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# Design and Fabrication of an Automatic Waste Segregation and Monitoring System

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**Abstract**

The quantity and composition of solid waste are increasing rapidly due to continuous economic development in many countries. Variation in quantity and composition of waste has become a serious problem for the waste management system in ensuring effectual and eco-friendly management of solid waste. The world generated approximately 2.01 billion tonnes (BT) of solid waste in 2016, which is anticipated to increase to 2.58 BT by 2030 and 3.40 BT by 2050. Currently, only one-fifth of the waste generated is being processed and the rest is dumped in landfills without any treatment. The optimal economic benefit derived from solid waste is attained when all its components are thoroughly segregated. Waste segregation at source helps significantly in reducing complexity in waste treatment plants. There is no system for segregating dry, wet, organic, plastic, and metallic waste at household, office, college, and industrial levels. So, the goal of this paper is to design, fabricate, and testing of an easy-to-use and cost-effective automatic waste separation system for homes and small local societies so that waste can be directly sent to the waste management plants. This system minimizes human interference and shortens the time and cost of segregation. Powered by Arduino UNO and various sensors, this system easily separates solid waste into three main categories namely metal, dry, and wet. During the performance testing of the system, the accuracy of the system was noted at 98% for 100 samples and also the time taken by the system to separate metal waste, wet waste, and dry waste respectively was 2.5, 3.5, and 5.6 seconds.

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## Introduction

Around 62 metric tons of solid waste is generated every year in India but it is not being managed effectively in most of the cities which is leading to serious health problems and environmental destruction in many cities.[1] In many Indian cities, open dumping of waste in landfill sites is unplanned and unregulated but has become a common method of waste disposal.[2] Currently, India is dealing with many challenges out of which improper waste management is a major challenge. The most difficult challenges in waste management are waste segregation and waste-to-energy conversion. Improper waste collection, treatment, transportation, and disposal of waste generated causes significant damage to the environment.[3] Waste generation due to industrialization, urbanization, and increasing urban population is continuously increasing.[4,5] Many researchers have found that segregation, collection, transportation, treatment, and disposal in the scientific manner of solid waste is grossly inadequate in many Indian cities, leading to environmental problems and reduced quality of life.[6–10] If we talk about India, right now only five states are working on the source separation of waste, all other states are still dumping mixed waste together at the dump sites.[9,11] Segregation of waste, door-to-door waste collection, recycle and reuse options, waste treatment techniques, availability of land, and discarding capacity are some of the major issues of waste management.[12–14]

The fruitful value of solid waste cannot be obtained until the recycled waste is completely recycled, and the energy extracted from the non-recyclable waste must be extracted.[15,16] Most cities in India still use the traditional method of waste segregation in which waste is segregated by ragpickers. This method is time-consuming and ineffective and also adversely affects the health of people coming in contact with such waste.[17–19] Despite awareness campaigns, people are not segregation waste at their houses. In such a situation, households and municipalities need an affordable and easy-to-use solution to segregate waste automatically.

Modern solid waste management regulations are heavily focused on the segregation of waste composition at source and their treatment with their specific treatment methods. Government of India launched a program of "Swachh Bharat Mission" to make a clean India.[20,21] Now, the waste management authority is focused on waste collection and separation of waste in a useful manner. There are various technologies available around the world to manage solid waste but systematic segregation of waste is an important part of any successful waste management technology. Source segregation of solid waste is useful to decrease the amount of waste for landfills but also increase the rate of recycling.[22–24] There are many benefits of AWSMS, including: protecting the environment by reducing pollution, reducing the amount of waste going to landfills, reducing the need for manual labour, a cost-effective, efficient, time-saving, and easy-to-control system.[5,11] Therefore, the objective of this paper is to design and fabricate an automated waste segregation and monitoring system (AWSMS) that automatically segregates waste into dry, wet, and metal without human intervention. This paper is divided into two parts. Section 1, provides a component wise working and methodology of automatic solid waste segregation system. Section 2 is well-focused on the design, fabrication, and performance testing of the system. This paper can assist the municipal decision-makers, administration, and researchers of countries those are still looking for effective, low-cost, environmentally compatible waste segregation systems.

## Methodology

Microcontroller Arduino UNO has been used to operate the automatic waste segregation system. Each component linked to the Arduino UNO is configured using the Arduino IDE as shown in Figure 1. Embedded C++ language is used to write the program in the Arduino UNO which reads out the input/output signals of all the connected components.

All the sensors sense the garbage when it enters the system and send a signal to the Arduino Mega 2560. These signals help the servo motor to rotate in both directions i.e. clockwise and anti-clockwise directions so that the waste can be dumped into respective dustbin. All the data received from the Arduino UNO using the sensors is sent to the cloud through the use of the Node MCU. Thus, messages displayed in the LCD to users, and the received status will be communicated to those authorized to send the BIN status via the MQTT protocol. LCD display the type of waste detected by the sensor and also display the level of the bins level to the operator.

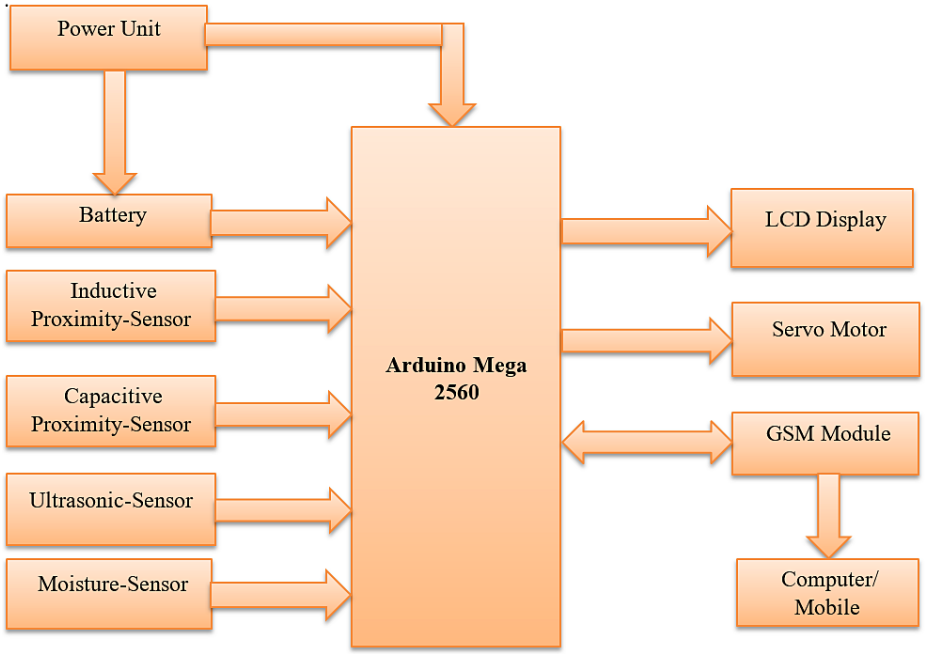



**Fig. 1: Block diagram of the work**

**Working Principal**

In this system, six sensors have been used of which three are used to determine the type of waste while the remaining three are used to find out the status of the bin either the bin is full or not. In order to determine the type of waste capacitive proximity sensor, moisture sensor, and inductive proximity sensor, while, three ultrasonic sensors have been used to detect whether three different bins are full or not. A capacitive proximity sensor has been used to sense dry waste i.e. paper, cardboard, plastic, wood, etc., a moisture sensor detects wet waste i.e. food waste, vegetable & fruit waste, etc., while an inductive proximity sensor detects metallic waste i.e. copper, aluminum, iron, etc.

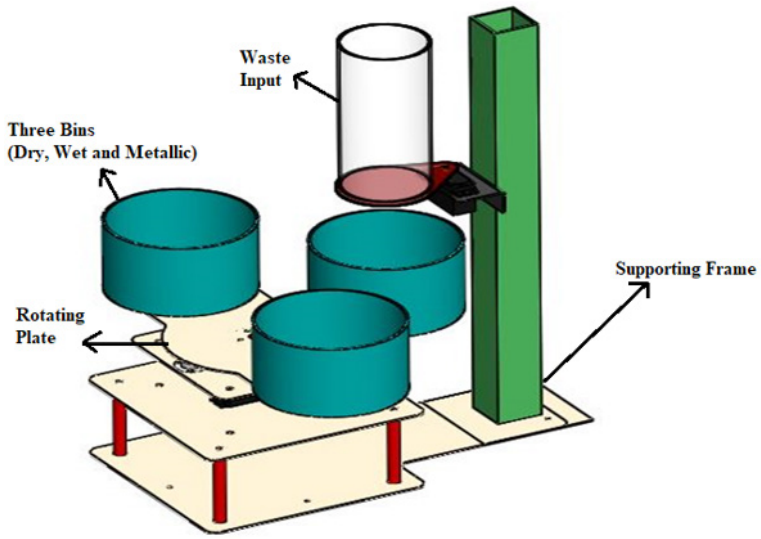



**Fig. 2: Layout of Waste Segregator**

When any object i.e. garbage is inserted into the waste hopper unit of the system, the sensors detect it. After detecting the object, if it is dry then the rotating plate brings the dry bin below the waste hopper, similarly if the object is wet or metallic then the dry and metallic bin allows the object to fall inside. The rotation of the plate and the falling of the waste into the bin is done by the use of relay and servo-motor. As soon as the waste is detected and sensed, the LCD of the system also displays whether the waste is dry, wet, or metallic. LCD also tells the count of garbage. The layout of the waste segregation system is displayed in figure 2.

The GSM module gives communication between the rotating bin and workers. When the bin is full then with the help of the GSM module a message is sent to the cleaning authority that "bin is full".

**Hardware and Software Requirements**

**Technical Specifications**

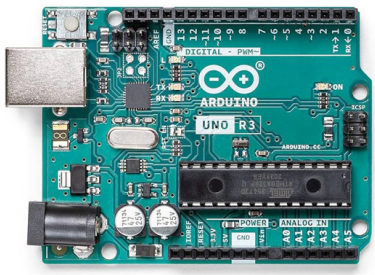
a) Voltage required- 5V
b) Voltage at the input- 7-20V
c) DC per I/O pin- 20 mA
d) Memory of flash- 32 KB
e) Frequency of clock- 16 MHz.
f) Digital pins required: 14
g) Analog pins required: 6

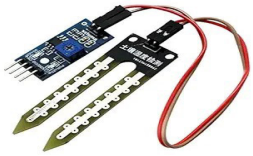
**Components Requirements**

A List of various components and their working is listed in table 1.

**Table 1: Components required for automatic waste segregation system**

| | | |
|---|---|---|
| 1. | Arduino UNO[25,26] | It is a publicly accessible electronics framework that works on user-friendly hardware and executable code. The classification of chips and associated controllers installed in it is facilitated by the structure framework of the Arduino board. The Arduino board is equipped with 14 digital pins that can function as either input or output, in addition to 6 analog pins designated for input purposes, facilitating the connection of diverse circuits. Additionally, customizable embedded C and C++ programming codes have also been used in microcontrollers. The Integrated Development Environment (IDE) provided by the Arduino microcontroller which supports different languages of programming. The Arduino board used in the project is programmed using a Universal Serial Bus (USB). |
| 2. | Servo Motor [27] | It is utilized to dump the garbage into the individual containers. A servomotor can be characterized by an angular motion actuator or a straight motion actuator, designed to facilitate precise control over position, velocity, and acceleration. A suitable motor is connected to a sensor to obtain positional input. In this configuration, the digital or analog |




| | | |
|---|---|---|
| | | input control flag corresponds to the position aligned with the output shaft. |
| 3. | Moisture Sensor [28] | It is used to determine the moisture content of waste by identifying the presence of water within the waste. The presence of moisture content within the waste is sensed and based on this assessment the waste is put into a suitable container.  |
| 4. | Capacitive Proximity Sensor[29] | It is used to identify whether the waste is metallic or non-metallic such as such as plastic, paper and more. It can also detect light or small pieces that cannot be found using mechanical limit switches. It comprises a high-frequency oscillator as well as a detecting surface shaped by two metal anodes. When any object comes close to its detecting surface, it enters the electrostatic field of the cathodes and changes the capacitance of the oscillator.  |
| 5. | Inductive Proximity Sensor [30] | It is used for the detection of metallic components without contact. This sensor does this in a way that is not sensitive to the size or colour of the object. An important property of inductive sensors is that they are cheap and reliable.  |
| 6. | Ultrasonic Sensor [31] | It is used to measure the motion and distance of any object by using the waves of ultrasonic sound. This sensor uses a transducer that sends and receives ultrasonic pulses to provide information about the proximity of an object. In this project, ultrasonic sensors have been used to measure the filling level of dry, metal, and wet bins.   |
| 7. | LCD (Liquid Crystal Display) [32] | This display technology is characterized by its flat panel design and operates thro -ugh the manipulation of liquid crystals. This LCD remains connected to the setup and displays the nature of waste detected by the sensor as well as the filling level of bins.   |

**Design and Fabrication**

**Design**

Components of Automatic Waste Segregation and Monitoring System has been designed on an AutoCAD software. A rough sketch of the system is drawn including all the dimensions as shown in the fig.3.

The supporting frame designed on AutoCAD is shown in fig.4. which contain base and vertical design of the supporting pillar of the frame.

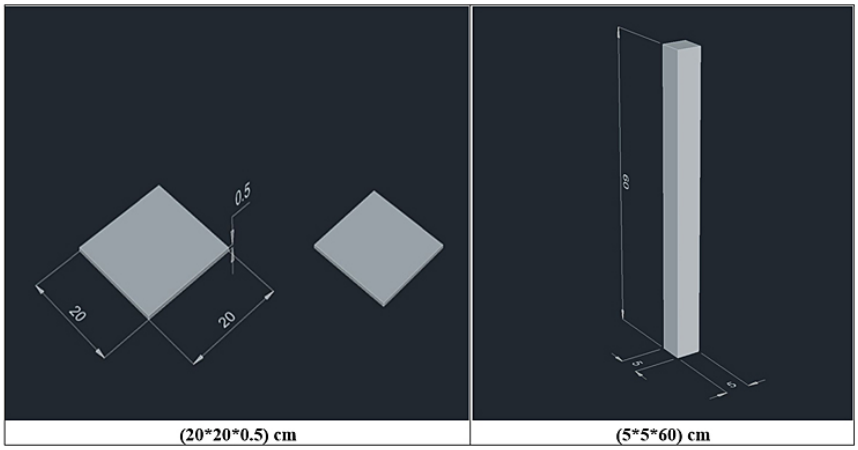



**Fig. 4: Supporting Frame**

Three bins, each of capacity 5 kg, and one hopper have been designed with the help of AutoCAD as shown in the fig.5. Each bin has been rigidly fixed on the rotating plate.

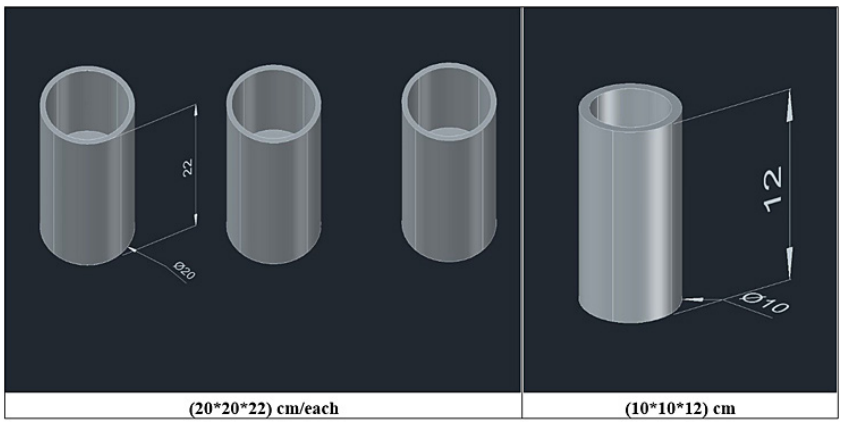



**Fig. 5: Three Bins (Dry, Wet and Metallic) and Waste Hopper**

**Fabrication**

Almost all components are nut-bolted or riveted together but the vertical iron column and the base of the system are joined through arc welding as shown in fig.6.

A complete assembly of the system is shown in Figure 7, on which various samples have been tested to separate wet, dry, and metal waste into separate bins.

**Results**

All components of automated waste segregation system are designed on AutoCAD software. After assembling all the components, the performance test of the system was conducted on household waste which included dry waste like paper, dry cloth, wood chips, plastic waste, cardboard pieces, etc., wet waste like vegetable peels, fruit pieces, lemons, Bananas, etc., and metal waste like safety pins, small metal pieces, aluminium sheet pieces, tin sheet pieces, etc. During testing of the system, it was found that the system takes approximately 2.5 seconds to separate metal waste, approximately 3.5 seconds to separate wet waste, and approximately 5.6 seconds to separate dry waste. This system segregates only one type of waste at a time. If a waste was previously wet but now it has become

dry, then the system will consider it as dry waste. The accuracy of the system was noted to be around 98% for 100 samples of waste. Table 2 shows the test results of the waste after being subjected to the waste segregator.

**Table 2: Testing results of the waste**

| Type of waste | Waste Name | Identified or Not |
|---|---|---|
| Dry waste | Paper | Yes |
| | Wood Chips | Yes |
| | Plastic | Yes |
| | Cardboard pieces | Yes |
| Wet Waste | Vegetable peels | Yes |
| | Fruit pieces | Yes |
| | Lemons | Yes |
| | Banana | Yes |
| Metal Waste | Safety pins | Directly goes down |
| | Small metal pieces | into metal waste bin |
| | Aluminium sheet pieces | |
| | Tin sheet pieces | |

**Discussion**

During testing, it was also found that the amount of waste should be proportional to the size of the system. This technology proves useful in ensuring that waste segregation is realistic and good for the environment. Mixed waste can be separated by being put through a rotating system (trommel system) before being put into the automated waste separation system. The trommel system is a rotating drum enclosed with a sieve. Due to the rotational motion of the trommel, the waste separates into individual particles, causing the smaller particles to pass through the sieve (<300 mm), while the bulk (>300 mm) stays inside the drum. The agitation action of waste removes the necessity for actions of manual stirring. The moisture content can be removed by airflow through the trommel's drum.

**Conclusion**

India is a developing country and its population is the largest among all the countries of the world, generates a huge amount of waste every day. Urban India has generated abound 62 million tons of MSW annually of which, 70% is collected and only 20% is treated. Different types of waste have different natures so dumping all the waste together is not good at all as it makes it very tough to reuse the waste. Segregation of waste plays a key role in reusing the waste. The process of waste management is significantly simplified when segregation occurs at the source.

Hence, the model presented in this paper is an automated waste segregation model which is efficient, sustainable, low power driven as well as requires very little human supervision. This system can detect the status of when the bin is full and calls the workers to collect the waste from the bin. It effectively reduces the manpower, collection time, and fuel consumed by the collection vans. This system is in perfect sync with the idea of a smart city and can replace the old garbage bin collection system. In the future, it is anticipated that collection bins will utilize solar energy, complemented by advanced segregation technologies such as digital image processing. This innovation will enhance the quality of the waste collected, thereby optimizing storage capacity. This system can be effectively used in local societies, colleges, offices, industries, etc. It can also be recommended on a larger scale with slight modifications like using robotic arms and conveyor belts to ease the separation process. Additionally, more sensors can be used to separate biodegradable and non-biodegradable waste, plastic, recyclable, medical, e-waste, etc.

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The author(s) do not have any conflict of interest.

**Data Availability Statement**
The manuscript incorporates all datasets produced or examined throughout this research study.

**Ethics Statement**
This research did not involve human participants, animal subjects, or any material that requires ethical approval.

**Informed Consent Statement**
This study did not involve human participants, and therefore, informed consent was not required.

**Author Contributions**
Kapil Dev Sharma contributed in Conceptualization, Data curation, and Formal Analysis. Rishi Kumar Prajapati worked on Resources and Methodology. Vivudh Fore contributed in Validation and writing original draft. Amrish contributed in writing–review & editing. Shobhit Srivastava worked as a Project administration and Supervision.

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