Municipal waste handling using IoT

Dr.S. Chellam[1], Indhupriya M[2], Madumica M K S[3], Samyuktha G[4]

[1]Assistant professor, Dept. of Electrical and Electronics Engineering, Velammal College of Engineering and Technology, Tamil Nadu, India.
[2,3,4]Student(U.G), Dept. of Electrical and Electronics Engineering, Velammal College of Engineering and Technology, Tamil Nadu, India.

Abstract - *The main part of upgrading a city into a smart city involves, using the digital advancements in favour of city functioning. As a step towards a smart city, our project tends to manage the municipal waste collection bins using IoT. The wastes dumped into the municipal bins are separated into organic and inorganic wastes by a conveyor belt setup, driven by a DC motor and monitored by a smart camera. The camera is computed to recognise different wastes. When organic waste is detected, the belt will move towards the bin for organic waste and for inorganic waste, the belt will move in other direction. Once they are segregated, the waste level in the bin is sensed by an ultrasonic sensor, which is connected to the micro controller. As the waste level in the bin reaches a pre-set level, an alert message indicating the fullness of the bin, along with its location, will be sent to the operator. Following this, a truck will be dispatched to collect the segregated waste. The segregated organic waste is recycled in a mechanical setup, by treating the wastes at an optimum temperature, pH level and moisture level. The treated wastes serve as organic fertiliser.*

***Key Words*: Waste separation, IoT, smart camera, Ultrasonic sensors, recycle, fertiliser.**

1.INTRODUCTION

Waste is an unavoidable by-product of human activities. The growing population is a direct factor responsible for increasing the municipal solid waste (MSW) generation. Most of the cities in India are experiencing unrestricted growth and heavy pressure of population. The net result is an enormous generation of municipal waste. The quantity of generated municipal waste mainly depends on the population and the efficiency of the reuse and recycling system. Municipal Solid Waste is mainly composed of household refuse, which is generated from the living community. It includes

- Degradable wastes: paper, textiles, food and vegetable waste.
- Moderately degradable wastes: cardboard and wood.
- Non-degradable wastes: leather, plastics, rubbers, metals, glass and electronic waste.

In most developing countries, the MSW composition is highly degradable, mainly composed of an organic fraction with excess moisture content. However, due to inaccurate facilities to collect them has led to overflow of many waste bins, across the cities, causing unhygienic conditions. Even if they are collected properly, due to improper separation, recycling has become very difficult. Domestic recycling is almost non existent in majority of cities, when compared to their waste generation level.

1.1 Municipal waste in India

Each year about fifty five Million tons of Municipal Solid Waste (MSW) and thirty eight billion litres sewage is generated in the urban areas of India[4]. The yearly spike is estimated to be around 5%. With the rapid increase in the population of urban areas, it is estimated that waste generation will increase at a per capita rate of 1 to 1.33% annually.

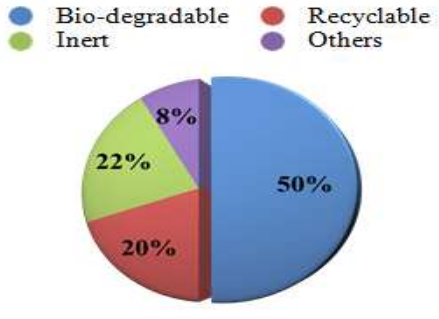

Chart -1: MSW composition in India

The area of land required to dispose the waste has been increasing significantly along with cost of collecting, transporting and disposing waste. The wastes generated are either dumped in lands or find their way to water bodies.

Nearly half of these waste can be easily recycled even at domestic levels, only if appropriate steps are taken. This paper proposes such an effective mechanical setup to recycle the organic wastes, both in domestic and commercial levels. This is an essential step to be taken for better waste management.

The system can further be improved by connecting the system with the GPS system to determine the location of the bin and notify the nearby waste management centre to empty the bin as well as use internet of things to monitoring and access bins from anywhere[8].

1.2 Paper outline

This paper proposes a solution to overflowing bins and better segregation of wastes, along with the concept of domestic recycling[7]. The segregation will be done with a smart camera setup. Monitoring of bin is done using IoT, through a cloud application. Lastly, recycling is done in a mechanical container, monitored by several sensors[1].

The paper is structured as follows,

- Section 2 discusses the motivation or origin of thought for handling municipal waste.
- Section 3 is the literature review of currently existing methods for solving the problem.
- Section 4 explains the proposed methodology of this paper.
- Section 5 is about the block diagram and components used for the system.
- Section 6 discusses the merits of the proposed system over

Table -1: Projected Municipal Waste Generation for the Urban Population in India

***Population projection data from United Nation Population Division**			
Year	Projected Urban Population* (in thousands)	Waste generation rate (gms/capita/day)	Total MSW generation (million tons)
2015	401898	571	83.8
2020	455823	696	115.8
2025	517178	848	160.1
2030	586052	1032	220.7

To cope with the increasing MSW generation, proper handling is crucial. This paper aims at solving the waste management problems by monitoring and handling at three levels as follows, existing solutions.

2. MOTIVATION

Municipal waste handing is one of the huge challenges faced by the city authorities, especially in a developing country like India, where the population density is very high. The Municipal Solid Waste Management and Handling Rules of 2000 explains, collection, segregation, transportation and suitable disposal of municipal wastes as an obligatory part of the municipal authorities. However, being a developing country, the budget allotted is comparatively very less. For instance, Rs 237.4 crore was allocated in the 2016-17 budget for the solid waste management department project works. Out of which, over 80% of the budget is allocated for collection and transportation. The remaining 20% is not sufficient for processing and disposal of wastes, for such a vast country like ours.

Segregation is rarely undertaken. Also, incentives are not given to encourage people for practicing segregation. With such limited efforts to educate citizens, the lack of knowledge about environmental consequences leaves them apathetic to segregation. When segregation is poor, recycling becomes ineffective and almost impossible.

Compared to the budget allotted for municipal waste management, the scale of waste needed to be handled is very high.

Also, the rate of generation is constantly increasing for every passing year, which the budget fails to cope up with. Proper waste handling is possible within the budget, only if the public co operate by actively taking part in waste segregation and recycling.

The following table shows the increase in municipal waste generation for urban population in every half decade.

- Stage I : Separating organic and inorganic wastes.
- Stage II : Monitoring the fullness of bin.
- Stage III : Collection and recycling.

This would help in completion of waste management with better efficiency and cost effective when compared to current practices.

3. EXISTING SOLUTIONS

Several solutions have been proposed over past years, in order to address the previously discussed issues regarding municipal waste handling. Literature review on these existing solutions is given in brief.

3.1 Customer RFID based Collection system

Every waste generating entity is allotted a RFID[1]. This system is in use for food waste collection. This system is developed in the Korean context. Weight sensors fixed at the bottom of waste collection bins calculate the amount of waste present in a particular bin. The payment will be calculated respectively. Also, accessing of bins is allowed only after RFID is scanned. If not, the lids of the bin will remain closed.

3.2 IoT based waste collection system

A waste collection management solution with smart waste bins, using IoT with sensors. It reads, collects and transmits a huge volume of data over the Internet[2]. Such data, when processed by intelligent and optimised algorithms, can be used to dynamically manage waste collection system.

3.3 Automation of waste bins

In this system, the bins are monitored by RF technology, to prevent bin overflow. A conveyor belt is used to close the lid when the bin is completely filled. This is one of the most basic solution to control overflowing of bins.

3.4 Installation of Recycling plants

This method makes use of the fact that huge wastes are generated everyday, to produce more useful products through recycling. If municipal wastes are not managed and handled properly, it becomes a serious aspect which causes environmental degradation[4]. This paper explains various methods such as incineration, Anaerobic digestion and Pyrolysis, to describe the waste to energy (WTE) conversion.

3.5 Intelligent vehicle monitoring system for waste collection

The control of vehicles using big data achieves accurate and intelligent vehicle management. 5 layers framework of the system and its working principals are described. It has been working in Nanjing city for the convenience of scientific management of vehicles[5].

4. PROPOSED METHODOLOGY

The overall system can be viewed in three parts, based on the three stages of waste handling of,

- Segregation
- Monitoring
- Recycling

The *first part* includes the conveyor belt setup, featuring a smart camera, which differentiates between organic and inorganic wastes, based on the input fed to it. Whenever organic waste is identified by the cabers, the motor will be given a high signal from the micro controller. At high signal, the motor pushes the waste on the conveyor belt to one of the two sections of the bin, where the organic wastes are supposed to be collected. The remaining inorganic wastes fall into the other section, directly from the conveyor belt(Fig-1).Hence the wastes are separated into organic wastes and inorganic wastes and are collected in separate sections of the bin.

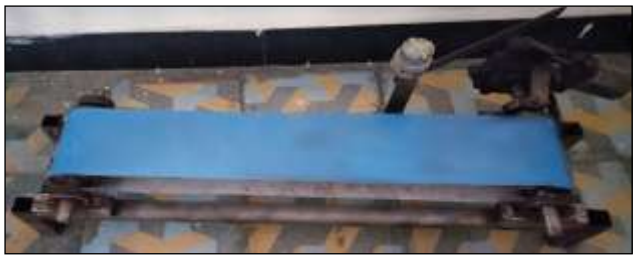

Fig -1: Conveyor belt

The *second part* of the system is related to collection and transportation of separated waste. For this purpose, ultrasonic sensors are fixed on the rims of the bin. This will determine the level of waste present inside the bin. The value of fullness will be monitored until it reaches a preset value. Once this value is reached, an alert message indicating the fullness of the bin, along with its location will be sent to the waste manager or operator[9]. Then the operator will dispatch a truck to collect the waste from the specified location. This is done using IoT, which uses a cloud platform for displaying purpose[1].The process of notification and garbage collection is described by the following flow chart(Fig-2).

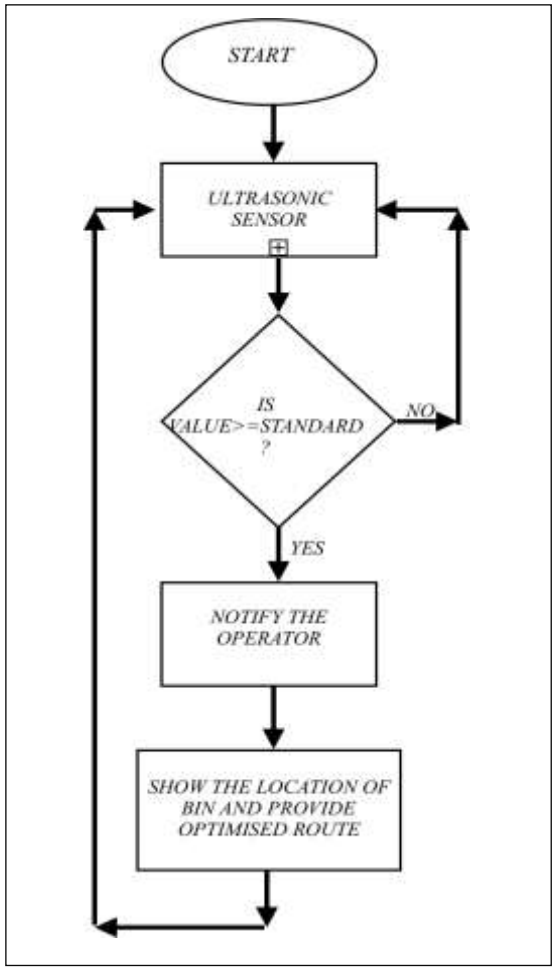

Fig -2: Flow chart

The *third* part of the system is recycling the collected organic wastes. This paper focusses mainly on domestic recycling of organic wastes, as they form the major part of municipal wastes and can be recycled easily without requirements of any high tech equipments.

The proposed mechanical setup(Fig-3) is attached with a pH sensor, a temperature sensor and a moisture sensor. These sensors read the values which indicates the stages of decomposition process. The heater fixed inside the drum will help in maintaining the optimum temperature to assist the process of organic waste breakdown[5]. Here, the wastes are converted into organic fertiliser by treating them at controlled temptation and pH levels.

Maintaining required temperature for effective breakdown of organic compounds. The values indicated by these sensors are monitored till the formation of fertiliser is indicated[8].

Fig - 3: Recycling mechanical setup

5. BLOCK DIAGRAM AND COMPONENTS

The functional block diagram has two main parts. One is for waste segregation and transportation(Fig-4). The other one is for waste recycling(Fig-5).

The wastes, when dumped into the dumpsters, fall on the conveyor belt. As the belt takes forward the wastes, the smart camera will recognise the organic waste and the micro controller will send the signal to the DC motor, which will push the organic waste into its respective side of the partitioned bin. And the inorganic wastes will fall on the other side. As the waste level gets increasing, the ultrasonic sensor senses the fulness of the bin. Once the level of waste exceeds the previously set value, an alert signal indicating the fullness of the bin, along with its location to the operator using a GSM module. Based on this, the operator will assign a truck to collect the wastes[3].

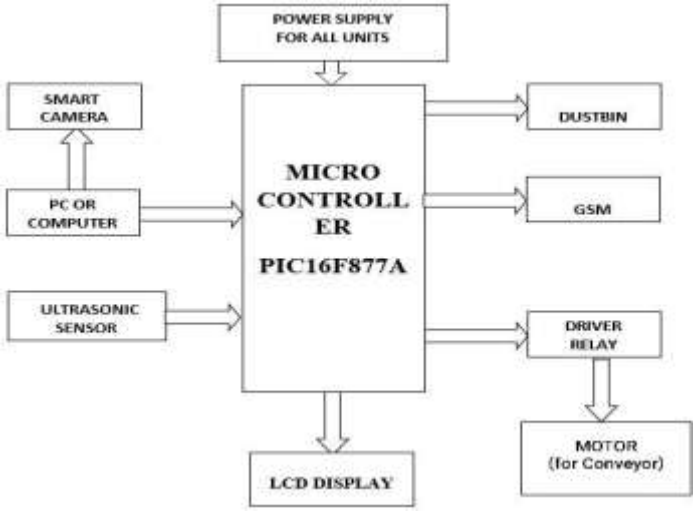

Fig - 4: Segregation and transportation block

The organic wastes are recycled in a drum, fitted with heater and various sensors. Optimum temperature and moisture has to be maintained for effective decomposition. This is done by monitoring them using sensors and the heater will help

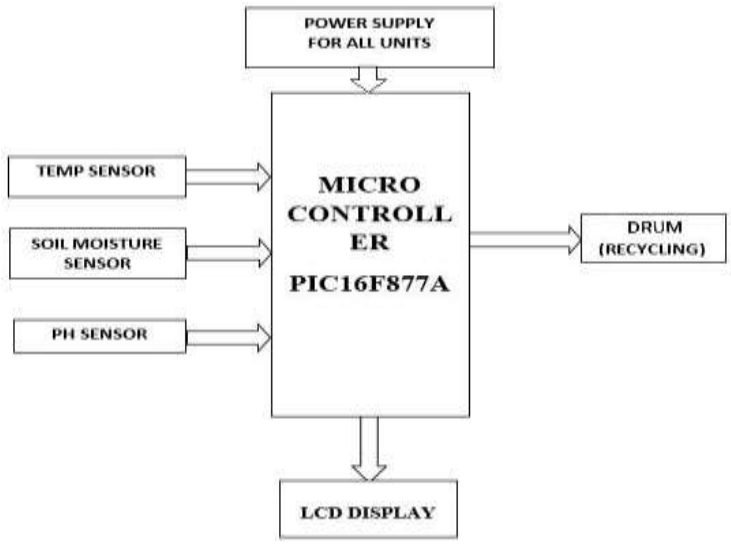

Fig - 5: Recycling block

5.1 Hardware requirements

5.1.1 Micro controller PIC16F877A

PIC16F877A is a powerful yet easy-to-program CMOS FLASH-based 8-bit microcontroller. It has only 35 single word instructions. The PIC16F877A features 256 bytes of EEPROM data memory.

5.1.2 GSM-SIM800

SIM800 is a quad-band GSM/GPRS module designed for the global market. It works on frequencies GSM 850MHz, EGSM 900MHz, DCS 1800MHz and PCS 1900MHz.

SIM800 can meet almost all the space requirements in users' applications, such as M2M, smart phone, PDA and other mobile devices.

5.1.3 DC motor

The motor used is a 45 RPM 12V DC geared motor.

Weighs about 125 grams. Torque specification is 2 kgcm.

5.1.4 Sensors

A variety of sensors are used for different purposes, in both segregation and recycling. They are Ultrasonic sensor-HC SR04, Moisture sensor-YL69, Temperature sensor-LM35, pH sensor.

5.1.5 Mechanical setup

The three main components of the mechanical setup are Conveyor belt, Smart camera, MS steel drum (for recycling).

5.2 Software requirements

A web application named Cayenne Cloud is used for tracking the trucks and monitoring the bins. The use of Google Maps API provides very efficient mechanism information with fast response time and user-friendly interaction.

6. POSITIVE IMPACTS OF THE SYSTEM

6.1 Cost effective

The hardware components last long and the maintenance costs involved are very low. The USB camera used is relatively cheaper than those interfaced with RaspberryPi board**s.**

6.2 Ultrasonic sensors over IR sensors

Ultrasonic sensors are found to be completely resistive to hindering factors like Light, Dust, Smoke, Mist, Vapour, Lint, etc.

6.3 Compatibility in the Indian context

In India, most of the municipal bins are open type or lidless, thus making it more compatible for the camera to detect and separate wastes. Also, ultrasonic sensors can be fitted easily in the bins very easily.

6.4 Increased efficiency

Usually, in our country, garbages are cleared at fixed time intervals, which might lead to overdamping or underdamping of certain bins. Monitoring the bins in real time facilitates dynamic scheduling.

6.5 Betterment of environment

The overflowing of bins in prevented.So hygiene is taken care . Also recycling of waste is a huge step towards balancing of nature.

7. CONCLUSION

The solution to the optimisation of waste collection process lies not only in recycling the wastes, but also in generation of real time data about the filling up of waste bins placed at different distant locations. This proposed IoT based methodology can provide this information with ease. The overflowing of waste bins will also be avoided, along with segregation and recycling of wastes. The most important point is that, this technology is robust, cheaper and easy to use due to the low cost of the sensors used, its advanced utility in both lid and lid- less situations.

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