# Thermal Disposal of Sanitary Pads/Diapers using Advanced Waste Biomass Combustion Device

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The after-use disposal of sanitary pads/diapers is causing a serious problem for the environment. The current disposal practices of burning them in open or dumping them in landfills lead to serious environmental as well as health hazards. Current electrical incinerators available in the market designed for hostels/hotels/other commercial establishments fail~~s~~ to serve the purpose due to their poor design and high electrical consumption. A low-cost yet very efficient and environmental friendly solution for the thermal disposal of sanitary pads/diapers is discussed in the paper. An advanced waste biomass combustion device is used as the heat source for the process, which ensures clean combustion and high efficacy. An inclined chamber with a chimney was integrated into the biomass combustion system to conduct the trials of waste disposal. A temperature greater than 1100 K is maintained to ensure pollution-free combustion of the plastic and other chemicals (super absorbent polymer) of the waste and multiple trials were conducted to understand the system performance. A 3.5-6 kg/h of biomass combustion system can burn 30-40 sanitary pads or 10-15 baby diapers with a cycle time of 15-20 min. without any pollution. The system was tested for emission levels and these are within the CPCB-prescribed limits.

**Keywords: Sanitary pads disposal, biomass combustion, Incinerators**

## Introduction

Sanitary pads and diapers have become an inevitable part of our life. And they provide hygiene practices to deal with the problem of menstruation and baby/adult care. The after-use disposal of these products is also equally important. But this class of waste is causing a large-scale problem in terms of disposal practices especially in developing countries [Elledge et.al.,2018]. The common disposal practices are throwing them in the open, wrapping them in paper/plastic bags and throwing them in dust bins, burying them in soil, and burning them in open [MHM Guidelines, 2018; Menstrual Waste Disposal in India, 2020]. Several efforts had been made to manage sanitary pads/diaper waste by different authorities. These include early segregation, promotion of decentralized incinerators, treating them in centralized incinerators and so on. But still there exists a gap in understanding the problem as well as implementing the right solution. For instance, considering the case of small-scale incinerators, it is impossible to integrate environmental emission control devices in small-scale incinerators and there are no separate guidelines provided for the design and operation of small-scale incinerators [Danawala, 2018]. According to Batterman (2004), "best practices" need to be set out in the case of small-scale incinerators, as installing the process and emission monitors to meet modern emission standards will increase the cost by an order of magnitude.

The 'best practices described by Batterman(2004) and the recommendation given by the Technical Assessment Report on Incinerators(2014) summarize the following common points, a) Proper segregation and hygienic handling b) An engineered design, ensuring that combustion conditions are appropriate, e.g., sufficient residence time and temperatures to minimize products of incomplete combustion c) Setting up of operation protocol for the proper working of the incinerators.

In view of the above recommendations, this paper describes the design, development and testing of small-scale incinerators based on an advanced waste biomass combustion device. Sanitary pads/diaper incinerators with biomass as primary fuel have not been explored so far. This work aims to develop a small-scale incinerator which can dispose of sanitary pads/diapers in a clean, efficient and with minimal emissions.

## Material and Methods

Most of the sanitary pads available in the market contain up to 90% plastics and the rest is wood pulp. Similarly, diapers contain cellulose, polypropylene and a super-absorbent polymer (sodium polyacrylate). Samples were collected from the market from leading seller brands (both sanitary pads and diapers). Used sanitary pads/diapers were not used in the initial experiments. Instead, to simulate at least in part, the thermodynamic segment, 40 ml of water was added to sanitary pads and 120 ml was added to diapers before using them for the experiment.

The source of heat used is the Advanced Waste Biomass Combustion Device working on quasi-gasification technology[Mukunda et.al.,2018]. It ensures clean and efficient combustion of biomass. The system consists of a combustion chamber, fuel feed zone and air supply ducts as shown in Fig. 1. There are two air supplies – one below the grate and one in the gas path. The bottom air allows the gasification of char and the top air helps the combustion of these gases and some volatiles – this is the reason for calling it quasi-gasification. The cross-section of the combustion chamber is filled with a specific number of air ducts depending on the power level. Each of the ducts has a specific number of air nozzles. Jet diameters are 3 mm for small systems

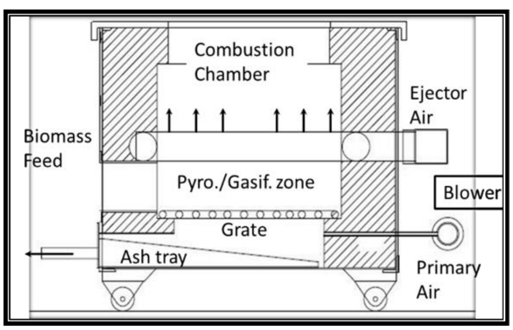


*Figure 1 Advanced Waste Biomass Combustion Device*

and go up to 10 mm for large systems.

## The Experiments

The early stage experiment was conducted on a 1.5 kg/h Horizontal Clean Continuous Combustion Device(HC$^3$D). As shown in Fig. 2, three wet diapers (adding 120ml of water) were kept on a grate provided at the outlet of the stove. The hot gases were allowed to pass over the diapers. After 20 min. of running the stove, the diapers started contracting and melting. The super absorbent polymer (SAP) was coming out and was falling through the grate. Drying of diapers was happening in the


*Figure 2 a) Wet Diapers kept on the stove  b) Diapers shown directly on the flame*

first 15-20 min. and during this period smoke was observed. To understand the behaviour of the diapers on direct flame, one diaper is kept directly on the flame. The diaper was burning completely without any smoke and the SAP was also converted into ash.

From the understanding of the experiment, a system prototype was envisaged with a 3.5 kg/h Vertical Ejector Based COmbustion Device (VEBCOD). As shown in Fig. 3, an attachment was created on the top of the VEBCOD with a 40-degree inclination. A chimney was provided on the rightmost end and a grate was set at an angle of 20 degrees from the side edge. A window for dumping the sanitary pads/diapers is provided on the right side with a gravity-hinged door. Here, the idea was to keep the diapers/sanitary pads on to the grate and as the chimney is provided at the right-most end, pumping of hot gases at a very high temperature (> 1100 K) is expected to pass over the wet diaper/sanitary pads both from the bottom and the top. One set of experiments was carried out with this arrangement by introducing diapers into the grate once the stove attained steady high temperature. It was observed that the diapers on the grates were not completely burning at the end of one-hour time because hot gases finding less resistance path in the grate as its dense at some parts and lean at some other parts. The hot gases bypassed the diapers kept on the grate as the resistance offered by the bulk diapers was more in this case. To overcome this issue, a tray design was tested, where the used diapers/sanitary pads were kept on a tray having five compartments. The diapers/sanitary pads were arranged in an order on the tray and the tray was introduced into the chamber once the temperature of the system was high. This arrangement allowed equal facility for the hot gases to transfer the heat to the diapers/sanitary pads and as a result, all parts of the material were covered.  Experiments were repeated with this arrangement by using diapers and sanitary pads.

*Figure 3 Sanitary pad/diaper disposal system Prototype*

## Results and Discussions

The results from the experiments are collated in Table 1. Three experiments conducted on sanitary pads with a varying number of pieces showed a consistent performance in terms of burn time, biomass consumption and specific energy consumption. Forty pads completely occupied the tray area and their weight was 930 g out of which 730 g was water. In the case of diapers, only

| Test | Type | weight of the single unit(g) | No. of units | Total Weight (kg) | Water content (kg) | Burn Time (min.) | wood Consumption (kg) |
|---|---|---|---|---|---|---|---|
| **Test-1** | Diaper | 26 | 10 | 1.47 | 1.21 | 70 | 6.1 |
| **Test-2** | Diaper | 26 | 10 | 1.50 | 1.24 | 65 | 6.3 |
| **Test-3** | Sanitary pad | 5 | 30 | 0.70 | 0.55 | 35 | 1.8 |
| **Test-4** | Sanitary pad | 5 | 40 | 0.93 | 0.73 | 50 | 3.4 |
| **Test-5** | Sanitary pad | 5 | 35 | 0.91 | 0.73 | 45 | 3 |

*Table 1 Sanitary pads/diapers burn test results*

ten number of pads were possible in a batch and the weight was around 1.5 kg and the water content was 1.24 kg. Figures 4 and 5 show the burning of diapers loaded onto the system with diapers and sanitary pads respectively. In both cases, there was some unburnt part remaining in the 4$^{th}$ and 5$^{th}$ row of the tray. It was observed when the hinged door is opened in between the operation, the sanitary pads/diapers at the front end get ignited and burn. This was due to the suction of more air through the door.


*Figure 5 Burning of diapers loaded on to the tray*

*Figure 4 Burning of sanitary pads loaded on to the tray*

Figure 7 shows the temperature of flue gas at the outlet of the stove, on the grate and at the end of the exhaust pipe for the early design configuration for diapers. It can be seen that the exhaust gas temperature was around 820 K and it was the same for the grate. Also, right after introducing the diapers into the system, the grate and exhaust temperatures did not drop by more than 50 K. It is inferred that the gases were bypassing the diapers and going out through the exhaust pipe. Figure 7 shows the temperature variation of gases from the stove outlet, grate and exhaust for sanitary

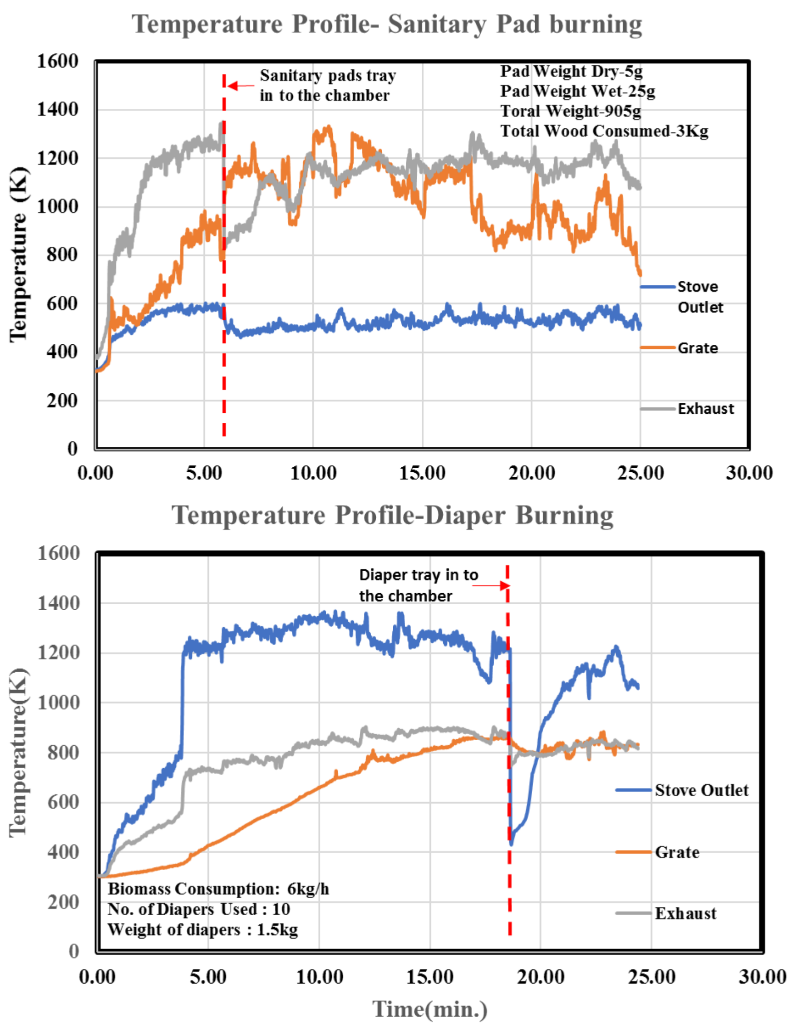


*Figure 6 Temperature data during trials*

pads introduced to the system with tray. Here, the stove outlet, grate and exhaust show a clear decrease in value after introducing the wet sanitary pads. Exhaust gas temperatures were varying between 200 to 300 K and the grate temperature was above 900 K. The drop in outlet gas temperature in the case of diapers is more as they contain almost 6 times more water than their dry weight.

### Pilot System Design and Testing

Based on the results obtained from the previous experiments, the final system is designed based on the 3.5-6 kg/h of advanced waste biomass combustion system as shown in Fig. 8. The stainless-steel tray had been given 10 mm gaps so that the hot gases would flow through these channels heating the sanitary pads/diapers. To ensure the flow bends and pass over the grate, the exhaust pipe was kept right above the hinged door. And the whole compartment was provided with 25 mm insulation with the ceramic board. The tray was capable of holding 50-60 sanitary pads and 15-20 diapers.

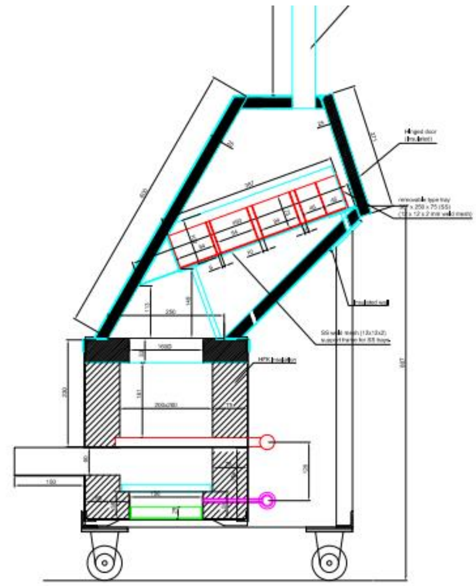

*Figure 7 Sanitary pad/diaper disposal pilot system*

Testing of the system was carried out by loading 45 sanitary pads weighing 1125 g. The combustion system was run at a peak power of 6 kg/h and the tray was introduced into the system 15 min after the start of the stove. The temperature of the chamber at the time of insertion of the tray was 1200 K. The tray was introduced into the chamber and closed by the hinged door, and within 8-10 mins, all the sanitary pads were completely burned. Emission testing was carried out during the test run and various parameters including particulate matter were measured. The results are shown in Table 2. All the values are within the limits prescribed by CPCB.

*Figure 8 In-situ performance and emission testing*

| **S.NO.** | **TEST** | **UNIT** | **RESULTS** | **PROTOCOL/TEST METHOD** |
|---|---|---|---|---|
| **1** | Oxygen as $O_2$ | %(v/v) | 9.90 | IS 13270:1992 |
| **2** | Carbon Dioxide as $CO_2$ | %(v/v) | 5.50 | IS 13270:1992 |
| **3** | Carbon monoxide as CO | $mg/Nm^3$ | 53.5 | USEPA method 10:1999 |
| **4** | Sulphur dioxide as $SO_2$ | $mg/Nm^3$ | 163.0 | IS : 11255(Part-2):1985 |
| **5** | Nitrogen dioxide as $NO_2$ | $mg/Nm^3$ | 345 | EPA Method 7E:2005 |
| **6** | Particulate Matter | $mg/Nm^3$ | 9.2 | IS : 11255(Part-2):1985 |
| **7** | Methane | ppm(v/v) | 32.6 | IS 13270:1992 |
| **8** | Ethane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **9** | Propane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **10** | Acetylene | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **11** | Iso-butane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **12** | n-butane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **13** | Iso-pentane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **14** | n-pentane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **15** | Hexane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **16** | Heptane | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |
| **17** | Ethylene | ppm(v/v) | Below detection limit of 0.1 | IS 13270:1992 |

*Table 2 Emission test results of Sanitary pad/diaper disposal system*

## Economic Aspects

The manufacturing cost for sanitary pad/diaper incinerator which can burn 30-50 pads/cycle (cycle time is 30 min.) or 10-15 pads/cycle is Rs. 50000.The biomass consumption per cycle is around 3kg and considering Rs.3/kg as the biomass price, the average cost incurred per pad is Rs.0.18-0.30. There isn't any biomass based incinerators available in the market and the electric incinerators which is matching the no. of pads/cycle is costing around Rs.35000 and rated 1.2 kW. Based on the stakeholder interactions, it was found that the electrical incinerators are not able to burn the waste without pollution. Inhalation of smoke generated from these kind of incinerators cased serious respiratory issues for the operators. Considering the environmental and health costs associated with electric-incinerators, biomass based sanitary pads/diaper disposal system is offering economic, social and environmental benefits.

## Concluding remarks

The only route available for the safe disposal of sanitary pads/diapers is to burn them cleanly and efficiently. A decentralized approach for the collection and disposal of sanitary pads/diapers is needed along with deploying small-scale incineration systems. Biomass-based incinerators have remained unexplored before this development and this work will open up more possibilities for deployment. The system designed can burn waste completely with emissions below the norms of CPCB. Operation protocols are set and the training of the operating personnel has been considered mandatory for the satisfactory use of the system. It is suggested that the adoption of such systems in place of electricity-based incinerators will add value to societal health systems in a meaningful and economic manner.

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