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RESEARCH ARTICLE

Smart Photocatalytic Self-Cleaning Urinal System for Public Hygiene & Sustainable Sanitation

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ABSTRACT: Public sanitation facilities in India, particularly high-footfall public urinals, continue to face persistent challenges, including microbial contamination, unpleasant odors, irregular maintenance, and inefficient water usage. These issues increase public health risks, discourage usage, and limit the effectiveness of national sanitation initiatives such as the Swachh Bharat Mission. The COVID-19 pandemic further highlighted the need for preventive, hygiene-focused sanitation solutions that reduce human contact and dependence on manual cleaning. To address these challenges, an IoT-based Smart Photocatalytic Self-Cleaning Urinal System was developed that integrates titanium dioxide (TiO_2) – based photocatalysis, ultraviolet (UV) disinfection, and a microcontroller-based automated system for sustainable sanitation. A TiO_2 nano-coated surface activated by UV-A illumination (365–385 nm) generates reactive oxygen species that decompose organic residues and neutralize ammonia-based odors, while complementary UV-C exposure (200–280 nm) ensures effective microbial inactivation by disrupting bacterial and viral DNA and RNA. The system incorporates an ESP32 microcontroller, a Time-of-Flight (ToF) sensor, UV LEDs, a two-channel relay module, an ammonia (NH_3) gas sensor, a DHT11 temperature and humidity sensor, a DFPlayer Mini audio module with speaker, a water flow sensor, an ultrasonic sensor, and a solenoid valve. System operation is managed by the ESP32 microcontroller, enabling Time-of-Flight–based user detection, safety-controlled UV activation, and a touchless solenoid valve–based flushing mechanism. Parameters such as temperature and humidity, ammonia concentration, water flow, user count, and tank water level are continuously monitored to support real-time hygiene assessment, water leak detection, water availability monitoring, and optimized system performance. The DFPlayer Mini audio module delivers automated voice announcements to guide users, promote hygiene awareness, and encourage proper usage, thereby supporting improved public sanitation practices. The ESP32 microcontroller is programmed using the Arduino IDE. A web-based dashboard has been developed to monitor urinal vacancy status, user count, temperature, humidity, hygiene status (based on NH_3 levels), UV light ON/OFF status, flushing status, water leakage and consumption, and tank water availability using ultrasonic sensing. The dashboard also allows customization of flush cycles and flush activation distance. The proposed system demonstrates the potential to improve hygiene standards in public urinals through continuous self-cleaning and self-disinfection, reduced water and chemical usage, minimized manual intervention, and remote monitoring, with alerting capabilities. This can be further upgraded into a scalable and sustainable solution for enhancing public sanitation infrastructure and improving user experience in public spaces.

KEYWORDS: Photocatalysis, Titanium Dioxide (TiO_2), Self-cleaning Surfaces, Sustainable Sanitation, Internet of Things (IoT).

Introduction

Field observations conducted during visits to public toilets in cities such as Vijayawada (Figures 1, 2, 4) and Guntur (Figure 3), as well as sanitation facilities encountered during railway travel, shopping malls, and bus stations, revealed consistently poor hygiene conditions. Common issues identified include persistent foul odors, inadequate maintenance, manual flushing systems, non-availability of water, water leakages, lack of supervision, excessive use of cleaning chemicals, and high chances of microbial contamination. Due to these unhygienic conditions, many individuals avoid using public urinals and instead resort to open urination, which further aggravates environmental pollution and public health risks. Access to safe and hygienic sanitation facilities is a critical determinant of public health and human dignity.

To address the issue of open defecation, the Government of India launched the Swachh Bharat Mission in 2014. Under this initiative, more than 6,36,826 community and public toilets[1] were constructed across the country. This program has significantly improved sanitation infrastructure nationwide. However, the hygienic maintenance of public urinals continues to remain a persistent challenge. To ensure that these efforts are sustainable and effective in the long term, it is essential to adopt smart technologies that simplify the operation, maintenance, and supervision of public sanitation facilities.

Figure 1: Unhygienic Surroundings.

Figure 2: Excessive use of chemicals.

Figure 3: Filthy urinals and surroundings.

Figure 4: Badly maintained urinals.

Public urinals act as potential transmission points for pathogenic microorganisms through shared surfaces and contaminated environments. The COVID-19 pandemic further highlighted the vulnerability of public sanitation facilities as high-risk zones for disease transmission, emphasizing the need for continuous disinfection and preventive, hygiene-focused sanitation systems. Conventional sanitation practices largely depend on frequent manual flushing and manual cleaning using chemical disinfectants. Although automatic and sensor-based urinals are available, most lack integrated self-disinfection mechanisms, real-time hygiene monitoring, and sustainable water management systems, which limits their effectiveness in maintaining consistent hygiene standards.

Recent advances in material science have demonstrated that self-cleaning surfaces[4,5] based on titanium dioxide (TiO_2) photocatalysis can effectively degrade organic pollutants and inactivate microorganisms when activated by ultraviolet (UV) light. Similarly, UV-C irradiation[13] is well established for its germicidal effectiveness. In parallel, Internet of Things (IoT) technologies have enabled real-time monitoring, automation, and data-driven remote supervision of systems.

These insights motivated the development of a low-cost sanitation solution suitable for public urinals, termed the Smart Photocatalytic Self-Cleaning Urinal System, which aims to ensure:

- Touchless and automated water flushing
- Continuous hygiene maintenance with minimal manual intervention
- Reduced physical workload and chemical exposure for sanitation workers
- Odor-free, hygienic, and user-friendly public sanitation environments
- Conservation of water and minimizing cleaning chemicals
- Remote monitoring of usage patterns, hygiene status, and maintenance needs
- Early warning alerts through preventive maintenance indicators
- Voice-guided prompts to promote hygienic behavior and public awareness
- Smart operation using a low-cost Internet of Things (IoT)–based solution

Limitations of Existing Urinal Systems:

- Touch-based flushing causes the spread of germs
- Incomplete or absent flushing leaves urine residues behind
- Odor buildup occurs due to ammonia and uric acid accumulation
- Frequent chemical cleaning is costly and harmful to the ecosystem
- Excessive and inefficient water usage leads to wastage
- No built-in disinfection mechanism for microbial control
- Absence of real-time monitoring and alert systems
- Health and safety risks for sanitation workers continue
- Lack of transparency in maintenance and cleanliness activities
- There are automatic urinals; most of them are not smart and are expensive. Not a comprehensive solution.

Proposed Solution:

The proposed solution is an integrated system that combines Photocatalytic TiO_2 nano coating,[3] UV-A, UV-C light, and IoT automation to deliver a sustainable sanitation model:

a. Photocatalytic Self-Cleaning Mechanism: The urinal surface is coated with TiO_2 nanoparticles using the materials listed in Table 2, as illustrated in Figure 8. When exposed to UV-A light, TiO_2 generates reactive oxygen species that break down urine residues, organic matter, and the microbial deposits at the molecular level. This process reduces odor, sterilizes surfaces, and ensures continuous cleaning without manual intervention.

b. UV-C Activation: UV-C LEDs turn on during idle periods to ensure effective microbial inactivation.

c. IoT-Enabled Monitoring: Sensors measure distance, footfall count, ammonia (odour), temperature, humidity, flushing status, water flow, water consumption, and water level in the tank. Real-time data is sent to a dashboard for maintenance alerts, usage tracking, and remote supervision. The hardware circuit diagram is shown in Figure 9, and the main components used are listed in Table 2.

d. Water Conservation Approach: Minimal-flush reduces water consumption. The flush cycle and flush duration are customizable. Reduced chemical cleaning further saves water used during manual cleaning. Water Leakages can be detected based on water flow.

e. Public Healthcare Impact: Continuous disinfection lowers the risk of microbial transmission. Improved hygiene encourages more people to use public urinals, reducing open urination. Sanitation workers are protected from harmful pathogens and chemical exposure.

f. Scalability & Usability: Designed to be low-cost and easy to retrofit into existing urinals. Suitable for high-usage environments such as bus stands, markets, educational institutions, malls, trains, railway stations, etc.

Scientific Basis:
Photocatalysis using TiO_2 + UV Light:[2]

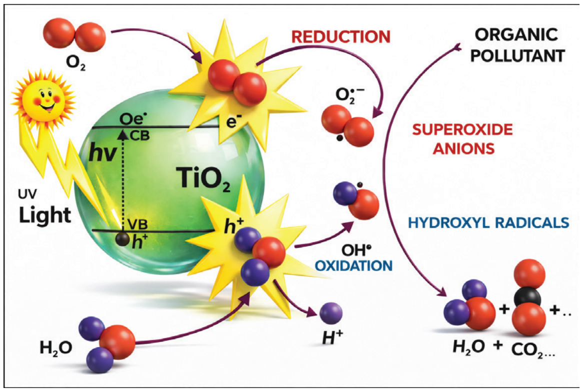

Figure 5: Photocatalysis.[2]

Working of Photocatalysis:[2] When sunlight (or UV light) shines on a special material like titanium dioxide (TiO_2), it absorbs light energy – photons. The light energy makes electrons jump from the Valence Band inside TiO_2 to a higher level – The conduction band, leaving behind empty spaces called holes. These electrons and holes react with water and oxygen in the air to generate reactive species such as hydroxyl radicals (•OH) and superoxide anions (O_2^-). The detailed chemical reactions are presented in Table 1. These reactive species are very powerful, and they break down harmful substances (like bacteria, dirt, or chemicals) into harmless ones such as water (H_2O) and carbon dioxide (CO_2), as illustrated in Figure 5.

Table 1: Hydroxyl Radicals vs. Superoxide Anions.

Hydroxyl Radicals (•OH)	Superoxide Anions (O_2^-)
Hydroxyl radicals are tiny, very reactive particles made up of one oxygen and one hydrogen atom (OH). They are called "radicals" because they have an unpaired electron, which makes them unstable and highly energetic. $h^+ + H_2O \rightarrow \bullet OH + H^+$ When TiO_2 is exposed to light, the excited electrons and holes react with water molecules (H_2O) on the surface. These •OH radicals are super strong oxidizers — they attack and break down harmful organic molecules.	Superoxide anions are formed when oxygen (O_2) molecules gain an extra electron, giving them a negative charge. $e^- + O_2 \rightarrow O_2^-$ These anions are powerful reducing agents — they can further react to form other useful oxidizing particles like hydrogen peroxide (H_2O_2). Together with hydroxyl radicals, they decompose toxic gases (like NO_x and VOCs) and kill bacteria or viruses.

Thus, the system achieves dual-action self-cleaning + Self-Disinfecting[7], as illustrated in Figure 7.

Applications of Photocatalysis:[8] There are several applications of photocatalysis, as illustrated in Figure 6.

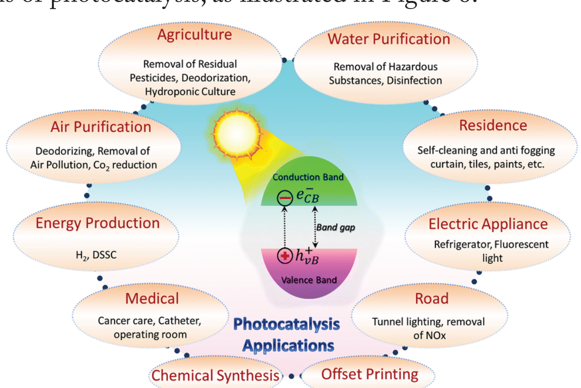

Figure 6: Applications of Photocatalysis.

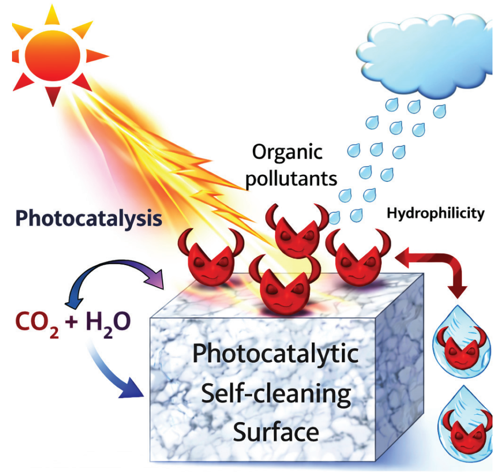

Figure 7: Self Cleaning through Photocatalysis.[5]

Preparation of Titanium Dioxide Solution:

Table 2: Items used for preparing TiO_2 nano solution.

Material	Quantity	Purpose
Titanium Dioxide (TiO_2) nano Powder	1 gram	Main photocatalyst
Ethanol (≥95%)	80 ml	Solvent for spray
Polyvinyl Alcohol (PVA) Powder	0.5 gram (~0.5% w/v)	Binder for adhesion
Distilled Water	20 ml	For dissolving PVA
Beaker / Glass	1	For measuring
Conical Flask	1	For mixing
Small Spray Bottle	1 (100 ml)	For application
Stirring Rod	1	For uniform mixing

For experimental validation, a ceramic tile sample was coated with TiO_2 nanoparticles using the materials listed in Table 2 to simulate the urinal surface under controlled laboratory conditions. Figure 8 depicts the conceptual design of a typical urinal system.

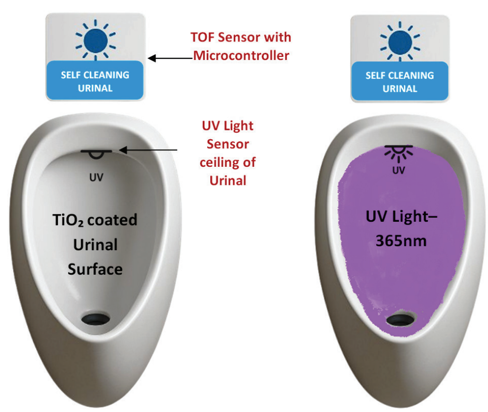

Figure 8: Urinal coated with TiO_2 when exposed to UV light.

Limitations of Photocatalytic Tile Test:

The experiment was conducted in a lab and may not fully represent real public restroom environments. Variations in light intensity, humidity, surface wear, and long-term exposure were not extensively evaluated. In addition, the durability of the TiO_2 coating under continuous usage and cleaning chemicals was not tested. Therefore, further studies on TiO_2 coating methods and durability are required to confirm real-world performance.

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Circuit Diagram:

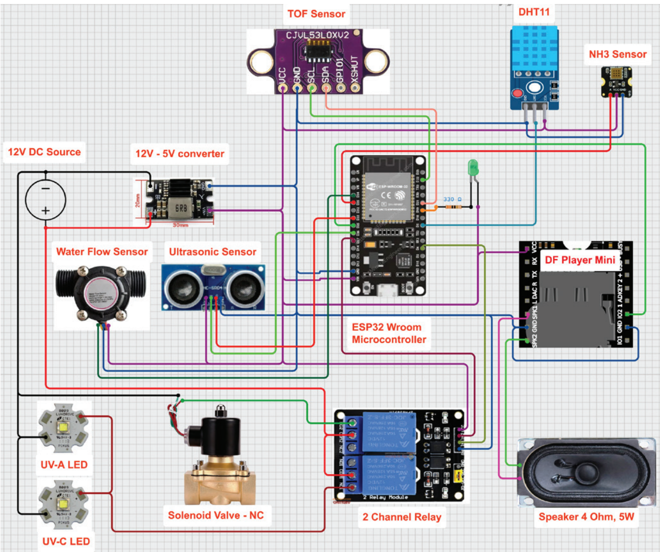

Figure 9: Hardware Circuit Diagram – ESP32 Wroom microcontroller, sensors, UV LED.

Table 3: Core Components of the circuit. The approximate cost of the prototype is INR 2,950. This cost can be reduced significantly through optimization and bulk production.

Component	Cost	Component	Cost
ESP32 microcontroller	289	DF Player Mini + Speaker	150
TOF Sensor: VL53L0X	120	Micro SD Card 2GB	120
DF NH3 Gas Sensor	850	Water Flow Sensor	130
UV-A LED (365–385 nm)	250	Ultrasonic Sensor	74
UV-C LED (254 nm/275 nm)	460	AC to DC converter (12V)	85
Solenoid valve (12V, NC)	250	12V to 5V DC-DC Converter	63
Temperature & Humidity Sensor DHT11	44	2 Channel Relay module	65

Working:

In standby mode, the UV-A and UV-C lights remain active, allowing the urinal to continuously self-disinfect and self-clean. A green LED stays ON to indicate that the urinal is free to use. At the same time, the DHT11 sensor continuously measures temperature and humidity, the NH_3 gas sensor monitors ammonia levels in the surroundings, and the TOF sensor keeps measuring distance in real time.

When a user is detected, that is, when the TOF sensor measures a distance of 70 cm or less (this distance can be customized), the UV lights instantly turn OFF for safety, and the green LED also turns OFF. A voice announcement plays: "Introducing Smart Self-Cleaning Public Toilets – a step towards hygiene, dignity, and a cleaner future for all! Please use responsibly." (This message is customizable). The flush counter starts at zero. If the user leaves within 5 seconds (this duration can be adjusted), no flushing occurs. However, if the user stays longer than 5 seconds, the counter continues until the user moves away from the urinal (distance greater than 70 cm), after which flushing is activated. The flush cycle itself is programmable and can be customized, allowing options such as a short pre-urination flush followed by a longer post-urination flush.

During the post-usage stage, once the user moves beyond 70 cm, the microcontroller triggers the normally closed solenoid valve to flush water. The system is programmed to flush for 6 seconds by default, though this duration is customizable. After flushing, the UV-A and UV-C LEDs turn ON again for disinfection, and the green LED lights up to indicate that the urinal is vacant. A continuous cleaning cycle operates in the background, where the TiO2 coating under UV-A light initiates photocatalysis to break down organic matter, while UV-C light sterilizes microbial contaminants.

The system also performs continuous hygiene monitoring using the DFRobot Fermion MEMS NH_3 (ammonia) gas sensor. The Hygiene Index is calculated as HygieneIndex = map(nh3Raw, 0, 4095, 0, 500). Based on this value, hygiene is classified as Excellent for values below 50, Acceptable for values between 50 and 120, Poor for values between 120 and 250, and Unhygienic for values above 250.

In addition, there is continuous monitoring of water flow and water level. The system constantly checks water flow to detect and alert to any leakage. The water level in the tank is also monitored in real time, displaying its status and providing alerts when the level is low or the tank is empty.

Results and Discussion

a. System Performance:

The developed smart photocatalytic self-cleaning urinal system was evaluated under simulated real-world conditions to assess its functional efficiency, reliability, and applicability in public sanitation environments. The integrated system successfully demonstrated automated sensing, self-cleaning activation (UV-C, UV-A LED ON / OFF), and real-time monitoring, complemented by voice announcements to promote user hygiene. The coordinated operation of IoT sensors, control units, and the self-cleaning mechanism ensured consistent performance across repeated usage cycles. TOF accurately identified user presence, triggering the flushing and cleaning sequence only when required.

Water leakage was tested by implementing a predefined condition in which continuous water flow exceeding 15 seconds was identified as a leakage event and triggered an alert on the web dashboard. Similarly, water level monitoring was verified using a storage tank of 30 cm depth. The water level status was categorized into four levels: Nil, Low, Half, and Full, based on the measured tank depth.

Due to fabrication and safety constraints, photocatalytic testing was conducted using a TiO_2-coated ceramic tile as the test surface instead of an actual urinal, as shown in Figure 15. The tile was subjected to coffee staining and ultraviolet (UV) light exposure to evaluate its self-cleaning behavior, as shown in Figure 16. The results showed minimal observable differences between samples with and without TiO_2 coating under the given UV (torch) exposure conditions, as illustrated in the corresponding Figure 17. These findings indicate that the photocatalytic efficiency of the TiO_2 + UV system requires a more controlled and optimized experimental setup for clearer performance evaluation.

b. Real-Time Monitoring and Data Accessibility:

The ESP32 microcontroller enables real-time transmission of operational data, including usage frequency, cleaning cycles, hygiene level, water leakage status, tank water level, temperature and humidity, UV light ON/OFF status, flushing status, and overall system health. The IoT device was tested by connecting it to a Wi-Fi router to validate reliable data communication. The dashboard has been verified during idle condition – Figure 10, during flushing – Figure 11, exposed to ammonia vapor – Figure 12, and water tank leak alert – Figure 13. This functionality allows facility managers to remotely monitor system performance and identify maintenance requirements. A web-based portal provides options to adjust system parameters such as sensing distance and flush duration. A Real-time demonstration was conducted at IIT Kharagpur, as shown in Figures 18 and 19.

In addition, the collected data can support planning, informed decision-making, and efficient resource allocation in high-footfall public spaces such as railway stations, schools, hospitals, and commercial complexes.

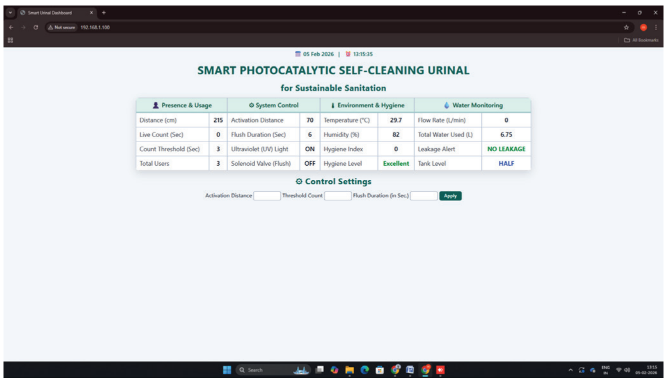

Figure 10: Web Portal – Dash Board – Idle condition i.e no Flushing.

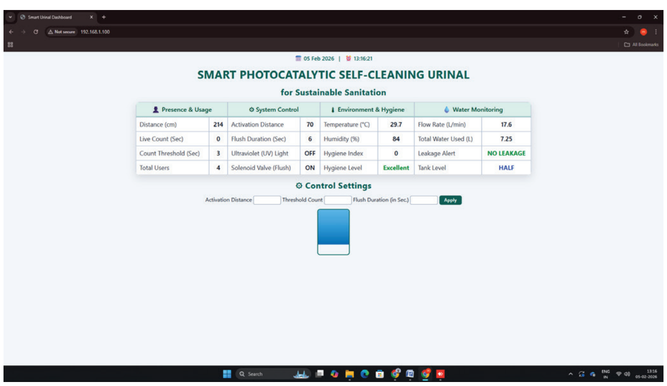

Figure 11: Web Portal – Dash Board – During Flushing.

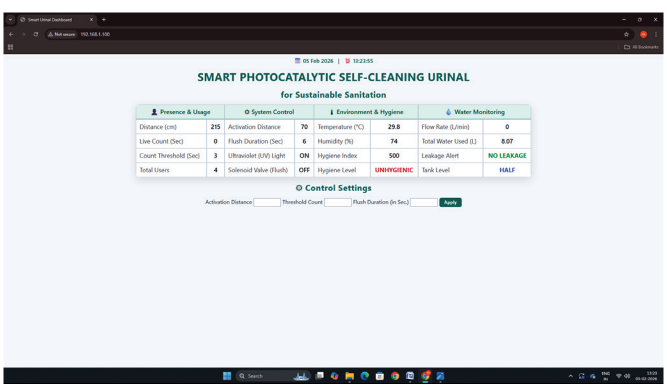

Figure 12: Web Portal – Dash Board – Hygiene Status – exposed to NH_3vapor.

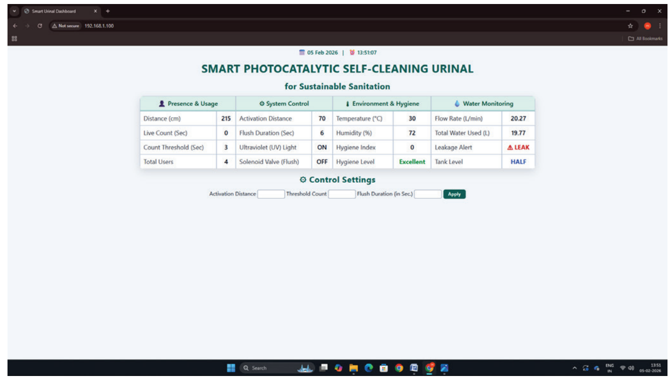

Figure 13: Web Portal – Dash Board – Water Leak Alert Test.

c. Comparative Advantages over Conventional Systems:

When compared with existing public urinal systems, the proposed solution offers multiple advantages, including enhanced hygiene, reduced water consumption, automated operation, and improved monitoring capabilities. Conventional systems largely depend on manual cleaning and fixed flushing intervals, which are inefficient and often result in poor hygiene standards.

The smart photocatalytic urinal addresses these limitations by integrating advanced materials (TiO_2) and IoT into a single, scalable solution. The ability to customize operational parameters further enhances adaptability across diverse usage environments.

d. Limitations and Scope for Future Improvements:

While the system demonstrated promising performance, certain limitations were observed. Photocatalytic testing was limited to tile-based evaluation rather than full-scale urinal integration. Future work may focus on optimizing UV source efficiency, incorporating commercial-grade Time-of-Flight (ToF) sensors, exploring visible-light-activated photocatalysts,[12] conducting quantitative microbial analysis, integrating advanced AI-based usage analytics, and performing long-term field trials to more precisely quantify microbial reduction and water savings.

Public Healthcare Impact:

The system significantly reduces disease transmission by using UV-C light to eliminate harmful germs, while its touchless operation minimizes cross-contamination. Air quality is improved as the TiO_2 coating decomposes ammonia and organic odors, helping reduce respiratory discomfort. It also protects sanitation workers and the public by minimizing the need for manual cleaning, reducing exposure to harmful chemicals, and lowering the risk of occupational infections.

In addition, the system enables remote supervision and monitoring by providing real-time information on hygiene levels and usage status, allowing quick detection of faults, misuse, or poor sanitation, and supporting data-driven maintenance decisions. Cleaner and well-maintained facilities encourage greater use of public toilets, helping reduce open urination and improve overall community hygiene, while customized voice announcements raise awareness on hygiene and usage among users. Furthermore, conserve water and cleaning chemicals by

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optimized and controlled usage, continuously monitoring for leakages, and issuing alerts when needed, making the entire system more sustainable.

Applications & Scalability

The design is modular and retrofittable, making it suitable for installation across a wide range of locations. It can be implemented in schools, colleges, and universities; hospitals and Primary Health Centers (PHCs); railway stations and bus stands; workplaces and shopping malls; villages and slum rehabilitation areas; public transport systems such as trains and buses; and public urinals managed by urban and rural local bodies. Its adaptable structure makes it suitable for both rural and urban infrastructure, ensuring flexibility and scalability across diverse environments.

Future Enhancements

Future enhancements include advanced IoT-based odor sensing through NH3 and H2S detection, along with solar-powered operation to improve sustainability. A comprehensive cloud-based dashboard and mobile application will enable real-time supervision and monitoring, supported by an automated maintenance and fault alert system. In addition, AI-driven hygiene prediction and intelligent alert mechanisms (as shown in Figure 14) will facilitate proactive sanitation management. With the adoption of advanced technologies, the system can be further optimized using visible-light-activated doped TiO2 nano coatings for enhanced photocatalytic efficiency. A mechanism to analyze urine parameters and generate alerts may also be incorporated for early health risk indication. Integration with maps will assist users in locating facilities and sharing feedback easily. Dedicated efforts will be made to innovate the urinal's physical design, making it simple, cost-effective, and easy to use and clean, while ensuring practicality alongside technological advancement.

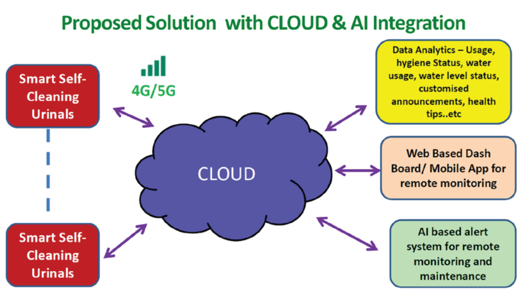

Figure 14: Proposed Solution with Cloud & AI.

Conclusion

This project demonstrates a low-cost, science-driven hardware solution that addresses a critical public health challenge - maintaining hygiene in public urinals. By integrating TiO_2-based photocatalysis, UV disinfection, touchless automation, and IoT-enabled monitoring, the system helps maintain a cleaner, odor-free, and infection-resistant environment.

The proposed solution reduces reliance on manual cleaning, minimizes the use of chemical cleaning agents, lowers operational and maintenance costs, reduces water wastage, and enhances user safety. It also supports sanitation workers by reducing their exposure to unhygienic conditions and promotes sustainable sanitation practices through remote supervision and monitoring.

Future Vision: With advancements such as re-engineering of the electronic circuitry, cloud-based analytics, AI-supported hygiene prediction, and integration with smart city infrastructure, this system has the potential to transform existing public toilets into cleaner and more user-friendly public spaces. With further refinement and large-scale deployment, the proposed innovation can help improve hygiene standards across India, support the objectives of the Swachh Bharat Mission, and contribute to healthier and more dignified communities.

References

1. https://sbmurban.org/ Swachh Bharat Mission-Urban.
2. Heterogeneous Photocatalysis: Recent Advances and Applications Heterogeneous Photocatalysis: Alex Omo Ibhadon 1,* and Paul Fitzpatrick 2 Catalysts 2013, 3, 189-218; doi:10.3390/catal3010189 https://www.mdpi.com/2073-4344/3/1/189
3. Photocatalysis Types, Mechanism and Applications https://chemistrydocs.com/photocatalysis-types-mechanism-and-applications/
4. Photocatalytic Properties of TiO2 https://www.kamatlab.com/research_photocatalysis.html
5. Self-Cleaning Smart Surfaces: Nano-Coating Solutions for Modern Architecture & Engineering https://vnbuilding.vn/en/blog/self-cleaning-smart-surfaces-nano-coating-solutions-for-modern-architecture-engineering
6. TOF Sensor –VL5310x interfacing with ESP32 https://www.espboards.dev/sensors/vl53l0x/ . https://www.electronicwings.com/esp32/vl53l0x-sensor-interfacing-with-esp32
7. Howard A. Foster, Iram B. Ditta, Sajnu Varghese & Alex Steele. Photocatalytic disinfection using titanium dioxide: spectrum and mechanism of antimicrobial activity. Appl Microbiol Biotechnol 90, 1847–1868 (2011). https://doi.org/10.1007/s00253-011-3213-7
8. Applications of Photocatalysis https://pubs.rsc.org/image/article/2024/CE/d4ce00630e/d4ce00630e-f8_hi-res.gif
9. https://app.cirkitdesigner.com/ - This portal was used for hardware circuit schematic drawing.
10. https://terra-docs.s3.us-east-2.amazonaws.com/IJHSR/Articles/volume5-issue7/IJHSR_2023_57_18.pdf Bhupen Sai Bandi, FIITJEE Junior College, Andhra Pradesh - 520010, India.
11. https://www.mdpi.com/2073-4344/14/12/855 Visible-Light-Activated TiO2-Based Photocatalysts for the Inactivation of Pathogenic Bacteria by Farhana Haque, Allison Blanchard, Baileigh Laipply and Xiuli Dong.
12. https://en.wikipedia.org/wiki/Ultraviolet_germicidal_irradiation Ultraviolet germicidal irradiation.

Author

Mithra Sri Bandi is a junior at VIVA The School. She is interested in public health, hygiene, and sustainability, and enjoys using science and technology to solve real-world problems. Her interests include smart infrastructure, sustainable sanitation systems, and the use of advanced materials and AI for monitoring and automation. This research shows her curiosity-driven and systematic approach to developing practical, affordable, and scalable solutions to improve public hygiene. Through this work, she aims to contribute to sustainable development while building strong research and interdisciplinary skills.

Prototype

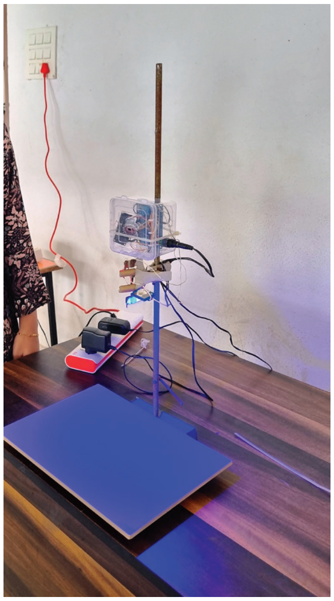

Figure 15: Tile coated with TiO_2 solution and exposed to UV light.

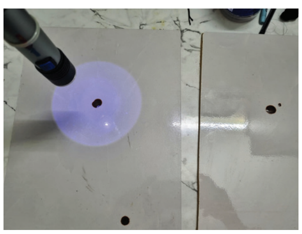

Figure 16: Tile sample coated with TiO_2, with a coffee stain on the right side, exposed to UV light.

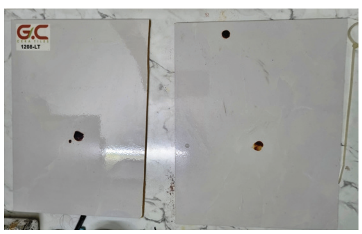

Figure 17: Slight degradation of the coffee stain on the right side of the TiO_2-coated tile sample.

Dashboard

Figure 18: Real-Time Testing at IIT Kharagpur.

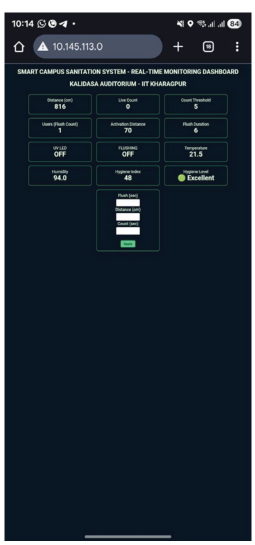

Figure 19: Web dashboard to view the status of urinal.

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