Technical Assessment of Incinerators to Support Girls' WASH Programming

Final Report, March 2018

Acknowledgements

On behalf of Geolinks Private Limited and DevTrio Consultants, we are grateful to all those who contributed to the successful completion of this technical assessment.

We are thankful to the administrators, teachers and students of the schools we visited in Muzaffargarh. We hope that the findings and recommendations drawn from this assessment enable both AGAHE and WaterAid in Pakistan to improve and scale-up the current incinerators attached to the girl-friendly toilets.

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We hope the findings and recommendations may contribute to informed and responsive planning, as the project concludes and begins to become a part of national planning priorities in Pakistan.

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Acronyms

AGAHE	Association for Gender Awareness and Human Empowerment
EPA	Environmental Protection Agency
PEPA	Punjab Environmental Protection Agency
NEQS	National Environmental Quality Standards
PEQS	Punjab Environmental Quality Standards
FGD	Focus Group Discussions
PPE	Personal Protective Equipment
KIIs	Key Informant Interviews
MHM	Menstrual Hygiene Management
GPL	Geolinks Private Limited
DTC	DevTrio Consultants
WAP	WaterAid Pakistan
WASH	Water, Sanitation and Health
TOR	Terms of References
WDU	Waste Disposal Unit
TTIL	Textile Testing International Labs

Relevant Technical Definitions

The following are terms used throughout the document, including the text, tables and figures, and the appendices. These are here for the reader's convenience.

Incinerator: An internationally recognized apparatus for destroying hazardous and non-hazardous waste with a high temperature furnace, in a controlled and concealed manner.

Combustion: The process of burning something and the rapid chemical combination of a substance with oxygen, involving the production of heat and light.

Complete Combustion: The right combination of carbon and oxygen that ensures that the all of the energy within the waste is utilised.

Feed End: An opening or door through which the waste is placed into the incinerator

Incomplete Combustion: Incomplete combustion occurs when the supply of air or oxygen is poor. Water is still produced, but carbon monoxide and carbon are produced instead of carbon dioxide. Carbon monoxide is poisonous and contributes to air pollution.

Emissions: The levels of gases and particles which are created as a product of the incineration process. The monitoring and regulation of these levels mitigates the effects of air pollution (refer to section 4.3.1 for in-depth explanations of emissions related components).

Grate: A pre-fabricated metal framework within the incinerators that is used as a surface to hold solid waste prior to complete combustion

Ash: An incombustible solid residue that forms after complete combustion has occurred.

Blower: A machine for supplying air

Refractory: The ceramic material primary used as the lining of the incinerator to ensure strength and form of the incinerator when it is burned at high temperatures. In incinerators this tends to be fire bricks.

Stack: An area usually at the roof of the incinerator, through which smoke is emitted into the air.

1. Executive Summary

WaterAid Pakistan (WAP) established girl-friendly toilets in Pakistani government schools, which facilitate young girls in the process of menstruating with the proper knowledge and dignity. For these toilets to achieve this purpose, it is essential to have a private and secure place to change sanitary materials (cloth or pads), clean water and soap for washing their hands, bodies and sanitary napkin/ absorbent materials, and facilities for safely disposing of the used sanitary/ absorbent materials. For disposal, these girl-friendly toilets are constructed in each school with an adjacent disposal/burning facility, or incinerators.

WAP contracted DevTrio Consultants (DTC) and Geolinks Private Limited (GPL) to conduct a technical assessment focused on the incinerators that are integrated into girls' friendly toilets in Muzaffargarh district under WAP's WASH in Schools project. These incinerators are from the following representative schools in Muzaffargarh. These were sampled based on strata of adolescent girl populations (Section 4).

1. GGHS Basira
2. GGES Noor Kubra
3. GGES Tibba Qazian
4. GGES Dogar Kalasra
5. GGHS Sinawan
6. GGHS MochiWala
7. GGHS Kotaddu
8. GGHS Chak # 518
9. GGHS Rohillan Wali
10. GGHS Shehr Sultan

The incinerators that WAP has integrated into this project are helpful in disposing of menstrual waste in a manner that mitigates the much more harmful effects of cheaper alternative options, such as open dumping or deep burial (Section 3.4). While incineration is not optimal, for commercial menstrual waste which contains plastic and PVCs that are generally not biodegradable, it is the next best option in Pakistan

After observing and testing the technical components of ten incinerators that WAP built as part of the MHM girl-friendly toilets in the Muzaffargarh district, GPL and DTC observed potential points for improvement in the following areas. The team devised recommendations based on findings in categories below. In addition, the team employed qualitative methods in its assessment to understand how the incinerators were being operated as part of each school's management of the menstrual waste.

Summary of Findings and Corresponding Recommendations

Based on international and national standard guidelines for incineration, seven categories of findings and recommendations were developed in order to improve the incineration design and process for future scale-up of this project (Section 5 and 6). While improvements to the design may seem the most concrete for further scale up, uniform process improvements around safety, operations, maintenance and training are essential to ensuring the best use of the incinerators. The operator of the incinerator (in this context, mostly the caretakers) comes in the greatest contact with the incinerator.

1.1. Construction and design

a. The incinerators currently have no mechanism that allows for a warm-up period – which ensures quicker burning, higher temperatures and complete combustion of menstrual waste. In other words, the waste cannot be in the incinerator while it begins to burn.

Recommendation: In order to reach better temperatures and maintain a warm-up process inside of the incinerator, the team has recommended a design which incorporates a “sliding plate” inside of the incinerator that remains separate from the main combustion chamber. After the combustion chamber has been warmed up for about 30 to 45 minutes, the caretaker can release the waste from the “sliding plate” by pulling on a lever. Appendix 3 provides this design along with guidelines.

b. There is currently no method for identifying an appropriate combustion chamber sized based on the school’s population of adolescent girls.

Recommendation: The two-stage Sher Sultan model is most appropriate incinerator design, but its combustion chamber volume will not work for every school. In the future, before building incinerators in schools, it is important to understand the population size of adolescent girls and to project the amount of menstrual waste expected to be generated (See Table 5).
By understanding these numbers, engineers can also design a combustion chamber size that serves the typical waste disposal quantities of the school. From an implementation standpoint, this also allows for the development of an appropriate burning schedule (i.e. weekly, biweekly, or monthly).

c. The loading doors as they currently stand allow for smoke to escape from the incinerator chamber into the girl-friendly toilet. This, in turn, increases the odor in the toilets and in the vicinity of the incinerator.

Recommendation: The loading door should have a spring mechanism so after loading, upon release the door immediately shut tight.

d. No ash pit is located near the incinerator in order to store the ash that comes from burning the waste.

Recommendation: An area for burial of ash should be designated near the school grounds. Caretakers should be trained on how to bury this ash.

e. Burning is occurring too close to the school population and perhaps to nearby communities.

Recommendation: The length of chimney should be increased to 4m in future incinerator designs, especially in cases where it may not be possible to place the incinerator at least 30 meters away from the classroom.

1.2 Safety

a. Operators (mostly government and privately employed school caretakers) did not have any protection against the smoke from incineration or the handling of waste

Recommendation: Personal Protective Equipment (PPE) items, especially gloves, masks, and goggles, should be incorporated into any MHM and girl-friendly toilet operational guidelines for incineration and any future standard operating procedures (SOPs)

b. No standard operating procedures (SOPs) for operator safety currently exist for these incinerators

Recommendation: SOPs need to be developed for all operators across schools, outlining safety procedures and considerations throughout the entire incineration process, from disposal and handling to igniting and warming up the incinerator to removal and burial of the ash.

c. Some schools conducted their incineration during school hours with students in the vicinity of burning. Some schools also had their students do the burning.

Recommendation: The SOPs should particularly emphasize that all incineration occurs outside of school hours and that students should always be in the presence of an adult and wearing proper PPEs if they must do the burning. Choosing this timing mitigates the risk of the smoke entering into the classrooms (which are already too close to the incinerator), and therefore affecting the students during school hours. An igniter should be used to prevent the care taker from getting any burn injuries to the caretaker/operator.

1.3 Operations

a. Most caretakers could not really remember the volume of waste that was generated, and did not have a very consistent schedule for burning

Recommendation: Schools should be tracking how much waste is generated in one month in order to develop a consistent system of burning times in the week or month. This can be done through weighing the waste, or at least assessing how full the combustion chamber should be with the waste before igniting the incinerator.

b. Incinerators were not able to reach the best temperature for complete combustion

Recommendation: The incinerator needs time to heat up to at least 540 °C before actually burning the waste. This is also known as the “warm-up” period, in which the incinerator is burned on its own WITHOUT any waste inside of it.

Because of the sensitivity of menstrual waste and the taboos around handling it in the areas of these schools, GPL has proposed a model which adds a separate chamber inside of the incinerator to store this waste. That chamber has a manual lever that the operator/caretaker can pull to release the waste into the incinerator ONLY AFTER the incinerator has been warmed up.

c. In relation to design recommendation 1.1b, burn times are generally arbitrary and operators are not aware of how full (or empty) incinerators are before allowing for the best possible burn cycle

Recommendation: Table 12 provides the recommended combustion chamber capacities based on this population, as well as how often burning should occur.

d. There was no protocol for storing and disposing of ash both on school grounds and outside of them

Recommendation: The ash from incineration needs proper storage before being dumped. After about a month, when the weight of the ash reaches a sizeable amount (5 kg), it can be either disposed to a government designated area or buried in the ground by the caretakers.

1.4 Maintenance

a. Incinerators are not being used to their full capacities. The sizes of incinerators are sufficient to accommodate 20% more weight.

Recommendation: Add heavier waste from the school grounds. However, that said, the caretaker should avoid adding too many polyvinyl chloride (PVC) plastics among the waste, as this can cause issues for the already below-emissions rates.

b. Plaster was chipped in some of the incinerators, hence, indicating that there might not be training on upkeep for the incinerators.

Recommendation: Incinerator plaster walls must be routinely repaired by adding quality plaster over the affected areas. Keeping the bricks covered is important to ensure that the bricks are not exposed to external damage from the environment outside.

1.5 Training

a. Operators did not have formal training (even government ones) on how to operate and maintain the incinerator

Recommendation: Standard Operating Procedures (SOPs) should be integrated into the current MHM/girl-friendly toilet guidelines and programs in order to be able to replicate training measures throughout all of the schools. Training programs should address **both** literate and illiterate operators through appropriate guidelines. Operators must understand the risks associated with incineration process and provide consent and an acknowledgement that they understand all proper standard operating procedures (SOPs)

In addition, to avoid the effects and costs of constant retraining, more than one person should at least be properly trained in incineration practices.

1.6 Compliance

a No documentation exists to ensure compliance with local (Punjab) and national (Pakistan) Environmental Protection Agency (EPA) standards.

Recommendation: According to the EPA Review of IEE and EIA Regulations, 2000, schedule 1, section H, all waste disposal facilities which handle domestic waste less than 10,000 cubic meters must obtain an Initial Environmental Examination (IEE). The waste incinerators installed in the girl-friendly toilets may fall within this regulation or under section J ‘other projects’, hence, for future scale-up this should be considered.

2 Introduction

Having access to clean water for drinking, appropriate sanitation facilities to defecate and being able to maintain personal hygiene (WASH needs) are essential needs to live healthy life with respect and dignity. The poor state of WASH conditions in developing countries such as Pakistan carry consequences in terms of poor health, perpetuating and reinforcing the underlying causes for social (gender) exclusion and economic deprivation. This is negatively impacting the lives of millions of women, adolescent girls and children.

Menstrual management (for women and adolescent girls) is an integral part of personal hygiene and relates directly to access/availability of water and waste management. It remains a neglected domain in the highly gender-segregated and patriarchal socio-cultural context of Pakistan. The situation is relatively adverse for rural women and adolescent girls. For this reason, WaterAid Pakistan (WAP) established girl-friendly toilets in Pakistani government schools, which facilitate young girls in the process of menstruating with the proper knowledge and dignity.

This project is supported by UK-AID. WAP is working with two local implementing partners in Muzaffargarh and Swat to increase access to safe, inclusive WASH facilities for school children, with a special focus on empowering women and girls to manage menstruation hygienically and with dignity. This project is being implemented in 110 girls' middle and high schools of the Muzaffargarh and Swat district.

For girls to manage menstruation hygienically and with dignity, it is essential that girls have access to water and hygienic sanitation. They also need a private and secure place to change sanitary materials (cloth or pads), clean water and soap for washing their hands, bodies and sanitary napkin/ absorbent materials, and facilities for safely disposing of the used sanitary/ absorbent materials. For this purpose, girl-friendly toilets are constructed in each school with an adjacent disposal/burning facility, or incinerators.

Pakistan currently does not have legislation which adequately deals with solid waste.[1] The Pakistan Environmental Protection Act (1997) section 11 prohibits the discharge of waste above NEQS limits, and provides a framework for the development of national and regional environmental legislation. However, till date there are no national quality standards for solid waste management.[2] Specifically, the Pakistan EPA's Hospital Waste Management Rules 2005 & Hazardous Substances Rules 2003 do not mention sanitary napkins (or sanitary pads, menstrual waste).

However, the semi-government organization Lahore Waste Management Company (LWMC), which is widely seen as the most modern government waste management company in Pakistan, designated sanitary napkins as a 'diaper' (municipal waste) and not as a hazardous waste (which included medical waste) in its Waste Characterization Study (2012).[3] Based on this, menstruation related waste, such as sanitary napkins/pads as **municipal waste**.

Therefore, the use of incinerators to address the disposal of menstrual waste combined with the taboos of handling this waste in Pakistan remains the most feasible option. The main objectives of this assignment along with the outputs that fall under them were the following:

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[1] Policy and Regulations on SWM– Pakistan (2010) UNEP

[2] Government of Punjab Website: http://epd.punjab.gov.pk/solid_waste

[3] Consulting services project for integrated solid waste management of Lahore city of the state of Punjab in Pakistan: Summer 2012 Waste Characterization Study, Kadir Sezer

1. Assess the overall operation and performance of the current incinerators
    - Through a nationally certified laboratory, collect results of the stack emissions of 10 incinerators (after combustion) that are attached to these girl-friendly toilets in Muzaffargarh District
    - Assess these stack emissions against national quality standards and regulations
    - Determine the type of material being used to burn the sanitary napkins/ absorbent material and its availability in the schools
2. Identify any technical/operational deficiencies
    - Collect data from school maintenance staff, teachers, and students on the operations of these incinerators
    - Capture user experience, orientation, and awareness levels of the incineration process
    - Connect findings on disposal and treatment of menstrual waste to bigger social issues around menstruation
3. Suggest improvements for improving its efficiency and effectiveness
    - Recommend improvements on existing design and practices to reduce the emissions but low cost and local material use
    - Measure whether emissions are entering in the school, classrooms, and/or WASH toilets, and suggest mitigation measure to avoid this in the future
    - Analyze the benefits and drawbacks of direct disposal of sanitary materials versus incineration and disposal of residual materials (ash)

In order to achieve these objectives, WaterAid Pakistan (WAP) contracted DevTrio Consultants (DTC) to conduct a **technical assessment of incinerators that are integrated into girls' friendly toilets in Muzaffargarh district** under WAP's WASH in Schools project. DevTrio enlisted the technical leadership of a reputable waste management company in Pakistan, Geolinks Private Limited (GPL), to conduct the data collection for this project. GPL specializes in the business of incinerator manufacturing and ethical disposal services in Port Qasim Authority near Karachi. Dealing with all type of waste on an industrial scale to select hospital and biomedical waste, along with asbestos cleaning, GPL has firsthand insights into current gaps in waste management needs in Pakistan.

Along with conducting a technical assessment of the incinerator design along with the burning process, GPL worked closely with a certified lab in Pakistan by the Punjab Environmental Protection Agency (PEPA) in order to conduct all appropriate emissions testing. These emissions tests were a vital part of assessing the environmental impact of the incinerators. All field facilitation was made possible by field managers from the Association for Gender Awareness and Human Empowerment (AGAHE) TTI Labs conducted the emissions tests for each incinerator.

3 Literature Review

Types of Literature Reviewed

- Wateraid Pakistan MHM Project Documents
- Literature on small-scale incineration practices based on international and local best practices

Access to clean water for drinking and appropriate sanitation facilities, along with knowledge of effective personal hygiene are essential human needs in order to live a dignified life. The state of WASH in Pakistan remains a major contributing factor to the inability to curb preventable illnesses and infectious diseases. Implementation of WASH strategies and interventions focus on the systematic constraints to optimal outcomes not only in health, but also in gender and economic equity.[4]

Menstrual management (for women and adolescent girls) is an integral part of personal hygiene and relates directly to access/availability of water and waste management. For menstruation being directly linked to health, social and economic conditions for women and adolescent girls, it requires priority attention from the authorities to institutionalize measures for education and awareness, and improved services around menstrual hygiene management (MHM).
Based on WaterAid's past evaluation reports, the baseline analysis from Wateraid's MHM program focused on two primary components: (1) knowledge management, and (2) facilities for safe and private menstrual hygiene for older girls.

Of these two components, this report focuses the on the second one. The facilities for safe and private menstrual hygiene begins with the availability of menstrual products at school. The use of these facilities begins with the availability of menstrual products at school. In the Pakistani context, these products can range from commercial pads (such as those from local brands or foreign brands such as Always) or a thick cloth. The issue remains of whether pre-adolescent and adolescent (ages 10-17) female students have access to a toilet that allows for them to change their menstrual products.

As part of its intervention, WaterAid built such a toilet in Pakistan and Nepal. This toilet essentially consists of sex-separated toilets with at least one toilet or washroom equipped with a locking door and an opening leading to an incinerator, plus handwashing facilities.[5]

The Association for Gender Awareness and Human Empowerment (AGAHE) is currently working to improve the MHM practices of women in the district of Muzaffargarh, Punjab, as a part of implementing "ensuring girls" rights through school and community based WASH and improved MHM in Pakistan" project. The WaterAid funded project is to focus on improving the condition of sanitation facilities in schools and community, leading to better MHM practices.

The project is being implemented in 50 Government Girls Schools including the adjoining communities of District Muzaffargarh targeting school children focusing adolescent girls in and out of schools, teachers, mothers, Lady Health Workers (LHWs), Community based

[4] MHM Baseline Report – AGAHE and WaterAid,
[5]WaterAid South Asia Midterm Review, March 2017

entrepreneurs, officials of Government departments, members and representatives of District WASH Forum (DWF) and other representatives of CSOs.

3.1 Background: girl-friendly toilets and attached incinerators

The toilets were structured according to WASH standards and to adapt to MHM guidelines. Specific aspects of the WASH facilities that respondents cited as being beneficial included improved access to water for cleaning and handwashing, access to discrete disposal system for sanitary materials, improved latrine cleanliness, and continual availability of soap. Specific aspects of these toilets include access to water for cleaning and handwashing, access to discrete disposal system for sanitary materials, improved latrine cleanliness, and continual availability of soap.[6]

From a design perspective, all of the toilets contained a latch through which girls could dispose of their pads straight into the incinerator, a mirror to check if any stains were on their clothes, and a handwashing station. All of these areas within the toilet included instructions.

Figure 1: Photographs of Girl-Friendly Toilets and Incinerators – GGHS Basira

Incinerators are an internationally recognized apparatus for destroying hazardous and non-hazardous waste with a high temperature furnace, in a controlled and concealed manner. Based on GPL's experience with various entities across Pakistan, commercial incinerators are mostly dysfunctional and those which are functional are being utilised by a few hospitals and private waste management companies to dispose of hazardous waste.

3.2 Other low-cost alternative methods for disposing menstrual waste

While incineration may not be optimal based on international standards, the current waste management standards in Pakistan make it the next best option environmentally. In conducting this assessment, the team also considered other low cost options that are currently being used in rural communities.

3.2.1 Deep burial

[6] MHM DFID Nepal and Pakistan Midterm Review, March 2017

The deep burial method of disposing health-care related waste is widely used in rural areas in neighboring India. The Biomedical Waste Rules provide guidelines as to how a deep burial site should be excavated, and where it must be located.[7] Deep burial is recommended for rural towns which do not have the relevant waste management infrastructure. Pakistan currently does not have any standards or guidelines on the deep burial method. The following have been recommended by the Association of Physicians of India and the World Bank[8]:

a. The pit/trench should be two meters in depth
b. The soil should be relatively impermeable, and the area not prone to flooding/erosion
c. No inhabitants or shallow wells nearby
d. No animals should have access to the site, fencing is advised
e. Waste should be added to the pit, the covered with 10cm of soil
f. Once pit is half filled, it should be covered with lime within 50cm of the surface, and then filled with soil

Deep burial can be economic and require low maintenance, however if located in an inappropriate area, it can contaminate surface water and/or groundwater.[9] In this context, the deep burial method requires the menstrual waste be handled by caretakers until it is buried in the pit. This may impede on cultural sensitivities, and in the end be difficult to implement.

3.2.2 Municipal waste collection & disposal

Government waste management bodies are currently only collecting 50% of waste accumulated from cities in Pakistan. According to the Government of the Punjab, the rural areas currently have a 'non-existent solid waste management system' and in turn, are a breeding ground for vector diseases.[10] Pakistan has only two sanitary landfill sites, one in Lakhodair, managed/operated by the LWMC and the second in Habiba Sial, managed/operated by the Multan Waste Management Company (MWMC). The Muzzafrabad and Kot Addu areas have only government approved open dumping sites or 'unofficial' open dumping sites.

The municipal waste collection and disposal of used sanitary pads/napkins in Pakistan will almost certainly lead them to be disposed in an open dump site, which in turn may lead them to be openly burned, or build up with other forms of non-biodegradable waste to create a haven for disease, lead the creation of leachate (which will contaminate groundwater) and create hazardous gases from the decomposing waste.[11]

3.3 Introduction to incineration

Incineration is widely associated with energy and heat production in developed countries, however in developing countries governments, international organizations such as UNICEF and the WHO perceive small scale incinerators (12-100kg per/hour capacity) as a viable and economical waste management technology. These are especially useful in the disposal of

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[7] Health Care Waste Management in India: Lessons from Experience, Bekir Onursal, The World Bank 2003
[8] Biomedical Waste Management: A Step Towards a Healthy Future, Kamlesh Tewary, Vijay Kumar, Pamit Tiwary, The Association of Physicians of India, 2007; Health Care Waste Management in India: Onursal, The World Bank 2003
[9] Tewary, Kumar and Tiwary, 2007
[10] http://lgcd.punjab.gov.pk/Rural%20Solid%20Waste%20Management
[11] Wasted Health: The tragic case of dumpsites. Antonis Marvopoulis. ISWA, 2015

biomedical and menstruation related solid waste, which are typically burned openly with significant health related effects.[12] Incineration utilizes combustion to destroy infectious waste and reduce waste volume and mass by over 90 percent.[13]
Complete combustion is necessary for wastes to be converted into relatively harmless gases and incombustible solid residues, such as ash.

Commercial 'clean burning' incinerators which are automatic and fitted with air pollution control mechanisms require electricity and a fuel source for ignition, such as gas or diesel. The technology requires significant initial and ongoing economic investment, and a degree of technical literacy to be maintained according to best practices.[14] This represents a challenge for rural areas, which lack the funds, infrastructure, stable utilities and technical personnel to establish and maintain a commercial incinerator.[15]

The De Montfort incinerator was designed by Professor Jim Picken at De Montfort University in the United Kingdom in the 1990's with the aim to provide a waste management technology, or waste disposal unit (WDU) which utilized primarily local materials and did not require electricity or substantial amounts of fuel (gas or diesel) to operate. No specialised tools are required in construction.

The construction, maintenance and operational guidelines are provided free of cost, thus making the De Montfort a cost effective alternative to commercial incinerators. The incinerators are small-scale and are made of firebricks and prefabricated metal segments. Like commercial incinerators, they are two stages, with a primary chamber for the combustion of waste and a secondary chamber for the burning of hazardous gases. The De Montfort incinerators purport to achieve approx 600c in the primary chamber, and 600-900c in the secondary chamber, the high temperatures are necessary to achieve complete combustion. There are no global standards for small scale incinerators; however, the WHO recommends the following design/operational parameters (Figure 2).

Figure 2: Recommendations of key parameters for small-scale intermittent incinerators

[12] Assessment of Small-Scale Incinerators for Health Care Waste, Stuart Batterman, 21 January 2004, Stuart Batterman, World Health Organization, Water, Sanitation, and Health Protection of the Human Environment
[13]Batterman 2004; Guidelines on How to Construct, Use, and Maintain a Waste Disposal Unit, September 2004
[14] Managing health care waste disposal: Operator's manual, PATH & WHO, 2004
[15]DeMontfort Incineration Guidebook and Website

Type	*Parameter*	*Recommendation*
Capacity	Destruction rate, safety boxes capacity	District/subdistricts in Taylor (2003) that regularly used incinerators destroyed an average of 58 safety boxes per month, about 14 per week, equivalent to ~12 kg/week. Remote areas may only generate 1 kg per month. Proper sizing is important. Ideally, unit should burn for long periods (~4 hrs) to save fuel. (De Montfort units are not suitable for short sharp burns without a warm up period, though this appears to be common practice).
Temperatures	Primary chamber Secondary chamber Gas entering air pollution control devices, if any	540 to 980 C 980 to 1200 C (EPA 1990 recommendations) >850/1100* C (S. African and EU standards) >1000/1100* C (Indian and Thai standards) * more than 1% chlorinated organic matter in waste <230 C
Residence times	Gas (secondary chamber)	>1 s
Air flows	Total combustion air Supply and distribution of air in the incinerator Mixing of combustion gas and air in all zones Particulate matter entrainment into flue gas leaving the incinerator	140 – 200% excess Adequate Good mixing Minimize by keeping moderate air velocity to avoid fluidization of the waste, especially if high (>2%) ash waste is burned.
Controls & Monitoring	Temperature and many other parameters	Continuous for some, periodic for others
Waste	Waste destruction efficiency Uniform waste feed Minimizing emissions of HCl, D/F, metals, other pollutants Load/charge only when incinerator operating conditions are appropriate	>90% by weight Uniform waste feed, and avoid overloading the incinerator Avoid plastics that contain chlorine (polyvinyl chloride products, e.g., blood bags, IV bags, IV tubes, etc. Avoid heavy metals, e.g., mercury from broken thermometers etc. Pre-heat incinerator and ensure temperatures above 800 C. Avoid overheating.
Enclosure	Roof	A roof may be fitted to protect the operator from rain, but only minimum walls.
Chimney	Height	At least 4 – 5 m high, needed for both adequate dispersion plus draft for proper air flow
Pollution control equipment	Installing air pollution control devices (APCD)	Most frequently used controls include packed bed, venturi or other wet scrubbers, fabric filter typically used with a dry injection system, and infrequently electrostatic precipitator (ESP). Modern emission limits cannot be met without APCD.

Source: WHO 2004

In low income localities which lack infrastructure, basic utilities and skilled labor, auto combustion incinerators are most suitable as they do not require additional fuel to support combustion.[16] The fuel is only required for ignition, the waste itself has sufficient calorific value and can generate enough heat to support its own combustion. Fuel assisted incinerators, typically known as commercial incinerators are necessary when the waste has low calorific value and cannot generate the necessary amount of heat for combustion. However, their operational costs are high as they require electricity, a fossil fuel source and skilled labor to operate efficiently.

3.4 Explanation of key parameters for this assessment

This section provides further details of the parameters that the team used as reference for its assessment of the Muzaffargarh school incinerators. These include some of the parameters and recommendations detailed in Figure 2, along with others that were not covered. These also provide explanations of how these parameters apply to the nature of this particular assessment.

[16]The Incinerator Guidebook, PATH & JSI, 2010

3.4.1 Combustion

Complete combustion requires a plentiful supply of air so that the elements in the fuel react fully with oxygen.

1. Air inlets have to be the right size and in the correct locations in order to feed sufficient amounts of oxygen to the waste. The right amount of oxygen also allows for initial ignition to occur with ease, and the temperature to increase within the combustion chamber.[17]
2. Ash must be removed routinely, otherwise the ash can hinder the amount of oxygen being supplied into the chamber, and ash residues can spread into the wider environment.
3. Smoke clear or light in color is desirable and an indication of complete combustion. Smoke should have the least amount of solid particulate matter, and not be black or dark in color. Dark smoke is a sign of incinerator design flaw or incorrect operations. [18]
4. Waste weight reduced by 90% or more once incinerated.

3.4.2 Temperature

The primary chamber of the incinerator should reach 600°C in order to avoid emitting an excess of hazardous gases, which are released in temperatures below 600°C.[19] The secondary chamber which burns hazardous gases and chemicals should reach 800°C to 1200°C.

3.4.3 Waste to fuel ratio

The waste to fuel ratio is dependent on the calorific value of wastes being incinerated. The calorific value of the waste determines the amount of heat they produce. Generally, waste which holds the sufficient amount of oxygen, carbon and hydrogen can burn if its moisture level is low. However, commercial sanitary pads contain plastics which typically have a high calorific value of 11000Kcal/kg and do not require much assistance in order to burn.[20] And biodegradable cotton pads share a similar calorific value (4400 Kcal/kg) with certain kinds of coal (4000-7000 Kcal/kg).[21]

3.4.4 Design

It is imperative that the design of an incinerator attain the operating standards stated in table 1. The incinerator should have a primary and secondary chamber, reach the desired temperature, residence time, evade unnecessary damage to the refractory and exterior lining, have a four-meter chimney and operate within PEQS limits as stated by PEPA. The design should ideally incorporate a temperature gauge to indicate the temperature within the primary and secondary chamber. The incinerator should also be of necessary capacity, not too small or too large, as the more full it is the more efficiently it operates.[22]

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[17]Waste Incineration Handbook, Paul Cheremisinoff, 1992
[18] Managing health care waste disposal: Operator's manual, PATH & WHO, 2004
[19]Managing Health Care Waste Disposal: Guidelines on How to Construct, Use, and Maintain a Waste Disposal Unit, PATH & WHO, 2004
[20]Converting waste plastics into a resource, UNEP, 2009
[21]To improve the calorific value of cotton by anaerobic digestion, IJSRD, Ansari, Thakkar &Varadani, 2013
[22]Findings on an Assessment of Small-scale Incinerators for Health-care Waste, S. Batterman, 2004

3.4.5 Site Location

The incinerator should be located in an area where it has minimum effects on nearby communities, and the local environment. The incinerator should also accessible and convenient as to not impede operating staff any more than necessary.[23]

- A flat, open terrain is desirable. Not areas with tall trees and vegetation as it will prevent the smoke from dispersing.
- Ideally not near populated areas, such as residential areas, sports clubs, markets, etc.
- Not near areas used for agriculture, such as leafy vegetables and animal feed.
- At least thirty meters away from the nearest building and storage areas holding flammable materials.
- Ideally in areas with low security risks.

3.4.6 Construction

The incinerator should be constructed under the supervision of engineers who can manage the project, understanding technical drawings and implement quality control measures. The metallic and non-metallic components should be sourced from quality manufacturers, ideally local as to keep costs low. It is imperative that the refractory bricks or firebricks be able to withstand temperatures of 1200c, and that a shed be made to house the incinerator, so it is protected from rain and an area is provided for the operator to store PPE's and dry fuel to warm-up the incinerator. Furthermore, the shed provides support for the chimney.[24]

3.4.7 Operations

The waste is loaded from the loading door, and exposed to high temperatures in the primary chamber, where it is dried, burned and melted into a incombustible residue. The ash door remains open to provide additional oxygen to maintain burning. The partially burned gases and particulates are burned again in the secondary chamber, which is separated from the primary chamber by a wall of refractory bricks. Air inlets allow for additional oxygen to be fed into the secondary chamber so combustion of the gases and particulates can occur for the second time. The flue gases are then emitted through the stack into the atmosphere. Standard operating procedures for small scale incinerators, such as the De Montfort call for a three phase burning cycle. [25]

1. Warm up/preheating phase: The primary chamber is initially loaded with dry fuels, such as wood, dried shrubs, agricultural waste, and possibly a small amount of fuel (diesel/gas) then ignited.
2. Waste disposal phase: The waste is loaded in intervals to maintain a steady flame, and only once the desired temperature (540-600) is achieved.
3. Burn down/close down phase: Approximately ten minutes after the waste has been loaded, additional dried waste is loaded to ensure complete combustion occurs. Allowing the combusted material to cool down provides time for the 'fixed carbon' in the waste to settle and burn, in turn reducing the toxicity of emissions.[26] The incinerator

[23] The Incinerator Guidebook, PATH & JSI, 2010
[24] The Incinerator Guidebook, PATH & JSI, 2010
[25] Managing Health Care Waste Disposal: Guidelines on How to Construct, Use, and Maintain a Waste Disposal Unit, PATH & WHO, 2004
[26] Managing health care waste disposal: Operator's manual, PATH & WHO, 2004

requires approximately three hours to cool down, then the incombustible residue (ash) can safely be removed.

3.3.8 Safety

The incineration of hazardous and nonhazardous waste poses a legitimate safety risk for operators. The exposure to high temperatures, and potentially toxic smoke can have devastating health effects in the short and long terms.
The safety and well-being of the incinerator operator is imperative. The operators should be provided with quality PPE's to protect themselves from the dangers posed by incineration and they should wash their hands routinely.[27]

3.3.9 Training

Operators should be trained by an experienced individual who can develop and implement a training program which is easy to understand, explains the importance of the role and risks involved. The operators should understand the basics of incineration, and feel a sense of pride in their work. The sincere involvement of the operator is imperative in achieving the desired results from the incinerator, tests have shown that the operators actions can impact the emissions generated from the incinerator, as he/she will ensure that the primary chamber is reaching the minimum temperature and loading the waste accordingly.[28]

3.3.10 Maintenance

Incinerators require servicing and preventative maintenance on a regular basis. A maintenance log which tracks daily, weekly, monthly and yearly maintenance activities through checklists and inspections from the operator and qualified technicians can extend the life cycle of the incinerator, and enable optimal performance.

- Daily: Keep the area clean, check for damage on the exterior lining and refractory.
- Weekly: Clean chimney, remove ash, clean grate.
- Monthly: Check the various seals and doors, check cement/plaster seal to bricks, take inventory of PPE's, tools.
- Yearly: Inspect and replace metal components, and any damaged bricks, perform annual audit.

4 Methodology

4.1 Methods

The team used **a mixed approach of quantitative and qualitative research.** Quantitative research is useful because it allowed for assignment of numerical values to certain indicators, which is an objective method of reporting data. This also made it easier to show to what degree things have changed over time, in case an indicator value also changes, and to link certain values to other variables to demonstrate where correlations may occur.

4.2 Variables, Indicators and Areas of Interest

Quantitative Indicators: The quantitative data was collected by the deployed field team using paper questionnaires designed so that routing was clearly indicated, and so data collectors were able to efficiently administer the questionnaires. **The field engineer from the GPL team**

[27] Findings on an Assessment of Small-scale Incinerators for Health-care Waste, S. Batterman, 2004
[28] The Incinerator Guidebook, PATH & JSI, 2010

collected this data, with on-the-ground feedback from the project lead. Upon return from the field by deployed team, all of the questionnaires were entered into Excel order to ensure data integrity. Table 2 highlights both the continuous and categorical variables that would arise from the quantitative data collection process.

Table 1: Quantitative Data Collection Measures

Continuous Variables – Via Observational Survey& Stack Emissions Testing	Categorical Variables – via Survey & Observation
Stack & Combustion Chamber Temperatures	Type of Machine
Oxides of Nitrogen (NO, NO2 and NOx)	Incinerator Operating Method (automatic/manual)
Sulphur Dioxide (SO2)	Type of Waste
Oxygen (O2)	Education/training of staff
Carbon Monoxide (CO)	Direction of smoke (N,S,E,W,NE,SE,NW,SW)
Smoke	Location of where the ash is disposed
Particulate Matters	Safety measures
Gross& Net Efficiency	
Burning capacity (kgs/hr)	
Distance of classrooms from burning site	
Typical time of incineration	
Design specifications (height & diameter of chimney/stack, width of refractory, and volume)	

Qualitative Indicators: Qualitative data collection was entered into an electronic device in order to ensure real-time corrections and electronic data entry. Notes were reviewed at the end of the day to ensure that they made sense and were coherent. All qualitative data was stored in a qualitative data software. The database was designed such that filters enable various comparisons of transcripts/ notes across groups, genders, questions, communities, etc. The database also included a field where responses types have been coded for each question (the coding will occur both at the field level, by the data collector and note-taker, and then later verified by the supervisor).

Quality assurance during the data collection: A pre-test of the data collection tools, especially the surveys and qualitative tools, was done on Saturday March 10, 2018. Because the caretaker from the pre-test school was not available, a separate pre-test occurred on Monday. All appropriate changes were made to the questionnaires for flow and to make sure that the respondent could understand and answer the questions.

At the end of each day, a debriefing meeting took place in which the team shared their experiences (learning, problems etc) with other team members. Throughout the fieldwork, quantitative and qualitative data was manually entered into a computer soon after completing fieldwork activities by the data entry operators.

Qualitative findings were coded and logged, and analysed for trends. This was particularly useful when dealing with factors, which require a more significant level of explanation and subsequent discussion. Close-ended questions (blind-voting) from focus group discussions were analysed in order to highlight trends and associate those findings with rich narratives. The field team members from AGAHE conducted the KIIs and FGDs with probing and continuous feedback from the project lead in order to ensure that key information was not missed. The project leader did the note-taking.

4.3 Tools and Instruments

All tools and instruments used throughout the study are listed in Annex B. Majority of these tools were pretested on Saturday March 10, 2018, and then refined to flow better and become clearer. The assessment was divided into three parts, and with a total of five tools.

1.) The first part of the technical assessment was based upon a combination of stack emissions testing by a sub-contracted, nationally accredited laboratory, TTI Labs Pakistan (Tool 1, listed in Annex 2A)
2.) The second part of the assessment consisted of two surveys, which totaled to two tools (Tools 2 and 3, listed in Annex 2B and 2C).
3.) The third part of the assessment consisted of focus group discussions (FGDs) and key informant interviews (KIIs) (Tools 4 and 5, listed inAnnex 2D).

4.3.1 Stack Emissions Testing & Burning Temperatures

Based on the industry standard of nationally accredited lab conducting stack emissions testing, the test of the resulting smoke from the incinerators consists of the following components. In addition a baseline standard is provided to show the allowable limits for these gaseous emissions. Note that the laws and regulations of the national Environmental Protection Act (EPA) in Pakistannow require that all allowable emissions limits fall under the corresponding laws of the province in which testing occurs. Hence, in this case, the allowable EPA limits will fall under the Punjab Environmental Quality Standards (PEQS).

These limits are listed in Appendix 2A, and are based on the Punjab Environmental Protect Act (clause c, subsection 1, section 4, PEPA, 1997, XXXIV of 1997) . Below, each aspect of the stack emissions testing is explained below (United State EPA 2017), along with the rationale for testing for these particular gases and chemicals and what they indicate about the incineration units.

4.3.1.1 **Smoke**

Smoke was measured on a scale from 1-5, 1 being all white and 5 all black. The apparent darkness of the smoke indicated unburned carbon, concentration/size of particulate matter in the smoke, and incomplete combustion.

4.3.1.2 Particulate Matter

Particulate Matter (PM) consists of inhalable hazardous solid particles and liquid droplets which are made up of a variety of chemicals, unburned fuel, sulfur compounds, carbon, ash and dust. Particles less than 10 micrometers contribute towards reduced visibility and can cause serious health problems.

4.3.1.3 Stack Temperature

The high temperature of the flue gases inside the chimney (above 370c) may be caused by various design/technical issues, such as an undersized furnace, defective combustion chamber, incorrectly sized combustion chamber, overfired burner and/or soot formation on the heating surfaces.

Note: Later in the findings section of this report, a variable of the **“combustion chamber temperature”** is shown. This should not be confused with the stack temperature. The stack temperature is taken to measure the difference between the temperature of the gases **emitted** from the chimney and the temperature inside of the combustion chamber.

4.3.1.4 Oxides of Nitrogen (NO, NO2 & NOx)

Oxides of Nitrogen were determined by USEPA Method 7. In this method, a sample of the effluent gas is continuously sampled and conveyed to the analyser for measuring the concentration of NOx. NO and NO2 can be measured separately or simultaneously together and their sum would be reported as NOx. High levels of NO, NO2 & NOx can have detrimental effects on plant life, cause acid rain and lead to the formation of ground level ozone, which damages agriculture and other materials.

4.3.1.5 Sulphur Dioxide (SO2)

Sulphur dioxide was determined by US EPA Method 6-C. In this method, effluent gas is continuously sampled and conveyed to an analyser that measures the concentration of SO2. SO2 easily reacts with various substances to form harmful compounds, such as sulfuric acid, sulfurous acid and sulfate particles.

4.3.1.6 Oxygen (O2)

Oxygen was determined as per USEPA CTM-034/3A

4.3.1.7 Carbon Monoxide (CO)

Carbon Monoxide was determined as per USEPA 10. CO is a gas which is hazardous to human health. It cannot be seen, tasted or smelled. High levels of CO have adverse effects on the amount of oxygen carried by hemoglobin around the body in red blood cells. Therefore, organs such as the brain, heart and nervous tissues do not receive enough oxygen to function properly.

4.3.1.8 Gross Efficiency

Gross combustion efficiency calculations assume that the energy contained in the water vapors or anything else is not recovered.

4.3.1.9 Net Efficiency

Net combustion efficiency calculations assume that the energy contained in the water vapour or incinerator burning which is formed as a product of combustion is recovered and is not exhausted from the flue or stack.

The team also checked the **temperatures** at which the waste materials are being burnt inside of the **primary chamber of the incinerator**. This is essential to understanding whether complete combustion of the waste materials has occurred.

4.3.2 Surveys

There were two surveys. Originally, the team proposed one combined survey, but upon reaching the field and conducting pretesting, they changed their approach.

The **first** survey contained direct observation questions in which the engineer observed, measured, and recorded the technical design and infrastructure of the incineration units to make sure they are appropriate and technically sound. He measured the height and size of the combustion chamber, the chimney and checked the air inlets to determine if sufficient air was being circulated within the incinerator. The engineer also assessed the hardware of the incineration units to make sure they were well-maintained. If it was determined that they were not, he would recommend ways in which the hardware can be maintained or upgraded (with cost-effectiveness considerations). Alongside this survey, the engineer and technical team took photos of each girl-friendly toilet along with the incineration unit.

The **second survey** consisted of questions for the caretaker and/or handler on the operations and safety components of the incinerator or burning unit of the girls' friendly toilet. When the caretaker was male, this survey was conducted by the GPL engineer. When the caretaker was female, the project lead from GPL conducted the survey in order to make her comfortable in answering questions and to respect local norms and customs. Due to language barrier issues, AGAHE field staff assisted the project lead and/or the engineer in conducting the second survey. Beyond the survey, caretakers were asked to provide any other relevant information. Their responses were taken independent of any school administrators.

4.3.3 Focus Group Discussions (FGDs)

Upon consent, qualitative data was collected through FGDs with female students who came into contact with the girl-friendly toilets and/or help facilitate the process of hygiene and disposal. One FGD was conducted per school with a minimum of 5 girls. Among these girls, about half includedgirls involved in the schools' WASH programming, and the others were regular users (or non-users) of the toilet. The team conducted a total of 10 FGDs. The project lead conducted these with the assistance of the WAP field facilitator from Agahe. Each interview lasted about 20 to 30 minutes.

The focus groups honed in on the following categories of questions (as provided in Appendix 2D):

1.) Types of menstrual products used and disposed
2.) Ease of disposing feminine hygiene products with the current girl friendly toilets
3.) Challenges with disposal
4.) Where applicable, involvement in the incineration process

4.3.4 Key Informant Interviews

Key informants can provide comprehensive and 'insider' information for the benefit of our study. Upon providing consent from informants, interviews were semi-structured (guided by a key informant questionnaire, but conducted with a trained facilitator who intervened when necessary). KIIs were conducted with the teachers. Since teachers were not always available, the team spoke to 2 to 3 teachers per school.

4.4 Sampling Size and Methods

A stratified sample was taken of 50 rural Muzaffargarh schools that WAP serves in its WASH in school's project for the survey. The strata were based on of the enrollment of adolescent students in schools. These were the numbers that the team was able to actually obtain for the schools (most were secondary and high schools, but others were bigger with elementary level) We see this as most relevant, given the fact that the proximity of student populations, and more importantly, dense ones, to burning sites is important to developing tailored recommendations. The schools were divided into four strata:

- <300 students
- 300-500 students
- 500-1000 students
- >1000 students

Based on cost-efficiency considerations for testing emissions, AGAHE and WAP selected 10 schools to be tested for emissions based on the stratified sample. The selection of the schools for these samples was based on consultations with WAP and any available data on the type of waste burning methods being employed at each school. Due to various factors and the nature of the project, schools were chosen based on consent from headmistresses, availability of caretaking staff, and other factors taking place during data collection, such as exams. The selected schools are listed in Table 2.

Table 2: Rural Muzaffargarh District Schools Selected for Sample Emissions Testing of Girl-Friendly Toilet Incinerators

Name of Schools	Union Council	Tehsil	Student Population Strata
GGHS Basira	Basira	Muzaffargarh	500-1000
GGES Noor Kubra	Baseera	Muzaffargarh	<500
GGES TibbaQazian		KotAddu	<500
GGES DogarKalasra	DogarKalasra	KotAddu	<500
GGHS Sinawan	Sinawan	KotAddu	500-1000
GGHS MochiWala	KotAdu 2	KotAddu	300-500
GGHS Kotaddu	KotAddu	KotAddu	>1000
GGHS Chak # 518	Meer PurBhagal	KotAddu	300-500
GGHS RohillanWali	RohillanWali	Muzaffargarh	>1000
GGHS Shehr Sultan	Shehr Sultan	Jatoi	500-1000

4.5 Data Processing & Scheme of Analysis

All quantitative and categorical variables within the emissions testing reports from TTI labs along with the survey data were collected through paper-based questionnaires. These results were then entered electronically into Excel and checked for quality. All relevant results from these three data tools employed here are presented in this report into different categories of concern for assessing the effectiveness and efficiency of the incinerators connected to the MHM program's girl-friendly toilets.

All qualitative data was entered electronically into word documents. These responses were then assessed and processed in relation to the observational and operational data collected by the technical team. Essentially the qualitative methods were used to: (1) Gauge the level of usage of the girl-friendly toilets (though this was not tangibly measured) and (2) Understand the experiences with girl-friendly toilets and more importantly, with the incinerators attached to these. These findings are in Section 6.

4.6 Scope and Limitations

After careful planning and coordination with relevant stakeholders, the following limitations came from the assessment. These included:

- A time constraint, in light of which the team was still able to work efficiently and effectively coordinated to ensure completion as per given timelines.
- The team found that it was difficult for caretakers to be able to assess the typical quantity of waste at the schools, hence, after pretesting this question was excluded from the survey questionnaires.
- The hierarchical structures of a few schools made it difficult to be able to talk to teachers or even the caretaker separate from the headmistress at times. However, all attempts were made to keep discussions separate in order to make sure there were candid responses in the FGDs and KIIs.
- The varying interventions and nature of objectives/research questions of the study will demand that the data collection is based on comprehensive tools developed through a rigorous literature review
- Recall bias by the caretaker became a limitation in calculating the time it to took to completely burn the waste. This was especially the case since training was not very

formalized for the regular caretakers or (in some cases) students doing the burning of the incinerators.

- The operational design of putting the pads directly into the loading door of the incinerator in the MHM girl-friendly toilet did not allow for the team to be able to observe a complete burning cycle, as stated by the De Montfort guidelines. Therefore, the potential to reach desired temperatures for complete combustion was not realized.
- The team was not able to test for dioxins and furans due to financial and technical constraints. It is important to note that incineration facilities in Pakistan are **not legally required** to get dioxins and furans tested. Even labs using international standards that are recommended by the government do not have the capacity to test for these. Hence, these tests are sent abroad and only done in very special cases and where financial constraints may not be an issue.

5 Findings and Analysis

The assessment tools used in the assessment provided a comprehensive picture of the effectiveness and efficiency of the incinerators attached to the MHM girl-friendly toilets.

5.1 Incinerator Design

As mentioned in Section 4, the engineers at AGAHE originally built the incinerators in Muzaffargarh and based their design and measurements off of the De Montfort small-scale, cost-effective model. Measurements and specifications were based off of some De Montfort guidelines, but the design was tweaked to accommodate the specific and local needs of this project.

All of the toilets during data collection were functional and all incinerators were able to burn, but some had some issues due to lack of proper maintenance or operator error. All incinerators were ignited manually, contained a chimney as a stack emissions mechanism, contained uniform measurements of plaster as their external coverings (12.5 mm), and contained uniform thickness of fire bricks as refractory material (100 mm). They were also all were single-chamber, **except for the newer incinerator model at Shehr Sultan**.
The photos in Figure 3 an example of the detailed components of the girl-friendly toilet incinerators **BEFORE** burning.

Figure 3: Girl-friendly toilet incinerators – before burning

Table 3 displays all other design specifications that were not completely uniform throughout the ten incinerators, such as the combustion chamber volumes, maximum incineration capacities, chimney heights, shapes, and chimney perimeters (for square shapes) and diameters (for circle shapes).

Table 3: Design Specifications of 10 Muzaffargarh Incinerators

School	Combustion Chamber Volume (m^3)	Maximum Incineration Capacity (kgs/hr)	Projected Weight of Menstrual Waste in One Month (kilogram)s	Chimney Height(m)	Chimney Shape	Chimney Perimeter / Diameter (mm)
GGHS Basira	0.3	6 to 10	9.2	2.13	circular	100
GGES Noor Kubra	0.85	17 to 20	0.9	2.4	circular	100
GGES TibbaQazian	0.438	8 to 10	1.7	2.4	circular	100
GGES DogarKalasra	0.425	8 to 10	1.2	1.67	square	160x160
GGHS Sinawan	0.4	8 to 10	5.8	1.99	circular	100
GGHS MochiWala	0.67	13 to 15	3.5	1.96	square	80x80
GGHS KotAddu	0.54	11to 13	12.7	1.87	square	150x150
GGHS Chak # 518	0.362	7to 10	3.6	2.4	circular	100
GGHS RohillanWali	0.256	5to 7	13.8	2.116	circular	80
GGHS Shehr Sultan	0.05	1	9.2	2.23	circular	120

As shown in Table 3, it was difficult to weigh the waste due to cultural sensitivities and little ability of caretakers to recall how much waste they burned at a time. However, since the team had an estimate of the population of adolescent girls at each school (Class 6-10) and of the individual weight of a used sanitary napkin/pad, it was possible to project how much waste should be generated in a month based on those numbers.

The equation used to calculate the total weight of menstrual waste generated for one month was:

Average weight of a **used** sanitary napkin x # of adolescent girls

The average weight of one commercial cotton sanitary pad is about 11 grams (based on manufacturer details). There are different types on the market, so for this purpose, these are the pads for a "normal" flow. When adding in the weight of period blood into a normal pad, the maximum amount of blood it can absorb is about 12 grams. [29]

In total, the weight used in this equation for one sanitary napkin/pad is **23 grams**.

In addition, as detailed in the focus group discussions (section 5.4.3), many of the younger adolescent girls and girls who just experienced menarche were more reluctant to use the girl-friendly toilet. Hence, keeping this information as an assumption for this projected equation, the team assumed that half of the adolescent girls in all schools were not using the toilet nor disposing of their menstrual products. The exact numbers of adolescent girls in each school is outlined in Table 9. Finally, the weight used here does not account for any loss of weight that may occur during evaporation of any menstrual liquid.

While the team could not obtain exact weights, through observation as well as measurement of the combustion chamber volumes, the team could confirm that incinerators were never even one-third full during one burn cycle. The team had to add non-menstrual waste to the incinerator in order to ignite and maintain burning, as a result.

[29] My PCOS Website: http://www.mypcos.info/1/q-a/what-is-a-normal-menstrual-period/

Figure 4: Burning process from ignition to incineration of waste

In connecting these findings to what caretakers told the team, the caretakers would in many cases have to leave the incinerator to burn for a very long time at low temperatures. However, this is not optimal, as leaving the incinerator to run at lower temperatures for longer creates more emissions. This is explained further through the results of surveying caretakers in section 6.2. All of the incinerators included menstrual waste and had some mixture of municipal solid waste to help manually ignite the incinerators.

The field team tested the ignition of the incinerators and how they operated when burning waste (Table 4). None of the incinerators could reach complete combustion through the temperatures sustained. In other words, the temperatures were too low for all of the incinerators, and all lacked oxygen except for the incinerator in Shehr Sultan.

Two of the incinerators did not have an appropriate mixture of moist and dry waste, and almost all of the incinerators lacked distribution in heat inside of the incinerator. Figure 4 shows this burning and emissions testing process (results in Section 5.3) through a series of photographs.

A question on odor was included with a scale of 1-5, with 1 being no odor at all to 5 being a very strong odor. In all schools, the odor of the smoke was between 3 and 5. While odor with this smoke is natural, understanding the strength of it is important for health considerations of the operator. The strength of the odor is directly related to the opening of the loading door during burning, which allows for smoke to be released into the girl-friendly toilets and thus strengthens the odor around the incinerator.

In terms of distance of the incinerators from the nearest classroom, the benchmark for a safe distance would be 30 meters based on EPA standards. However, this is particularly in the case when a population is present. Since most of the schools conducted their burning after school, this does not present an issue. But for those who conducted burning during school hours or have students conducting it, it does present potential hazards to human health.

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Table 4: Burning Indicators of 10 Muzaffargarh Incinerators

School	Distance b/w Incinerator and Nearest classroom	Maximum Temperature of combustion chamber (°C)	Direction Of smoke	Odor of Burning (1-5)
GGHS Basira	12.7	150	**West**	**3**
GGES Noor Kubra	14.2	76	**Southeast**	**4**
GGES TibbaQazian	5.4	120	**East**	**3**
GGES DogarKalasra	0.3	128	**Southeast**	**4**
GGHS Sinawan	13.6	168	**Northeast**	**4**
GGHS MochiWala	11.7	197	**East**	**4**
GGHS KotAddu	3.9	75	**Southeast**	**3**
GGHS Chak # 518	15.9	105	**East**	**4**
GGHS RohillanWali	18.3	186	**South**	**4**
GGHS Shehr Sultan	10.1	230	**North**	**3**

5.2 Incinerator Operators

Majority of the caretaking and upkeep of the incinerators was done by females in the schools, especially given the taboos that exist in Pakistan around males handling menstrual waste. However, the team observed that when male caretakers were involved, they were not as willing to make sure that the waste was properly dispersed throughout the incinerator to ensure complete burning. Or they were not heavily involved with the maintenance.

The four government caretakers in the ten schools observed received some training, but none of it was formal or very comprehensive. In two out of the ten schools, the female students did the burning. Almost all schools burned their waste after school hours (70%).

None of the schools used any personal protective equipment (PPE), other than a scarf to the mouth and in some cases, using plastic bags to cover the hands as “gloves”. Most caretakers in the assessment claimed that even after leaving the incinerator on for 1-2 days they saw ash. However, this is not, in fact, complete combustion. This is **also not, by definition, ash, but rather ash-like substances** that renders the waste “unrecognizable”. In other words, to the naked eye, it seems that the trash has been completely burned.

Eighty percent of the caretakers burned the waste weekly or biweekly, while twenty percent burned only monthly (See Table 5). Only three of these schools within this 80 percent determined set days of the week to burn their waste. These days generally fell at the beginning of the week on Sunday or Monday or towards the end of the week on Friday or Saturday. Otherwise, majority of the caretakers were not able to point to any operating schedule of when to burn the incinerators, pointing to two potential reasons: no standard operating procedure (SOP) or not enough girls using the toilets to change their menstrual products. This is further discussed in qualitative findings.

Table 5: Caretaker questions around burning frequency and odors, by school

School	Who does the burning?	Gender	Time burning usually occurs in the school day	Frequency of burning waste	Time Caretaker waits after igniting (HH:MM)	Time Caretaker waits to remove ash (DD:HH:MM)	Odor before burning waste (1-5)	Odor during burning (1-5)
GGHS Basira	Caretaker	F	after	Weekly	00:15	01:00:00	5	4
GGES Noor Kubra	Caretaker	F	after	Biweekly	00:30	02:00:00	1	5
GGES TibbaQazian	Students	F	Second half	Weekly	00:15	00:00:30	3	4
GGES DogarKalasra	Caretaker	M	after	Monthly	00:30	00:03:00	3	4
GGHS Sinawan	Caretaker	F	after	Monthly	01:00	01:00:00	1	5
GGHS MochiWala	Caretaker	M	after	Biweekly	00:30	01:00:00	3	4
GGHS KotAddu	Caretaker	M	after	Biweekly	01:00	01:00:00	1	2
GGHS Chak # 518	Students/peon	F & M	First half	Weekly	01:00	01:00:00	1	3
GGHS RohillanWali	Caretaker; sweeper		after	Monthly	00:20	01:00:00	1	3
GGHS Shehr Sultan	Caretaker		Second half	Weekly	00:30	01:00:00	1	4

In terms of the times that it takes to burn the waste, the team found that this question was limited, and based solely on recall. Since the caretakers had no training in understanding what complete combustion or completely incinerated waste looked like, the numbers they reported were most likely neither accurate, nor indicated complete combustion. Therefore, the results of question 12 in this caretaker survey in which the caretakers are asked how long it takes to burn the waste (See Appendix 2), are not worth reporting here. Table 5, however, reports the amount of time that the caretakers wait with the incinerator and how much time the wait between burning and removing the ash.

Again, the caretakers nor the team could ascertain exactly how much time the burning itself continues. However, because the times the caretakers said complete burning occurred did not match up with the temperatures reached in the incinerators, the team was able to ascertain that this may cause the incinerators to not burn the waste with efficiency. This is further discussed in the recommendations section.

On average, the caretakers waited about 35 minutes after igniting the incinerator and starting burning and they waited about one day (in almost all of the cases) until letting the ash cool and removing it from the incinerator. From the qualitative aspects of the survey, the team found that they usually let the incinerator run until the waste becomes partially burned ash. In addition, in some schools, basic observations by the team showed that the ash may not have been removed as often as it should.

None of the schools had any enclosed areas for storing their ash. Ash was mostly just thrown with other municipal solid waste in the school, and may have in some schools been stored in a tin, a plastic bag, or a dustbin, at most. Only one school kept the ash stored in a closed tin, but this is again placed with other trash and thrown to an unofficial dumping site or somewhere near school grounds. Only one school that was nearer to a city center, Shehr Sultan disposed of its municipal waste at a government-approved site, but the incinerated menstrual waste is just mixed in with it.

5.3 Emissions Testing

The data collection methodology for reporting emissions is in Appendix 2A. The findings in Table 7present emissions results for each school and how it measures up to the Punjab Environmental Quality Standards (PEQS) allowable limits by the Punjab Environmental Protection Agency (PEPA). The PEQS and the NEQS standards are the same.[30] According to PEQS standards the ten incinerators passed emissions testing and remained under the allowable emissions limits when it came to levels of carbon monoxide (CO), sulfur dioxide (SO_2), oxides of nitrogen (NO_x), and particulate matters (PM), and smoke levels. These limits are presented at the bottom of the table through the 14 indicators. Oxygen (O_2), carbon dioxide (CO_2), nitric oxide (NO), and nitrogen oxide (NO_2) do not have any specific standards according to PEQS guidelines.

Since complete combustion was never achieved, the team could not observe the maximum efficiency of the incinerators even from the emissions' results. Out of ten readings, the maximum flue temperature recorded was 240.5 °C (see GGHS Basira in Table 6).

[30] Statutory notification 549 (I/2000), August 2000, Annex II: National Environmental Quality Standards for Industrial Gaseous Emission

Table 6: Emission Testing Results on 10 Incinerators from WASH Girl-Friendly Toilets in Muzaffargarh

School	Emissions Indicators													
	O_2 (%)	CO_2 (%)	CO (mg/ Nm³)	NO (mg/ Nm³)	NO_2 (mg/ Nm³)	NO_x (mg/ Nm³)	SO_2 (mg/Nm³)	Flue Gas	Ambient Temp (°C)	Diff Temp (°C)	Net Efficiency (%)	Gross Efficiency (%)	PM (mg/ Nm³)	Smoke (Ringelmann Scale)
GGHS Basira	14.83	6.08	167.75	25.95	2.66	28.62	14.25	240.5	33.4	207.1	74.2	68.4	26	01
GGES Noor Kubra	15.04	5.84	593.7	4.01	0.2	4.21	11.4	76.7	23.2	53.5	96.6	90.6	15.7	01
GGES TibbaQazian	14.93	6.01	266.75	19.26	2.46	21.72	17.1	176.1	28.9	147.2	80.8	74.4	13	01
GGES DogarKalasra	14.81	6.10	165.37	25.95	4.30	30.26	39.9	110.0	24.6	85.4	92.6	85.1	22	01
GGHS Sinawan	15.56	5.33	510.12	18.73	2.87	21.60	17.1	177.7	23.4	154.3	79.3	73.4	21.4	01
GGHS MochiWala	14.90	6.04	209.12	71.04	2.87	73.91	59.85	122.6	34.4	88.2	88.5	81.4	32	02
GGHS KotAddu	15.27	5.64	189.12	4.41	6.15	10.56	8.55	75.1	34.4	40.7	96.4	88.6	18	01
GGHS Chak # 518	14.94	5.67	165.37	42.54	8.2	50.74	19.95	99.6	25.7	73.9	90.2	83.0	23	01
GGHSS RohillanWali	18.75	1.64	255.62	33.85	15.17	49.02	8.55	79.1	32.0	47.1	83.8	79.1	23	01
GGHS Shehr Sultan	14.86	4.04	347.25	13.91	4.51	18.42	36.19	170.8	33.7	137.1	91.7	84.3	11	01
PEQS Standard	**No Standard**	**NS**	**800**	**NS**	**NS**	**400**	**1700**	**-**	**-**	**-**	**-**	**-**	**300**	**02**

5.4 Qualitative Findings

Both design and caretaker surveys include “free-answer” questions in which the respondents and or observer was able to write any notes that may not have been captured through the survey questions.

5.4.1 Technical Qualitative Findings

In the observational survey on the design of the incinerators (both before after the engineer and field team tested the burning abilities), the team observed small nuances that could not be captured in the questions. The following are some of those themes that helped the team come up with the operations and training recommendations (section 6.5 and 6.6):

a. **Small amounts of schoolyard waste deposited into the ash area of the incinerator**
   The incinerator’s ash area is not a storage area for any extra waste. That should only be loaded through the loading area from inside of the toilet.
b. **Waste is being ignited from the loading area (for the pads)**
   This loading door is kept open to feed oxygen to the flames. Hence, this leads to smoke exiting from the door and into the bathroom. The team some observed smoke stains in the area around the loading door. This can cause long-term damage to the girl-friendly toilet.
c. **Based on the observations of the waste that each school generates, incinerators from 90% of the schools were too large**
   This was also a finding in the focus group discussions (discussed in 5.4.2). By pure observations of the incinerator and the waste put into it, waste was either burned too frequently or insufficient amounts are generated.

d. **None of the incinerators had a temperature gauge**
   Without a gauge, it is difficult for the operators to be able to definitively note whether complete combustion has occurred. Complete combustion typically occurs when the combustion chamber temperatures is at the minimum of 540°C.

The following were themes that came from the qualitative components of the caretaker survey (as well as the focus group discussion). These were also essential for formulating training recommendations (section 6.5):

5.4.2 Operational Qualitative Findings

The following were themes that came from the qualitative components of the caretaker survey (as well as the focus group discussion). These were also essential for formulating training recommendations (section 6.5):

a. Training was extremely basic and did not include necessary details that make incineration more efficient
b. The caretakers/operators being DIRECTLY exposed to the foul odor of the burning may impede their ability to effectively carry out their tasks

5.4.3 User Experience Qualitative Findings

As expected, while selecting the female students for the focus group, the field team could not gain much understanding about the toilets from girls who very recently underwent menarche. Hence, the girls chosen were between the ages of 13-15 and mostly in class 7 and up. Class levels of some of the girls were used in place for their age of menarche, as some were not aware of their exact age of menarche. Most of the girls had completed anywhere between one and four years of menstruation

Table 7: Background of participants by each school

School	Grade Levels Represented	Estimated Age	First Menarche (Age & Class)	Years since Menarche	Leadership in MHM Peer Group?
GGHS Basira	8th and 9th	14	12-13, 6th-8th	2-3	Yes
GGES Noor Kubra	8th and 9th	13-14	11-12, 6th-7th	2-3	Yes (students incinerate)
GGES TibbaQazian	7th and 8th	12-14	11-12, 5th-7th	1-3	Yes (students incinerate)
GGES DogarKalasra	9th	13-14	10-12, 5th – 8th	2-4	Only one student
GGHS Sinawan	9th	13-14	5th – 8th	2-4	Yes
GGHS MochiWala	8th and 9th	13-15	6th-7th	1-3	Yes
GGHS KotAddu	9th	14-16	8th and 9th	1-2	Only one student
GGHS Chak # 518	9th	14-16	5th – 7th	2-4	No (students incinerate)
GGHS RohillanWali	8th and 9th	14-15	5th -8th	1-3	Yes
GGHS Shehr Sultan	7th	13-15	3rd – 6th	1-4	Only one student

Table 8 highlights the social and user-based themes that emerged from the FGDs with female students. These were important in capturing how the girls personally interacted with the girl-friendly toilet, including disposal of their menstrual products.

Table 8: Themes of Student Focus Group Discussions

Theme/Topic	Common Statements/General Answer
Benefits of the Girl-Friendly Toilet	"We like the mirrors to be able to check for any stains on our uniforms" "The toilet has helped us maintain a lot of hygiene. We used to just throw our pads anywhere before" "We can wash our hands properly and take part in making sure that soap is available" In Sher Sultan school the girls reported that the use of the bathroom is not very high, and many girls still continue to miss school
Types of Menstrual Products Used	Commercial pads from a bazaar or a "sooth" (close to linen) cloth. None of the students reported no usage of any menstrual products, but could be very possible in the younger girls newer to menstruation

Menstrual hygiene practice at home	(Especially in more remote schools far from town centers) "The pads or 'sooth' cloths used for menstruation are cleaned and then either burned or buried, and maybe even thrown into a river if it's nearby" "The 'sooth' cloths are only used about once or twice before being disposed and either buried or burned" (In less remote schools)"We dump our cloths with other waste in the house after covering it in a cloth"
Comfort of changing menstrual products at school	The comfort varied from different students. Most of the girls who led MHM peer groups were comfortable changing pads, but in some schools not all of the girls changed their pads at school. They preferred to just wait until they went home, and this could indicate that many more don't use the toilet to change pads (especially in schools where less waste was observed and burning was conducted monthly)
Incineration (3 schools)	Students have been trained through AGAHE MHM leads

Another part of the user-based qualitative findings was the key informant interviews, which consisted of two teachers per school. At times, one teacher was newer to the school, while the other had more experience. However, this varied in some schools, but for the most part, all teachers interviewed had enough experience in the school to provide comments on the MHM program and the girl-friendly toilets. Interviews were conducted with both teachers at one time.

When possible, a MHM focal teacher was included in this interview. However, due to different limitations of time, it was not possible in every KII to have these teachers. Most of the questions in the interview were centered around the **teachers' experiences with the toilet, the staff that manages it, and managing their students during menstrual emergencies**

Table 9: Key informant interview close-ended questions by each school

School	School Population of Adolescent Girls	Teacher's Typical Class Size	Teacher 1: Years of Teaching (in the current school)	Teacher 2: Years of Teaching	Year that girl-friendly toilet was installed
GGHS Basira	800	60	3.5 years	1.5 years	2016
GGES Noor Kubra	76	25	6 years	22 years	2015
GGES TibbaQazian	150	35	6 months	10 years	2017
GGES DogarKalasra	100	30	5 years	5 years	2015
GGHS Sinawan	500	80	10 years	7 years	2016
GGHS MochiWala	300	50	3 years	9 years	2015
GGHS KotAddu	1100	60	14 years	3 years	NA
GGHS Chak # 518	310	50	20 years	4 months	NA
GGHS RohillanWali	1200	70	22 years	1.5 years	2016
GGHS Shehr Sultan	800	60	6 years	4 years	2017

As expected, almost all teachers were satisfied with the benefits of the toilets. They reported having to send students home due to not having emergency access to menstrual pads. The teachers also reported the confidence of their students in changing their pads at school. More of the general themes throughout these KIIs are outlined in Table 10.

Table 10: Themes of Teacher Key Informant Interviews

Theme/Topic	Common Statements/General Answer
Benefits of the Girl-Friendly Toilet	"These are rules in Islam. [Period waste] is unhygienic, and burning it openly is a problem. The incinerator is closed and this should be there. Women's products should not be out in the open." "We do not want our menstrual waste to be going just anywhere. This is shameful, and to conceal the waste as soon as possible makes it much easier." "The girls would hide it [menstrual waste] somewhere, but then the peon [a male] would find it and would be hesitant to clean it up. Nobody wanted to clean it up."
Burning that occurred at three schools during school hours	Teachers complained about issues with breathing. This was especially pronounced for those teachers with preexisting conditions such as asthma.
Operational Issues	In one of the bigger schools, GGHS Kot Addu, the team's conversation with the teachers indicated some ongoing operational issues at the school that did not keep the trash burning. Some teachers confirmed that rather than just waiting for the waste to fill inside of the incinerator, caretakers would incinerate the waste sooner since the odor from it would start to become noticeable. From a technical perspective, this may point to the possibility that the incinerators are not able to burn at proper temperatures because not enough waste is being burned at one time
Operator Knowledge	The lack of training and understanding of how to distribute the waste throughout the incinerator may be an issue as to why it remains only partially burned.

	With bigger schools like GGHS Kot Addu, relying on untrained staff and even on students may not be the best way to ensure menstrual waste is burned completely and timely.

6 Recommendations

Based on the findings, the team divided recommendations for future scale-up of these incinerators to other schools in Punjab and throughout Pakistan in the categories of: construction and design, safety, and operations and maintenance. These categories were outlined and introduced earlier in the report in the Literature Review (Section 3.3)

6.1 Construction and Design

6.1.1 According to the engineers' observation, the Shehr Sultan two-stage incinerator was the best in terms of design because it receives sufficient air to maintain burning via air holes. It also has a sufficient combustion chamber size for the school population. Single-stage incinerators should be avoided, as they are not as efficient in reducing emissions.

6.1.2 However, the Shehr Sultan combustion chamber alone is not appropriate for every school. Hence, when designing incinerators in the future, the school population of adolescent girls should be considered in order to provide projections of how much waste menstrual waste is generated per month (See Table 5). With these projections, implementers can custom-design an appropriate, two-stage combustion chamber size (these are outlined in Section 6.3.4 on operations).

6.1.3 Based on recommendations 6.1.1 and 6.1.2, the team recommends a design option which expands upon the two-stage incinerator from Shehr Sultan by separating a small portion of the chamber inside of the incinerator with a mild steel plate (a sliding plate) which allows for waste to be stored separately away from the burning area.

This separate storage allows for warm up to occur properly AND for the caretaker to avoid having to come in direct contact with the menstrual waste (as this was the major taboo in the first place). After warm-up has occurred, the caretaker simply has to pull a lever to slide the plate out, which will release the waste onto the grate.

While the team is not recommending this change to current incinerators, future models can benefit from it. The added cost for this would be nominal since it is manual and does not require any major energy requirements or changes to the size of the incinerator.

The drawings and specifications that engineers from AGAHE used as their design plan for the Shehr Sultan incinerator are shown in Appendix 1. **Appendix 3** builds upon that design with the recommended sliding plate option. Another secondary option of a “waste storage box” is also outlined.

6.1.4 The chimney’s heights were all too short. The length of chimney should be increased to 4m in future designs (as specified in the parameters discussed in Section 3 – Literature Review). This will create a natural draught and will assist the fumes to flow through chimney smoothly in one direction and move out through the outlet of the stack. This allows for the smoke to move further away from the classrooms.

The purpose of the chimneys is to carry the smoke from the furnaces to the atmosphere. It may be that if the chimneys are tall, it makes a better draught for the furnaces. The higher something goes into the atmosphere becomes light as eneral rule. This facilitates the flue gas to move out through chimney freely. The higher it is sent into the air, the better is its chance of being blown away and thinning out before it settles.

6.1.5 Most schools are disposing of the ash in unofficial dump sites. An alternative is to construct an ash pit to store ash on school grounds.

6.1.6 The loading doors as they currently stand allow for smoke to escape from the incinerator chamber into the girl-friendly toilet. This, in turn, increases the odor in the toilets and in the vicinity of the incinerator. The team recommends the loading door should have a spring mechanism so after loading, upon release the door immediately shut tight.

6.2 Safety

6.2.1 No proper personal protective equipment (PPE) items, even the minimum of gloves, face mask for mouth and nose, safety shoes, and goggles, are currently being used. A scarf over the face, or plastic bags over the hands do not qualify as PPE items. These items should be incorporated into any MHM and girl-friendly toilet operational guidelines.

6.2.2 In line with the previous recommendation, Standard Operating Procedures (SOPs) should be written into the current MHM/girl-friendly toilet guidelines. The caretaker should understand importance of these SOPs. He or she should be knowledgeable about all procedures to conduct the incineration process – from collecting the waste to ignition to the disposal of the ash.

6.2.3 One observation that the team came across that needs to be firmly established in the SOPs is to make sure all incineration only occurs outside of school hours. It should not be occurring during school hours, especially since in most schools the incinerators are in close proximity to the school.

6.2.4 In about two schools the team also observed that students handled the burning. Given the age of the students and not knowing any potential health issues they may have (such as asthma and other respiratory illnesses), students should always be in the presence of an adult and wearing proper PPEs if they absolutely must conduct the burning.

6.3 Operations

6.3.1 In order to get a clearer idea of how much waste is actually being burned, schools should be tracking how much waste is generated in one month. The waste should be weighed where possible, or if possible, some estimations can be more accurately made through projections. This can be done by finding out how many of the girls **actually** use the girl-friendly toilet to dispose of their products and how often. Due to the limitations of this assessment, our team was not able to do this.

6.3.2 The girls dispose of the pads directly into the incinerator and these are never removed before igniting the incinerator. Therefore, it is not possible to run a warm-up cycle. In other words, a warm-up process allows the incinerator time to heat up to at least 540 °C before actually burning the waste. We have recommended an alternative model which incorporates a storage of the menstrual waste separate from the incinerator (Please see Recommendation 6.1.1).

In addition to the model, caretaker SOPs should state that the caretaker must spend about 30 to 45 minutes to conduct the warm-up period before releasing the waste into the incinerator and letting it burn.

6.3.3 Appropriate mechanisms of ash disposal do not exist for any of the schools. The ash can be stored in a ash pit, drums, or in tins if that is the only vessel available (which was the case in some schools). After about a month, when the weight of ash reaches a sizeable amount (5Kg), it can be either disposed to a government designated area or buried at a suitable site by the caretaker.

6.3.4 As mentioned in Recommendation 6.1.2, Table 11 places three data variables together from the quantitative data components: school population of adolescent girls, projected weight of menstrual waste, combustion chamber volumes, and maximum incineration capacity. Table 12 provides the recommended combustion chamber capacities based on this population, as well as how often burning should occur.

Table 11: Incineration capacities and waste generation based on adolescent female student populations

School	School Population of Adolescent Girls	Combustion Chamber Volume (m^3)	Maximum Incineration Capacity (kgs/hr)	Projected Weight of Menstrual Waste in One Month

				(kilogram)s)
GGHS Basira	800	0.3	6 to 10	9.2
GGES Noor Kubra	76	0.85	17 to 20	0.9
GGES TibbaQazian	150	0.438	8 to 10	1.7
GGES DogarKalasra	100	0.425	8 to 10	1.2
GGHS Sinawan	500	0.4	8 to 10	5.8
GGHS MochiWala	300	0.67	13 to 15	3.5
GGHS KotAddu	1100	0.54	11to 13	12.7
GGHS Chak # 518	310	0.362	7to 10	3.6
GGHS RohillanWali	1200	0.256	5to 7	13.8
GGHS Shehr Sultan	800	0.05	1	9.2

Table 12: Recommended design parameters and burn cycles based on school population and waste generation

School Population of Adolescent Girls	Average Weight of Menstrual Waste in One Month (kilos)	Recommended Combustion Chamber Volume (m^3)	Recommended Incineration Capacity (kgs/hr)	Recommended Cycle
<200	1.26	0.05	1	monthly
200-500	4.3	0.1	2	bi-weekly
501-1200	11.22	0.25	5-6	bi-weekly

6.4 Training

6.4.1 Training programs should address both literate and illiterate operators. These must emphasize health and safety of the operator, as the operator is a vital part of ensuring safe and effective incineration. One can have the best design and equipment, but without operator knowledge, the effectiveness of the incinerator decreases. Operators must understand the risks associated with incineration process and provide consent and an acknowledgement that they understand all proper standard operating procedures (SOPs)

Proper incineration is not only based on the design of the incinerator, but the operator who handles it. A revolving door culture with little to no training of operators is undesirable and will affect the incinerators' efficiency. If this is not possible, then more than one person should at least be properly trained in incineration practices.

6.5 Maintenance

6.5.1 The team estimated capacities of the incinerators in Kg/hr, and they are not being used to their full capacity. It is possible to add heavier waste from the school grounds. The sizes of incinerators are sufficient to accommodate 20% more weight. However, that said, the caretaker should avoid adding too many plastics among the waste, as this can cause issues with the already below-limit emissions rates.

6.5.2 Incinerator plaster walls must be routinely repaired by adding quality plaster over the affected areas. Keeping the bricks covered is important to ensure that the bricks are not exposed to external damage from the environment outside.

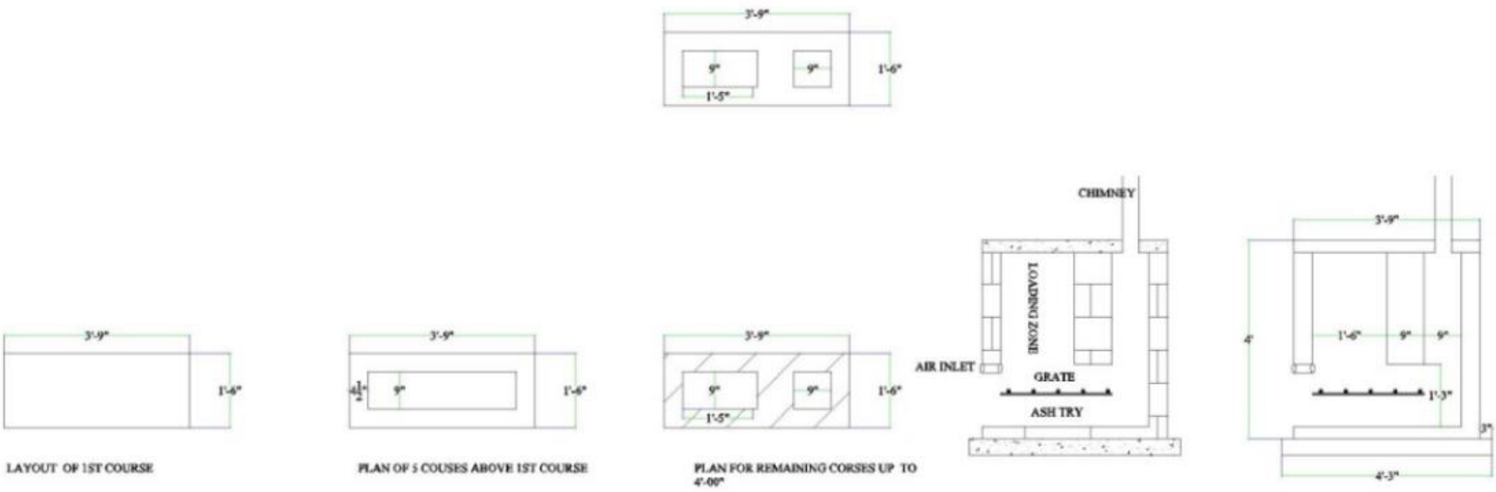
6.6 Compliance

6.6.1 According to the Review of the Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) regulations, 2000, Pakistan Environmental Protection Agency (EPA) Schedule 1, Part H and J (other projects), all waste disposal facilities which handle domestic waste less than 10,000 cubic meters must obtain an Initial Environmental Examination (IEE). The waste incinerators installed in the girl-friendly toilets may fall within this regulation.

7 Appendices

Appendix 1: Incinerator Design Plans by AGAHE Engineers

One design was made by the previous engineer when the project began in 2016, and the other design (displayed below) was later refined and used in newer incinerators that were more recently installed. The team observed this one in Sher Sultan.



Appendix 2: Data Collection Tools

2A: Emissions Testing Methodology

Emissions Testing Checklist & Methodology (to be conducted by TTI Labs)

In accordance with scope of work, the following parameters would be monitored from the stacks for emissions estimation.

Temperature
Oxides of Nitrogen (NO, NO2 and NOx)
Sulphur Dioxide (SO2)
Oxygen (O2)
Carbon Monoxide (CO)
Smoke
Particulate Matters
Gross Efficiency
Net Efficiency

METHODOLOGY

The following methodology will be adopted by TTI labs for the measurement of exhaust from Stacks. The reference methods and procedures are available on request.

Oxides of Nitrogen *US EPA Method 7*

Oxides of Nitrogen will be determined by USEPA Method 7. In this method, a sample of the effluent gas is continuously sampled and conveyed to the analyser for measuring the concentration of NOx.
NO and NO2 can be measured separately or simultaneously together and their sum would be reported as NOx.

Sulphur Dioxide
Sulphur dioxide will be determined by US EPA Method 6-C. In this method, effluent gas is continuously sampled and conveyed to an analyser that measures the concentration of SO2.

Oxygen
Oxygen will be determined as per USEPA CTM-034/3A

Carbon Monoxide

Carbon Monoxide will be determined as per USEPA 10.

Particulate Matters
Particulate Matters will be determined as per USEPA/ASTM standards.

Smoke

Smoke will be determined as per Ringlemann Scale method.

Punjab Environmental Quality Standards for Industrial Gaseous Emissions (mg/Nm^3, unless otherwise defined)

No.	Parameter	Source of Emission	Standard
1	Smoke	Smoke opacity not to exceed	40% of 2 Ringlemann Scale or smoke equivalent
2	Particulate Matter	Boilers & Furnaces a) oil fired b) cement kilns	300
3	Stack Temperature C	--	--
4	Oxides of Nitrogen (NO, NO2 & NOx)	a)Oil fired b)Gas fired	400 600
5	Sulphur Dioxide (SO2)	Other plants except power plants operating on oil and coal	1700
6	Oxygen (O2) Vol.%	--	--
7	Carbon Monoxide (CO)	Any	800
8	Gross Efficiency %	--	--
9	Net Efficiency %	--	--

2B: Incinerator Observational Survey (conducted by engineers and technical staff)
Incinerator Design Survey (Conducted by Engineer & Technical Team)

7.1.1 Basic Information

Name of School:

Tehsil:

7.1.2 Incinerator Design Questions (To be answered before burning process begins)

1. What type of device is being used?
  a. Single chamber incinerator
  b. Double chamber incinerator

2. Is the incinerator/burning system automatic or manual?

Automatic	Manual

3. What is the source of power for the incinerator/burning unit?
  a. Self-ignition (i.e. burning with matches or lighter)
  b. Gas
  c. Electricity
  d. Diesel

4. What materials have been used for the external covering of the incinerator? Check all that apply.

Bricks	
Concrete	
Plaster	
Other (please specify below)	

____

5. Please measure the total thickness of the external covering of the incinerator

Millimeters

6. Which refractory materials does the incinerator contain?

Insulation Bricks	

Fire bricks

Glass wool

Other (please specify below)

7. Please measure the total thickness of the refractory material

Millimeters

8. What is the quality or condition of the refractory?

___

___

9. Please measure the combustion chamber volume.

m³

10. What is the maximum total incineration capacity of the unit in kgs/hour

Kgs/hour

11. Is there a chimney?

Yes	No

12. What is the height of the chimney?

Meters

13. What is the diameter of the chimney

Millimeters

14. Is the chimney/flue positioned in a way that smoke is not immediately inhaled by those in the vicinity?

Yes	No

15. Is there any fire safety equipment located near the incinerator?

Yes	No

16. What type of personal protective equipment (PPE) is being used during burning (check all that apply)?

Masks for mouth and nose

Shoes

Goggles

Gloves

None

Other (please specify)

____

17. What is the distance between the nearest classroom or office and the incinerator/burning site?

Meters

18. Is there a roof or shed over the incinerator?

Yes	No

19. What type of material waste is disposed?
Note: Check all that apply by opening the incinerator

Commercial pads

Biodegradable/cotton cloths

Washcloths from home

Other Waste (Please Specify)

For "other waste" place answer here

____

7.1.3 Burning Questions (To only be answered upon observing operators igniting the incinerator and collecting stack emissions results)

20. What temperatures are being reached in the combustion chamber?

Degrees – Celsius

21. Which direction is the smoke from the burner/incinerator going?
    a. North
    b. South
    c. East
    d. West
    e. Northeast
    f. Northwest
    g. Southeast

h. Southwest

22. On a scale of 1-5, with 5 being the strongest, and 1 being the weakest, what is the odor of incineration area **during**burning? Circle the appropriate answer.

1 2 3 4 5

23. Is complete combustion achieved?

Yes	No

24. If no to 23, then why? Check all that apply.

The temperature in primary chamber is too low	
Lack of distribution of heat in the chamber	
There isn't a appropriate mixture of moist and dry waste	
Lack of oxygen in the chamber	

25. Please use this space to discuss any other relevant observations not covered in this observational survey

____

____

____

____

____

____

2C: Incinerator Operator Survey

Incinerator Operation Staff Questions

Instructions: These questions will be asked to the person(s) who usually operates the incineration unit for the school

Name of School & Tehsil:
Name of Caretaker/Key Maintenance Staff Person:

Questions about Maintenance

1. What type of employee is the caretaker?
   a. Private

b. Government
c. Other (please specify) ______________________________

2. What is your role at the school? Check all that Apply

Caretaker ☐ Other (Please Specify) ☐

Teacher ☐

Student ☐

For "other" place answer here

____

3. What is your level of education?
   a. No schooling
   b. Primary School Only
   c. Secondary School Certificate (SSC)
   d. >SSC

4. If you said yes to options a or b in question 3, can you read and write?

Yes	No

5. Please discuss what you have learned in training (if you have received any)

____

____

____

6. What steps do you follow for the incineration process (beginning to end)

____

____

____

____

____

7. How frequently is the waste burned?
   a. Greater than once a week
   b. Weekly
   c. Biweekly
   d. Monthly
   e. Greater than once a month

8. If weekly, what day(s) of the week does burning occur? Circle **all** that apply.
   a. Monday
   b. Tuesday
   c. Wednesday
   d. Thursday
   e. Friday
   f. Saturday
   g. Not applicable

9. If monthly, what week does it occur?
   a. Beginning of the Month (first week)
   b. Middle of the Month (second – third week)
   c. End of the month (final week)
   d. Arbitrary (not a set time)

10. What time of the school day does incineration occur?
    a. Before school
    b. First half of school
    c. Second half of school
    d. After school

11. How long do you wait after turning on the incinerator?

Hours

Minutes

12. How long does it take to burn all waste?

Days

Hours

Minutes

13. On a scale of 1-5, with 5 being the strongest, and 1 being the weakest, what is the odor of incineration area **<u>prior to</u>** burning? Circle the appropriate answer.

1 2 3 4 5

14. On a scale of 1-5, with 5 being the strongest, and 1 being the weakest, what is the odor of incineration area **<u>during</u>**burning? Circle the appropriate answer.

1 2 3 4 5

15. How long do you wait until taking ash out of the incinerator?

Days

Hours

Minutes

16. Once the ash has been removed from the incinerator, what steps do you take right after removing ash from the incinerator?

____

____

____

17. Do you have a designated storage area for your ash?

Yes	No

18. How is the ash stored after burning?
    a. Drums
    b. Bags
    c. Burial in a pit
    d. In a plastic bag or waste basket
    e. No storage
    f. Other (please specify) ___________________

19. How is the ash disposed after burning?
    a. At a government-approved dumping site
    b. Within the school grounds
    c. Nearby the school grounds
    d. Unofficial dumping site
    e. Other (please specify) ____________

20. What type of personal protective equipment (PPE) do you have in stock (check all that apply)?

Masks for mouth and nose	
Shoes	
Goggles	
Gloves	
None	

21. Please use this space to discuss anything else that is relevant to your role in incinerating this waste. Any observations, challenges, or successes.

____

2D: Qualitative Tools

Focus Group Discussion Questions with Students

1.) Observer Checklist (before beginning discussion):

- Record current ages and grade level of students/girls
- Age of first period (and/or class in which you got your first period)
- Role in maintaining girl/friendly toilets
- (Only for observer) Calculate years the student has been menstruating based on current age and age of first period

Types of menstrual products used and disposed

7.2 Which menstrual products do you use?

7.3 How do you dispose of your menstrual products at home?
Probes: Where do you throw your products?
How does your household handle those products?

Ease of disposing feminine hygiene products with the current girl friendly toilets
7.4 Describe your experience with the girl-friendly toilets at school

Probes: How are the products disposed (any type – not just sanitary napkins)? After how many hours do you change your pad or menstrual product at school? Personal hygiene components (handwashing, disposal, cleaning of surroundings, etc)?

7.5 How are you involved in the process of burning the menstrual waste? (Only where applicable)

Key Informant Interviews with Teachers

- Record Names of Teachers Interviewed
- Years of teaching experience
- Start date of girl-friendly toilet

1.) How many adolescent girls are enrolled in this school, from grades 6-12?

2.) What is your typical class size (average estimate)?

3.) What is your role in facilitating menstrual hygiene for your students?

4.) Who usually makes sure that the incinerators/burners are being turned on?

5.) **If the incinerator is turned on during school hours**, what impact (if any) does this have on your classes?

6.) What are your attitudes towards the girl-friendly toilets and the entire process from disposal to incineration?
Probe: Do you experience any odors if the incinerator runs during school hours?
Probe: What was it like before the toilets?
Probe: If incinerators run during school, do you experience any odors?

Appendix 3: Geolinks Pvt. Ltd. Modifications to Incinerators Modeled by AGAHE (with a "sliding plate" that allows for a warm-up period)

Figure 5: Proposed future incinerator design with lever and box for waste storage

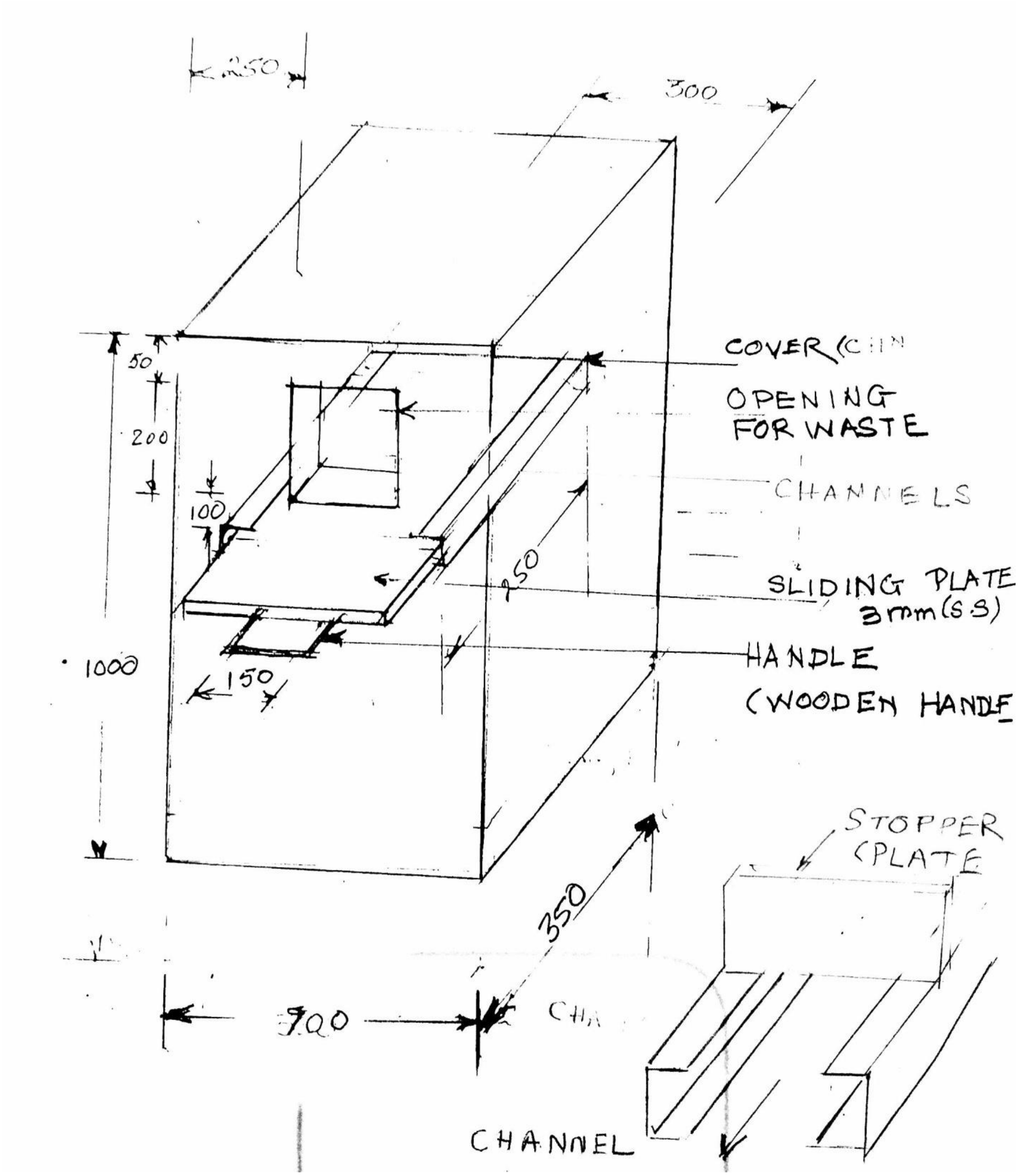
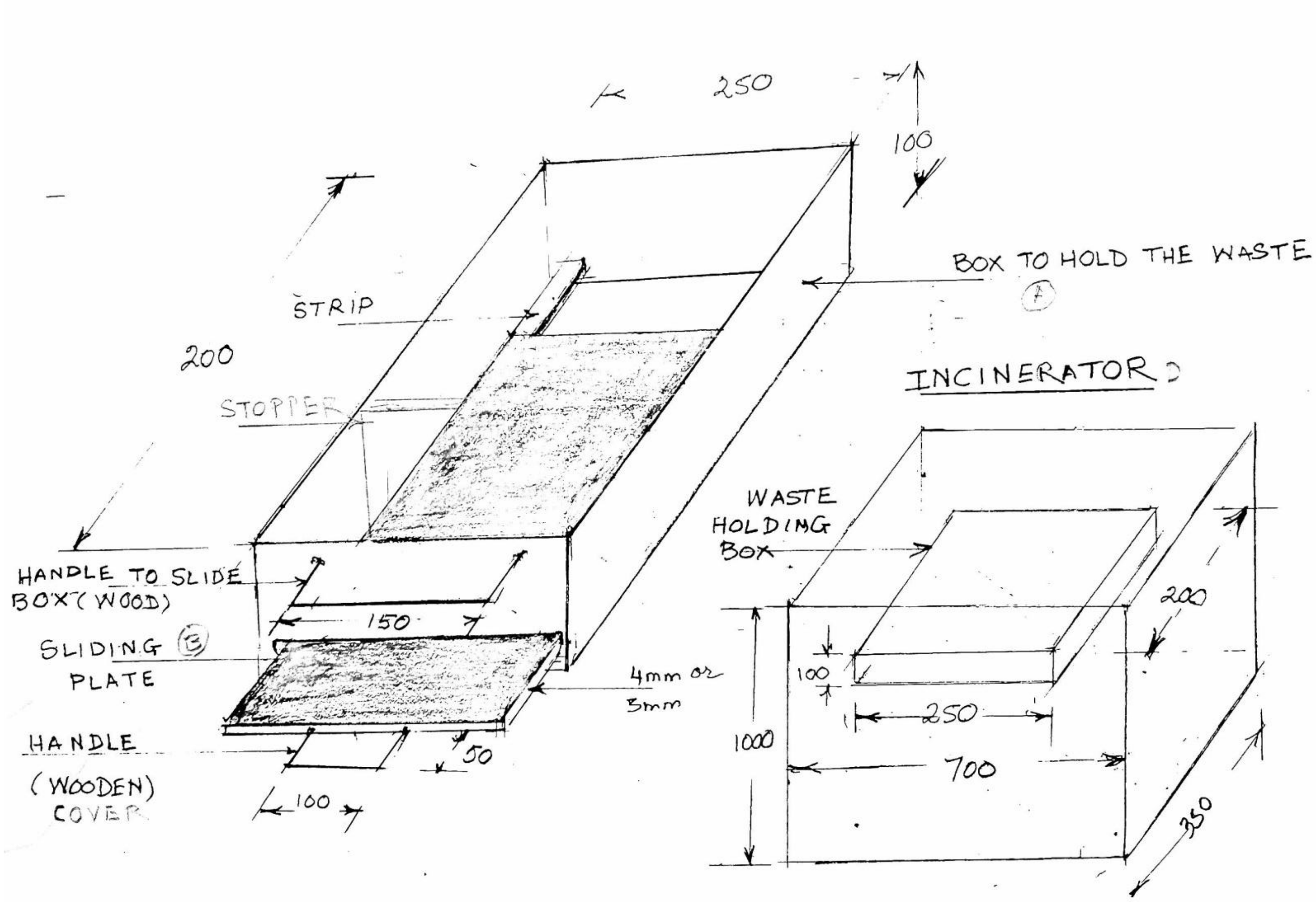


Figure 6: Secondary Option – Proposed Waste Holding Box



Appendix 3 Continued: Procedures for using proposed new design with “sliding plate”

- Waste is loaded through loading door.
- Waste will land on sliding plate which is set between two channels.
- The two channels are 25mm (MS - Mild steel)
- The sliding plate is MS, 300mm x 250mm and 3-4mm thick.
- When plate is filled with waste, dried waste can be loaded through ash area, then ignited, and the warm up period can begin.
- Approx 30-45 minutes of continuous dried waste feeding should lead the chamber to obtain desired temperature.
- Caretaker can pull the plate out using the wooden handle, and stoppers will push the waste onto the grate.
- Caretaker will push the plate back, and continue with the incineration process.

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