STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 11, Special Issue 12, 2023
DOI (Journal): 10.37591/JoPC

http://engineeringjournals.stmjournals.in/index.php/JoPC/index

Review JoPC

Restructuring of Sanitation Structures: Reviewing Technological Changes

Patil Abhijeet[1-3,*], Sangami Sanjeev[4,6], Chandak Piyush[5,6]

Abstract

This paper comprehensively reviews the latest technological advancements in rural sanitation systems, focusing on developing urinals and toilets. In many rural areas, improper toilet waste disposal directly into water bodies has led to environmental contamination. In addressing this issue, biological processes are used to degrade fecal matter. However, contemporary challenges include bacterial infections from unhygienic toilets, persistent foul odors, and poorly designed toilet pans. Additionally, more community engagement is needed to improve effective sanitation management. These limitations underscore the need for technological innovation in sanitation. The study investigates advancements such as enhanced toilet pan designs, creating of organic fertilizer from human waste, the integrating of artificial intelligence and the Internet of Things in sanitation, and the imperative of community collaboration alongside governmental and non-governmental organizations to promote sanitary facility usage. A significant focus is placed on fecal waste composting. The research encompasses developments from the 1980s to the present day. Notable progress in sanitation technology is highlighted through an extensive literature review. The paper emphasizes incorporating technological innovations when designing sanitation infrastructure in any locality. Among the emerging technologies, Biochar utilization, Perforated urinals, waterless urinals, urine-diverting toilets, community-led total sanitation, Mechanical Automatic Urinal Toilet Flushers, innovative toilet systems, and collaborative robotics methods have gained prominence in recent years. The paper further examines potential modifications based on the reviews conducted. An innovative concept, the Eco toilet, powered by solar energy to minimize waste, is introduced. Also referred to as a sensor-operated solar-based urine-diverting toilet, this concept holds promise for sustainable sanitation solutions.

Keywords: Toilet; Urinal; Organic Fertilizer; Biochar; sanitation structure.

***Author for Correspondence**
Patil Abhijeet

[1]Research Scholar, Visvesvaraya Technological University, Belagavi, Karnataka, India
[2]Research Scholar, Department of Civil Engineering, Jain College of Engineering, Belgaum, Karnataka, India
[3]Assistant Professor, Department of Civil Engineering, Annasaheb Dange College of Engineering & Technology, Sangli, Maharashtra, India
[4]Professor & H.O.D., Department of Civil Engineering, Jain College of Engineering, Belgaum, Karnataka, India
[5]Associate Professor, Department of Civil Engineering, Annasaheb Dange College of Engineering & Technology, Ashta, Sangli, Maharashtra India
[6]Research Supervisor, Visvesvaraya Technological University, Belagavi, Karnataka, India

Received Date: October 30, 2023
Accepted Date: November 30, 2023
Published Date: February 20, 2024

Citation: Patil Abhijeet, Sangami Sanjeev, Chandak Piyush. Restructuring of Sanitation Structures: Reviewing Technological Changes. Journal of Polymer & Composites. 2023; 11(Special Issue 12): S67–S80.

INTRODUCTION

India has 64% of the population living in rural areas. After independence (1947), the government faced challenges like water for everybody, agriculture developments, irrigation facilities, and industrialization. It is evident that, as industrialization progressed and the population increased to 141 crores, effects like air pollution, water pollution, and infectious diseases started predominating in India. The government and scientists focused more on water and air pollution until the 1970s. The rural sector for communication, literacy, sanitation, and solid waste management still needed to be addressed. In the last 30 years, environmentalists and the public in general have been more focused on rural sanitation, solid waste management, and health care systems.

Infectious diseases like plague, viral infections, SARS, etc., along with the recent COVID-19, have threatened people's lives towards healthy living with proper sanitation facilities. Crisis periods frequently lead to significant social shifts, as history has demonstrated. Some of the consumer behavior patterns that were typical of the early COVID-19 epidemic have been chronicled by Kirk (2020), and some of them may portend developments that may ultimately revolutionize life as we know it. We have provided theory-based insights to explain these behaviors better to guide future research and marketing activity from the standpoint of environmental constraints. Each of the three phases of consumer behavior reacting, coping, and longer-term has been covered. (Ciotti, et al, 2020; Yang, Li, et al, 2020; Velavan et al, 2020).

TECHNOLOGICAL DEVELOPMENT OF SANITATION STRUCTURES:

Worldwide, people lack basic sanitation facilities. Open defecation is practiced by around eight percent of the world's population. In the decades of 2000 & 2001, most people have gained access to improved toilets & latrines. It is around 2.4 billion (Sridhar et al., 2020).

By 2020, just 54% of the world's population had access to sanitary facilities correctly. Rural areas have less access to sanitation because urban areas' sanitation coverage statistics are distorted (Hutton & Chase, 2016). Since that access only sometimes translates into use, the number of rural sanitation users is probably significantly fewer. This shows how far behind the Sustainable Development Goal of providing access to and managing sustainable sanitation by 2030, we are from that goal (WHO, 2021). The goal of resource recovery systems that can help communities is far from the sanitary reality. 80% of the world's wastewater is untreated. Therefore, only a small percentage of instances need treatment alone (U.N., 2020). Only 2 of the 12 urban sanitation systems in low- and lower-middle-income countries examined by Blackett & Adelle, 2014 demonstrated any capacity for fecal sludge reuse or recycling. EcoSan (Ecological Sanitation) toilet systems are one category of solutions created to solve sanitation and resource recovery needs.

The problems identified and technological solutions adopted worldwide are placed in Table 1.

Access to safe and hygienic sanitation facilities is crucial for human well-being and public health. However, traditional sanitation systems like pit latrines and flush toilets connected to centralized sewerage networks often need to be more suitable and available in remote areas, informal settlements, or regions with water scarcity. Eco-toilets, also known as ecological or composting toilets, offer an innovative and sustainable alternative that addresses these challenges (Tilley et al., 2014). These toilets efficiently manage human waste by promoting decomposition and transforming it into safe and valuable resources, such as compost. The concept revolves around separating solid and liquid waste to facilitate composting. Solid waste, mixed with organic materials like sawdust or coconut coir, is stored in a composting chamber, where it undergoes natural aerobic decomposition, eliminating pathogens, reducing volume, and producing nutrient-rich compost. Liquid waste is diverted for treatment or disposal separately (Kvarnström et al., 2012).

A case study conducted in a rural community in a developing country provides insights into the implementation and outcomes of eco-toilets. The community, consisting of approximately 500 households, faced limited access to sanitation infrastructure, with most individuals engaged in agriculture and needing more centralized sewerage networks or proper sanitation facilities. The community implemented eco-toilets as an innovative solution to address their sanitation challenges. The eco-toilets were designed to suit the local context and cultural practices, with active community involvement in the planning and implementation. Constructed using locally available materials, the toilets were accompanied by training programs to educate users about proper operation and maintenance.

The implementation of eco-toilets yielded several positive outcomes:

Access to improved sanitation facilities significantly improved the community's overall hygiene and health conditions.

Table 1. Evolution of toilets since past few years.

S.N.	Limitations/problem Observed	Proposed Technical Solution	Factors/Applications	Reference
1	Lack of proper sanitation facilities leading to water contamination and health issues	Introduction of eco-toilets that use composting or anaerobic digestion to break down waste and produce fertilizer	Improved sanitation, reduced water pollution, and production of organic fertilizer	Meegoda, J. N., et al, 2016
2	Overload of sewer systems causing frequent blockages and sewage overflow	Implementation of waterless urinals and vacuum-assisted toilets to reduce water consumption and strain on the sewer infrastructure	Water conservation, prevention of sewage overflow, and improved urban hygiene	Tierney, R., 2017
3	Inadequate sanitation infrastructure leading to unhygienic conditions and health risks for students.	Installation of eco-toilets with water-saving fixtures and efficient waste treatment mechanisms	Improved hygiene, reduced water consumption, and better health outcomes for students	González Salgado, I., 2017
4	Bacterial infection while touching toilet appliances	Intelligent toilet/Electronic toilet/Smart toilet	To minimize human risks & threats	Ming et al, 2020
5	Wastage high amount of water to flush toilet, public toilets	Solar Powered Self-Cleaning Toilet	Reduces human intervention, bacterial transmission	Shah, et al, 2020
6	Transmission of bacteria due to carriage of urine for laboratory testing	Smart Toilet System for Home-Based Urine Infection Prediction	It analyses urine with help of IOT on daily basis and informs user about symptoms of infection/disease	Bhatia, et al, 2020
7	Lack of sanitary facilities and limited water availability in remote mountain areas	Introduction of dry toilets and urine diversion systems to minimize water usage and facilitate waste management in challenging terrain	Water conservation, improved hygiene, and preservation of fragile mountain ecosystems.	Patrick, M., et al, 2021
8	Difficulties faced by astronauts while toileting	Tech Lunar Toilet	A toilets for astronauts	Bustamante, et al, 2021
9	Lack of access to proper sanitation facilities, leading to open defecation and spread of diseases.	Implementation of community-based eco-toilet systems with biogas generation for energy production.	Improved sanitation, disease prevention, and sustainable energy generation	Eom, Y. S.,et al, 2021
10	Lack of extraction of nutrient in efficient manner	IoT based toilet	In corporate places where high budget is sanctioned for sanitation systems	Mbonu et al, 2022
11	High water consumption and inefficient waste management in commercial restroom facilities.	Implementation of smart eco-toilets with sensors, water-saving features, and integrated waste management systems	Water conservation, cost savings, and promotion of sustainable practices in commercial settings	Macedo, L. S. V. D., et al, 2022

The compost produced from the eco-toilets served as a valuable resource for agricultural activities, reducing the dependency on chemical fertilizers and improving soil fertility.

The eco-toilets proved cost-effective and environmentally friendly, requiring minimal water and energy inputs.

However, implementing and operating eco-toilets also revealed certain limitations that required attention. Cultural acceptance and behavior change concerning the use of eco-toilets posed a challenge. Therefore, community engagement and awareness programs were conducted to promote cultural acceptance and behavior change. This involved involving community leaders, conducting workshops, and providing ongoing support and feedback. Regular maintenance and monitoring were essential to ensure proper functioning and prevent odor or hygiene issues. As a solution, maintenance and monitoring committees were formed to ensure regular cleaning, compost management, and timely repairs. Additionally, the capacity to handle peak usage and safely dispose of liquid waste requires careful consideration. Therefore, implementing appropriate wastewater treatment methods, such as constructed wetlands or decentralized systems, was explored to manage liquid waste safely.

In highly developed countries/regions, intelligent toilets, also known as electronic or smart toilets, have been proposed to minimize human risks and threats. These toilets incorporate automated flushing, seat heating, odor control, and self-cleaning (Ming et al., 2020; Gong, M. et al, 2020). Furthermore, solar-powered self-cleaning toilets have been suggested to address the lack of water availability for flushing, especially in public settings. These toilets utilize renewable energy to power self-cleaning mechanisms, reducing the need for human intervention and minimizing the risk of bacterial transmission (Shah et al., 2020). In rural areas with inadequate sanitation facilities, eco-toilets using composting or anaerobic digestion have been recommended. They offer improved sanitation, reduced water pollution, and organic fertilizer production (Meegoda et al., 2012).

Moreover, the development of intelligent toilet systems incorporating IoT technology aims to provide home-based urine infection prediction, alleviating the inconvenience of laboratory testing (Bhatia et al., 2020). In urban areas facing sewer overload, waterless urinals, and vacuum-assisted toilets have been proposed to reduce water consumption, prevent sewage overflow, and improve urban hygiene (Tierney, R., 2017). Introducing dry toilets and urine diversion systems in remote mountain areas promotes water conservation, improves hygiene, and preserves fragile mountain ecosystems (Patrick M. et al., 2021). Furthermore, lunar toilets with advanced technologies are being developed to ensure efficient and hygienic toileting for astronauts during space missions (Bustamante et al., 2021). IoT-based toilets have been suggested for cases where nutrient extraction is essential, optimizing waste management in corporate settings with a high sanitation budget (Mbonu et al., 2022). In educational institutions, installing eco-toilets with water-saving fixtures and efficient waste treatment mechanisms improves hygiene, reduces water consumption, and enhances the overall health outcomes for students (González Salgado, I., 2017). Community-based eco-toilet systems with biogas generation are recommended to address inadequate sanitation infrastructure, improve sanitation, prevent disease, and generate sustainable energy (Eom et al., 2021). Finally, implementing smart eco-toilets in commercial restroom facilities equipped with sensors, water-saving features, and integrated waste management systems promotes water conservation, cost savings, and sustainable practices (Macedo et al., 2022). The need for sustainable and hygienic sanitation solutions has driven the evolution of eco-toilets. Eco-toilets have emerged as a response to various challenges, including the lack of proper sanitation facilities, water scarcity, environmental concerns, and public health risks. To address these issues, these toilets incorporate innovative technologies such as composting, anaerobic digestion, waterless systems, and waste separation. They offer improved sanitation, reduced water consumption, waste management, and energy generation through biogas production. The evolution of eco-toilets has been extensively studied and documented by environmental engineering and sanitation researchers, highlighting their benefits and effectiveness in diverse contexts (Meegoda et al. et al., 2012).

The need for sustainable and hygienic sanitation solutions has driven the evolution of eco-toilets. Eco-toilets have emerged as a response to various challenges, including the lack of proper sanitation facilities, water scarcity, environmental concerns, and public health risks. To address these issues, these toilets incorporate innovative technologies such as composting, anaerobic digestion, waterless systems, and waste separation. They offer improved sanitation, reduced water consumption, waste management, and energy generation through biogas production. Environmental engineering and sanitation researchers have extensively studied and documented eco-toilets' evolution, highlighting their benefits and effectiveness in diverse contexts (Meegoda et al., 2012).

Journal of Polymer & Composites
Volume 11, Special Issue 12
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

THE PROPOSED MODEL OF ECO TOILET

General

The "Eco Toilet" paradigm is suggested to address the shortcomings in the literature review. It is also called a sensor-operated solar-based urine-diverting toilet. This toilet uses human waste to create organic fertilizer directly. In the suggested model, the separation of urine and feces has been planned (see figure 1).

The walls of this toilet are constructed from PET plastic bottles. Locally available soil is placed in the bottles to strengthen the wall. The bottles are arranged to form a wall so that precise vertical fissures do not appear. Steel wires connect every bottle to every other bottle. The horizontal plate is fastened to each vehicle at a distance of two feet to support the bottles. To enable cement plaster to adhere to bottles, the plastering mesh is fastened to the outside of the bottles.

For the flush mechanism, the sensors are mounted within the toilet. When someone uses the loo, the flush begins immediately. The toilet flushing operation will begin again after two minutes. After using the loo, the user will maintain their hand in front of the motion sensor. Therefore, the flush and water jet will clean the user and the toilet. The toilet pan has been set up with an automatic separation between feces and pee. On the front side of the pan, there is a compartment.

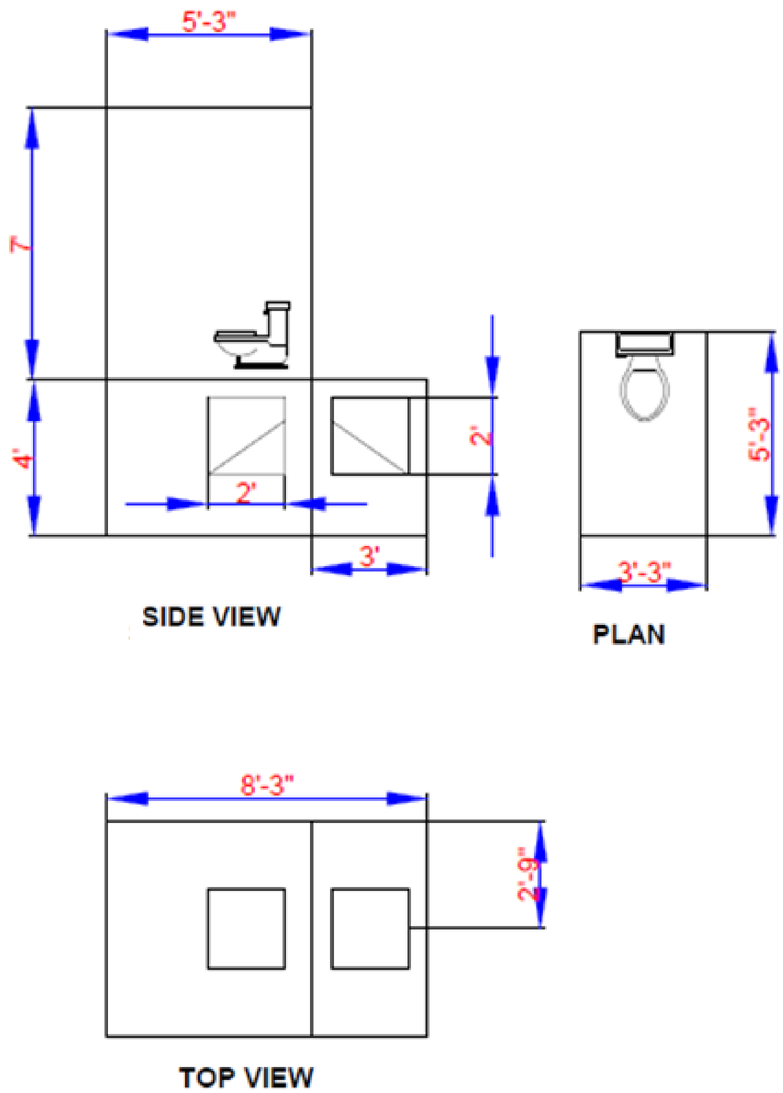

Figure 1. Plan, Top view & Side view of toilet.

The feces enter the intended tank by a trap mechanism. However, after using the toilet, the pee mixes directly with the sewage line. Two inclined mesh are inside the tank. The first uppermost mesh is formed of mild steel and has 0.5 mm-diameter holes. This mesh will still contain substantial solid content. Another mesh at the bottom of it has nylon fabric that only enables the liquid to be inside. The cloth will still have the micro solid and powered components—solar power and the sensor system power the entire system. Sensing technology was used at various stages of atomization. This may make it easier to make fertilizer using feces.

The blending tank, situated next to the mesh tank, receives the filtered material. The organic materials will be mixed in this tank to facilitate quicker composting. Without touching it, this toilet will prepare fertilizer. The Scavengers Act forbids handling human waste before it is degraded. With the aid of this model, fertilizer can be prepared without being handled or coming into contact with it.

Methodology

Building an eco-toilet wall using PET bottles involves several steps (see Figure 2). First, PET bottles are collected from local establishments like restaurants, bars, canteens, and scrap merchants to obtain the required material. These bottles, commonly used for packaging beverages, are highly recyclable. In the next step, the bottles are filled with foundry sand to enhance their strength and reduce air voids. This not only strengthens the bottles but also helps reduce industrial waste. After that, the toilet frame is installed, providing structural support and holding all components together. The toilet pan, made of durable materials like ceramic, is then installed and connected to the plumbing system for waste disposal and flushing.

To enable touchless operation, sensors are installed in the toilet. These sensors detect human presence, control lighting, initiate flushing, and determine seat occupancy. They also activate water jets for personal hygiene and trigger odor-removing sprays. After several uses, the toilet floor is self-cleaned with a water jet, and the entire system operates on solar power. The flush water and human feces enter a tank with two compartments. A filtration tank separates water from the flush material, transferring the separated feces to a storage tank for a 15-day drying process to remove odor and bacteria.

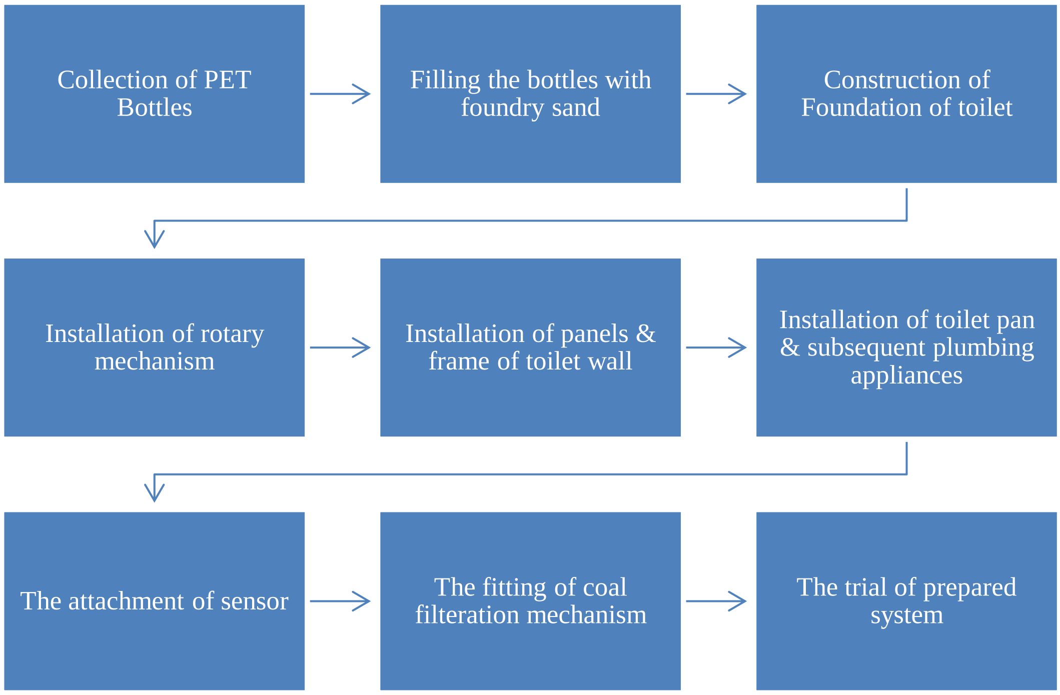

Figure 2. Flow chart of Eco-toilet.

To reuse the separated flush water, an activated charcoal filter is introduced. The filter removes fine particles from the water, making it suitable for gardening. Finally, composting of the fecal sludge takes place. This controlled aerobic process decomposes the sludge and bio-additives like sawdust and flour mill waste, producing nutrient-rich soil amendments. The composting process follows specific temperature requirements and considers the NPK values of the resulting compost. These steps ensure that the eco-toilet system maximizes resource efficiency, reduces waste, and promotes sustainable practices.

Relevance to Society

Fecal waste is currently combined with sewer lines via septic tanks. The strain on the sewer pipe may rise as a result. In contrast to chemical fertilizers, which are insoluble, fecal waste is a soluble form of fertilizer. Long-term effects include an increase in soil fertility. Water bodies have been collecting PET plastic bottles for a while. This harms aquatic life. The use of these bottles effectively has been demonstrated by the model. The sensors can lessen bacterial infection. Effective implementation is also possible for the intelligent toilet system. For feces and urine, there are multiple approaches to nutrition recovery. The toilet pan separating urine makes collecting nutrients from human waste simple. Additionally, urine can be heated to the proper temperature to extract the urea. In the modern era, the problem of carbon emissions is persistent. This problem can be resolved by using solar energy. Utilizing solar energy is simple because toilet activities demand less energy than other home tasks. The creation of fertilizer from human waste can improve the functionality of the current sewage system. One can get money after selling fertilizer, which advances civilization.

The precise user group that would benefit from an eco-toilet includes various stakeholders, each with their interests and needs.

Firstly, individuals living in areas with limited access to sanitation infrastructure would greatly benefit from eco-toilets. These areas may need proper sewage systems or better waste management practices, leading to poor sanitation and hygiene. Eco-toilets provide a sustainable and environmentally friendly alternative by efficiently processing human waste and reducing strain on existing sewage systems. This improves public health, reduces water pollution, and enhances overall living conditions for these communities.

Secondly, environmentally conscious individuals and organizations focused on sustainable living and resource conservation would find eco-toilets appealing. These users are concerned about minimizing their environmental footprint and actively seek solutions contributing to a circular economy. Eco-toilets offer a way to recycle and recover valuable nutrients from human waste, reducing the need for chemical fertilizers and promoting soil fertility. This group is motivated by the potential long-term benefits of eco-toilets in terms of environmental preservation, conservation of water resources, and reducing carbon emissions.

Lastly, eco-toilets can benefit entrepreneurs and businesses involved in waste management, agriculture, or renewable energy sectors. The by-products of eco-toilet systems, such as nutrient-rich fertilizers and urea, can be utilized as valuable resources and sold for profit. This not only creates economic opportunities but also incentivizes the adoption of eco-toilets by providing a financial return on investment. Moreover, these businesses can leverage the integration of solar energy in eco-toilet systems to enhance their sustainability credentials further and reduce operational costs. In summary, the precise user group that would benefit from eco-toilets includes communities with limited sanitation infrastructure, environmentally conscious individuals and organizations, and entrepreneurs and businesses seeking sustainable solutions and economic opportunities in waste management and renewable energy sectors.

Merits and demerits

The system's design aids in reducing the amount of toilet waste produced. However, since the system is new, it is necessary to discuss the effects. Plastic rather than bricks can impair the wall's durability (Haque et al., 2019). Another significant problem is the adhering of cement plaster on plastic. Due to poor adhesion between the bottle and cement plaster, cracks may form on the surface of the walls. The primary problem with the system is routine maintenance. Water is constantly in contact with the toilet. While running the system, it is tough to maintain a dry atmosphere for the sensors (Zhang Z. et al., 2021). Making a mold for a toilet pan is difficult for manufacturers because the molds come in various sizes. Compared to a standard toilet, the system has a higher installation cost. Skilled laborers must install all of the components. It is strongly advised to seek the assistance of professionals in various sectors, such as plumbing, metal science, electrical, solar, civil, and mechanical engineering (Eom et al., et al., 2021).

IMPLEMENTING AN ECO-TOILET SYSTEM

The Eco-Toilet model has several implications for improved sanitation and environmental sustainability. It offers numerous merits, such as automated sensor-operated flushing, water-saving mechanisms, enhanced hygiene, reduced maintenance, and longer lifespan. PET bottles in construction reduce plastic waste, while urine separation capabilities contribute to efficient waste management and odor control. The incorporation of sensors enables touchless operation and activates water jets for personal hygiene and odor-removing sprays. The system operates on solar power and promotes water reuse for gardening. Additionally, the model converts feces into compost, providing a valuable resource for soil enrichment.

However, there are demerits to consider. Some drawbacks include the expertise required for installation and maintenance, higher initial investment, complex automated systems demanding more maintenance, occasional delays in flushing, and potential water splashing. Resistance to innovation, unfamiliarity for some users, limitations in urine separation, challenges in manufacturing fertilizer from waste compost, higher costs compared to traditional toilets, and logistical challenges in ceramic toilet production are also factors to consider.

The research findings demonstrate positive outcomes regarding the Eco-Toilet model's design, functionality, and benefits. Repurposed PET bottles reduce plastic waste, and sensor integration enhances convenience and efficiency. The urine separation capability improves waste management and water conservation is achieved through automated flushing. The hygienic qualities, durability, and long lifespan make it a sustainable solution. The transformation of feces into organic fertilizer supports sustainable agriculture. However, expertise requirements, higher costs, maintenance demands, and some limitations are challenges to address. Overall, the Eco-Toilet model shows promise in addressing sanitation and sustainability challenges with further research and implementation efforts required.

LIMITATIONS IN CURRENT TOILET SYSTEM AND SOLUTIONS ADOPTED IN ECO-TOILET

KEY POINTS OF REVIEW & DISCUSSION

The fundamental idea of the sanitation system is the toilet's design. Those currently below the poverty level cannot afford the cost of a toilet building. It is necessary to research the toilets that can be produced utilizing locally available materials. In this instance, it is necessary to establish the bare minimal norms. In the case of inexpensive restrooms, characteristics like strength, durability, aesthetic appeal, and alignment are crucial, but privacy is still the most critical factor. In India, 38% of the population still needs proper sanitary facilities. Hence, innovation in the relevant field can be helpful in this way.

The engineering profession has a moral duty to update its antiquated ideas on human waste. The civil engineering approach to sanitation and the treatment of human waste needs to be updated, which requires the development of a targeted agenda. The biggest hurdle to overcome in order to obtain acceptance may be the public's negative opinion of human waste, and engineers must be the ones to bring about this transformation. The engineering community must acknowledge the unsustainable nature of chemical fertilizers while appreciating the enormous role that human waste may play in redistributing nutrients throughout the environment.

Creating a toilet model that efficiently degrades fecal sludge is necessary in light of the current degradation mechanism. The toilet's output should be constructed such that the sludge can be transformed into organic fertilizer without the involvement of a human. Scavengers' actions should not cause any disruption to the system's designed model. Therefore, that is why it should be designed. To reduce the unpleasant fumes and effectively employ the septic tank's high nutrient content as a soil conditioner, organic compounds, and other microorganisms can be added. This line of thinking is also applicable to urinals. There are many rich nutrients in urine. The electrolytic technique can separate the ineffective compounds as soil conditioners. In this case, the programming-based system needs to be developed. This system will detect the nutrient-filled content, which the low nutrient content can separate (see table 2).

Table 2. Limitations and solutions adopted in ECO Toilet.

Limitations observed in current toilet system (mentioned in table No. 1)	**Solutions adopted in ECO Toilet**
Bacterial infection while touching toilet appliances	Eco-toilets with touchless features and antimicrobial surfaces minimize the risk of bacterial infection while using toilet appliances.
Wastage high amount of water to flush toilet, public toilets	Water-saving features in eco-toilets reduce wastage of water during flushing, addressing the high water consumption in public toilets.
Lack of proper sanitation facilities leading to water contamination and health issues	Eco-toilets provide proper sanitation facilities, preventing water contamination and health issues associated with inadequate sanitation.
Transmission of bacteria due to carriage of urine for laboratory testing	Smart toilet systems for home-based urine testing eliminate the need for carrying urine, reducing the transmission of bacteria during laboratory testing.
Overload of sewer systems causing frequent blockages and sewage overflow	Implementation of waterless urinals and vacuum-assisted toilets in eco-toilets mitigates the overload of sewer systems, preventing frequent blockages and sewage overflow.
Lack of sanitary facilities and limited water availability in remote mountain areas	Eco-toilets in remote mountain areas offer sanitary facilities with minimal water usage, addressing the lack of sanitary facilities and limited water availability.
Difficulties faced by astronauts while toileting	Advanced toilet technologies are being developed for astronauts to overcome the difficulties faced during toileting in space.
Lack of extraction of nutrient in efficient manner	Eco-toilets with optimized waste management systems ensure efficient extraction of nutrients, addressing the inefficient nutrient extraction problem.
Inadequate sanitation infrastructure leading to unhygienic conditions and health risks for students.	Installation of eco-toilets in educational institutions improves sanitation infrastructure, creating hygienic conditions and reducing health risks for students.
Lack of access to proper sanitation facilities, leading to open defecation and spread of diseases.	Community-based eco-toilet systems provide proper sanitation facilities, eliminating the need for open defecation and reducing the spread of diseases.
High water consumption and inefficient waste management in commercial restroom facilities.	Smart eco-toilets in commercial restroom facilities reduce water consumption and improve waste management, addressing the high water consumption and inefficient waste management issues.

The prevalent practice of disposing of fecal waste on-plot currently poses a serious threat to both the environment and public health. There is much potential to help society by managing fecal sludge better. Moreover, the size and nature of the issue indicate that a concerted effort involving both public and private action is likely to be required to support and promote a sludge management service, which will be crucial in the years to come. In the most recent demographic health survey data available for each country, there is a need for fecal sludge management that can be evaluated based on the standard sanitation metric. This self-reported measure primarily focuses on where defecation occurs rather than the ultimate fate of the household's fecal sludge. To gauge safe containment along the entire sanitation chain, developing more thorough, quick, practical, and potentially risk-based assessments of fecal sludge management and sanitation facilities is necessary.

Nowadays, water bodies are allowed to interact with urine. To stop urine from leaking out, a remedy must be found. By creating toilets or urinals with perforations, this can be decreased. It must create a mechanism that eliminates the adverse effects of the bacteria found in fecal sludge. Also, it must develop the material for urinal manufacture that will allow urine to percolate into the urinals. This may result in less water being used for flushing. The main problem in many places is the need for more water. So, the urinal that absorbs and releases water in the air over time is advantageous in some areas. The scented urinal is also needed for future generations, which mixes with the urine and resists a foul odor.

Toilets that effectively redirect urine must be manufactured. Feces can be used to separate the urine in this. This makes applying the two components individually easier while utilizing soil conditioner. Both materials have unique features. Also, the method used to extract nutrients is unique. UDT can, therefore, be utilized in these senses efficiently. It is necessary to innovate the robotic toilet. This can carry out all toileting-related tasks automatically. It handles cleaning, maintaining water flow, removing bacteria, and removing foul odors. It benefits in many ways, including reduced water use, decreased bacterial growth, odor reduction, etc.

Work must be done to reduce the bacterial infection brought on by toilets. Introduce automated flush toilets where the flushing mechanism is powered by hydraulics. It is necessary to build standing urinals to eliminate urinal touch connectivity. The hydraulic toilet pans are also challenging to clean and can reduce bacterial infection. Effective community participation with multiple NGOs and governmental agencies is required. This may raise awareness about using the restroom. This aids in maximizing the advantages of government programs. This might lead to the establishment of plans for specific regions. Regarding sanitation services, every region faces a unique set of challenges. Collaboration can assist in identifying sanitation system deficiencies.

Artificial intelligence in sanitation systems has the potential to make using toilets easier. The AI can recognize a person's habits and gather usage information. This can lessen the need to flush the toilet with your hands and conserve water. AI and IOT simulations can provide the ideal answer for people with disabilities. This aids in flushing the system and can be used as support. It can recognize the issue presented by a disabled individual after being connected to the neural system. It decreases bacterial infection, falls by impaired people, and the amount of time and water needed to flush the toilet. It is necessary to work on the proper sensors so that the intelligent toilet may be connected to a smartphone app, where users can turn on or off specific functionalities of the intelligent toilet and get data from it. By doing this, a database can be built, which can then be used to incorporate user feedback into the developed prototype's design.

It is necessary to build an automatic bacterial floor identifier to recognize the germs on bathroom floors. This can automatically clean the floor. By doing this, one might need less water to clean the floor. Moreover, this method can reduce the need for repeated washing.

Based on a vertical bar orientation, efforts could be made to provide hand support for usage in a toilet environment. A modular system that can adapt to a family's changing needs might be considered. For instance, this system might include modules for vertical supports, transfer surfaces, a toilet with changeable height and tilling, and a washbasin with 3D positioning capabilities. The modern society also requires the use of portable toilets. Moving toilets that are not maintained are used at these events. In the modern period, there is much potential for toilets that require less maintenance or toilets where feces can be used directly as a soil conditioner. This objective can be accomplished with the aid of chemical additives to ceramic.

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

Masonry skills are the only ones acknowledged for toilet construction in rural India; installation expertise still needs to be developed. On the other hand, in cities, masons build the structures, and plumbers install the toilet accessories. The standardization of green technology latrine accessories and design is another crucial lesson learned from the toilet revolution. The design would lower water use, and standardized installation would lower leakage and recurring maintenance costs. Like energy-related products, toilet accessories could receive star ratings based on how effectively they use resources. This would address proper waste management because the continual dumping of human waste into the ground untreated could contaminate the soil. Millions of rural women social entrepreneurs have been mobilized into self-help organizations in response to these cultural and technological difficulties at the micro level, and policies must acknowledge and foster collaboration in social transformation.

CONCLUSIONS

The Eco-Toilet model presents a promising solution to address the existing limitations within current sanitation systems. It incorporates various innovative features and technologies to improve sanitation, water conservation, waste management, and overall sustainability. Eco-Toilets are equipped with touchless features and antimicrobial surfaces to counter bacterial infection concerns, thereby reducing the risk of contamination from direct contact with toilet appliances. Water-saving mechanisms incorporated into these toilets effectively address the issue of excessive water consumption in public facilities, thus minimizing water wastage during flushing. Providing adequate sanitation facilities by Eco-Toilets prevents water contamination and related health risks, contributing to a healthier environment.

A notable advantage Eco-Toilets offers is eliminating the need for external urine testing. Intelligent toilet systems enable urine testing at home, reducing bacterial transmission and enhancing user convenience. Eco-Toilets integrate waterless urinals and vacuum-assisted toilets to tackle the strain on sewer systems, mitigating frequent blockages and sewage overflow. In remote mountainous areas with limited water access, Eco-Toilets provide sanitary amenities with minimal water usage, addressing the absence of proper sanitation infrastructure. Advanced toilet technologies are also being developed to cater to the specific needs of astronauts during space missions, overcoming challenges posed by zero-gravity environments. Eco-Toilets also tackle the efficient extraction of nutrients from waste. These systems are designed with optimized waste management mechanisms to ensure adequate nutrient extraction for further utilization. Installation of Eco-Toilets in educational institutions improves sanitation infrastructure, leading to hygienic conditions and reduced health risks for students.

Community-based eco-toilet systems are crucial in areas lacking proper sanitation facilities, eliminating the need for open defecation and curbing disease transmission. In commercial restroom settings, smart eco-toilets contribute to water conservation and streamlined waste management, promoting sustainable practices.

Eco-toilets benefit many contexts, including rural and urban areas facing challenging conditions. These include rural households without access to traditional sewer systems, urban residents dealing with overloaded sewer networks, mountain communities with limited water availability, educational institutions lacking proper sanitation, coastal communities and tourists concerned about marine pollution, and individuals in disaster-prone areas requiring emergency sanitation solutions. Moreover, Eco-Toilets cater to tourists visiting recreational parks and heritage sites, commercial complexes aiming for water conservation, and even astronauts during space missions, all benefiting from the innovative features and sustainable practices of Eco-Toilets.

In contrast to conventional toilet systems where fecal sludge is mixed with sewer lines, thereby straining the system, the proposed Eco-Toilet design offers substantial potential for reducing toilet waste. Utilizing human feces to produce organic fertilizer from waste showcases an efficient and eco-friendly approach. Incorporating sensors significantly reduces the risk of bacterial infections. The use of PET bottles prevents long-term plastic waste accumulation. By integrating solar technology, the system's energy requirements can be minimized.

Present sanitation systems often rely on biological mechanisms to break down fecal waste, which can result in incomplete decomposition. Some waste mixes into sewer lines, leading to heightened water body contamination. This is particularly problematic in some rural regions where fecal matter is not fully decomposed before entering water bodies, resulting in severe pollution. Additionally, conventional toilet pan degradation is limited and requires careful modification. After 67 years of independence, the fact that half of Indians lack access to public restrooms is telling. One out of every six urban Indians is forced to urinate outdoors every day, as the Ministry of Urban Development Report acknowledges. Many children, especially those in upper grades, who were affected by unfavorable opinions of school restrooms developed unhealthy bathroom habits while attending school (aged 13 to 16 years). Students typically base their unfavorable opinions of school restrooms on how the facilities look and how uneasy they feel about using them. A trip to the bathroom away from home can be stressful for many kids. As a result, kids frequently find it simpler to put up with the physical difficulty of holding it in than the psychological and social anguish of using the toilet at school. This situation forces researchers to find an optimum solution for the effective degradation of fecal matter.

REFERENCE

1. Bhatia, M., Kaur, S., & Sood, S. K. (2020) “IoT-inspired smart toilet system for home-based urine infection prediction”. ACM Transactions on Computing for Healthcare, 1(3), 1-25.
2. Blackett, Adelle. (2014) "Introductory note to the decent work for domestic workers convention, 2011 (No. 189) and Recommendation (No. 201)." International Legal Materials 53.1: 250-266.
3. Bustamante, D. G., Perez, A. M., Calderon-Cerquera, K., Orozco-Donneys, C., Orozco, A. M., Giron-Sedas, J. A., & Perea, J. D. (2021) “Tech Lunar Toilet: A STEM Project with High School Students”. European Journal of STEM Education, 6(1), 8.
4. Ciotti, Marco, et al. (2020) "The COVID-19 pandemic." Critical reviews in clinical laboratory sciences 57.6: 365-388.
5. Eom, Y. S., Oh, H., Cho, J., & Kim, J. (2021). Social acceptance and willingness to pay for a smart Eco-toilet system producing a Community-based bioenergy in Korea. Sustainable Energy Technologies and Assessments, 47, 101400.
6. Gong, M., Li, K., Tian, T., Mao, X., & Wang, (2020, November) “Research and analysis on the development of intelligent toilet”. In Journal of Physics: Conference Series (Vol. 1684, No. 1, p. 012038). IOP Publishing C.
7. González Salgado, I. (2017). Optimization and monitoring of two pilots plants: a mesophilic anaerobic digester and urine diversion toilets in a context of source separation wastewater management.
8. Haque, M. S. (2019). Sustainable use of plastic brick from waste PET plastic bottle as building block in Rohingya refugee camp: a review. Environmental Science and Pollution Research, 26(36), 36163-36183.
9. Hutton, Guy, and Claire Chase. (2016) “The knowledge base for achieving the sustainable development goal targets on water supply, sanitation and hygiene." International journal of environmental research and public health 13.6: 536.
10. Kvarnström, E., McConville, J., Bracken, P., Johansson, M. (2012). EcoSanRes Publication Series 2012-1: EcoSanRes Guidelines for Ecological Sanitation, Swedish University of Agricultural Sciences (SLU), Uppsala, Sweden.
11. Kirk, C. P., & Rifkin, L. S. (2020) “I'll trade you diamonds for toilet paper: Consumer reacting, coping and adapting behaviors in the COVID-19 pandemic”. Journal of business research, 117, 124-131.

12. Macedo, L. S. V. D., Bellezoni, R. A., Oliveira, J. A. P. D., Salehi, P., Currie, P., Jones, A., ... & Boothroyd, T. (2022). Innovating in urban green and blue infrastructure to improve the food-water-energy nexus: an implementation guide for cities and subnational governments.
13. Mbonu, C. C., et al. (2022) "Smart Toilets and Toilet Gadgets in Sustainable Smart Cities: An Overview of Personal Health Monitoring." Advanced Manufacturing in Biological, Petroleum, and Nanotechnology Processing: Application Tools for Design, Operation, Cost Management, and Environmental Remediation: 143-156.
14. Meegoda, J. N., Hsieh, H. N., Rodriguez, P., & Jawidzik, J. (2012). Sustainable community sanitation for a rural hospital in Haiti. Sustainability, 4(12), 3362-3376.
15. Patrick, M., Tsige, Y., Adow, A., Abdirashid, M., Yunis, H., Githiri, D., ... & Handzel, T. (2021). Acceptability of urine diversion dry toilets in Dollo Ado refugee camp, Ethiopia. International Journal of Hygiene and Environmental Health, 234, 113745.
16. Shah, A., Karmiani, D., Mehta, D., & Kulkarni, S. (2020) “Solar Powered Self-Cleaning Toilet”. In International Conference on Business Management, Innovation & Sustainability (ICBMIS).
17. Sridhar, M. K. C., O. T. Okareh, and M. Mustapha. (2020) "Assessment of knowledge, attitudes, and practices on water, sanitation, and hygiene in some selected LGAs in Kaduna State, Northwestern Nigeria." Journal of environmental and public health 2020.
18. Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., Zurbrügg, C. (2014). Compendium of Sanitation Systems and Technologies (2nd Revised Edition). Swiss Federal Institute of Aquatic Science and Technology (Eawag) and Sandec, Department of Water and Sanitation in Developing Countries, Dübendorf, Switzerland.
19. Tierney, R. (2017). The potential of reverse innovation to improve urban toilets (Doctoral dissertation).
20. Velavan, Thirumalaisamy P., and Christian G. Meyer. (2020) "The COVID-19 epidemic." Tropical medicine & international health 25.3: 278.
21. World Health Organization. (2021) “Progress on household drinking water, sanitation and hygiene 2000-2020: five years into the SDGs”.
22. Yang, Li, et al. (2020) "COVID-19: Immunopathogenesis and Immunotherapeutics." Signal transduction and targeted therapy 5.1: 128.
23. Zhang, Z., Shi, Q., He, T., Guo, X., Dong, B., Lee, J., & Lee, C. (2021). Artificial intelligence of toilet (AI-Toilet) for an integrated health monitoring system (IHMS) using smart triboelectric pressure sensors and image sensor. Nano Energy, 90, 106517.

