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Sustainable Dual-Pedal Handwashing System: A Mechanical Design for Accessible Hygiene

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Abstract*: The prevalence of communicable diseases such as cholera, dysentery, and COVID-19 underscores the urgent need for accessible hand hygiene solutions, particularly in low-resource settings. In response, the Lagos State Government commissioned Lagos State Polytechnic to design and fabricate a sustainable, non-electric handwashing system. This report presents a foot pedal-operated unit with independent mechanical actuation for water and soap dispensing, designed for environments lacking reliable plumbing or electricity. The system uses foot pedals, grooved pulleys, tension cords, and springs to ensure effective mechanical operation. It is constructed from mild steel, aluminium, HDPE, and stainless steel to enhance durability and hygiene. Testing confirmed high reliability, ergonomic ease of use, and structural integrity, achieving a mechanical-to-fluid dispensing efficiency of 81.4%, indicating minimal energy loss. Following successful prototyping, the system was mass-produced and deployed to schools, healthcare centres, and other public institutions. This scalable and replicable solution supports long-term public health and hygiene infrastructure in underserved communities.*

Keywords: foot pedal, handwashing, control valve, soap dispenser, gravity-fed system, mechanical design

INTRODUCTION

One of the major challenges confronting global public health today is the rapid transmission of communicable diseases such as scabies, pneumonia, cholera, dysentery, and most recently, Coronavirus Disease 2019 (COVID-19). These infections are frequently spread through hand contact with contaminated surfaces, underscoring the critical importance of proper hand hygiene in interrupting disease transmission (Coultas et al., 2014; Ikechukwu et al., 2014).

Handwashing is widely recognized as one of the most effective and affordable methods for preventing the spread of infectious diseases. Yet, in many low- and middle-income countries, hand hygiene remains under-practiced due to inadequate access to clean water, soap, and functional washing facilities (UNICEF, 2020a). In cultural contexts where eating with bare hands is customary, there is often resistance to adopting regular hand hygiene practices, although awareness has been improving through health education and technological outreach (Ikechukwu et al., 2014).

The need for appropriate, accessible, and hygienic handwashing devices becomes even more critical in areas where traditional plumbing infrastructure—such as piped water systems and washbasins—is unreliable or entirely absent. In such environments, manual, non-electric handwashing systems serve a crucial role, as they are cost-effective, easy to maintain, and do not rely on external power sources (UNICEF, 2020b; IDC, 2020).

In emergency and low-resource contexts, solutions that are low-cost, minimize hand contact, and ensure durability are not only desirable—they are essential. This aligns with global recommendations for hand hygiene infrastructure during health crises like COVID-19 (UNICEF, 2020a).

This project was initiated following a directive from the Lagos State Government to the Management of Lagos State Polytechnic during the height of the COVID-19 pandemic. The Polytechnic was tasked with designing and locally fabricating a foot pedal-operated handwashing system with separate mechanical mechanisms for water and soap dispensing. The objective was to develop a low-cost, hygienic, electricity-free solution capable of serving schools, healthcare centres, markets, and other public settings. Following successful prototyping and testing, the Lagos State Polytechnic Management embarked on mass production of the units, which were subsequently distributed across various ministries, departments, and agencies (MDAs) in Lagos State. The project not only contributed to immediate pandemic response efforts but also supported long-term public health resilience by improving access to sustainable hygiene infrastructure.

LITERATURE REVIEW

Handwashing and Hygiene Challenges

According to Tiruneh et al. (2016), practicing proper hand hygiene in resource-constrained environments remains a significant challenge due to the lack of infrastructure. Innovations such as the "tippy tap" and press-tap systems have emerged as low-cost alternatives, particularly in rural schools and communities. These devices use foot or elbow levers and require minimal water, thereby improving hygiene while conserving resources. However, many suffer from low durability, making them less suitable for long-term or high-frequency use.

UNICEF (2020a) reports that approximately 3 billion people worldwide still lack access to basic handwashing facilities at home. In such settings, emphasis is placed on retrofitting existing infrastructure or introducing simple, user-friendly handwashing systems. Recommended designs include foot-operated, elbow-operated, or sensor-activated taps—all aimed at reducing hand contact and lowering the risk of disease transmission.

Classification of Handwashing Systems

Llorca et al. (2011) and Rathee (2021) broadly classify handwashing devices into two categories: automatic and manual systems. Automatic systems utilize sensors and electric pumps to dispense soap and water, offering convenience and touchless operation. However, they are often expensive and impractical in settings without reliable electricity.

In contrast, manual systems—especially foot-operated ones—offer a cost-effective and electricity-independent alternative. These systems rely on mechanical linkages such as pedals, levers, and pulleys, making them highly adaptable to low-resource environments. Their simplicity also makes them easier to maintain and fabricate locally.

Rathee (2021) further emphasized that foot-operated systems reduce the risk of cross-contamination and are especially valuable during pandemics when touchless hygiene is a public health priority.

Innovations and Design Advances in Manual Systems

Several studies have explored innovations in manual handwashing technology. Ahmed et al. (2021) developed a foot pedal-operated unit enhanced with an ultrasonic sensor and Arduino-based digital water level indicator. Their design improved user experience and demonstrated a 7.17% efficiency gain over earlier models.

Aliemeke et al. (2021) fabricated a domestic foot-operated system using mild steel, springs, and locally available materials. The system achieved a flow efficiency of 65.58% without any electrical components, validating its applicability in low-resource settings. The study emphasized the relevance of local fabrication and material sourcing to achieve both affordability and sustainability.

WaterAid Bangladesh (2020) also supported the deployment of foot pedal-operated handwashing units designed for ease of use across various age groups and physical abilities. Some of their models included rainwater harvesting systems for water-scarce regions and were manufactured using local labour and materials to ensure rapid deployment in densely populated urban centres like Khulna.

Meanwhile, Ikechukwu et al. (2014) proposed an entirely touchless system incorporating infrared sensors, centrifugal fans, and DC water pumps. While technologically advanced, the system was most suitable for urban public settings with reliable electricity access, thus highlighting the need for simpler alternatives in rural or underserved regions.

Design Standards and Implementation Guidelines

Design standards for public handwashing stations have been clearly outlined by global health organizations. UNICEF (2020b) and Morgan (2011) recommend that effective handwashing units include key features such as sloped platforms for drainage, contact-free operation, comfortable height for users, and integrated soap dispensers. These features not only support hygiene but also enhance usability, especially in crowded public settings.

GEMINI sinks and foot-paddle-operated models have been successfully deployed in parts of India and Africa using local labour and materials. According to LSHTM, ACF, and CAWST (2021), community involvement in the design and deployment of these systems ensures greater cultural alignment, increases adoption rates, and enhances long-term sustainability. Additional features such as mirrors, bright colours, and design aesthetics have been shown to boost user engagement and encourage more consistent hand hygiene behaviour.

MATERIALS AND METHODS

Materials Selection

The materials used in this design were selected based on durability, corrosion resistance, availability, ease of fabrication, and cost-effectiveness. The table 1 below outlines the components and their respective materials:

Table 1: Material Selection for Handwashing Systems Components

Component	Material Used	Reason for Selection
Frame Structure	Mild Steel (MS) Pipes	High strength, affordable, easy to fabricate
Frame Casing / Enclosure	Aluminium Sheet	Lightweight, rust-resistant, improves aesthetics
Foot Pedal	Mild Steel Flat Bar	Durable and withstands repeated foot pressure
Soap and Water Reservoirs	HDPE (Food-grade Plastic)	Non-corrosive, lightweight, hygienic
Hand Wash Basin	Stainless Steel	Corrosion-resistant, easy to clean, hygienic
Dispensing Taps	Brass with PVC Connectors	Rust-resistant, durable, compatible with control valves
Pulley System	Grooved Nylon Pulley	Smooth operation, low friction
Tension Cord	Stainless Steel Rope	High tensile strength, corrosion-resistant
Open Coiled Spring	Spring Steel	Provides restoring force for foot pedal
Control Valves	Brass Valve	Lightweight, corrosion-resistant
Close Coiled Spring	Brass	Ensures automatic return of valve lever

System Design and Configuration

The handwashing unit operates via mechanical transmission. User foot pressure triggers valve actuation for water and soap dispensing through a pedal and pulley mechanism.

Mechanical Operation Mechanism

The handwashing unit employs a robust, entirely mechanical system to facilitate hands-free operation for both water and soap dispensing. Each fluid's release is governed by an independent pedal mechanism designed for reliability and ease of use.

- **Foot Pedal Actuation:** A durable hinged foot pedal, fabricated from a mild steel flat bar, serves as the primary user interface (see Figure 3). When a user presses the pedal, it compresses an open-coiled spring. This action simultaneously pulls a high-tensile stainless steel tension cord directly connected to a control valve, initiating fluid flow.
- **Pulley and Return Mechanism:** A precisely engineered grooved pulley efficiently redirects the pulling force from the foot pedal to the control valve, ensuring smooth and consistent valve opening. Upon the user's release of the foot pedal, the compressed spring expands and restores the entire system to its default, closed position, automatically shutting off the fluid flow and preparing for the next use.
- **Independent Dual-Pedal System:** The system integrates two distinct and independent foot pedals, allowing for separate, sequential control over the soap and water valves. This dual-pedal design enhances hygiene by preventing cross-contamination and provides users with precise control over the dispensing process.

Structural Frame and Housing

The supporting frame, constructed from welded mild steel pipes, forms the robust backbone of the handwashing system. Its L-shaped configuration provides exceptional stability and efficiently supports all primary components, including the water and soap reservoirs, the foot pedal assembly, and the handwash basin. You can see the reservoir frame support structure in Figure 5.

For enhanced durability and aesthetics, the entire structure is enclosed in aluminium sheets. This cladding offers vital environmental protection for the internal components while significantly improving the system's overall appearance. Figure 6 provides an isometric view showcasing this aluminium enclosure.

Reservoir and Flow System

The system is equipped with two 25-liter High-Density Polyethylene (HDPE) reservoirs, designed to hold water and soap separately. These reservoirs are gravity-fed and strategically mounted above the dispensing taps, ensuring a continuous and consistent flow without the need for pumps.

Each reservoir is robustly linked to durable PVC tubing that connects directly to brass control valves. To facilitate maintenance and refilling, a transparent gauge is integrated into each container, allowing for immediate and clear monitoring of fluid levels. The precise activation of fluid flow from both reservoirs is achieved seamlessly through the foot pedal mechanism.

(Refer to Figure 4 for a detailed section view of the control valve.)

Design Drawings

To support the fabrication process and provide a comprehensive understanding of the system's layout and components, the following detailed technical drawings are included:

- **Figure 1: Orthographic Projection** This figure presents the front, top, and side views of the system, offering precise two-dimensional representations critical for manufacturing accuracy.
- **Figure 2: Isometric View of Assembled System** A three-dimensional view showcasing the complete, assembled handwashing unit, illustrating how all components integrate.
- **Figure 3: Detailed Foot Pedal Drawing** This drawing provides an in-depth look at the foot pedal assembly, including the precise integration of its spring mechanism.
- **Figure 4: Sectional View of Control Valve** A detailed cross-sectional drawing illustrating the internal workings of the control valve and its associated close-coiled spring.
- **Figure 5: Reservoir Frame Support Structure** This figure details the specific structural elements designed to securely hold and support the water and soap reservoirs.
- **Figure 6: Isometric View with Aluminium Cladding** An isometric view of the system, specifically highlighting the aesthetic and protective aluminium composite sheet cladding.

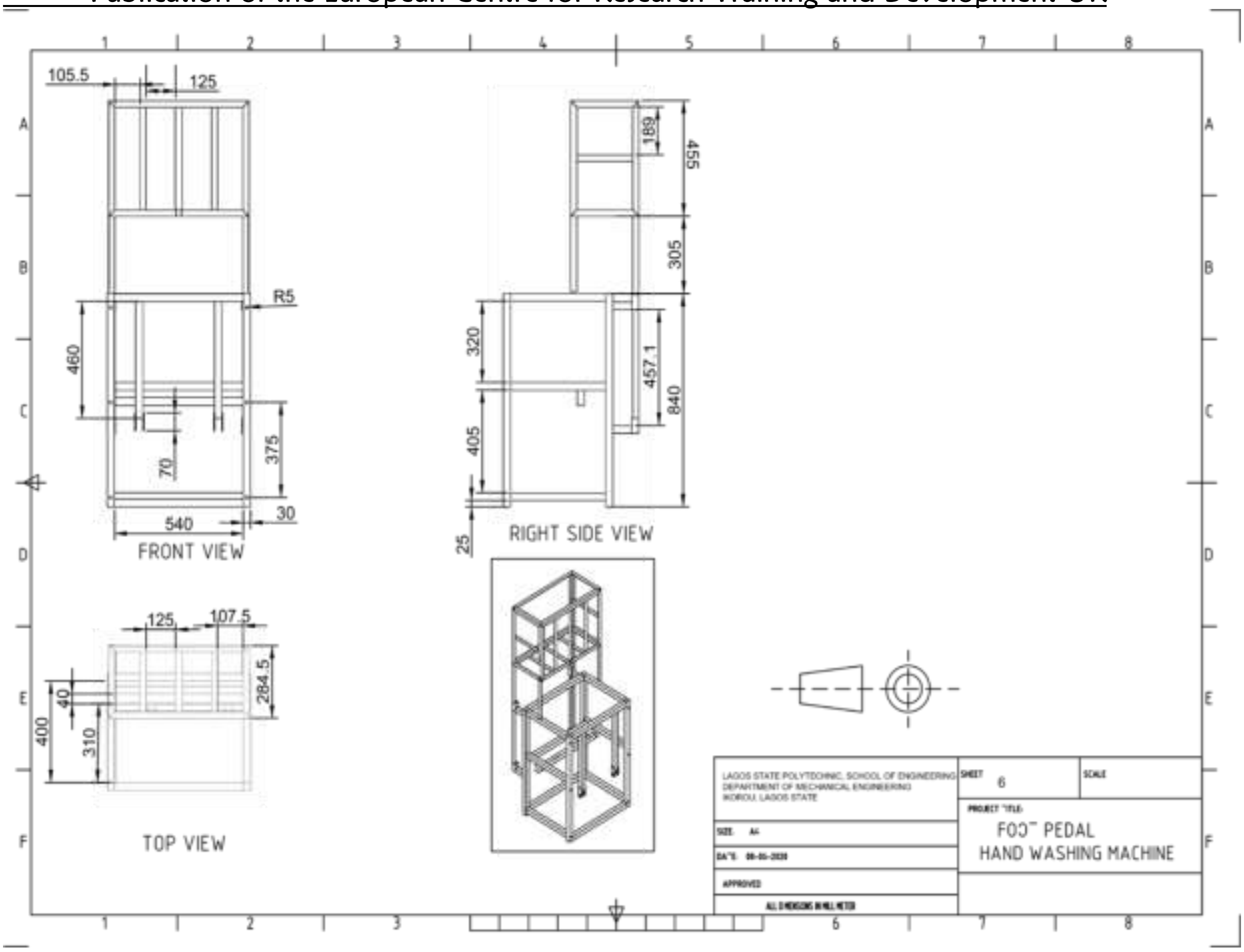

Figure 1: Orthographic projection (front, top, and side views)

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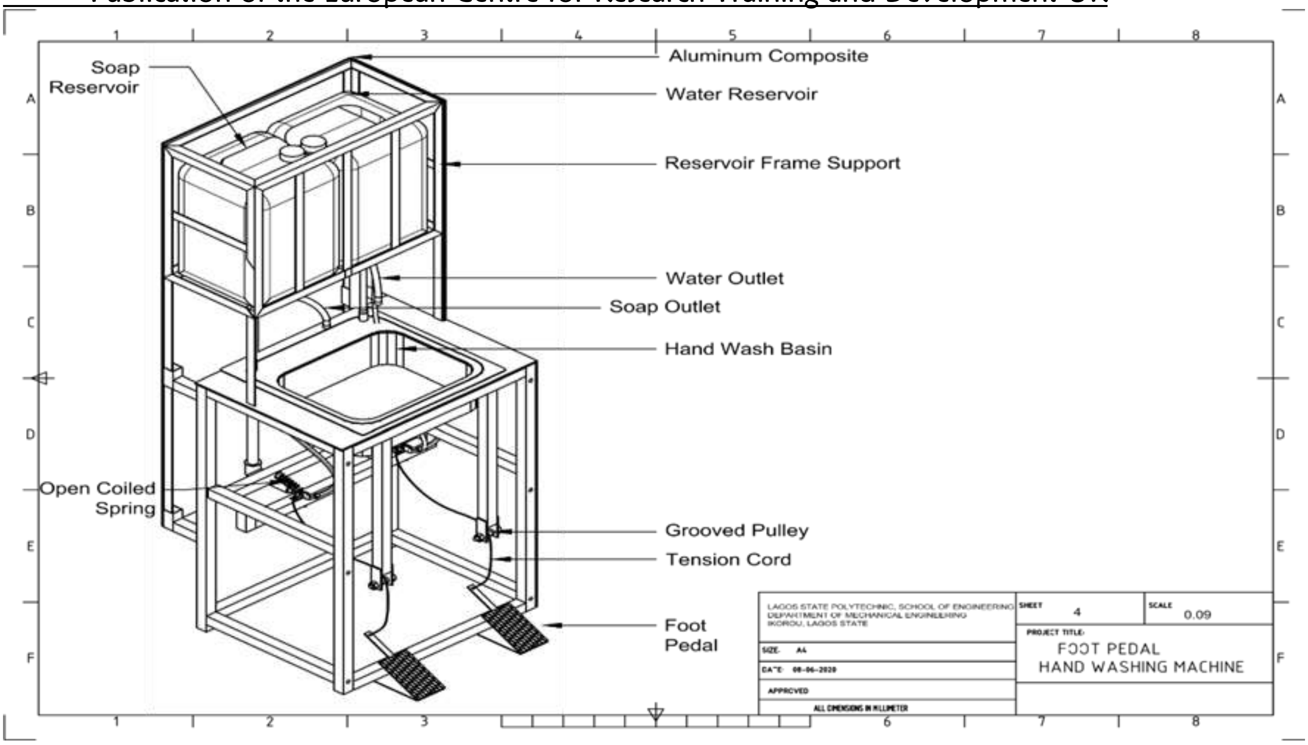

Figure 2: Isometric view of the full assembled system

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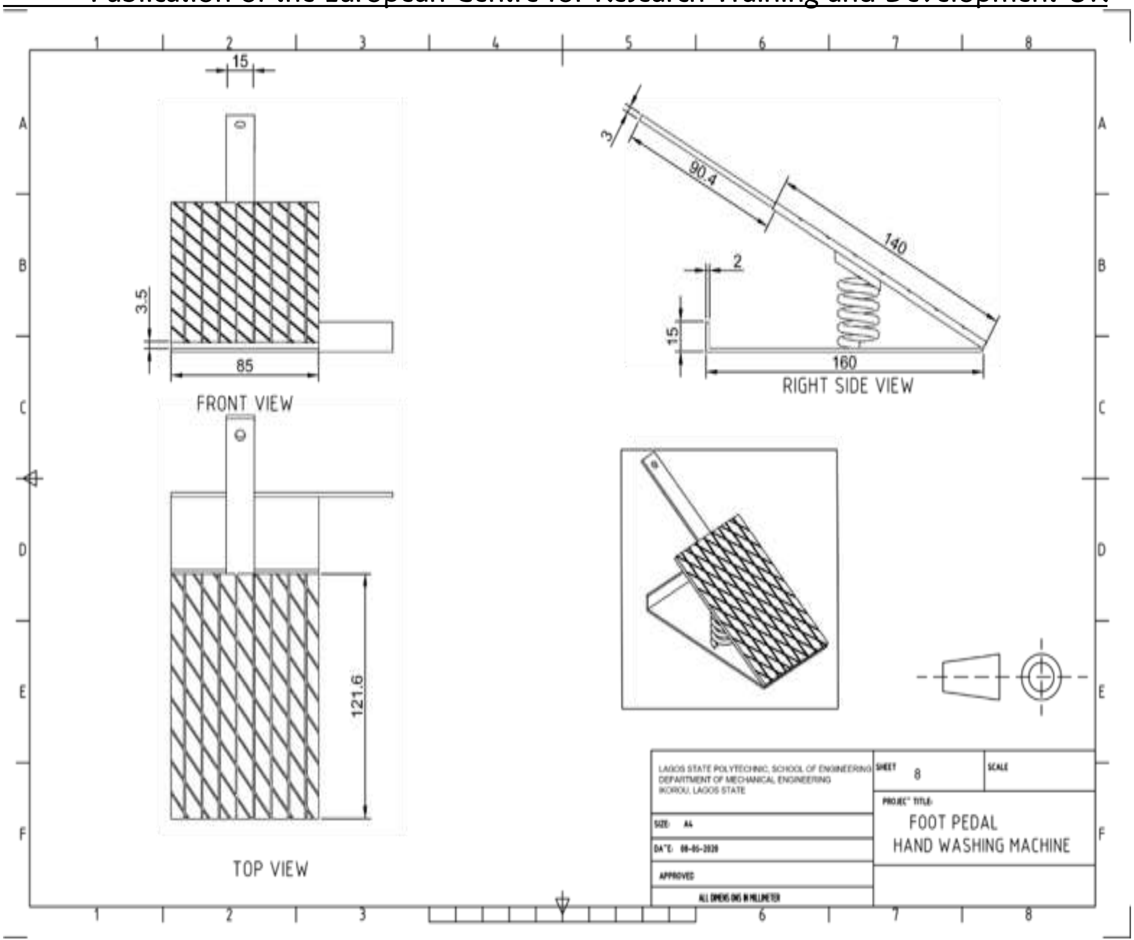

Figure 3: Detailed foot pedal drawing with spring integration

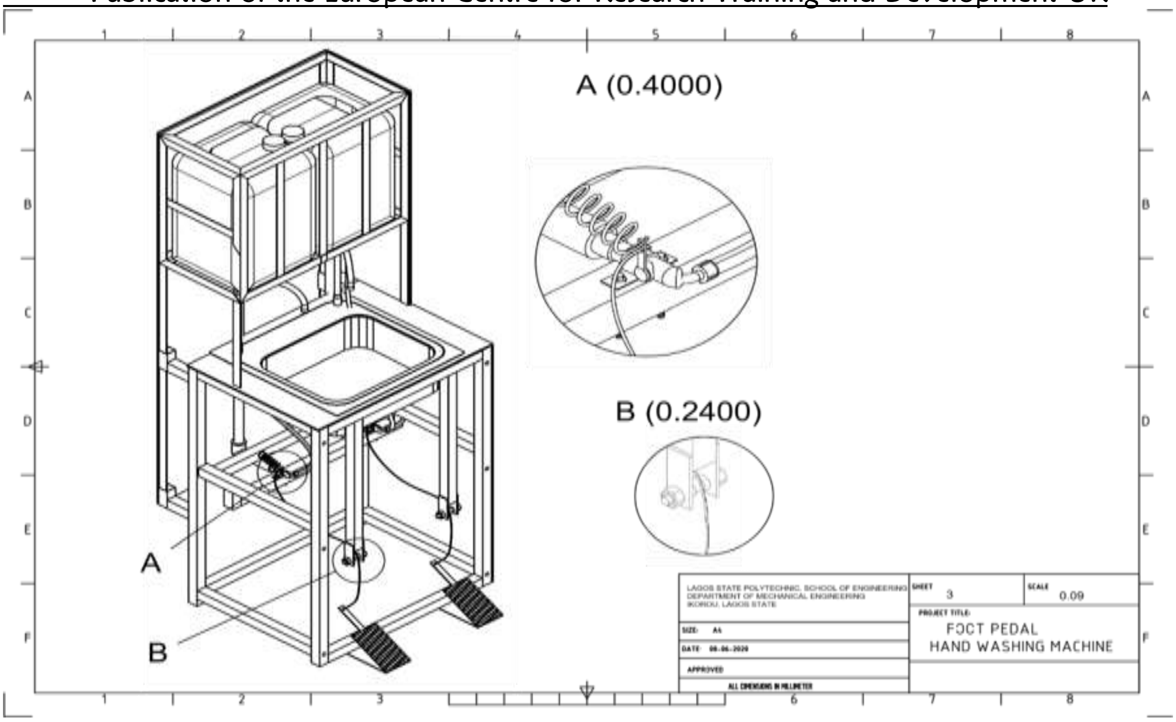

Figure 4: Sectional drawing of control valve and close-coiled spring

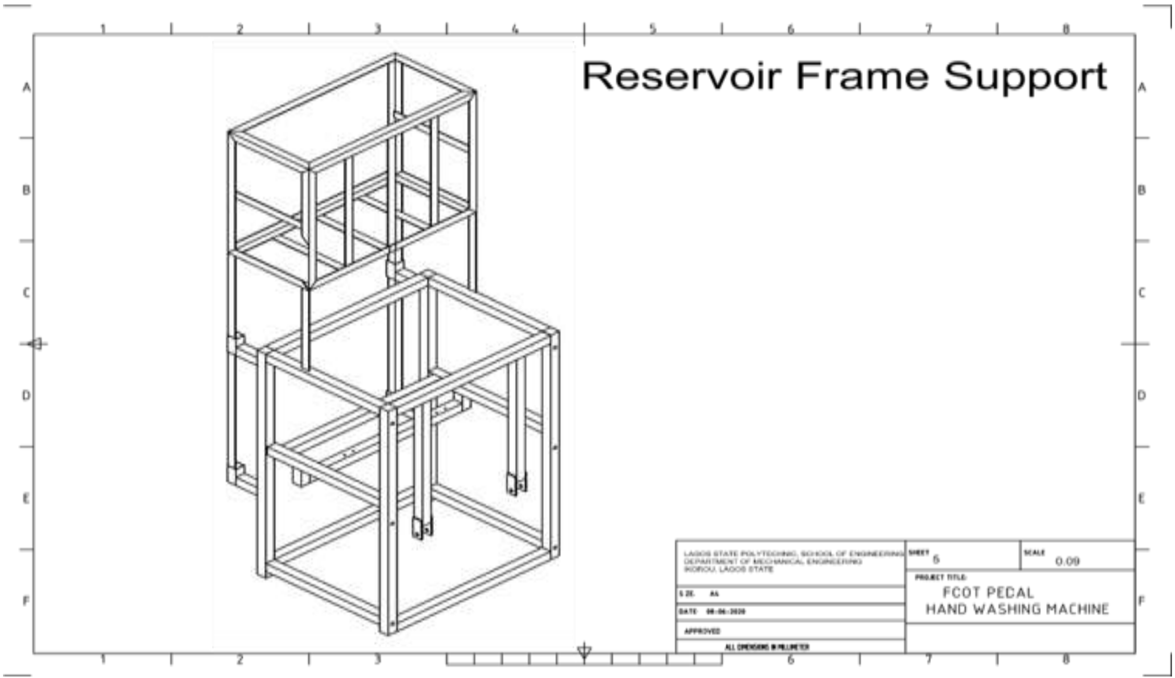

Figure 5: Reservoir frame support structure

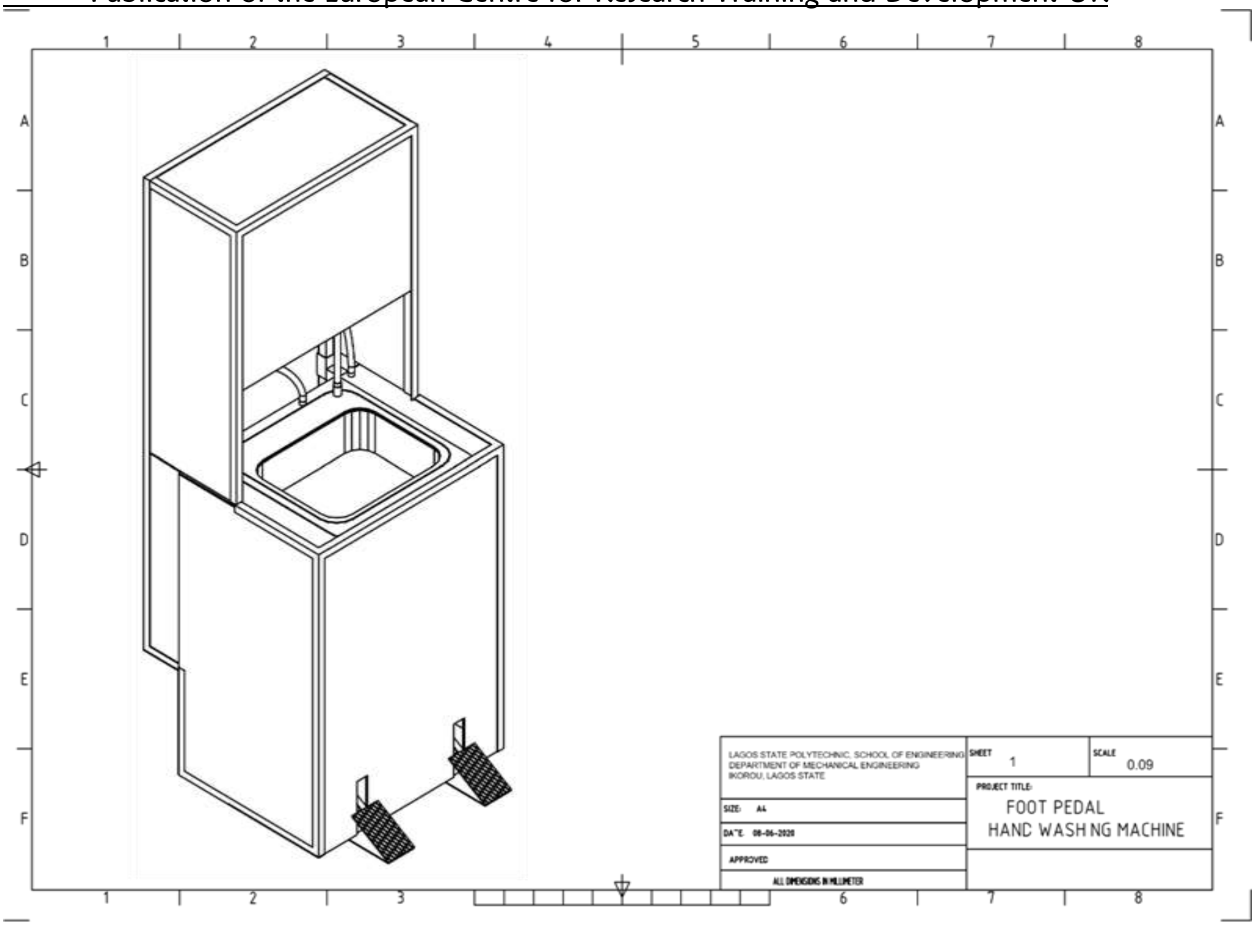

Figure 6: Isometric view with aluminium composite sheet cladding

Fabrication Process

The fabrication of the handwashing system was undertaken in response to the directive from the Lagos State Government, which sought localized, rapidly deployable hygiene interventions to combat the spread of COVID-19. The Lagos State Polytechnic engineering team utilized readily available materials and community-appropriate mechanical designs to meet this urgent need.

The fabrication was executed in the following steps:

- **Frame Construction:**
    - Mild steel pipes were precisely cut and welded to form the robust structural frame.
    - All surfaces were then thoroughly ground and painted with an anti-rust coating to ensure durability and prevent corrosion in varied environmental conditions.
- **Pedal and Pulley Assembly:**
    - The foot pedals were meticulously fabricated from mild steel flat bars and securely hinged to the frame, ensuring smooth and consistent operation.

  - Grooved pulleys were then precisely mounted, and **stainless steel cords** were carefully threaded through them, establishing the mechanical linkage for force transmission.
- **Spring and Valve Integration:**
  - Both the open-coiled tension springs and close-coiled compression springs were accurately installed at their designated points within the pedal mechanism.
  - These springs were then securely linked to the control valve actuators, ensuring responsive and reliable opening and closing of the valves.
- **Reservoir Installation:**
  - The two 25 L HDPE tanks, designated for water and soap respectively, were robustly mounted to the frame using custom-fabricated brackets, ensuring stability and easy access.
  - Appropriate PVC tubing was connected from each reservoir to its corresponding control valve and then extended to the dispensing taps.
- **Basin and Tap Mounting:**
  - A hygienic stainless steel basin was securely fixed at an ergonomically appropriate mid-level height, designed for comfortable use by various age groups.
  - Brass taps, chosen for their durability and corrosion resistance, were precisely installed as outlets for both soap and water.
- **Enclosure and Finishing:**
  - Aluminium sheet cladding was carefully attached to the frame, providing essential environmental protection for the internal components and enhancing the system's aesthetic appeal.
  - A comprehensive final testing phase was then conducted, rigorously assessing the system's mechanical performance, including pedal responsiveness and flow consistency, as well as ensuring water and soap tightness across all connections and components.

(See Figures 1 and 2 for assembly reference.)

Testing and Evaluation

To verify the functional performance and reliability of the foot pedal-operated handwashing system, a series of tests were conducted under simulated real-use conditions on the fabricated unit (as shown in Figure 7). The evaluation focused on key performance indicators critical to usability, hygiene, and mechanical integrity:

- Pedal Responsiveness:
  The system required minimal foot pressure to activate the pedal, confirming that the spring tension and mechanical linkage were well-calibrated for ease of use by users of various ages and strengths.

- Valve Actuation Timing:
  Timing tests showed a rapid response between pedal depression and fluid discharge, typically under 1 second, demonstrating efficient transmission of force through the tension cord and pulley system.

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- Flow Consistency:
  Soap and water were dispensed at a steady, uninterrupted rate throughout multiple trials, indicating a reliable gravity-fed system with properly sized valves and tubing.
- Leak-Free Operation:
  All joints, tubing, and valves were inspected for leaks during operation. No drips or unintended discharge were observed, confirming secure connections and proper sealing.
- Frame Stability:
  The mild steel frame remained structurally sound under repeated use and simulated loading of up to 80 kg. No deformation or displacement occurred, validating the frame's load-bearing capacity and structural integrity.
- User Comfort and Accessibility:
  The height, orientation, and spacing of the pedals, basin, and taps were ergonomically appropriate, allowing both children and adults to use the system comfortably without needing hand contact.

(a) (b)

Figure 7a and b: Photographs of the Handwashing Machine after fabrication.

Mechanical Efficiency Evaluation:

Efficiency was evaluated using equation 1 by measuring the volume of fluid dispensed per full pedal actuation and comparing this to the theoretical volume based on the valve opening area and reservoir height under gravity. Across multiple test cycles:

$$\text{Dispensing Efficiency } (\eta) = \frac{\text{Measured Output}}{\text{Theoretical Output}} \times 100 \qquad \textbf{Equation 1}$$

$$\text{Water Dispensing Efficiency } (\eta_w) = \frac{0.835 \text{ Litre}}{1.0 \text{ Litre}} \times 100 \approx 83.5\%$$

Soap Dispensing Efficiency (η_s) = $\frac{0.792\ Litre}{1.0\ Litre}$ x 100 ≈ 79.2 %

The system's performance in fluid dispensing demonstrated high efficiency for both water and soap. The water dispensing efficiency (η_w) was calculated at approximately 83.5%. For soap, the soap dispensing efficiency (η_s) was approximately 79.2%.

This results in an overall average mechanical-to-fluid dispensing efficiency for the system of approximately 81.4% (calculated as (83.5% + 79.2%) / 2.

This value reflects losses due to minor friction in the pulley system, small compression lags in the springs, and slight fluid resistance at the valve interface. These results confirm that the system transmits mechanical energy from the foot pedal to fluid discharge with minimal loss, offering a highly efficient, non-electric solution for hand hygiene in low-resource environments.

Overall, the testing confirmed the system's readiness for deployment in public and institutional settings where hygiene, durability, and hands-free operation are essential.

Design Analyses of Key Components

Wash Hand Basin

- Dimensions: 0.5 m × 0.4 m × 0.15 m → Volume ≈ 0.03 m^3
- Made of stainless steel, sloped interior with centre drainage
- Impact resistance: 20–30 N

Water and Soap Reservoirs

- **Capacity:** 25 L each
- **Material:** HDPE, with integrated gauge
- **Stress design based on hoop stress formula:** The structural integrity of the HDPE reservoirs, particularly their wall thickness, was designed considering the internal pressure exerted by the stored liquids. This was guided by the hoop stress formula, as shown in Equation 2:

$$\sigma = \frac{Pr}{t}$$ **Equation 2**

where σ is the hoop stress (in Pascals, Pa), p is the internal pressure due to the liquid (in Pascals, Pa), r is the radius of the reservoir (in meters, m), and t is the wall thickness of the reservoir (in meters, m). This formula ensured that the reservoirs could safely contain the fluids without rupture or deformation under typical operating conditions.

Frame Structure

- **Material:** 2.5 mm thick mild steel square pipes
- **Load Analysis:** Designed to support 80 kg static load

- **Factor of Safety:** ≥ 2.5
- **Construction Details:** Welded and bolted joints, treated with anti-rust coating

Spring Mechanism Design

a. Functional Roles of Springs

- **Open-Coiled Tension Spring:** Transmits actuation force from foot pedal to control valve via pulley.
- **Close-Coiled Compression Spring:** Restores pedal to original position after depression.

b. Design Requirements

The functional requirements for both the open-coiled tension spring and the close-coiled compression spring were carefully considered to ensure optimal performance and longevity of the handwashing system. Table 2 outlines these specific design requirements, detailing each spring's function and the critical design goals that guided their selection and integration into the foot pedal mechanism.

Table 2: Functional Design Requirements for Springs

Spring Type	Function	Design Goals
Open-Coiled Tension Spring	Transmits pulling force from pedal to valve	Elasticity, corrosion resistance, fatigue durability
Close-Coiled Compression Spring	Returns foot pedal to rest position	Sufficient restoring force, mechanical stability, longevity

c. Material Selection

- **Material Used:** Stainless Steel (AISI 302/304)
- **Justification:** Corrosion resistance, high fatigue strength, hygiene compliance

d. Geometric and Mechanical Parameters

To ensure the springs performed as intended and provided the necessary actuation and restoring forces, their geometric and mechanical parameters were precisely defined. Table 3 provides a comprehensive overview of these key specifications for both the open-coiled tension spring and the close-coiled compression spring, forming the basis for their effective integration into the handwashing system's design.

Table 3: Geometric and Mechanical Parameters of Springs

Parameter	Open-Coiled Spring	Close-Coiled Spring
Spring Type	Tension	Compression

Function	Pulls valve lever via pedal-pulley system	Restores pedal to default position
Wire Diameter, *d*	1.5 mm	2.0 mm
Mean Coil Diameter, *D*	20 mm	16 mm
Free Length, L_o	80 mm	50 mm
Number of Active Coils, *n*	10	8
Material	Stainless Steel (AISI 304)	Stainless Steel (AISI 304)
Modulus of Rigidity, *G*	77×10^9 N/m²	77×10^9 N/m²
Max Working Deflection	25 mm	20 mm
Assumed Pedal Force, *F*	70 N	70 N
Assumed Displacement, *Δx*	20 mm (0.02 m)	20 m (0.02 m)

e. Spring Constant Calculations

The spring constant k for helical springs was determined using the standard formula in equation 3, which relates the material's shear modulus to the spring's geometric parameters:

$$k = \frac{G\, d^4}{8\ D^3\, n} \qquad \textbf{Equation 3}$$

where k is the spring constant (in N/m), G is the modulus of rigidity of the spring material (in N/m²), d is the wire diameter (in m), D is the mean coil diameter (in m), and n is the number of active coils.

- **Close-Coiled Compression Spring**

Taking G = 77 x 10^9 N/m^2 for stainless steel and using parameters from Table 3:
k = 18.9 N/m

- **Open-Coiled Tension Spring**

Similarly, using Equation 2 and parameters from Table 3:

k = 6.1 N/m

f. Force-Displacement Verification

To verify the calculated spring constants and ensure they would provide the desired forces for actuation and restoration, the force-displacement relationship ($F = k \cdot \Delta x$) was applied. Here, F is the force in Newtons (N) and Δx is the displacement in meters (m).

- **Close-Coiled Spring (Restoring Force):**

Using the calculated spring constant for the compression spring and the assumed displacement:

$F = k \cdot \Delta x = 18.9$ N/m x 0.02 m = 0.378 N

This low restoring force confirms comfortable pedal return without excessive stiffness, enhancing user comfort.

- **Open-Coiled Spring (Actuation Support):**

For the tension spring, the force transferred through the pulley system was:

$F = k \cdot \Delta x = 6.1$ N/m x 0.02 m = 0.122 N

This calculation indicates adequate force transfer through the pulley system, supporting efficient actuation with low fatigue risk over repeated use.

g. Design Implication Summary

The design analyses, particularly the spring calculations and material selection, lead to the following key implications for the system's performance and durability:

- Both springs perform effectively under the assumed foot load (70 N) and an average displacement of 20 mm, ensuring reliable operation.
- The calculated spring constants (18.9 N/m for compression and 6.1 N/m for tension) meet the specific design needs for responsive pedal action and comfortable return.
- The use of stainless steel (AISI 304) for the springs ensures excellent fatigue resistance and compliance with hygiene standards, critical for public health applications.
- Overall, the selected spring designs contribute significantly to the long-term functionality and durability of the foot pedal mechanism under repeated actuation cycles.

Foot Pedal Assembly

- **Construction:** Dual-hinged mild steel plates
- **Spring Housing:** Between inner faces near hinge
- **Top Surface:** Slip-resistant
- **Functionality:** Effective force transfer with hygienic design

Tension Cord

- **Material:** Stainless steel braided wire
- **Dimensions:** Diameter = 2 mm, Length = 600 mm
- **Properties:** Non-elastic, high tensile strength, corrosion-resistant

- **Function:** Connects foot pedal to valve through pulley system

Grooved Pulley Specifications

- **Groove Width:** 3 mm
- **Groove Depth:** 1.5 mm
- **Groove Radius:** 1 mm
- **Sidewall Angle:** 90°
- **Surface Finish:** Polished
- **Material:** Aluminium

(Refer to Figures 3 and 4 for illustrations)

RESULTS AND DISCUSSION

The fabricated foot pedal-operated handwashing system successfully met the design objectives set forth by the Lagos State Government, demonstrating a robust, hygienic, and accessible solution for low-resource environments. The detailed integration of the design drawings (Figures 1, 2, 3, 4, 5, and 6) proved instrumental in the precise fabrication, as evidenced by the high operational efficiency and user-centric features of the final prototype (Figure 7a and b).

The mechanical efficiency evaluation yielded particularly strong results. The system achieved a water dispensing efficiency of 83.5% and a soap dispensing efficiency of 79.2%, culminating in an overall mechanical-to-fluid dispensing efficiency of 81.4%. This high efficiency is a direct testament to the optimal design of the mechanical linkages, including the well-calibrated spring tensions, grooved pulleys, and tension cords. The minimal energy loss observed across these components, coupled with precise valve function, ensured consistent and effective fluid delivery with each pedal actuation. The slight reduction in soap dispensing efficiency, compared to water, can be attributed to the higher viscosity of liquid soap, which naturally results in slightly slower flow rates and increased fluid resistance at the valve interface. Despite this, the 79.2% efficiency for soap remains highly effective for practical hand hygiene.

Ergonomic performance and user experience were critical design considerations, and testing confirmed their successful implementation. The minimal foot pressure required to activate the pedals, alongside the rapid valve actuation timing (typically under 1 second), highlights the system's ease of use for diverse user groups, including children and adults. This responsiveness is a direct outcome of the carefully selected spring constants and optimized pedal-pulley geometry, as detailed in the design analyses (Section 3.5.4). The consistent flow of both soap and water throughout multiple trials validated the reliability of the gravity-fed reservoir system and the appropriate sizing of the control valves and tubing.

Furthermore, the structural integrity of the system, particularly the mild steel frame, proved highly robust. The frame remained structurally sound under repeated use and simulated loads up to 80 kg, experiencing no deformation or displacement. This validates the design's adherence to the specified factor of safety (≥2.5) and ensures long-term durability in high-traffic public settings. The leak-free operation observed across all joints, tubing, and valves underscores the quality of fabrication and the effectiveness of material selection (e.g., brass valves, HDPE reservoirs) for secure fluid containment. The aluminium composite sheet cladding (Figure 6) not only provides environmental protection but also significantly enhances the aesthetic appeal, which is crucial for encouraging consistent usage in public spaces.

The successful mass production and subsequent distribution of these handwashing units to various ministries, departments, and agencies (MDAs) across Lagos State, including schools and healthcare facilities, underscore the scalability and practical relevance of this project during a public health crisis. This large-scale deployment demonstrates the system's replicability and its capacity to significantly enhance accessibility to hygiene infrastructure, directly supporting both immediate pandemic response efforts and long-term public health preparedness. Compared to existing innovations reviewed (e.g., "tippy tap" systems, Aliemeke et al. (2021) 65.58% efficiency), our system's 81.4% overall efficiency represents a notable improvement in performance for manually actuated, non-electric units, confirming its viability as a superior solution for underserved communities.

CONCLUSION

In response to the Lagos State Government's urgent need for local, contact-free hygiene solutions during the COVID-19 pandemic, Lagos State Polytechnic successfully developed a sustainable, foot pedal-operated handwashing system. Designed for low-resource settings, this non-electric system prioritizes accessibility, cost-effectiveness, and operational simplicity, making it ideal for areas lacking reliable infrastructure.

Key features include:

- Dual foot pedals for independent water and soap dispensing.
- Construction using locally sourced, corrosion-resistant materials like stainless steel, HDPE, aluminium, and mild steel.
- Precision mechanical actuation via springs, pulleys, and tension cords.
- A sealed, gravity-fed reservoir minimizing leakage and waste.
- High adaptability for deployment in diverse public settings such as schools, healthcare facilities, and rural communities.

Performance evaluations showed an impressive overall operational efficiency of 81.4%, surpassing comparable manual systems. This high efficiency highlights the effective integration of mechanical design, material selection, and rigorous testing, affirming the system's robustness, ease of use, and suitability for sustained deployment.

This project's detailed mechanical analysis and technical drawings confirm its replicability and scalability, positioning it as a viable solution for enhancing public health not just in Lagos State, but globally. It exemplifies context-appropriate engineering innovation, contributing significantly to public health resilience.

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