Control Bio-Digester Toilet System for Environmentally Sustainable Railways

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Abstract: *The primary purpose of introducing the Control Bio-Digester toilet system on the Indian Railways is to eliminate the practice of spilling toilet waste onto the railway station and in the populated areas of the city. The spillage of toilet waste in train tracks causes corrosion and a pungent smell. Railways spend vast amounts of money annually to maintain and paint the tracks. In populated areas, it causes waterborne diseases like Hepatitis B, Cholera, and Typhoid. The excretion should not be discharged into train tracks to overcome all issues. Further, The Control Bio-Digester toilet system is introduced, which operates with a pressurized water bowl wash that covers 100% of the toilet bowl area. The proposed work is a toilet system in which the waste is transferred to the retention tank with a certain amount of water. Then, it uses bacteria to break down human excreta into liquid and gas states. The liquid state is stored in the excretion system, and the gas state is stored in the Methane gas holder. This proposal will deal with and speak about the issues faced by Indian railways regarding discharging waste into the environment. It also provides significant benefits to protect the environment, reducing maintenance costs. This toilet system will provide a maintainable solution for the Railway system. In the future, further research is needed to determine the real-time impact..*

Keywords: *Control Discharge, Toilet System, Bio-Digester, Indian Railways, Waste Management, Environment*

I. INTRODUCTION

In the 19th century, the first ever toilet was introduced on a train. George Hudson(1840). In India, the toilet system was implemented in 1909 after a letter was written by a Bengali person named Babu Okhil Chandra Sen to the Sahibganj Divisional office in West Bengal. The railway system plays a major role in India's transportation system. As it is used for long-distance travel, the railway system faces many issues related to the disposal of human waste. The railways spend more and more money on the maintenance of train tracks, which get corrosion due to the disposal of human waste and cause waterborne diseases when discharged into water bodies. It also causes health-related issues.We have developed a control bio-digester toilet system where human waste decomposes using anaerobic bacteria. After decomposition, the solid waste gets processed to semi-solid and gaseous form. The semi-solid wastage gets stored in the septic tank, and in the meantime, the gaseous state of methane gas gets stored in a methane gas holder. Here, there is no need to dispose of human waste directly into the track; instead, it gets stored and processed. The semi-solid form of wastage is stored in the fertilizer hub, which is used as fertilizer. The gaseous form of waste is used in the cooking process. We have completed this project using MATLAB SIMULINK. This system also helps discharge waste using the excretion system in railway stations. It provides the extra luxury of discharging the waste and filling the fresh water in any railway station. This system consists of indicators and displays that provide the exact values and levels of the water tank, septic tank, and methane gas holder. As a result, we can create a healthier environment and decrease the maintenance cost for railways. It also provides a suitable environment around the train and its terminals. We have created a prototype using ESP32 WROOM. As the existing toilet system in train is not environment friendly, the above technology is quite environment friendly. Our railway system consists of various types of toilets but it is not environment friendly.

II. RELATED WORKS

The Indian Railways, one of the world's largest railway networks, transports over 23 million passengers daily on over 68,400 routes across the country [1]. Trains must have an effective excretion system to maintain a sanitary and safe environment. Trains use a variety of closed toilets, such as vacuum toilets, circulating toilets, and automatic discharge toilet systems. Vacuum toilets can save water, but the smaller outlet pipe often causes dirt and odour issues [2]. Circulating types discharge waste using previously stored wastewater and chemicals to remove dirt. While this process saves water, the use of chemicals may result in pollution [2]. The automatic discharge toilet system collects waste and cleans the toilet system by separating excrement and urine at the source and treating them separately. This system has effectively solved the problem of direct excrement and urine discharge into the surrounding environment [2]. Solid waste can be converted into pure water in a vacuum-controlled green toilet system by biodegrading with anaerobic bacteria, which is then chlorinated before discharge. This water can then be used to clean tracks and bogies. At the same time, the remaining sludge can be used as fertilizer for agriculture [3]. The automatic discharge toilet system prevents waste spills in densely populated areas and within railway stations [5]. The Modular Controller Discharge System (MCDS) is a modernized train toilet system that prevents spillage in undesirable locations or railway platforms. It uses speed sensors to dump waste at an appropriate distance from the railway station. An intermediate tank is used under the toilet seat. It is designed using simulation, with the storage tank's action controlled by a Programmable Logic Controller [6]. Despite the availability of various toilet systems, the open discharge of waste by toilets causes track corrosion. Human excreta and urine contain a wide range of germs that contribute to pollution and the spread of diseases such as hepatitis A, waterborne diseases, typhoid, cholera, and others. Indian Railways spends much money yearly to keep the tracks clean and corrosion-free [9]. To address the issues with open discharge sanitary systems, the Indian Railways and DRDO developed bio-toilets. A bio-toilet converts waste into energy and fertilizer. However, all converted waste is eventually discharged onto the train tracks [10]. The sewage is not discharged while the train runs, but only when it arrives at a central station. The tracks must be restructured to include a canal-like structure beneath the platform's racks, allowing water and sewage discharge to flow [11]. Using bio-toilet systems is an excellent strategy for ensuring the sanitary conditions of the biodegradation process. The track should be visually appealing, and any annoyance caused by human excrement can be eliminated. Furthermore, water is conserved, and corrosion caused by faeces can be reduced. By implementing a green toilet system, we can use anaerobic bacteria to biodegrade solid waste into clean water that is then chlorinated [13]. In railway transport, biogas can be used as a fuel for self-propelled locomotives, wagon heating, and stationary boilers. When combined with biotechnology, mobile biogas stations installed on trains can generate heat, energy, and biofertilizers [14]. Using environmentally friendly green toilets will eliminate human waste from railway tracks, resulting in cleaner and greener station premises and tracks [5]. So far, no faecal matter has been detected in the toilet discharge from any of the coaches, and no foul odour has been detected in this Anaerobic Biodigester. The test parameters for TDS, TS, pH, volatile solids, and COD were all within acceptable limits, and neat and clean under-gear encouraged maintenance personnel to work more efficiently [15].

III. METHODS

In this research work, the Control Bio-Digester Toilet System in Indian Railways is introduced, and it aims to revolutionize sanitation practices by eradicating the hazardous discharge of toilet waste into railway station areas and urban environments. This innovative system operates through a pressurized water bowl wash, ensuring comprehensive coverage of the toilet bowl area to maintain cleanliness and hygiene standards. Waste from the toilets is efficiently transferred to a retention tank along with water, initiating a process facilitated by bacteria to decompose human excreta into a liquid and gaseous state. The liquid waste is managed within the excretion system. At the same time, the gaseous byproduct, predominantly methane, is stored in a designated gas holder. This environmentally friendly approach enhances sanitation and contributes to sustainable waste management practices within the railway infrastructure. The workflow of the proposed system is shown in Fig 1.

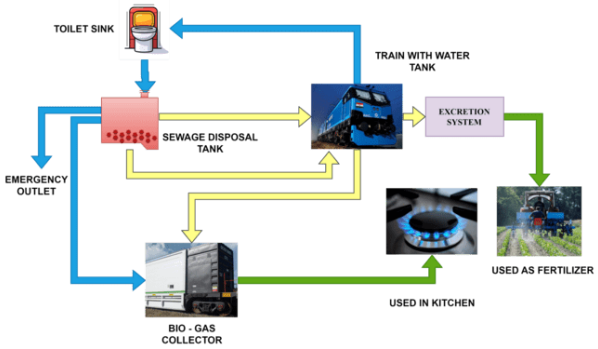

Fig. 1. Work flow of Control Bio-Digester Toilet System

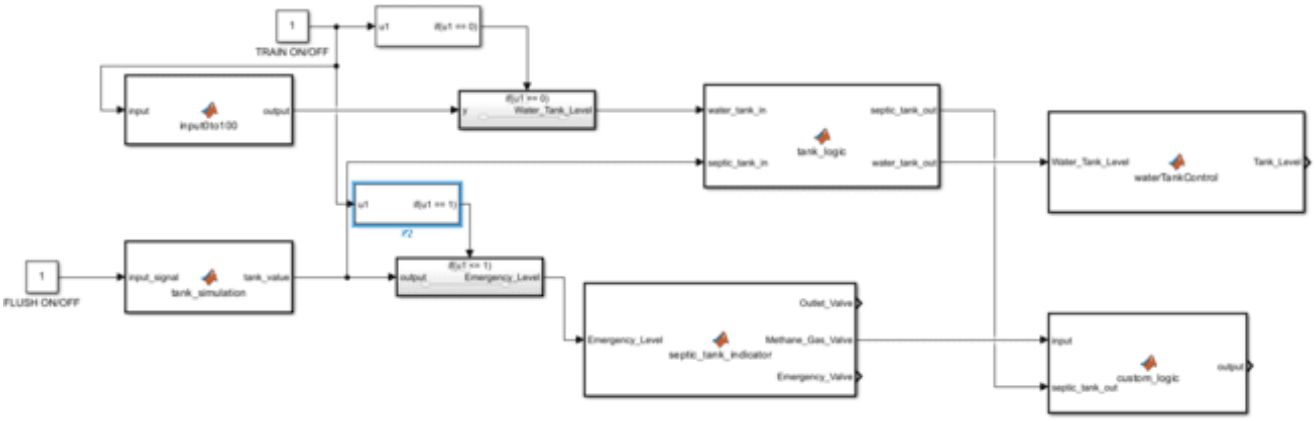

Fig. 2. Work flow of Control Bio-Digester Toilet System

a) ***Water Tank***

At the heart of this system is the water tank, a vital component that serves multiple purposes. It provides the necessary water for flushing toilets and maintaining hygiene onboard the train. However, unlike conventional trains where water is sourced externally, this system relies on manual station filling, ensuring water consumption is carefully monitored and controlled. This manual filling process conserves water and allows efficient resource management throughout the journey.

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b) Toilet System

The toilet is adjacent to the water tank, a crucial facility for passengers' comfort and convenience. After each use, the toilet bowl undergoes thorough cleaning to maintain hygiene standards. Waste from the toilet is not simply flushed away into the environment; instead, it is directed into a specialized septic tank equipped with decomposing bacteria.

c) Sewage Disposal Tank

The septic tank is pivotal in the train's waste management process. Within this tank, specialized bacteria facilitate the decomposition of solid waste, breaking it down into semi-solid and gaseous states. This natural decomposition process is both eco-friendly and efficient, eliminating the need for chemical treatments or external disposal methods. Solid waste decomposes and transforms into semi-solid residue, accumulating within the septic tank over time. However, this residue is not simply discarded; it is repurposed as fertilizer, offering a sustainable waste management solution while contributing to agricultural practices. By converting waste into a valuable resource, the train compartment exemplifies the principles of circular economy and resource efficiency.

d) Sewage Disposal Tank

Meanwhile, the decomposition process also generates methane gas as a byproduct. Despite releasing methane gas into the atmosphere as a greenhouse gas, this methane gas is collected and stored in a separate holder onboard the train. This innovative approach to waste management mitigates environmental impact and harnesses renewable energy resources in biogas. The stored methane gas serves a dual purpose onboard the train. Firstly, it is utilized for kitchen and cooking appliances, providing a clean and efficient energy source for meal preparation. The train reduces its reliance on non-renewable resources by substituting conventional fuels with biogas. It minimizes carbon emissions associated with cooking activities.Furthermore, utilizing methane gas onboard the train exemplifies the concept of energy self-sufficiency, wherein waste products are transformed into valuable energy resources, thereby reducing external dependencies and enhancing operational resilience. This closed-loop approach to energy management ensures that resources are utilized sustainably and efficiently throughout the train's journey.

e) CBDTS

In the proposed Control Bio-Digester Toilet System (CBDTS), the train compartment represents a holistic approach to waste management and resource utilization, integrating innovative technologies with sustainable practices to create a self-sustaining ecosystem onboard. From water conservation and waste treatment to energy generation and utilization, every aspect of the system is carefully engineered to minimize environmental impact while maximizing efficiency and utility. By embodying the principles of circular economy and renewable energy, the train compartment sets a precedent for sustainable transportation and waste management practices in the modern era. The model of the designed system is shown in Fig 2.

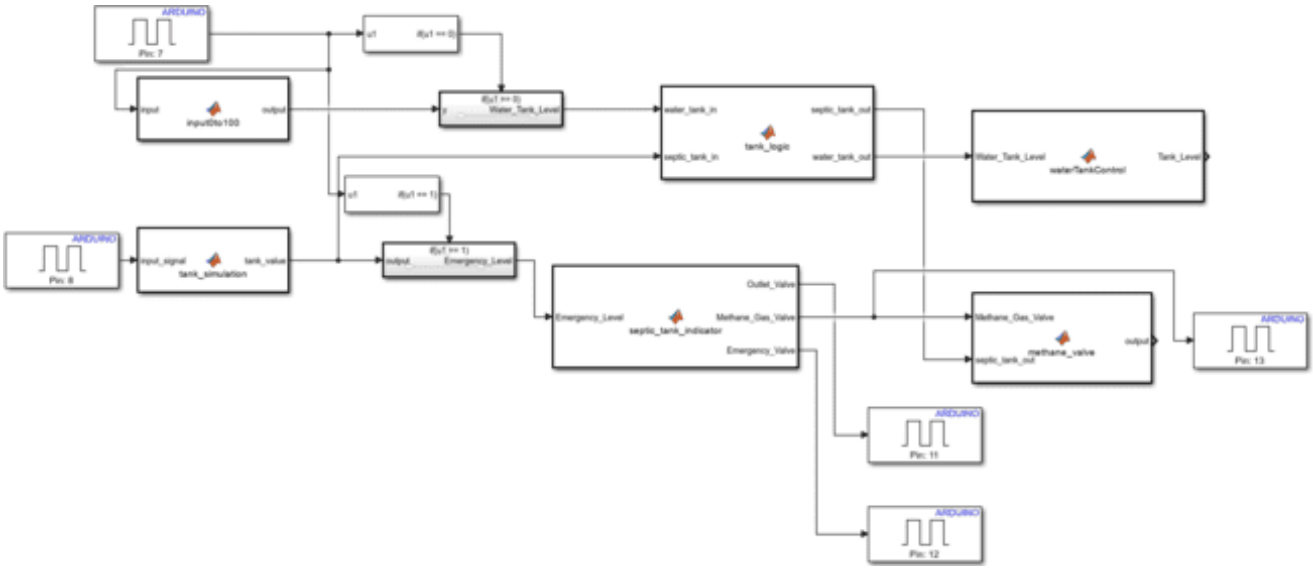

Fig. 3. Work flow of Control Bio-Digester Toilet System

V. RESULTS AND DISCUSSION

The proposed CBDTS is programmed to the ESP32 module for real-time validation, and results are verified. The real-time program is shown in Fig 3.

A)The train is at the station.

The railway station scenario is simulated and shown in Fig 4. When the switch toggles to off, it states that the train is in the off state. If the "water tank level" is below 5%, the water tank gets to be filled in the railway station. The quantity of water is visualized in a *"water tank"* via animation. The water level is shown in the *"level of a tank."* If the *"water tank level"* is about 25%, it is displayed as LEVEL 1. If the *"water tank level"* is more than 50%, it is displayed as LEVEL 2; if the "water tank level" is more than 90%, it is displayed as FULL. The % of the water in the tank is shown in another display named *"Water tank value,"* as shown in Fig 5.

B) Using the Flush

In Fig 6, the toilet scenario is simulated by pressing the flush button in train compartments. After the toilet is used, a flush is pressed. It discharges the water from the upper tank and stores it in the septic tank. As a result, the water quantity in the upper tank decreases, and the waste quantity in the septic tank increases. Each flush carries up to 5 % of the water from the upper tank. So, the water level decreases and the sewage increases, as seen in the figure.

C) *Turning ON the methane valve*

From Fig 7, we can also understand three indicators representing valves: *"outlet valve," "methane gas valve,"* and *"emergency valve."* When flush is used several times, water from the main tank gets lowered, and the sediments in the Bio-Digester septic tank get increased. Due to the chemical reaction of Bio-Digester organisms, sediments get segregated into semi-solid substances, liquid and methane gas. The filling animations are shown in Fig 7 as *"Septic tank"* and *"Methane gas tank."* Their values are shown in the "Septic tank value" displays and *"Methane tank value."* In this figure, we have simulated the condition as, after several flushes, water from the tank is decreased, so the sediments in the *"Septic tank"* and gas in the *"Methane gas tank"* is increased, so we have turned on the *"methane gas valve."* Hence, the indicators turn on and are shown as green in color.

D)Turning on the Emergency Valve

If the *"Septic tank"* and *"Methane gas tank"* are beyond threshold value and have no place for further storage due to gas expansion. Then, the *"emergency valve"* is turned on. At the same time, we are closing the *"methane gas valve"* to prevent gas leakage into the atmosphere. This scenario is shown in Fig 8.

E)The train arrived at the destination.

When the train arrives at the final station, the *"outlet valve"* is turned on, and the sediments are extracted manually. At the same time, water is refilled for the next cycle, and this scenario repeats. This output is shown in Fig 9.

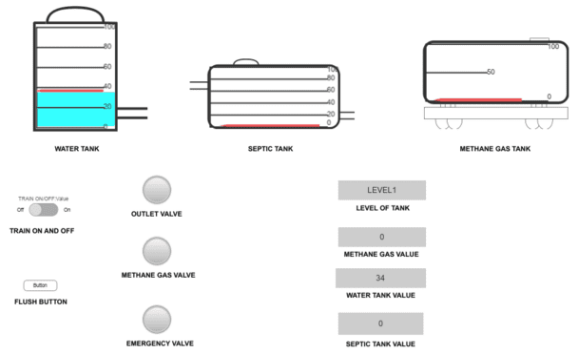

Fig. 4. Train is in station

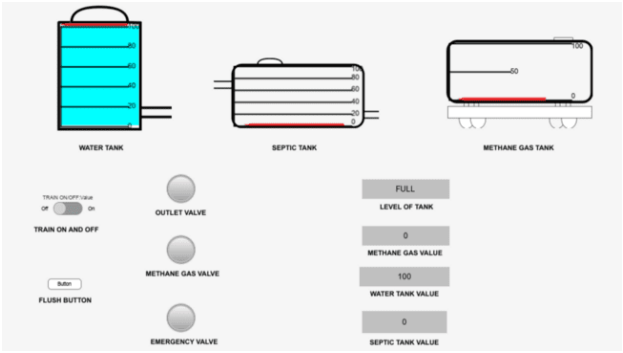

Fig. 5. Tank full

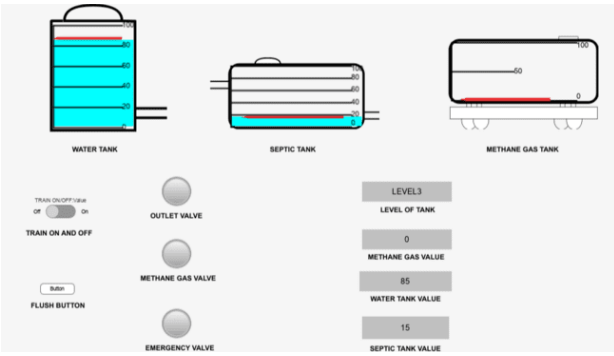

Fig. 6. Using the flush

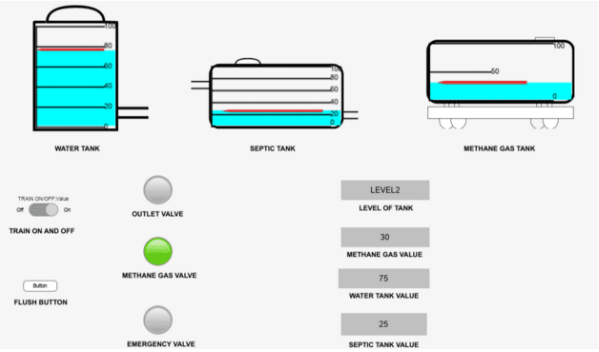

Fig. 7. Turning ON the methane valve

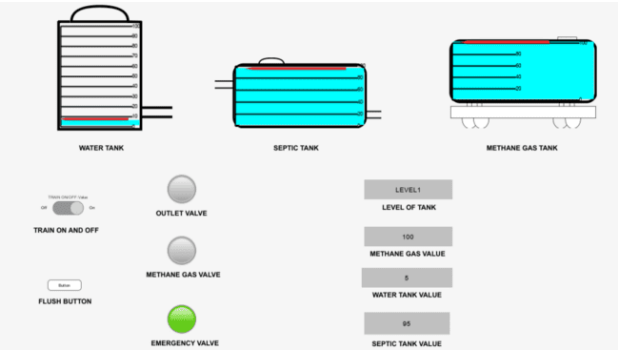

Fig. 9. Turning on Emergency Valve

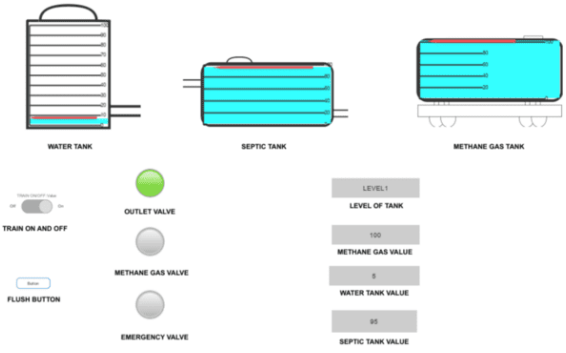

Fig. 8. Train arrived in desination

VI. CONCLUSION AND FUTURE WORKS

Discharging waste onto tracks from train toilets poses environmental and health risks due to contamination from pathogens and bacteria. It creates unpleasant Odors and unsanitary conditions and attracts pests, impacting nearby communities, railway workers, and passengers. The practice also harms ecosystems and biodiversity in sensitive habitats along railway lines. Proper waste management practices and infrastructure improvements are essential to mitigate these issues and meet environmental, health, and safety standards. We have concluded this project successfully. This toilet system will play a significant role in the revenue of Indian Railways as the Indian Railways spent more money maintaining the tracks due to the direct discharge of wastages. MATLAB 2022(b) with Simulink is used to simulate this project. This project deals with one compartment in a train. In the future, we can implement this in connecting all the compartments in the serial. We can also acquire more effective results when we develop this project in Simscape.

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