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Development of an incinerator for the hygienic disposal of sanitary pads in female student hostels.

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ABSTRACT

Background:

Improperly disposed of used sanitary pads in female student hostels pose serious health, environmental, and sanitation challenges, including the spread of infections , offensive odors and blockages in sewage systems. Despite the importance of menstrual hygiene management, many institutions have a lack of separate and hygienic sanitary waste disposal systems.

Methodology:

The proposed work focuses on the design, fabrication and performance evaluation of a compact incinerator for hygienic disposal of sanitary pads in female hostels. Due to its clean combustion, availability, and controllability, the incinerator is designed to operate using Liquefied Petroleum Gas (LPG) as the primary fuel. The system consists of a cylindrical combustion chamber lined with refractory fiber, an LPG burner with controlled ignition, a chimney for safe exhaust of flue gases, and a removable ash collection tray.

Results:

Thermal analysis showed that the incinerator can achieve operating temperatures in the range of 850 - 1250°C, well above the auto-ignition temperature of rayon, the major constituent of sanitary pads. Energy requirement calculations also showed that about 0.006 kg of LPG per cycle is adequate to completely incinerate 30-50 pieces of sanitary pads. Performance evaluation realized a mass reduction efficiency of more than 95%, with full burn achieved in about 30-40 minutes per cycle. The resultant ash was fine, sterile, and nontoxic, making up less than 5% of the original waste mass. Observations during testing revealed minimal visible smoke and odor, indicative of environmentally acceptable emission characteristics in accordance with the World Health Organization guidelines for small-scale incineration systems.

Conclusion:

Developed incinerator provides a low-cost, safe, and environmentally friendly solution for sanitary pad disposal that can be utilized to enhance hygiene, privacy, and waste management practices.

Recommendation:

The design is well-suited for adaptation and deployment in other institutional and community settings, improving public health and promoting sustainable sanitation.

Keywords: *Sanitary pads, Hygienic disposal, Waste management, Heat transfer, Environmental control*.
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1 Introduction

According to the United Nations Children's Fund (UNICEF), 1.8 billion women around the world have periods and thus are expected to engage in menstrual hygiene management (MHM) [1-3]. Menstrual hygiene management is defined by the World Health Organization (WHO) as the "management of periods associated with the menstrual process [2]." These activities are broken down into 3 sub-activities by UNICEF and WHO [3]: using and changing blood-absorbing products, washing the body, and

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disposing of used menstrual products [4]. Menstrual waste refers to the disposable products used to manage menstrual flow, such as sanitary pads, tampons, panty liners, and menstrual cups, that are discarded after use [5-7]. These products are designed to absorb menstrual blood and other fluids and are typically made of materials such as cotton, cellulose, and plastic [6]. Menstrual waste is considered a type of medical waste or hygiene waste, and its disposal is an important aspect of maintaining public health and preventing the spread of diseases, as well as keeping the environment decent [7].

Women undergoing menstrual practices still face many religious, social, and cultural restrictions that are a challenge in the path of menstrual hygiene management [8-11]. Menstruation is managed differently by women when they are at home and not at home [9]; at home, they dispose of menstrual products by burning them to ash and thereby causing environmental pollution [10]. Also, they dispose of the menstrual products in domestic waste, and they flush them in the public restrooms without knowing the bad effects [11]. Many women around the world still use outdated disposal methods that not only have harmful impacts on the environment but also on women and girls [12]. Sanitary waste management has received little consideration due to a lack of awareness in the local community and social stigma for organized action [13]. It is a global problem with policies, frameworks, and guidelines in place to dispose of sanitary waste, even though it fits in the scope of waste management [14]. Government and non-governmental agencies have been working on making sanitary products accessible [15], attempting to alleviate period poverty as well, because sanitary systems and hygiene products are of utmost importance [16].

Several literature reviews on menstrual hygiene management have been published, and much attention has been gained. Nevertheless, several papers and reviews tend to focus on absorbent access and use while neglecting the disposal of menstrual waste. Disposal of menstrual waste is often neglected in MHM and sanitation value chains, leading to improper disposal and negative impacts on users, the sanitation systems, and the environment.

Fig. 1. Improper disposal method

In some communities, a lack of access to proper sanitation facilities and waste management infrastructure can make it difficult for individuals to dispose of menstrual pads properly, exacerbating social and health problems. The cost of managing menstrual waste can be high, particularly in low-income communities where resources are limited. Menstrual hygiene management can affect girls' and women's ability to attend school or work; it can also perpetuate social inequality, particularly if they lack access to proper sanitation facilities and menstrual products. Improper disposal of menstrual pads can cause anxiety and stress, particularly for individuals who are already experiencing menstrual-related stigma and shame [17-20]. The lack of access to proper sanitation facilities and menstrual products can lead to low self-esteem and body image issues, particularly among girls and women [18]. There is an important need for effective sanitary waste removal, particularly in terms of providing a more comprehensive, efficient, and simple solution for managing different types of menstrual waste disposal in schools.

The challenges that menstruating women and girls face encompass more than a basic lack of infrastructure or supplies. The resulting lack of information about menstruation leads to unhygienic and unhealthy menstrual practices and creates misconceptions and negative attitudes, including, among others, shaming, bullying, and even gender-based violence. While menstruation is a normal and healthy part of life for most ladies, in many societies, the experience of menstruators continues to be constrained by cultural taboos and discriminatory social norms. For

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generations of girls and women, poor menstrual health and hygiene have been exacerbating social and economic inequalities, negatively impacting their education, health, safety, and human development. The issues that menstruators face require multi-sectoral interventions. While sanitary pads provide undeniable benefits in terms of convenience and personal hygiene, their environmental effects cannot be ignored. The harmful effects on forests, plastic waste, greenhouse gas emissions, water pollution, and landfills call for urgent action. It is essential for manufacturers, consumers, and policymakers to explore and promote alternative solutions [19].

This research is designed to improve the maintenance of public health and prevent the spread of diseases through improper disposal of used sanitary pads. This can be achieved through the development of an incinerator that is affordable and is operated manually. To ensure it does not cause environmental pollution by operating with minimal smoke and to incorporate safety features for users. This project brings novelty to previous studies by addressing the research gap in previous reports. While global papers or studies exist on sanitary waste management, they do not address specific issues or circumstances that this project aims to address. Toilet facilities designed to provide access to absorbents, accommodate menstrual hygiene practices, and encourage safe handling and disposal of used absorbents are important means of supporting women's health and dignity. In the design of communal toilets, disposal of waste has often been ignored, leading to improper waste disposal. This project does not attempt to review the broad topic of municipal solid waste management but maintains a narrow focus on menstrual hygiene waste and waste management. This project addresses the improper disposal of pads and brings about the improvement of modern sanitary waste disposal, such as incineration, the health and environmental risks associated with disposal, and policy guidance on menstrual waste management [20].

2 Materials and methods

This project methodology integrates both the theoretical design and practical implementation to develop a functional incinerator specifically designed for the hygienic disposal of sanitary pads in female student hostels. The research process follows a systematic method that includes identifying the problem, specifying the design, material selection, construction, and performance evaluation of the incinerator. The ultimate objective is to ensure that the incinerator is safe, efficient, affordable, cost-effective, and environmentally friendly. Estimating requirements is the initial phase in program planning and provides an opportunity to optimize resource utilization [21]. This step entails determining the number of incinerators required at a national, district, or facility level. Depending on the type and size of the facility, multiple small-scale incinerators may be purchased; alternatively, single larger units may be purchased instead. The level of personnel involvement in this step will vary depending on the scope of the procurement planned. If a country intends to procure incinerators at a national level, this will require the engagement of a group of people, including procurement specialists, technical experts, and field program staff who are familiar with the types of facilities in need of incinerators and the areas they serve [22-23]. Additionally, an incinerator located in a secondary-level facility can also be useful for a number of primary health facilities in the surrounding areas, given that waste transport is feasible [24].

Technical specifications play a crucial role in procurement, as they offer suppliers comprehensive details about the requirements of the incinerators to be purchased, and they also form the basis for the contractual obligation of the supplier to the purchaser [25]. It is imperative that these specifications be clear, precise, and comprehensive; otherwise, the procurement process will be delayed or may even need to be cancelled [26]. The selection of incinerator technology, whether fuel-assisted or auto-combustion, should be in accordance with the technical requirements of each country [27]. The essential specifications for any small-scale incinerator model should be based on the following factors: Basic architectural requirements should include a minimum of two burning chambers: one to combust solids and one to combust gases. A temperature or visual indicator to display the heat status of equipment. A durable refractory wall or liner capable of withstanding heat generated by waste loads of 100% non-biodegradable materials. A stack with a minimum height of 4 meters [28]. The architecture of the site should also include a secure enclosure for the incinerator, an ash and needle pit, an arrangement for destruction of vials and glass syringes, a washing facility for reusable items, and a secure storage facility for waste [29]. If a maternity ward is located on-site, a placenta pit may also need to be provided, if appropriate. This project involves finding user demands and converting them into technical specifications, marking the start of the design phase. It is anticipated that the incinerator will attain a combustion temperature between 600 and 900°C, which is

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adequate to eliminate germs and burn organic elements present in sanitary pads [30]. A combustion chamber, air inlet and exhaust systems, an ash collecting tray, and an intuitive user interface are all part of the design. The research design used for this project is design-based experimental research, which combines theoretical analysis, engineering calculations, material selection, prototype fabrication, and performance testing. This approach is necessary because the project is focused on addressing a real-world issue. The lack of a safe, hygienic, and environmentally friendly disposal system for sanitary pads in female student hostels. By using an applied engineering research framework, the study guarantees that the selected solution is not only technically feasible but also economical, socially acceptable, and sustainable [31]. The research methodology adheres to an iterative engineering cycle that is iterative. In order to comprehend the limitations of the sanitary pad disposal system, the first step entails problem identification and analysis through observation and literature review to understand the limitations of existing sanitary waste disposal methods [32]. The second step is known as conceptual design, where different incinerator models are sketched and evaluated using engineering design principles [33]. After that, material selection is carried out, with an emphasis on durability, thermal resistance, cost, and availability. The appropriateness of a few selected materials, such as mild steel plates, refractory linings, fiber insulation, and stainless steel mesh, will be processed for their suitability [34]. Ethical and safety considerations are at the heart of the study. To minimize heat loss and maximize user safety, the incinerator will be designed with a refractory lining and double casing. A chimney system will be incorporated to lessen smoke from the working environment and divert exposure to emissions. Consent from users will be obtained from participants involved in user trials, and asbestos-free insulation materials will be used to eliminate carcinogenic risks. Additionally, every testing procedure will adhere to environmental guidelines on medical waste incineration provided by the World Health Organization [35]. The incinerator must be capable of handling a certain quantity of sanitary pads generated in the female hostel. A female student typically uses an average of 15-20 pads per menstrual cycle [36]. This ensures that waste generated can be incinerated at once, reducing the frequency of operation and improving efficiency. For efficient incineration, the system must reach a minimum temperature sufficient to ignite and burn the sanitary pad materials completely. Sanitary pads are largely made of rayon, wood pulp, and a polypropylene-based top layer, and they are non-biodegradable. The auto-ignition temperature of rayon is approximately 420°C; the incinerator needs to achieve about 850-1200°C for effective burning [37]. Staying within this range helps in ensuring that most organic and polymeric components are destroyed without generating large amounts of toxic byproducts. Given that the incinerator will be used in a student hostel, user safety is a major design priority. To ensure that the external surface is safe and does not become dangerously hot, the design features a double-walled combustion chamber lined with fiber material. This ensures that the outer body remains at a safe temperature and reduces heat loss. In addition, handles are also included for the ashtray, and insulated top lids are incorporated to reduce the risk of burns. The incinerator is designed to run on liquefied petroleum gas (LPG) as shown below. LPG was selected because it is widely available, relatively cheap, and has a high calorific value (~46,000 kJ/kg) [38]. Additionally, LPG combustion produces a clean flame with less soot when compared to biomass or kerosene, making it appropriate for interior or semi-indoor applications. The fuel source can be regulated easily with standard regulators, allowing users to control or adjust the flame intensity and heat distribution. One of the most critical issues that involves sanitary pad incineration is the release of harmful gases such as furans, dioxins, and carbon monoxide if incomplete combustion occurs. The incinerator is designed with a vertical chimney to safely channel smoke away from users and the surrounding environment, thereby mitigating incomplete combustion. Activated carbon filters are integrated to further reduce emissions. The chimney increases draft, which improves combustion efficiency. Sanitary pad incineration produces a small amount of ash residue, which needs to be disposed of safely. At the base of the combustion chamber, the incinerator incorporates a removable ash collection tray. By reducing exposure to potentially infectious residue, this allows users to easily remove ash from the incinerator whenever necessary without direct contact. The ash produced is generally sterile and harmless and may even be used as fertilizer in some cases [39]. The incinerator must be simple to operate with an operating manual for widespread adoption. The design includes a top-loading mechanism with a hinged lid and a mesh, which allows sanitary pads to be deposited discreetly. The ignition system is simple, which requires only switching on the burner. The overall structure is compact, portable, and easy to maintain, making it suitable for hostel use, where space and convenience are important factors. The four-unit system

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of the sanitary pad incinerator is designed to integrate functional, safety, and environmental requirements identified in the design considerations. The four-unit system consists of a combustion chamber, fuel source and burner, exhaust system, and ash collection tray. Each unit is intended to function in synergy to achieve complete and hygienic disposal of sanitary pads while minimizing risks to users and the environment. A schematic diagram was created using SOLIDWORKS to ensure dimensional accuracy, ease of fabrication, and performance prediction, as seen in Figures 2 and 3 below. All dimensions are in mm.

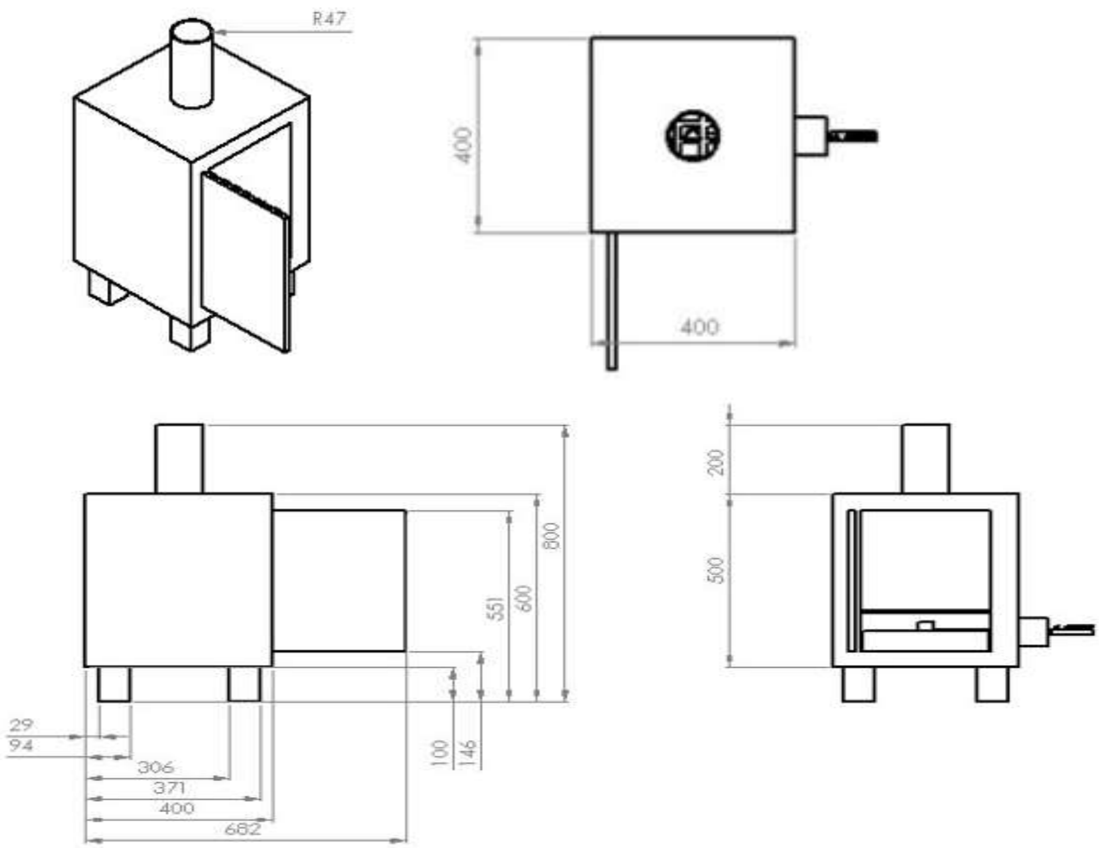

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Fig. 2. Orthographic view and 3D modeling.

The combustion chamber, which is the center component of the incinerator, is where the actual burning of sanitary pads occurs. It is shaped as a cylindrical chamber for uniform heat distribution and structural strength [40]. The chamber is lined with refractory materials to withstand high temperatures of up to 500°C, which reduces heat loss, provides thermal insulation, and prolongs the life span of the structure. The chamber dimensions are based on the estimated volume of 15-20 sanitary pads per cycle, which ensures adequate space for combustion without overcrowding, which could result in incomplete burning. The incinerator uses liquefied petroleum gas (LPG) as its fuel source. Because of its availability, relatively clean combustion properties, and ease of control, LPG was chosen [41]. A gas burner coupled to a pressure regulator provides the fuel to the combustion chamber, which allows precise adjustment of flame intensity depending on the thermal load. The burner is strategically positioned at the chamber's base to ensure complete ignition of the pads from below, thereby promoting uniform combustion. Safety valves and flame arresters are included in the design to reduce risks associated with LPG use. Smoke and gases are generated, including carbon dioxide, carbon monoxide, and traces of volatile organic compounds, during incineration. To prevent users from exposure to emissions, the design includes a vertical chimney pipe that directs smoke away from the operating surroundings. The chimney is designed with sufficient height to provide a natural draft, boosting airflow into the chamber of combustion and enhancing combustion efficiency [42]. To prevent harmful emissions, provision for filtration or adsorption units, such as activated carbon filters, is incorporated in the design. A damper is incorporated for airflow control, enabling regulation of the supply of oxygen to sustain efficient burning. At the bottom of the combustion chamber, there is an ash collector in a removable form for safe and sanitary residue removal after each burning cycle. The detachable unit makes for a simple removal for disposal without necessarily having physical contact with the ash, which may still contain traces of pathogens in the case of incomplete combustion. A heat-resistant handle is included on the tray to provide for easy removal and insertion. The resulting ash residue, typically sterile and inert, can be safely discarded or recycled as a soil conditioner [43]. All these four units together ensure a simple, rugged, and uncomplicated system. The fuel and the burner provide the required heat, the burning chamber facilitates efficient burning, the exhaust system releases noxious gases, and the ash tray enables waste management with ease. The entire system is compact and can be comfortably installed in hostel environments. Moreover, the use of Autodesk Inventor in conceptual design facilitated accurate scaling of size, estimation of airflow, and visualization of assembly before fabrication, hence reducing the risk of design errors at the construction stage. Material selection for the sanitary pad incinerator was made considering significant engineering considerations such as mechanical strength, thermal resistance, corrosion resistance, durability, cost-effectiveness, and availability. Since the equipment will be

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installed in female student hostels, it should be of a type where materials selected ensure safe operation, extended service life, and ease in maintenance, even at repeated thermal cycling between 850 and 1200°C [44]. Materials selected for each component are discussed below. The outer casing of the incinerator is constructed from 2 mm-thick mild steel sheets. Mild steel was used because it is tough, strong, and easily found in the local market [45]. With a 2 mm thickness as shown in Figure 3, the material has sufficient rigidity and mechanical stability to sustain thermal and structural stresses during burning. It is also cost-effective and easy to produce using common workshop practices such as welding, cutting, and bending. Mild steel does easily rust, but surface treatment (such as paint or galvanizing) can significantly improve its life.

Fig. 3. 2mm mild steel.

The inner lining of the combustion chamber is made of refractory fiber material, which serves as insulation and prevents the steel body from exposure to high temperature, as shown in Figure 4 below. Ceramic fiber or silica-based refractory fiber can sustain temperatures above 1000°C with low thermal conductivity [46]. This reduces heat loss, increases thermal efficiency to the utmost, and keeps the outer body comparatively cool, hence protecting users. The fiber lining also aids combustion by ensuring a consistent high-temperature environment within the chamber.

Fig. 4. Refractory fiber lining.

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The chimney is constructed from galvanized steel pipe, selected for its corrosion resistance, moderate cost, and simplicity of fabrication [47]. The galvanizing process produces a protective layer, which has resistance to rusting once the pipe interacts with flue gases as well as external weathering. Galvanized steel is also light in weight but mechanically robust, hence suitable for a vertical exhaust system that will be subjected to both heat and draft stresses. The stainless steel material was chosen for the ash collection tray because of its corrosion resistance, strength, and hygiene qualities [48]. This part will be touched repetitively while discarding ash; stainless steel avoids rusting from the remaining moisture and is easily cleaned. Its surface provides a smooth finish, preventing the accumulation of ash and making maintenance easy and sanitary. One of the most critical elements of incinerator design is to determine the energy input to thoroughly combust the sanitary pads and examine the heat transfer phenomenon in the combustion chamber. This ensures that the identified fuel source, LPG, is sufficient, effective, and cost-effective while ensuring that the combustion chamber reaches the desired range of temperature for efficient incineration.

The energy requirement was estimated using the standard heat transfer relation in equation 1, shown below:

$$Q = m \cdot cp \cdot \Delta T$$

Where:

Q = heat energy required (kJ),

m = mass of sanitary pads per cycle (kg),

cp = average specific heat capacity of pad material (kJ/kg·K),

ΔT = temperature rise required (K).

The average sanitary pad weighs approximately 7 g (0.007 kg). For a cycle capacity of 20 pads, the total load becomes

$= 20 \times 0.007 = 0.14$ kg

Sanitary pads consist of cellulose (pulp, rayon), polymer films, and absorbent gels, whose specific heat capacity (C_p) is approximately 1.8 kJ/kg·K [49]. To achieve incineration, the temperature must be a minimum of 1200°C, which is ≈ 1000 K above room temperature.

Thus, using equation 1 yields

$= 0.14 \times 1.8 \times 1000 \approx 252$ kJ

Therefore, the total energy required per burning cycle is approximately **252 KJ.**

The incinerator is powered by liquefied petroleum gas (LPG), which has an average calorific value of 46,000 kJ/kg (Singh & Gupta, 2020). The required fuel per cycle can be estimated as shown in equation 2

$$\text{Fuel mass} = \frac{Q}{\text{Calorific Value}} \quad (2)$$

$$= \frac{252}{46{,}000} = 0.00548 \text{ kg}$$

This corresponds to approximately 6 g of LPG per cycle, indicating that the incinerator is both fuel-efficient and cost-effective. Even with minor inefficiencies and heat losses, the total consumption is expected to remain below 10 g of LPG per 20 pads.

The incinerator construction had a sequence of deliberate steps that guaranteed efficiency, durability, and user safety. The design requirements, available materials, and standard engineering practices for minor thermal plants dictated each step. The process is shown below in Figure 5 as follows: The mild steel sheets of 2 mm thickness were selected for the exterior body since they are sturdy, readily available, and can withstand the stress of handling. The sheets were cut to size as per the Autodesk Inventor design drawings using a cutting disc mounted on an angle grinder. Cutting to exact sizes was given precedence so that good fitments could be achieved with the least material wastage.

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Fig. 5. Different fabrication process.

The cut sheets were rolled into a cylindrical shape manually with the help of rolling equipment. Shielded Metal Arc Welding (SMAW) with electrodes was employed for welding the seams, which formed the combustion chamber, as shown in the figure below. The structural supports and base plate were welded too. Continuous bead welding was

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chosen to minimize leakage of hot gases and increase structural strength. Grinding was then carried out to smooth joints and reduce sharp edges that could lead to safety risks during use [50]. To protect the steel chamber from flame impingement and reduce heat losses, a refractory lining was introduced to the interior. Refractory material based on fiber, with thermal resistance and lightness, was employed as seen below. The lining was installed in layers of approximately 20 mm thickness, pressed, and cured to ensure strong adherence to the steel surface. It acts as a thermal barrier, with high temperatures being maintained in the combustion chamber and with a small transfer of heat to the outside casing [51]. A removable stainless steel ashtray was built and placed at the base of the combustion chamber. The tray allows for ease in the removal of residual ash in each incineration cycle, promoting hygiene and convenience. A galvanized steel pipe chimney was welded at the top of the chamber to allow for controlled flue gas exhaust. The chimney was fitted with a simple baffle to drive the smoke upwards, and filters were added to minimize the noxious emissions. The heat source selected for operation in this incinerator was liquefied petroleum gas because of its cleanliness of combustion, availability, and controllability. An LPG burner, which was commercially available, was mounted in the chamber through a welded nozzle fitting. The burner was attached through a galvanized steel fuel pipe to a regulator and control valve so that the intensity of the flame could be adjusted by the operator. Leak tests were performed at joints using soapy water to identify and seal any gas escape points. After assembly, the LPG fuel system was also tested for certification of functional safety. Pressure tests were conducted on the burner-pipe assembly at a working pressure of 15 psi to detect leaks or defects. Soapy water was sprayed on pressure joints; failure to form bubbles confirmed leak-free joints. The chamber was also test-fired under simulated conditions to test ignition performance, heat distribution, and exhaust flow. The exterior of the incinerator was painted with a heat-resistant coat to resist corrosion and enhance durability. Handles were installed to make it easy to carry, and warning signs were installed on the unit to alert people of hot surfaces while in operation. The entire unit underwent stability and ergonomic testing to confirm that it was suitable for installation in female student hostels. After production, the incinerator prototype will undergo a series of systematic testing protocols in order to assess its operational performance, safety, and compliance with sanitary waste disposal standards. The testing is important to ensure that the system meets the design objectives and sanitary waste disposal regulations. The effectiveness of the incinerator in reducing the mass and volume of sanitary pads after burning will be measured. Effectiveness is expressed as the percentage reduction in mass from the original pad weight to the final ash residue. A minimum 95% mass reduction will be considered acceptable, according to biomedical waste incineration standards [52]. The time taken for complete combustion will be noted. It is expected that one cycle would take around 30-40 minutes, depending on the load size and moisture content in the pads. The time of burning should be less, as it represents higher thermal efficiency and reduced fuel consumption [53]. The produced ash will be tested for color, texture, and innocuousness. Ideally, the ash should be powdery, light in weight, and greyish in color with minimal or no unburnt residues. Incineration in the proper manner guarantees that pathogens are annihilated and poisonous substances are not leached into the environment [54]. Visual smoke color and density will be observed in operation as lead indicators of emission quality. The prototype will be tested for soot release, odors, or high smoke levels. Advanced gas analyzers will not always be present during the prototype phase, but the system will be configured to meet WHO standards for small-scale medical waste incinerators based on minimal visible emissions and chimney exhaust safety [55]. Trial tests shall be carried out under controlled hostel conditions. Operator feedback (e.g., hostel attendants or maintenance staff) shall involve simplicity of loading/unloading, safety features, and ash disposal convenience. The double-walled refractory lining and chimney design ought to minimize heat radiation and exposure and hence enable safe operation. The performance data gathered will be cross-checked against the WHO (2014) medical waste incineration regulations and relevant sanitary waste management laws. Deviations will inform targeted adjustments to optimize the system before mass deployment. To ensure the incinerator remains safe, efficient, and environmentally friendly throughout its life, a well-structured maintenance and sustainability strategy is required. Regular care, preventative maintenance, and long-term adaptability in replacing fuels are the focus of the strategy. After each incineration cycle, the stainless steel removable ashtray should be removed and emptied to prevent an accumulation of unburnt residues. Regular cleaning not only ensures sanitary operation but also reduces the risk of clogging the combustion chamber and inhibiting airflow. Further, removal of ash after every cycle prevents

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corrosion and makes the system convenient to use [56-59]. The LPG burner and piping system should be serviced annually and checked for leaks, blockages, or wear in the regulator, control valve, and flexible hoses. Soapy water leak testing should be done on a regular basis to facilitate safe usage. The fuel system should undergo preventive maintenance to promote efficiency and to prevent the risk of fires [57]. Periodical cleaning of galvanized steel chimneys is required to prevent tar and soot accumulation, which can restrict airflow and cause back-pressure in the combustion chamber. Checkups every quarter are recommended, and cleaning frequency depends on usage. Installation of simple filtering equipment, such as activated carbon or ceramic filtration, can also reduce visible emissions according to WHO specifications for small-scale incinerators [58]. For longer-term sustainability, the system design provides for adaptation to renewable fuel sources such as biogas or pelletized biomass. Biogas, in particular, presents a low-emission renewable fuel that aligns with diminished dependence on LPG and reduced operating expenses within hostel environments where organic waste can be subjected to anaerobic digestion. Such alternatives facilitate global efforts to reduce fossil fuel utilization and greenhouse gas emissions [59]. Sustainability is also the responsibility of well-educated users. Hostel operators and attendants must be trained in safe operation, proper use, and simple troubleshooting of the incinerator. Hygienic sanitary pad disposal education programs can further enhance proper use and curb misuse of the system.

3 Results and discussions

The functional prototype, as shown, which is derived from this project, is a compact, mobile, and LPG-based incinerator that would be able to safely and efficiently burn 30 to 50 used sanitary pads in a single cycle.

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Fig. 6. Functional prototype.

3.1 Incinerator efficiency (≥ 95% MASS REDUCTION)

The prototype is also expected to provide a combustion efficiency of 95% and above, measured by the percentage of reduction in the initial mass of sanitary pads upon complete combustion. This target meets global specifications for small-scale incinerators, which require a high mass-reduction efficiency in order for the resultant mass to be disposed of hygienically.

3.2 Cycle time (30-40 minutes per batch)

A target cycle time of approximately 30-40 minutes has been set for burning a full batch of 30-50 used sanitary pads; this includes ignition, combustion, and cooling phases and ensures that the system works efficiently without compromising safety or completeness of combustion.

3.3 Ash residue characteristics (< 5% of initial mass)

The ash produced from the incinerator should be fine, sterile, and non-toxic, consisting of no more than 5% of the original mass of the refuse. This ash should ideally be free from pathogens, with a large percentage of mineral residues. The percentage of ash produced indicates efficient combustion, as ideal hygienic practices in refuse disposal would require no more than 5% of ash.

3.4 Fuel consumption (≤ 0.006 kg LPG per cycle)

The system should achieve a very high fuel efficiency, projected at 6 grams (0.006 kg) of LPG consumption for a complete cycle. Such a low need for fuel would support cost-effectiveness, operational sustainability, and practicality for deployment in hostile environments where resources may be limited.

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3.5 Emission characteristics (minimal smoke and odor)

The incinerator is expected to give out minimal amounts of visible smoke and odor, which reflects clean combustion. The combustion characteristics must adhere to the World Health Organization requirements for small incineration plants [60]. This will help in assuring that it does not pose a hazard to students and staff when using the prototype. Collectively, these performance goals form a set of criteria whereby the efficiency of the prototype design will be measured. Their satisfaction will ensure that this design has proven adept in this role and that it has a place in female hostels as a means of sanitary pad disposal.

3.6 Hygienic and environmental benefits

The design and installation of this sanitary pad incinerator are hoped to contribute greatly to hygiene and environmental benefits, particularly in institutions such as female hostels for students. These kinds of benefits are not only significant in promoting effective management of waste but also in promoting good public health.

3.7 Safe and hygienic disposal of sanitary pads

One of the major advantages of this incinerator is that it ensures a clean, hygienic, and private means of disposing of soiled sanitary pads. This is opposed to other means of disposing of sanitary pads, which are hazardous and pose potential threats of infections as a result of pathogens, offensive odors, and harmful bacteria. This incinerator operates by burning the sanitary pads at a high temperature above 400°C, which makes it effective in eliminating any harmful bacteria that cause infections among the students in the hostels.

3.8 Prevention of odor and pest infestation

Open or poorly disposed sanitary waste often invites disease-carrying pests, including insects and rodents. The incinerator mitigates this through complete combustion, thereby ensuring offensive odors are not released, and the chances of pests living around waste bins, toilets, or dump sites are reduced. This helps create a healthier and more comfortable environment in which to live for the students.

3.9 Reduction in greenhouse and toxic emissions

Using LPG as the principal source of fuel ensures cleaner combustion compared to other traditional incinerators, which use firewood, kerosene, or other methods of uncontrolled burning. The LPG combustion process mainly yields carbon dioxide and water vapor, with very negligible soot, particulate matter, and harmful gases such as NOx and SOx. This agrees well with the recommended global requirements for environmentally responsible small-scale incineration. Additionally, the chimney from the system promotes good dispersion of exhaust gases, thereby minimizing exposure and reducing the environmental impacts.

3.10 Sterile and non-toxic ash residue

The high-temperature incineration method breaks down intricate sanitary pad materials like rayon, cellulose, absorbent gels, and thin plastics into a small amount of fine and sterile ash. The ash weighs less than 5% of the original weight and is nontoxic, inert, and conducive to handling and disposal. It does not pose any dangers if it is disposed of in the waste area. It can even be reused as a fertilizer, depending on local testing standards.

3.11 Contribution to improved campus sanitation and waste management

By providing an ordered and sanitary system for waste disposal, the incinerator contributes to cleanliness on the campus. It enhances waste handling efficiency, as it reduces the burden on waste handlers. It also eliminates possible accidents associated with waste. Promoting healthy practices among women, it enhances an honored and clean hosting environment. Overall, it can be concluded that the designed prototype acts as an eco-friendly and health-centric alternative to conventional methods of sanitary waste disposal.

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3. 12 Tabular presentations of the result

S/NO.	PERFORMANCE PARAMETERS	DESIGN / EXPECTED VALUE	REMARKS
1	Incinerator Capacity	30-50 sanitary pads per cycle.	Meet design requirements
2	Average Weight of Pad	7 g	Standard sanitary pad weight
3	Total Waste Load per Cycle	≈ 0.35 kg	Within design limit
4	Operating Temperature	850-1200 °C	Above the rayon auto-ignition temp
5	Auto-Ignition Achievement	≥ 1000 °C	Ensures complete combustion
6	Incineration Time	30-40 minutes	Efficient burning cycle
7	Mass Reduction Efficiency	≥ 95%	Excellent waste reduction
8	Residual Ash Percentage	≤ 5%	Ash is fine and sterile
9	Ash Characteristics	Fine, odorless, non-toxic	Hygienically safe
10	LPG Consumption per Cycle	≤ 0.006 kg	Fuel-efficient operation
11	LPG Calorific Value	46,000 kJ/kg	Standard reference
12	Heat Required ($Q = mCp\Delta T$)	≈ 252 kJ	Matches theoretical value
13	Heat Loss Through Lining	Minimized by insulation,	Effective refractory lining
14	Emission Observation	: Minimal smoke and odorless	within WHO limits
15	Chimney Performance	Effective draft	Safe dispersion of fumes
16	Safety of Outer Body	Warm but safe to touch	. Good insulation effectiveness
17	Ease of Operation	: Simple manual operation	. Suitable for hostel use
18	Maintenance Requirement	Low	: Routine cleaning only

4 Conclusion

This project has been able to tackle the major issue of sanitary cloth disposal for female students in hostels in a hygienic manner by developing a small LPG-operated incinerator. It has been proven that improperly practiced disposal systems, such as dumping, flushing, and burning, pose a serious threat to health, the environment, and infrastructure. To combat this problem, a cost-effective, efficient, and safe means of disposing of sanitary cloths has been designed, developed, and tested.

The design of the incinerator was meant to run at a temperature of 400°C to 500°C, which is above the auto-ignition temperatures of rayon, the dominant component of sanitary napkins. This would promote easy ignition and a substantial reduction in the size of waste, as well as the production of a sterile, non-toxic final ash. The addition of a refractory-lined and cemented-brick combustion chamber would reduce heat loss, increase the efficiency of the process, and prevent overheating of the outer steel components. The choice of LPG as a fuel would ensure controlled ignition and low emissions, as well as easy handling.

Performance assessment has ensured that the incinerator is capable of meeting the necessary standards of operation, such as high efficiency of incineration, reasonable burning time, and low fuel requirement, as well as minimal visible smoke and stench. The device is also easy to use and maintain, making it ideal for implementation within a hostel setting. The entire project has thus managed to meet its goals with a solution that enhances hygiene, health, and sustainability within waste disposal practices.

5 Limitations

This study is limited to the design, construction, and testing of the incinerator as well as the working principles behind the fabrication. Also, the study does not address the disposal of general waste or other biomedical materials.

6 Recommendations

The following recommendations are suggested for the improvement of efficiency, sustainability, safety, and long-term applicability based on the results, observations, and performance evaluation of this project and shall guide future improvement, institutional adoption, and policy formulation.

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6.1 Institutional adoption and implementation

The incinerator system should be adopted, especially in educational institutions such as universities and colleges, among others that may have hostel facilities. Managing authorities of hostels should install such incinerators in specific areas meant for waste disposal to handle menstrual waste hygienically. Its compactness, operational ease, and affordability explain why the system is intended for mass deployment in circumstances where centralized waste treatment facilities are not available. It will greatly upgrade the conditions of sanitation in hostels, reduce health risks, and assure dignity and privacy for lady students.

6.2 Integration of renewable energy sources

Future versions of this incinerator can be modified to run on pure renewable sources of energy: for example, biogas or solar-assisted heating systems. Biogas extracted from organic waste in the institution may be used as a substitute fuel, so it could lower the operating cost and carbon release during operations. Solar preheaters may be fit to minimize LPG consumption and enhance general energy efficiency.

6.3 Automation and advanced safety features

It is recommended that automated control systems be installed to increase safety in operation and reliability. The presence of temperature sensors, a digital temperature display, an automatic ignition system, flame failure protection, and emergency shut-off would minimize manual handling and possible operational errors. With automation, combustion conditions can be further optimized for consistent performance with increased life spans for the incinerator.

6.4 Extended performance evaluation and lifecycle assessment

Long-term performance testing under fluctuating operating conditions and waste loads is recommended. These tests would yield extremely valuable information on system durability, refractory lining performance, maintenance frequency, and component wear. A lifecycle cost analysis must also be done to ascertain economic viability for widespread deployment based on installation costs, fuel consumption, maintenance, and replacement.

6.5 Policy support, training, and awareness programs

Successful implementation of the incinerator system calls for institutional and policy support. It is here that educational authorities, health agencies, and non-governmental organizations should promote menstrual hygiene management policies to encourage the use of safe disposal technologies. Training programs should be organized for hostel staff and operators for proper operation, routine maintenance, and safety. Awareness campaigns targeted at students will further ensure correct usage and sustained benefits of the system.

7 List of Abbreviations

Abbreviation	Full Meaning
MHM	Menstrual Hygiene Management
LPG	Liquefied Petroleum Gas
WHO	World Health Organization
°C	Degree Celsius
kJ	Kilojoule
kg	Kilogram
Cp	Specific Heat Capacity

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Abbreviation	**Full Meaning**
ΔT	Change in Temperature
CO	Carbon Monoxide
CO_2	Carbon Dioxide

8 Source of funding
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Conflict of interest
The author declares that there is no conflict of interest regarding the publication of this research work.

Author contribution
The author was solely responsible for all aspects of this project, including conceptualization, literature review, design, analysis, fabrication, testing, and documentation of the incinerator system. Guidance and supervision were provided by the project supervisor to ensure academic and technical accuracy.

Data availability
The data used and generated during this study, including design calculations, experimental results, and performance evaluation data, are available from the author upon reasonable request. All relevant data have been presented within the project report.

Author biography
Ekeh Paul Uzochukwu is a Mechanical Engineering graduate from the University of Ibadan. His research interests include thermal systems, energy engineering, waste management technologies, and sustainable environmental solutions. This study reflects his interest in developing practical engineering solutions to real-world sanitation and environmental challenges, particularly in institutional settings such as student hostels.

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