DEVELOPMENT OF AN AUTOMATIC SOLAR-DRIVEN HAND SANITIZING SYSTEM (AHSS) USING PROXIMITY SENSORS

Original Research Article

ABSTRACT

Inception of COVID '19 has brought new normal globally. Contagious nature of various infectious diseases necessitated frequent hand washing in order to reduce rate of contamination and community transmission. The need to contain the spread of COVID-19 necessitated the development of an Automatic Hand Sanitizing System (AHSS). The AHSS employed proximity sensor (IR) to sense the hand and actuate the 5V DC submersible pumps in charge of both water and sanitizer units of the AHSS. The DC voltage that powered the system was harvested from the Sun with the help of 5v Photovoltaic cell connected to a controlled charging circuit. The system responded to presence of user object within the active zone of the IR proximity sensors. This presence sends signal to the pumps to release either the Sanitizer/water. Evaluation based on Delay Time (DT), Average DT (ADT), True Positive (TP), False Positive (FP), Unable to Detect (UTD) and Accuracy (A) was conducted. The system was tested 180 times among students of School of Engineering, Federal Polytechnic, Ile-Oluji (FEDPOLEL). Results of evaluation indicate 12s, 180, 0.00, 0.00 and 100% for ADT, TP, FP, UTD and Accuracy, respectively. Accuracy of the designed AHSS was encouraging. An AHSS that can notify user about level of water and sanitizer, also test for presence of COVID-19 infection can also be designed and constructed

Keywords: Proximity, photovoltaic cell, proximity, sensors, active zone, COVID-19

1. INTRODUCTION

COVID-19 was identified and confirmed as the cause of an outbreak of respiratory illness globally [1]. It belongs to a family of viruses that may cause various symptom such as pneumonia, fever, breathing difficulty, lung infection [2]. This virus is common in animals worldwide, but very few cases have been known to affect humans. World Health Organization (WHO) gave the term 2019 novel corona-virus to refer to the coronavirus that affected the lower respiratory tract of patients with pneumonia globally. Coronaviruses were believed to be enveloping viruses and in particular SARS-CoV-2. The virus that causes COVID-19 is believed to spread from human-to-human through aerosols of infected person or through other routes such as contact with contaminated surfaces in public utilities [3].

Community transmission is the main cause of constant infection rates nowadays among countries since January 2020 [4]. Transmission of Covid-19 virus from asymptomatic person to other persons takes place by touching infected surfaces by any part of human body and further transmission of the virus into the body by touching, either the face, mouth or nose, with the infected hand. Infection of the hand is majorly by touching virus prone surfaces which cannot be avoided. These include handling of money, holding of handrails, touching of taps, touching of door handles, use of Automatic Teller Machines (ATM), sitting in public transport etc, which cannot be totally avoided.

Community transmission of communicable diseases is having an increased transmission [5]. Research showed that the lever of hand sanitizer dispensers (HSDs) yielded one or more bacterial species, including commensal skin flora and enteric gram-negative bacilli. Increase in population of the virus (colonization) was greatest on the lever, where direct hand contact is made [6]. Conventional hand sanitizers were touch-based and their deployment in institutional settings may pose a significant health hazard by promoting infection spread.

Researchers identified methods for prevention and control of the infection for suspected or confirmed cases to include regular performance of hand hygiene, especially after contact with the patients or with any surface frequently touched by people. It is also noted that frequent washing of hands, faces, especially before and after preparing food, before eating, and after using toilets can reduce risk of infection [7]. Because of massive effort that will be required to monitor level of dispensers, Mohita developed water level monitoring system in water dispensers which calls the attention of individuals concerned to water level [8].

A foot-operated hand sanitizing system was developed by Mahesh [9]. Limitation of the design is that, if the body is contaminated, disinfecting the hand only doesn't solve the problem. The virus will still spread over the body soonest. There had been engineering developments (smart water dispenser) that was able to automatically dispense water and also monitor level of water in the system [10]. Once the water level is lower than necessary, an android message is sent to a personnel in charge of the water. Though, the android application may not be applicable everywhere because of internet access and android facilities. Home usable touchless hand sanitizer was developed by Arnab [11]. Laser beam was employed to trigger the pump. Juhui developed a touchless hand sanitizer which used IR sensors for its operation but the limitation there was that the hand sanitizer tube must always be purchased for replacement of the hand sanitizer [12]. In a public place of great volume of human passage, there must be a lot of tubes to be consumed in a day. Moreover, somebody must be positioned for constant replacement of the tube.

A design that could be used in areas of large volume of people was developed which employed ultrasonic sensor [13]. It automatically dispense the sanitizer for students' hand disinfection. Jadhav developed a touchless hand sanitizer that employed ultrasonic sensor, and used 3s dispensing of hand sanitizer gel [14]. Edozie, in a design, developed an ultrasonic sensor driven hand sanitizer which prompted door users to sanitize the hand before it automatically opens the door for access into any utility or room [15].

Majority of these existing designs does not make consideration for health effects of the use of hand sanitizer gel to disinfect. According to WHO, there are two major types of skin reactions pertaining to hand antisepsis. The first kind could be mild to debilitating and commonly referred to as irritant contact dermatitis. It can include irritation, dryness, itching or even cracking and bleeding. The other kind of skin reaction, alluded to as the allergic contact dermatitis, is scarce and usually stems from an allergy to some ingredient in the disinfectant liquid [16, 17]. In view of the afore-mentioned health hazards, the use of water with soap was encouraged [18]. It is therefore necessary that Engineering designs and developments should bear in mind, health consequences of developments and innovations. Therefore, the designed Automatic Hand Sanitizing System (AHSS), made provision for both hand sanitizer disinfection and water cleansing of the hand after usage of the sanitizer. Moreover, a user may decide to use only water for cleansing of the hand.

2. METHODOLOGY

The Automatic Hand Sanitizer System (AHSS) consist of four (4) units. These units are: sanitizer unit, water unit, power unit and the control unit. Sanitizer unit contains the liquid hand sanitizer. Water unit houses the water for washing the hand. Power unit of the system supplies the needed voltage to drive all the devices that need electric current for their operation. These include the pumps, the proximity sensors, water and the sanitizer pumps. Power to drive the system was derived from the sunlight, such that the system can be used anywhere such as rural and urban places and offices. Control unit co-ordinates operation of all the units for optimum performance of the system.

Figure 1 shows the conceptual representation of the sensing unit of the AHSS. The system, among other characteristics possessed the following features: it shall be solar energy driven system. The design consists of four (4) basic units which include: Water and Sanitizer dispensing system, Sensing and power unit, Electrical and control unit, and the Mechanical frame.

Water and sanitizer units

These units will house water and sanitizer separately, in the AHSS workstation. Each of them will also contain a pump which will pump out either water or sanitizer separately whenever they are triggered.

The Sensing and power unit

The proximity sensors senses an approaching hand immediately the hand comes within the range of the sensor. It sends signal to the induction coil which invariably sends signal to initiate the operation of pump to release either water or sanitizer from their units. Solar panel shall be used to drive the workstation by providing 5V DC to the sensor and pump. Components employed in the design include: 5V DC Water Pump, IR Proximity Sensor (Obstacle Avoidance), TIP 32C Transistor, 1kΩ Resistor, USB Cable, Tube Pipe, Lion Battery Charging module and Lion Batteries.

The Infrared Proximity sensor has an IR receiver and IR emitter LED respectively, by the operation the sensor was adjusted through the distance adjust to sense object within particular distance. When the hand was placed within the required distance, the sensor sensed and signaled to trigger and activate the DC motor to pump sanitizer/Water. The automatic hand sanitizer worked using the IR proximity sensor to check the presence of hands in the top or middle compartment. It sends signal to DC submersible pump to pull the content whenever any obstacle such as hand was detected.

Electrical circuit and control unit

Electrical charges harvested from the solar panel were stored as DC current stored in a 6 * 2v battery used to drive the proximity sensors, the two (2) pumps and the control unit of the AHSS workstation. Electric power to drive the station was derived from charges derived from the 20 Watts solar panel employed to harvest renewable energy which is stored in the electric batteries.

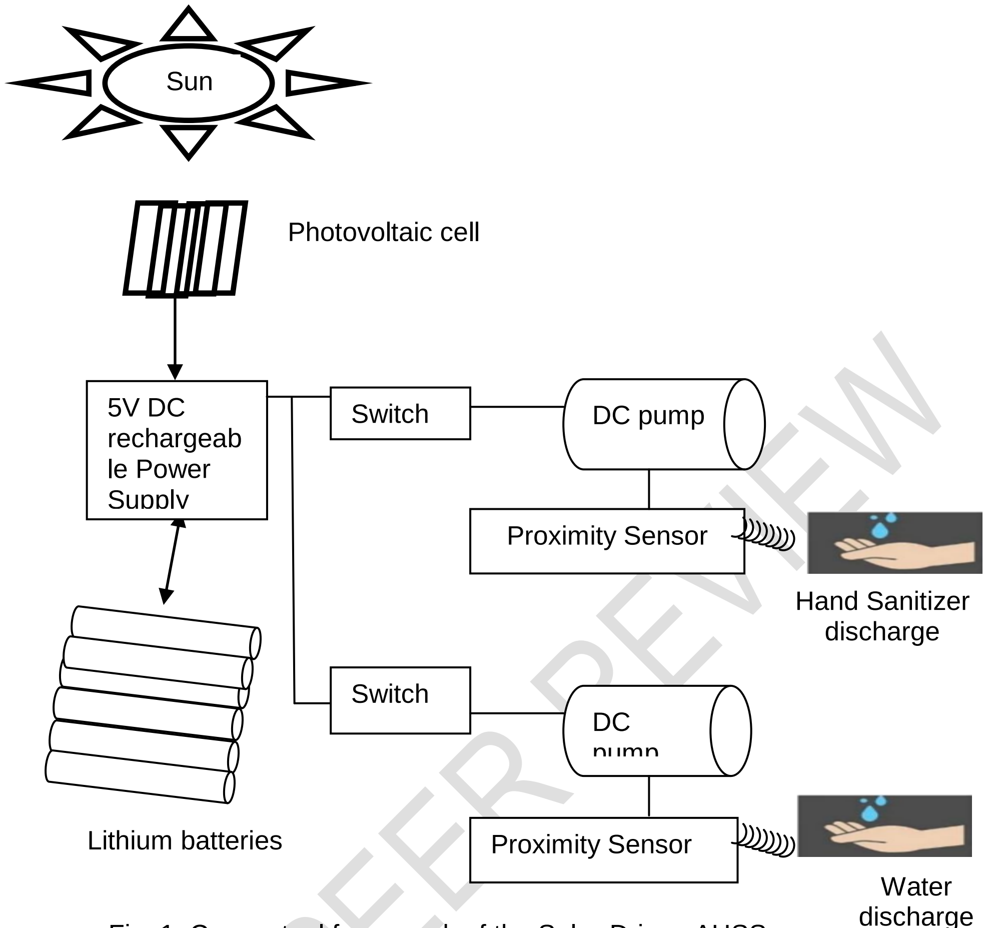

Fig. 1. Conceptual framework of the Solar-Driven AHSS

The System Power Supply Unit

Some of these require 12V DC while others work on a 5V DC. In an ordinary power supply, the voltage regulation is poor that the Vdc output voltage changes appreciably with load current. Moreover, output voltage also changes due to variations in the input AC. voltage. This is due to: firstly, in practice, there are considerable variations in the a. c. line voltage caused by outside factors beyond control. This changes the output voltage causes the weighing balance, just like most of the electronic circuits, would fail to work satisfactorily on such output voltage fluctuations. This necessitated the use of a regulated d. c. power supply. Secondly, the internal resistance of an ordinary power supply is relatively large (> 30 Ω). Therefore, output voltage is remarkably affected by the amount of load current drawn from the supply. Variations in DC voltage may cause erratic operation of the system electronic circuits. Therefore, a regulated DC power supply was the only solution in such situations. Two regulators, one of which supplies 12 V and the other 5V output were used.

In each voltage regulator circuitry, output voltage is measured, compared with the desired value, and conditions adjusted automatically so that the difference between the two is zero. Figure 2 shows the regulated power supply circuit diagram.

Mechanical frame

The mechanical frame was used to hold all the components of the AHSS workstation. It has three compartments, namely the water container compartment; the hand sanitizer container compartment and the electronic and control circuitry compartment, where the circuitry and its components are located. The electronic and control circuitry is in the topmost compartment. Next is the sanitizer gel container compartment, because of its size. On the ground floor compartment is the water container compartment, because of its size and volume required for a day delivery of the construction.

Operation of AHSS

Figure 3 and 4 shows the flowchart for operation of the AHSS workstation. At initialization, the workstation scanned for an approaching hand. Once an approaching hand was detected, it determines whether it was towards the sanitizer or towards the water unit of the workstation. This decision assisted the workstation to direct activities to either water unit or sanitizer unit. The proximity sensor sensed the presence of hand and thereafter sent signal which immediately signaled the control unit and activated the pump for release of water/sanitizer for as long as the hand of the user was in front of the sensor

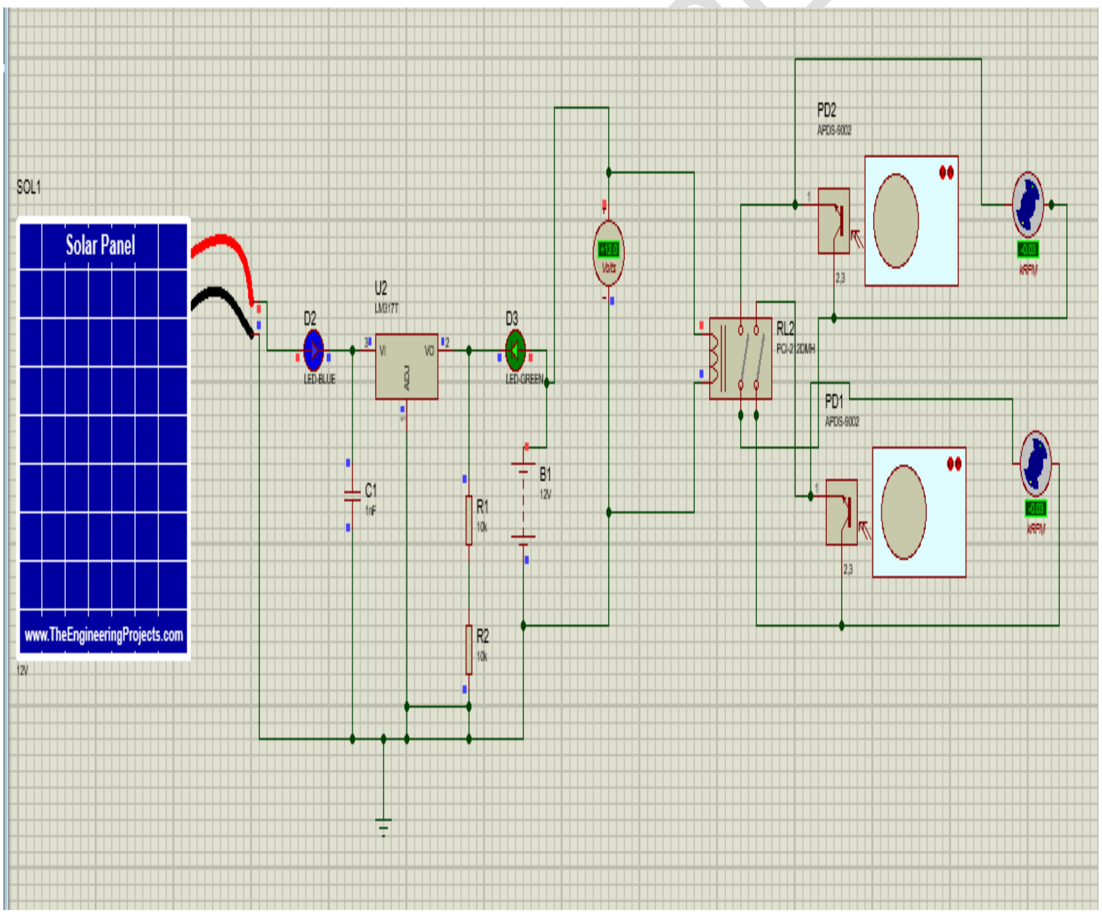

Figure 2: Regulated Power Supply Circuit Diagram of AHSS

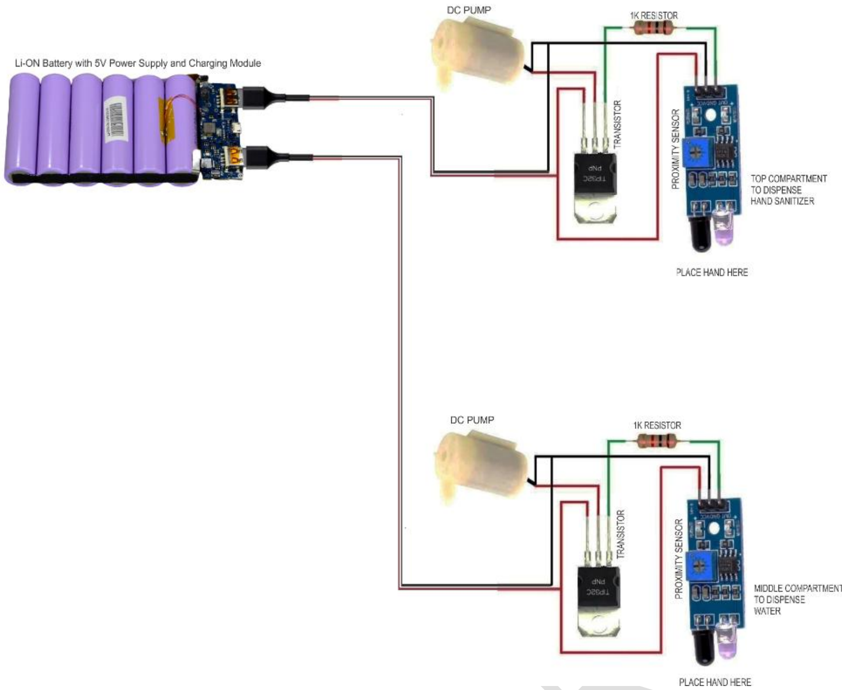

Figure 3. Circuitry of the Hand Sanitizer System

The model construction for the design is shown in Appendix I. It showed the design's top view, front view, and back views of the construction.

3. RESULTS AND DISCUSSION

Performance of the system was tested on ten, 7 males and 3 females, with different age ranges, from among students of School of Engineering, Federal Polytechnic, Ile-Oluji (FEDPOLEL), Nigeria. The Delay Time (DT) was recorded. DT is the time it takes the device to respond to the approaching hand to be sanitized or to be washed. The True Positive (TP) is the responsiveness of the constructed device to an approaching hand. False Positive (FP) is a measure of responsiveness of the equipment, while there is neither an approaching hand nor a user around. The results are presented in Table 1.

Table 1. Results

Respondents	R_0	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	***Total***
Total DT (s)	194	202	202	201	202	204	202	204	203	201	197	
Ave Delay Time (ADT)s	10.78	11.22	11.22	11.17	11.22	11.33	11.17	11.23	11.07	11.21	10.93	**12.22**
TRUE POSITIVE (TP)	18	18	18	18	18	18	18	18	18	18	18	**180**
FALSE POSITIVE (FP)	0	0	0	0	0	0	0	0	0	0	0	**0**
UNABLE TO RECOGNIZE (UTR)	0	0	0	0	0	0	0	0	0	0	0	**0**

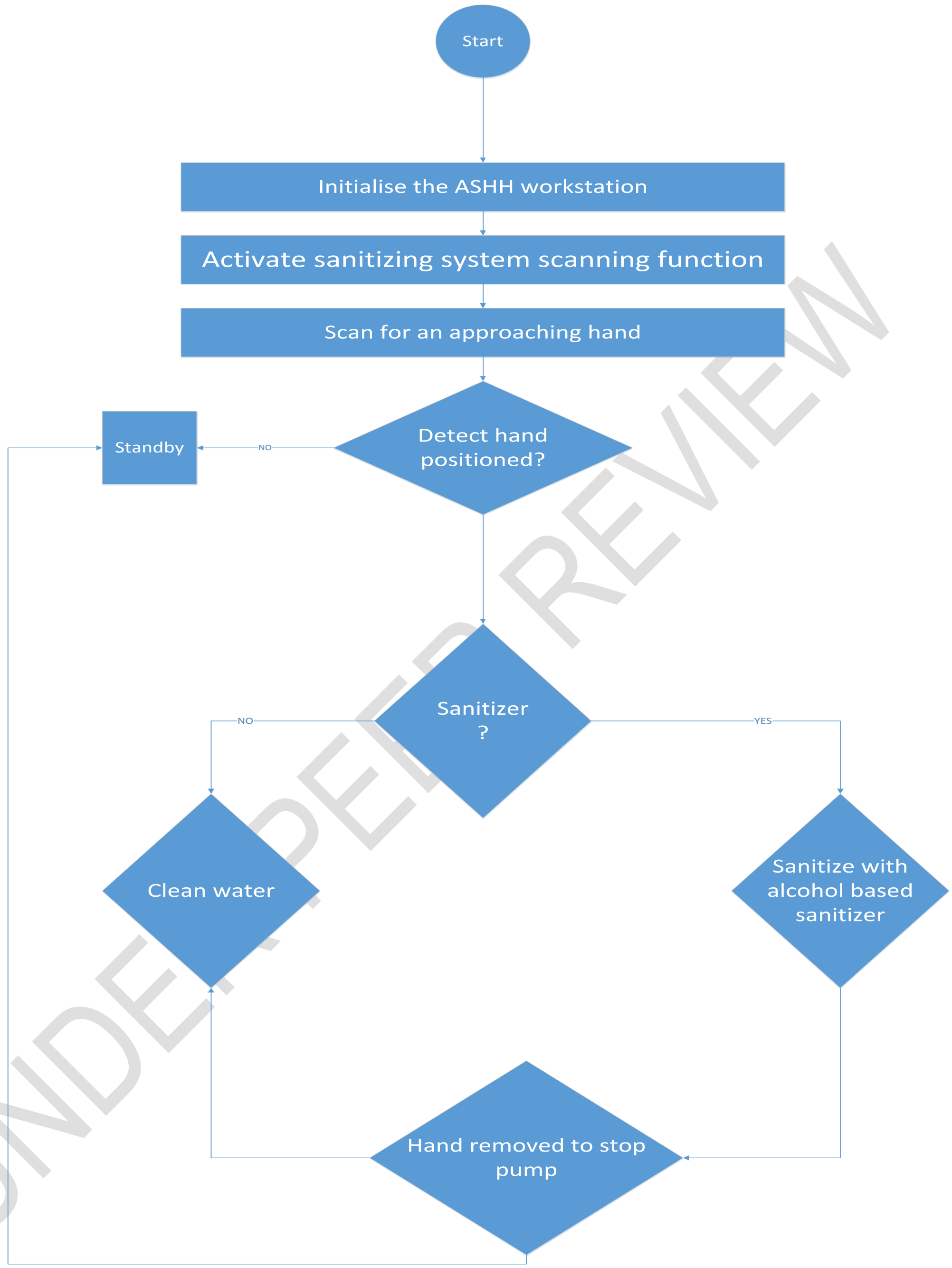

Figure 4. AHSS System Flowchart

The results obtained from the constructed AHSS workstation shows an average DT of 11.16s. This implies that a user needs to be patient for 11.16s before release of either sanitizer or water for users. The TP value for the device was 1 while FP was 0. This value implies that, at every approach of users to the system, it was able to respond to users. The FP value implies that the system did not respond abnormally at all, after being positioned at a conducive location where it was used. Sensitivity of the system was 1, resistivity was 0 while Accuracy was 100%. It was noticed that sun rays affected response of the design, which is due to limitation of the proximity sensor employed in the design. It is therefore recommended that the system should be improved on by using a light friendly sensor which will be able to differentiate between human being and any other approaching object.

4. CONCLUSIONS

An effective AHSS workstation was successfully developed. It was neither age nor gender dependent. It was noted that the system responded to rays of light more often, except when positioned in a room, or not facing the direction of sunlight. Also, the proximity sensors employed was not able to differentiate between human being and every other approaching object. There should be a switch which will allow for the system to boot and also be able to be on standby for an improved power management. Charging and discharging level indicator should be incorporated into the device so as to know when to either go for/stop charging the device. A mean of measuring the discharge rate should also be incorporated. A means of reducing the disinfection time to the barest minimum should be considered in future design. Liquid level in both water and sanitizer unit can be automatically controlled to safeguard against wastage of resources. Water wastage due to negligence is one of the major problems in megacities (Anuradha, Jadhav and Mahamani, 2019). Future design can also include, hand drying unit.

ACKNOWLEDGEMENT

CONSENT (WHERE EVER APPLICABLE)

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

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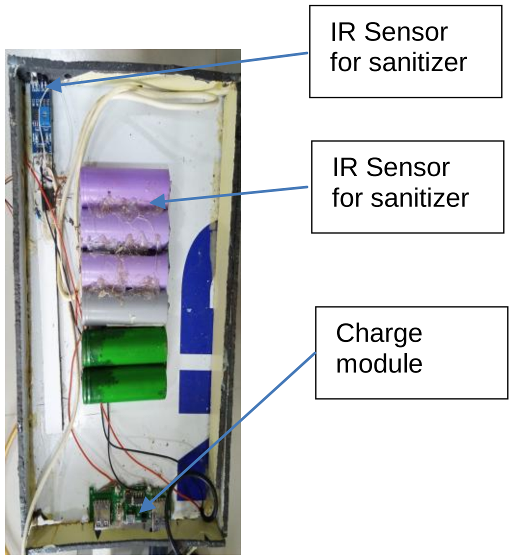
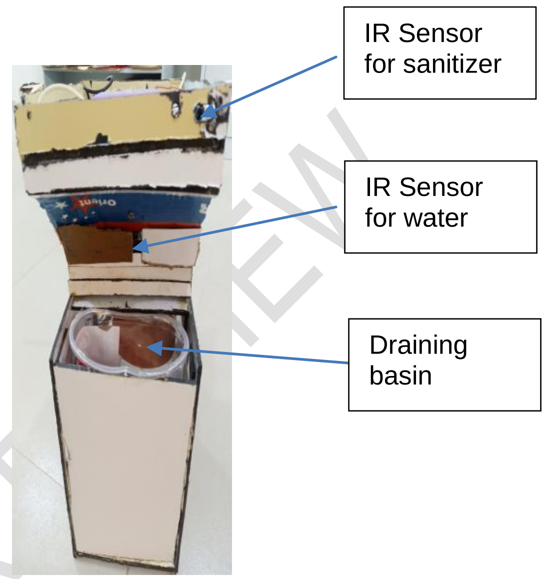
APPENDIX



(a)



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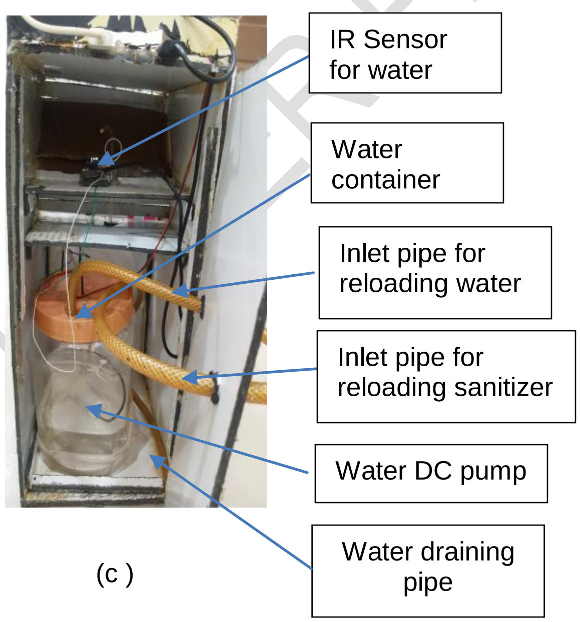

(c)

(a) Top view (opened) (b) Front view

(c) Rear View

Figure 5. Model construction for AHSS