JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A HIGH-ACCURACY AUTOMATIC WASTE SEGREGATOR FOR DECENTRALIZED SOLID WASTE MANAGEMENT

[1]Vaibhav Madane, [2]A K Biradar, [3]Siddesh S D, [4]J K Patil, [5]R S Deshmukh
[1]Assistant Professor, [2]Associate Professor, [3]Professor, [4]Assistant Professor, [5]Assistant Professor
[1]Department of Mechanical Engineering,
[1]Thakur College of Engineering and Technology, Kandivali Mumbai, India.

Abstract : Rapid urban expansion and population growth have intensified the challenges associated with municipal solid waste (MSW) management in developing countries. India alone produces over 42 million tons of waste annually, much of which remains unsegregated and contributes to the spread of infectious diseases and environmental pollution. To address these issues, this study presents a cost-effective, sensor-driven Automatic Waste Segregator (AWS) designed to classify household waste into metallic, wet, and dry categories. The system employs an infrared detection unit, a parallel-resonant impedance module for metallic identification, and capacitive sensors for wet–dry discrimination. A servo-actuated assembly directs the segregated waste into designated containers based on real-time sensor outputs. Experimental trials confirm the system's accuracy, reliability, and suitability for small-scale or community-level deployment. The proposed AWS reduces manual handling, enhances recycling efficiency, and aligns with smart city waste management frameworks.

Index Terms - Automatic Waste Segregator, Smart Waste Management, Sensor-Based Automation, Solid Waste Processing, Wet and Dry Waste, Environmental Sustainability.

1. Introduction

The management of municipal solid waste remains a major public health and environmental concern in rapidly urbanizing regions. India generates nearly **60 million tonnes** of solid waste annually, with metropolitan hubs contributing a significant share. Inadequate segregation at the source results in overflowing landfills, contamination of soil and groundwater, greenhouse gas emissions, and increased exposure of waste workers to hazardous materials. Reports from the **Swachh Bharat Mission** reveal that nearly half the population faces issues associated with improper waste disposal and collection. Source-level segregation is a proven strategy to improve recycling efficiency and reduce the environmental footprint of waste. Organic waste can be transformed into compost or biogas, while recyclable metallic and dry wastes can be routed directly to processing facilities. Despite large-scale industrial segregation systems, affordable household-level solutions remain limited.

This study introduces an **Automatic Waste Segregator (AWS)** tailored for decentralized waste management. The system automates the classification of mixed waste into metallic, wet, and dry fractions, thereby reducing manual labor, minimizing contamination, and promoting sustainable waste disposal practices.

The proposed AWS system offers the following advantages:

1. **Source-Level Segregation:** Enhances the quality of recyclable materials and improves the efficiency of subsequent waste processing.
2. **Automated Bin Operation:** Supports timely clearing of segregated waste, encouraging cleaner surroundings.
3. **Reduced Human Intervention:** Minimizes labor requirements and reduces occupational health risks.
4. **Integration Capability:** Can be integrated with municipal systems for real-time waste monitoring and collection optimization.

II. Literature Review

A range of studies has explored technological approaches to waste segregation:

- Al-Maaded et al. emphasized the importance of sustainable waste disposal and plastic recycling in the Middle East.
- Case studies by Raghumani Singh and colleagues highlight the challenges faced by Indian municipalities in handling unsegregated waste.
- Gupta et al. developed a system using capacitive sensors and impedance-based methods for preliminary segregation of metallic and wet/dry waste.
- Suchitra and team demonstrated that automation reduces health risks and operational costs in waste handling.
- Chandramohan et al. presented a household-level AWS but noted limitations in differentiating ceramic waste due to dielectric similarity.
- Kothari et al. implemented ultrasonic sensors for bin-level monitoring.
- Bajaj et al. proposed integrating image processing for improved accuracy and continuous segregation.
- Kittali et al. explored using PLCs to enhance precision and safety in waste-processing environments.

These studies collectively underscore the growing need for robust, economical, and efficient waste segregation systems that can operate at local scales.

III. Methodology

The fabrication of the AWS is carried out through a systematic three-stage process involving cutting, bending, and assembling. In the cutting phase, raw metal sheets are shaped using tools such as torches, CNC laser cutters, or water jets to achieve the precise geometries necessary for a stable and well-fitted structure. This is followed by the bending stage, where the cut components are formed into the required shapes through manual hammering, power hammers, or press brakes, creating frames, brackets, and casings that will support sensors and other mechanical elements. Finally, during the assembling stage, these components are joined using welding, screws, or other fastening methods to construct the complete mechanical framework. The sensor units are positioned accurately for efficient waste detection, and the servo-driven mechanism is incorporated to ensure proper routing of the waste into its designated compartments.

Design Considerations

The design prioritizes the following criteria:

1. Use of materials compatible with local manufacturing capabilities.
2. Cost-effective construction using widely available components.
3. Simplicity in operation, maintenance, and repair.
4. Capability to serve multiple functional requirements in rural or urban settings.
5. Utilization of standard parts such as steel rods, plates, and angle iron.
6. Avoidance of permanent structural alterations for ease of customization.
7. Light and robust structure designed for durability and portability.

The selection of materials for the AWS is guided by a comprehensive evaluation of their mechanical properties to ensure durability, reliability, and efficient performance. Key considerations include the strength and stiffness required to withstand operational loads, along with adequate elasticity and plasticity to accommodate minor deformations without failure. Materials must also exhibit suitable ductility to allow shaping during fabrication, while maintaining low brittleness to resist sudden fracture. Additionally, high toughness and fatigue resistance are essential for enduring repeated cycles of waste processing. Properties such as machinability and resilience support ease of manufacturing and the ability to recover from stresses. Finally, hardness and creep resistance ensure that the components retain their structural integrity over long periods, even under continuous mechanical and environmental stress. These attributes ensure a reliable mechanical structure under repetitive operational cycles.

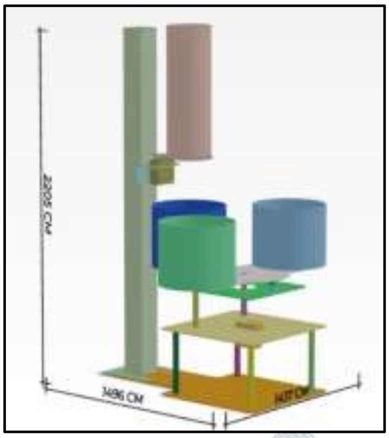
Aesthetic Considerations

Although functionality is the primary objective, the system is also designed with attention to:

- Compactness and user-friendly dimensions
- Appropriate color schemes and surface finishing
- Ergonomic placement of the inlet and controls

- Clean and modern visual appeal suitable for homes or public spaces

Fig 1 Model Diagram of Waste Segregator



The main components include:

- Screws, Rod Spacers, and Couplers
- Capacitive Sensor Module
- IR Sensor
- DS3218 Servo Motor
- Parallel Resonant Impedance Circuit
- Base and Supporting Frames
- Containers and Mounting Fixtures

IV. WORKING PRINCIPLE

1. Waste is deposited into the inlet chute.
2. The IR sensor detects the presence of waste and activates the sensing module.
3. Metallic waste is identified using the impedance sensor; the servo mechanism positions the metallic bin accordingly.
4. Wet waste is detected using capacitive sensors, and the system redirects it to the wet waste bin.
5. Waste that triggers neither sensor is classified as dry and routed to the dry waste bin.
6. The servo motor controls the movement of the chute and ensures accurate deposit of waste.

V. RESULTS AND DISCUSSION

Testing with common household waste demonstrated that the AWS reliably classified materials into metallic, wet, and dry categories. The sensor outputs were consistent, and the mechanical system showed high operational stability. The integrated monitoring feature supports timely waste collection and contributes to cleaner environments. The system's performance confirms its suitability for decentralized waste management and its potential contribution to sustainable urban development.

VI. CONCLUSION AND FUTURE SCOPE

The presented Automatic Waste Segregator offers an effective solution for addressing the growing challenges of municipal waste management. Its automated classification mechanism minimizes manual labor, enhances recycling pathways, and supports cleanliness in urban and semi-urban settings. The system is scalable and can be implemented at households, residential complexes, educational institutions, and public facilities.

Further developments may include:

1. Integration of shredding or crushing mechanisms for compacting waste.
2. On-site composting units for organic waste processing.
3. Solar-powered operation for energy efficiency.
4. Adoption of machine vision or AI algorithms for enhanced accuracy.

5. Cloud connectivity for real-time waste tracking and analytics.

REFERENCES

1. M. Al-Maaded et al., "Solid Waste Management and Plastic Recycling in Qatar," *Journal of Polymers and the Environment*, vol. 20, no. 1, pp. 186–194, 2012.
2. R. R. Arinta and D. B. Watomakin, "Smart Waste Management for Tourist Areas in IoT Environments," *ICoSTA*, 2020.
3. N. S. Kumar et al., "IoT-Based Smart Garbage Alert System," *TENCON*, IEEE Region 10, 2016.
4. S. Shetty and S. Salvi, "SAF-Sutra: Remote Smart Waste Monitoring System," *International Conference on Communication and Signal Processing*, 2020.
5. R. Singh and C. Dey, "Municipal Solid Waste Management in Thoubal, Manipur," *International Conference on Green Technology and Environmental Conservation*, 2011.
6. Vaibhav M, A Yadav et al, "Automated Waste Seggregator" ICAMCE 2023