Resilient Model for Water Conservation with Advancement in Toilet System for Sustainable Sanitation

Mouna priya.S[1],P.Shivaprakash[2],Manoj.J[3,]
K.SGiriPrasath[4]M.Sc Data Science and Business Analysis[1,2], Assistant Professor[2,4] Rathinam College of Arts and Science [1,2,3,4]

Abstract- Improving public lavatory water efficiency is crucial given the growing demand on freshwater resources. In public restrooms, conventional flush toilets are the primary source of water consumption. The goal of this project is to create an intelligent, waterless public lavatory system that will significantly cut down on water usage. The suggested design eliminates the need for water cleansing by using a vacuum diaphragm pump to remove waste. The pre-liquid flow creates a slick surface to stop waste from sticking to the bowl. Vacuum pump control along with Cyamposis tetragonoloba and waste level monitoring are handled via sensors. The method, which completely does away with flushing in high- traffic public restrooms, is an innovative approach to sustainable sanitation. Testing indicates the waterless vacuum toilet can effectively remove waste using 1/50th the water of a standard toilet. Installing these could result in significant water savings in public areas. Additionally, the hands-free feature enhances hygiene. The bidet replaces toilet paper, allowing for water savings. Additionally, the hands-free feature enhances public hygiene. The toilet can function independently thanks to sophisticated sensing, which maximises energy and water use. This project shows that flush- free public restrooms are feasible. Performance and user experience will be further validated through field testing. The paperless, waterless design offers a creative way to address the expanding demands for conservation and public sanitation. **Keywords: Water efficiency, Public lavatory, Vacuum diaphragm, Sustainable sanitation,Cyamposis tetragonoloba, Hands free, Bidet,Energy efficiency, Paperless design**

I. INTRODUCTION

Public restrooms represent a major opportunity for improving water efficiency as populations expand. Standard flush toilets in public facilities account for substantial water consumption with each use. Reducing the water demands of public toilets is essential for conservation efforts. This project aims to develop an innovative smart public toilet system that eliminates flushing entirely through a waterless vacuum waste removal design. The hands-free system uses sensory input and automation to optimize operation.The technology of waterless hoover toilets is a revolutionary solution to sustainable sanitation in public areas. The technology reduces toilet water usage by over 98% when compared to traditional flush toilets since it uses air instead of water to eliminate waste. Material adhesion and blockage can be successfully removed by the vacuum pump and slick bowl coating[8]. When compared to traditional flush toilets, the technology significantly reduces toilet water usage by eliminating waste with air instead of water. The toilet may function independently and only activate the hoover when necessary thanks to sophisticated controls and sensors. Automation and digitalization combined is a clever development of this ground-breaking hoover technology designed for general public use.Using only 1/50th of the water needed for a typical flush toilet, the waterless hoover toilet consistently cleared trash in laboratory testing. Significant water savings could result from installing them in public restrooms. Additionally, the hands-free feature enhances public hygiene[1]. Field testing the lavatory in busy establishments will confirm its functionality in the real world. If this study is successful, it may be possible to address the increasing need for water saving and long-term viability in public sanitation systems by enabling the widespread use of waterless hoover toilets. Additionally, the clever design enables interaction with building tracking devices for even more efficient use of energy and water.

II. LITERATURE REVIEW

1) Microbial contamination of hands with or without the use of bidet toilets (electric toilet seats with water spray) after defecation

The efficiency of bidet toilets in lowering hand microbial contamination following faeces was investigated in a study. Thirty-two nursing student volunteers, both with and without a bidet, utilised toilet paper after removing their faeces while wearing double gloves. Microbes were examined on the outside gloves. The average contamination per glove, in the absence of the bidet, was 39,499 colony forming units (cfu). The average level of contamination dropped to 4,147 cfu per glove after using the bidet. Compared to the non-bidet group, 65.6% of bidet users had an average microbe count of less than 10%. The use of a bidet considerably decreased the spread of faecal germs to hands. This in vivo study, which involved 32 participants, shows that bidet toilets can contribute significantly to infection control by promoting hand cleanliness following faeces. According to the findings, bidets lessen the adhesion of microorganisms on hands and faces. Although more research is required, the results suggest that using a bidet can help minimise outbreaks by reducing the spread of infections from contaminated hands.

2) Decontamination effect of neutral electrolysed water for spray nozzles of electric warm-water bidet toilet seats in the healthcare setting

To lessen any bacterial contamination, a recent study investigated the use of neutral electrolyte water (NEW) for disinfecting warm-water bidet toilet seats in hospitals. Drug-resistant strains of germs on these nozzles were a source of concern. The best disinfection against a common bacterium was determined by lab experiments to involve the right water content and cleaning frequency. Additional testing at a hospital with ten bidet seats demonstrated that bacterial presence on the nozzles was effectively decreased by using NEW and general manual cleaning. This provides a viable strategy for enhanced hygiene in these settings by indicating that regular cleaning and appropriate NEW concentration can reduce the danger of horizontal bacterial transmission through bidets in healthcare settings.

3) Flow Field Simulation Analysis of Train Siphon Toilet with Variable Pipe Diameter Based on the Investigation of Siphon Performance

Train restrooms frequently use syphon designs to effectively drain trash. This study examined the effects of various syphon pipe forms on flushing performance using computer simulations (CFD). Over the length of the pipe, they tried four different designs with different diameter profiles. The overall performance declines regardless of the profile as the maximum diameter rises above 45 mm, according to the results. Surprisingly, the top performer wasn't just the one with the shortest diameter overall. Rather, the best results were obtained with the large-small-large diameter sequence of the LSL design. This implies that the key to the best flushing is a deliberate change in diameter, first reducing and then increasing again. These results provide useful information for improving the architecture of train restrooms, which may result in increased effectiveness and trash disposal.

4) Study on the Influence of Toilet Siphon Pipe Shape on Flushing Performance

This study focused on using computer simulations to optimise the design of toilet syphons. They looked into how the angles, widths, heights, and diameters of the syphon pipe, among other shape and size characteristics, affected the efficiency of flushing. They found that the following configuration would yield the best results: 48° climbing angle, 45mm arc width, 210mm arc height, 50mm diameter, 90mm climbing width, and 30mm climbing height. They did this by analysing variables such as water velocity, pressure, and flow rate. It's interesting to note that there is a sweet spot for this measurement because going beyond 50–53 mm didn't result in any more improvement. For the best flushing, this study highlights the significance of taking into account several flow parameters rather than just one or two. These results provide important information for creating potent and effective toilet syphon systems, which will enhance water sustainability and sanitation.

5) A bio-inspired exploration of eco-friendly Bael gum and guar gum-based bio adhesive as tackifiers for packaging applications

The goal of the research was to develop a safe substitute for traditional adhesives, which frequently emit toxic vapours. Using organic components such as neem oil, olive oil, guar gum, and Bael gum, they created a biodegradable glue. This adhesive outperformed certain other adhesives on the market in terms of its ability to bind fabric and paper together. It also naturally degrades, therefore there are no environmental issues. Paper binding, cloth-reinforced bags, and multilayered films are examples of potential applications. More research will examine its long-term effectiveness and potential for broader application.

6) Practical Performance and User Experience of Novel DUAL-Flush Vacuum Toilets

Vacuum toilets have become a focal point in circular urban development initiatives due to their significant water-saving capabilities compared to traditional flush toilets.Additionally, they offer the potential for resource recovery, including energy in the form of biogas and phosphorus (such as struvite) from concentrated wastewater. A novel dual-flush vacuum toilet, developed and tested within the EU Horizon 2020 project Run4Life, demonstrated promising results. By reducing flushing water consumption by 25– 50%, it achieved

1.5–2 times higher nutrient concentrations. Interestingly, residential homes showed greater adoption of the dual flush feature compared to office buildings, which also had urinals. However, practical limitations related to cleaning effectiveness may prevent further reductions in water use for this type of toilet.

Methodology

3.1. Utilizing Vacuum Diaphragm Pumps for Water-Saving Sanitation Solutions

The vacuum diaphragm pump is in charge of emptying the toilet bowl of waste without using water; instead, it uses air pressure differentials to help move waste. The pre- liquid flow mechanism increases the effectiveness of waste disposal by coating the toilet bowl with a slippery liquid to prevent waste from sticking. The system's sensors keep an eye on waste levels and regulate the bidet's and vacuum pump's operations as needed.

The waterless vacuum toilet system relies heavily on the vacuum diaphragm pump to remove waste from the toilet bowl without the need for conventional water flushing methods. Here is a summary of the vacuum diaphragm pump's operation and the formula that goes along with it:

Working Principle: The idea behind the vacuum diaphragm pump's operation is to transfer gases or liquids by establishing a pressure differential. When a waterless vacuum toilet system is in place, the pump generates a vacuum in the waste collecting system, which forces waste from the toilet bowl into the collection chamber or sewage system using atmospheric pressure.

The diaphragm pump is made up of a flexible membrane that oscillates inside a chamber. The pressure inside the chamber drops as a result of the diaphragm moving away from the chamber and creating a vacuum. Waste from the toilet bowl might enter the chamber due to this drop in pressure. The waste is released into the collection system when the diaphragm travels back towards the chamber and the pressure rises.

The formula $Q = A * V * (\Delta P / \Delta P0)$ relates to the flow rate (Q) of a vacuum pump used for sucking semi-solid substances in a toilet bowl[10]. Here's an explanation:

- Q represents the flow rate, which indicates how quickly the vacuum pump can remove waste from the toilet bowl.
- A is the area of the diaphragm or the opening through which the waste is being sucked.
- V is the velocity of the diaphragm, representing how fast it moves back and forth to create suction.
- ΔP is the pressure difference generated by the pump. This pressure difference is crucial for creating suction and pulling waste into the vacuum system.
- $\Delta P0$ is a reference pressure, usually atmospheric pressure, against which the pressure difference is measured.

Explanation of Testing Procedures and Protocols: for the above heading we used siphonic type of toilet instead of normal toilet for water conservation, compare these two and give its advantages of using siphonic type along with vacuum pump.

3.2 Bidet:

Human health is seriously at risk from bacterial contamination, especially when it comes to personal hygiene habits[1]. It's possible that some bacteria and faeces remain on the skin after using the lavatory, despite the effectiveness of conventional cleansing techniques such dry wiping with toilet paper. A other method of cleaning that has been demonstrated to lower the chance of bacterial contamination and improve sanitation and hygiene is the use of bidets.

Fig 1Water flow from Bidet

3.3 Siphonic type toilet:

Siphonic-type toilets equipped with a vacuum motor for water suction offer enhanced water conservation benefits compared to traditional siphonic toilets[9].

Fig 2 Siphonic Type Toilet

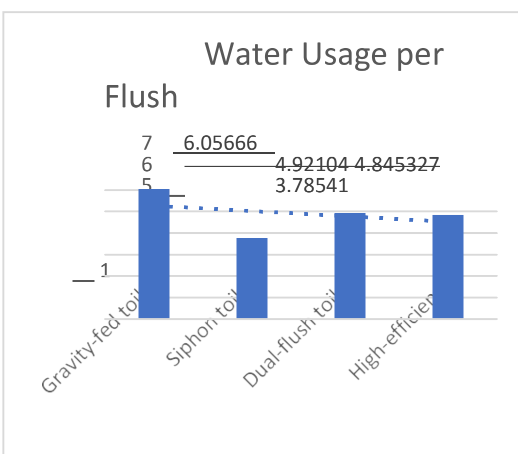

Fig 3 Statistical data for using a siphonic toilet

3.3.1 Testing Methodologies and Protocols:

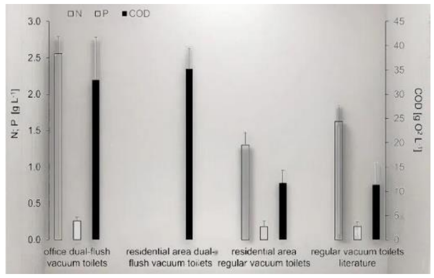

Fig 4: Static data

Flow Chart

For conventional flushing techniques. Furthermore, slimy liquid technology can be implemented in a variety of contexts, including public, commercial, and domestic ones, because to its scalability and versatility. This study offers insightful information about how toilet flushing systems could be revolutionised and how slimy liquid technology could contribute to a more sustainable and greener future

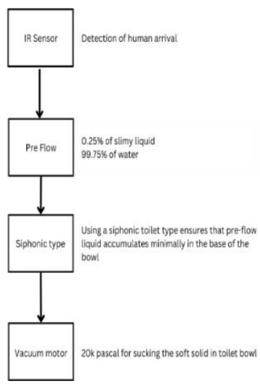

Fig 5 Working Flow Chart

SLIMY LIQUID (Cyamposis tetragonoloba)

Traditional toilet flushing systems consume a substantial amount of water with each flush, contributing to freshwater scarcity and environmental degradation. In response to these challenges. [5]This study investigates the use of slimy liquid, derived from natural plant extracts, as a pre-liquid flow in toilet flushing systems to optimize water conservation. The research methodology involved experimental testing of slimy liquid dispensation in toilet flushing systems equipped with IR sensors. The addition of slimy liquid resulted in a notable reduction in water consumption, with levels ranging from 2.5 to 3 Litres per flush, as opposed to traditional flushing systems that used about 6 Litres of water per flush. Utilising the inherent qualities of plant extracts and utilising automation via infrared sensor technology, slimy liquid presents a financially viable and ecologically sustainable substitute

Fig 6 Pre flow of slimy liquid

Overview of Data Collection Methods and Analysis Techniques

Data collection methods employed in this research include direct observation, sensor readings, user surveys, and system performance monitoring. Sensor data on waste levels, vacuum pump operation, and bidet usage is collected continuously throughout the testing period.

Analysis techniques include statistical analysis of quantitative data such as water usage metrics and waste removal efficiency. Qualitative data from user surveys and feedback is analysed to identify patterns, trends, and areas for improvement in the waterless vacuum toilet system design and operation.

Results and Discussion

Water Savings: According to laboratory testing, a waterless hoover toilet can efficiently eliminate waste using just 1/50th of the water needed for a typical flush toilet. This huge decrease in water use represents a major advancement in water conservation efforts, especially in areas where water resources are being stressed by urbanisation and population increase.

Hygiene Improvement: The integrated bidet function and hands-free operation improve public lavatory hygiene standards. Through automated cleansing and the removal of manual controls, the system reduces the possibility of cross-contamination and fosters a safer and more hygienic lavatory environment. Furthermore, waste adhesion is lessened by the proactive coating of the toilet bowl surface, which enhances cleaning and simplifies maintenance.

Efficiency and Automation: The smart sensing capabilities of the waterless vacuum toilet enable autonomous operation, optimizing water and energy usage. Sensors detect user presence and trigger pre-emptive cleanliness measures, bidet activation, lid closure, and waste removal, all seamlessly and efficiently. This integration of automation not only enhances user experience but also ensures the efficient use of resources, making the system environmentally friendly and cost-effective in the long run.

CONCLUSION

In conclusion, the development of a waterless vacuum toilet system represents a promising solution for enhancing water efficiency and improving sanitation in public restrooms. With significant reductions in water usage, enhanced hygiene features, and efficient automation, this innovative technology offers substantial benefits for both water conservation efforts and public health. Future research should focus on scalability, user acceptance, continuous improvement, and environmental impact assessments to ensure the widespread adoption and effectiveness of this resilient model for sustainable sanitation.

REFERENCES

[1] "A hierarchical multi blockchain for fine grained access to medical data," by V. Malamas, P. Kotzanikolaou, T. K. Dasaklis, and M. Burmester IEEE Access, volume 8, 2020, pages 134393–134412.

[2] . "An architecture and management platform for blockchain-based personal health record exchange: Development and usability study," J. Med. Internet Res., vol. 22, no. 6, Jun. 2020, Art. no. e16748, was written by H.-A. Lee, H.-H. Kung, J. G. Udayasankaran, B. Kijsanayotin, A. B. Marcelo, L. R. Chao, and C.-Y. Hsu.

[3] . "A decentralized blockchain-based architecture for a secure cloud-enabled IoT," by M. Marwan, A. A. Temghart, F. Sifou, and F. AlShahwan J. Mobile Multimedia, Nov. 2020, vol. 2020, pages. 389–412.

[4] . A safe charging method for electric vehicles with smart communities in energy blockchain, Z. Su, Y. Wang, Q. Xu, M. Fei, Y.-C. Tian, and N. Zhang IEEE Internet Things Journal, June 2019, vol. 6, no. 3, pp. 4601–4613.

[5] . "Performance analysis of the raft consensus algorithm for private blockchains," by D. Huang, X. Ma, and S. Zhang Jan. 2020; IEEE Transactions on Systems, Man, Cybern., Syst., vol. 50, no. 1, pp. 172–181.

[6] "A comprehensive review of blockchain consensus mechanisms," by Lashkari and P. Musilek IEEE Access, volume 9, 2021, pages 43620–43652.

[7] 10. "Digital health in physicians' and pharmacists' offices: A comparative study of e-prescription systems' architecture and digital security in eight countries," by Aldughayfiq and S. Sampalli. In February 2021, OMICS, J. Integrative Biol., vol. 25, no. 2, pp. 102–122.

[8] C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012.

[9] C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011.

[10] C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- Taylor & Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011.

[11] C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.

[12] Nagarajan C., Neelakrishnan G., Akila P., Fathima U., Sneha S. "Performance Analysis and Implementation of 89C51 Controller Based Solar Tracking System with Boost Converter" Journal of VLSI Design Tools & Technology. 2022; 12(2): 34–41p.

[13] C. Nagarajan, G.Neelakrishnan, R. Janani, S.Maithili, G. Ramya "Investigation on Fault Analysis for Power Transformers Using Adaptive Differential Relay" Asian Journal of Electrical Science, Vol.11 No.1, pp: 1-8, 2022.
[14] G.Neelakrishnan, K.Anandhakumar, A.Prathap, S.Prakash "Performance Estimation of cascaded h-bridge MLI for HEV using SVPWM" Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:750-756
[15] G.Neelakrishnan, S.N.Pruthika, P.T.Shalini, S.Soniya, "Perfromance Investigation of T-Source Inverter fed with Solar Cell" Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:744-749
[16] C.Nagarajan and M.Madheswaran, "Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation" has been presented in ICTES'08, a IEEE / IET International Conference organized by M.G.R.University, Chennai.Vol.no.1, pp.190-195, Dec.2007
[17] M Suganthi, N Ramesh, "Treatment of water using natural zeolite as membrane filter", Journal of Environmental Protection and Ecology, Volume 23, Issue 2, pp: 520-530,2022
[18] M Suganthi, N Ramesh, CT Sivakumar, K Vidhya, "Physiochemical Analysis of Ground Water used for Domestic needs in the Area of Perundurai in Erode District", International Research Journal of Multidisciplinary Technovation, pp: 630-635, 2019