SMART WASTE MANAGEMENT SOLUTION USING IOT FOR SMART CITY

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Abstract

The Internet of Things (IoT) paradigm, which analyses and controls city processes in real-time, serves essential for enhancing applications relevant to smart cities. Solid waste management, which has an adverse impact on both the environment and the overall wellness of the society, is one of the most vital issues connected to smart city applications. Waste produced by city inhabitants and disposed into the garbage cans is where the traditional waste management process starts. On an assigned schedule, trucks from the municipal department collect and transport the discards to the recycling facilities. Outdoor dumpsters receive little attention by municipalities and garbage management firms, making it difficult to know when to clean them or when they are filled. In order to get beyond the drawbacks of conventional waste management systems, this work proposes an IoT-enabled solid waste management approach for smart cities. The proposed layout includes a LoRaWAN gateway, a sensor-enabled anti-littering system, and a bin monitoring system with a GPS module, which are used to track bins in public and residential regions. This approach infers the location and the level of the garbage can, processes the information, and sends it to a central monitoring station for storage and analysis. The garbage collection authority may observe and assess the unfilled status of each trash can, due to an evident Graphical User Interface. Numerous data have been gathered to validate the suggested system architecture, and direct visits to the dump yards have been made in order to analyse the current scenario. As a result of the proposed smart waste management solution using IoT, the life expectancy of living things is said to increase, and this will be clearly visible.

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1. Introduction

A smart city is one that incorporates digital technologies into its infrastructure, services, and networks. “One that makes optimal use of all the interconnected information available today, to better understand and control its operations, and optimize the use of limited resources," is what a smart city is, according to IBM. To provide linked solutions for the general public, it combines an array of software, user interfaces, and communication networks with Internet of Things (IoT). The IoT is a network of linked devices that connects and shares data.

Data compiled from these devices is archived on servers or in the cloud, allowing for increased efficiency in the public and private sectors as well as enhanced economic performance and standard of life for inhabitants. The smart city develops, implements, and promotes development methods to address urban challenges using a framework of technologies associated with information and communication. The management of solid waste is one among these urban challenges, and is referred as the process as a whole of collecting, treating, and disposing solid wastes. Additionally, it offers suggestions for recycling materials that don't belong in the trash or garbage. Waste management is all about transforming solid waste into a useful resource.

Unsanitary conditions led by improper municipal solid waste disposal can result in environmental contamination and epidemics of vector-borne diseases, referring to illnesses spread by rodents and insects. Several tonnes of solid garbage are disposed on a daily basis at various landfill locations. These landfills emit a bad stench. If garbage is not adequately managed, it can have a negative impact on the environment, wildlife, and human health. Any system that makes use of technology to increase the effectiveness, affordability, and environmental friendliness of trash collection is referred to as waste management.

Implementing IoT and associated technologies can successfully address some of the major issues with Solid Waste Management (SWM). The adoption of waste management solutions as a whole can benefit significantly from IoT-enabled waste collection and transportation. IoT technologies can be employed in particular by municipal corporations that have contracted out the task to independent contractors to track and monitor the effectiveness of those contractors. The problems of monitoring and clarity can be effectively solved by the

deployment of smart bins, tracking of garbage pickup vehicles and sanitation staff, route optimised functioning for trucks, cross-checking of trash weight, etc.

IoT-enabled solutions can also assist in trash segregation at the stage of waste generation, greatly benefiting the subsequent phases of the lifecycle. By equipping currently used trash cans with sensors to turn them into "smart bins" and by implementing an anti-littering system using microcontrollers and sensors, the amount of garbage dumped in open areas might be significantly reduced. These sensors pick up the data and send it through the existing cellular infrastructure to a server set up in the city's data hub. Waste is tracked to make sure it is moved and handled in a way that helps stop forbidden waste management activities and to lower the amount of fuel used by the trucks that collect garbage. Trash collection systems incorporate GPS modules to manage and track movement as well as streamline collection routes. The garbage that is collected is recycled into a variety of useful goods, such as manures, fertilisers, vermicompost, eco-bricks, plastic roads, etc. As a result, IoT is effectively used to control solid waste in smart cities.

2. Existing System

A. Details of the Implementation of Existing Method of Solid Waste Management

Five prevalent problems can be identified with regard to municipal solid waste management: insufficient service protection, inefficiency in the operation of services, confined reuse and recycling activity usage, inadequate treatment of non-industrial toxic materials, as well as specific difficulties with solid waste disposal in its entirety. Around 42 million tonnes of solid waste are currently produced annually in India. Waste generation ranges from 200 to 600 kg per person per day, whereas collection effectiveness is between 50 and 90%. Most generated wastes are domestic waste, household waste, municipal trash, biomedical waste, hazardous waste, industrial waste, agricultural waste, and radioactive waste.

Waste management entails handling toxic, liquid, gaseous, or solid materials. If not properly gotten rid, non-biodegradable and toxic wastes like radioactive remains have the ability to pose a threat to both the environment and people's health. Here are a few techniques of existing system for disposing of waste: landfills, recycling, composting, burning, fermenting, and animal feeding. Composting would be a superior way to dispose of waste because it turns organic waste into nutrient-rich fertiliser, even though organic waste like paper and food may also be recycled. The process of converting non-recyclable garbage into heat,

power, or fuel utilising renewable energy sources including anaerobic digestion and plasma gasification is known as Waste to Energy. The removal of contaminants, harmful substances, and pollutants by bioremediation is an additional method for getting rid of the hazardous material.

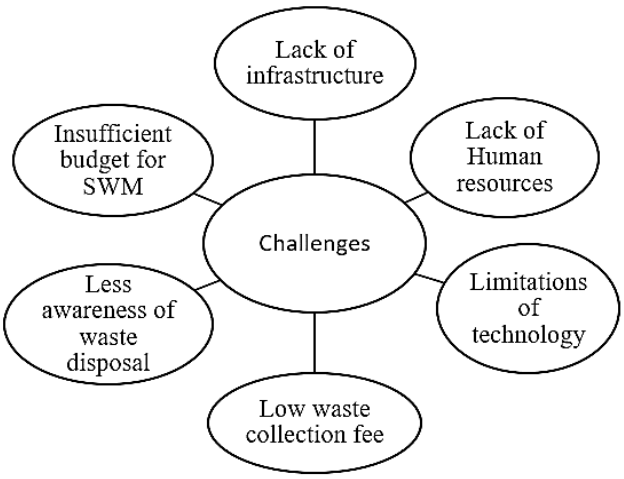

Figure 1. Existing system challenges in Solid Waste Management

The government is unable to sort and treat all the wastes that have been collected, and the segregation is done in unsafe and dangerous ways that lay the health of waste collectors at risk and might result in casualties. Garbage accumulates in vacant sites, sewage lines, and on the streets, and mixed garbage is dumped in the landfills as a result of lack of infrastructure and incompetent safety measures.

Often, societies begin garbage reduction, segregation, and composting initiatives with sufficient engagement but gradually lose interest and fall back on old routines of collecting waste and yielding more waste. To ensure that no moist waste is dumped in the municipal waste in the absence of information and supervision, composting corporations can further recruit volunteers, guards, and sanitation workers.

The existing methodology uses three approaches for attaining sustainable solid waste management. Reduction approach deals with the per-person usage of natural resources using one or more of the following strategies such as making more robust purchases, by purchasing more energy-efficient cars, homes, and appliances, by reducing expensive purchases to lower consumption and also limiting products to use less material overall. In an effort to reduce the use of new resources, proponents of the reuse strategy urge for constant utilization of materials.

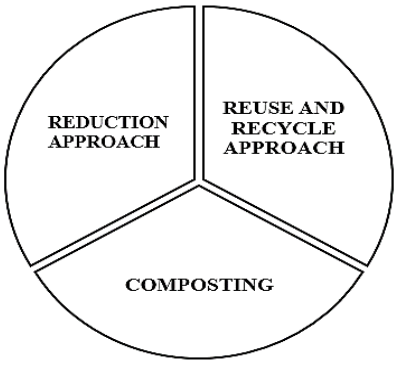

Figure 2. Approaches of Existing system

For instance, donating boxes, clothes, and appliances that would otherwise end up in the trash. Recycling is a type of reuse that typically entails changing the material's state from one to another. For instance, before making new glass, an existing glass needs to be crushed and melted. When organic material, including kitchen scraps, yard leftovers (leaves and branches), and even paper and cardboard are allowed to degrade, a sort of recycling takes place.

B. Problems with the Existing Methodology

Limitations over the prevailing technique are:

a) When the wind changes, an offensive stench is released that irritates nearby inhabitants.

b) When garbage is burned, harmful by-products from burning rubber, plastics, and other materials fill the air in the form of black smoke.

c) If the soil or rock is porous, there may significantly runoff that contaminates the groundwater.

d) Rotten trash releases methane, a gas that may be explosive.

e) When plastics and other materials containing chlorine are burned, they release a harmful group of substances known as dioxins, which have been linked to cancer and weaken the immune system.

f) The current SWM approach is not always economical.

g) Pollution may result from waste that should have been processed by humans, but instead ends up on the soil or other land.

h) The adverse effect that pollution has on the world's climate is a major problem that arises from all types of pollution.

i) Other consequences include habitat loss, decreased biodiversity, and the extinction of flora and fauna.

3. Proposed System

The suggested methodology combines two modules: gathering waste and processing it after it has been gathered. To achieve exceptional outcomes in the field of waste management, two structural components are combined. For the creation of a module for an IoT-enabled waste management system for smart cities, each garbage can is equipped with a GPS module and an ultrasonic sensor to detect the level of rubbish inside. The components are powered by a solar panel, battery, and solar charge controller, ensuring portability and clean energy for the garbage containers.

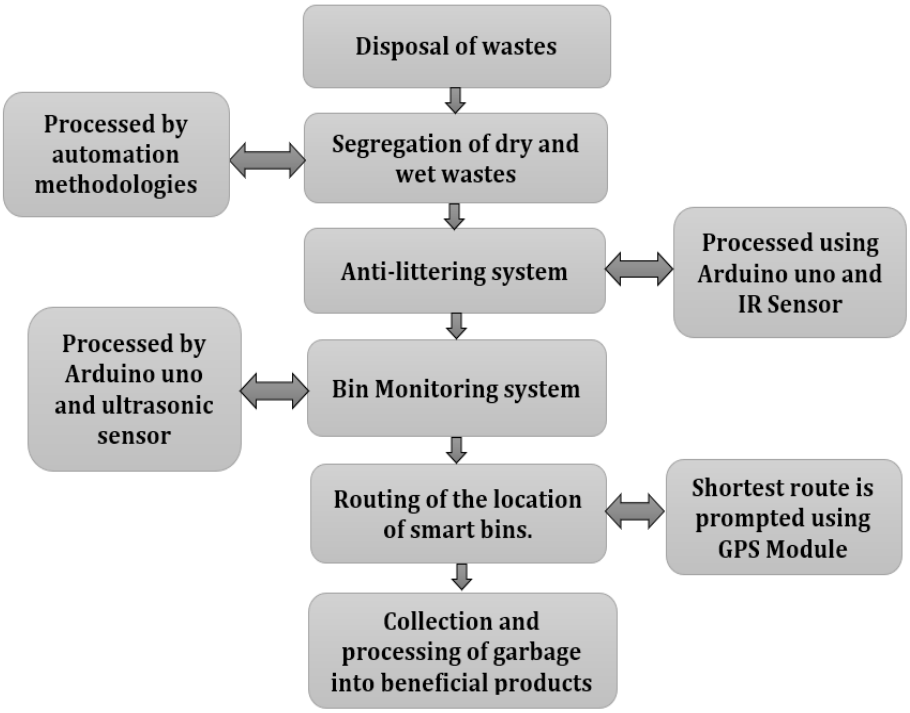

Figure 3. Block diagram of the proposed system

Progression communicates data via embedded sensor systems, a LoRa gateway, and microcontrollers. The continuously sensed data from trash cans is saved on a cloud server and

is accessible to both the waste management authority and garbage pickup truck drivers. Once the waste in the disposal container reaches a certain level, a signal is sent for its collection, and garbage collection truck drivers are assisted by directing them via an Android application along the quickest route for greater optimization.

The waste containers are gathered and separated into dry and wet waste categories, making it easier to identify recyclable material and keep it useable without degrading. Wet garbage is composted while the dry waste is separated and recycled. Wet trash is primarily made up of organic materials and is extensively employed as fertilizers and manures, while plastics, metals, and glasses are recycled based on their individual qualities. Producing real-time data on garbage disposal at different places is one way to automate waste collection processes. Environmental contamination will be significantly decreased owing to the brilliant IoT-based apps. The recycled goods can potentially be utilized for additional benefit.

A. Modules of the Proposed System

In this proposed system, five stages of modules are categorized as follows:

Segregation

Anti-littering System

Bin Monitoring

Collection & Routing

Recycling

It is impossible to understate the essence of waste segregation in the world. The first stage in an execution waste management plan that will assist in protecting the environment and enhance the quality of the breathable air, is waste segregation. Starting at the domestic level, waste management is rather simple to implement. Even a few slight changes make an enormous impact. It is because waste segregation makes recycling considerably simpler, and is also a financially advantageous idea.

Additionally, it encourages the efficient use of the resources and aids in their preservation for future generations. Waste can be divided into two categories: wet waste and dry waste. Dry waste can be further divided into recyclable and non-recyclable wastes under

this classification. Garbage segregation is a proactive approach that makes utilizing and processing garbage into multiple beneficial goods, easier.

Littering is the improper disposal of garbage. Although leaving trash behind can be done knowingly or unknowingly, doing so can have detrimental effects on the ecosystem. Effective waste management has emerged as a critical concern for the environment. Many people disregard the trash they leave behind in public and natural areas. Even locations that are supposed to be safeguarded are contaminated with garbage. Avoidance of littering is everyone's obligation in order to safeguard people and the environment. There are several problems and causes associated with littering that have an impact on living things.

Bin monitoring systems quickly identify, classify, and sort waste using microcontrollers, sensors, and machine learning. By integrating IoT sensors, smart bins can continuously monitor the amount of waste being generated. Artificial Intelligence (AI) algorithms can communicate information to the appropriate authorities to share garbage collection and routing data. The fact that the trash cans are frequently not cleaned indicates that there is no sufficient maintenance being kept on cleaning the bins. Smart waste management and monitoring systems need to be implemented to prevent this. And in order for these smart systems to be adopted, there needs to be a conceptual change in support of IoT technology. This will assist in streamlining the waste management process and lowering the amount of fuel that the current system requires. IoT technology has been used to construct a smart garbage management and monitoring system that has been shown to be highly useful for environmental issues.

The garbage level in the bins is detected by an IoT sensor called an ultrasonic sensor in the bin monitoring system. The system is programmed to determine a threshold level in the trash cans; when the trash reaches the threshold level, the system notifies the corporate and requests that the trash to be collected as soon as feasible. For optimal maintenance, the Municipal corporate officials are routinely updated on the bin's level. Even if the amount of trash in the bin is below the threshold, it must nevertheless be picked up every two days in order to maintain a healthy environment.

There are many methods and tactics for increasing the collection of solid trash that can reduce expenses and boost effectiveness. These tactics can range from straightforward operational adjustments to significant day-to-day collection changes. These methods can be used to numerous forms of routing and are frequently based on common sense. Nowadays,

there are various possibilities for automated routing with the help of technological advancements. The biggest cost reduction opportunities often lie in the collection sector because these expenses account for between 40 and 60 percent of the overall expenditures associated with the solid waste management system.

Recycling of solid waste includes reusing manufactured goods. Reducing the amount of garbage produced, composting, incineration, and landfills are all parts of an integrated strategy to solid waste management that also includes recycling and recovery. Recycling is a crucial method for preventing a lot of solid waste from ending up in landfills, saving resources, and reducing energy use. Recycling technique encompasses collection, separation, material preparation to buyer criteria, and market sale. Recycling transforms things into useful resources from waste that would otherwise be thrown away. Less solid waste is produced when recycled materials are used. Recycling aids in lowering pollution levels in the environment.

B. Role of Artificial Intelligence

Environmental sustainability, trash recognition, and waste from space are a few of the issues that artificial intelligence is assisting mankind with. Artificial intelligence is capable of analysis, prediction, and guidance. Researchers have been working on an effective and scalable environmental monitoring system employing AI as a solution to the anti-littering system. The technology utilizes AI-based image recognition to identify those who don't properly dispose of waste and then cautions them with a pre-programmed notice.

The proposed system is developed with the use of AI and IoT. When a person does not properly dispose his waste in the garbage can, an alert will sound to remind him to do so. In this system, the sensor detects the presence of humans near the trash cans. The region where littering may occur is always being watched by the surveillance camera. Data is automatically and continually kept in the cloud, including photographs that have been collected and behaviours related to littering. The municipal authorities will receive the stored data for subsequent action. If someone is observed littering, they have to deal with penalties. The Municipal Corporation intend to carry out this action using the data listed on the website. To ensure correct waste disposal in the corporation's trash cans, each person must register themselves.

C. Analysis over prevailing situation

The key problems in today's Municipal Solid Waste Management include inadequate service coverage, service operating inefficiencies, restricted recycling activity utilisation, insufficient management of non-industrial hazardous waste, and insufficient landfill disposal. On average, garbage generation ranges from 200 to 600 kg per person per day, and collection effectiveness is 50 to 90%. Wastes are disposed through solid waste management, land filling, and incineration. Under the present solid waste collection programme, door-to-door collection of municipal waste has been adopted to reach 95% of households. This requires a total of 19109 personnel, including permanent employees, panchayat workers, maintained workers, and workers hired by private contractors.

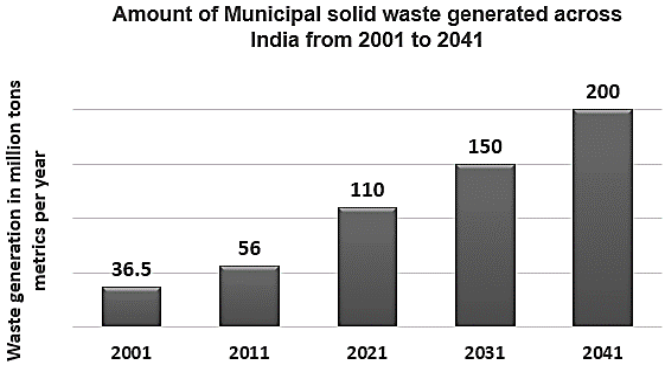

Figure 4. Solid Waste Generation across India

The current scenario over the waste management system is studied for a particular district in Tamilnadu, Coimbatore as an instance. Pushcart employees and waste truck drivers collect trash, transport it to bins, and then transport it via lorries to transition ports. The trash is compressed at the two transit points, Peelamedu and Ukkadam, to transport it to Vellalore for processing. Even though each plant's daily operational limit is 200 tonnes (20–25 tonnes per hour over an eight-hour shift), they recently began processing at least 300 tonnes per day. The garbage is gathered and deposited in bins, but the corporation fails to recycle or dispose it the same day.

The corporation gathered 1,000 to 1,100 tonnes of garbage in a day. At the two transit stations, it delivered about 600 tonnes of trash each day, which the Coimbatore integrated rubbish management company pvt. ltd. then transported to Vellalore for processing. The corporation processed only 30 tonnes of the remaining 500+ tonnes at the micro compost

centres and another 50 tonnes at its vermin compost facilities in Vellalore. The other 400+ tonnes were dumped in Vellalore in the open space.

It can be noticed that, even in one particular part of the state in India, it's been highly challenging to get rid of all the waste which is generated per day. Hence the management system which prevails currently need to be reorganized via smart management system, so that the key notes of challenges can be overcome and it will also benefit in obtaining a sustained and improvised healthy environment.

Table 1. List of Analysed Data – Current Scenario

AREA OF THE CITY - COIMBATORE	257.36 Square Km
NO. OF ADMINISTRATIVE WARDS	100
QUANTITY OF MSW GENERATED:	815 TPD
QUANTITY OF WASTE COLLECTED	775 TPD
PER CAPITA WASTE GENERATION	550 gms
TOTAL NUMBER OF SLUMS EXISTING	173
NUMBER OF HOUSEHOLDS	5,06,009
COVERAGE DOOR-TO-DOOR COLLECTION OF WASTE	80%
AVAILABILITY OF LAND FOR WASTE DISPOSAL	654.54 Acres

D. Experimental System Progression

The objective of the IoT-enabled solid waste management system in smart cities research is to regulate waste disposal, keep an eye on how trash cans are used and maintained, routing of filled trash cans, and reproduce segregated wastes. By implementing a mechanism called "anti-littering system", will help to minimise the amount of solid waste pollution in the environment. This system employs a machine learning algorithm to alert people who litter in public areas rather than utilising trash cans. It accomplishes this by using speakers to alert them and by taking pictures of the people who litter using microcontrollers and artificial intelligence. The components used for antilittering system are Raspberry Pi, surveillance camera, speakers and power supply. Tensor Flow trained model is used to detect humans and objects.

The database programme MYSQL-RDS is used to store, view, and retrieve the information gathered from each home and neighbourhood. The waste management system

offers a productive platform for keeping track of, gathering, and disposing of waste from each home and community. Each record in a table is uniquely identified by the primary key constraint. Primary keys cannot have null values and must have distinct values. A field (or group of fields) in one table that refers to the primary key in another table is known as a foreign key. User_id and area_id are the foreign keys in this schema.

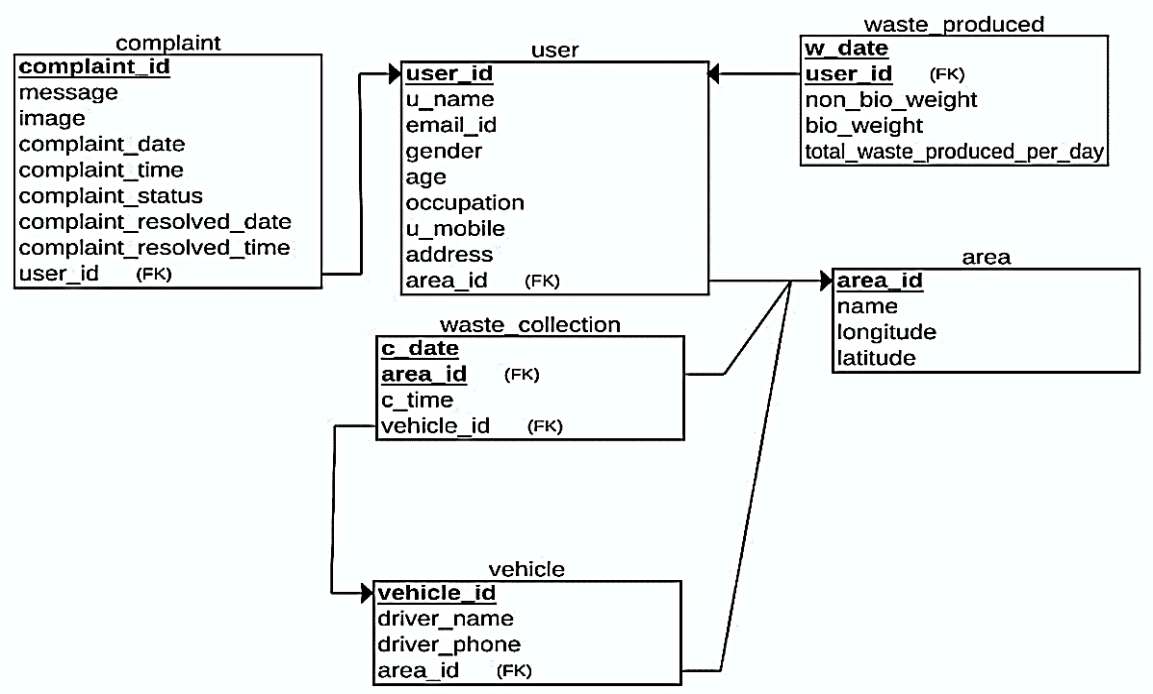

Figure 5. Schematic representation of Database Programme

Bin monitoring systems efficiently identify, classify, and sort waste using microcontrollers, sensors, and AI. By combining with IoT sensors, smart bins can automatically keep track of the waste levels. AI are able to relay information to the appropriate authorities so that details about waste collection and routing can be shared. The elements are Arduino UNO, ultrasonic sensor, IR sensor.

Employing IoT-enabled methods of handling solid waste for collection, segregation, anti-littering, bin monitoring, and recycling, aids to resolve this problem of waste management. By mounting a camera on a pole behind the trash cans, the camera feed is continuously processed using sensors, and a trigger function is programmed to detect people who are littering outside the smart bin, an anti-littering system can control and regulate the amount of waste that is typically dumped around areas since it is not governed by the municipality. The Internet of Things assists technically in limiting the amount of trash left on the ground and in sorting trash for future use.

4. Results and Discussion

The code for the data transfer is also created using Android Studio. The workings of the anti-littering system and bin monitoring system are compiled, and the output is obtained in the serial output of the Arduino IDE. The illustrations display the output of the smart solid waste management system in smart cities that is IoT enabled.

A. Serial Output of Anti-Littering and Bin Monitoring System

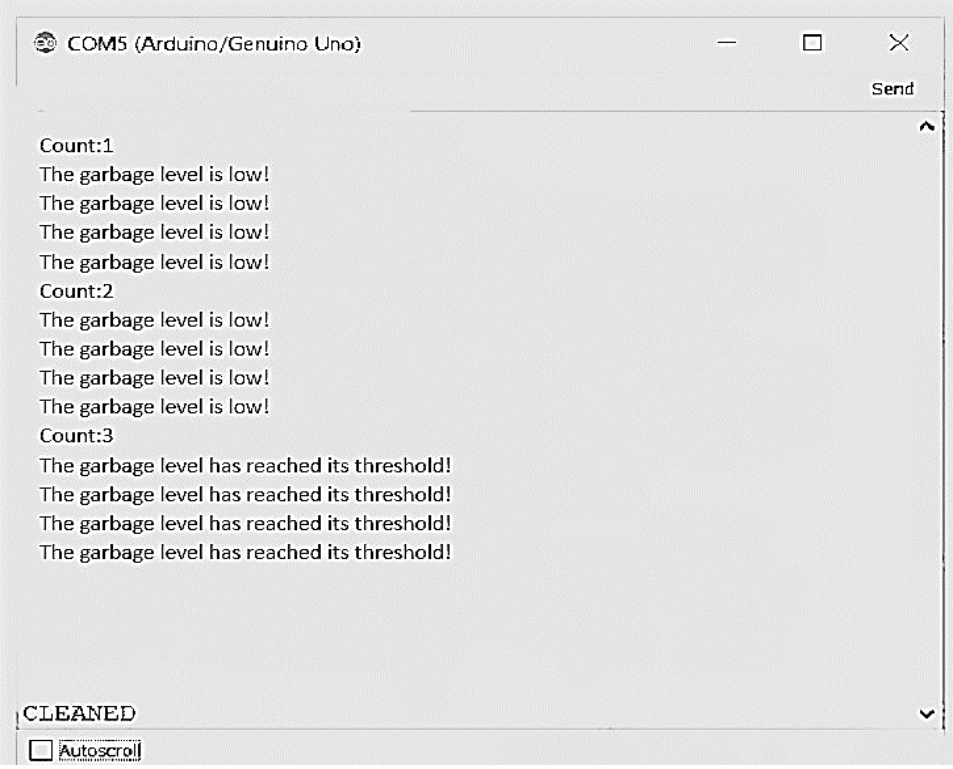

Figure 6. Serial Output

B. Android Software

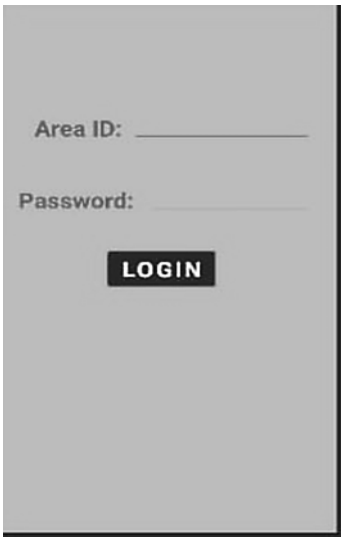

Figure 7. Web Login page

5. Conclusion

The key objective of the research is to manage solid wastes, which when left unattended can pollute the land and harm the ground's waste table. When these wastes are burned, they can also pollute the air and release greenhouse gases. These factors highlight the need for solid waste management, and as a result of this smart city solid waste management technique with the Internet of Things (IoT), a technical approach in gathering information and data analysis, which the municipality can use for various social consequences, has been developed. Additionally, littering in open areas can be controlled and recycled goods that can be used commercially can be obtained by effectively utilizing the IoT. As a result of this initiative, waste can be recycled into plastic toys, eco-bricks, blocks, ceramics, or tiles, while paper and degradable waste can be made into rough-use tissue paper, packing paper, paper cups, and other items. Additionally, manures and fertilizers can be created from the dry food waste. When segregation, anti-littering, and bin monitoring systems are correctly implemented, the need for raw materials and natural resources for the production of new products is significantly decreased.

6. Future Work

Future works will incorporate provisions, procedures, requirements, and implications that will improve the use of technology. A smart city with Wi-Fi routers should be created for better data transfer to the inhabitants and the municipality. People should be informed via

software about the level of trash cans and garbage pickup, which enables them to understand the value of waste segregation. The firm can inform the public about the useful items made from the waste materials gathered from a certain area, which encourages people to refrain from leaving rubbish lying around. Different tactics, such as circular economy initiatives, on-demand services, and Waste to Energy products, might be applied as post-marketing support through tax advantages and financial incentives. With the use of sensors, fully automated smart bins can be created.

References

[1] M. N. Jafar, M. Saeed, K. M. Khan, F. S. Alamri and H. A. E. -W. Khalifa, "Distance and Similarity Measures Using Max-Min Operators of Neutrosophic Hyper soft Sets with Application in Site Selection for Solid Waste Management Systems," in IEEE Access, vol. 10, pp. 11220-11235.

[2] S. R. J. Ramson, S. Vishnu, A. A. Kirubaraj, T. Anagnostopoulos and A. M. Abu-Mahfouz, "A LoRaWAN IoT-Enabled Trash Bin Level Monitoring System," in IEEE Transactions on Industrial Informatics, vol. 18, no. 2, pp. 786-795, Feb. 2022, doi: 10.1109/TII.2021.3078556.

[3] Artificial intelligence applications for sustainable solid waste management practices in Australia_ A systematic review – ScienceDirect.

[4] An overview of progress towards implementation of solid waste management policies in Dhaka, Bangladesh – ScienceDirect.

[5] A strategic review on Municipal Solid Waste (living solid waste) management system focusing on policies, selection criteria and techniques for waste-to-value – ScienceDirect.

[6] Assessing the transition of municipal solid waste management by combining material flow analysis and life cycle assessment – ScienceDirect.

[7] T. Zaki, I. T. Jahan, M. S. Hossain and H. S. Narman, "An IoT-Based Complete Smart Drainage System for a Smart City," 2021 IEEE 12th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), Vancouver, BC, Canada, 2021.

[8] A. H et al., "IoT assisted Waste Collection and Management system using QR codes," 2021 International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, 2021, pp. 1-4.

[9] Sustainable design of a municipal solid waste management system considering waste separators_ A real-world application – ScienceDirect.

[10] Solid waste management_ Scope and the challenge of sustainability – ScienceDirect.