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Investigating the Feasibility of Incorporating a Bio Toilet into the Sanitation Infrastructure of Bangladesh Railway

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Abstract

The railway provides a comfortable and affordable mode of transportation. In Bangladesh, the state-owned rail transport agency, Bangladesh Railway (BR), encompasses an extensive geographic region of approximately 8,135 million passenger-kilometers, operating simultaneously in the eastern and western regions of the country. It is the most cost-effective transportation system, allowing a large number of passengers. However, this leads to a significant amount of fecal sludge generation, which is currently disposed on the track that poses a severe health risk to the surrounding environment. This paper aims to describe the current state of the sanitation system in Bangladesh Railway, propose an improved alternative, emphasize its shortcomings, and suggest modifications to modernize the sanitation system for BR. Implementing these modifications could potentially revolutionize the public health sector by effectively addressing this issue.

Keywords: *railway sanitation system; fecal sludge; solid waste management; public health*

1 Introduction

Bangladesh Railway (BR), the government-owned rail transport agency, plays a crucial role in the country's transportation system. It oversees a vast route operated by a dedicated team of 25,526 regular staff members. As of the year 2018-2019, BR had a total route length of 3018.88 kilometers. During that period, Bangladesh Railway transported approximately 92.71 million passengers, compared to around 90.06 million in the previous year, 2017-2018. To improve passenger services, BR introduced Intercity Train services in 1985, These particular trains transport roughly 30.72% of all passengers who avail themselves of the services provided by Bangladesh Railway. In June 2019, there were 254 trains operating daily, including 54 intercity trains. (CPO_BR, 2019). During long hauls specially on Intercity trains, passengers require access to toilets and eventually generate waste. We need to figure out better way to store, collect, and dispose of this waste that can potentially create both health and ecological problems. Solid waste is a big burden and a major concern, particularly in developing countries where infrastructure and services for solid waste management, such as hygiene, effective collection, and proper disposal, are inadequate. The disposal of human waste not only creates visual disturbances but also possesses a threat of organic pollution and the spread of various infectious diseases, especially in densely populated and developing nations. (Gunaki & Devaraj, 2020). However, research has shown that the existing toilets in Bangladesh Railway are not feasible in terms of human waste management and environmental concerns. A potential solution could be the incorporation of an alternative eco-friendly sanitation system in BR. Indian Railway (IR) has installed the bio-toilets in 79,269 passenger coaches during 2021-22 (Rajesh Kumar Thakur, 2022). It's a revolutionary approach to mitigate the existing issues of environmental hazard, and diseases. Bangladesh Railway has taken initiative to incorporate Bio toilet in BR Sanitation system. According to Kudrat-E-Khuda, CME, BR, West Zone, typically, human waste from the train toilets in the West zone railway is often disposed of either on the railway tracks or on the Jamuna railway bridge. Consequently, the metal clips attached to the railway tracks quickly become rusted and damaged. Hence, in order to align with developed nations, a modern and eco-friendly railway service will be implemented by equipping all coaches with bio-toilets. (Sarker Shariful Islam, 2020). Recently BR started procurement 150 South Korean modern Coach (TBS Report, 2023) and 100 Chinese CRRC Coach (TBS Report, 2022), that have Bio toilet incorporated in The AC Coaches by default.

2 Objective & Methodology

Our primary objectives encompass a comprehensive assessment of the existing sanitation system in BR, including an examination of its current state and practices. We will try to visualize the amount of wastes being generated per haul. We also aim to propose the potential implementation of bio toilets as an effective solution. To support this proposal, we plan to conduct a thorough feasibility analysis, ensuring its viability for our context. Moreover, we

intend to offer suggestions for additional modifications, a crucial step before considering the replacement of the current system with the proposed solution. Our methodology comprises four core components. Firstly, we gathered data from the Information Book 2019 by BR (CPO_BR, 2019) focusing on railway coach details and daily passenger counts for accurate excreta generation rate calculations. Subsequently, we evaluated the existing sanitation practices within BR, pinpointing their limitations. In response, we identified two feasible alternative solutions, selecting one through a comprehensive feasibility analysis. Finally, we formulated a set of necessary modifications that must be addressed before the direct integration of the chosen technology into our existing system. This systematic approach guides our exploration of the sanitation system enhancement within Bangladesh Railway.

3 Current Sanitation System

The current system utilized for disposing of human waste on railroads involves flush-type frameworks. This method involves directly releasing human waste onto the tracks. Consequently, this leads to contamination and unsanitary conditions at stations, causing discomfort for passengers and difficulties in maintaining the tracks properly. (Gunaki & Devaraj, 2020). Passenger trains typically include various types of toilets on board, with each serving a specific purpose. Among them, the simplest train toilets are known as “Drop Chute Toilets” or “Hopper Toilets”. In the case of a Drop Chute Toilet, the toilet bowl opens into a vertical chute or tube with no bottom, measuring approximately 4-5 inches or 10-12 cm in diameter. This design allows the waste to drop directly onto the tracks. See Figure 1 which illustrates the functioning patented design (C. M. Williams, 1915). Figure 2 shows the use of the hopper toilet. On the other hand, the term "Hopper Toilet" refers to a toilet without a storage tank or hopper to contain the waste. Similar to a hopper car used for transporting grain, this type of toilet disposes of waste directly onto the track. (*Train Toilets — Toilets of The World*, 2016). Another commonly utilized toilet variant is the "hole in the floor" design, which gains popularity primarily due to its alignment with the traditional squatting posture prevalent in the Indian subcontinent. See Figure 3.

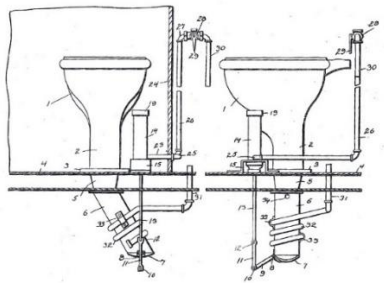

Figure 1. Traditional Drop Chute Toilet Functioning (C. M. Williams, 1915)

Figure 2. Traditional Drop Chute Toilet (*Train Toilets — Toilets Of The World*, n.d.)

Figure 3. Traditional Hole in Floor Toilet in LHB Coaches (Indian Rail Info, 2022)

However, this practice is often seen as unhygienic and hazardous to both health and the environment. It leads to littering along the railway lines and causes serious health hazard. Consequently, passengers are usually discouraged from flushing or using toilets while the train is at a station or stopped at a red signal. (*Passenger Train Toilet - Wikipedia*, n.d.). But this practice is rarely observed in our sub-continent. (Vegad & Paruthi, 2017).

4 Data Collection and Analysis

4.1 Railway Data

By the end of the 2018-2019 fiscal year, Bangladesh Railway possessed a fleet of 1605 vehicles for passenger transportation. (CPO_BR, 2019). Additionally procured modern coaches makes it 1975.
There are 3 types of railway coaches imported in BR. (Wikipedia, n.d.)

1. Iranian Coach
2. PT INKA Coach, Indonesia
3. CRRC Coach, China (15/100 Procured) (TBS Report, 2022)
4. Linke Hofmann Busch (LHB) (120 Procured) coaches, India (PTI, 2016)
5. South Korean Coaches (58/150 Procured) (TBS Report, 2023)

4.2 Analysis

During the year 2018-2019, a total of 20194000 Intercity passenger trains run on the meter Gauge, 11805000 on broad gauge. They covered a total of 5328992 and 3595869 train kilometers in combined meter and broad. Daily number of trains run in June 2019 was 254 including 54 Intercity trains. (CPO_BR, 2019) We will consider a coach that needs to be reformed with bio toilet. For example, we consider Kapotaksha Express (715/716). This train runs with 11 Indian LHB Coaches consisting of one AC chair car and eight non-AC chair cars with two power cars. It has 15 stoppages in its run between Rajshahi-Khulna (263.2 km). Let's assume the onboarding and deboarding rate is 10% and 10% per stoppage. So, the ultimate passengers remain constant (Imagine). Capacity of these 9 passenger coaches 72 people each. Past studies have concluded that a normal person urinates about 250ml and excretes 128g feces.(Rose et al., 2015). We assume around 10% of the whole passenger may use the toilet during journey. The following Table 2 enumerates the appx waste generation in some of the intercity trains of BR along with eight other intercity trains.

Total feces discharge (D_f) = 0.1 * Total Passenger (p) * Journey duration (t) * Feces discharge per hour (d_f)
Total urine discharge (D_u) = 0.1 * Total Passenger (p) * Journey duration (t) * Urine discharge per hour (d_u)

$$\text{Here, } d_u = 250ml \text{ and } d_f = 128gm$$

Table 1 Some intercity trains and their generated wastes (appx.)
(Bangladesh Railway Portal, 2019), (Shohoz-Synesis-Vincen JV, n.d.)

Train Name (Express)	**Coach Type & Capacity,** c	**Journey Duration ,** t $(H:M:S)$	**Journey Duration,** t $(Hour)$	**No. of Passenger Coaches,** n	**Total Passenger** $p = n \times c$	**Urine Discharge (Appx.)** $D_u = 0.1ptd_u$ (ml)	**Feces Discharge (Appx.)** $D_f = 0.1ptd_f$ (gm)
Kapotaksha	LHB (72)	5:25:00	5.42	9	648	87804.00	44955.65
Parabat	PT INKA (92)	7:05:00	7.08	11	990	175230.00	89717.76
Panchagarh	PT INKA (92)	6:50:00	6.83	9	828	141381.00	72387.07
Ekota	PT INKA (92)	6:25:00	6.42	13	1196	191958.00	98282.50
Shonar Bangla	PT INKA (92)	5:20:00	5.33	15	1380	183885.00	94149.12
Suborno	Korean (100)	5:20:00	5.33	15	1500	199875.00	102336.00
Joyantika	PT INKA (92)	7:45:00	7.75	10	920	178250.00	91264.00
Sagardari	LHB (72)	6:00:00	6.00	9	648	97200.00	49766.40

5 Alternative Sanitation System

5.1 Controlled Discharge Toilet System (CDTS)

The Controlled Discharge Toilet System (CDTS) is an advanced sanitary technology that offers efficient and controlled waste disposal in vehicles such as trains, buses, and other mobile environments. It operates through a combination of electrical and pneumatic mechanisms, ensuring a hygienic and user-friendly experience for passengers and maintenance personnel alike. The highlighting features of CDTS are –

1. Retention Tank with Dual Openings: The CDTS includes a retention tank with upper and lower openings, serving as waste discharge points.
2. Pneumatic Cylinder Activation: Pneumatic cylinders, powered by compressed air from the vehicle's brake system, control the openings' movement.

3. User and Automatic Flush: Passengers trigger flushing via a button, accessing the upper opening. An automatic cycle opens the lower opening after specific flush cycles and vehicle speed criteria are met. Figure 4 and Figure 5 illuminates the functioning of CDTS and location of the CDTS tank respectively.

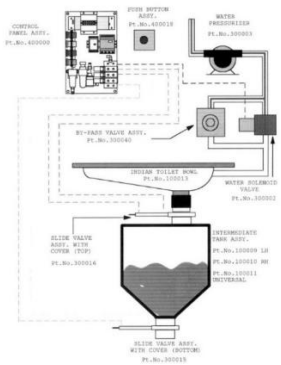

Figure 4. Controlled Discharge Toilet System (CDTS) and functioning (Bhavani Prasad, 2018)

Figure 5. Controlled Discharge Toilet System (CDTS) Tank Beneath the Coach

4. Precise Pressure Regulation: Pneumatic pressure for openings is regulated by solenoid or magnetic valves, ensuring accurate movement coordination.
5. Pressurized Water Supply: A pressurizer delivers water for efficient waste flushing, enhancing cleanliness.
6. Logical Control System: Monitors flush cycles and vehicle speed through the Wheel Speed Sensor (WSP), enabling optimal lower opening activation.
7. Optimal Waste Disposal: CDTS employs data-driven decisions to discharge waste efficiently, reducing odor and inconvenience. .(Bhavani Prasad, 2018)

5.2 Bio Toilet

The Bio-Toilet is an integrated waste management solution that efficiently transforms solid human waste into bio-gas and water using a specialized bacterial Inoculum. This process involves the anaerobic decomposition of human excrement within bio-digester tanks. Representing an innovative technology, the Bio Toilet facilitates the eco-friendly, cost-efficient, and hygienic disposal of solid human waste (DRDO & IR, 2015). Train coach restrooms are equipped with bio-digesters positioned beneath them. These stainless-steel rectangular bio-digesters measure 540 mm x 1150 mm x 720 mm, with a capacity of 400 liters. Each bio-digester comprises two chambers: one for biological treatment and the other for chemical treatment, encompassing sludge settling and chlorination. By synergizing these treatments, the bio-digesters ensure the resulting effluent is both odorless and safe for discharge.(Gunaki & Devaraj, 2020) Figure 6 & Figure 7 illustrates position of bio digester tank beneath the coach and figure 8 enumerates the parts and structure of a bio digester tank.

Figure 6. Position of Bio-digester Tank (DRDO & IR, 2015)

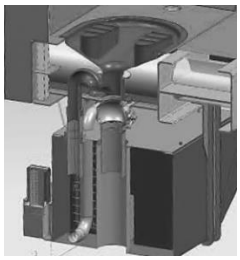

Figure 7. Pan to Digester supply (DRDO & IR, 2015)

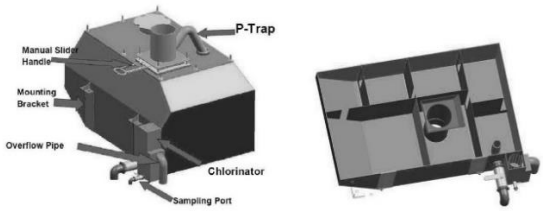

Figure 8. IR-DRDO Bio-digester Tank for Coaches (DRDO & IR, 2015)

The functioning of these systems revolves around gathering human waste within a containment reservoir. Within this tank, solid waste undergoes decomposition via anaerobic bacterial actions, leading to the generation CO_2 and CH_4. These gases are then emitted into the surrounding atmosphere. Simultaneously, the liquid waste or effluent undergoes chlorination before being directly expelled into a drain. Refer to Figure 9 for a visual representation of

this process as depicted in the flowchart. By converting waste into quiet harmless gases and effectively treating liquid effluent, these systems contribute to sustainable waste management.

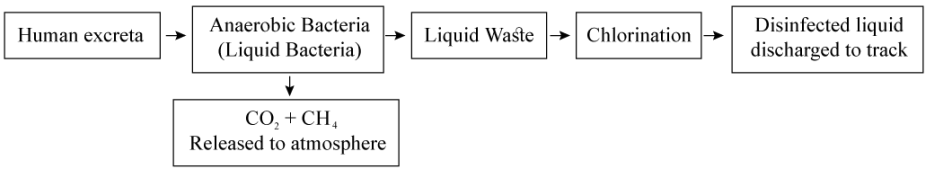

Figure 9. Bio Toilet working mechanism (DRDO & IR, 2015)

According to DRDO, Anaerobic bacteria exhibit remarkable capabilities. A 120-liter inoculum is initially introduced into the bio-digester tank, and due to their swift reproduction, their population doubles within just 6 to 8 hours. These bacteria play a crucial role in the decomposition process by converting organic substances into liquids and gases. Notably resilient, they can endure for 3-4 months at room temperature and are unfazed by extreme temperatures ranging from subzero to 60 degrees Celsius. Interestingly, their internal processes remain unaffected by cold temperatures as the exothermic anaerobic process generates heat within the chamber through chemical reactions, even in colder conditions. (CAMTECH, 2013)

6 Feasibility Analysis

In order to determine the feasibility and viability of a project or initiative, taking considerations about technical, financial, operational, legal, and environmental we conducted a feasibility analysis to take decision about Bio toilet incorporation. Whether it is both feasible and worthwhile.

Table 2. Bio Toilet vs CDTS Feasibility Comparison (Bhavani Prasad, 2018; DRDO & IR, 2015)

Specification	Bio Toilet	CDTS
Cost	Low	Relatively high
Maintenance	No	Yes
Reduction of Solid waste	Yes	No
Bad Oduor Generation	No	Yes
Reduction in organic matter	Yes	No
Operation Time	Simultaneous	Intermittent (Automated)

7 Challenges in Bio Toilet Integration

But some concerns have been raised too. According to Vinod Tare, 61, who headed the study on bio digesters, is currently a professor, Environmental Engineering, IIT Kanpur, The Indian context presents several challenges. Firstly, unlike Western countries where "dry cleaning" practices are common in toilets, Indians have a habit of "wet cleaning," resulting in a significantly higher volume of waste in Indian trains. Additionally, temperature variations in Indian trains range from a high of 45°C to as low as 4°C. (Srinand Jha, 2018). In September 2017, an internal assessment of bio digesters was conducted on five divisions of the Northern Railway Zone. The findings revealed certain issues within the system. Specifically, the Delhi division of Northern Railways experienced a 10% failure rate due to internal choking. Additionally, there were 15.7% instances of clutch wire failures and 19.4% failures in lab sample testing. (Srinand Jha, 2017). Before incorporating bio toilet in BR, following concerns should be emphasized

1. The bio-digester toilets emit a strong odor if any malfunctioning appears in mechanical components.
2. The toilets can frequently get clogged, because passengers dispose of bottles, cigarette butts, gutka packets, and soiled sanitary napkins in them.
3. The water pressure provided for flushing in these toilets was insufficient (bio-digesters require five liters of water per flush).
4. The installation and securing mechanism of the toilet tanks sometimes found to be defective, resulting in frequent breakage of the rubber connector and safety wires. (Srinand Jha, 2017)

8 Result & Conclusion

Based on a comprehensive analysis of feasibility and multiple credible news sources, our assessment underscores the imperative of implementing bio toilets to tackle the prevailing issue of open discharge toilets on trains. However, prior to the integration of this innovation, it is of paramount importance to ensure a widespread understanding among individuals regarding the essential protocols. These include refraining from disposing solid waste directly into the bio toilets to prevent potential pipe and fittings from clogging. A key emphasis should be placed on advocating the use of water exclusively for anal cleansing.

In essence, the introduction of bio toilets possesses the capacity to bring about a transformative shift in the railway system. To advance this endeavor, there is a need for comprehensive research into the efficacy of the inoculum. Furthermore, dedicated studies should be directed towards optimizing the flushing mechanism, given the substantial water consumption of the current system (5 liters). Concurrently, ongoing efforts to enhance and refine the sanitation system should persist with unwavering commitment.

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