



REVIEW OF SENSOR BASED AUTOMATED SMART WASTE SEGREGATION SYSTEM

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Abstract:

The rapid increase in urbanization, industrialization, and population growth has resulted in a significant rise in solid waste generation, creating major environmental and public health concerns. Efficient waste segregation at the source is a crucial step toward sustainable waste management and improved recycling. However, conventional waste segregation methods are largely manual, time-consuming, labor-intensive, and susceptible to human error. This review paper presents a comprehensive study of sensor-based automated smart waste segregation systems that enhance the efficiency, accuracy, and reliability of waste classification. These systems employ a combination of sensors, including moisture sensors, metal detectors, infrared sensors, and other sensing technologies, integrated with microcontrollers to automatically identify and classify waste into biodegradable, non-biodegradable, and metallic categories. Furthermore, the incorporation of Internet of Things (IoT) technology enables real-time monitoring, remote system control, and efficient data management, making these systems suitable for smart city applications. The paper reviews recent research, system architectures, sensing techniques, automation strategies, and implementation methodologies, while comparing their performance, advantages, limitations, and cost-effectiveness. It also discusses the role of intelligent waste segregation in reducing landfill waste, minimizing environmental pollution, improving recycling rates, and decreasing human intervention in hazardous waste handling. The findings indicate that sensor-based automated waste segregation systems provide a scalable, reliable, and sustainable solution for modern waste



management challenges. Overall, this review highlights the potential of integrating sensor technologies, automation, and IoT to develop smart waste management systems that contribute to cleaner environments, resource conservation, and the advancement of sustainable urban development.

Keywords: -Waste Segregation, Sensors, Automation, IoT, Smart Waste Management, Recycling, Microcontroller.

1. INTRODUCTION

The rapid growth of population, urbanization, and industrialization has significantly increased the amount of solid waste generated across the world. Effective waste management has become one of the major environmental challenges of the 21st century. Improper disposal and inadequate segregation of waste lead to pollution of land, water, and air, resulting in serious health hazards and environmental degradation. Traditional waste collection methods rely heavily on manual segregation, where different types of waste are separated by human workers. This process is time-consuming, labor-intensive, inefficient, and often exposes workers to harmful substances and infectious materials. Therefore, there is a growing need for intelligent and automated waste segregation systems that can improve waste management practices while reducing human effort and environmental impact.

Waste segregation is the process of separating waste into different categories based on its physical or chemical properties. Proper segregation at the source enables efficient recycling, composting, and safe disposal of waste.

It also reduces the burden on landfills, conserves natural resources, minimizes pollution, and supports sustainable development. However, in many developing countries, waste segregation is still not practiced effectively due to lack of awareness, insufficient infrastructure, and dependence on manual sorting methods. These challenges have encouraged researchers and engineers to develop smart waste management solutions using modern electronics, sensors, automation, and Internet of Things (IoT) technologies.

A Sensor-Based Smart Waste Segregation System is an advanced automated solution designed to identify and separate different types of waste using various sensors and a microcontroller. Unlike conventional waste bins, this system can classify waste into categories such as biodegradable, non-biodegradable, and metallic materials with minimal human intervention. The integration of sensors improves the accuracy and speed of waste identification while reducing errors associated with manual segregation.

The proposed system generally consists of multiple sensors, including an Infrared (IR) sensor, a moisture sensor, and a metal detection sensor. The IR sensor detects the presence of waste placed into the system and initiates the segregation process. The moisture sensor measures the moisture content of the waste to determine whether it is wet (biodegradable) or dry (non-biodegradable).



The metal detector identifies metallic objects by detecting changes in the electromagnetic field around the sensor. A microcontroller, such as an Arduino Uno or ESP32, processes the signals received from these sensors and controls servo motors or other actuators to direct the waste into the appropriate collection bins. In advanced implementations, the ESP32 microcontroller enables wireless communication, allowing real-time monitoring and control through IoT platforms.

The integration of IoT technology further enhances the functionality of the smart waste segregation system. IoT enables remote monitoring of waste bins, allowing municipal authorities or facility managers to track bin status, waste levels, and system performance in real time. Data collected from sensors can be transmitted to cloud platforms or mobile applications, providing valuable information for optimizing waste collection schedules and reducing operational costs. Smart monitoring also prevents overflow of waste bins, improves collection efficiency, and supports data-driven decision-making for smart city waste management.

Automation plays a significant role in increasing the efficiency and reliability of waste segregation. Automated systems can process waste continuously without fatigue, ensuring consistent performance and reducing dependency on manual labor. They also improve workplace safety by minimizing direct contact between workers and hazardous waste materials. Moreover, automated segregation enhances the quality of recyclable materials by reducing contamination, thereby increasing the economic value of recycling processes.

The proposed Sensor-Based Smart Waste Segregation System offers several advantages over conventional waste management methods. It reduces human effort, improves segregation accuracy, minimizes environmental pollution, and supports sustainable waste disposal practices. The system is relatively cost-effective because it utilizes widely available sensors and microcontrollers, making it suitable for implementation in residential buildings, educational institutions, hospitals, industries, shopping malls, public places, and smart cities. Its modular design also allows future upgrades with advanced technologies such as artificial intelligence, machine learning, computer vision, and robotic sorting mechanisms for even more accurate waste classification.

Despite these advantages, certain challenges remain in the development of automated waste segregation systems. Variations in waste size, shape, moisture content, and mixed waste composition can affect sensor accuracy. Regular calibration and maintenance of sensors are required to ensure reliable operation. Environmental factors such as dust, humidity, and temperature may also influence system performance. Therefore, continuous research is being carried out to improve sensor technologies, data processing algorithms, and intelligent decision-making techniques for more efficient waste management.

In recent years, governments around the world have emphasized sustainable development and smart city initiatives to address increasing environmental concerns. Proper waste segregation is one of the essential components of these initiatives. Automated waste segregation systems



contribute significantly to achieving cleaner cities, reducing greenhouse gas emissions, improving recycling rates, and promoting a circular economy where waste materials are reused instead of being discarded. Such systems align with global sustainability goals by encouraging responsible consumption and efficient resource utilization.

In conclusion, the Sensor-Based Smart Waste Segregation System represents an innovative approach to modern waste management by integrating sensors, microcontrollers, automation, and IoT technologies. The system addresses the limitations of conventional manual segregation by providing accurate, efficient, and reliable waste classification with minimal human intervention. It enhances environmental protection, improves recycling efficiency, reduces operational costs, and supports sustainable waste management practices. As sensor technology and IoT continue to evolve, smart waste segregation systems are expected to become an integral part of future smart cities, contributing to cleaner environments, healthier communities, and more sustainable urban development.

2. LITERATURE SURVEY

Anagha Dinesh et al. (2025)[1] proposed an automatic waste segregation system using image and audio data for improved classification. Their model applies machine learning techniques to enhance detection accuracy. The multimodal approach increases reliability compared to traditional sensor-only systems. The study demonstrates improved performance in waste identification.

Anbalakan M. et al. (2021)[2] presented a sensor-based automatic waste segregation system using Arduino. Moisture and metal sensors are used to separate wet and dry waste. The system focuses on low-cost and practical implementation. It improves segregation efficiency at the household level.

Zulkifli and Mohamed Nasir (2021)[3] designed an automatic garbage segregation system using proximity sensors. A microcontroller processes sensor data to direct waste into appropriate bins. The system reduces manual intervention and improves accuracy. Their model emphasizes automation in waste handling.

Rindi Wulandari et al. (2023)[4] developed a smart trash system using inductive proximity sensors. The system effectively detects metallic waste for accurate separation. Microcontroller-based control ensures efficient operation. The design enhances metal detection reliability.

Zurain Jamil Mirza and Dr. Mehwish Mirza (2025)[5] focused on the design and fabrication of an automated waste segregation system. Sensor-based detection and mechanical separation were implemented. The system ensures hygienic and efficient waste sorting. Their research highlights practical hardware development.

The Journal of Material Science and Devices (2025)[6] introduced an IoT-based automated waste segregation system. Real-time monitoring and remote data access improve waste management efficiency. The system integrates sensors with cloud connectivity. It supports smart city infrastructure development.



Shweta Dhawan Chachra et al. (2019)[7] proposed smart dustbins for automatic waste segregation using IoT solutions. The system enhances solid waste management in urban areas. Sensors are used for identifying and sorting waste types. Their work contributes to smart city waste solutions.

IJISRT (2024)[8] designed and implemented a smart dustbin for automated wet and dry waste segregation.

Embedded sensor systems ensure accurate classification. The system reduces manual effort and improves hygiene. It is suitable for residential and public applications.

Anita S. Joshi et al. (2024)[9] developed an Arduino-based smart waste management system. Multiple sensors were integrated for improved sorting efficiency. The system automates waste separation effectively. It offers a cost-effective and scalable solution.

Shwetashree Vijay et al. (2019)[10] presented a low-cost Arduino-based waste management system designed mainly for public places. The system ensures basic automatic waste segregation. The focus was on affordability and ease of implementation. It demonstrates practical usability in common areas.

Md. Shahariar Nafiz et al. (2023)[11] proposed “ConvoWaste,” a deep-learning-based waste segregation machine. Advanced neural networks improve classification accuracy significantly. The system performs better than traditional sensor-based models. It highlights the importance of artificial intelligence in waste management.

Dipesh Gyawali et al. (2020)[12] analyzed various deep CNN models for waste classification. A comparative study was conducted to evaluate performance and accuracy. The research improves detection capability using optimized architectures. It supports the advancement of AI-based segregation systems.

Prakriti Tripathi et al. (2025)[13] worked on image segmentation and classification techniques for efficient e-waste segregation. Advanced image processing methods were applied for accurate detection. The system enhances identification of electronic waste components. It promotes sustainable e-waste management practices.

Shivaank Agarwal et al. (2020)[14] studied computer vision techniques for automatic plastic waste segregation. Image processing methods were used for material identification. The system improves sorting accuracy using visual data. It contributes to automated recycling processes.

Malathi A. et al. (2019)[15] proposed an IoT-based smart waste management system for efficient monitoring. Real-time monitoring improves waste collection efficiency. Sensors detect bin status and waste levels accurately. The system supports intelligent and data-driven waste handling.

Kale S. and Kadam P. (2018)[16] presented an automatic waste segregator with monitoring features. Sensors and microcontrollers were integrated for effective sorting. The system enhances operational efficiency and automation. It reduces dependency on manual segregation.

Kumar N. et al. (2020)[17] introduced an IoT-based smart garbage monitoring and segregation system. Waste levels and types are detected using sensors. Data is transmitted for real-time analysis and monitoring. The system improves urban waste management practices.

Thakur P. and Kumar R. (2022)[18] developed a microcontroller-based automatic waste segregation system using different sensors. The system identifies waste categories accurately. It ensures faster and safer segregation processes. The design provides a practical and economical solution.

Rajesh P. et al. (2021)[19] designed and implemented a smart waste segregation and monitoring system using Arduino. Sensor integration improves sorting efficiency. The system supports automated waste handling and monitoring. It is suitable for smart city applications.

Karthik R. et al. (2019)[20] proposed “Smart Bin,” an IoT-based intelligent waste management system. Sensors detect waste type and bin status effectively. The system ensures efficient collection and segregation. It enhances overall waste management efficiency.

Singh A. et al. (2021)[21] focused on deep learning-based waste classification for smart recycling systems. AI models improve segregation accuracy significantly. The approach reduces errors in manual sorting. It demonstrates the potential of intelligent recycling technologies.

3. PROPOSED METHODOLOGY

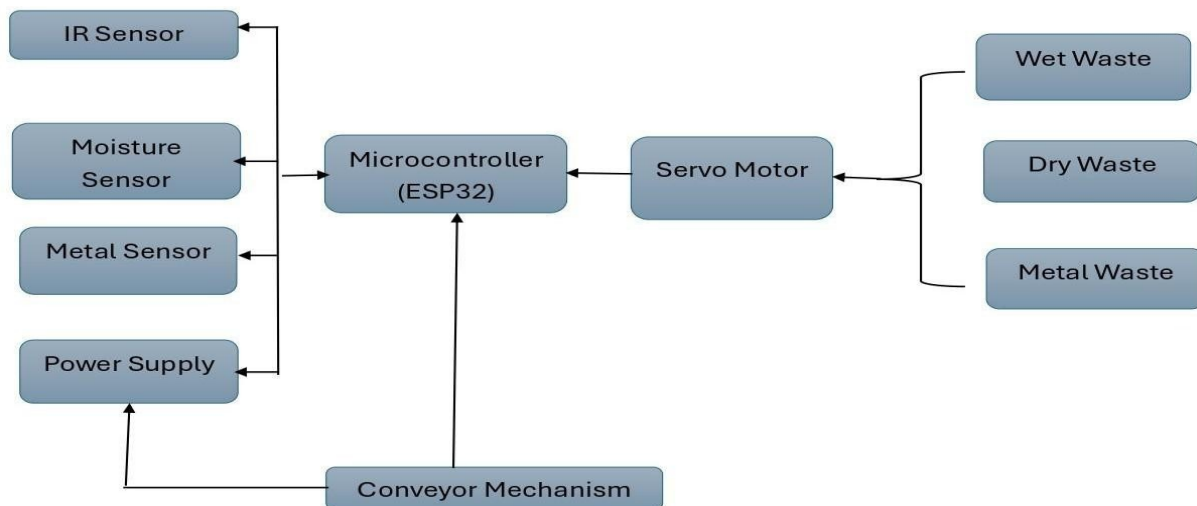


Figure 1 Block Diagram of Proposed System

The sensor-based waste segregation system is designed to automatically classify waste into different categories such as wet, dry, and metal waste using a combination of sensors, a microcontroller, and mechanical components. The overall system operates in a sequential and automated manner, ensuring efficient and accurate segregation of waste materials.

The process begins with the power supply unit, which provides the required electrical energy to all



components of the system, including sensors, microcontroller, and actuators. A stable power source is essential for the proper functioning of the system.

Waste materials are placed onto a conveyor mechanism, which acts as the transportation system. The conveyor belt moves the waste items through different sensing zones. This ensures continuous operation and reduces manual handling of waste.

As the waste moves along the conveyor, it first encounters the Infrared (IR) sensor. The IR sensor detects the presence of waste material on the conveyor belt. It works by emitting infrared radiation and detecting its reflection. When an object is present, the reflected signal is captured, and the sensor sends a signal to the microcontroller indicating that waste has been detected.

Next, the waste passes through the moisture sensor, which is responsible for identifying wet and dry waste. The moisture sensor measures the water content present in the waste material. If the moisture level exceeds a predefined threshold, the waste is classified as wet waste (biodegradable). Otherwise, it is considered dry waste (non-biodegradable). The sensor sends the corresponding signal to the microcontroller for further processing.

After moisture detection, the waste moves to the metal sensor. This sensor detects the presence of metallic components in the waste using electromagnetic principles. When a metal object is detected, the sensor generates a signal that is sent to the microcontroller, indicating that the waste belongs to the metal category.

The core of the system is the microcontroller (ESP32), which acts as the brain of the entire setup. It receives input signals from all sensors (IR, moisture, and metal) and processes the data according to predefined logic. Based on the sensor inputs, the microcontroller determines the type of waste and decides the appropriate action for segregation.

Once the waste type is identified, the microcontroller controls the servo motor, which is responsible for

directing the waste into the correct bin. The servo motor rotates to specific angles corresponding to different waste categories. For example, one position may direct waste into the wet waste bin, another into the dry waste bin, and another into the metal waste bin.

The segregation mechanism ensures that:

Wet waste is collected separately for composting or biodegradable processing. Dry waste is directed towards recycling processes.

Metal waste is collected for reuse and industrial recycling.

The entire system operates in a continuous loop, allowing multiple waste items to be processed efficiently. The use of automation reduces human intervention, increases accuracy, and enhances hygiene in waste management systems.

In conclusion, the working of the sensor-based waste segregation system integrates sensing,



processing, and actuation to achieve efficient waste classification. The combination of sensors and a microcontroller ensures reliable operation, while the conveyor and servo mechanisms enable smooth and automated segregation. This system plays a vital role in modern waste management by promoting sustainability and reducing environmental impact.

The sensor-based waste segregation system represents a significant advancement in modern waste management by automating the process of sorting waste materials. Through the integration of various sensors such as moisture sensors, infrared sensors, and metal detectors, the system efficiently distinguishes between biodegradable, non-biodegradable, and metallic waste. This automation reduces human effort, minimizes health risks, and improves the accuracy of segregation.

The review highlights that such intelligent systems contribute to enhanced recycling efficiency and support sustainable environmental practices. However, challenges such as high initial cost, maintenance requirements, and sensor limitations still exist. Future developments can focus on improving sensor accuracy, incorporating artificial intelligence for better classification, and making the system cost-effective for large-scale implementation.

Overall, sensor-based waste segregation systems play a crucial role in achieving smart waste management and promoting a cleaner and greener environment.

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