ERGONOMIC DEVELOPMENT OF A PEDAL-OPERATED, DUAL HAND WASHING MACHINE TO AMELIORATE THE DEADLY EFFECT OF COVID-19 PANDEMIC

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Abstract

Coronavirus (COVID-19) pandemic is one of the defining global health crises the world has ever faced after world war two. From the time of its emergence in Wuhan, China, the virus has spread to all the continents. Every day, people are losing their lives, jobs and income, with no way of knowing when normality will return as a result of the spread. The pandemic spreads primarily when people are in close contact or when one person or more inhale(s) small droplets produced by an infected person who is coughing, sneezing, talking or singing. Due to this, the World Health Organization (WHO) gave advice to the public on how to contain COVID-19 spread. They are: social distancing, regular hand washing, hand sanitizing, temperature measurement, self-isolation of infected persons and the use of nose mask. This research endeavor focuses on design and development of a mechanical means of safe hand washing. The machine major components are frame, liquid soap dispenser, water reservoir, water taps, waste water tank, piping, foot pedals, and wash hand bowl. The machine was designed to work without electricity as it is foot pedal powered. The foot pedal acts as an actuator either to depress water tap or liquid soap dispenser. Machine design capacities for both intermediate and full level of depression are respectively 94 users in 16 minutes and 68 users in 12 minutes. Direct implication is that 2,880 users can engage it in a day of 8 hours operation for intermediate depression, leaving number of batches for prolonged use averagely as 30 batches. For full pedal depression, 2,720 users will engage the machine for 8 hours, leaving number of batches as 40. Social distancing was measured as 1 meter when engaged simultaneously by users. The materials for the fabrication of the machine were sourced locally so as to minimize the cost of production and as well make it readily available for low income earners in developing nations. Findings from this technical brief should be given wide adoption as hand washing has become a recommended way of staying safe in public places.

Keywords*:* Foot Pedal, Soap Dispenser, Waste Water Tank, Hand Washing, Covid-19

Introduction

The origin of human coronavirus can be traced back to 1960 when Tyrrell and Bynoe isolated a virus named B814 from a boy while working at the British Common Cold Unit of the British Medical Research Council (Huang *et al.*, 2019). More than 8,000 people were infected by July 2003, and 774 died. A small outbreak in 2004 involved only four more cases [2]. The novel coronavirus refers to as SARS-CoV-2 is responsible for coronavirus disease (COVID-19) pandemic which originated in Wuhan, China, December 2019 has now spread to 113 countries and territories outside of China [3; 4]. SARS-CoV-2 is a beta coronavirus that causes fever, headache, and respiratory problems such as cough and shortness of breath (Sun *et al.,* 2020). Healthcare Workers (HCWs) and other public personals are at risk of been infected by COVID-19 due to constant exposure to infected people and contaminated surfaces [6; 7]. SARS-CoV-2 appears to be transmitted person to-person through respiratory droplets and close contact, as previously seen in SARS-CoV and MERS-CoV, the two other zoonotic coronaviruses.

COVID-19 outbreak has now become a global pandemic, with more than 4 million cases reported across all continents (Francesco *et al.*, 2020). Empirical facts gathered reveal that scientists and health care workers may not be so lucky in containing the spread of the novel virus because it is transmissible even before symptoms arise. However, transmission will certainly reduce if containment strategies by WHO is strictly adhered to. The strategies have been broadly identified as restrictive, permissive, and hybrid as explained by Bob (2020).

Economies around the world are fighting the effects of COVID-19 pandemic, not least in Nigeria, which was already tackling its own fiscal challenges [10]. Nigeria's economy is facing collapse as it largely depends on oil exports. The oil markets have been on a downward trend as COVID-19 has crippled demand. However, if the virus continues to spread at its current rate, or at an even higher rate through its evolution, the novel coronavirus could be with us indefinitely.

There is no specific cure yet for COVID-19. There are many ongoing clinical trials to test various potential antivirals. Current management of cases aims to relieve the symptoms while the body's immune system fights the illness. To reduce the risk of infection or spread of COVID-19, members of the public are advised to adhere to hand and respiratory hygiene measures by WHO.

The wake of Coronavirus pandemic threw challenge at a team of researchers in Agricultural and Bioenvironmental Engineering Department, Federal Polytechnic Ilaro, Ogun State, Nigeria to come up with noble invention on hand washing system as an intervention to contain the spread.

The construction of mechanical hand washing machine becomes essential as a major requirement by WHO for staying safe in public places. Empirical facts gathered show that getting infected with the virus was largely due to using contaminated hands to touch the eyes, nose or the ears, and hence regular washing of the hands with soap and running water or the use of alcohol-based sanitizer was prescribed.

The lock down currently being experienced in Nigeria can be eased and public places reopened only if appropriate safety measures are put in place for people to stay safe in the public. One of the key requirements is washing of hands without getting infected with the virus while trying to stay safe. Hence, the development of mechanical hand washing machine with double outlets to cater for people's safety in public places is essential.

Developed countries like the United States of America, China and Italy who suffered major mortality as a result of the corona virus have been able to slow the spread of the deadly disease down through success made developing ventilator, disinfectant booth and hand washing machines, face shield etc. The price of these machines will be too expensive if they were to be imported to developing economies like Nigeria. This paper therefore focuses on development of a low-cost, pedal operated hand washing machine to ameliorate the deadly effect of COVID 19 pandemic.

There are various problems being faced by individuals, rural families, offices and organizations as regards washing of hands and sanitization during the corona virus pandemic. They are:

a) Price range being too high to afford;

b) High maintenance of an electrically operated hand washing machine with added baggage of electricity to run it;

c) High cost after service of these machines;

d) Prior knowledge requirement in operating an automatic hand washing machine.

A pedal operated hand washing machine advantages are enormous. The machine can be used by any individual from any level of social class but our main focus is to bring forth an inclusive way of hand washing for the people who are living below poverty line or those who can't afford imported hand washing machine.

Materials and Methods

Design philosophy

Pedal power is the transfer of energy from a human source through the use of a foot pedal depression to dispense either water or liquid soap for hand washing process. This is a design concept that works as an alternative to the electrically operated stationary machines. The foot pedal was adopted as a means of powering the machine to prevent inter-person contamination as this will help to curtail the spread of the pandemic ravaging the world presently. More also, two users can engage the machine at a time and still observe social distancing. The design consideration adopted made this possible. Moreover, the beauty about the machine is that it can perform without electricity and when placed in a crowded environment like schools, market places, religious centers, event centers, banking halls, shopping malls, and farm, it will serve them well.

Hand washing involves use of soap dispenser, water tap and wash hand basin. Major components include amongst others liquid soap dispenser, water tap, wash hand basin, foot pedal, water reservoir, waste water tank and frame. The invention can be up scaled into multiple users depending on end user's requirements. The aim of this research is to achieve washing of hands through a mechanical means and simultaneously preventing body contact with the machine so as to avoid exposure to the virus.

Design considerations

Some relevant factors were considered in the design and development of the hand washing machine. Such factors are cost of maintenance, power requirement and ease of replacement of various components and labour requirement. The machine is easy to maintain. Angle iron of 5mm thickness was used for the fabrication of the frame to avoid shearing of parts and eventual machine failure while in operation. The spring-loaded actuator impacts strong depression force on the liquid soap dispenser and water tap to achieve supply of soap and water respectively for hand washing exercise.

Components of the hand washing machine

The foot pedal hand washing machine is a machine that assists in achieving hand washing process without the use of electricity. The machine designed and constructed comprises of the following parts:

***Support frame for water reservoir/ waste water bucket*:** is the section that supports the weight of water reservoir on the top and as well reactions of other parts. It is made of mild steel square pipe of 4mm thickness with dimension of 45mm x 45mm x 1300mm. For this machine, they are four in number.

***Stud rod*:** The stud rod is 13 mm in diameter and 115 mm long.

***Spring valve for Tap*:** Two spring valves were used for each pedal system. One experiences a tensile force while the other experiences compression forces to achieve different levels of depression.

***Pedal*:** The pedal is trapezoidal in shape. It is 5mm thick and has dimension of 67.2mm x 92.9mm x 5mm

***Water reservoir*:** The water reservoir is of 50 liters capacity and is made of plastic.

***Strap for liquid soap support*:** The strap partially supports the weight of the liquid soap dispenser. It assumes similar dimension as that of the dispenser bottle.

***Wash hand basin*:** This is the bowl that collects waste water from hand washing process. The water is then directed through piping to the waste water reservoir.

***Piping*:** This is the plumbing work for supply of water either to the tap or waste water reservoir.

***Waste water reservoir*:** The waste water reservoir is the container that supplies water to the taps through gravity for hand washing exercise. Plastic bucket of 50 liters capacity was considered for the development of the machine to avoid corrosion

***Wash hand basin hanger*:** The hanger is the component that supports the weight of the wash hand basin. It has thickness of 4mm and diameter of 315mm.

***Liquid Soap bottle*:** The bottle is the container for the liquid soap. Its capacity for liquid soap is one liter.

***Press bar*:** This component is attached by bolting to the stud rod inside the square pipe that acts as part of support frame. Upward and downward movement of the stud rod due to depression force of the pedal makes the press bar to depress the dispenser bottle for discharge of liquid soap. Similar operation is achieved for the press tap for discharge of water.

Material selection

Table 1 below shows the list of major components of the hand washing machine and the design considerations for materials selection. Some components were purchased while some were machined or fabricated.

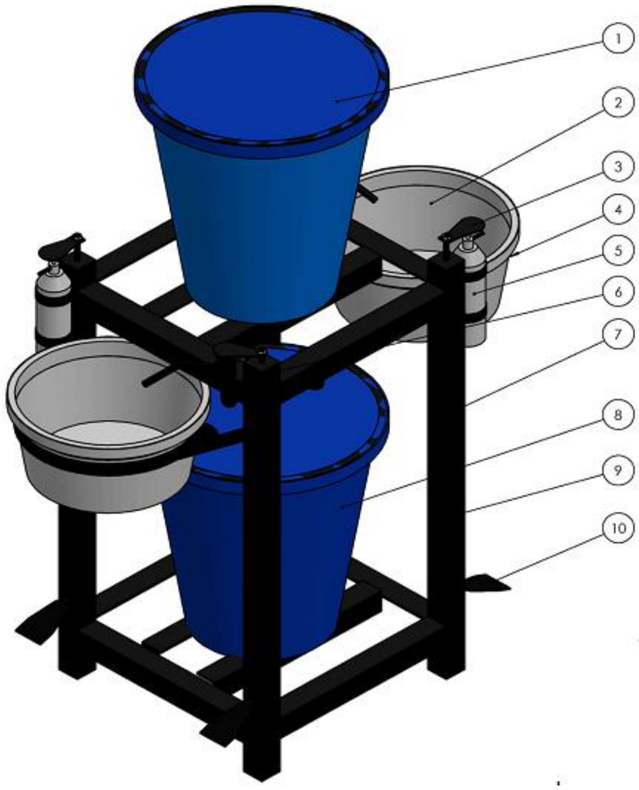
Table 1: Materials Selection for the components of the hand washing machine

Machine component	Criteria for material selection	Materials selected	Dimension	Remark
Support frame for water reservoir	Must be strong and able to withstand compression force	Mild steel of 4mm thickness square pipe	44mm x 45mm x 4mm	It does not twist and has ability to accommodate more pressure from other component parts (fabricated)
Support frame for waste water	Ability to withstand shear force	Mild steel of 4mm thickness square pipe	44mm x 45mm x 4mm	Durable (fabricated)

Stud rod	Must be strong and be able to withstand tensile and compression impact.	Iron rod of 13mm thickness	1100mm long and ф 13mm	Machined
Spring	Must be strong and be able to withstand compression force	Stainless spring	75mm long	Purchased
Press plate for pedal	Ability to withstand depression force	Mild steel of 10mm thickness	100mm x 100mm	Machined
Support frame for pedal	Must be strong and not flexible	Mild steel	5mm thick	Stable (It was Machined)
Water reservoir	Ability to withstand corrosion property	Plastic bucket	50 liters	Purchased
Waste water bowl	Ability to withstand corrosion property	Plastic bucket	40 liters	Purchased
Strap for liquid soap support	Ability to withstand load of the liquid dispenser for balancing	Mild steel of 3mm thickness	Φ 50mm	Machined
Seat for tap	Must be able to withstand dead load imposed by the self-weight of the tap	Mild steel of 6mm thickness	75mm x 75mm x 6mm	Constructed
Wash hand bowl	Must be hard, durable and be able to withstand corrosion impact	Alloy steel	11 litters	Purchased
Piping	Must be able to allow free flow of water	PVC pipes	Various dimensions	Purchased

Machine description

The machine comprises of four-square pipes, the dimension of each pipe being 45mm x 45mm at a total length of 1300mm. The square pipes have stud rods suspended in them by stoppers welded around them and spring-loaded mechanism to achieve different levels of depression. The dimension of each rod is 1100mm in length and 12mm diameter. The threading on the rod makes its attachment to a pedal easy through a nut attached to the pedal plate by welding. The arrangement of the stud rod gives an adjustable depression of 10 - 15 cm as may be required. This adjustable depression assists in achieving two depression levels, intermediate and full depression. The two pedals on each side of engagement control the discharge of soap or water. The pictorial view and the autographic projection of the hand washing machine is shown in Figure 1 and Figure 2 respectively. The exploded view which shows the disassembled parts of the machine is shown in Fig. 3.



S/N	COMPONENT	SPECIFICATION
1	Water Reservior	2mm Plastic
2	Wash Hand Basin	2mm Plastic
3	Press Plate	3mm Sheet Metal
4	Wash Hand Basin Hanger	3mm Flat Bar
5	Liquid Soap	-
6	Spring Valve	25mm
7	Frame	50x50x4mm Angle Iron
8	Plunger Barrel	50x50 Square Pipe
9	Waste Water Reservior	2mm Plastic
10	Pedal	3mm Steel Plate

Figure 1: Pictorial view of the hand washing machine

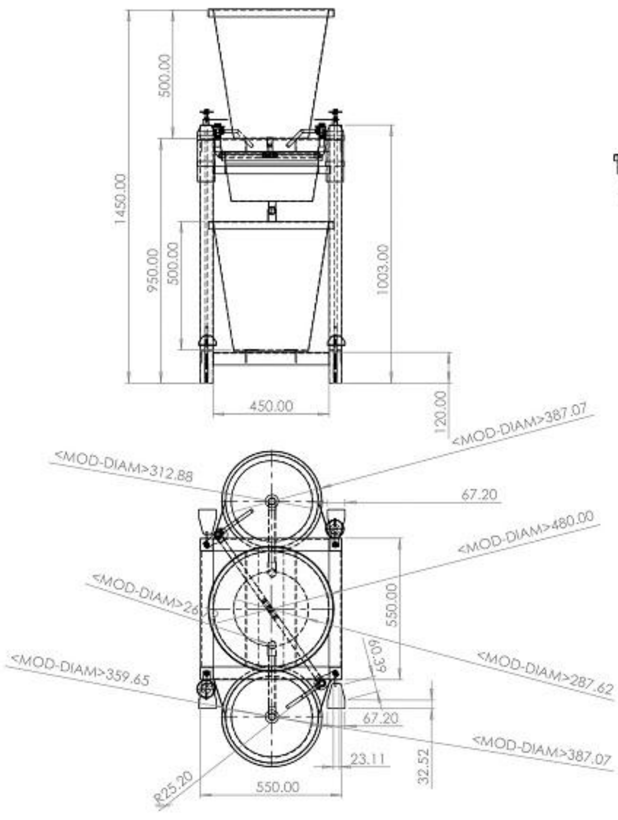


Figure 2: Autographic projection of the hand washing machine

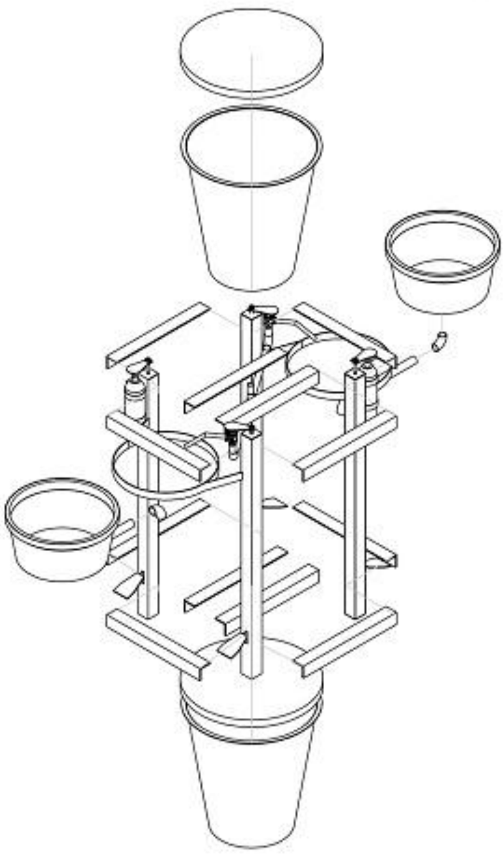


Figure 3: Exploded drawing of the hand washing machine

Design Calculation for the Machine

Determination of the spring stiffness

According to “Hooke's law” which states that the force F needed to extend or compress a spring by some distance X is proportional to that distance. Force downward = Upward pull by the spring (due to extension)

$$Mg = kx \quad (1)$$

Mg = numerical value of the weight
x = extension or displacement
k = spring constant.
That is:

$$F = kx \quad (2)$$

where *k* is a constant factor characteristic of the spring: its stiffness, and x is small compared to the total possible deformation of the spring.
The spring constant k is measured in newton per meter (N/m), or kilograms per second squared (kg/s^2)

The force exerted by the weights at intermediate depression level where the average mass m = 5kg and acceleration due to gravity:

g = 9.81m/s ^{2},

$$F = m\,x\,g = 5\,x\,9.81$$

$$= \mathbf{49}N$$

$$F = kx$$

where x is the displacement produced in the spring when the weight is suspended. If the displacement in this case is 10cm

$k = \frac{f}{x} = \frac{49}{0.1}$
$= 490 \frac{N}{m}$
k = 490 N/m is the stiffness of the spring

Machine design capacity

The design capacity of the machine is a function of volume of water available in the reservoir.

$V = \pi r^2 h$ (3)

where r = radius of the container and h = height

Since the water reservoir is a standard bucket of 50 liters of water.

It implies V = 50 liters.

Assume that 50cl and 75cl of water are respectively required for intermediate and full depression of the pedal.

$N = V/v$
(4)

N = number of users per batch

V = Volume of water in the reservoir

$v = volume\ of\ water\ used\ per\ individual\ engagement$

For intermediate level of depression where V = 50 liters and v = 50 cl

$N = \frac{50}{(50 \ x\ 10^{-2})} = 100\ users$

For full depression of foot pedal where V = 50 liters and v = 75cl

$N = \frac{50}{75\ x\ 10^{-2}} \approx$ 66 users

Assuming it will take 20 seconds for an individual to engage the machine for use, time, T can be calculated.

$T = \frac{N}{2}\ x\ t$
(5)

T = time to engage the machine per batch

N = number of users per batch

t = recommended time adequate for hand washing

For intermediate depression, $T = \frac{100}{2}\ x\ 20 = 1000s$

$T = \frac{1000}{60} = 16.8\ m$

$T \approx 17\ m$

For full depression, $T = \frac{66}{2}\ x\ 20\ seconds = 660\ s$

$T = 11\ m$

Hence, machine design capacities for both intermediate and full level of depression are respectively 100 users in 17 minutes and 66 users in 11 minutes. For 8 hours of use, they are respectively 2,823 and 2,880 users.

Bill of Engineering Measurement and Evaluation

Cost of engineering products like newly developed hand washing machine can broadly be grouped under direct or indirect cost. Direct cost is the cost of factors which are directly attributed to the manufacture of a specific product (i.e. materials and labour costs). Indirect cost on the other hand is that indirectly attributed to the manufacture of a specific product, such as overhead cost (usually expressed in percentage of direct labour cost).

The cost analysis of the machine is shown in table 2 below. It involves direct materials cost, direct labour cost and overhead cost.

Table 2 Bill of Engineering Measurement and Evaluation (BEME) of the hand washing

Machine Mechanical Components (Direct Material Cost)

Qty.	Material Specifications	Rate (□)	Amount (□)
1	Angle Iron One Length, 45mm x 45mm x 5mm	4,500	4,500
2	Square pipe 45mm x 45 x4mm	4,500	9,000
1	Flat Bar 4.5mm thick	1,000	5,000
1	Plain rod □ 12mm	6,000	6,000
20	Bolts & Nuts M10Hcx. 13mm	80	1,600
1	Cutting Stones □ 230mm size 2.5mm	500	500
1	Grinding Stones □180mm thickness 5mm	500	500
2	Drill Bits 13mm & 14mm	250	500
4	Springs	500	2000
4	Pedal Plate 10mm thick	400	1,600
2	Press Tap	3,500	7,000
1	Waste water reservoir (40 liters bucket)	2,500	2,500
1	Water reservoir (50 liters bucket)	3,000	3,000
1	Emery cloth	500	500
-	Paint	2,000	2,000
-	Transport	6,000	6,000

Sub Total = ₦ 52,200

Direct labour cost

Machining of stud rod 1,000

Fabrication 5,000

Sub Total = ₦6,000

Indirect/overhead cost

1. Over head of direct material cost = 20% of □6,000 = **₦1,200**
2. Over head of direct labour cost = 20% of □52,200 = **₦10,440**

Sub Total = ₦11,640

TOTAL = ₦52,200 + ₦6,000 + ₦11,640

= ₦69,840

Materials for Evaluation and Variables Considered

Materials used for evaluation of the foot pedal hand washing machine are liquid soap, clean water, sensitive measuring scale, stop watch and recording materials. Variables considered during evaluation are depression force, volume of water used, time used in engaging the machine for hand washing exercise and design capacity.

Method of Analysis of Results

Null hypothesis for variables considered is H_o: $0.5 \leq r \leq 1$; while alternative hypothesis is H_1: $r < 0.5$. For H_o in the range of values stated above, it means there is a strong relationship between the dependent variable and independent variable. If the correlation coefficient is not within acceptable region, alternative hypothesis is accepted. The implication of this is that the relationship between them is weak. Therefore:

$$a = \bar{y} - b\ddot{x} \qquad (6)$$

From equation 6 above, regression line "y = bx + a" can be determined. Relationship between the observed variables and the predicted variables was established through statistical instrument.

Procedure for Evaluation

To achieve hand washing, the pedal on the left hand is depressed to dispense liquid soap. On the other hand, the pedal on the right hand is pressed to discharge sufficient quantity of water into the hands of the user in order to complete the process. Pressing the water pedal for about 20 seconds or more is sufficient for washing of hands. To replace or refill the soap, the knob on each assembly can be loosed, turned aside to give access to the empty bottle. Figure 4 shows the fabricated machine and how it was used to achieve hand washing by a single user, various stages involved in the hand washing operation are discussed in the following steps:

Step 1: Hand washing and soap dispenser.

- Open your palms to receive the liquid soap from the left bottle
- Press the left leg pedal for the machine to dispense soap on your palm.
- Release the pedal immediately.

Step 2: Washing and rinsing with clean water

- Stretch your hand in the basin under the tap.
- Press the right leg pedal for water to dispense intermittently
- Rub your hand properly and rinse with clean water for not less than 20 seconds
- Release the pedal by taking off your foot from the pedal

Fig. 4: Hand washing machine and its operation

For intermediate depression:

$N = \frac{V}{v}$

N = number of users per batch

V = Volume of water in the reservoir

$v = volume\ of\ water\ used\ per\ individual\ engagement$

$N = \frac{50}{53.5\ x\ 100^{-2}} = 93.5$

$N \approx 94\ users$ (See design calculations for details)

$T = \frac{N}{2}\ x\ t$

T = time to engage the machine per batch

N = number of users per batch (two users at a time)

t = recommended time adequate for hand washing (20 s)

$T = \frac{94}{2}x20\ = 940\ s$

$T = 15.7\ m$

$T \approx 16\ m$

For full depression:

$N = \frac{V}{v} = \frac{50}{73.2\ x\ 100^{-2}} = 68.3$

$N \approx 68\ users$ (See design calculations for details)

$T = \frac{68}{2} x20 = 680\ seconds = 11.3\ m$

$T \approx 12\ m$ (Approximating value to next whole number)

RESULTS AND DISCUSSION

The machine was evaluated to determine the volume of water dispensed per time in relation to the amount of force required to press the foot pedal at both intermediate and full depression level. The results of the evaluation are shown in Table 3 and 4 bellow.

Table 3: Machine evaluation using intermediate level depression of foot pedal

S/N	Type of User	Volume of Water Used (cl)	Time (s)	Pedal Level Depression Force (N)
1	User 1	52	24	44.15
2	User 2	54	22	49.05
3	User 3	53	23	46.11
4	User 4	53	23	45.13
5	User 5	54	22	50.01
6	User 6	55	20	50.03

Table 4: Machine evaluation using full level depression of foot pedal

S/N	Type of User	Volume of Water Used (cl)	Time (s)	Pedal Level Depression Force (N)
1	User 1	73	17	96.20
2	User 2	75	15	99.08
3	User 3	73	17	96.16
4	User 4	74	16	98.10
5	User 5	72	19	94.78
6	User 6	72	19	94.58

Discussion

From Table 3, the average volume of water used for hand washing exercise is 53.5cl for intermediate depression of foot pedal. For full depression in table 4 above, the average volume of water used is 73.2cl. The design capacity of the machine is a function of the volume of water available for use in a batch of hand washing exercise. Machine design capacities for both intermediate and full level of depression are respectively 94 users in 16 minutes and 68 users in 12 minutes (see design calculation for details). Direct implication is that 2,880 users can engage it in a day of 8 hours operation for intermediate depression, leaving number of batches for prolonged use averagely as 30 batches. For full pedal depression, 2,720 users can engage the machine in a day of 8 hours operation, leaving number of batches as 40.

Figures 5, 6, 7 and 8 show the effect of pedal depression force and pedal retention time on the volume of water dispensed at intermediate and full depression level during hand washing operation. Figure 5 and 6 clearly illustrates that there is a relationship between depression force and pedal retention time on the volume of water dispensed. An increase in pedal retention time or an increase in depression force will produce a corresponding increase in the volume of water dispensed. For intermediate depression, measure of the degree of linear correlation between depression force and volume of water dispensed is within acceptable range (R^2 = 0.8709,

Figure 5). Also, there exists a strong positive correlation between volume of water used and retention time (see Figure 6).

Moreover, figures 7 and 8 also show a similar trend when compared with figures 5 and 6, but a higher volume of water was dispensed at full pedal depression level when considered under the same pedal retention time or at a much lower retention time.

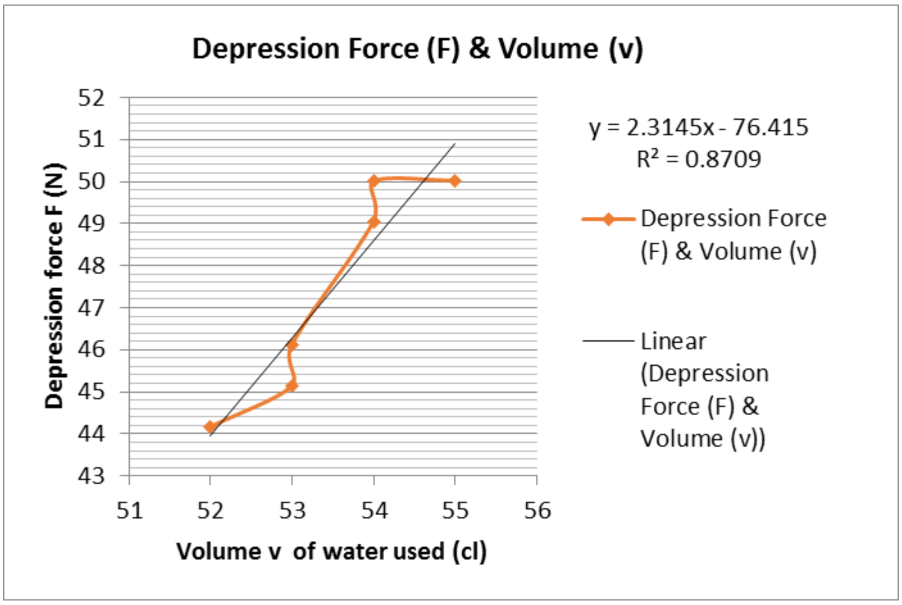


Figure 5: Effect of depression force on washing time (intermediate level)

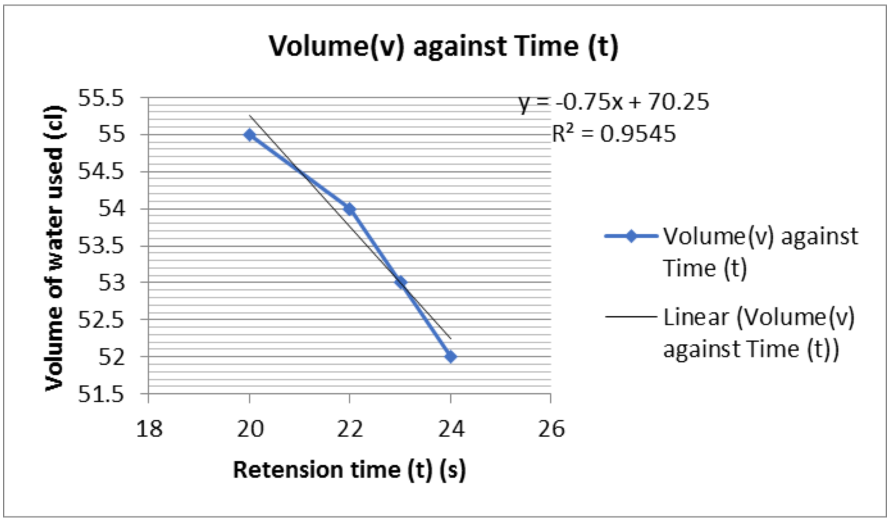


Figure 6: Effect of volume of water on washing time (intermediate level)

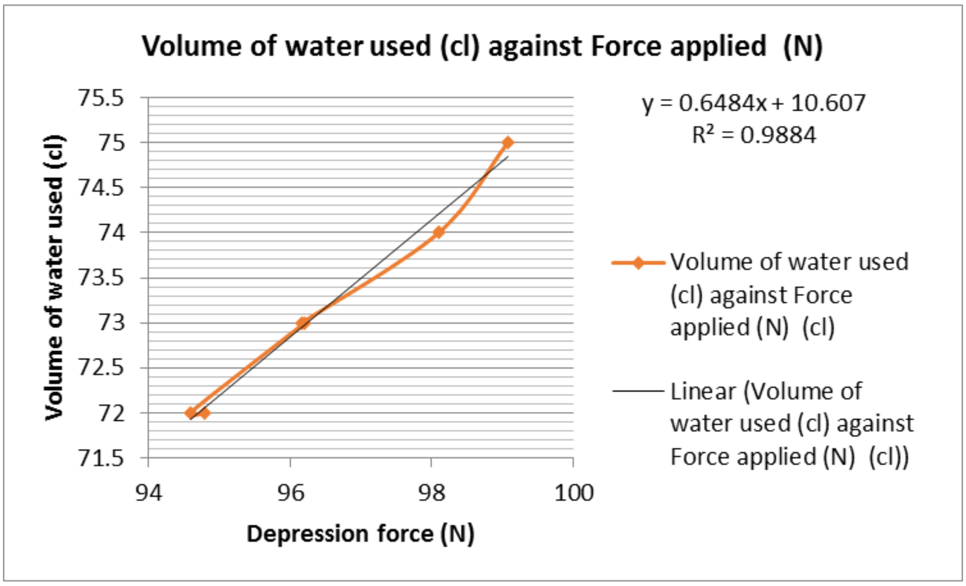


Figure 7: Effect of depression force on washing time (full depression)

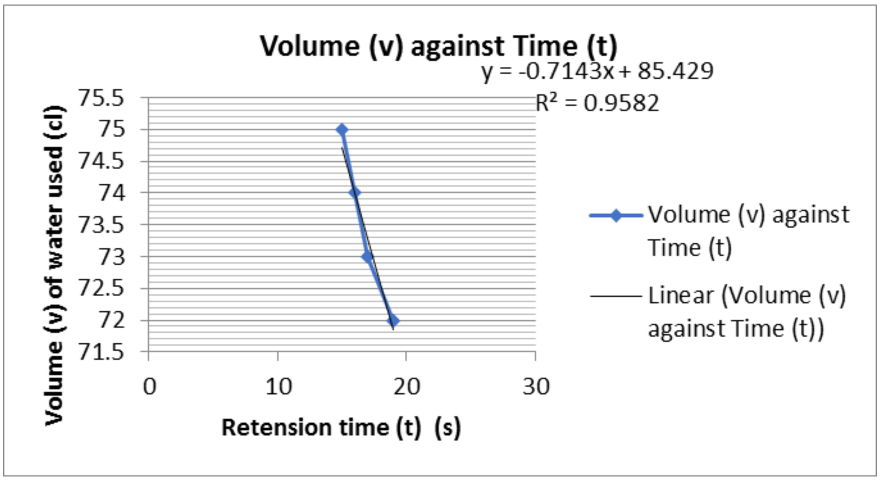


Figure 8: Effect of volume of water on time for hand washing (full depression)

Conclusions and Recommendations

A manual hand washing machine was designed, fabricated and tested to eliminate hand contact with the machine throughout the washing process in order to minimize the spread of corona virus transmission. The materials used for the construction were locally sourced.

The machine was designed to work without electricity as it is foot pedal powered. The foot pedal acts as an actuator either to depress water tap or liquid soap dispenser. The design capacity of the machine was evaluated, based on recommended standard by WHO for safe hand washing. Machine design capacities for both intermediate and full level of depression are respectively 94 users in 16 minutes and 68 users in 12 minutes. Direct implication is that 2,880 users can engage it in a day of 8 hours operation for intermediate depression, leaving number of batches for prolonged use averagely as 30 batches. For full pedal depression, 2,720 users engage the machine in a day of 8 hours operation, leaving number of batches as 40.

It is recommended that

- The mass production of the machine when supported and funded by NGOs or Government will go a long way to reduce the spread of the deadly corona virus. This will also make it available to the poorest of communities.

- The machine should be designed from the start with low cost in mind. The machine should contain parts that are readily available in rural areas. This will eliminate the need to order or import components just for the hand washing machine.

- Suspected or confirmed COVID-19 patient(s) should be provided with a separate hand washing machine which should be properly operating with functioning drain taps. If possible, flushing should occur with the lid directed into a septic tank.

References

Huang C, Wang Y, Li X, Ren L, Zhao J and Hu Y. (2019).” Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China”. Lancet. 2020;395(10223):497-506.

WHO, (2020a) “Coronavirus disease 2019 (COVID-19) situation report”–51. https://www.who.int/docs/default-source/coronaviruse/situationreports/2020031 1-sitrep-51-covid-19.pdf?sfvrsn=1ba62e57_4. Accessed March 11, 2020

Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y. (2019).” Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China”. Lancet. 2020;395(10223):497-506.

WHO, (2020a) “Coronavirus disease 2019 (COVID-19) situation report” – 51. https://www.who.int/docs/default-source/coronaviruse/situationreports/2020031 1-sitrep-51-covid-19.pdf?sfvrsn=1ba62e57_4. Accessed March 11, 2020

Sun P, Lu X, Xu C, Sun W, and Pan B.(2020). Understanding of COVID-19 based on current evidence. J Med Virol. 2020.

Phan LT, Maita D, Mortiz DC, Bleasdale SC, Jones RM. (2019). Environmental Contact and Self-contact Patterns of Healthcare Workers: Implications for Infection Prevention and Control. Clin Infect Dis.2019;69(Supplement_3):S178-S184.

Lotfinejad N., Peters A. and Pittet D.(2020). “Hand hygiene and the novel coronavirus pandemic: The role of healthcare workers” Journal of Hospital Infection DOI: https://doi.org/10.1016/j.jhin.2020.03.017

Francesco Pinotti, Laura Di Domenico, Ernesto Ortega, Marco Mancastroppa, Giulia Pullano, Eugenio Valdano and Pierre-Yves Boëlle (July 17, 2020). Tracing and analysis of 288 early SARS-CoV-2 infections outside China: A modeling study. Published: July 17, 2020. https://doi.org/10.1371/journal.pmed.1003193the economic impact

Bob Travica (2020) Containment Strategies for COVID-19 Pandemic. (Under review for publication). https://www.researchgate.net/publication/341463283 Accessed September, 2020.

CDC Group Economic Impact of COVID 19 in Nigeria of COVID-19 in Nigeria. https://www.cdcgroup.com/en/news-insight/insight/articles/what-is-the-economic-impact-of-covid-19-in-nigeria/ Accessed, August, 2020.