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Optimization of Organic Waste Collection for Generation of Bio Gas using IoT Techniques

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Abstract: India is facing some major challenges in waste collection, segregation, transportation, treatment and disposal. Hence, there is a need to spread awareness about waste disposal and define better waste management techniques in India. The purpose of this paper is to utilize Internet of Things for waste management and optimized collection of wet (biodegradable) waste to produce bio-gas. It focuses on improving the current waste management system by using ultra-sonic sensors, Arduino-UNO and EC-GSM. Collection and segregation of waste in an optimized way is necessary because wet waste can be useful in producing bio-gas which in turn can be used to produce clean electricity and natural gas. Lastly, the paper also gives emphasis on cost analysis of this method to calculate revenue generation.

Index-Terms: EC-GSM, Ultrasonic Sensor, Arduino UNO, IOT, Bio-gas, Bio-CNG, wet waste.

1. Introduction

Most human activities generate waste and these wastes are generally collected and disposed of in dumping grounds. This can affect the environment and pose risks to human health [1]. Rapid urban and industrial growth in the country has resulted in overburdening of urban infrastructure services, including municipal solid waste management (MSWM) services. Solid waste management is one of the biggest difficulties faced by the civic bodies of the country today, other than supply of water, roads, electricity, education and public sanitation. Suitable facilities for disposal of MSW are not available, and the available facilities are not utilized properly due to poor management. Moreover, the increasing amount of waste generated daily in metropolitan cities is making its management more difficult. Along with household waste, industrialization is leading to generation of loads of industrial waste that may be hazardous in nature. Unscientific disposal of this waste causes an immense impact on environment and human health [2]. For the safety of life and environment, we need to devise waste management methods that are economical, efficient and reliable in nature.



Internet and its applications have become an integral part of today's human lifestyle. It has become an essential tool in every aspect. Various fields like industrial automation, transportation, etc. are experiencing rapid growth with the application of IoT. Yet, not much has been achieved in the field of waste management using IoT. This paper aims to improve the waste management system of the country by implementation of IoT. The technology and its applications have been discussed briefly. All the equipment used in our day to day life can be controlled and monitored using IoT. Majority of the technology developed in this paper makes use of sensors. Sensors are deployed everywhere, and they convert raw physical data into digital signals and transmit them to its control center. EC-GSM and Arduino-UNO help in collecting data from the biogas plants and also in sending messages via internet to the waste collection trucks, where the message indicates the nearest available plant for waste disposal in a particular zone of a city. This system will therefore help in reducing the unused biodegradable waste in urban cities.

2. Literature Survey

Our plan focuses on implementation of IoT for optimized waste collection and utilization of wet waste generated in urban households for production of biogas. The following papers depict the advancements in the field of waste management using IoT:

1. Waste management Issues in India by Dr. Raveesh Agarwal, Mona Chaudhary & Jayveer Singh. It gives an idea of current practices related to the various waste management initiatives taken in India for human well-being.
2. Sustainable Waste Management Issues in India by Shikha Saxena, R.K. Srivastava and A.B. Samaddar. It highlights the possible improvement for sustainable solid waste management considering the technological, institutional and financial factors. It also gives a generalized statistics about types of waste in various states of India.
3. IoT Based Smart Garbage and Waste Collection Bin by S.S. Navghan, M.S. Killedar and Dr. V.M. Rohokale. This paper gave a basic idea about the type of sensors, micro-controllers and routers which can be used for segregation.
4. Automation of Smart Waste Management Using IoT To Support "SWACHH BHARAT ABHIYAN" – A Practical Approach by Bharadwaj B., M. Kumudha, Gowri Chandra N., Chaithra G. This paper gives an insight of how wet and dry waste can be segregated and how IoT can help in giving information about the level of garbage in a particular apartment.
5. IoT Based Solid Waste Management System by Abhay Shankar Bharadwaj, Rainer Rego and Anirban Chowdhury. It gave information about usage of LoRA technology for segregation of wet and dry waste and in a way helped to us identify which could be a better option for the system.

3. Motivation for Research

Current systems in India cannot cope with the volumes of waste generated by the increasing urban population, and this has an impact on the environment and public health. The usual practice followed is to lift solid waste from the point of generation and hauling it into distant places known as dumping grounds or landfill sites [3]. Over 160,000 metric tons of municipal solid waste is generated daily in the country out of which approximately 91,152 tons is collected and approximately 25,884 tons gets treated.

The government of India is promoting setting up of lakhs of biogas plants throughout the country. Central subsidy is being extended for setting up of biogas plants. Unfortunately, around 4.5% of the inspected Biogas plants are non-functional. The main reasons for this as explained by the government are:

1. Construction & Maintenance defects.
2. Lack of raw material.
3. Problems related to equipment (burners, pipeline and fittings).

Moreover, the biogas plants being setup focus on utilization of agricultural and animal wastes as raw material. As per statistics, almost 65-70 % of the waste in households consists of bio-degradable waste like food, garden waste, etc. Out of this, almost 80% biodegradable waste goes untreated because there is no segregation. There are no fixed government policies for utilization of organic waste generated in urban households to produce biogas. Thousands of tons of organic waste generated in the major cities ends up being disposed at dumping sites. If this waste is systematically segregated and used as a raw material in biogas plants, it can generate enormous amounts of biogas. This will solve the problems of waste disposal and availability of renewable energy sources. But it remains a big challenge for India to manage such huge amounts of waste. Current waste management systems are more focused towards the traditional method of managing waste. The motive of our project is to develop an efficient waste management system using IOT techniques.

4. Research Methodology

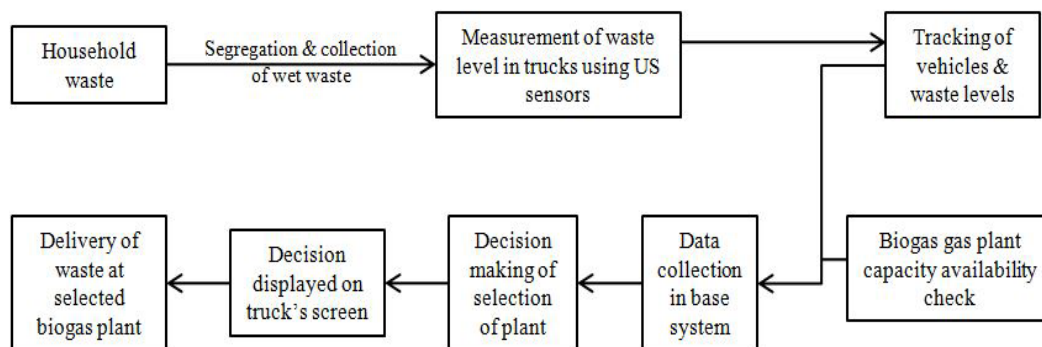


Fig. 1: Process Description Flowchart

5. Process Description

Currently, most of the cities use centralized way of waste management. For cities like Mumbai, centralized way of managing waste becomes hectic, complex and costly. Application of a decentralized system would be more efficient and effective in such cities. It focuses on division of city in several zones and effectively collecting, segregating and managing waste of each zone separately. Our aim is to provide a decentralized, efficient and simple waste management system using IOT techniques.

Critical to the implementation of such a system is segregation of waste into wet and dry waste. The best way to segregate waste is to segregate at the source itself. Hence, pertaining to 'Swachh Bharat Abhiyan', people can be motivated to perform segregation of household waste into wet and dry waste by giving some considerable allowances. The enormous amount of wet waste generated in cities can be used to generate huge amount of biogas which can be sold as fuel and thus generate revenue. This generated revenue will help in providing the desired allowance to people.

5.1. Application of IoT

After segregation of waste, optimized collection will begin. The level of wet waste in collection trucks will be measured by ultrasonic sensors embedded in them. Arduino-UNO will be used for programming the stored data. EC-GSM will transmit this data to the Municipality Base Center. Simultaneously, data from each bio-gas plant will be manually fed in the web-page and this data will be directly transmitted to the database via internet to the base system. GPS will be used to track the position of trucks. Once the

ultrasonic sensors sense that the truck is completely filled with waste, and after receiving the location of the trucks and capacity information of the plant, the center will assign the nearest available biogas plant to the truck. We have divided our system into device and management layers [4] as explained below.

5.1.1. Device layer: The device layer here consists of the vehicle which is carrying waste with the embedded hardware. Ultrasonic sensors in the vehicle will sense the garbage level in the vehicle. These sensors interfaced with Arduino will sense the garbage level and ensure that the vehicle is filled up to its total capacity and share information with Arduino. The Arduino will use the information received from the sensor and check if it is filled to the maximum capacity of the vehicle. The Global positioning system will also be connected to the vehicle so that the location of the vehicle can be tracked.

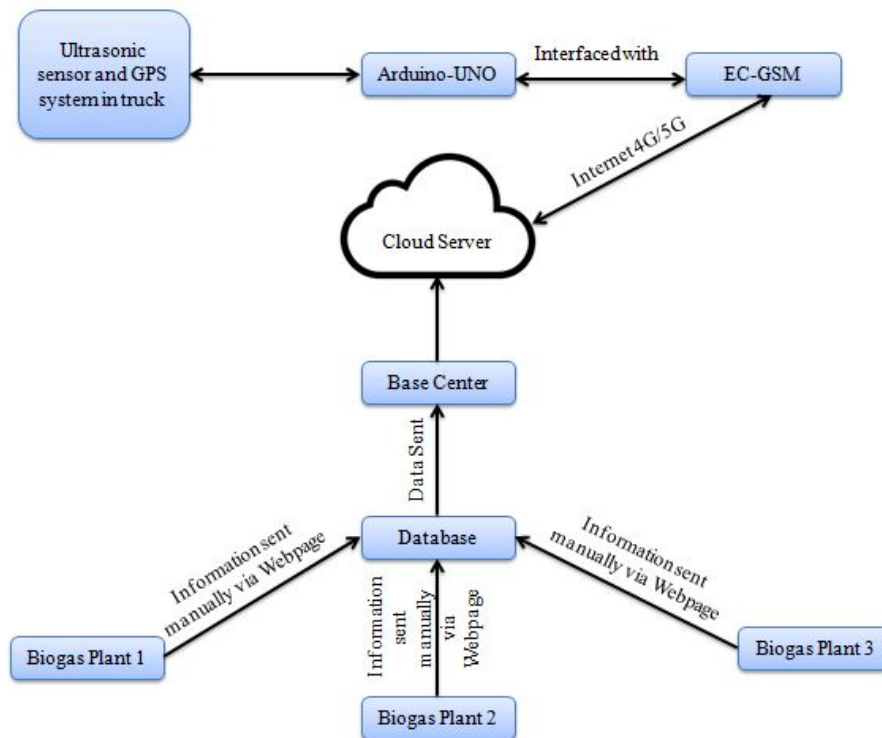


Fig. 2: IOT Network Flowchart

5.1.2. Device Transmission Layer: The Transmission device used is GSM module interfaced with Arduino-UNO. This device will be placed in each vehicle and programming will be done in such a way that data taken from the sensor will get stored and manipulated. This manipulated data or garbage level will be sent to the Municipality Base Centre by transmitting device i.e. GSM module interfaced with Arduino.

The data from the bio-gas plant about the waste required for generating electricity or natural gas is stored manually in the web page. This stored data is directly transmitted to the database via internet to the Municipality Base Center.

5.1.3. Device Communication Layer: The communication device which is used is the EC-GSM module. Data stored in the micro-controller will be sent to EC-GSM Transmitter pin in the vehicle. This data will be delivered to the EC-GSM receiver pin at the base center through the internet.

5.1.4. Management Layer: The single Arduino based module which is at the base center will compare the data received from the vehicle (level of wet waste in the vehicle) and the bio-gas plant (how much more wet waste is required to operate the plant) and the appropriate location will be assigned to the vehicle operator. If there is a similar requirement by all the bio-gas plants, the GPS will track the vehicle and assign the nearest available location.

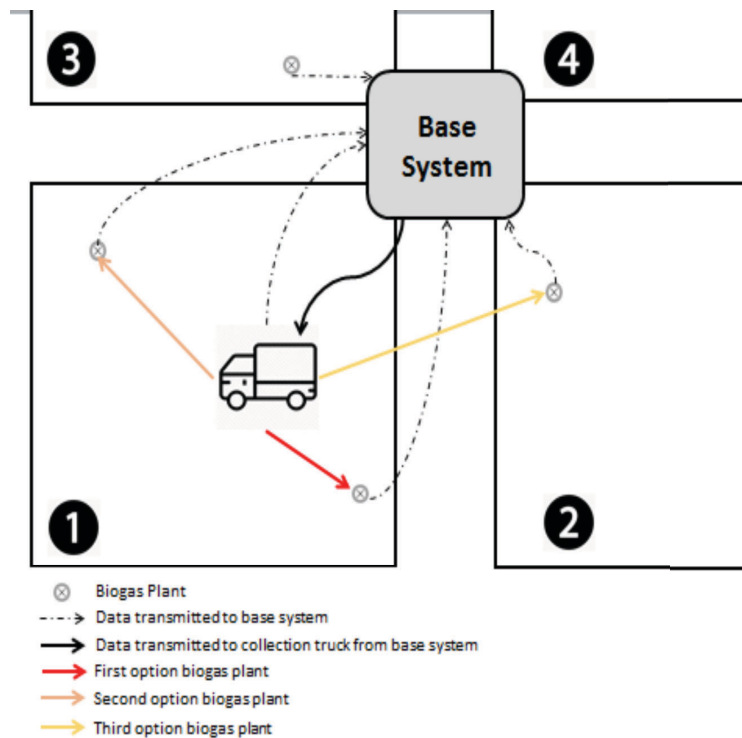


Figure 3: City Structure

6. Cost Analysis

Basic cost calculations were done to calculate the revenue generated from the process for the city of Mumbai. Over 70% of household waste is organic in nature and can be used to generate biogas. This biogas can be sold back to the households in the form of bio-CNG which can be used as fuel for cooking and other purposes. This biogas generated can also be used to generate electricity (this form of utilization is not considered in the cost analysis).

Essentials	Value	Unit
Revenue Calculation		
Waste generated per day	7,500.00	Metric ton
Wet waste generated per day	5,250.00	
Waste collection efficiency	60	%
Wet waste collected per day	3,150.00	Metric ton
Biogas generated per ton of wet waste	100.00	m ³
Biogas produced per day	31,500.00	m ³
Density of biogas	1.15	Kg/m ³
Weight of biogas produce per day	36,2250.00	kg
Cost of bio CNG	35.00	Rs./kg
Revenue generated per day	12678750.00	Rs
Fixed Cost Calculation		
Cost of 25 ton capacity biogas plant	6,000,000.00	Rs.
Land cost per plant (0.25acre)	20,000,000.00	Rs.
Total fixed cost per plant	26,000,000.00	Rs..
Total no of bio gas plant required	126	nos
Total fixed cost	3,276,000,000.00	Rs.
Variable Cost Calculation		
Water cost rate	4.80	Rs./metric ton
Water required per day	3,150.00	Metric ton
Water cost per day	15,120.00	Rs.
Break Even Analysis		
Days achieve breakeven	256.69	Days

The analysis shows that even at the collection rate of 60%, we would be able to generate enough revenue to break even in less than one year. This revenue will also help provide incentives to people to motivate them to segregate waste.

Moreover, waste water from households can be used in these plants, reducing the amount of water required. The bi-product of the process (fermented slurry) can be sold as fertilizer, thus providing an alternative revenue source.

7. Discussion

7.1. Advantages:

Firstly, this method focuses on motivating people to segregate waste at home by providing incentives. This will solve the problem of waste segregation. Secondly, the major chunk of urban household waste, i.e. wet waste, which is getting disposed of in dumping grounds will be used to generate biogas which will ultimately help in revenue generation. Thirdly, this system will ensure that vehicle moves at full capacity and thus save the cost of transportation by avoiding extra trips. Finally, implementation of IoT in the waste management system makes it more reliable and efficient. The better management and decision making achieved with the help of IoT integration creates scope for infinite future improvements in the waste management system for cities.

7.2. Future Scope

Fabrication of an IoT based product that segregates waste at home. This will promote waste segregation which is a critical success factor for the whole system. Complete automatization of the system without any human interference. The data of biogas plant capacity can be sensed and transmitted automatically to the base system. Human help will then be required for monitoring purposes only.

7.3. Limitations

Availability of good and continuous network connectivity is necessary. Any kind of barrier in communication can hamper the smooth functioning of the system. The success of this system has a high dependency on the fact whether people will segregate waste at home or not. Provision of incentives will promote waste segregation.

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