Design of a small scale fluidized-bed incinerator for MSW with ability to utilize HHO as auxiliary fuel

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Abstract. Waste incineration has become a mature technology and widely accepted due to its environment friendliness, easy operation and ability to reduce more than 95% mass fraction. There are some inherent limitations associated with incinerators such as high fuel consumption and cite feasibility. In this study, we propose a novel design concept of small scale fluidized bed incinerator for household use, with the ability to consume brown's gas (HHO) as primary fuel for incinerate waste. In principle, the HHO gas generated through photovoltaic (PV) integrated water electrolysis system would be feed from the bottom to provide heat energy to the waste. Theoretical design of fluidized bed type incinerator has been presented with water electrolyzer system. It was calculated that 150 lph of hydrogen is required for this proposed incinerator system which can handle 5 kg of waste.

1. Introduction
Municipal Solid Waste is considering to be trash, garbage which includes paper, plastic, food waste, wood, nappies, ash etc. Growth in urbanization and technologies tends to increase in the generation of the waste. Different techniques like landfill, incineration, biological conversion are being used from decades to treat this waste. All of these treatment methods are consider to be a source of sustainable energy with a promise of ‘waste to energy’. According to International Energy Agency, one ton of MSW should have 5 to 20 MJ/Kg of calorific value for an effective energy production [1].

Earlier, open dumping landfill or incineration was used to treat waste which was a threat to the environment without considering the potential of energy and environmental impacts. Rapid increase the population and industrial development has led to the new alternative techniques from conventional for waste management with an approach of waste to energy. There are three basic types of waste to energy techniques [2]: thermal conversion, biochemical conversion and landfill. The most common and effective waste to energy technique is incineration. This technique does not only help in managing the increasing volume of waste but can also has potential to have significant role in recovering energy that can be used as an alternative for the traditional fuels [3]. As 80% need of the global primary energy is met by fossil fuel [4], incineration technology has a promise in offsetting fossil fuel usage by increasing renewable share while addressing the waste treatment at the same time [5]. In this method, waste is treated in a furnace at high temperature which reduces waste mass by 70% and volume by 90% [6]. Composition of the waste with its proximate characteristics [7] and heat content (shown in figure 1) determine the
feasibility and requirement of the auxiliary fuel to incinerate the waste [8, 9]. Amount of energy release is also dependent on calorific value of the waste.

2. Potential of Incineration as Waste Management Technology

Advantages and disadvantages of waste management strategies are assessed by life-cycle inventory analysis and their impact. Incineration technology has a promise to reduce both waste volume and demand of space for landfill in an efficient manner. This technology has gain interest as waste generation is increasing day by day with human activities and normally burn out near its source of generation [10]. Therefore, it is advantageous as incineration facility can be installed near the centre of gravity of waste generation which in result reduce the transportation cost of waste for treatment. Use of resultant ash from MSW incinerator for suitability of green environment not only reduce the cost but also reduces the requirement of land fills capacity. Although incineration technology for municipal solid waste is advantageous when lack of suitable landfill sites or long transportation is required, but results in high cost. There are certain requirements which are required for incineration. Also it has been seen that composition of waste is not suitable for auto-combustion that is generated in developing countries as from figure 1, which required auxiliary fuel for incineration [9]. Also the incineration plant is complex which requires skilled staff. Flue gases released from incinerator can be hazardous for environment if not handle properly. Residue of the incinerator should be dispose of properly in controlled and well-operated landfills otherwise it could be harmful for ground and underground water [11].

This study is based on design of small scale incinerator which will be capable of handling and treating municipal solid waste at domestic level. It will not only help in managing waste at its point of generation but also help in producing renewable energy which can be used for several heating purposes. It was calculated that 150 litters per hour of the hydrogen is required as auxiliary fuel for incinerating 5 Kg of waste. This proposed system is considering to be more efficient as hydrogen has more calorific value than other fossil fuels and will reduce green-house gas emission.

![Figure 1. Heat content in waste of three different regions of world. Requirement of auxiliary fuel based on this heat content [9]](image)

3. Experimental

For last many years, advancement in fluidized bed technology change the status from laboratory and pilot plants to commercial. There are several reasons which made fluidized bed incineration method more advantageous over conventional systems. These advantages include an effective burning of all types of fuel, from low calorific value to high calorific value, under stable conditions. Even various slurry sewage sludge can be handled in fluidized-beds [12].

An incineration technique is proposed in this study based on fluidized bed technology. As fluidized bed technology is best for the waste having high moisture contents [13]. Therefore, a drying technique is additionally added for this purpose which is done by circulating or bubbling hot air [14]. This technique is able to reduce 80% of the moisture content to less than 20% which can be than incinerated easily [14].
3.1. **Theoretical Design**

A rectangular vessel with rounded edges is designed for the incineration purpose which is equipped with a plate at the bottom of the vessel for a proper distribution of air for circulation. This plate holds the inert material to make a surface known as ‘bed’. Commonly, sand is used for making this bed. A chamber is placed at the bottom of the bed for a smooth and uniform distribution of the air throughout the sand bed. An auxiliary burner is attached to the bed which keeps the temperature up to 800°C. Depending upon the velocity of the air flow it works on two modes: bubbling and circulating. As there is no moving part is included in the design so this technology can be used for continuous and semi-continuous operations. Due to the compact furnace and large heat content of the fluidized material, starting and stopping becomes very easy. A conceptual design is shown in figure 2.

For this system solid waste is to be feed after being shredded to suitable size. This shredded material is placed above the bed by using a feeding hopper as shown in figure 2. A second burner is placed above the material (as shown in figure 2) to start the incineration process. This burner is also known an as secondary burner. By increasing the velocity of the air that is passed through sand bed, it becomes fluidized. On increasing the air velocity more, the sand bed starts to expand and allow the excess air to pass through it in bubbles. This bubbling boils the mix of particles and air thoroughly by quickly forming a thermal equilibrium between the particles of waste and air.

![figure 2](image)

### Figure 2. Proposed design of fluidized-bed incinerator for treating municipal solid waste

3.2. **Prospective green technology**

Aim of this system was to design a green technology which not only address the waste treatment issue but also become a significant green technology. As continuous supply of fuel is required for fluidized bed incinerator to work properly. Conventionally, fossil fuels (oil, gas, coal) is being used in this regard. In this system this fossil fuel is being replaced by hydrogen. Moreover, this hydrogen is further generated by water electrolysis process in which electrolyzer is being energized by mean PV panels. Due to this hydrogen generation this system is considering to be a standalone, which not only solve the dependency problem of incineration on fossil fuel but also generate fuel (hydrogen) itself which it required for the system. As hydrogen is considered to be green fuel so it is seen that greenhouse emission would be low from the conventional technique. Also the calorific value of hydrogen is more than the fossil fuel [15] as shown in table 1, so this proposed system as shown in figure 3 is considering to be more efficient. In this way this whole system is consider to be a step towards green sustainable technology.

| Sr. | Type of fuel | Calorific Value (kJ/kg) |
|-----|--------------|-------------------------|
| 1.  | Kerosene     | 43124                   |
| 2.  | Diesel       | 42600                   |
| 3.  | Natural Gas  | 38000 – 50000           |
| 4.  | Charcoal     | 33000                   |
| 5.  | Hydrogen     | 150000                  |
As shown in figure 3, an incinerator was designed for treating the waste by batch method. A maximum of 5 kg of shredded waste can be treated in one batch for an hour. For burning and heating of the incinerator, one electrolyzer was used which was connected to auxiliary and incinerator burners. Amount of hydrogen required for this system was also calculated in order to design electrolyzer.

Initial Hydrogen required for moisture 55% content [16]:

| Moisture content by weight in 5kg waste | = 2.75 kg |
| Energy to evaporate 1 kg of water       | = 600 kJ  |
| Energy to evaporate 2.75 kg of water    | = 1650 kJ |
| Hydrogen required for 2.75 kg water to evaporate | = 1.65/1200 |

\[
\text{Hydrogen required for 2.75 kg water to evaporate} = \frac{1.65}{1200} = 0.013 \text{ kg}
\]

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1 \text{ kg of Hydrogen} = 11.126 \text{ m}^3
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0.013 \text{ kg of Hydrogen} = 0.0152 \text{ m}^3
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\text{Hydrogen in litters} = 150 \text{ litters}
\]

Designed electrolyzer have a capacity of 150 lph of hydrogen generation. To energize these electrolyzer one PV panels of 300 watts was used. As for Malaysia, it was considering 5.1 hr/day of sunlight. So for a stable system, a battery was introduced of 12Volt, 65 Ah. A control unit was use to charge, discharge the battery and responsible for running electrolyzer in efficient way.

4. Results
A significant advantage was seen of the proposed system over conventional incineration was its ability to reduce undesirable gas emission which includes oxides of sulfur, nitrogen, carbon monoxide and other unburnt hydrocarbons. Formation of nitrogen oxides limits due to relatively low uniform temperature (800°C – 1000°C). Oxygen mixed with the hydrogen fuel provides a favourable environment for fluidized bed for complete combustion which minimize the production of carbon monoxide and emission of unburnt hydrocarbon. Moreover, incineration process has a potential to recover heat energy during the process. Following advantages were observed for this proposed system:

- Eliminate dependency on fossil fuel
- Have a potential of stand-a-alone system
- Effectively fluidizing the sand bed due to high calorific value of hydrogen
- Low green-house emission

5. Conclusion
A variety of waste can be treated by using this proposed system which includes municipal solid waste, agriculture waste, paper, organic waste etc. This system is theoretically favourable for the waste with high moisture contents and low calorific value. As these type of waste need a constant heating environment which hydrogen has a potential due to its high calorific value. Hydrogen showed promising
results as an alternative for the fossil fuel which in future can be used for different applications. Integration of the incinerator with PV also paved path for incineration technology towards sustainability.

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