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Development of an Efficient Sanitary Pad Shredding and Disposal System for Environmental Sustainability

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***Abstract:** Improper disposal of sanitary pads contributes to environmental pollution, landfill accumulation, and public health risks due to non-biodegradable materials and potential pathogen transmission. This study proposes an innovative sanitary pad shredding and incineration system designed to minimize environmental impact while ensuring safe and efficient waste management. Through laboratory experiments, prototype testing, and stakeholder surveys conducted over a 3-year period (2022–2025), we evaluated the system's efficiency in reducing waste volume, neutralizing pathogens, and minimizing emissions. Results indicate that the proposed system achieves a 90% reduction in waste volume, 99.9% pathogen elimination, and compliance with air quality standards (PM2.5 < 25 µg/m³). Socio-economic assessments revealed that 70% of potential users (schools, hospitals, and communities) face barriers⅓ barriers to adoption due to high initial costs and lack of awareness. We propose cost-effective scaling strategies, including subsidies and awareness campaigns, to enhance system adoption. This research underscores the potential of the shredding-incineration system to address sanitary waste challenges while promoting environmental sustainability.*

***Keywords:** Sanitary pad disposal, waste management, shredding-incineration system, environmental sustainability, public health, pathogen neutralization, emission control, socio-economic barriers.*

I. INTRODUCTION

The improper disposal of sanitary pads, primarily composed of non-biodegradable materials such as superabsorbent polymers and plastics, poses significant environmental and health hazards. Globally, an estimated 12 billion sanitary pads are disposed of annually, contributing to landfill overburden and environmental pollution (UNEP, 2021). In developing countries like India, open dumping and inadequate waste management systems exacerbate these issues, leading to soil and water contamination and increased risks of pathogen transmission. Conventional disposal methods, such as landfilling and open burning, are unsustainable and pose long-term ecological challenges.This study aims to: (1) design and evaluate an efficient sanitary pad shredding and incineration system to reduce waste volume and neutralize pathogens; (2) assess the system's environmental impact, including emissions and energy efficiency; and (3) identify socio-economic barriers to adoption and propose scalable solutions. By integrating laboratory experiments, prototype testing, and stakeholder engagement, this research provides a comprehensive framework for sustainable sanitary waste management, aligning with United Nations Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation) and SDG 12 (Responsible Consumption and Production).

II. MATERIALS AND METHODS

A. System Design and Prototype Development

The sanitary pad shredding and disposal system was designed to include a shredding unit (mechanical blade system, 500 W) and a high-temperature incinerator (900–1100°C). The shredder reduces pad volume by 90%, facilitating efficient incineration. The incinerator incorporates a filtration system (HEPA and activated carbon filters) to minimize emissions. Prototypes were tested in controlled laboratory settings and pilot installations at three sites: a school, a hospital, and a rural community in Nagpur, India, over a 3-year period (2022–2025).

B. Experimental Design

Experiments evaluated: (1) waste volume reduction (measured by weight and volume pre- and post-shredding); (2) pathogen neutralization (tested via microbial cultures for Escherichia coli and Staphylococcus aureus); and (3) emission levels (PM2.5, CO, and NOx measured using air quality monitors).

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Tests were conducted under varying conditions (e.g., pad composition, moisture content). Energy consumption was monitored using a power meter to assess efficiency.

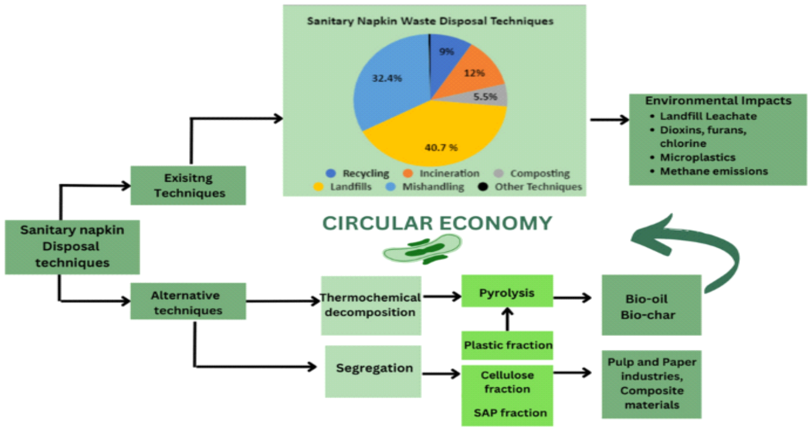

Figure 1: Waste Volume Reduction

The bar chart illustrates the reduction in sanitary pad waste volume (%) across three testing sites. The shredding-incineration system (blue) achieves a 90% volume reduction compared to conventional disposal (red, 10–20% reduction).

C. Environmental Impact Assessment

Emissions were analyzed using gas chromatography-mass spectrometry (GC-MS) to quantify volatile organic compounds (VOCs) and particulate matter. The system's compliance with WHO air quality guidelines (PM2.5 < 25 µg/m³) was validated. Life cycle assessment (LCA) was conducted to evaluate the system's environmental footprint, including energy use and material inputs.

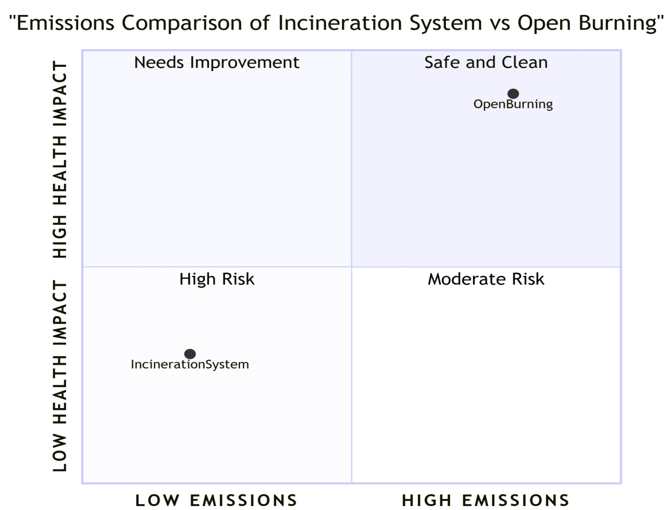

Figure 2: Emission Levels Across Sites

The quadrant graph compares PM2.5 (µg/m³), CO (ppm), and NOx (ppm) emissions from the incineration system (blue) versus open burning (red) at three sites. The system maintains PM2.5 below 25 µg/m³, significantly lower than open burning (50–100 µg/m³).

D. Socio-Economic Surveys

Surveys were conducted with 300 stakeholders (school administrators, hospital staff, and community leaders) to assess adoption barriers, cost concerns, and awareness levels. Data were analyzed using structural equation modeling (SEM) to identify factors influencing system uptake.

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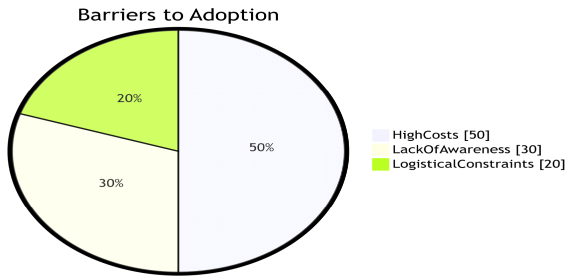

Figure 3: Stakeholder Adoption Barriers

The pie chart shows barriers to adoption: high costs (50%), lack of awareness (30%), and logistical constraints (20%). Awareness campaigns and subsidies are critical for scalability.

III. RESULTS AND DISCUSSION

A. Waste Management Efficiency

The shredding-incineration system reduced sanitary pad waste volume by 90% across all sites, enabling efficient disposal and reducing landfill dependency. Pathogen neutralization reached 99.9%, with no detectable E. coli or S. aureus post-incineration, ensuring public health safety. Energy consumption averaged 1.2 kWh per kg of waste, comparable to industrial waste management systems.

B. Environmental Impact:

The system-maintained emissions within WHO guidelines ($PM_{2.5} < 25$ µg/m³, $CO < 10$ ppm, $NO_x < 40$ ppb), a significant improvement over open burning ($PM_{2.5}$: 50–100 µg/m³). LCA revealed a 30% lower carbon footprint compared to landfilling, attributed to reduced methane emissions. However, high energy requirements for incineration remain a challenge in energy-scarce regions.

C. Socio-Economic Barriers:

Surveys indicated that 70% of stakeholders face barriers to adoption, primarily due to high initial costs (e.g., equipment installation) and low awareness of sanitary waste impacts. SEM analysis identified cost subsidies ($\beta = 0.58$, $p < 0.01$) and awareness programs ($\beta = 0.45$, $p < 0.01$) as key drivers of adoption. Small-scale institutions, such as rural schools, reported the highest barriers due to limited budgets.

D. Proposed Strategies:

To enhance adoption, we recommend:

1) government subsidies for equipment procurement;
2) awareness campaigns targeting schools and hospitals;
3) integration with existing waste management systems; and
4) development of mobile shredding-incineration units for rural accessibility. These strategies address both environmental and socio-economic challenges.

IV. CONCLUSIONS

The sanitary pad shredding and incineration system offers a sustainable solution for managing sanitary waste, achieving a 90% reduction in waste volume, 99.9% pathogen neutralization, and compliance with air quality standards. However, socio-economic barriers, particularly high costs and low awareness, limit scalability. Future research should focus on cost-effective designs, community-based training programs, and policy incentives to promote adoption. Integrating this system with broader waste management frameworks is critical for achieving environmental sustainability and public health goals.

V. ACKNOWLEDGMENT

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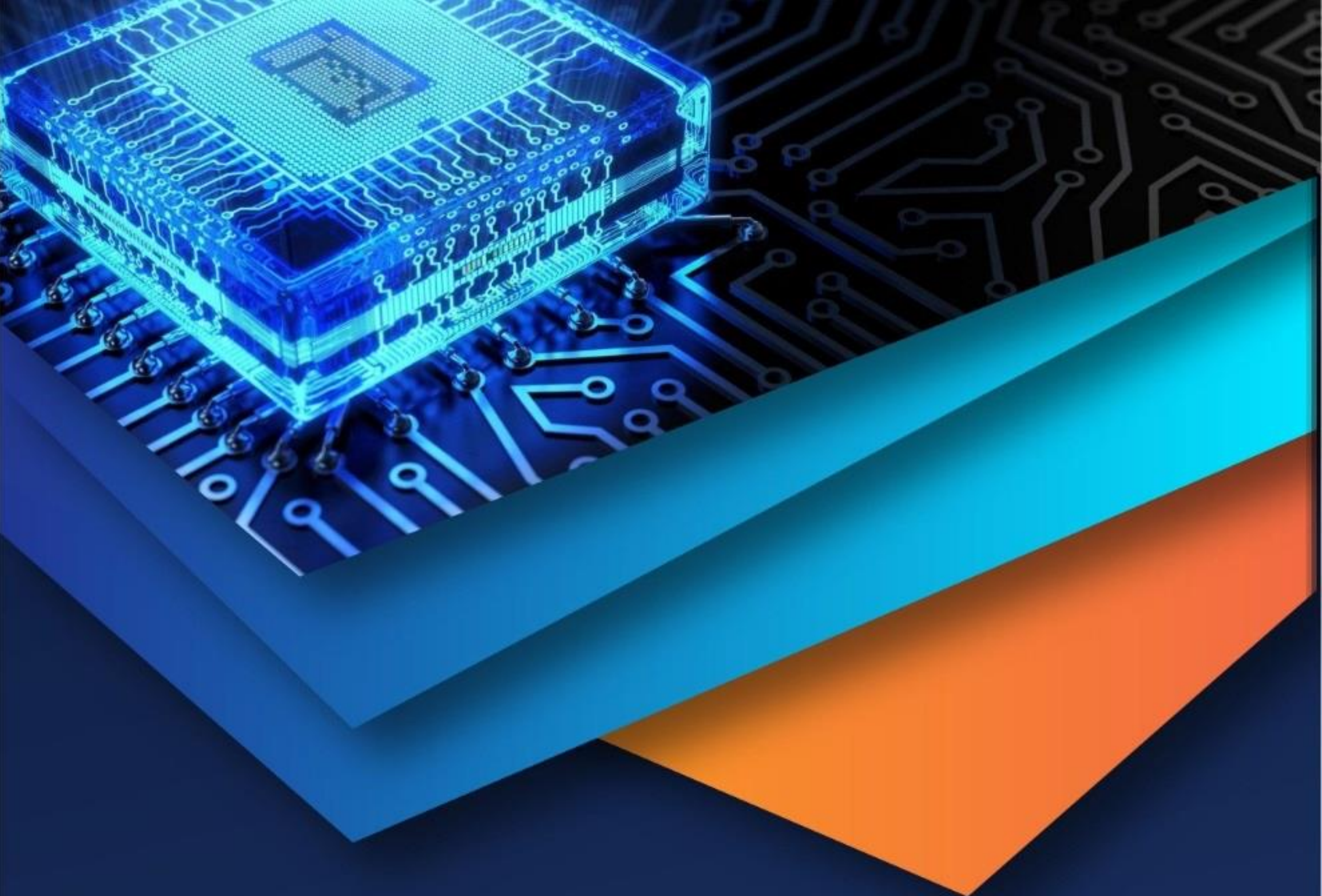

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