DEVELOPMENT OF AN ERGONOMIC HAND WASHING CISTERN FOR CONTAINING THE SPREAD OF COVID-19 EPIDEMIC

[1]Buari Olamilekan Kazeem,[1*] Hezekiah Oluwole Adeyemi and [2]Shaibu Hamid-AmehAlhassan
[1]Department of Mechanical Engineering, Olabisi Onabanjo University, Ago-Iwoye, Nigeria
[2]Department of Mechanical Engineering, Federal polytechnic, Idah, Kogi state, Nigeria
Corresponding Author: *[1]adeyemi.hezekiah@oouagoiwoye.edu.ng, [1]Buarikazeem@gmail.com, [2]shaibuhamid@gmail.com

ABSTRACT

This project developed a leg operated hand washing machine with the objectives to comply with the basic human factors' requirements and the washing guideline as recommended by WHO. The project went through three distinctive processes; planning (where functionality of the equipment, aesthetics, economics and the environment impact were considered); design using the 5th and 95th percentile of the users' recent available anthropometric data for components having to do with heights and; fabrication using local materials. The machine was developed using Solid work 2018 and successfully manufactured. He machine can accommodate 3 users at same time in each of the hand washing station comprise of three leg operating pedals for soap, water and sanitizer discharges. When put into use the system performed satisfactorily meeting the objectives of the project. The average time expended by an individual user was 48.09 ± 16.6 seconds which complied with the guideline of WHO for 40-60 seconds hand washing. The Ergonomic Hand Washing Cistern, designed with local materials, is cheap and maintainable. It can be used in homes, religious centres, commercial places, hotels, hospitals, educational institutes, industries and at any gathering of more than two people.

Keywords: Design, Hand, Washing, machine, COVID-19

***Accepted Date:** 10 Oct., 2020*

Introduction

The novel family of coronavirus began in Wuhan, which is an emerging business hub in China, at the end of 2019. The virus killed more than eighteen hundred and infected over seventy thousand individual within the first fifty days. Since its emergence was in Wuhan, it was named Wuhan coronavirus or 2019 novel coronavirus (2019-nCoV) by Chinese researchers and SARS-CoV-2 and COVID-19 by The International Committee on Taxonomy of Virus (ICTV) (Chih-Cheng *et al*, 2020).Through the movement of people, Coronavirus began spreading rapidly in China and other part of the world in early 2020 to which Africa continent is not excluded with a total of 108,121 cases and 2700 deaths as of 2nd of June, 2020, South African and Nigeria topping the chart with 34,357 and 10,578 cases respectively. The human-human transmission of the virus combined with the scarcity of crucial health equipment and challenges of implanting widespread physical distancing and case isolation, poses a grave threat to the continent (Chard et al., 2020).Nigeria being the most populous black nation worldwide recorded its first case of 27th February, 2020 in Ogun state, and as since then become communal regardless of the measures initiated by the state and Federal government to combat the virus and return to normalcy (Bernard, 2020).Some of the measures put in place for prevention of the virus transmission include social distancing, use of nose mask, self-isolation and most important of all, regular hand hygiene. Regular hand hygiene with soap and water

helps break transmissibility of infection and viruses into human body system (Harrison, 2020).
Recommendations were made by WHO (2020)to member states on how to improve hand hygiene practice to prevent the transmission of COVID-19. Some of the recommendations are listed as follows:

- Hand hygiene station should be placed at all entry points in public places
- It should also be provided at transport locations such as bus and train stations.
- It must be usable by all age groups and waiting time should be reduced.
- Use of hand washing device should be obligatory before entrance into public places.

Hence, design of hand washing system which can be mounted at the entrance of any building where visitors and staff members can easily have access to become very necessary.
The aim of this project is to develop an Ergonomic Hand Washing Cistern (Eheac), leg operated, to contain the spread of COVID-19. The objectives of the project are to develop a;

i. system that will comply with the basic human factors' requirements for public use.
ii. hand washing machine that will perform in compliant with the recommendation of the WHO

Material and Method

The proposed Ehwac was carefully designed and fabricated to detail. In other to make the machine a user-friendly, low cost and durable, the materials used were carefully selected and were 100% locally sourced. The project went through three distinctive processes. These include planning, design and fabrication.

Planning phase-In the planning stage, consideration of the various requirements and factors were carefully made. The primary consideration was the functionality of the equipment. Secondary considerations such as aesthetics, economics and the environment impact were equally considered.

Design phase-this involved a detailed consideration of the solutions defined in the planning phase. This resulted in the determination of the most suitable concept, dimensions and details of all the elements. Solid work 2018 software was used for the necessary engineering drawings and for stress analysis.

Determination of relevant parameters

The 5th and 95th percentile of the users' anthropometric data were considered. According to Kothiyal & Tettey (2001), this was to consider 5th female and 95th male so as to accommodate 90% of the target population. This data was obtained from the recent available data as reported by Muhammad (2018) and Oduma & Oluka (2017). This decision was taking because it is the shortest distance along the horizontal axis of anthropometric frequency distribution chart which encloses 90% of the population in the study area. These percentiles were carefully selected because it represents the normal distribution used in designing system for public use. The anthropometric data used affected the decision for the height of wash hand basing and all the draw off points (water, soap and sanitizer collection points)
Flow rate, as applied to this project, is the volume of fluid which passes through a draw off point per unit time. Flow rate can either be calculated experimentally or via formulas. If by formula [1] is applicable (Chris, 2019).

$$Q = \frac{\text{Volume}}{\text{Time taking}} \qquad [2]$$

The average time taken for an individual to complete the hand washing routine, and also the average volume of water used per individual were calculated from [3] and [4]

$$\text{Average time taking (seconds)} = \frac{\text{Total time taking by all users}}{\text{No. of users}} \qquad [3]$$

$$\text{Average volume of water used (cubic meter)} = \frac{\text{Total volume of water used}}{\text{No.of user}} \qquad [4]$$

Stress analysis- The external loads were estimated. These included self-weight of members together with wind loads. The critical (worst combinations) loading was also determined (dead loads alone, and then dead and imposed loads combined) and analysed the framework to find forces in all members. According to Chegg (2008), the minimum amount of the stress that is exerted by the external force acting over the body, which is

required for initiating the motion towards causing the failure is known as critical stress. Hence the material and section to produce, in each member, a stress value that does not exceed the critical value was selected.

Fabrication phase - The fabrication phase involved mobilization of personnel; procurement of materials, and job shop process which include cutting, filling, welding, grinding.

Performance evaluation

In other to test the performance of the Ehwac, eleven (11) individuals randomly selected from the study domain were instructed on how to use the machine after the operation was demonstrated. The subjects were allowed to use the machine without any further influence. For the purpose of the evaluation, one side of the cistern was made available for users. This was to help monitor the users and to avoid errors in time recording. The volume of water used by individuals was measured. This was done by collecting the waste water from the discharge pipe into a container, for each of the users. The waste water was measured using a well calibrated measuring cup graduated in cubic meter. The time taking per individual to complete the hand washing routine was recorded using a stopwatch. The total time was derived by adding all individual time spent. The total water used was equally computed by adding the volume of water used by individual. The time taken to complete the hand washing process by an individual was calculated using [3] while the total volume of water used by individual was computed using [4]. The total number of people that the tank can service was calculated using [5]

$$\text{No. of individual per tank capacity} = \frac{\text{Tank capacity}}{\text{Average volume of water per used by one user}} \quad [5]$$

Results and Discussion

The Ehwac Component Parts -Figure 1 -3 show the parts of the major components of Ehwac. As indicated in the figure, the frame consists of 1.2 m height stanchion leg (four in number) and 0.9 m square base plate designed to support the water tank. Figure 2 shows the pedals used. Each of the component was made up of a hollow galvanized pipe of 50 mm diameter and 1.066 m high provided with a footpad for human comfort

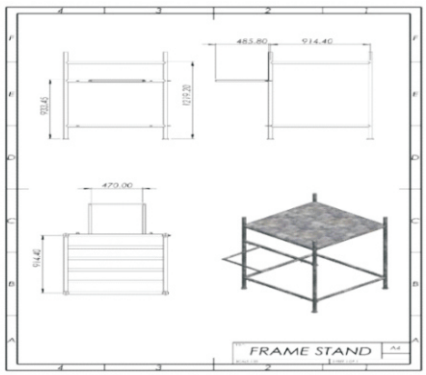

Fig.1,Supportsystem

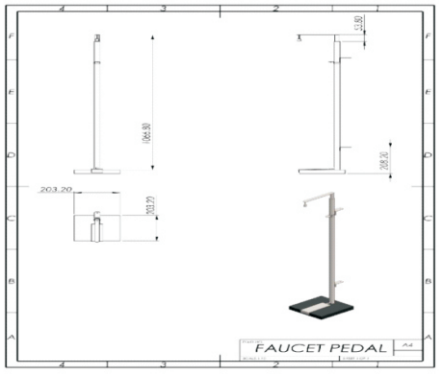

Fig.2, Soap dispenser, Sanitizer dispenser and water f aucetpedals

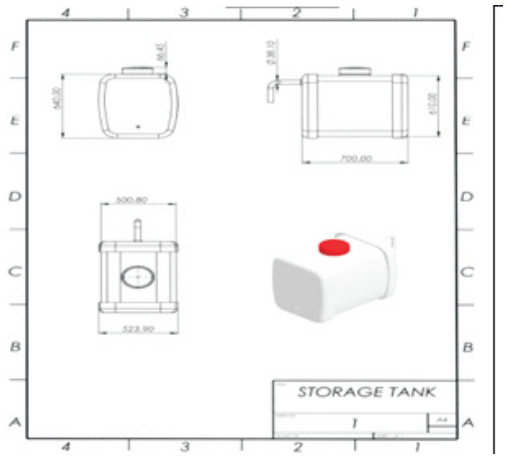

Fig.3,Water storagetank

Mode of Operation – The COVID-19 Ehwac was designed and fabricated for easy use by all categories of users whether literate or illiterate. It is very simple to use. According to WHO (2020), the droplets of COVID-19 virus may land on surfaces where the virus could remain viable making direct contact one of the main routes of transmission. In accordance with this fact, Ehwac was designed to be operated by leg alone. This is to ensure there is no hand contact with any surface on the machine. The user appropriately activate the soap pedal as the first step for dispensing the liquid soap. The user rubs the soap solution into the hand region as recommended by WHO (2020). He then moves to the second compartment to push the faucet pedal to discharge water. The leg remains on the pedal for a period of at least 20 seconds for running water as recommended by the WHO. The third and the last pedal dispenses sanitizer. The user presses on the pedal where sanitizer is released into hands to complete the process for a user. Each user is expected to spend a total time of 40 - 60 seconds as recommended by WHO. According to WHO, (2020) there are no studies on the survival of the COVID19 virus in sewage as there is no evidence that the COVID-19 virus has been transmitted via sewage systems with or without wastewater treatment. Hence the wastewater PVC pipe of diameter 50mm was provided for to conveys waste water from the wash hand basin outlet to a designated nearby soak away pit.

The pictorial view of Ehwac is as shown in Figure 4. From the figure, the facility can service three (3) users simultaneously.

Fig. 4, The pictorial view of the developed ergonomic hand sanitizer cistern

Stress Analysis Report: -Based on the result from Solid works software, the support is rugged enough to carry a tank of more than a thousand liter capacity, and it was built as such. The support member can accommodate a higher capacity of tank. Figure5 shows the effect of load placed on the support and how it responded to it. The result observed from the simulations shows that the support can carry the proposed weight successfully without failure.

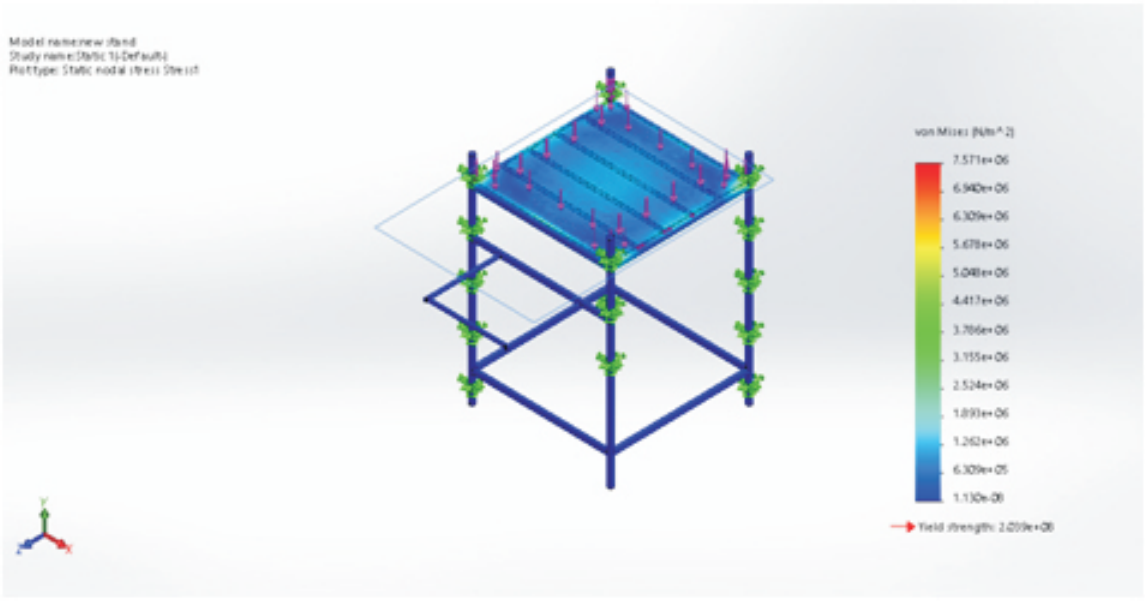

Fig. 5, Support system stress analysis

The effect of pressure exerted by the liquid on the inner wall of the tank is shown in Figure 6 and it is within the permissible stress limits of $1.568*10^4$- $1.623*10^5$ *N*/*M* 2 of the tank as indicated by the colour code blue and green. The critical stress ranges from $1.218*10^5$- $1.623*10^5$ *N*/*M* 2 with colour code yellow, orange and red, which is absent on the tank.

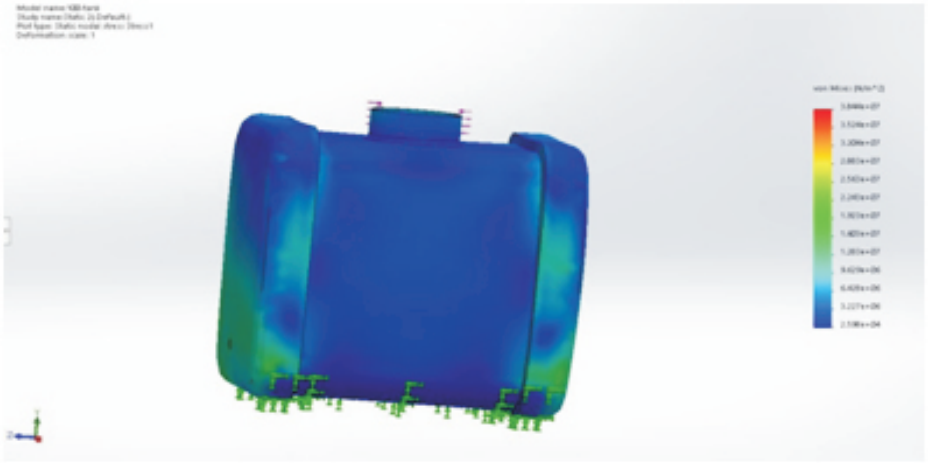

Fig. 6, Tankstress analysis

Performance evaluation

The developed Ehwac was subjected to test to ascertain the functionality of the machine. Table 1 shows the recorded data obtained from the randomly selected users who used the machine under initial instructions. From the table, the highest time spent by the users was 72 seconds (for user 5) while the minimum time was 25 seconds (for user 9).

The total time used by all the subjects was 480.50 seconds.. Hence the average time expended by an individual user was 48.09 ± 16.6 seconds. This complied with the World Health Organization (2002), 40 – 60 seconds, recommended time for hand washing. The time spent by all users ranged from 25 seconds to 86 seconds. While user 5 used the highest time (86 seconds), user 9 used 25 seconds. Figure 7, however, shows the variation of the time spent by each user when compared with the minimum and maximum standard recommended by WHO (2020). From the figure, about six users (users 2, 3, 6, 7, 8 and 10) representing (54.5 %) were in between the minimum and the maximum standard of 40-60 seconds. While two (2) (18.2%) users (users 5 and 11) were above the maximum recommended time and deviated by 43.3% and 6.7% respectively, three users (1,4 and 9) representing 27.3% used lesser times than recommended.

Table 1, Data collected on average time and volume of water used by users

Users	Mean Time Taking (Seconds)	Mean Volume of water used (litre)
1	36.54	0.25
2	60	0.5
3	45	0.21
4	34	0.35
5	86	0.4
6	47	0.38
7	45.78	0.28
8	43.69	0.25
9	25	0.18
10	42	0.3
11	64	0.2
Sum	**529.01**	**3.3**

The total volume of water used by all the users is 3.3 liters. While user 5 used the highest volume of 0.5 liters, user number 11 used the smallest of 0.2 m^3.

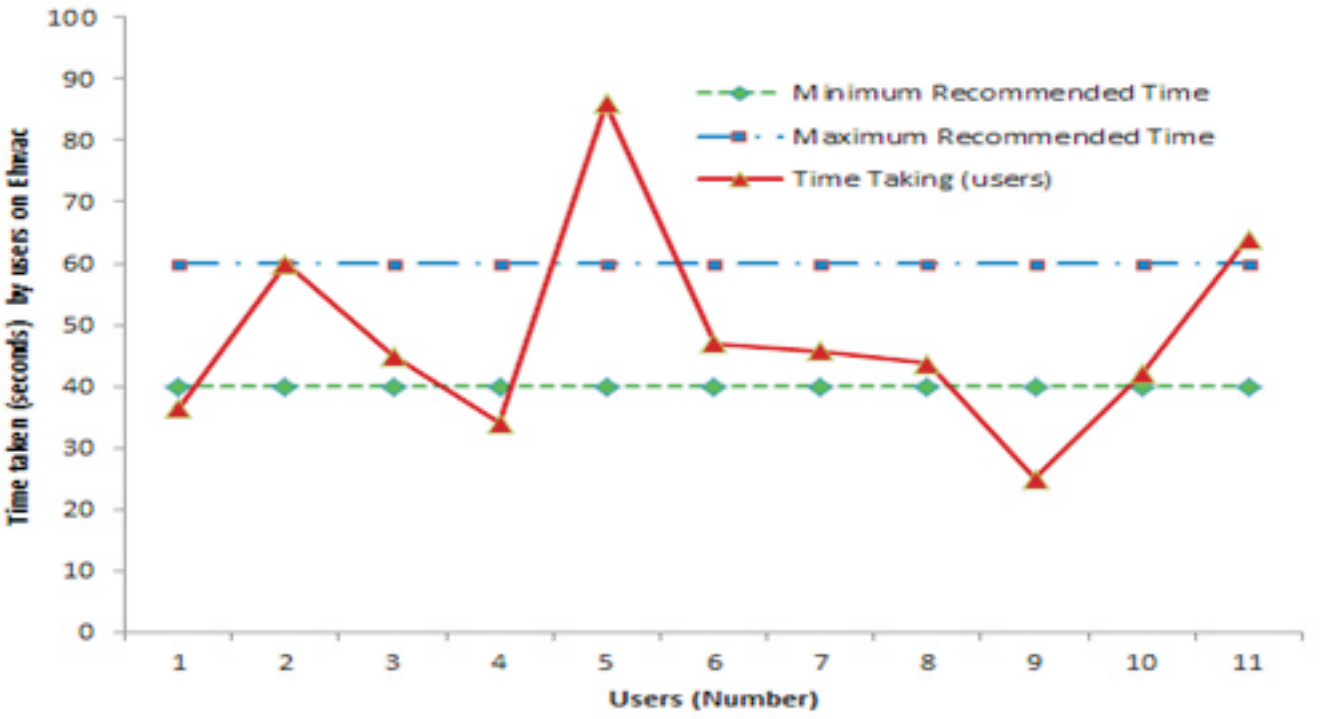

Fig. 7, Comparing the time spent by users with the WHO recommended time

It was noted during the performance testing that there was no contact of hand with any component of Ehwac as the anthropometric data used for the design of Ehwac was effective.

Bill of Engineering Measurement and Evaluation for Construction of Ehwac

Table 2 shows the summary of the cost of materials and consumables used in the design and fabrication of the Ehwac. From the table, a total cost of Seventy Nine Thousand, Five Hundred and Ninety Four Naira (N79,594.00) only will produce a unit of Ehwac where only one wash hand basin is provided for a user. However for a complete full components as displayed in Figure 4 it may cost a total sum of One Hundred and Six thousand, Eight hundred and seven naira (N 144,032) only

Table 2,Summary of the Bill of Engineering Measurement and Evaluation to produce a single unit of Ehwac

S/N	DESCRIPTION	Production Cost	
		One Point of Use	Three Point of Use
1	SanitaryWares	13,536.00	40,608.00
2	ColdWaterPipework	1,978.00	5,334.00
3	WasteWaterPipework	2,560.00	7,180.00
4	TanksAndSupportMember	42,325.00	42,325.00
5	OtherComponents	12,195.00	32,585.00
6	Paints	5,000.00	10,000.00
7	Liquid	2,000.00	6,000.00
	TOTAL	**79,594.00**	**144,032.00**

Conclusion

The ergonomic hand washing cistern (Ehwac) system was developed and validated to be used as a measure to contain the spread of COVID-19. The system which considered the anthropometric data of the target population, complied with the basic ergonomic requirement for a machine produced for public use. The facility can accommodate three users simultaneously and can be built to accommodate a single user to reduce the cost of production. Ehwac can be used in homes, religious centers, commercial places, hotels, hospitals, educational institutes, industries and at any gathering of more than two people. When put into use the system performed satisfactorily meeting the objectives of the study. The average time expended by an individual user was within the time recommended by World Health Organization and the water storage can conveniently service many people making it relevant in the commercial and/or social gathering. The Ehwac, designed with local materials, is cheap and maintainable.

Acknowledgements

The authors would like to thank many individuals who contributed directly and indirectly to the success of this study especially the 2018/2020 executive of Nigeria Society of Engineers (NSE), Abeokuta Branch, Ogun State, Nigeria, personnel used for all measurements, recording and other supports. We wish to recognize the entire subjects who volunteered to be part of the project.

Declaration of Competing Interest

The authors will like to state that there is no any conflict of interest. The project was self-sponsored by all the authors.

References

World Health Organization (2020). Coronavirus disease (COVID-19) advice for the public Geneva [website]. Geneva:.Available from https://www.who.int/emergencies/diseases/novelcoronavirus-2019/advice-for-public, accessed 12 May 2020.

Chegg Study (2008).Critical Stress. Available from https://www.chegg.com/homework-help/definitions/critical-column-stress-8 accessed 12 May 2020

World Health Organization (2009). Guidelines on hand hygiene in health care, Geneva. Available from https://www.who.int/gpsc/5may/tools/9789241597906/en/

accessed 12 June 2020.

World Health Organization (2020). Water, sanitation, hygiene, and waste management for the COVID-19 virus Interim guidance Available from https://apps.who.int/iris/bitstream/handle/10665/331846/WHO-2019-nCoV-IPC_WASH-2020.3-eng.pdf Accessed 2 June 2020.

Wang X-W, Li J-S, Jin M, Zhen B, Kong Q-X, Song N, et al.(2005). Study on the resistance of severe acute respiratory syndrome-associated coronavirus. *J. Virol Methods*.126(1):171-7. doi.org/10.1016/j.jviromet.2005.02.005.

Oduma, O., and Oluka, S. I. (2017). Comparative Analysis of Anthropometric Dimensions of Male and Female Agricultural Workers in South-Eastern Nigeria. *Nigerian Journal of Technology* 36(1), 261 – 266.

Muhammad A. U. (2018). Representative Nigerian Anthropometric Data for Automotive Applications.*Journal of Mechanical Engineering*. SI 5 (4): 68-88

Chris, B. (2019). How to Calculate Flow Rates. Available from https://sciencing.com/calculate-flow-rates-6199676.html Accessed 4 June 2020.

Kothiyal, K and Tettey, S. (2001). Anthropometry for design for the elderly, *Int. J. Occup. Saf. Ergon.: JOSE* 7 (1) (2001) 15–34.

Chih-Cheng, L., Tzu-Ping, S., Po-Ren, H. (2020). "Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges", *International Journal of Antimicrobial Agents*, 105924

Bernard, K. (2020). COVID-19 in Nigeria: a disease of hunger". *The Lancet.* Https//doi.org/10.1016/S2213.2600(20)30220-4

Chad, R. W., Jason, K. S., Pascal, L., Alison, P. G., (2020) COVID-19 on African continent. *The Lancet.*doi: 10.1016/S1473-3099(20)30374-1.

Harrison, N., (2020).Novel Coronavirus (Covid-19) Preventive Measures The general approachdoi:10.13140/RG.2.2.18901.37601