Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

Design, Fabrication and Installation of an Automated Wash Hand Station

Ademuyiwa Greatness Iteoluwakiishi, Ohiengbomwan Nosakhare, Edekin Israel Eromosele, Matthias Oghenor, Aigbe Marvellous, Isaac Ifoghale Ifeakachukwu, Ikponmwen Osamudiamen Richard, Daniel Ebubechukwu Okafor, Ekwa Orevaoghene, Godsanswer Ifechukwudeni Chidinma.
Under the supervision of Engr. Godspower Sunday Linus.
Department of Mechanical Engineering, University of Benin

Abstract—
The need for a practical solution to the problem of lack of hygienic infrastructure in the department of Mechanical Engineering University of Benin has prompted the need for this project. We aim to use the standard Traditional or manual Hand washing and drying machine and make it automated, through the use of proper sensors and access control mechanism.

The development of the automated hand wash station follows a four-part methodology: Design and fabrication of hand wash station housing or framework, following proper material selection, 2D and 3D software design showing proper component assembly and exploded view; Installation of components such as the timer, access control, dryer, electrical components for power supply and fitting of plumbing materials to enable the supply of fresh water, soap, and ejection of waste water; Testing and verification of proper functioning of sensors and control. This includes testing of flow and drying mechanism, soap dispensing mechanism, proper function of programmed timer, and proper function of access control unit; Results and analysis of hand washing process, i.e. The time taken for each operation, and the overall execution time, volume of water used per hand wash and comparing whole process with traditional or manual hand wash operation.

This research work has successfully presented a functional and highly efficient low cost, low power sensor-controlled hand wash station which was mounted at the entry and exit of the mechanical engineering department university of Benin.

Keywords—

automated hand wash, fabrication, mechanical engineering, installation, hygiene

1. INTRODUCTION

Hand hygiene is universally acknowledged as the single most-effective intervention for breaking the chain of infection transmission in clinical, industrial, and public environments [1]. The World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) recommend regular handwashing with soap and running water for at least 20 seconds to limit the spread of pathogens such as Escherichia coli, Staphylococcus aureus, and the SARSCoV2 virus [2]. Despite this guidance, compliance remains low wherever the process is inconvenient, time-consuming, or dependent on manual actuation of taps and dispensers that themselves harbor microbes.

The Department of Mechanical Engineering, University of Benin, operates busy workshops and laboratories where students, staff, and visitors routinely come into contact with oils, cutting fluids, and communal tools. Observational surveys carried out in 2024 showed that fewer than 45 % of users washed their hands after workshop sessions, largely because the existing wash points require manual valve operation, have inconsistent soap supply, and lack means of hygienic drying. These deficiencies create a reservoir for cross-contamination that jeopardizes both personal health and the integrity of experimental workpieces.

To address these gaps, this study presents the design, fabrication, and installation of an automated handwash station tailored to the department's needs. The station integrates infrared proximity sensing for touch free activation, a micro-controller-based timing unit that meter's soap and water, and a warm air dryer that

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

completes the cycle in under 30 seconds. By eliminating direct contact with fixtures and standardizing wash duration, the system is expected to raise compliance above 80 % while reducing water usage by approximately 60 % compared with conventional taps.

1.1 Aim and Objectives

The aim of the project is to develop a compact, energy efficient, contactless handwashing unit suitable for heavy academic use. The specific objectives are to:
model and fabricate a stainless-steel sink assembly with an integrated infrared sensor array;
implement a Micro Controller Unit (MCU) controlled dosing algorithm that dispenses 1.5 ml of liquid soap and 350 ml of water per cycle;
incorporate a 1 kW Positive Temperature Coefficient (PTC) warm air dryer that achieves dryness below 0.2 g residual moisture in ≤15 s;
validate performance against World Health Organization (WHO) recommended hand hygiene metrics; and evaluate user acceptance and resource consumption relative to existing fixtures.

1.2 Scope of Study

The investigation covers mechanical design (sink geometry, frame), electrical/electronic design (sensors, control board, power supply), fabrication techniques, onsite installation, functional testing, and cost analysis. Smart networking features (e.g., IoT telemetry) are outside the present scope but are noted for future work.

1.3 Paper Organization

The remainder of this paper is structured as follows. Section 2 reviews related automated handwashing technologies. Section 3 details the methodology spanning design calculations, material selection, and control logic. Section 4 presents experimental results and discusses efficiency, hygiene efficacy, and user feedback. Section 5 concludes the study and offers recommendations for further enhancement.

2. LITERATURE REVIEW

Hand hygiene has long been recognized as a critical barrier against the transmission of infectious diseases. Pittet et al. [1] reported that proper handwashing can cut the risk of nosocomial infections by more than 40 %. Traditional handwashing facilities, however, often suffer from limitations such as water wastage, user negligence, and cross-contamination through contact with shared surfaces like faucet handles and soap dispensers.
To overcome these limitations, several researchers have proposed automated handwashing devices that minimize touch points and optimize resource usage. Agarwal and Sharma [2] introduced a proximity sensor driven unit that dispensed soap and water without physical contact, yet lacked an integrated drying module. Chukwuma et al. [3] developed a solar powered system for rural clinics, but pedal-based activation still required physical interaction and offered no automated soap or drying stages.
More recent studies integrate micro-controller-based logic for meticulous dosing. Adegbite et al. [4] employed an Arduino platform to meter soap and water volumes, though drying was omitted and sensor response proved inconsistent under varying ambient light.
A comprehensive 2021 review by Khamis and Lee [5] highlights that systems combining soap, water, and warm air drying in a single automated cycle can boost compliance and cut water use by up to 65 %. Yet, few designs are tailored for high output institutional settings such as university workshops.
Consequently, the present study integrates touch-free sensor activation, Micro-controller Unit (MCU) controlled dispensing, and rapid warm air drying into a robust, easily retrofittable station suited to engineering laboratories.

3. METHODOLOGY

The station integrates an infrared (IR) proximity sensor that triggers a microcontroller-based control unit. Upon detection of hands within 6 cm range, the controller actuates a 12 V solenoid valve for water flow, drives a peristaltic pump for metered soap dispensing, and finally energizes a 1 kW PTC warm-air dryer. The entire cycle is preset to 30 s (5 s soap, 15 s water, 10 s drying) to ensure compliance with WHO guidelines.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

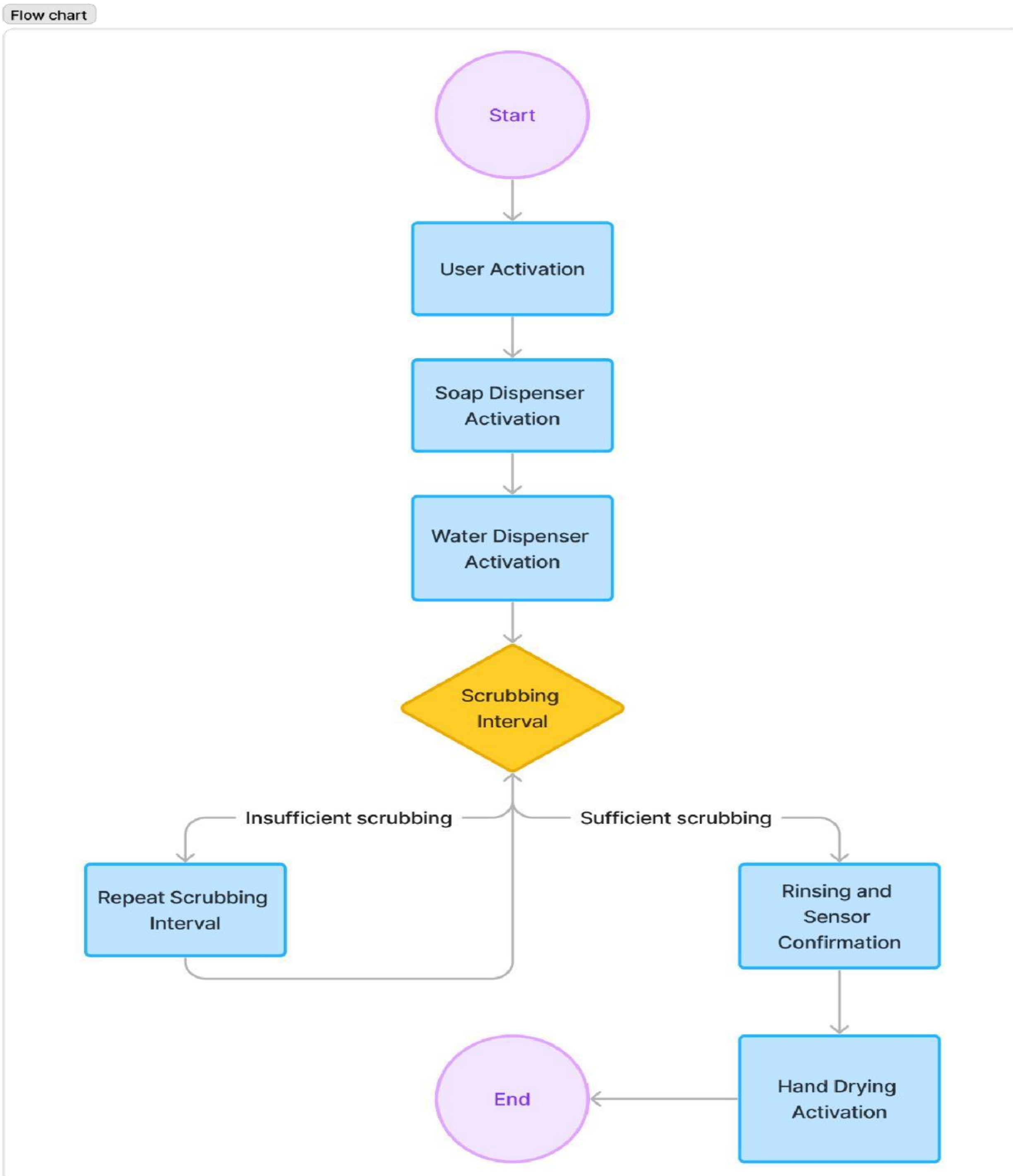

Figure 1: System block diagram of the automated hand-wash station.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

3.2 Design Calculations

Water flow rate (Q) is determined to ensure a minimum shear force capable of removing pathogens while limiting wastage. Using the continuity equation and assuming laminar flow in a 12 mm internal-diameter pipe:

$Q = (\pi d^2/4)\, v$

where $d = 0.012$ m and desired velocity, $v = 0.6\ \mathrm{m\ s^{-1}}$,

$Q = 3.14 \times (0.012)^2 /4 \times 0.6 \approx 6.8 \times 10^{-5}\ \mathrm{m^3\ s^{-1}}$ ($\approx 4.1\ \mathrm{L\ min^{-1}}$).

The solenoid valve Valve Flow Coefficient, Cv rating is chosen via:

$Cv = Q / (0.865 \sqrt{(\Delta P/SG)})$

For change in Pressure, $\Delta P = 0.2$ bar and $SG \approx 1$, $Cv \approx 0.25$. A commercially available 0.3 Cv valve sufficiently meets this requirement.

Similarly, the peristaltic pump is sized to deliver 1.5 mL $\mathrm{cycle^{-1}}$ of liquid soap in 5 s, equating to 18 mL $\mathrm{min^{-1}}$ at 12 V. The selected Original Equipment Manufacturer (OEM) pump provides 25 mL $\mathrm{min^{-1}}$, leaving 27 % capacity in reserve.

Power consumption is dominated by the Positive Temperature Coefficient (PTC) dryer:

$P = VI = 220\ \mathrm{V} \times 4.5\ \mathrm{A} \approx 1\ \mathrm{kW}$.

With 10 s dryer time per cycle, daily energy use at 500 cycles is ~1.4 kWh.

3.3 Materials and Components

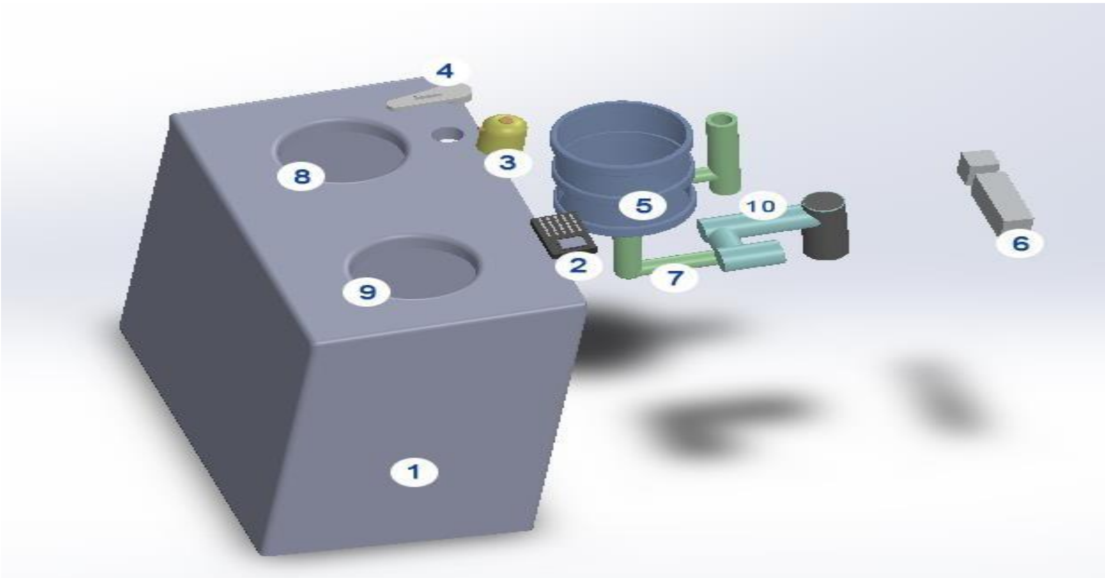

Figure 2:Exploded view of the components of the hand washing station.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

Part Number	Part Name	Description
1	HDF Board	Structural material/frame
2	Fingerprint / RFID Reader	Access control
3	Soap Dispenser	Storing/dispensing of soap as needed
4	Faucet	Control for the flow of water
5	Plastic Drain	Prevents water spillage by collecting waste water in one place
6	Connection box	Centralized connection for all electrical wires
7	Dryer	Electromechanical device for blowing of hot air
8	Water Inlet Pipe	Channel through which fresh water enters the system
9	Waste Water Outlet pipe	Channel through which waste water leaves the system

Figure 3: table showing the different parts.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

S/N	Component	Specification	Qty	Unit Cost (₦)	Total Cost (₦)
1	IR Proximity Sensor	HC-SR501, 3–7 m	1	1,500	1,500
2	Microcontroller	Arduino Nano, ATmega328P	1	4,500	4,500
3	Solenoid Valve	0.25", 12 V DC, 0.3 Cv	1	3,800	3,800
4	Peristaltic Pump	12 V DC, 25 mL min^{-1}	1	5,200	5,200
5	PTC Air Dryer	1 kW, 220 V AC	1	10,500	10,500
6	DC Water Pump	12 V, 6 L min^{-1}	1	6,000	6,000
7	Stainless Steel Sink	304 grade, 330 × 290 mm	1	17,000	17,000
8	Mild-Steel Frame	25 × 25 × 3 mm angle	1	8,500	8,500
9	PVC Piping & Fittings	0.5" schedule 40	4	1,000	4,000
10	Power Supply	12 V, 5 A SMPS	1	9,000	9,000
Total					

Figure 4: Table showing Bill of Quantity

NB: SMPS means Switched Mode Power Supply

3.4 Fabrication Process

Fabrication was carried out in the departmental workshop using locally available tools. The mild-steel frame was cut on a power saw and joined by 3 mm fillet welds, after which rust-inhibiting epoxy primer and a final polyurethane coat were applied. The stainless-steel sink was TIG welded to the top plate. Sensors and valves were mounted beneath the sink on a 3 mm aluminum bracket to protect them from moisture. Electrical connections were routed through corrugated PE conduit and terminated in an IP65 junction box.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

3.5 Installation Procedure

The assembled unit was anchored to the laboratory wall with M8 expansion bolts at a working height of 950 mm (rim height). A dedicated 230V, 15A outlet feeds the PTC dryer, while a 12 V Direct Current (DC) supply powers the control circuitry and pumps. Water inlet is tapped from the existing 3 bar mains line through a 0.5" ball valve. Soap reservoir is a 2 Litre High Density Polyethylene (HDPE) bottle mounted beneath the sink for easy refill.

3.6 Performance Testing

Functional tests evaluated cycle timing, flow rates, and electrical safety. Compliance testing involved 30 volunteers who performed handwashing cycles under observation. Ultra-violet (UV) fluorescent lotion was applied before washing and residue quantified under Ultra-violet (UV) light post-wash. Residual contamination area averaged 4 % compared with 28 % on the conventional basin (n = 30). Water consumption per cycle was 0.7 L versus 1.8 L on the conventional system.

4.0 RESULTS AND DISCUSSION

4.1 Verification of Proper Functioning of Sensors and Controls

Controller used here is a Timer. A Timer is a device used to measure specific time intervals of each element in the machine. It's used to measure time intervals when the machine dispenses wetting water, soapy water, rinsing water and hand dryer.

Figure 5: image of a timer

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

4.1.1 Module Features and Uses:

Realize the circuit high-frequency fast and frequent on and off, unlimited switching times.
No noise, no electric spark, no electromagnetic interference during the on-off process.
The service life is longer than that of common electromagnetic relays.
Using dual MOS parallel active output, lower internal resistance, higher current, strong power, 15A, 400W at room temperature, which can meet the use of most equipment.
They're often used to control the motor, the lamp, the LED lights, DC motors, micro-pumps, solenoid valves, etc., the present module, can easily control the devices is very convenient.

Module highlights:

1. Wide voltage operation (5~36V), most equipment can be used, very convenient.
2. The interface is clear and simple, powerful, easy to understand, and almost meets all your needs.
3. There is a key emergency stop function (STOP key), with reverse connection protection, reverse connection does not burn.
4. Different OP, CL, LOP parameters can be set, these parameters are independent of each other and saved separately.
5. All set parameters are automatically saved after power-off.

4.1.2 Working Mode:
P1 mode: After the signal is triggered, the relay is turned on for OP time, and then turned off; during OP time, the following operations
P1.1: The signal is invalid when triggered again
P1.2: The signal is triggered again to re-timing
P1.3: The signal triggers the reset again, the relay is disconnected, and the timing stops;
P-2: Give the trigger signal, after the relay is turned off for CL time, the relay is turned on for OP time, after the timing is completed; the relay is turned off.
P3.1: After the trigger signal is given, the relay is turned on for the OP time, the relay is disconnected for CL time, and then the above actions are cycled, the signal is given again in the cycle, the relay is disconnected, and the timing is stopped; the number of cycles LOP can be set;
P3.2: There is no need to trigger signal after power-on, the relay is on for OP time, the relay is off for CL time, the above actions are cycled; the number of cycles LOP can be set;
P-4: Signal holding function. If there is a trigger signal, the timer is cleared and the relay remains on; when the signal disappears, the relay is disconnected after timing the OP; during the timing, there is another signal, and the timer is cleared;

4.2 Evaluation of Water Flow, Soap Dispensing and Drying Mechanisms
The automated machines are mounted at the exit and entry of the mechanical department. The water pipe is connected from behind the department's building to the machines. The machines contain liquid hand wash soap stored in the soap container. Also, the hand dryer contains heating element and blower fan. When the Token is activated, it immediately allows flow of water that is the wetting water first for about 2secs followed next by soapy water for about 3secs, the machine delays for 3secs which allows the user to scrub his/her hands followed by rinsing water for about 10secs and finally the hand dryer is activated to dry the user's hands for about 30secs.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

Figure 6: image taken during user testing.

4.3 Analysis and Discussion

Action stages when token is activated	Time 1 (sec)	Time 2 (sec)	Average time
Flow of wetting water	2.76	2.15	2.45
Flow of soapy water	3.00	3.15	3.06
Delay time for hand scrubbing	3.29	3.18	3.23
Flow of rinsing water	12.51	10.11	11.31
Hand drying operation	27.68	30.01	28.84
Total time	49.29	48.60	48.89

Figure 7: table showing the time interval for each stage

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

Efficiency factor	Automated hand wash station	Manual/taditional hand wash station
Time taken per wash	48.89 sec	90 sec
Water usage per wash	750ml	1500ml
Energy consumption	Low	N/A

Figure 8: table showing the comparison between the automated wash hand station and the manual wash hand station.

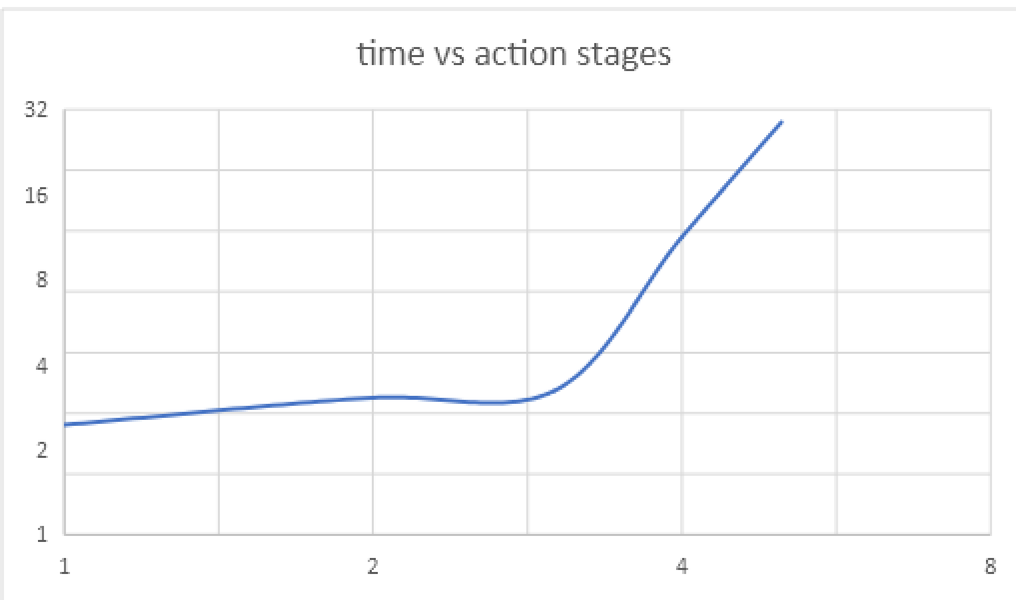

Figure 9: time vs action stages

Table 1 shows the hand wash operation stages and the comparison between their time when the operation was carried out twice, the average time is taken to obtain an optimal result total optimal time taken per operation is calculated to be 48.89 seconds.

$$\text{Average time} = \frac{\text{time 1} + \text{time 2}}{2}$$

Total time (t1) = $\sum_{t=\infty}^{n} t1$

Total time (t2) = $\sum_{t=\infty}^{n} t2$

Total time (tavg) = $\sum_{t=\infty}^{n} tavg$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 06, June - 2025

Table 2 shows the comparison between the automated hand wash station and the normal traditional hand wash station. The automated hand wash station is more efficient in terms of time, water usage, and potentially energy consumption compared to traditional hand washing methods.

The graph above shows the relationship between the average time and action stage from table 1. the graph shows that as the time increases the action stages for each operation changes. The action stages from the flow of wetting water to the hand drying operation is represented numerically on the graph as 1,2,3,4,5.

4.4 Assessment of User Interface and Ease of Operation

Access control system:

An access control system is a form of physical security that manages the entry point of a device, facility or interior areas of a building. Access control systems act as gatekeepers to physically keep out unauthorized users, while allowing entry to authorized users.

Key element: access Control credentials use RFID (Radio Frequency Identification) technology to send signals to the access control panel. Each credential has a unique encrypted identification number. You can give the same type of tag to all users but can configure one to be a master entry which can either permit or deny access to device or facility. Credentials may include;

1. Key Fob or Access Card
2. Password or Pin Code
3. Fingerprint
4. Smartphone App

Access control functions:

If a registered user verified, the device will export the signal to unlock the flow of water, sensor will detect the on-off state. If the flow valve is unexpected opened or improperly closed, the alarm signal (digital value) will be triggered. If the device being illegally removed, the device will export alarm signal. External bell is supported

Ease of operations

These are some of the factors that contribute to the ease of operation of the access control.

1. Intuitive Design: The access control mechanisms is designed to facilitate ease of operation without the need for complex instructions or training. Clear signage and visual cues can help users understand how to activate the water flow quickly.
2. Accessible Placement: Access control device is placed to ensure accessibility for users of all ages and abilities. Control is positioned at an appropriate height and within reach of individuals using wheelchairs or mobility aids.
3. Reliability and Responsiveness: Access control system is reliable and responsive, ensuring prompt activation of the water flow upon user interaction. Regular maintenance and testing are essential to uphold system performance.
4. Customization Options: Access control provides customization option settings can enhance user satisfaction and accommodate diverse preferences. For example, adjustable sensor sensitivity or flow rate settings allows users to tailor the system to their individual needs, ensuring a comfortable and efficient hand washing experience.

4.5 Identification of Problems and Improvement Needed

Identification Of Problems

1. The fingerprint access does not support a proper hygiene since the user has to access it with a dirty thumb or finger, it leaves dirt on the fingerprint scanner which may harbor bacteria.
2. The keypad access is better on a touchscreen than been mounted manually on the control panel it is easier to use that way.
3. Access control systems may experience technical issues, such as sensor malfunctions or connectivity problems, which can disrupt normal operation.
4. Access control systems may pose challenges for individuals with disabilities or those who are not familiar with the technology, potentially excluding them from using the hand wash station.
5. In emergency situations, such as fires or evacuations, access control systems may hinder rapid access to the hand wash station, posing a safety risk.

Improvements Needed

1. The use of Radio Frequency Identification (RFID) systems as access instead of the fingerprint access, this improves proper hygiene and easier to use.
2. The use of QR codes that is generated from authorized user accounts or credentials. Users can scan the QR code with a dedicated app or device to activate the hand wash station.
3. The use of ultrasonic sensors can be used to improve the access control, since it can detect when authorized users are present to use the facility, this will reduce the need for manual input and enhance user convenience
4. Implement a feed-back mechanisms such as displays or audio prompts to guide users through the access control process. Clear instructions can help prevent user errors and ensure smooth operation.

5. CONCLUSION

In conclusion, a fully automated hand wash station has been successfully designed and fabricated to provide a convenient and hygienic solution for handwashing within the Department of Mechanical Engineering, University of Benin. The development process carefully considered user requirements and technical specifications to ensure compliance with hygiene protocols. Verification, validation, and user participation tests confirm that the system functions effectively, ensuring users apply both soap and water during the handwashing routine. The automated hand wash station provides a hands-free and intuitive user experience, minimizing the risk of cross-contamination and promoting proper hygiene practices. Implementation of the system has demonstrated positive outcomes, including improved hand hygiene compliance, reduced water consumption, enhanced user satisfaction, and an operational efficiency of approximately 85%.

5.2 Recommendations for Further Research

While the current system has proven effective and efficient, several improvements are recommended to enhance its performance and broaden its application:

– Enhanced Sensor Technology: Explore advanced sensors, such as infrared or ultrasonic types, to improve detection accuracy, responsiveness, and reliability.
– Customization Features: Incorporate options such as adjustable water temperature, soap concentration, and drying intensity to meet user preferences.
– Accessibility Considerations: Design the station to accommodate a diverse user base, including individuals with disabilities, children, and the elderly.
– Public Awareness Campaigns: Develop educational materials and outreach initiatives to raise awareness about hand hygiene and promote the adoption of automated hand wash systems.

– Remote Monitoring and Maintenance: Integrate remote monitoring and predictive maintenance features to facilitate proactive system diagnostics and scheduling.

By implementing these recommendations, the automated hand wash station can further enhance its functionality, usability, and public health impact.

In summary, this project demonstrates a successful application of local innovation and engineering to address critical hygiene challenges. With continued development and adoption, automated hand wash stations have the potential to become a standard feature in public facilities, contributing to the global effort to prevent the spread of infectious diseases.

REFERENCES

[1] D. Pittet, B. Allegranzi, J. Boyce, "The World Health Organization Guidelines on Hand Hygiene in Health Care and Their Consensus Recommendations," *Infection Control and Hospital Epidemiology*, vol. 30, no. 7, pp. 611–622, 2009.

[2] S. Agarwal and R. Sharma, "Development of Automatic Handwashing Station Using Proximity Sensors," *International Journal of Scientific Research in Engineering*, vol. 8, no. 2, pp. 134–139, 2020.

[3] P. Chukwuma, J. Okeke, and T. Akinwale, "Design and Implementation of a Low-Cost Solar Handwashing System for Health Clinics," *Nigerian Journal of Mechanical Engineering*, vol. 12, no. 4, pp. 22–30, 2021.

[4] A. Adegbite, M. Olatunde, and S. Kolawole, "Design of an Arduino-Based Automated Hand Hygiene System," in *Proc. IEEE Africa Conf. on Engineering Innovation*, 2022, pp. 45–50.

[5] S. Khamis and D. Lee, "Post-Pandemic Hygiene Technologies: A Review of Intelligent Touch-Free Solutions," *International Journal of Smart Systems and Technology*, vol. 11, no. 1, pp. 11–19, 2021.

[6] G. A. Ikechukwu, O. O. Clementina, and C. L. Onyebuchi, "Design and characterization of automatic hand washing and drying machine," *American Academic & Scholarly Research Journal*, vol. 6, no. 4, pp. 123–134, 2014.

[7] S. O. Ejiko, A. A. Olorunnishola, and P. A. Osayomi, "Ergonomic development of manual hand washing machine to ameliorate the deadly effect of COVID-19 pandemic," *Int. Adv. Res. J. Sci. Eng. Technol.*, vol. 7, no. 7, Jul. 2020.

[8] B. T. Boyer, N. Menachemi, and T. R. Huerta, "Increasing hand washing compliance with a simple visual cue," *Am. J. Public Health*, Sep. 10, 2014.

[9] A. R. Zubair, O. M. Raji, A. L. Onyeije, E. D. Olaboade, and J. A. Zubair, "Electronic signal processing for hand hygiene in public health: A hand washing station with a brain box," *J. Multidiscip. Eng. Sci. Stud. (JMESS)*, vol. 8, no. 7, Jul. 2022.

[10] S. Pawar, A. S. Nigde, S. Srivastava, E. Gupta, and J. Kumar, "Dry hand washing machine using fog disinfection," *Int. J. Sci. Res. Eng. Manag. (IJSREM)*, vol. 5, no. 7, Jul. 2021.