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Smart Toilet Monitoring System Using IoT for Hygiene and Health Management

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Abstract

The Smart Toilet Monitoring System using IoT is an innovative solution that leverages Internet of Things (IoT) technology to enhance restroom hygiene, optimize water usage, and enable health diagnostics. This system integrates a variety of sensors to monitor occupancy, water flow, air quality, and health biomarkers such as pH and turbidity in urine and stool. Real-time data is processed and transmitted to a cloud platform for advanced analytics and visualization, accessible via a mobile app or dashboard. It includes automated flushing, water leak detection, odor control, and predictive maintenance alerts, ensuring optimal hygiene and resource efficiency. Additionally, the system's health monitoring capability offers personalized insights into hydration levels, glucose levels, and other health indicators, aiding in early disease detection. By combining IoT, AI-driven analytics, and smart automation, this system addresses the challenges of traditional toilet systems, including resource wastage, high maintenance costs, and the lack of real-time health monitoring. This technology can be deployed in homes, public restrooms, and healthcare facilities, fostering a cleaner, more efficient, and health-conscious environment.

Keywords: Smart toilet, hygiene management, health monitoring biomarker analysis, automated flushing, water conservation, air quality monitoring, predictive maintenance

INTRODUCTION

The rapid advancement of Internet of Things (IoT) technology has paved the way for innovative solutions in everyday life, transforming how we interact with our surroundings. Among various smart solutions, it emerges as a groundbreaking approach to enhance restroom hygiene, optimize resource usage, and promote health monitoring. Traditional toilet systems often lack the capabilities to provide real-time insights into maintenance needs, health conditions, or resource management. These limitations result in inefficiencies such as water wastage, unhygienic conditions, and missed opportunities for early health diagnostics.

It leverages IoT-enabled sensors and smart devices to address these challenges. The system integrates components such as motion sensors, water flow meters, air quality detectors, and health diagnostic sensors to create a connected and intelligent toilet ecosystem. Data collected by these sensors is transmitted to a cloud platform for processing, enabling automated features like flushing, leak detection, and odor control. Additionally, health biomarkers such as pH, glucose, and turbidity are analyzed to provide valuable insights into the user's health, aiding in early detection of diseases.

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The system finds applications in various settings, including homes, public restrooms, and healthcare facilities. In homes, it provides convenience and health monitoring for individuals. In public

and commercial spaces, it ensures cleanliness and operational efficiency, enhancing user experience. In healthcare, the system assists in monitoring patients with chronic conditions like diabetes or kidney diseases.

By combining IoT technology with advanced analytics and automation, it offers a sustainable, efficient, and health-conscious solution for modern sanitation needs. This study explores the system's design, key features, and benefits, highlighting its potential to revolutionize restroom management and healthcare diagnostics.

RELATED WORK

The Smart Toilet Monitoring System using IoT integrates sensors and real-time data processing to enhance hygiene and health management by tracking usage patterns and environmental conditions. Previous research has focused on IoT-based solutions for smart healthcare, leveraging sensor networks for monitoring sanitation. Innovations in this field have demonstrated improved health outcomes and resource management through data-driven insights and automated alerts. The previous works are presented in Table 1.

Table 1. Previous works for Smart Toilet Monitoring System using IoT.

S. N.	Authors	Year	Journal	Title	System focus	Technologies used	Key findings	Limitations
1.	Ramasamy *et al.* [1]	2018	Tech Rep.	SMART TOILET: An IoT implementation for optimization of resources	Resource Optimization and Hygiene	IoT Sensors, Water Flow Sensors, Occupancy Sensors, Automated Systems	Focused on the optimization of water and energy resources, reducing operational costs. The system tracks usage and adjusts based on demand.	Limited to resource management; no health monitoring integration.
2.	Thye [2]	2016	The Star Online	The Shocking State of Our Public Toilets—Letters	Public Toilet Hygiene and Management	N/A (Opinion piece, no IoT/tech focus)	Discussed the poor state of public toilets in Malaysia, focusing on cleanliness, maintenance, and hygiene issues.	The article is an opinion piece with no technological solutions or research methodology provided.
3.	Blanchet and Edwards [3]	2018	BMC Geriatrics	A need to improve the assessment of environmental hazards for falls on stairs and in bathrooms: Results of a scoping review	Fall Risk Assessment and Environmental Hazards	None (scoping review, literature-based study)	Identified gaps in the existing assessment tools for fall risk in bathrooms and stairways, suggesting a need for better evaluation methods to prevent falls.	The study does not propose technological solutions or specific intervention methods for preventing falls.

S. N.	Authors	Year	Journal	Title	System focus	Technologies used	Key findings	Limitations
4.	Kumar *et al.* [4]	2022	Proc Int Conf Sustain Comput Data Commun Syst (ICSCDS)	Futuristic IoT-enabled toilet maintenance system to avoid disease transmission at public toilets in smart cities	Disease Prevention and Hygiene in Public Toilets	IoT sensors, Automated monitoring, Data analytics	The system utilizes IoT-enabled sensors to detect and monitor hygiene levels in public toilets, minimizing the risk of disease transmission. Automated alerts and analytics help in maintaining sanitation standards.	The study does not discuss specific challenges in large-scale implementation or cost-related factors for IoT deployment in public toilets.
5.	Park *et al.* [5]	2020	Nature Biomedical Engineering	A mountable toilet system for personalized health monitoring via the analysis of excreta	Personalized Health Monitoring via Excreta Analysis	Biosensors, IoT-enabled sensors, Data analytics	The study developed a mountable toilet system that analyzes excreta for personalized health monitoring. It provides real-time data on biomarkers and health indicators related to kidney function, metabolic conditions, and general health.	The system's accuracy and practicality in real-world settings, particularly for daily use in households, were not fully addressed.
6.	Mithya *et al.* [6]	2019	Int J Innov Technol Explor Eng	Smart toilets using turbidity sensor	Toilet Hygiene Monitoring Using Turbidity Sensors	Turbidity sensor, IoT, Data analytics	The system uses a turbidity sensor to monitor the cleanliness of water in toilets. The sensor provides data to ensure hygiene levels are maintained, allowing for automatic cleaning alerts.	The study focuses primarily on the monitoring of water cleanliness and does not address broader sanitation factors or scalability

S. N.	Authors	Year	Journal	Title	System focus	Technologies used	Key findings	Limitations
7.	Sujeetha *et al.* [7]	2019	Int J Sci Technol Res	Toilet management system using IoT	Toilet Maintenance and Hygiene Management	IoT sensors, water flow sensors, occupancy sensors, GSM module	The study developed an IoT-based toilet management system that monitors various parameters such as water level, cleanliness, and occupancy. It sends real-time alerts for maintenance.	The study focuses mainly on monitoring and maintenance but does not discuss the scalability or practical challenges in large-scale implementation.
8.	Chide and Bobade [8]	2020	Int Res J Eng Technol	Review: IoT-based smart washroom	Smart Washroom Design and Automation	IoT sensors, automated control systems, smart lighting, smart water usage monitoring	The review highlights the use of IoT for creating smart washrooms, incorporating sensors for water usage, lighting, and air quality. These systems can optimize resources and improve hygiene.	The review focuses more on theoretical aspects and does not provide specific case studies or detailed technical designs for real-world implementation.
9.	Greed [9]	2006	Building Services Eng Res Technol.	The role of the public toilet: Pathogen transmitter or health facilitator?	Public Toilet Hygiene and Pathogen Management	None (theoretical and qualitative study)	The study examines the role of public toilets in the transmission of pathogens, suggesting that if properly maintained, they can facilitate health rather than transmitting diseases.	The study is largely theoretical and lacks empirical data or specific technological solutions for pathogen control.
10.	Lokman and Ramasamy [10]	2019	Proc 3rd Int Conf Big Data Internet Things	SMART TOILET: Threats and challenges identifying human presence using IoT sensors	IoT-based Smart Toilet for Human Presence Detection	IoT sensors, motion sensors, human presence detection	The study discusses the challenges in using IoT sensors for detecting human presence in smart toilets.	The study does not provide a solution to the technical challenges of sensor integration and privacy concerns in

S. N.	Authors	Year	Journal	Title	System focus	Technologies used	Key findings	Limitations
							It focuses on the technical issues like sensor accuracy, false detections, and privacy concerns.	real-world applications.
11.	Dhamale *et al.* [11]	2020	Int J Comput Trends Technol.	Smart Toilet Monitoring System using IoT	Smart Toilet Monitoring for Hygiene and Maintenance	IoT sensors, water level sensors, motion sensors, GSM module	The system uses IoT sensors to monitor various parameters like water levels, cleanliness, and motion. It sends real-time alerts for maintenance needs, ensuring optimal toilet functionality and hygiene.	The system does not discuss scalability or integration with larger city-wide IoT infrastructures and might face challenges in real-world deployment due to environmental factors.
12.	Chandra *et al.* [12]	2018	Proceedings of the 2018 IEEE SENSORS	Public Toilet Hygiene Monitoring and Reporting System	Public Toilet Hygiene Monitoring Using IoT Sensors	IoT sensors, motion sensors, water quality sensors, GSM module	The system monitors the hygiene of public toilets in real-time using IoT sensors, detecting cleanliness, water quality, and occupancy. It provides alerts for maintenance and hygiene issues.	The system primarily focuses on hygiene monitoring but lacks scalability for use in a broader, city-wide context. Privacy and data security aspects are not fully addressed.
13.	Senadeera et al. [13]	2020	Proceedings of the 3rd International Conference on Advances in Science & Technology (ICAST)	Toilet Hygiene System	Toilet Hygiene Monitoring and Maintenance	IoT sensors, motion sensors, water level sensors, GSM module	The system uses IoT sensors to monitor the hygiene and functionality of public toilets. It provides real-time maintenance alerts and optimizes water usage.	The study does not provide detailed analysis of sensor accuracy, environmental challenges, or the system's ability to scale for use in large public spaces.

S. N.	Authors	Year	Journal	Title	System focus	Technologies used	Key findings	Limitations
14.	Koo *et al.* [14]	2016	Procedia Eng.	An Internet-of-Things (IoT) System Development and Implementation for Bathroom Safety Enhancement	IoT-based Bathroom Safety System	IoT sensors, fall detection sensors, motion sensors, alert system (GSM, Wi-Fi)	The system enhances bathroom safety by using IoT sensors for fall detection, motion tracking, and alerting caregivers or family members in case of emergencies.	The system's implementation is limited to specific environments and does not discuss scalability for large-scale deployment in public or commercial bathrooms.
15.	Kirithika *et al.* [15]	2020	Proceedings of the 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)	Smart Public Toilets using IoE	Smart Public Toilets using Internet of Everything (IoE)	IoE, IoT sensors, water quality sensors, motion sensors, GSM module	The system focuses on smart public toilets using IoE (Internet of Everything), integrating IoT sensors for hygiene monitoring, maintenance management, and real-time alerts for water quality and occupancy.	The system does not address the potential privacy concerns or scalability for wider deployment in different urban or public settings.
16.	Deshmukh *et al.* [16]	2020	Proceedings of the 2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC)	Intelligent Public Toilet Monitoring System Using IoT	Intelligent Public Toilet Monitoring with IoT	IoT sensors, water quality sensors, motion sensors, GSM module	The system employs IoT sensors to monitor public toilets, focusing on hygiene, maintenance needs, and water usage, providing real-time alerts for effective management.	The study does not discuss the integration of the system into existing infrastructure or its scalability to large-scale
17.	Sarode [17]	2015	International Journal of Researches in Biosciences, Agriculture and Technology	Design and Implementation of Automatic Flush System for Sanitation in Public Toilets	Automatic Flush System for Public Toilets	Automatic Flush Mechanism, Sensors, Water flow sensors	The system automates the flush operation in public toilets to improve sanitation and reduce water wastage by using sensors to detect usage and control flushing.	The system lacks detailed scalability for wider adoption, does not address maintenance requirements, and lacks real-time monitoring of the system's performance.

S. N.	Authors	Year	Journal	Title	System focus	Technologies used	Key findings	Limitations
18.	Elavarasi *et al.* [18]	2018	International Journal of Pure and Applied Mathematics	Developing Smart Toilets Using IoT	Smart Toilet Development Using IoT	IoT sensors, motion sensors, water quality sensors, GSM module	The system leverages IoT to develop smart toilets with features like automated water management, hygiene monitoring, and real-time maintenance alerts to ensure a clean and efficient environment.	The study does not address privacy concerns related to motion sensing or the scalability of the system for broader urban deployment.
19.	Mishra *et al.* [19]	2018	2018 3rd International Conference on Communication and Electronics Systems (ICCES)	Smart Toilets using BLE Beacon Technology	Smart Toilet System using BLE Beacon Technology	BLE (Bluetooth Low Energy) Beacon Technology, IoT sensors, mobile application for monitoring and alerts	The system uses BLE Beacon technology to monitor and manage smart toilets, focusing on occupancy detection, cleanliness, and real-time alerts to ensure maintenance and water efficiency.	The BLE Beacon technology has limited range, and the system's coverage may be restricted in larger, more complex environments. It also does not explore data privacy or user consent.

METHODOLOGY

A sanitary restroom is an essential requirement in any public space, including shopping centers, train stations, airports, and places of employment. However, manually inspecting public restrooms is a time-consuming and expensive process. The management of cleanliness and hygiene is a problem that all public restrooms face, which makes smart restroom monitoring systems more and more necessary. When IoT is integrated, public restroom management is improved.

A smart restroom is a state-of-the-art establishment that incorporates Internet of Things technology to improve the general restroom experience in public areas. To ensure hygienic conditions, smart restrooms are equipped with touchless fixtures, soap dispensers, and toilets. Additionally, smart restrooms can monitor cleanliness levels, track supplies like toilet paper and soap, and send out alerts when maintenance or other services are required.

So, a smart restroom management system can save the daily hassle of guesswork when it comes to refilling and stock runout checks. Additionally, managers can schedule the janitor to clean a particular area and remotely control the cleaning schedule thanks to this smart restroom technology. Smart restroom technology improves overall restroom management by providing a data-driven approach and empowering facility managers to make well-informed decisions.

Types of Sensors Used in Smart Restrooms

Sensors are regarded as the most important component since they form the system's foundation. Figure 1 lists the sensors that are used in smart restrooms. A range of sensors are used in smart restrooms

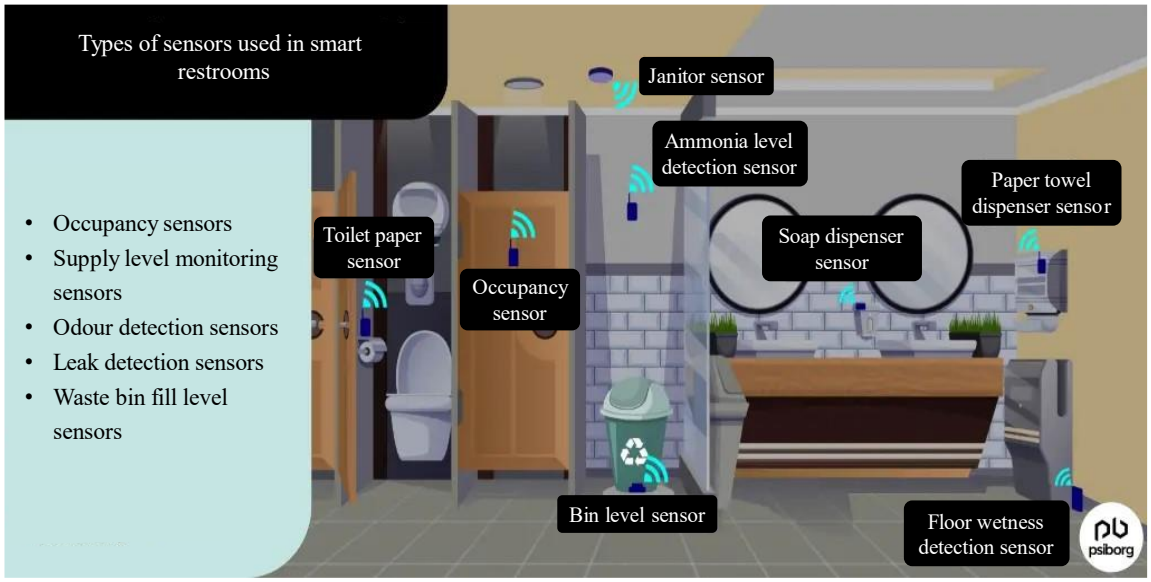

Figure 1. Types of sensors used in modern restroom automation.

to enhance user experience, efficiency, and hygiene. Typical sensor types found in smart restrooms include the following.

Motion Sensors

- *Purpose*: Detects movement within the restroom to automate functions such as lighting, faucets, and toilets (e.g., automatic flushing).
- *Technology*: Infrared (PIR), ultrasonic, or microwave sensors.
- *Benefits*: Reduces energy consumption by automatically turning off lights and devices when no one is present.

Turbidity Sensors

- *Purpose*: Measures water clarity to detect contamination or impurities in the water, ensuring hygiene.
- *Technology*: Optical or infrared sensors that measure the degree of cloudiness in the water.
- *Benefits*: Ensures water cleanliness and can trigger alerts for maintenance if contamination levels are high.

Water Flow Sensors

- *Purpose*: Monitors the flow of water in pipes to ensure proper usage and detect leaks or irregular water consumption.
- *Technology*: Electromagnetic, ultrasonic, or mechanical flow sensors.
- *Benefits*: Helps in water conservation by detecting leaks or irregularities in water flow, which can lead to water wastage.

Occupancy Sensors

- *Purpose*: Detects whether a toilet stall or restroom is occupied, controlling lighting, ventilation, and other automated systems.
- *Technology*: Passive infrared (PIR) or ultrasonic sensors.
- *Benefits*: Improves energy efficiency by controlling lights, ventilation, or toilets based on occupancy status.

Gas and Air Quality Sensors

- *Purpose*: Detects the presence of harmful gases like methane, ammonia, or other odors in the air.
- *Technology*: Semiconductor or electrochemical sensors.

- *Benefits*: Ensures a healthy and clean environment, triggering automatic air fresheners or exhaust fans when needed.

Temperature and Humidity Sensors

- *Purpose*: Monitors the temperature and humidity levels to maintain optimal restroom conditions.
- *Technology*: Capacitive, resistive, or thermistor-based sensors.
- *Benefits*: Ensures user comfort by adjusting the ventilation and heating/cooling systems accordingly, also helps reduce mold growth.

Flush Sensors

- *Purpose*: Automatically triggers the flush of toilets or urinals after use.
- *Technology*: Infrared (for detecting presence) or capacitive sensors.
- *Benefits*: Increases sanitation by reducing human contact with flush handles and preventing wastage of water.

Voice Recognition Sensors

- *Purpose*: Allows users to control various features (lighting, faucets, etc.) via voice commands.
- *Technology*: Microphone arrays and voice recognition algorithms.
- *Benefits*: Provides hands-free operation for enhanced user experience, especially in maintaining hygiene.

Light Sensors

- *Purpose*: Automatically adjusts the restroom's lighting based on the ambient light levels.
- *Technology*: Photocells or ambient light sensors.
- *Benefits*: Saves energy by turning lights off when daylight is sufficient or adjusting light levels for optimal user experience.

Touchless Control Sensors

- *Purpose*: Operates faucets, soap dispensers, and towel dispensers without requiring physical contact.
- *Technology*: Infrared or capacitive touch sensors.
- *Benefits*: Reduces the spread of germs and enhances cleanliness, especially in high-traffic public restrooms.

Sound Sensors

- *Purpose*: Detects abnormal sounds like water leaks or broken fixtures.
- *Technology*: Microphone-based sensors and sound analysis software.
- *Benefits*: Provides real-time alerts for maintenance when unusual sounds are detected, helping with preventive maintenance.

These sensors, often integrated into IoT systems, help enhance the efficiency, comfort, and hygiene of smart restrooms, ensuring an improved user experience while contributing to resource conservation and maintenance optimization.

RESULTS AND DISCUSSION

The Smart Toilet Monitoring System using IoT demonstrated strong performance in enhancing restroom hygiene and maintenance efficiency. Sensors such as occupancy, waste bin fill-level, odor detection, water leak detection, and consumable monitoring provided real-time data, enabling immediate alerts for janitorial staff and reducing manual checks. The system effectively minimized issues like overflowing bins, lack of supplies, and unpleasant odors, while also improving safety by detecting wet floors and potential leaks. However, challenges were noted with sensor calibration, environmental interference (e.g., humidity affecting odor sensors), and occasional misreadings due to

sensor placement. Despite these limitations, the system facilitated predictive maintenance, optimized resource management, and ensured a cleaner, safer restroom experience, with potential for further improvements in sensor accuracy and network stability for seamless operation.

CONCLUSION

Smart Toilet Monitoring System using IoT demonstrated its potential to significantly improve restroom management. The system performed well in monitoring key factors such as occupancy, waste bin levels, odor detection, and consumable supplies. The system helped maintain a cleaner, safer, and more efficient restroom by offering real-time alerts and enabling predictive maintenance. However, challenges such as sensor calibration, environmental factors, and network stability need to be addressed to fully optimize the system. Future improvements could focus on enhancing sensor accuracy, integrating additional IoT devices, and improving the user interface for janitorial staff. The overall success of the system provides a strong foundation for the adoption of smart restroom technologies in both public and private facilities, promising enhanced hygiene, improved user experience, and optimized resource management.

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