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Performance Evaluation of a Domestic Solid Waste Incinerator Water Heater

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***Abstract*— Solid wastes from domestic and commercial activities are abundant in Nigeria, which are untapped renewable energy. This paper analyzed the performance of a locally fabricated solid incinerator for water heating purpose. The principles of energy conservation principle and energy recovery were applied in evaluating data obtained from the pilot incinerator plant. Results obtained showed that the maximum water outlet temperature was 67.3 ^{0}C after 50 minutes of operation. In addition, the maximum energy gain and efficiency calculated was 22.1kW and 55.3% respectively. Thus, using the solid waste incinerator for domestic water heating purpose will reduce dependence on fossil fuel and littering of solid waste in the environment; therefore, minimize the effect of global warming and climate change. The used of the plant can serve as an alternative device in burning solid waste for water heating purpose.**

Keywords—solid waste; incinerator; heating; water, evaluation; energy gain

I. INTRODUCTION

The massive development activities in Nigeria have lead to release of waste into the environment in different form such as solid, liquid and gaseous waste. Human rely so much on material things, which mostly end up as waste. Waste has been regarded as any object that may or may not have served its intended use waiting for reuse or disposal [1,2]. Solid waste is considered in the work, which means any garbage, refuse, discarded materials from households, schools, offices, market places and other public places.

Most solid waste generated from household and commercial activities are not properly managed in some rural and urban areas in Nigeria [3,4]. The solid waste generated in Nigeria is in excess of 25 million tons annually [5]. Municipal Solid Waste (MSW) is one huge untapped energy source [6]. These waste can be burn using incinerators, which carried out by either sending the MSW to mass – burn incinerator, or it is pre - processed to produce a more homogeneous product called refused – derived fuel (RDF) that has much combustion characteristics.

Voelker [7] reported that waste combustion provides integrated solutions to the problem of modern era, by recovering otherwise lost energy, thereby reducing the use of precious natural resources, cutting down our emission of greenhouse gases, saving valuable land that otherwise be destined to become landfill and recovery land once scarified to the product of consumerism. Controlled incineration for energy recovery has contributed to individual/national energy supply; generation of energy reduces uncontrolled air pollution, fire hazards and explosion arising from indiscriminate practices.

Waste to Energy (WTE) has been recognized as a renewable energy under existing law [6]. This technology is a robust, proven, clean and safe designed for minimal environmental risk which has proven in practices over several decades [8]. Most studies on WTE have been on electricity generation and these require a large capital investment. For small scale consideration, WTE can be used for water heating purpose for domestic need. In Nigeria, most people especially in rural areas and many developing countries depend largely on fossil fuel or firewood for cooking and water heating [9-11].

Solid waste is widely distributed and available in the country as earlier mentioned, which can be used to fuel an incinerator. Egware and obanor [12] stated that it is necessary to evaluate existing thermal utilities to ascertain their performance level. Therefore, this study was carried out to determine the performance and possibility of utilizing solid waste incinerator water heater, which can serve as an alternative device in combusting the solid waste for heating water.

II. METHODOLOGY

A. *Description of the Incinerator*

First, A solid waste incinerator for domestic water heater was designed and fabricated using the following specification and materials as shown in Table1.

Table 1: Materials Specification of a domestic water heating solid waste incinerator

S/N	Part Name	Dimensions (mm)	Material
1	Base Stand	280 x 510 x 510	Mild Steel
2	Grate	Ø380. Mesh size	Mild Steel
3	Outer Shell	Ø480, 1200 high	Mild Steel
4	Inner Shell	Ø430,1200 high	Mild Steel
5	Insulator	50 thickness, 1200 high	Saw Dust
6	Water Tubing	Ø25, 2000 long	Copper

Figs. 1 and 2 show the sectional diagram and picture of the domestic water heating solid waste incinerator respectively.

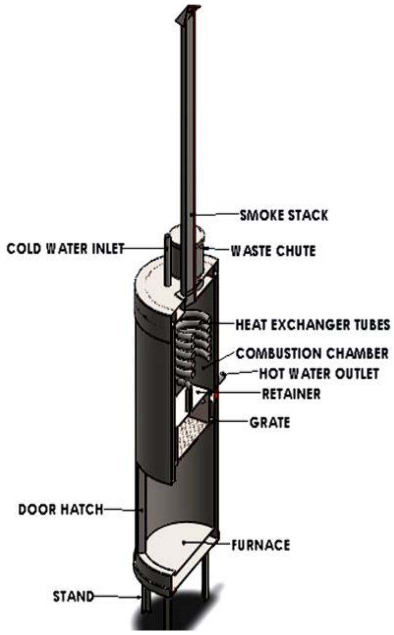

Fig. 1: Sectional view of cylindrical natural convection process water heating incinerator.

Fig. 2: Picture of the Domestic Water Heating Solid Waste Incinerator

This cylindrical incinerator is made up of external casing constructed of mild steel. Within the incinerator there is a combustion chamber which is located above the furnace. The base of the combustion chamber is a mild steel grate over which the waste is burnt. A door hatch serves as a cover for the entry into the furnace. Holes are made in the combustion chamber thereby aiding combustion. Sawdust which is the insulation material also serves as the primary source of fuel and is put into the furnace through the top. The waste is then feed into the combustion chamber through a chute situated on top of the incinerator. The cold water inlet pipe runs from the top and is connected to a retainer situated within the combustion chamber. The tube within the shell of the heat exchange section is made of copper. The retainer serves as a vessel where enough heat is accumulated by the water before leaving the incinerator to the hot water storage vessel.

B. Test and Analysis

The experimental test was carried out on the fabricated domestic water heating solid waste incinerator to evaluate its performance. This test was carried out after charging the saw dust and dried solid waste (waste papers, dry leaves, wood chips, food waste and other combustible solid waste) into the incinerator. To determine the mass flow rates of saw dust and dry solid waste their mass were measured before feed them into the incinerator. The saw dust was ignited to initiate combustion after which water was passed into the copper tubes. The test took an hour, which the mass of the saw dust and dry solid waste burnt gradually and readings of the water inlet and outlet temperatures were taken at intervals of ten (10) minutes for several times.

Based on the principles of conservation of energy and heat recovery, Equations (1) to (3) were used to evaluate the performance characteristics of the water heating solid waste incinerator on the energy release from solid waste (E_i), energy gain by water (E_o) and incinerator efficiency (η_i).

$$E_i = \dot{m}_s CV \tag{1}$$

where $\dot{m}_s = \dot{m}_{sw} + \dot{m}_{sd}$, total mass of mix solid waste

CV= Caloric value of mix solid waste

$$E_o = \dot{m}_w c_{pw}(t_f - t_i) \tag{2}$$

where $\dot{m}_w$ = mass flow rate of water

c_{pw} = Specific heat capacity of water at constant pressure

t_f = Water outlet temperature

t_i = water inlet temperature

$$\eta_i = \frac{E_o}{E_i} x100\% \tag{3}$$

$$CV = \frac{\dot{m}_{sw}CV_{sw} + \dot{m}_{sd}CV_{sd}}{\dot{m}_s} \tag{4}$$

where $\dot{m}_{sw}$ and $\dot{m}_{sd}$ are mass flow rates of dry solid waste and solid dust respectively.

CV_{sw} and CV_{sd} are Caloric Values of dry solid waste and solid dust respectively.

III. RESULTS AND DISCUSSION

The solid waste and water parameters such as mass flow rate, Caloric Value and specific heat capacity used for the analysis are shown in Table 2. The caloric value of saw dust and dry solid waste used were obtained from [13] and Equation 4 was used to determine the caloric value of the solid waste composition (saw dust and other solid waste). The results obtained from the test are shown in Table 3.

Table 2: Solid waste and water parameters

	Mass flow rate (kg/s)	Caloric Value (kJ/kg)	Specific Heat Capacity (kJ/kgK)
Dry solid waste	0.001322	16809.58	-
Saw dust	0.00119	15101.00	-
Mix Solid waste	0.002512	15912	-
water	0.1244	-	4.2

Table 3: Average Reading of the Solid Waste Incinerator Water Heater

S/N	Time (min)	t_i (^{0}C)	t_f (^{0}C)
1	10	25	37.1
2	20	25	40.3
3	30	25	50.6
4	40	25	61.1
5	50	25	67.3
6	60	25	65.4

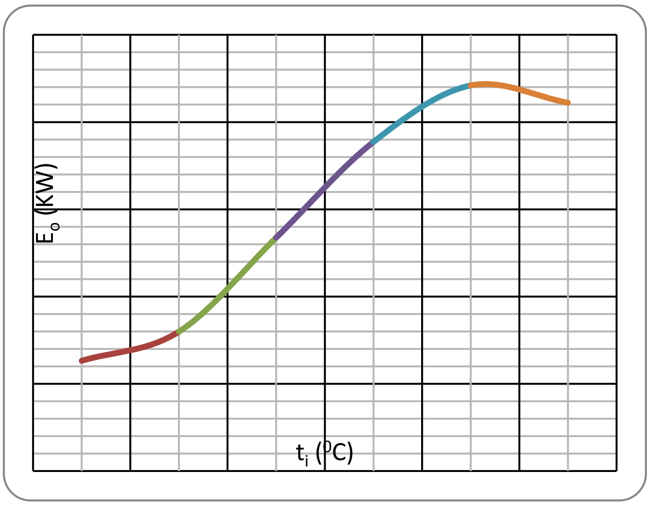

Fig. 3: The variation of water outlet temperature and energy gain

The values in the Tables 2 and 3 were used to compute the energy release, energy gain and efficiency of the fabricated incinerator applying Equations (1) to (3). The values of energy gain calculated from corresponding water outlet temperature are shown in Fig. 3. The energy release was 39.971 kW, the maximum energy gain was 22.1kW and its corresponding efficiency was 55.3%. Incinerator efficiency value obtained revealed that more than half of the solid waste heat energy was to produce hot water as useful energy. The maximum hot water temperature obtained was 67.3 ^{0}C, which reasonable for domestic consumption such as bathing and making of beverage foods.

The incinerator when in used will reduce global warming and climate problem because the solid waste fuel is regarded as renewable energy resource. It will also help in efficient way of managing environment solid waste and reduce demand for firewood , fossil fuel and electricity for water heating purpose.

IV. CONCLUSION

A solid waste incinerator for domestic water heating purpose performance was analyzed. The maximum energy gain and efficiency obtained was 22.1 kW and 55.3% respectively at a hot water outlet temperature of 67.3 ^{0}C. The use of the solid waste incinerator for domestic heating reduce fossil fuel and electricity consumption and help to make cleaner environment by reducing solid waste in the surrounding.

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