate heat or recover useful materials like ash and others for tiles industries. Incineration is an environmentally and technically superior method of waste management to dumping and open waste burning due to its safety, efficiency, materials recovery advantage, heat generation, and environmental friendly when the flue gas is trapped or treated. The first Czech Republic incinerator was built in 1905 in Brnos to manage the challenges of hazardous and toxic wastes[5].

The best practice of waste management is the reduction of waste generation, thus, decreasing hazardous gas and materials emissions, and health and environmental risks [7]. Waste management has defied several strategies both in developing and developed countries, aborting most efforts made by international bodies, federal governments, and state and city authorities [8].

One of the common practices in waste management is the provision of a dump site for the landfill where all manners of waste are dumped. Scavengers normally recover recyclable items and indiscriminately set the fields on fire causing dangerous infernos [9]. Investigations showed that effluent from dump sites caused by rainwater, known as leachate, sinks through the wastes which contain heavy metals and other hazardous compounds that are dangerous to human health and the environment [10]. It was reported by [11], that the analysis of boreholes water at sites around landfills indicates strongly polluted water which required treatment before use while the soil around the dump site was found to be unsuitable for crop farming due to the presence of dangerous and unfavorable elements to crops in the soil.

However, investigations of water from shallow boreholes and wells sited near the dump sites showed that they are highly polluted and dangerous to humans if consumed [11]. Gases emitted from dump sites contain compounds that can lead to the development of specific ailments, with

its attendant odour from rotting organic materials, dust, and concentration of rodents and birds [12]. To properly manage waste, there is a need for the sorting of the waste to determine the treatment process required to manage the waste. Most municipal solid waste in developing countries contains about 50% of organic waste [13]. The prolonged use of incinerators can cause thermal discomfort, thereby raising the temperature of the environment and eventually global warming [14], hence it is preferred to open-air waste burning.

In most developed countries, healthcare wastes are treated by incineration technology and the incinerated ash is disposed of at dump sites. Subsequently, studies have shown that the ashes from the incineration of waste have been actively recycled in the areas of roadbeds, asphalt paving, and concrete products in many European and Asian countries [15].

Burning of agro-combustible wastes in open air causes flies ash and environmental pollution. Ashes are stressful to collect except when wastes or materials are burnt in a closed chamber. Most times after harvest it is often stressful and cost implicative to collect wastes around the farm to a single point (dump site). An effective, economical and environmentally friendly waste management method was necessary on the farm for dried agro wastes. Bulk confidential documents such as past examination papers and official documents are not allowed to be in the public and they cannot be shredded due to their volume and mass. The document must be well managed for security reasons. The concept of this project is to design and fabricate an incinerator that can burn wastes such as dried agricultural wastes, waste paper, fabrics, wood, and other combustible wastes and convert the wastes to ashes for domestic and industrial uses. The incinerator is for burning bulk confidential documents for security reasons. The incinerator has four trolley tyres for mobility and can be moved from place to place to burn agro wastes and

reduce the stress and cost of waste transfer. The ashes recovered are meant to be sold to industries for the production of tiles, cleaning agents, and allied products

2. Materials and Methods

(a) Material Selection

The materials used for all the parts of the incinerator were selected based on their properties and service requirement. Table 1 shows the requirement for the selection of the material used for the incinerator.

Table 1: Materials selection for the fabrication of the incinerator

S/N	Parts	Materials Used for Fabrication	Properties	Service Required
1.	Incinerator body frame	2 mm mild steel sheet metal	Flat, strength	Wastes chamber
2.	Chimney	2 mm mild steel cylindrical Pipe	Cylindrical, hollow	Conveys flue gas
3.	Metal mesh	6 mm mild steel perforated metal	Perforation	Separate ash from burnt waste
4.	Trolley tyres	250 mm diameter trolley tyres	Rotation	Mobility of incinerator
5.	LPG Gas cylinder	6 kg thick-pressure gas cylinder	Thick pressure vessel	Gas storage
6.	Gas regulator valve	Gas regulator	Airtight, gas regulation	Regulate gas flow
7.	Gas hose	10 mm diameter flexible gas hose	Flexibility, hollow	Convey gas to discharge pipe
8.	Gas discharge pipe	0.024 mm galvanized pipe	Strength, heat resistance	Discharge gas

perforation

(b) Design Analysis

[16] stated that proper design analysis and construction of municipal solid waste incinerators cannot be achieved without the knowledge of combustion science, characteristics of wastes, and appropriate materials selection.

All dimensions are in a meter

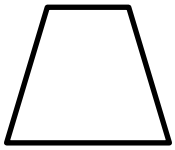
Chimney

The volume of the cylinder = $V = \pi r^2$h

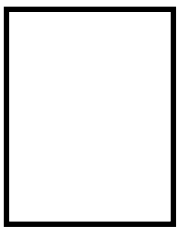
=3.142 x 0.$^{05^2}$ x 0.701 m

=0.00551 m^3

Combustion chamber

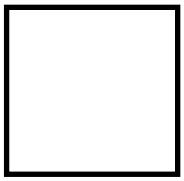


Volume of frustum = 0.04849 $m3$



Volume of cuboid = $l\ x\ b\ x\ h$=0.62 m ×0.596 m ×0.935 m= 0.455 m^3

Ashtray



$$\text{Volume of ash tray} = l \times b \times h = 0.62\ \text{m} \times 0.596\ \text{m} \times 0.08\ \text{m} = 0.0296\ m3$$

$$\text{Total volume of incinerator} = 0.00551\ \text{m}^3 + 0.04849\ \text{m}^3 + 0.455\ m3 + 0.029\ \text{m}^3$$
$$= 0.538\ \text{m}^3$$

(c) Fabrication Procedure

Fabrication of the mobile waste incinerator involved a series of machine operations with various tools including machine tools like folding machines, and lathe machines among others. The electrode of gauge 10 was used in all the welding processes. The arc welding process was used throughout the welding operations. The charging opening was cut to size using a hand-grinding machine with a cutting disc of 180 mm diameter. It was welded with a handle and attached to the incinerator body using hinges through a welding process for easy opening and closing. The sheet plate of 2 mm thickness was cut to size as specified and welded to form the ashtray and handle for pulling it in and out of the incinerator using an arc welding machine. The metal mesh was cut to size using a hand grinding machine with a 180 mm diameter cutting disc to conveniently stay in position in the burning chamber and welded with a handle for easy handling using an arc welding machine. The serial sequence of operations for the fabrication of the incinerator parts was an important factor that was considered in the construction of the incinerator. Two mild steel sheets of 1220 mm × 2440 mm × 2 mm were folded equally to a rectangular shape of dimension 610 mm × 1220 mm × 2 mm to make the combustion chamber. The rectangular shape was cut below the position of the mesh to allow the passage of the ashtray before folding the sheet. The sheet plates were folded to form the shape of the body frame of the incinerator by using a metal folding machine. A frustum shape was fabricated at an angle of 45˚ using a 2 mm thick sheet

plate and welded to the cuboid shape to make it a complete combustion chamber. A Hollow galvanized pipe of length 457.5 mm and diameter 70.1 mm. was welded to the frustum to form a chimney to the incinerator. The chimney was installed with a removable fiber flue gas filter at the top to filter the flue gas percolates to reduce environmental pollution and prevent fly ash. A rectangular shape was also cut from the second mild steel sheet with a dimension of 610 mm × 1220 mm × 2 mm to make a base for the incinerator. The standard angle iron of 51 mm and length of 8500 mm were welded to the base and body of the incinerator to ensure the rigidity of the incinerator. An opening dimension of 610 mm × 610 mm × 2 mm was cut out from the mild steel sheet and was fastened to the base which serves as a housing unit for the gas cylinder. A standard galvanized pipe of diameter 0.19 mm and of length 2000 mm was cut and welded to form a rectangular shape and placed at the base of the burning chamber to serve as the burner. It was perforated to discharge the gas for burning the wastes using a metal punch. Two cylindrical pipes of length 305 mm and diameter 30 mm were welded to the incinerator to serve as handles for pushing it. A high-pressure gas cylinder of 6 kg was purchased with a high-pressure gas regulator. The high-pressure regulator was connected to a hose of length 4572 mm and the other end was connected to a low-pressure regulator to regulate the flow of gas entering the burner. Four trolley tyres were fixed to the base of the incinerator on two cylindrical solid shafts. The shafts were drilled with a 13 mm drill bit to fix two stoppers for the tyres to prevent removal when in motion. The welded parts were grounded using a hand-grinding machine to remove rough surfaces and shape edges. Holes and dents were filled with body filler material to obtain a good finishing appearance. The incinerator was painted to achieve a good aesthetic appearance.

The incinerator was designed to contain and burn a bulk waste volume of 0.455 m^3 according to the design of the waste chamber for a batch. The incinerator was charged with solid wastes of

dried corn stalks, paper, wood, and other wastes. The gas was ignited to burn the wastes from the base of the burning chamber. Masses of wastes burnt and the ashes produced were recorded. Percentages of masses of ashes obtained concerning the masses of wastes burnt were calculated. The efficiency of the mobile incinerator was determined concerning the ashes produced. The effectiveness of the incinerator concerning mobility innovation was also determined.

3. Results and Discussion

The combustion chamber material is made up of steel because it is of reasonable market price and readily available [17]. Performance evaluation of the incinerator is detailed to time spent in wastes transfer to the dump site, the mass of wastes burnt and ashes produced, and the cost of transferring the wastes. It took 10 minutes to transfer 150 kg of waste through a distance of 1 km for a trip using a cart due to the rough nature of the farmland and the soil. The cost of hiring manpower for the transfer of 2000 kg is N2,000 through a distance of 1 km. During testing, dry agro wastes of mass 30 kg were charged into the incinerator 21 kg were burnt. The result showed that of 25 kg of waste 17 kg was burnt. The mobility of the incinerator reduced the movement time used for waste transfer across the farm in a day by 70%. The mobility also reduced the cost of waste transfer by 75%. Agro-combustible waste that is not suitable for recycling or materials reinforcement can be managed through different waste management methods [18]. The ashes passed through the metal mesh and dropped into the ash collector and this made the process neat and stress-free. [16] reported that incinerator efficiency is a function of its temperature, mass of ashes produced, and time of combustion among others parameters. No one method can be used alone to justify the efficiency of an incinerator. It is an integrated waste management system with environmental and economic benefits.

The burning of wastes was very effective and fast because the fire was ignited at the base of the burning chamber. Incineration is better than open burning where the fire is normally ignited at the top of the waste and most times it does not get to the bottom of the waste resulting in wastes of fuel and time. The fiber gas filter minimized the percolates that were released with flue gas. The use of gas resulted in quick burning and consumption of wastes which minimize the burning time and reduced the quantity of flue gas that was released.

The four trolley tyres provided the essential mobility of the incinerator from one place to another on the farm. The mobility of the incinerator is the most important factor which determined the efficiency of the incinerator system.

Plate 1 shows the fabricated mobile incinerator with various parts.

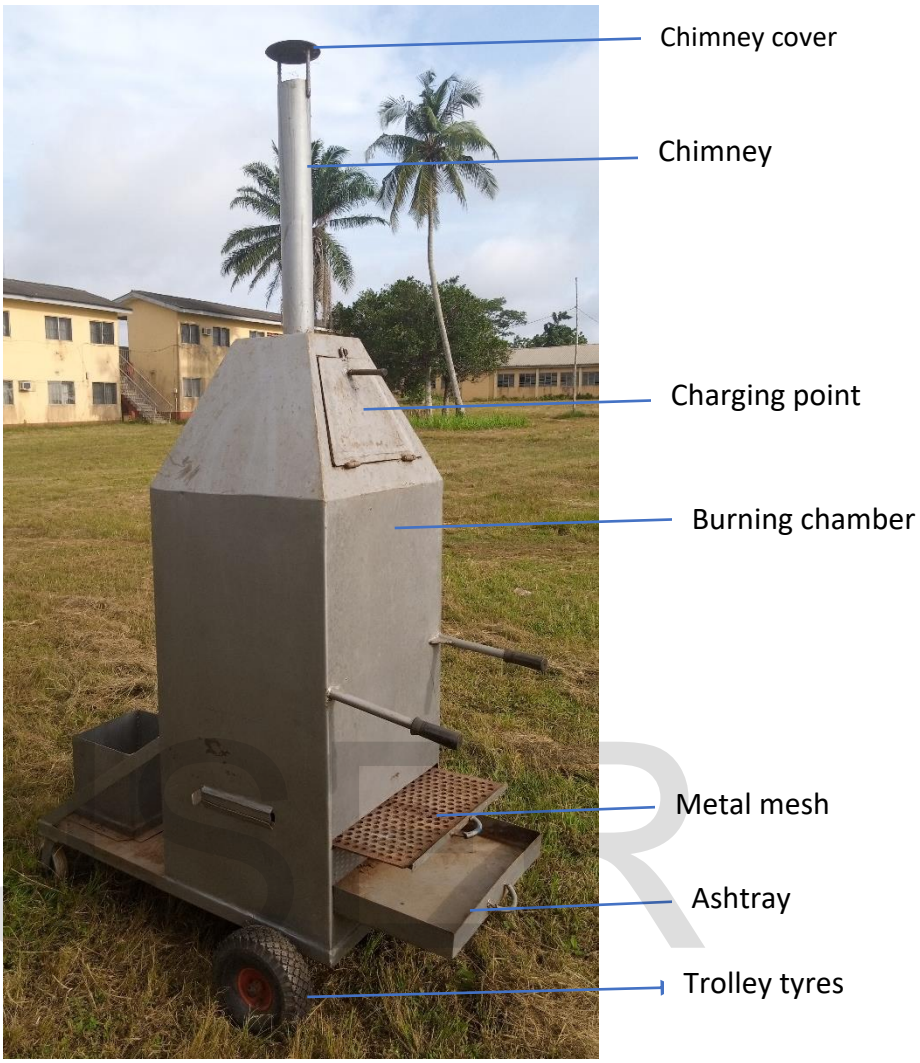


Plate 1 shows the parts and components of the incinerator

Table 2 shows the results of the tests carried out on the incinerator through waste burning and the masses of ashes obtained with the efficiency of the incinerator on each test.

Table 2: Shows the types and mass of waste incinerated, mass and % of ashes obtained

Mass of wastes (kg)	Mass of burnt wastes (kg)	Efficiency of incinerator (%)
32	24	75

28	20	71.4
24	16	71
20	14	70
16	8	75
12	9	75

It can be inferred from Table 2 that the reduction in the mass of wastes burnt resulted in a consequential decrease in the mass of ashes produced. The variances in the efficiencies are 0 – 5.

4. Conclusion

The mobile waste incinerator was designed, fabricated, and tested. The collection of the ashes was also achieved with minimum effort. The environment was protected from flue gas and fly ash pollution. Agro wastes of different masses produced different masses of ashes with little variant inefficiencies. The use of LPG as the source of fire kept the flue gas at the barest minimum. The incinerator was accessible at every necessary place on the farm. The incinerator can be used on the farm and in urban and rural areas for effective domestic and agro wastes management. Environmental pollution was reduced. The environment was made friendly. The efficiency of the incinerator is 72.6% The incinerator justified the design, fabrication, and use in the right direction.

References

[1] Knox, A. (2005). An Overview of Incineration and EFW Technology as Applied to the Management of Municipal Solid Waste (MSW). Retrieved 18/12/2020 from http://www.durhaenvironmentalwatch.org/incinerator

[2] Dunphy D., Griffiths, A., and Benn, S. (2007). 'Organizational Change for Corporate Sustainability 2nd edition, Taylor and Francis Inc.

[3] Ernst, M. (2008). The World Bank Technical Report: Municipal Solid Waste Incinerator, Washington DC, The World Bank

[4] Tait, P.W. Brew, J., Che, A., Costanzo, A., Danyluk, A., Davis, M., Khalaf, A., McMahon, K., Watson, A., Rowcliff, K., Bowles, D. (2020). The Health Impacts of Waste Incineration: A Systematic Review; *Australian and New Zealand Journal of Public Health.* 44(1), pp 40-48.https://doi.org/10.1111/1753-6405.12939

[5] Herbert, L. (2007). "Centenary History of waste Authority. 9 January 2007. Incineration Processes and Environmental Releases (IPER); (2000). National Research Council. *Waste Incineration and Public Health*. Washington, DC: The National Academies Press. p 34 – 48; DOI: 10.17226/5803.

[6] Niessen, W.R. (2014) Combustion and Incineration Processes, 3rd edition, New York, Marcel Dekker.

[7] Joseph, O.O., and Ibrahim, G.W. (2019). Merits and Demerits of Waste Disposal Methods in Federal Polytechnic, *Ilaro, Ogun State, Nigeria; Ilaro Journal of Environmental Research & Development;* 3 (1) 146 – 155. ISSN: 2736-0814146

[8] Adejobi O,S. and Olurunnimbe. R.O. (2012). Challenges of Waste Management and Climate Changes in Nigeria, Lagos State metropolis experience, *African Journal of Scientific Research* 7(1) pp. 346 –362

[9] Adewale A.T (2009). Waste Management towards sub Sustainability in Nigeria. *A case study of Lagos State, International NGO Journal* 4(4) pp 173 - 179

[10] Mahmoud, K., Batool, S. A., Rana, A. D., Tariq, S., Ali, Z. and Chaudhry, M.N. (2013). Assessment of Leachate Effects to the Drinking Water Supply Units in the Down Slope Regions of Municipal Solid Waste (MSW) Dumping Sites in Lahore Pakistan, *International Journal of Physical Sciences*, 8(28), pp. 1470-1480,

[11] Akinbile, C.O. (2011). Environmental Impact of Landfill on Groundwater Quality and Agricultural Soils in Nigeria, *Soil & Water Resources*, Vol 7, pp. 18–26

[12] Kotvicova, J. Toman, F., Vaverkova, M. and Atwjskal, B. (2011). Evaluation of Waste Landfill Impact of the Environment using Bio-indicators, *Polish Journal of Environmental Studies,* 20(2), pp. 371-377,

[13] Adigio, E. M. and Amula, E. (2011). Appraisal of Waste Management in Yenagoa Metropolis; *International Research, Journal in Engineering Science & Technology*, Vol. 7 pp. 114 -124

[14] O.O. Joseph, O.O. Joseph, J.O. Dirisu, A.E. Odedeji, Corrosion Resistance of Galvanized Roofing Sheets in Acidic and Rainwater Environments, HELIYON, https://doi.org/10.1016/j.heliyon.2021.e08647.

[15] Abdulahi M.M. (2009). Municipal Solid Waste Incineration Bottom Ash as Road Construction Materials; A U J.T 13(2), pp 121 - 128

[16] Oumarou, M.B., Abubakar, A.B. and Abubakar, S. (2018). Municipal Solid Waste Incinerator Design: Basic Principles; *Sustainable Energy*. 6(1), pp 11-19. DOI: 10.12691/rse-6-1-2

[17] Omoregie, M. J. and Odibi, T. I. (2017). Design and Fabrication of a Domestic Incinerator, *Journal of Applied Science and Environmental Management*, 21(5) pp 981-984

[18] Joseph O.O. and Babaremu K.O. (2019). Agricultural Waste as a Reinforcement Particulate for Aluminum Metal Matrix Composite (AMMCs): A Review. *Fibres;* 7(4): 33-42 DOI: 10.3390/fib7040033