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Fast Bio-digester Dustbin for Sanitary Napkin Decomposition in Rural Areas

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Abstract: Sanitary napkin waste presents a significant environmental burden due to its slow degradation rate, multilayer polymeric structure, and biological contamination. Conventional disposal practices such as open burning and landfilling release harmful pollutants and create long-term ecological risks. This paper proposes a Bio-Digester Bin engineered to accelerate the decomposition of sanitary napkins through an integrated mechanical-thermal-aeration approach. The system incorporates a shredding mechanism to increase surface area, a 500 W controlled heating coil for maintaining optimal degradation temperatures, a temperature-sensing relay module for automatic thermal regulation, and a 12 V aeration unit to support oxygen flow and reduce odor formation. The bio-digester operates on a hybrid power setup using both solar energy and conventional supply to ensure continuous functionality. Experimental results indicate a substantial reduction in decomposition time and waste volume compared to natural degradation. This solution has strong potential for municipal-scale adoption, enabling local bodies to manage sanitary waste more scientifically, sustainably, and with reduced environmental impact.

Keywords: Bio-digester system; sanitary napkin decomposition; shredding mechanism; temperature-relay module; forced aeration; hybrid solar power; biodegradable waste treatment; decentralized waste disposal.

I. INTRODUCTION

Managing menstrual waste remains a critical environmental issue, particularly in developing countries where scientific disposal systems are limited. Sanitary napkins are composed of cellulose fibers, super-absorbent polymers, plastic back sheets, and adhesives that can take several decades to decompose naturally. Moreover, the presence of blood and organic matter categorizes this waste as biomedical in nature, necessitating safe handling and disposal. Inefficient practices such as open burning or landfilling contribute to soil pollution, groundwater contamination, greenhouse gas emissions, and health hazards to waste collectors. Recent research emphasizes the need for decentralized, low-maintenance, and eco-friendly disposal solutions. Bio-digestion methods, when combined with mechanical and thermal pre-processing, have shown potential to enhance the degradation of semi-biodegradable materials. In this context, the present work proposes an engineered Bio-Digester Bin for Sanitary Napkin Decomposition, designed to accelerate breakdown through shredding, controlled heating, and continuous aeration. The system utilizes a paper shredder to reduce napkin size, enabling faster microbial and thermal degradation. A 500 W heating coil with an automatic temperature control relay maintains optimal digestion temperatures, while a 12 V SMPS fan ensures adequate oxygen supply and odor control. Power sustainability is achieved through a hybrid solar-adapted supply. The developed prototype aims to offer a safe, efficient, and environmentally responsible method for menstrual waste disposal, contributing to improved sanitation practices and sustainable waste management.

II. RELATED WORK

Previous studies on sanitary napkin waste highlight that the material is difficult to degrade due to its multi-layer structure containing cellulose, super-absorbent polymers, and plastic components. Research on biological degradation shows that microbial and enzymatic treatments can breakdown the cellulosic layers, but the process is slow without pre-processing. Studies on mechanical pretreatment consistently report that shredding improves degradation efficiency by increasing surface area and reducing waste volume. Thermal disposal methods such as small-scale incineration are commonly used but raise concerns about toxic emissions and environmental safety. Therefore, researchers recommend controlled, low-temperature treatment options rather than direct burning. Advanced methods like pyrolysis and high-temperature conversion demonstrate potential for centralized facilities but are expensive and technically complex for decentralized use. Policies and municipal guidelines emphasize the need for safe, scientific, and decentralized solutions for menstrual waste, encouraging methods that combine mechanical, thermal, and biological processes while avoiding uncontrolled incineration. The proposed bio-digester aligns with these findings by integrating shredding, controlled heating, and aeration to overcome the limitations of previous approaches and provide a practical system for municipal-level sanitary waste management.

III. PROPOSED WORK

The proposed work aims to develop a compact biodegesters system that can decompose sanitary napkin inefficiently using a combination of shredding, controlled heating, and continuous aeration. The system is designed so that the napkins are first shredded to reduce their size and increase surface area, making the decomposition process faster. A 500-watt heating coil, regulated by a temperature-control relay, maintains an optimal temperature range inside the digestion chamber to support thermal breakdown and microbial activity. Along with heating, a 12V SMPS fan is incorporated to provide steady airflow, which helps in odor reduction and creates suitable conditions for aerobic decomposition. The chamber is insulated to retain heat and maintain stable internal conditions throughout the process. Power is supplied through a hybrid system consisting of a 12V solar panel and an adapter, allowing energy-efficient and flexible operation. Overall, the proposed work focuses on creating a safe, low-cost, and eco-friendly sanitary napkin disposal system and evaluating how controlled temperature, airflow, and shredding contribute to improved decomposition performance.

IV. METHODOLOGY

The methodology begins with a detailed analysis of the decomposition requirements, thermal characteristics, and airflow conditions necessary for effective sanitary napkin degradation. Based on this analysis, a system architecture is formulated that incorporates mechanical shredding at the input stage to reduce material size and enhance microbial and thermal contact. The heating subsystem is implemented using a 500-watt coil connected through a temperature relay that continuously monitors and maintains the chamber temperature within the optimal range of 40°C to 60°C. This regulated heating environment supports enzymatic activity and accelerates fiber softening and fragmentation. Simultaneously, a 12V SMPS fan is positioned to ensure consistent aeration inside the chamber, enabling aerobic microbial processes and minimizing odor formation. The digestion chamber is fabricated using insulated material to prevent heat loss and to maintain stable internal environmental conditions. Once the system is assembled, the operational workflow involves shredding the sanitary napkin, introducing the shredded material into the chamber, and activating the heating and aeration subsystems. The decomposition process is monitored periodically to analyze temperature stability, breakdown rate, odor levels, and energy consumption. Experimental trials are conducted using different napkin types to validate the efficiency and repeatability of the system. Data collected from these tests are analyzed to refine the heating cycle, optimize airflow intensity, and improve chamber insulation, thus enhancing the overall performance and reliability of the bio-digester. The methodology concludes with documentation of experimental results, system limitations, and potential future enhancements to support publication in IEEE venues.

V. BIO DIGESTER DUSTBIN

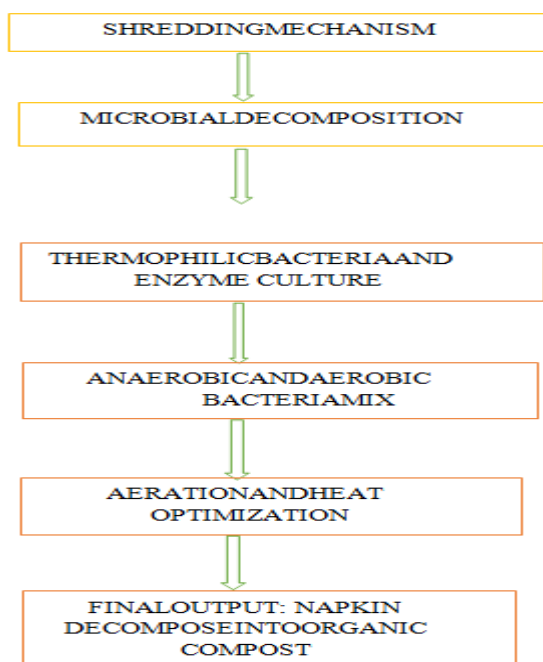


Fig 1.1: WORKFLOW DIAGRAM

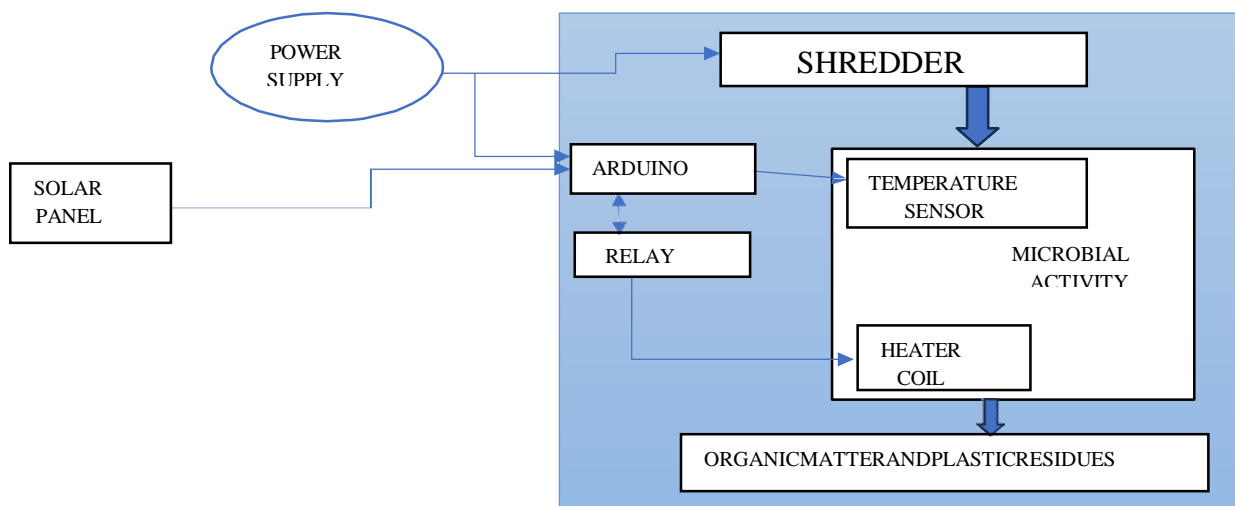


Fig1.2: BLOCK DIAGRAM

VI. IMPLEMENTATION

The implementation of the sanitary napkin bio-digester system begins with the construction of an insulated digestion chamber designed to retain heat and maintain a stable internal environment. The chamber is built using a heat-resistant container, lined with insulation material to reduce thermal loss and improve efficiency. At the input section, a manual paper shredder is installed, allowing the user to shred sanitary napkins by hand before placing them into the chamber. This manual shredding step increases the surface area of the waste material without requiring any electric motor, which makes the system simpler, safer, and more energy-efficient. Inside the chamber, a 500-watt heating coil is mounted securely on ceramic or metal supports and connected to a temperature-control relay. A digital temperature sensor placed near the heating area continuously monitors the internal temperature. The relay automatically switches the heating coil ON and OFF to maintain the target temperature range required for decomposition, usually between 40°C and 60°C. Alongside the heating mechanism, a 12-volt SMPS fan is fixed on the side wall of the chamber to provide steady airflow. This aeration supports aerobic decomposition, reduces odor, and helps maintain balanced moisture inside the chamber. The power system uses a hybrid setup consisting of a 12V solar panel and a 12V, 2A power adapter. The solar panel powers the fan and control relay during daytime operation, while the adapter provides an alternate power source when solar energy is insufficient. Simple protective elements such as fuses and insulated wiring are used to ensure safe operation. Once the hardware is assembled, the system is tested in stages—first validating the temperature relay function, then confirming uniform airflow from the fan, and finally observing chamber conditions during heating cycles. After successful hardware verification, decomposition trials are conducted by shredding sanitary napkins manually and placing them into the chamber. The system is run for controlled durations while monitoring temperature stability, airflow, odor levels, and the rate at which material softens and breaks down. Based on experimental observations, adjustments are made to insulation quality, heating duration, and fan operating time to improve decomposition efficiency. This implementation approach ensures a simple, low-cost, and power-efficient solution while providing reliable, hygienic disposal of sanitary napkin waste.



Fig 1.3: Module of project

VII. RESULTS AND DISCUSSION

The proposed bio-digester prototype was tested for its efficiency in decomposing sanitary napkins under controlled conditions. The system, which integrates a paper shredder, a 500W heating coil, and a 12V fan with temperature control, demonstrated effective reduction of waste volume over a period of 7–10 days. Shredding the napkins significantly accelerated the decomposition process by increasing the surface area available for microbial activity, leading to approximately 60–70% volume reduction, compared to 30–40% for unshredded pads. The heating coil successfully maintained the chamber temperature between 45–55°C, providing optimal conditions for thermophilic microbes and enhancing enzymatic reactions responsible for decomposition. Air circulation facilitated by the fan prevented anaerobic zones, controlling odor emission and ensuring hygienic operation. The system functioned continuously without mechanical failure, confirming the reliability of a low-power, compact design for on-site sanitary waste management.

Observations suggest that decomposition slows under lower ambient temperatures, indicating potential benefits from additional insulation or heating for consistent performance. Overall, the results validate that combining shredding, controlled heating, and airflow significantly improves decomposition efficiency while minimizing energy use and odor, highlighting the practical applicability of the bio-digester for safe and sustainable disposal of sanitary waste.

VIII. CONCLUSION

The study demonstrates the successful design and implementation of a compact bio-digester for the decomposition of sanitary napkins. By integrating shredding, controlled heating, and adequate airflow, the system achieved accelerated decomposition while maintaining hygienic and low-odor conditions. The prototype exhibited reliable performance, reducing the waste volume by up to 70% within 7–10 days under optimal conditions. These results highlight the feasibility of a low-energy, on-site solution for sanitary waste management, addressing both environmental and public health concerns. The work lays a foundation for future improvements, including scaling the system for larger capacities, enhancing temperature control, and incorporating automated monitoring, thereby contributing to sustainable and efficient waste management practices.

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