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Vacuum Tube-Based Train Waste Collection and Segregation Technique

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***Abstract*— The Indian Railways have significant problems with inappropriate management, which is crucial to preserving a clean environment and public health, as a result of poor infrastructure, low commuter knowledge, and a lack of recycling facilities. The research article advises the use of vacuum tubes dispersed throughout each compartment of each coach as well as an Internet of Things-based monitoring system to keep track of waste levels in order to address these difficulties. According to the suggested method, waste should be gathered, segregated, and stored in specified places, transported to processing facilities, and treated in line with local legislation while also being monitored and reported on waste management practices. The suggested remedy's efficacy and efficiency are evaluated, together with any potential advantages for the economy, society, and environment. The only difference between the two design concepts used in the study experiment—one with a single coach and the other with three coaches—is the number of vacuum pumps used. The research's findings assist the long-term expansion of the railroad industry and provide relevant information about managing ecologically friendly train garbage. The study highlights the significance of healthy and environmentally sustainable waste management practices. It emphasizes the possibility for the suggested strategy to be more widely adopted in the railroad industry.**

***Index Terms*—Waste Management, Indian Railways, Vacuum Tube, Waste Segregation, IoT, Failure Detection.**

I. INTRODUCTION

Indian Railways is one of the largest in the world, with the third largest global train network. Despite occasionally running late, the rail system is efficient. In India, up to 20 million passengers travel daily on trains that connect around 7,500 stations across a distance of more than 60,000 kilometers, and each person generates 670 grams of rubbish each day on average. This means that Indian Railways alone manages more than 15,000 Tonne of waste per day. How to manage train generated waste has been the railway industry's main environmental challenge for a long time. Lack of modern equipment that can handle the high pace of garbage production may be the root of this problem. It's important to properly dispose of solid waste from trains in order to protect the environment and the general public. Rail waste has been collected, transported, processed, and disposed of in a resource effective and creative way.

In order to minimize train waste, one such strategy that uses the Internet of Things (IoT) and vacuum tubes deployed throughout each compartment of a train coach is the subject of this study. For railway operations to be sustainable and responsible, waste management is essential. The objective of the waste management system for trains is to manage waste and dispose of it in a way that minimizes adverse environmental effects, creates the least amount of waste feasible, and optimizes the amount of waste that can be recycled. Despite being an ongoing issue, train waste management in Indian railroads has recently come under scrutiny. The infrastructure needed by Indian Railways to separate trash at the source is insufficient. The infrastructure for collection and transportation is ineffective.

Unawareness among regular travelers is a serious additional issue. Additionally, India's staff isn't sufficiently motivated to separate and compost rubbish, and there aren't enough facilities for recycling and composting.

The numerous wastes produced by trains must be properly managed. One of the most common forms of waste is passenger rubbish, which also includes paper, plastic, and food packaging waste produced while traveling. This garbage must be gathered and disposed of since it may accumulate fast, particularly during protracted train journeys. Another sort of waste produced by the crew is waste from the railway staff. Due to the necessity of these materials for their intended uses, plastic, cardboard, and paper are frequently utilized. Additionally, trash is produced as a result of maintenance activities, and this waste consists of chemicals, oil, and damaged pieces. To decrease their damaging effects on the environment, these wastes must be managed and disposed of in a certain manner. The numerous sorts of garbage produced in trains must be handled carefully and methodically. Trains may lessen their negative environmental effects and help to create a cleaner, more sustainable future by putting into place efficient waste management procedures. Waste management aboard trains must follow a multi-step, organized approach. The collection and separating of trash are the first stage. For effective processing, waste from trains must be collected separately based on kind. To lessen pollution and guarantee proper disposal, the second step is to keep garbage in a designated place. The third stage, transportation, necessitates sending garbage to certain facilities for processing in order to lessen its environmental impact. garbage management must be done in accordance with local laws during the fourth stage of disposal, which focuses on recycling and minimizing the quantity of garbage delivered to landfills. Finally, it's critical to track and document how well train operators adhere to environmental laws. To make sure these standards are satisfied, ship operators must keep track of and report on their waste management efforts. By putting these strategies into place, railway trash may be managed sustainably and effectively, minimizing any adverse effects on the environment and encouraging a cleaner future.

Recycling may be encouraged, trash can be decreased, and the environmental impact of train operations can be reduced with effective waste management. Sustainable ship management must include waste management. The "Swachh Rail, Swachh Bharat" campaign, newly introduced by Indian Railways, aims to enhance the cleanliness and hygienic conditions of rail infrastructure and trains. Additionally, several stations have incorporated waste management programs. To properly solve the issue of waste management in Indian Railways, however, additional considerable and ongoing efforts are required. Effective waste management may promote recycling, cut waste, and lessen the environmental effect of train operations. In order to operate ships sustainably, waste management is essential. The Indian Railways has introduced the "Swachh Rail, Swachh Bharat" campaign, which aims to improve the cleanliness and hygienic conditions of rail infrastructure and trains. At some sites, waste management systems have also been put in place. But substantial and ongoing further efforts are required to overcome the waste management issue in Indian Railways. The station manager will get the gathered data so that he may make arrangements for their correct treatment at the station. This study will assess the efficacy and efficiency of this waste management method as well as any possible advantages it may have for the environment, society, and the economy. This study will also look at how resource usage regulations and other variables impact solid waste management methods in the railroad sector. The findings of this study can help the railroad sector's long-term expansion by revealing vital information on responsible waste management.

The waste classification, as presented in Table 1, shows that different types of waste were generated in the railways. It was observed that plastic bottles were the major waste generated by the people, with a value of 23.33%, followed by garbage, with a value of 18.66%. Table 1 indicates that disposal goods were also generated in the railways with a value of 16% compared to reusable packaging waste at 15.33%, plastics at 14.70%, and food waste at the least with a value of 12%. However, this result shows that most of the waste generated in the area is biodegradable compared to non-biodegradable waste, which, when decomposed, can harm human health.

TABLE I
DIFFERENT TYPES OF WASTE GENERATED IN RAILWAYS

Variables	**Frequency**	**Percent**
Garbage	28	18.66
Plastic Bottles	35	23.33
Disposal Cutlery	24	16.00
Packaging Waste	18	12.00
Can	23	15.33
Food Waste	22	14.70

I. LITERATURE REVIEW

To run efficiently, train systems must have good waste management. Along with the population growth and urbanization, the amount of waste created by railroad systems has significantly increased. One of the primary sources of waste in rail networks is garbage produced by trains. Recent research has shown that vacuum tube-based waste collection and segregation techniques are a promising option to handle the garbage created by train systems. Vacuum tube-based rubbish collection and segregation systems are used to gather garbage from various railway compartments and classify it according to its type. Following that, vacuum tubes are used to transport the trash to a central collection station. Since the system is so automated, human input is only infrequently required. In comparison to vacuum tube-based trash collection and segregation systems, traditional waste management techniques provide a variety of benefits, including less exposure to rubbish, less air pollution, and more efficiency. Many studies have looked into the collection and sorting of train trash using vacuum tube-based techniques.

Ramya Srikanteswara et al. [1] conducted research on the Internet of Things (IoT) for train waste management. Waste management in the railroad sector includes the collection, transportation, treatment, and disposal of waste as well as monitoring and regulation. The authors proposed a technique for waste collection from moving trains that would make use of sensors that would detect waste in the tank and transmit that information to cloud computing. The station manager can then obtain data on waste levels using cloud computing to make plans for disposal at the railroad station. Using this innovative method of waste management on trains, trash disposal efficiency might be improved and human intervention might be reduced.

Raghuram et al. [2] address the issues with waste management and sanitation in Indian railways given the significant distances and volume of passengers it transports. The authors assess present sanitation system flaws and compare them to global railroad standards. They discuss the practical challenges of waste separation and disposal in addition to the behavioral changes that travelers must undertake to maintain personal hygiene. The paper, which also looks at successful waste management practices from Indian towns, makes a number of recommendations, including a seat-to-seat garbage pickup system, spot fines for littering, and smart dustbins. The authors urge private companies implement an integrated waste management strategy that links every stage of the waste hierarchy's value chain, from prevention to treatment and reuse.

Plastic bottles and wrappers were among the trash produced by railway passengers that was investigated by Senthil Kumar et al. [3] and frequently thrown out of train windows. They proposed setting up a garbage collection system outside the train windows to address this issue. The extending hinged support for the aluminum alloy collector runs the length of the compartments on both sides of the train. Passengers can dispose of their trash using a door mechanism, and the accumulated trash is removed using a screwing mechanism. Meanwhile, placing the trash collection outside the train would reduce its aerodynamic efficiency. The experts carried out computational and experimental experiments to compare the aerodynamic performance of the train with and without the waste collector. They used CATIA to model the reference component and conducted simulations in Ansys Workbench 16.2. They also tested a 1/45 scale model of the train in a wind tunnel and compared the results with numerical simulations.

D. Krishnakumar et al.[4] have found a solution to the problem of handling solid waste in Indian railroad wagons. The group's objective is to collect solid waste that passengers have thrown out the window and recycle or otherwise make use of it. Two parallel window frames are arranged between a system of two conveyor belts. Four collecting tanks are connected to each pair of the conveyor belts. Both a GSM module and an ultrasonic level sensor are present in these tanks. Two outlet pipes located inside the coach feed the trash onto the conveyor. The system is housed inside of a casing that spans the window's parallel frames. Inside the coach, each coop has a switch that starts the conveyor belt when pressed, preventing it from running unnecessarily. The team's solution aims to address the issue of solid waste management in railway wagons and contribute to a cleaner and more sustainable environment.

Abhishek Gawande [5] raised the issue of Indian Railways' poor garbage management, which has a detrimental effect on the environment [5]. To come up with solutions, a survey of passengers using a detailed questionnaire and in-person interviews was conducted. The waste management system of Indian Railways was discovered to have significant problems. The recommended solution is an extensive rubbish collection system that would ensure waste is correctly segregated and disposed of in all coaches, reducing the impact on the neighborhood ecosystem. The findings of this study might be useful for further investigation in this understudied area.

D. Nakou et al. [6] looked researched the financial and environmental effects of using an underground automated vacuum garbage collection system (AVAC) in place of a conventional garbage collection program in Athens. The study found that, when utilizing the equal annual cost technique (EAC), the cost performance of both systems was comparable, but that the AVAC system had significantly lower operational expenses and better environmental performance. The authors suggest pursuing AVAC systems because they provide equivalent financial performance and better operational and environmental attributes than traditional systems.

Dolores Hidalgo et al. [7] discuss the challenges of using traditional waste collection methods, especially in historic city centers with crowded streets and limited space for trash. These challenges go against the goal of maintaining the hygiene and cleanliness of tourist destinations, which can make sorting at source difficult. An innovative solution to these problems is underground vacuum waste collection. By using vacuum technology to move waste through an underground pipe system, this waste management concept significantly reduces CO_2 emissions compared to traditional collection methods. This method can be used for buildings, housing projects, communities and even entire cities.

According to Cesar Fernandez et al.[8], developing smart cities through the integration of IT and traditional infrastructure is important to improve urban sustainability. Automated vacuum waste collection (AVWC) is an innovative method that uses air suction and a closed network of underground pipes to move waste from collection points throughout the city to a central collection location. While minimizing the disadvantages and greenhouse gas emissions associated with traditional waste technique. One of the main issues of smart cities is waste management. Energy consumption represents a significant operating cost for an AVWC system. Therefore, the authors developed a constrained integer programming (CIP) model to reduce energy consumption by organizing daily discharge sequences at warehouse locations. The paper describes how to model this problem using CIP and reports experiments using real data from AVWC systems in different cities, demonstrating that CIP is a suitable technology to reduce energy consumption quantity in AVWC.Ramo'n Be'jar et al. [9] identified urban waste management as one of the trickiest problems in modern urban planning and a major issue for local governments due to the growing urban population and increasing rubbish production. Automated vacuum waste collection has emerged as a practical substitute that enhances waste recycling and reuse while reducing greenhouse gas emissions and public discomfort. However, because air impulsion requires transporting substantial amounts of trash, planning and scheduling waste collection must put a strong emphasis on limiting energy consumption. This project offers a chance to put computationally sustainable artificial intelligence methods into practice and show how well they can handle complex urban rubbish management problems. The garbage will be transported from each of the seating places to a collecting facility using a vacuum tube-based system that will be built underneath each train cabin. We also support the system's use of Internet of Things (IoT) technology so that train operators can check on and maintain it from a distance. There will be fewer system outages since operators will be able to address problems with the system before they become serious. The waste is first transferred by tubes to a central region beneath the structure, and then via vacuum tubes to a central collection facility. This approach has received a lot of application in urban settings. Such a device consumes a lot of energy to function, but its sporadic activity makes up for it. Very little energy will be needed because the vacuum tube only needs to travel a short distance in a railway coach layout. The subject of implementation-related factors is covered in the section that follows. It also assesses the system's viability in terms of the expense, energy use, and maintenance requirements for train coaches. The various factors that need to be taken into account when developing the vacuum-based waste management system have also been discussed. There have been two design components highlighted. A three-coach model with shared vacuum pumps is displayed in the first illustration. There were a few issues that such a model posed, so another design has been considered where every coach has a vacuum pump. The design consideration has been backed up by the corresponding calculation for the component selection and the various design challenges that implementing such a system can have.

III. PROPOSED METHODOLOGY

A. Three Coach Model

In this configuration, waste from the three following coaches is gathered by a single vacuum pump using connected pipes. The total efficiency of the concept is largely attributable to the single vacuum pump's lower power consumption when used to power three coaches. In order to assure that a moving train would consume less resources and less power, the three-coach configuration was proposed. In this setup, a single vacuum pump regulates the pressure of a single succeeding coach on either side. But there are a lot of issues with this design. Instead of doing on-site repairs, Indian Railways often replaces a coach that needs maintenance with another coach. The length and number of curves of the connection line increase as a result of using a single vacuum pump to power three coaches, making it more difficult to consistently locate and attach the right coach. As a result, the system needs more upkeep, and if there is even a small leak in the connecting pipe, it eventually causes the system to stop working altogether. Complexity increases in the control of solenoid valves for vacuum flow and section-wise vacuum pressure actuation.

B. Single Coach Model

Single coach design with an independent vacuum pumpeliminates all the flaws in the 3-coach model. The wholedesign is divided into several parts.

- Main Bins: The main bin will be placed at the end ofboth sides of the coach where we can find the usualbins well in the current train coaches. This main bin will collect garbage directly from vacuum tubes connected to sub bins.
- Sub Bins: Sub bins will be placed near seating areas where garbage can be thrown through smaller vacuum tubes. However, the placement of sub-bins has to be done above the main bin on a height basis. In other words, the ground clearance from the main bin has to be half of the ground clearance of sub bins. These sub-bins will have sensors that will actuate the vacuum pump once the garbage is full. The vacuum pump will suck/push the garbage to the main bins.
- Vacuum Pump: The vacuum pump will be

placed between the bio-toilet tanks. This pump is connected with 3 coaches on either side using flexible straw-based pipes with solenoid valves to direct the Air/vacuum flow accordingly.

- Sensor array: The entire vacuum system will have sen- sor arrays attached at various locations, indicating the system's status and the level of garbage collected in the main bins.

Figure 2 shows the isometric view of the coach. The yellowcomponent is the waste collection point which acts as theoutlet for the passengers to put their waste. There would be 3 to 4 waste collection points placed throughout the coach. The Waste collection point will have a simple hatch that can be operated with the leg. The waste collection point also connectsto the sub-bin beneath the coach.

Figure 4 shows the side view of the components attachedto a train coach. Adding the main bins causes the clearance of the coaches to become less. The overall power consumption ofthe coach goes up as the vacuum pumps need to be operated intermittently.

The below image shows the bottom view of a train coach depicting various components and their arrangement. The proposed single coach design with an independent vacuum pump aims to make garbage disposal easier and more efficient for train passengers. Passengers can use the sub bins near seating areas to dispose of their garbage through smaller vacuum tubes. Once the garbage level in the sub bin reaches a certain point, the vacuum pump will be activated by sensors, which will transport the garbage to the main bin at the coach's end.

This system ensures that garbage is quickly and efficientlytransported to the main bin, reducing the need for manual handling and improving overall hygiene. Using the provided sub bins and main bin, passengers can help maintain the cleanliness of the coach. One major reason for the passengers throwing their waste outside the window is convenience, and they are primed by the year of practice. This new system will provide a better alternative and allow the passengers to throw waste whiteout getting up from their seats. This will encouragemore use of the proposed system.

C. Component Selection

- Vacuum Pump: Side channel blower, Vortex air pump, turbine, vacuum pump SC-2200 2,2KW Side channel turbine (side channel fan) with a single impeller.
  - Air flow max: 325 m^3
  - Power: 2.2 kW
  - Power: 2.2 kW
  - Overpressure max: 300 mbar
  - Negative pressure max: -250 mbar

- Main Bins:
  - Length: 220.50 cm
  - breadth: 60.75 cm
  - height: 107.50 cm
  - volume: 1440002.81 cm^3

- Sub Bins:
  - Length: 98.25 cm
  - breadth: 81.50 cm
  - height: 51. 25 cm
  - volume: 410377.97 cm^3
- Connecting Pipe:
  - The cross-section & length of the pipes will changeaccording to the coach & train type.

D. Calculations

To calculate the population that will benefit from thewaste collection vacuum system, statistical data was used

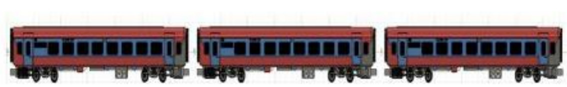

Fig. 1. Side view Of 3 coach model

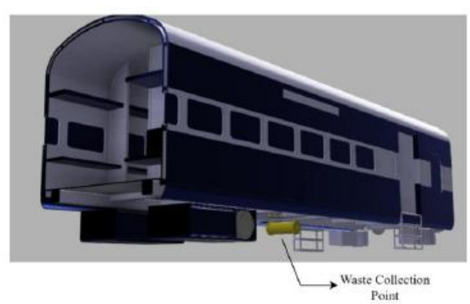

Fig. 2. Isometric view of the coach showing the bin used for collection

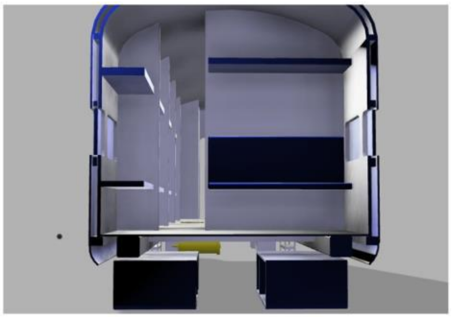

Fig. 3. Cross Section view of the coach

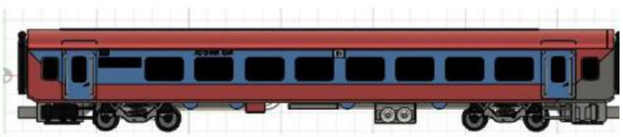

Fig. 4. Side view of one coach model

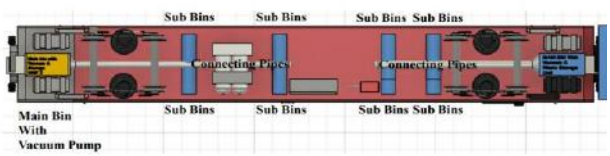

Fig. 5. Bottom view of a coachl

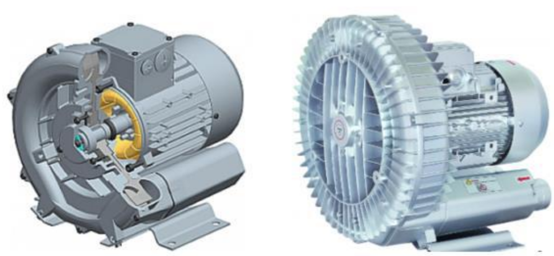

Fig 6. Isometric view & design of vacuum pump

by the Indian Railways for the last 5 years. The Coefficientof traveller occupancy was considered 30%, and the total number of people was calculated according to an annual average. Considering the total population that benefits from this system, the average index of waste production and the waste weight, it is possible to develop some calculations.

E. Control System

A system control unit is present in each coach. Each control unit is connected to the main control units in the engine room. The surrounding stations are able to monitor the amount of waste being accumulated in each coach's unique primary bins because of this main control unit's connection to the cloud. This enables the stations to schedule the trash can emptying for when the train comes. Touch and proximity sensors fitted in the collection area allow the system to detect a person opening the hatch to the collection area. The system can assess the size of the garbage thanks to the proximity sensors that are mounted to the pipe that leads to the sub-bin. Pneumatic actuators and a load cell are installed in the sub-bin. The load cell informs the coach control unit of how much trash has gathered in the sub-bin. The capacity of each sub-bin is checked by the central control units. All of the waste is sucked into the main collection bin at both ends of the coach once the sub-bin fills up and the vacuum pump is activated. The control unit also operates a pneumatic actuator in the sub-bin, which is actuated before the vacuum pump. Pressure sensors are included with each connecting pipe. The system's ongoing negative pressure created by these pressure sensors prevents any odor from the main bins or sub-bins from seeping into the compartments. Because leaks will result in a low overall negative pressure in the system, the control unit can also find leaks owing to the pressure sensors. This enables the staff to be informed of any issue that needs immediate attention.

IV. CONCLUSION

As a result of Travellers' poor attitude regarding rubbish generation and disposal, the human environment has been severely harmed. The environment is in a terrible state as a result of this neglect, which has negative effects on health. It is essential to put in place effective waste management and disposal systems to address this issue, and the suggested vacuum tube-based approach holds promise. Overall operating expenses can be reduced by retrofitting this system into already-built train bogeys with just modest modifications and by producing new bogeys with it already built in. The convenience this system offers will encourage commuters to use it as opposed to throwing rubbish out the window.

A practical choice for effective trash management in the train industry, the system's sensors enable waste to be efficiently discovered and disposed of at the subsequent station. Overall, the vacuum tube-based train waste collection and segregation technique is a promising solution to address the issue of poor waste management in the train industry. Its implementation can significantly improve the health and sanitation of the environment.

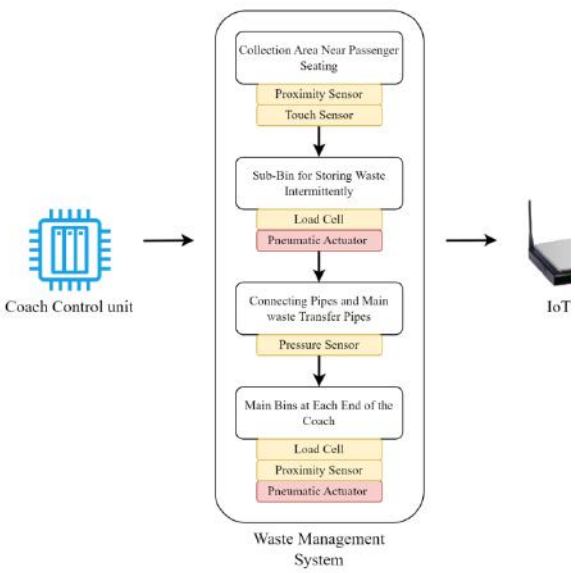

Fig. 7. Flowchart showing the data flow for the IoT system

Overall, the collection and sorting of train debris using vacuum tubes shows promise for overcoming the issue of poor waste management in the rail industry. Adoption of it can significantly enhance the environment's health and cleanliness.

V. FUTURE SCOPE

A vacuum tube-based waste disposal system is not yet in use by railroads. Further research will be required to determine the efficiency and power requirements of the system. A number of design modifications can increase the system's efficiency, such as grouping the bogies into collections of three instead of having a separate trash collection for each bogy. However, it can also increase the system's required power to generate the suction pressure while decreasing the cost of the materials and component needs. In order to achieve waste segregation at the collection point itself and save the effort on the waste management staff, we can develop a system where commuters are provided three separate locations for dry, moist, and recyclable waste.

Additionally, we can implement a credit system that rewards commuters for helping to gather and sort trash while they are on the road by reducing the cost of their transportation tickets. This will encourage commuters to stick with the plan. A cost-to-impact analysis must be done to establish the suitability of such a system for large-scale integration.

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