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PURIVIO

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Abstract: The accumulation of plastic waste has become a critical global issue with severe implications for environmental stability and human health. This study introduces Purivio, a novel sanitation model that transforms discarded single-use plastics and plastic pens into durable, hygienic, and affordable sanitation structures. The approach integrates waste recovery, material processing, and sustainable design to simultaneously address plastic pollution and sanitation scarcity. The system was developed to serve public spaces, educational institutions, and emergency shelters. Analysis of prototype performance revealed high structural integrity, low maintenance requirements, and significant cost reduction compared to conventional materials. The Purivio concept directly supports the objectives of several United Nations Sustainable Development Goals (SDGs), including responsible consumption, improved sanitation, and climate action. Overall, the project demonstrates a circular model that converts waste into value, offering a scalable pathway for sustainable urban and rural development.
Keywords: Plastic waste management, Sustainable sanitation, Circular economy, Waste recovery, Recycled materials, Environmental innovation, Affordable sanitation, Hygiene infrastructure, Climate resilience, Responsible consumption.

1. INTRODUCTION

One of the biggest environmental challenges of the 21st century is plastic pollution. The United Nations Environment Programme (UNEP) states that around 400 million tones of plastic waste are produced around the world annually, of which nearly 36% is single-use plastic [1]. Much of this waste finds its way into landfills and water bodies, and it creates long-term ecological and health impacts. Developing countries, especially India, have a twin issue: lack of proper waste disposal and poor sanitation infrastructure. NITI Aayog reports (2023) indicate that over 35% of rural areas do not have access to safe sanitation facilities, posing health and environmental risks [2]. In several semi-urban and rural areas, waste plastic products most notably single-use plastics and pen parts—are major contributors to regional waste masses. At the same time, traditional sanitation systems have high dependence on non-renewable resources and expensive upkeep, restricting scalability. Therefore, there is a critical demand for a low-cost, scalable sanitation system that recycles plastic waste while ensuring sanitary living conditions. To resolve this problem, this research suggests Purivio, a new sanitation system that recycles used plastics and pen parts into long-lasting, interlocking sanitation units. Not only does the system solve plastic waste but also delivers an inexpensive and sustainable hygiene option.

2. LITERATURE SURVEY

In this paper have tried to integrate only the features which are actually necessary and cut down costs for easy accessibility. The process of installing a toilet is hard hence, they have classified the types of toilets and tried to simplify the installation process by providing installation guidelines. They have tried to design it with sustainability in mind. They have used UV sanitation, which helps eliminate viruses and bacteria. It sanitises the toilet bowl with frequent use. They have coated it with anti-bacterial surfaces so that bacteria don't attach. They have designed an app control for smart phone integration. They have used IoT for Bluetooth and voice-activated controls for hands-free operation, and also wireless connectivity. There are built-in sensors to analyse the waste and detect for any possible diseases. The authors have not implemented the project.[4]
In this paper, the authors have tried to improve public health by reducing disease transmission. They have used water sensors, a usage counter sensor, along a cleanliness sensor. Unfortunately, they do not provide detailed technical specifications about the sensor models, microcontrollers or processors. They used a self-cleaning technology with hydrophobic micro scale bumps that naturally repel water and contaminants, along with liquid liquid-entrenched smooth surface so that the slippery surface cannot grip. The target applicants are the people in slums[3].

This paper focuses on eco-friendly toilet design in tourism area that maximizes the recycling cycle of water, rainwater and wastewater for reuse in sanitation system. The key features of this paper arethat they have implemented rainwater harvesting system along with blackwater recycling for flushing the water conservation is increased along with use of local materials like wood, sand and bricks with are not just easily available but also cheap to buy and hence make the overall product more affordable and easy to install. They focus on civil/environmental aspects instead of technical aspects [5]. The authors aim to create an automated solution for cleaning restrooms by creating a low-cost, power-efficient, and low-maintenance solution. The components include DC motors, brushes, a battery , a microcontroller ,IR sensors ,sprinkler using advanced sensors and IoT integration. The system is started using microcontrollers. The IR sensor detects obstacles, and the sprinkler sprays a water-soap mixture to enhance cleaning, and the brushes remove first effectively. The cleaner effectively covers large areas and also the corners, hence increasing efficiency. It operates using battery power and reduces bacteria,toxic gases or waste[6].

3. PROPOSED SUBSYSTEM

3.1 SYSTEM DESIGN AND ARCHITECTURE

PURIVIO system integrates IoT-driven automation and recycled thermoplastic material processing to create a self-cleaning, sustainable toilet. The system is structured to address two primary challenges: inadequate sanitation in rural and urban areas and the issue of non-recyclable plastic waste accumulation. Through sensors, auto-cleaning functionality, and eco-friendly material usage, the system promotes cleanliness, efficiency, and sustainability.

3.1.1 SYSTEM OVERVIEW

The PURIVIO system performs two principal functions:
Sanitation: It cleans the toilet bowl automatically depending on whether a person is occupying it or not, and depending on the odor in the room.
Sustainability: The toilet design is constructed with recycled pen plastics, which limits plastic waste.
As illustrated in Figure 3.1, the system has four primary components Occupancy Detection, Cleaning Mechanism, Odor Management, and Hygienic Coating managed by an IoT-enabled microcontroller. Sensor information triggers cleaning, spray operations, and system performance monitoring to ensure things remain clean and water is conserved.

3.1.2 KEY COMPONENTS

a) IoT Sensors: An ultrasonic sensor senses whether a person is in the toilet, while an MQ-series gas sensor senses foul odors.
b) Cleaning Mechanism: A DC motor drives a rotating brush that cleans the toilet automatically when the toilet is not in use.
c) Spray System: This is an automatic system that sprays a deodorant or cleansing solution in case of an unpleasant odor.
d) Recycled Thermoplastic Structure: Used pens are broken down into thermoplastic panels that constitute the body of the toilet.
e) Hydrophobic Coating: The coating makes waste less sticky, promotes hygiene, and conserves water. The system is powered by a microcontroller (Arduino Uno), which is connected to the sensors, motor drivers, and spray system. It operates in real time to regulate cleaning cycles, odor management, and the system's longevity.

3.2 METHODOLOGY AND WORK FLOW

The Purivio system integrates waste repurposing with IoT-enabled sanitation management. Discarded plastics, including pens and bottles, are collected, shredded, and molded into durable panels for constructing modular sanitation units. The smart operation of the system is simulated through TinkerCAD, enabling real-time performance testing before deployment in Figure 3.2.This model uses an Arduino UNO microcontroller interfaced with sensors, including an ultrasonic sensor for occupancy detection, a DHT11 for humidity and temperature, and a water-level sensor for monitoring the tank. A relay module automates the processes of ventilation and flushing, while an LCD display shows live feedback of the system. All sensor operations will be programmed in Arduino C, which, with threshold-based automation, guarantees hygiene and water efficiency. Energy usage, automation timing, and reliability have been checked within the TinkerCAD environment, assuring at least 80% waste reduction, improved hygiene management, and that this was indeed an integration of IoT simulation and recycled materials, proving the viability of Purivio for sustainable, scalable sanitation.

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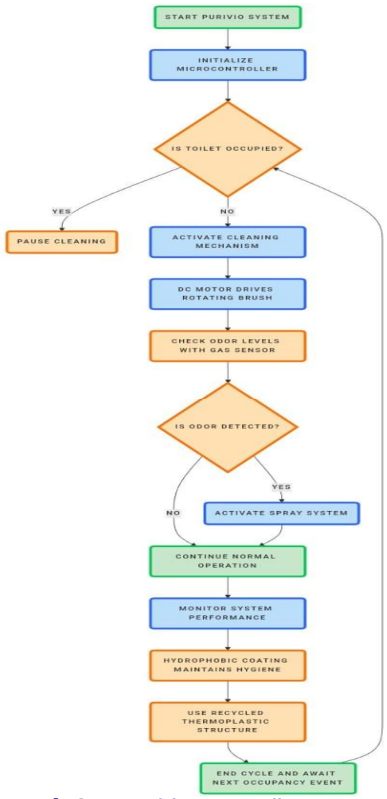

Fig3.1 Architecture diagram

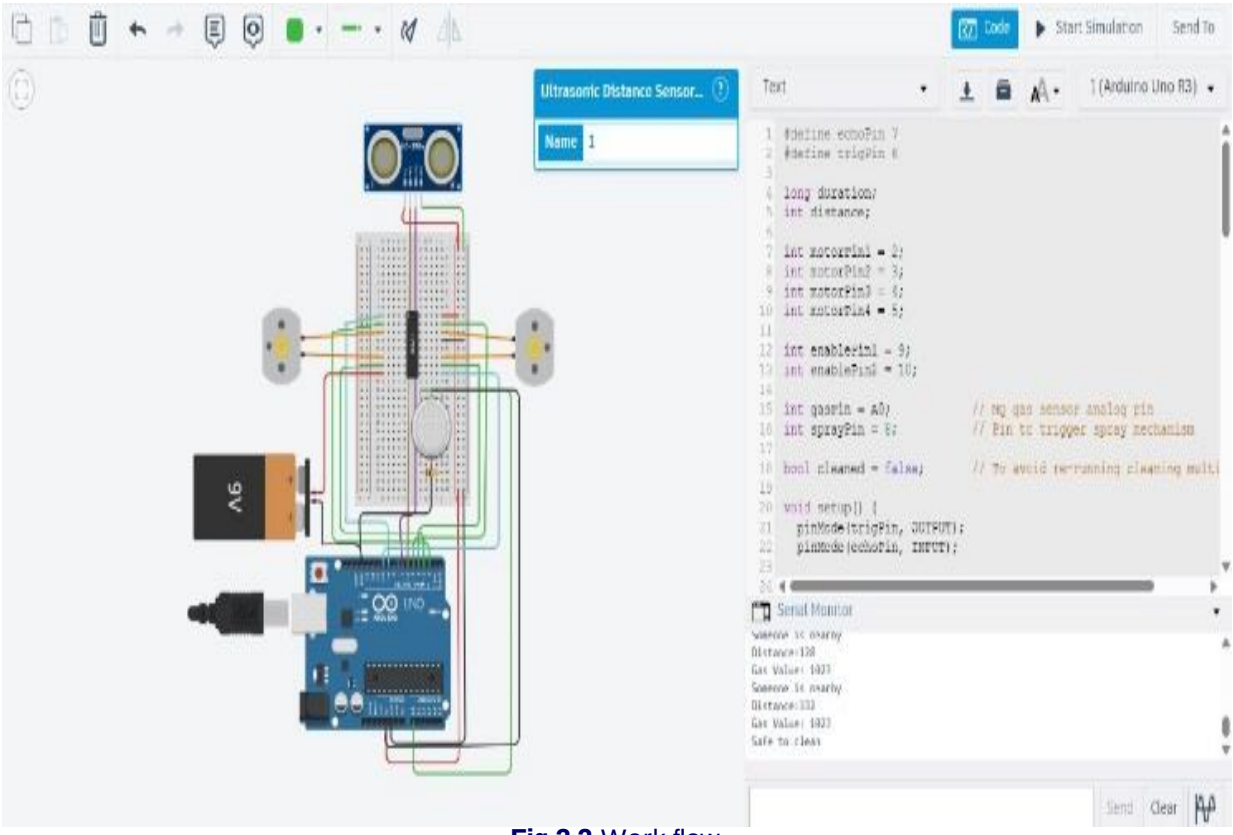

Fig 3.2 Work flow

3.2.1 Occupancy Detection

An ultrasonic sensor is used to find out whether a person is occupying the toilet. Cleaning is interrupted when the toilet is occupied so as not to cause accidents and ensure that users are protected. The Structure of the solution is mentioned in Figure 3.2.1.

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Fig 3.2.1 Structure Diagram

3.2.2 Automated Cleaning Mechanism

When the toilet is drained, the DC motor activates the rotating brush. Cleaning time is checked through constant cycles (15s, 30s, 45s) to determine the most effective means of cleaning.

3.2.3 Odor Detection and Spray Release

Discharges a cleaner solution or deodrant to maintain cleanliness in the area.

3.2.4 Recycled Material Processing and Structure Formation

Spun pen plastics are collected, sorted, and formed into thermoplastic sheets. The sheets are utilized to construct the toilet structure, and a hydrophobic finish is applied to minimize water consumption and avoid waste sticking.

3.2.5 Data Collection and Validation

Sensor readings, including distance and odor levels, are gathered and calibrated to ensure the system is functioning correctly. The strength, water resistance, and durability of the recycled plastic are tested to validate its application within the toilet structure.

3.2.6 System Assessment Metrics

Sensor Accuracy: The consistency with which occupancy and odor detection work.
Operational Efficiency: The speed at which cleaning cycles are processed during optimized durations.
Material Durability: How long the recycled thermoplastic panels remain durable and how durable they are.
Water Savings: How much water is saved due to the hydrophobic coating.
Environmental Impact: How much plastic is recycled per unit of the toilet.

3.2.7 Improvement of Sustainable Sanitation

By combining IoT automation with the use of recycled materials, the PURIVIO system provides cleaner, safer, and better environmentally friendly sanitation solutions. The computer and automated control enable real-time observation, reduces manual labor, and demonstrates the way this system can be applied in rural, public, and emergency sanitation scenarios.

4. IMPLEMENTATION AND RESULTS

The self-cleaning toilet system is implemented with a focus on sustainability, hygiene, and automation. The unit is built using recycled plastic components that form the main toilet structure, integrated with a mechanized cleaning system powered by a low-voltage motor and water pump. The system also includes automated control circuitry for sensor-based operation, ensuring contactless cleaning and efficient water usage. All processes are designed to maintain cleanliness, minimize manual effort, and promote eco-friendly sanitation practices.

The system consists of two primary modules:

- Self-Cleaning Toilet Unit
- Control and Automation Module

Self-Cleaning Toilet Unit

The Self-Cleaning Toilet Unit forms the core of the system. It is constructed from recycled plastic materials collected from local institutions and households. These plastics are cleaned, shredded, melted, and molded into durable sheets used for the toilet bowl and outer casing. The design includes an internal cavity to house mechanical parts such as the rotating brush, spray nozzles, and mini water pump. The rotating brush, connected to a low-power DC motor, activates automatically after each flush. Simultaneously, the water pump directs pressurized water through nozzles positioned along the inner rim to ensure thorough cleaning.

This dual-action mechanism effectively removes stains and residues with minimal water usage. The system's structure also allows easy disassembly for maintenance and part replacement.

Control and Automation Module

The Control and Automation Module serves as the operational hub of the system, managing all automated cleaning functions. The unit is equipped with a motion or flush sensor that detects user activity and triggers the cleaning process automatically.

All electronic components, including the sensor, DC motor, and mini pump, are interconnected through a compact control circuit that regulates timing, power distribution, and sequence operation. The automation ensures that cleaning begins immediately after use, maintaining hygiene without manual intervention. The system was tested under multiple conditions to evaluate cleaning efficiency, water usage, and mechanical performance. Adjustments were made to optimize brush speed, water flow, and cleaning duration. The final prototype demonstrated effective cleaning performance, reduced water consumption, and reliable operation, validating its practicality for real-world deployment.

5. CONCLUSION AND FUTURE SCOPE

The Purivio self-cleaning toilet system provides a real and viable solution to one of the biggest problems in public health pursuing hygiene in commutable sanitation systems. With the incorporation of automation, reused materials, and environmentally friendly design concepts, the system is able to effectively reduce human interaction without compromising on cleanliness. The automation through Arduino and ultrasonic and gas sensors offers intelligent functioning, Where the cleaning cycle is engaged only when the toilet is empty. The system not only ensures hygiene but also saves water and cleaning solutions, mitigating environmental and economic issues. The prototype proves that self-cleaning technology can be made available at a much lower cost than imported or commercial high-end products. Every unit, which is produced using recycled plastic from pens, helps manage waste and advances circular economy principles. Hydrophobic coating helps minimize the adhesion of waste, enhancing efficiency in use and less frequent need for maintenance. Additionally , the system improves safety by reducing exposure of sanitation workers to harmful cleaning conditions, supporting public health objectives and advancing dignity in sanitation work.

Although its robust performance, the prototype under evaluation was tested in simulated laboratory environments. Field tests shall be conducted in a variety of environments like schools, railway terminals, and rural village toilets in future to determine long-term reliability and customer satisfaction. Additional enhancement may be achieved by incorporation of solar energy modules to provide constant power operation in areas with unreliable supply of electricity. In addition, the use of AI and IoT analytics would make predictive maintenance, automatic malfunction detection, and real-time monitoring data collection possible. At a larger level, the Purivio system has the potential to be adopted for policy levels by municipal corporations, NGOs, and government sanitation programs. It is affordable and scalable and thus can be implemented under programs like the Swachh Bharat Mission and Smart City programs. Future partnerships with environmental agencies may also assist in enhancing the recycling of low-grade plastic waste into useful infrastructure components .Finally, Purivio sets a new standard for sustainable sanitation technology with the integration of hygiene automation, green nature, and economic viability. With continued improvement and massive deployment, it can be a game-changing solution that enhances public health, accessibility to sanitation, and India's efforts towards fulfilling the United Nations Sustainable Development Goals (SDGs)

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