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WASTE COLLECTION OPTIMIZATION THROUGH SOFTWARE LEVERAGING GPS LOCATIONS FROM CITIZEN-FILED COMPLAINTS

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ABSTRACT

In the face of relentless urban growth, our cities confront a growing challenge, effectively managing escalating waste volumes. This surge poses a significant threat to the crucial symbiosis between human activity and environmental harmony, vital for a sustainable future. Despite advancements like smart dustbins and routine garbage collection, conventional waste management methods fall short, often neglecting unorganized waste, a substantial contributor to the overall uncollected waste. This negligence perpetuates disease spread and persistent littering. To address these shortcomings, an innovative solution is proposed, seamlessly merging a software application with active citizen involvement. Developed with React and Node.js, supported by MySQL for robust database management, the system empowers citizens to report roadside garbage by uploading photos with precise GPS data collected via the JavaScript Navigator API. This information is stored in the database, providing real-time visibility to authorities for efficient task allocation. For filled dustbins, waste truck routes are optimized using the Dijkstra algorithm, enhancing fuel efficiency and time savings. The amassed data supports comprehensive area-wise, city-wise, and waste-wise analyses, marking a paradigm shift in waste management through a multifaceted approach that integrates technology, community engagement, and data-driven decision-making, promising unprecedented efficiency in waste collection processes.

Keywords: Efficient Waste Collection, Optimized Routes, Waste Prediction, User Complaints. Decision Making, Citizen Involvement.

I. INTRODUCTION

In recent years, cities have experienced significant growth, accompanied by an increase in both population and businesses. Consequently, our waste production has surged. Striking a delicate balance between human activities and the natural environment is paramount for ensuring a sustainable and healthy future. Over time, human actions have exerted a profound impact on the natural world. One major source of pollution, affecting the air, water, and soil, stems from our approach to handling municipal solid waste. This waste predicament is not confined to specific locations; it is a global challenge and particularly acute in developing countries like India. With a growing population, expanding industrialization, and improved living standards, the rate of waste generation is steadily climbing. However, due to financial constraints, we frequently lack a robust system for collecting and properly disposing of this waste. For a long time, we underestimated the environmental repercussions of inadequate waste disposal. Now, it is abundantly clear that improper waste disposal disrupts the entire ecosystem and threatens all forms of life. To establish a more efficient waste management system, it is imperative that we evaluate the current methods of waste collection and disposal. Waste management is a critical issue that demands attention. In urban India, approximately 62 million tonnes of waste (MSW) are generated annually, and it is projected that this figure will rise to 165 million tonnes by 2030. Regrettably, despite the substantial volume of waste generated, only about 11.9 million tonnes are treated. According to the Central Pollution Control Board (CPCB), in India, for the fiscal year 2020-21, approximately 76.4% of the 62.4 million tonnes of municipal solid waste (MSW) generated was collected. This means that a notable 23.6% of the waste remains uncollected, and within this uncollected waste, a significant proportion is classified as unorganized waste. The absence of a proper system for managing unorganized waste leads to widespread littering. This litter not only harms the environment but also poses health risks, disrupts ecosystems, reduces property values, and hinders economic development.

II. LITERATURE REVIEW

Waste management stands as an enduring challenge for urban centers worldwide. Rapid urbanization and population growth have compounded the complexities of handling municipal solid waste (MSW), resulting in improper disposal practices, environmental degradation, and public health concerns. Addressing these issues necessitates a comprehensive understanding of waste management, its underlying dynamics, and the innovative solutions that have emerged to combat the mounting challenges.

This paper addresses the critical issue of Municipal Solid Waste Management (MSWM) in Indian cities. It highlights the challenges caused by rapid urbanization and population growth, which lead to improper MSW disposal. This paper reviews various aspects of MSWM, including waste characteristics, generation, collection, transportation, disposal, and treatment technologies in India. It emphasizes the need for suitable infrastructure and proper management to combat this environmental problem. The study concludes with recommendations to encourage authorities and researchers to enhance the existing MSWM system for improved urban waste management in India.[1]

Presents a smart garbage management system designed for Indian conditions. The system employs ultrasonic sensors to measure waste levels in bins and uses GSM technology to send alerts to municipal authorities. It helps in efficient waste disposal and reduces manual monitoring efforts. The proposed system can significantly contribute to maintaining clean and healthy environments in Indian cities. Future enhancements could include gas sensors and user-friendly interfaces for civic bodies to manage multiple bins efficiently.[2]

Proposed model contains the sensor, the microcontroller, GPS, and GSM to detect if the waste bin is full. If the level of waste is high the sensor model will communicate with the GSM to send the data via the internet to the application being used in the monitoring center. The data will be containing the GPS coordinates of the waste bin and the level of waste. The municipal waste monitoring center will then send out waste collectors to collect the waste using google maps to help find quicker routes.[3]

Study explores the many definitions of garbage and looks at how waste management techniques have evolved historically. The writers contend that the definition of waste is arbitrary and that something that is regarded as garbage by one individual may be viewed as a resource by another. In order to create legislation for waste management that works, the article also addresses the significance of precisely identifying waste. Talked about several waste collecting techniques, such as community-based, mechanical, and manual collections.[4]

This paper delves into various waste classifications, regulations and the diverse methods employed for waste collection. Waste pickers, community bins, and door-to-door collection are among the different approaches. Door-to-door collection, predominantly administered by local government agencies, stands as the most prevalent method. Community bins are commonly located in public areas, serving as disposal points for residents. Waste pickers, on the other hand, engage in informal waste collection from streets, markets, and other public spaces. India faces several challenges in waste collection, including insufficient infrastructure, limited public awareness, and the presence of hazardous waste.[5]

Introduces an innovative system for efficient waste management on university campuses, focusing on a smart waste bin (SWB). Equipped with a hybrid scalar/visual sensor system and a dual-motor setup, the SWB accurately classifies and segregates waste. It leverages the 5G MEC architecture to reduce latency and energy consumption. The paper presents a SWB prototype and assesses its performance across various scenarios, highlighting the advantages of the MEC-based approach. Overall, it offers a well-conceived solution to enhance waste management on university campuses, with the note that individual waste disposal needs further consideration.[6]

Paper offers a comprehensive overview of solid waste management, covering waste categories, sources of generation, and the environmental and health implications of poor waste handling. Emphasizing the significance of integrated solid waste management (ISWM), the author acknowledges waste collection as a central aspect of this process. It's essential to consider the diversity of waste types in designing collection systems. It also highlights the challenges of garbage collection in informal settlements, underscoring the difficulties outlined in the paper concerning informal waste management.[7]

This article examines the connection between Sustainable Development Goals (SDGs) and solid waste management programs, suggesting that well-designed waste management can contribute to achieving various

SDGs. For example, it can improve public health, reduce greenhouse gas emissions, support economic growth, and job creation. The author mentions unorganized waste collection as an important aspect, which could be further elaborated in the paper.[8]

This study offers an extensive review of AI's role in smart city waste management. The authors explore AI applications in waste collection, emphasizing improvements in route prediction, recycling, and disposal. They also highlight the opportunities and challenges associated with AI in waste management. Notably, they point out the need for substantial big data sets to forecast waste generation patterns, potentially increasing costs. AI algorithms' ability to target high-waste areas is discussed. However, the paper raises the issue of limited information on unorganized waste for predictive purposes.[9]

Genetic algorithms (GAs) are a heuristic optimization method applicable to various problem domains, including municipal solid waste (MSW) collection and routing optimization. While GAs have demonstrated effectiveness in addressing MSW collection and routing optimization challenges, they may entail significant computational costs and sensitivity to parameter choices. Despite these issues, GAs remains a promising avenue for tackling MSW collection and routing optimization. As GAs continue to evolve and enhance, they are expected to play an increasingly vital role in the development and operation of MSW collection systems. However, information regarding the utilization of the best route algorithm for reporting and collecting unorganized waste can be helpful for the future implementations.[10]

The author proposed an embedded technology solution for waste management. This system monitors dustbins, alerting the waste management department when waste levels exceed a preset threshold. It can segregate waste by type and optimize collection routes using location data, reducing overflow issues within dustbins. However, it does not directly address garbage spilled outside of the bins.[11]

Proposed a smart waste management system to enhance urban waste control. This project involves monitoring garbage levels in real-time, ensuring rain resistance, and eliminating hazardous gasses. It optimizes dustbin management, with immediate access to data for municipal officers who can promptly notify waste collection drivers. This system spans multiple locations throughout the city and integrates IR, rain, and gas sensors, all coordinated by a central microcontroller.[12]

Tackles India's waste management challenges arising from population growth and urbanization. It underscores the necessity of an effective waste management system, emphasizing waste segregation and disposal. The paper reviews recent technological solutions, emphasizing convolutional neural networks for waste classification and favoring image processing over sensors. It also explores the role of IoT-based models for efficient waste management, focusing on sensor types and secure communication protocols for data transmission.[13]

Introduces an innovative waste management solution leveraging Internet of Things (IoT) technologies. It employs a smart bin system with sensors to continuously monitor waste levels in real-time. Data is processed through an IoT middleware, optimizing waste collection routes through GPS and providing valuable statistics for resource management. The system also engages citizens by offering access to waste bin information via a software application. With a real prototype and a practical experiment, the paper demonstrates how this IoT-based approach can revolutionize waste management, leading to improved resource optimization and community services.[14]

Underscores the crucial role of smart waste bins in contemporary waste management strategies. It highlights the importance of efficient waste bin monitoring and optimization. The research delves into various models of smart waste bins, including those equipped with object recognition, waste segregation capabilities, and automatic lid closures. These smart bins typically incorporate a range of technologies such as sensors, microcontrollers, communication modules, and display units to enhance their functionality. Despite the evident progress in smart waste bin technology, challenges like cost-effective implementation and widespread adoption, especially in developing nations, persist as important considerations.[15]

Proposed a simple IOT based architecture for garbage collection. For this, sensors are installed in bins. The data collected by sensors of a node(bin) is shared to the gateway via LoRa (Low power, long range) technology. MQTT (message Queue Telemetry Transport) is used to share the data to the cloud.[16]

This paper discusses a fascinating approach to collect waste from households. Bins are split in 4 based on type of waste (aluminum, paper, plastic, glass). Bins have some built-in mechanism for detecting the new added weight. Lid of the bins open only with an RFID of the user. The users are provided with RFIDs as identification on creating an account on their online platform. Users are rewarded for throwing sorted recyclable waste into the bins. The reward system takes three factors into account: type of waste (aluminum, paper, plastic, glass), its amount and weight. The users can exchange their points for some items or can redeem cash from banks.[17]

This paper proposed a software system that assists in planning and managing waste disposal. It deals with the issue of improper waste disposal by allocating and relocating waste bins based on surveys for the convenience of citizens. It also helps to maximize the usage of bins. Different types of bins are provided based on the previous waste collections so no separate segregation for recycling is necessary. There is no direct communication between citizens and waste management authorities. Instead, there is a message facility to send text messages on the authorities for inquiries etc. A hierarchical structure is created on platform administrator, middleman and users. Regional officers also get map interfaces to track and analyze the locations of bins.

In this paper the author proposed a web-based system to allocate / reallocate bins based on requirement and convenience of citizens and to manage and administer the entire organization. It provides a map interface for the officers to track all the bins. It also provides messaging features between officers and citizens for communication.[18]

This paper underscores the vital significance of precise Municipal Solid Waste (MSW) generation prediction in order to facilitate the efficient management of waste. It explores a spectrum of forecasting techniques, ranging from conventional methodologies like descriptive statistics and regression analysis to more advanced methods such as material flow models, time series analysis, and artificial intelligence models, including Support Vector Machine (SVM), Adaptive Neuro-Fuzzy Inference System (ANFIS), and Artificial Neural Network (ANN). These AI models have proven to be effective in forecasting MSW generation across various time scales. The primary aim of this study is to identify the most appropriate algorithm for forecasting MSW collected through kerbside service in the medium term, with the ultimate goal of improving waste management practices. [19]

In this research, a modified Backtracking Search Algorithm (BSA) is applied to the capacitated vehicle routing problem (CVRP) with the integration of smart bins to enhance waste collection route optimization. The study introduces the concept of the threshold waste level (TWL), which reduces the number of waste bins to be emptied by considering their fill levels, resulting in minimized travel distance and improved route efficiency. A comparative analysis is conducted between this optimized model and traditional collection systems, evaluating parameters such as travel distance, collected waste, fuel consumption, fuel cost, efficiency, and CO2 emissions. The findings demonstrate a notable reduction in travel distance, fuel consumption, fuel cost, and CO2 emissions, underscoring the potential advantages of this approach in terms of both economic and environmental aspects. This research effectively addresses the incorporation of real-time waste status data and an innovative optimization algorithm for more efficient waste management. [21]

This study addresses the challenge of improving predictive models for demolition-waste generation (DWG) with small datasets mainly comprising categorical variables in the construction and demolition waste management domain. The research introduces a novel hybrid model by combining the artificial neural network (ANN) and support vector machine regression (SVMR) algorithms, leveraging categorical principal components analysis (CATPCA) to convert categorical data into continuous form. This innovative approach substantially enhances prediction accuracy, offering a valuable tool for precise DWG estimation. The study underscores the significance of tailored data pre-processing and validation techniques for small datasets. Evaluation metrics like Pearson's correlation coefficient (R), root mean square error (RMSE), coefficient of determination (R2), and mean absolute error (MAE) are used to assess model performance. Among the models developed, the CATPCA–SVMR hybrid model emerges as the most effective, promising advancements in sustainable construction waste management. This research contributes to the progress of AI-driven predictive models in the context of construction and demolition waste. [22]

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III. METHODOLOGY

1. EXISTING SYSTEM

The current waste management systems encompass a range of methods.[5] This includes traditional waste collection methods: scheduled trips by garbage collection trucks to pick up trash from designated bins as well as to provide door-to-door collection service, and community-based initiatives from NGOs, schools or clubs. Schools and clubs also have city cleaning camps or beach cleaning camps on a periodic basis.

Nowadays, some advanced technologies are also integrated in traditional ways such as Internet of Things (IOT) and Artificial Intelligence (AI). Smart Dustbins with various sensors are used along with GPS tracking of bins to find the optimal path. Additionally, they can now sort waste into three main categories: dry, wet, and metallic materials [11]. There is also a growing trend in implementing AI-based models to predict waste generation in specific regions [9]. However, the current systems primarily target organized waste, often overlooking unorganized waste, which constitutes a substantial portion of the total waste that remains uncollected. Also generating datasets for these AI-based prediction models can be quite expensive.The utilization of smart dustbins with advanced features. These smart bins can send alerts to waste collectors when they reach capacity or if there are issues like garbage burning within them. Additionally, they can now sort waste into three main categories: dry, wet, and metallic materials [11]. There is also a growing trend in implementing AI-based models to predict waste generation in specific regions [9]. However, the current systems primarily target organized waste, often overlooking unorganized waste, which constitutes a substantial portion of the total waste that remains uncollected.

2. PROPOSED SYSTEM

The proposed waste management system introduces an accessible interface through a React.js-powered landing page, streamlining the process for users to report waste complaints. With an intuitive design, users can seamlessly upload photos of the waste site and categorize the type of waste, enhancing the clarity and specificity of each reported issue. The integration of the JavaScript Navigator API ensures an automatic retrieval of the user's location via GPS coordinates, ensuring accurate geotagging and providing authorities with a precise understanding of the complaint's origin. This systematic approach not only simplifies the complaint registration process but also lays the foundation for an efficient and organized database.

In the backend, the collected data, including geospatial details, photos, and waste types, is stored securely in a database. This centralized repository serves as a valuable resource for authorities, offering a comprehensive view of reported complaints. The administrative interface facilitates data-driven decision-making by incorporating Dijkstra's algorithm to optimize routes for authorities responding to complaints. This strategic approach ensures that resources are allocated judiciously, minimizing response times and improving the overall effectiveness of waste management efforts.

The heart of the system lies in the admin dashboard, where JavaScript libraries are employed to visually analyze and represent complaint data. Graphical insights into city-wise and region-wise complaint distributions empower authorities to make informed decisions. This graphical representation not only aids in real-time response coordination but also allows for historical trend analysis, enabling authorities to identify patterns and implement proactive waste management policies. In essence, the proposed system stands as a comprehensive solution, marrying user engagement with advanced technology to create a responsive and data-driven approach to urban waste management.

Utilizing a multi-tiered architecture with React.js for the front end and Node.js for the back end, our garbage collection system functions. The user-centric interfaces of the frontend allow users to report complaints using simple forms featuring radio buttons for different categories of complaints, the ability to upload images for visuals of waste sites, and the ability to retrieve the exact location of the complaint using live GPS data. Using strong authentication and permission procedures to guarantee safe login procedures, a network of API endpoints on the backend handles worker assignments, user complaints, and administrative functions. The SQL database utilized by the system to store user information, complaint details, worker assignments, and pertinent admin data—including picture URLs associated with individual complaints and users—is designed to maintain data integrity.

To protect data and guarantee controlled access for varying user levels, security measures include strict authentication methods and role-based access control. The system is deployed to a dependable server or cloud infrastructure with an emphasis on scalability and performance after undergoing thorough testing methods that ensure seamless functionality and address potential vulnerabilities. Strategies for continuous development, such as regular updates and feedback integration, support the system's evolution and promote a flexible and effective waste management solution.

Block Diagram:

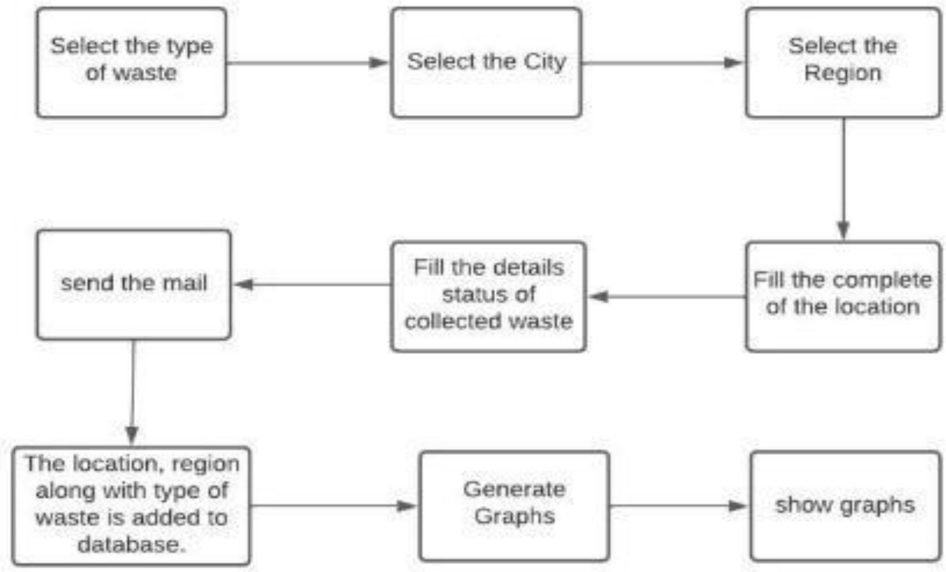

Fig 1: Overall Portal Process

Box 1 – As the user enters it selects the type of waste to add a complaint about littering waste on road.

Box-2 – After selecting the type of waste user select the city.

Box-3 – Then it selects the region of a city.

Box -4 – Then it fills all details like exact address and exact details.

Box-5 – Then the user clicks on the send email button to register a complaint.

Box-6 – All details of complaint are added to the database and email is sent to the concerned authority according to the area.

Box-7- Graphs are generated according to data like city regions and their respective number of complaints.

Box-8 – Graphs are shown.

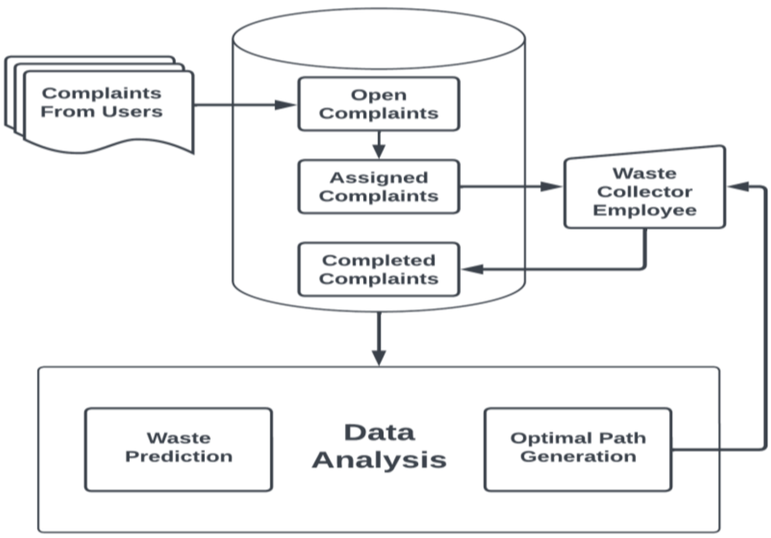

Fig 2: System Architecture

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In Figure 2 the complaints are received from users through user interface along with user location. These complaints are stored in database and made available to admin for assigning the work to different workers based on their area. After work completion workers can also upload the completed work photos. Also optimal path is suggested for waste collection and various graphs can be generated depending on the received data.

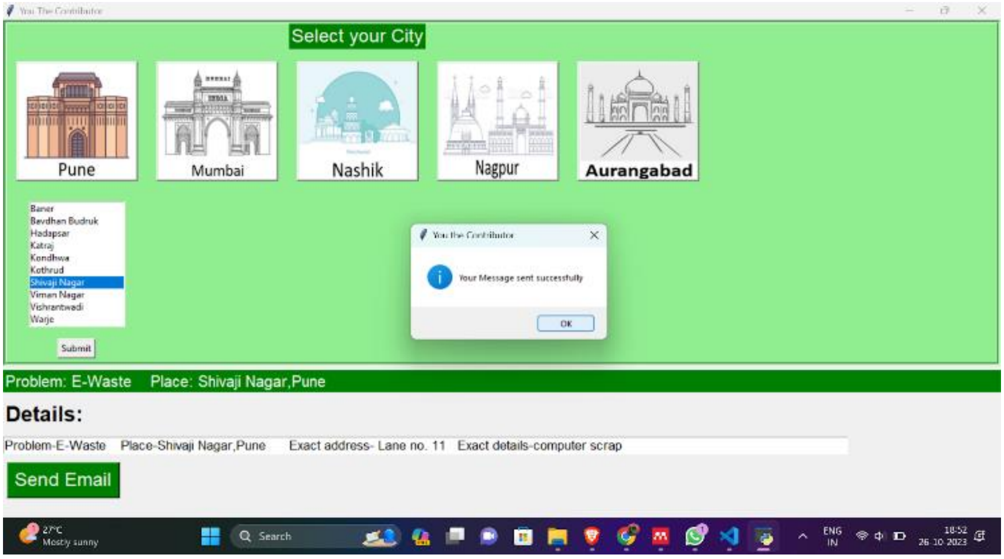

Fig 3: Complaint reporting by user

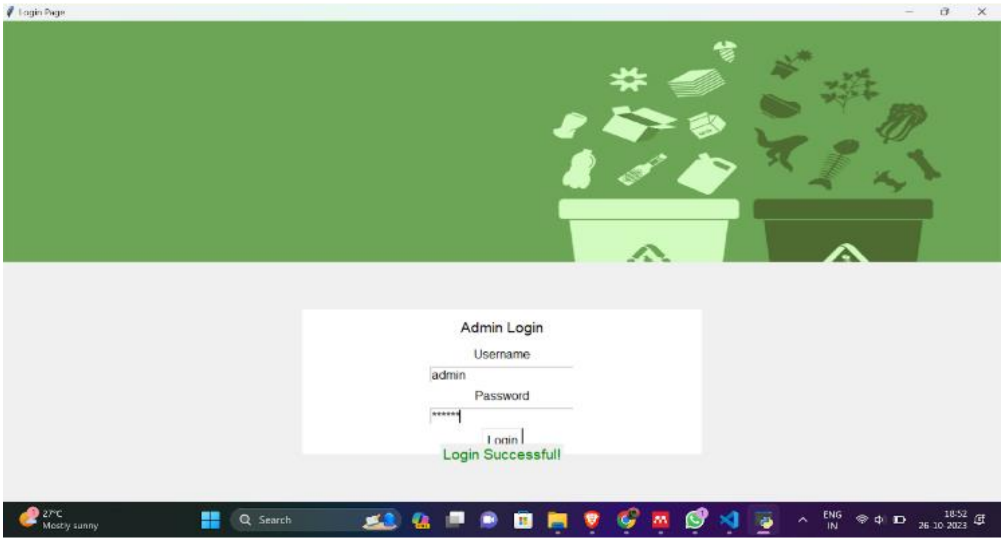

Fig 4: Admin Login

IV. CONCLUSION

In summary, The proposed waste management system, employing React.js and Node.js, provides a user-friendly interface for streamlined complaint reporting. The integration of GPS coordinates and secure SQL databases ensures accurate geotagging and robust data storage. With strong authentication and role-based access control, the system prioritizes security. The admin dashboard, powered by JavaScript libraries, offers graphical insights for real-time and historical trend analysis. Key features include route optimization, real-time updates, and an AI-based waste prediction model, promoting citizen engagement and efficient resource allocation. This holistic and technologically advanced approach bridges citizens, technology, and data, promising an effective and community-centric strategy for solid waste management, contributing to sustainability and environmental responsibility.

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