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Portable IoT-Based Disinfection Box

Muhammad Ikmal Muda[1], Shaharil Mohd Shah[2*]

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA

[2]Advanced Telecommunication Research Centre,
Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA

*Corresponding Author

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Abstract: The COVID-19 pandemic is an ongoing global health event that began in 2019. It is caused by a novel strain of coronavirus known as SARS-CoV-2. Bacteria and viruses can cause illness in human. Therefore, a Portable IoT-based Disinfection Box is developed in this work to disinfect small electronic devices such as smartphone, smartwatch or even a 13-inch tablet, that may come into contact with bacteria and viruses. There are three special features of this Disinfection Box which are the timer itself, Web Interface Monitoring, portable and spacious with dimensions of 29 × 18 × 14 cm^3. The ESP32 Wi-Fi module with NodeMCU-32S Base module as a microcontroller is used in this work and it controls the 2-channel Relay in order to turn ON and OFF the UV-C LED light strip. Besides that, it is also connected to the LCD display with I2C module to display the real-time of disinfection process. The Dashboard of Arduino IoT Cloud allows the user to control and monitor the operation of disinfection process. When a small electronic device is placed inside the Disinfection Box, UV-C LED light strip is turned on to begin the disinfection process. The effectiveness of the UV-C LED light strip is investigated by using the Petri dish with agar. It is shown from the experimental procedures that 10-minute disinfection time provided by the Disinfection Box is sufficient to disinfect small electronic devices such as smartphone and smartwatch. This is based on the great reduction of bacteria colonies on the agar in Petri dish after being kept in a dark place with room temperature for 4 days.

Keywords: Disinfection box, Internet of Things, Arduino IoT Cloud, UV-C LED light strip, small electronic devices

1. Introduction

During the COVID-19 coronavirus pandemic, UV light disinfection has received a lot of attention. The ability to eliminate pathogens such as viruses and bacteria is the key advantage. According to some scientists [1], UV products could help in the recovery of our economy as well as the cleanliness and safety of public spaces. One of the more recent technologies that has undergone extensive research as a potential replacement for traditional disinfection techniques for eliminating pathogenic and spoilage bacteria in hospital settings is the ultraviolet (UV) disinfection system [2]. At the moment, the majority of UV disinfection systems primarily use UV-C radiation with wavelengths between 200 and 270 nm. This UV-C radiation emit the light to ensure greater chances of destroying the virus. Numerous environmental bacteria can be destroyed by UV-C LED light strip at specific wavelengths, such as 254 nm, by rupturing chemical bonds and damaging DNA or RNA via pyrimidine dimerization. [3]. The spread of virus mostly via transmission of the infected individual. As a result, researchers concluded that social isolation and the usage of face masks are the most efficient ways to prevent the virus from spreading. However, the virus can also spread from contaminated surfaces in personal and public facilities. From the data that provided, over 30,000 Malaysians have died

*Corresponding author: shaharil@uthm.edu.my

due to the ongoing COVID-19 outbreak [4]. People can protect themselves outside the house by wearing masks, but they could not protect the items they carry from the market, mall, and shops, only to name a few. For instance, people could not sanitize the fruits, vegetables, packaged food, batteries, or other items that they purchased. Besides that, personal belongings such as files, paperwork, or other items that doctors, or employees exchanged with one another could not be sanitized as well [5].

Therefore, a portable disinfection box is proposed in this work as a solution to these problems. It is designed with a 360º wide disinfection angle that uses UV-C LED strip light that may kill influenza viruses which are the cause of seasonal and pandemics/endemics flu disease. In order to further improve the existing designs in the market, the proposed portable disinfection box is linked to Dashboard of Arduino IoT Cloud so that a notification could be sent to the user as soon as the disinfection process is completed. The disinfection box in this work is meant to be used to disinfect small electronic devices. The disinfection time is set to be 10 minutes for a sufficient disinfection process.

2. Methodology

This section discusses the methodology applied in completing this work.

2.1 Block Diagram

Fig. 1 shows the block diagram of disinfection box. The disinfection box is controlled by the controlling unit which include the ESP32 Wi-Fi module with NodeMCU-32S Base module, LCD display with I2C Module, push button and relay module. The following process is used by the users to disinfect the items. For the IoT platform, the disinfection box is connected to the Arduino IoT Cloud through the ESP32 Wi-Fi module. For this platform, the dashboard was created include the push button, the display of the timer. The following coding also was created in this platform an automatic save into cloud by create the account. The coding can run and automatically connected to the ESP32 Wi-Fi module by detecting the COM port of the controller. The ESP32 Wi-Fi module and its NodeMCU-32S Base module are connected to a 12-V DC adapter.

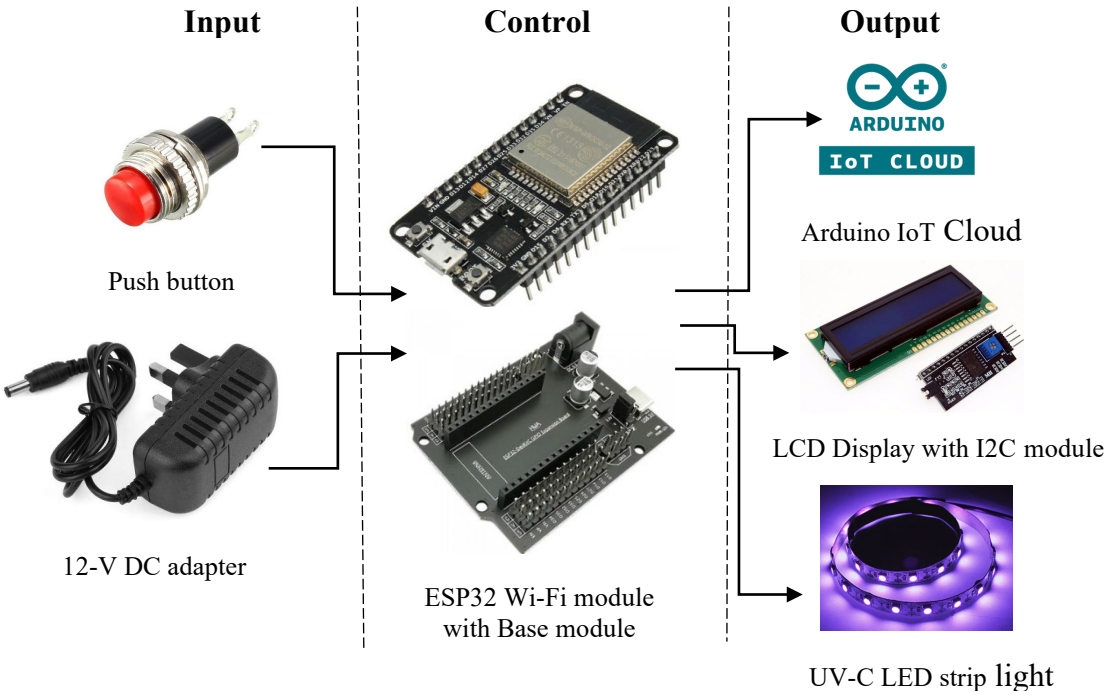


Fig. 1 - Block diagram of the portable disinfection box

2.2 Circuit Diagram

Fig. 2 shows the overall circuit diagram of disinfection box. This circuit is controlled by using ESP32 Wi-Fi module with the NodeMCU-32S base module. The LCD display is connected to the I2C module, which is equipped with VCC, GND, SDA and SCL pins. The ESP32 Wi-Fi module also controls the relay module. The 2-channel relay module is used to control the ON and OFF states of the UV-C LED strip light by connecting its COM and NO ports to the UV-C LED strip light. Alternatively, a push button is also attached to switch OFF the LED strip light. A 12-V DC adapter supplies the power to the ESP32 Wi-Fi module and its NodeMCU-32S Base module. If the power supply from

the adapter is cut off, the battery can be a substitute for the power supply. In this case, the battery acts as a backup power supply.

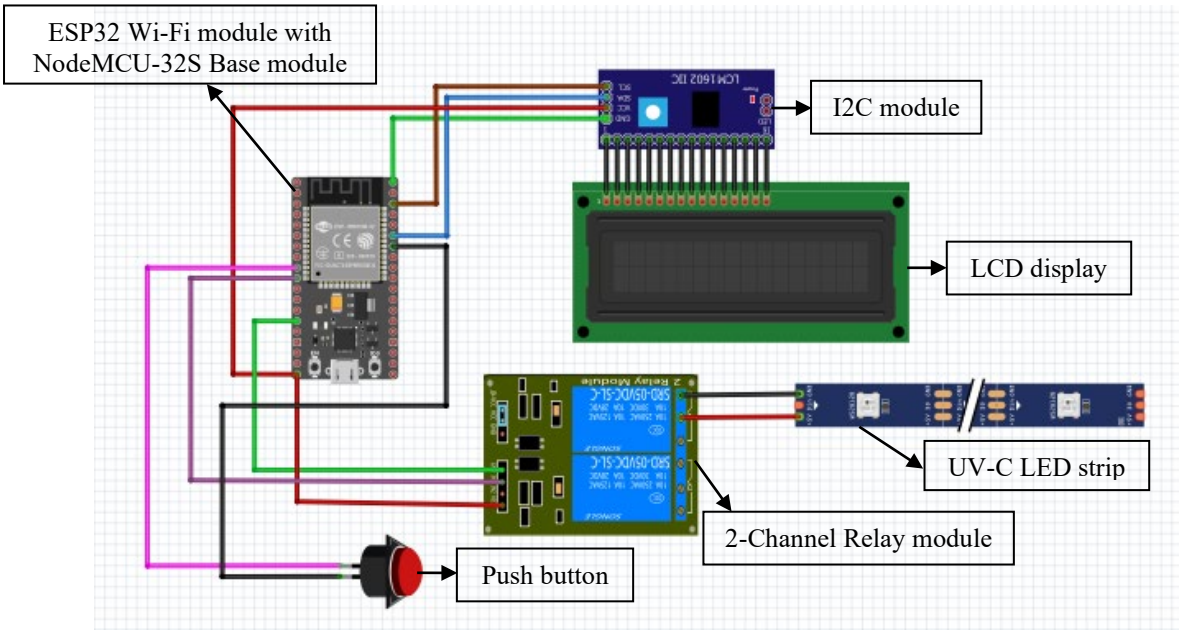


Fig. 2 - Overall circuit diagram of the portable disinfection box

2.3 Arduino IoT Cloud

An application called Arduino IoT Cloud enables makers to create linked things quickly, easily, and securely. It may link various devices together, enabling real-time data sharing. Using a straightforward user interface, the software also allows for remote data monitoring. The disinfection box is connected to the Arduino IoT Cloud through the ESP32 Wi-Fi module. For this platform, the dashboard is created to include the push button and display of the timer. The codings are also created in this platform and saved automatically into the Cloud. The coding can run and automatically connected to the ESP32 Wi-Fi module by detecting the COM port of the controller.

3. Results and Analysis

This section discusses the result obtained and analysis on the portable disinfection box. This section is divided into the final product, experimental procedure, and observation of bacteria colonies.

3.1 Final Product

The final product in this work, as shown in Fig. 3, is a combination of the controlling unit and disinfection box via connecting wires. Once the controlling unit is switched on, the UV-C LED light inside the box is turned on and the disinfection box is ready to use.

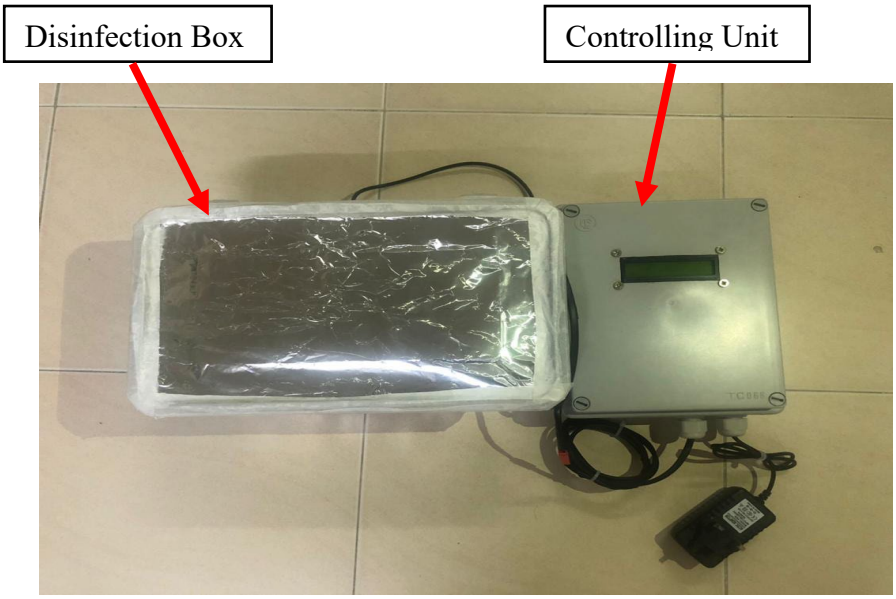


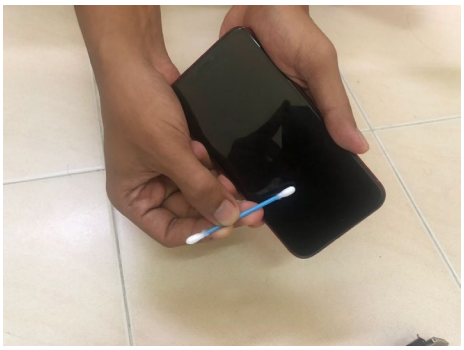
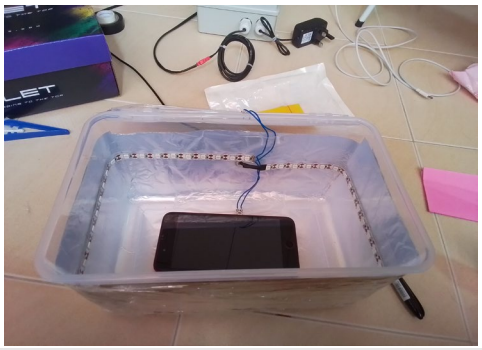
Fig. 3 - Final product of portable disinfection box

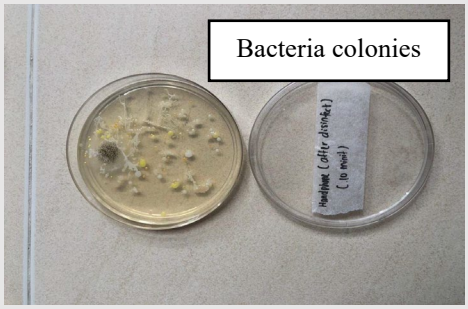
3.2 Experimental Procedure

In order to conduct a study on the effectiveness of UV-C LED light strip used in the disinfection box in disinfecting bacteria and viruses, Petri dish containing a nutrient agar is chosen. The procedures of effectiveness study are summarized in Table 1. The table shows the disinfecting procedures before and after the disinfection process.

Table 1 - Disinfecting procedures before and after the disinfection process

Procedure	Before Disinfection Process	After Disinfection Process
1	Prepare the tools for bacterial growth such as tweezer, sterile cotton swab sticks and Petri dish with agar. 	Prepare the tools for bacterial growth such as tweezer, sterile cotton swab sticks and Petri dish with agar. 

2	Take the sterile cotton swab stick and rub it on the surface of smartphone to collect the bacteria. 	Put the smartphone in the disinfection box. Switch ON the disinfection box and close the lid. Leave the smartphone for 10 minutes until the disinfection process is completed. 
3	Lightly rub the swab across the surface of the agar in a zigzag pattern and turning the Petry dish a few times for maximum coverage. **This must be down swiftly after removing the cover of petri dish.** After that, close the lid. 	Take out the smartphone from the disinfection box after 10 minutes. Lightly rub the swab across the surface of the agar in a zigzag pattern and turning the Petry dish a few times for maximum coverage. **This must be down swiftly after removing the cover of petri dish.** After that, close the lid. 
4	Label each dish and kept in a dark place with room temperature for 4 days such as inside a box for 4 days to observe the growth of bacteria. 	Label each dish and kept in a dark place with room temperature for 4 days such as inside a box for 4 days to observe the growth of bacteria. 

5	Observe and record the results after 4 days **Observation:** After 4 days, it can be seen that small and round of bacteria colonies are growing on the agar. Different kind of bacteria colonies will have different colours and textures. Thus, it is shown that the small electronic device before disinfection process is contaminated with bacteria and there is a need to be disinfected. 	Observe and record the results after 4 days **Observation:** After 4 days, it can be observed that small and round of bacteria colonies are growing on the agar. Different kind of bacteria colonies will have different colours and textures. Thus, it is shown that the small electronic device after disinfection process is effective in killing the bacteria and viruses. 

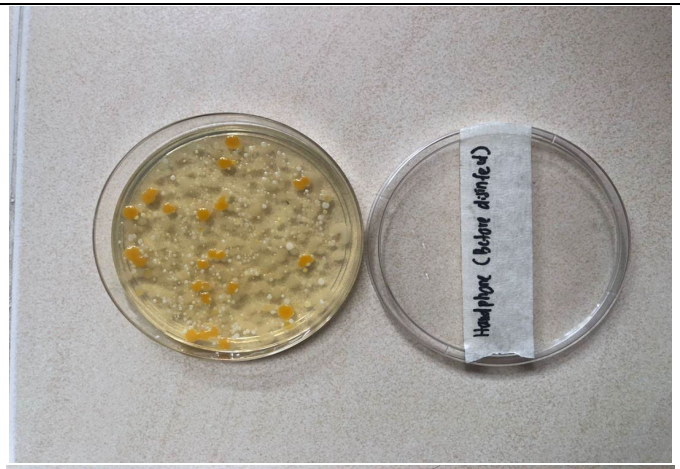
3.3 Observation of Bacteria Colonies on Petri Dish During the Disinfection Process

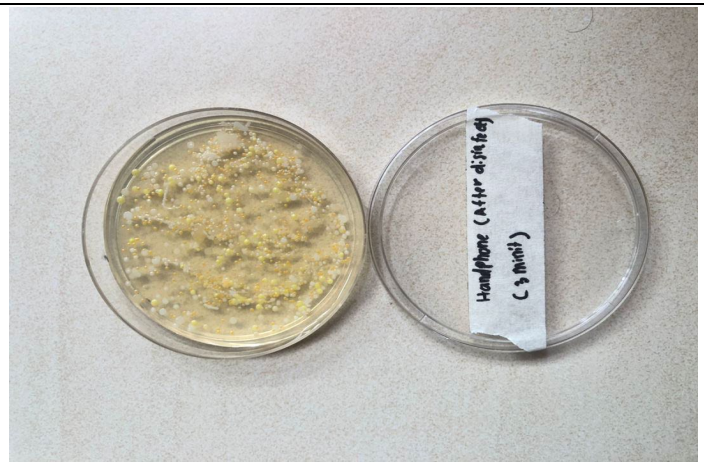
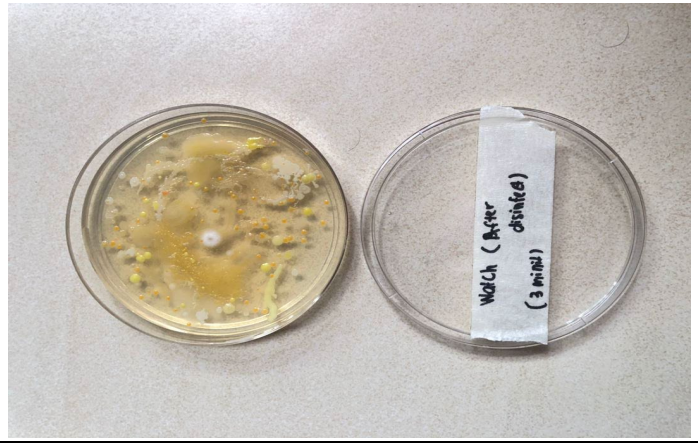
In order to observe the growth of bacteria on the agar in Petri dish during the disinfection process of 10 minutes, the procedures as summarized in Table 2 are designed and conducted. The table 2 shows the procedures of disinfection process before the disinfection process takes place which is 0 minute and during the process itself at 3, 8 and 10 minutes of disinfection time. The observation on the growth of bacteria on the smartphone and smartwatch are discussed in Table 3 based on different disinfection time.

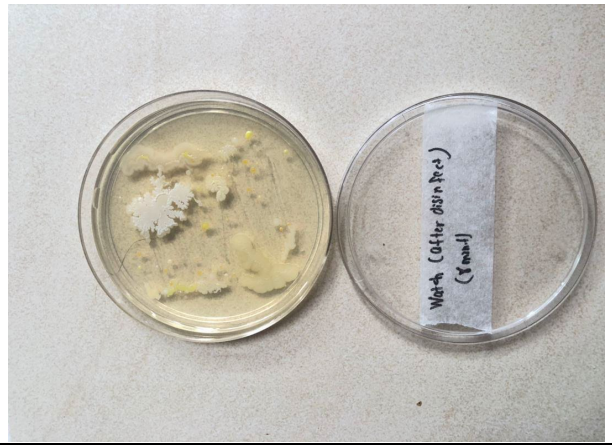
Table 2 - Procedures of disinfection process at 0 (before disinfection process), 3, 8 and 10 minutes of disinfection time

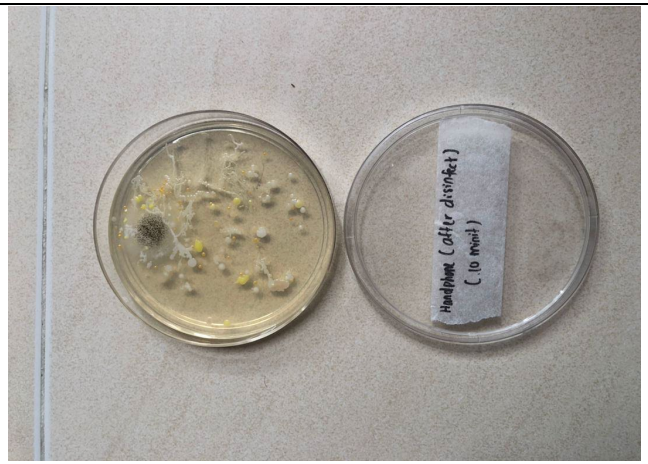
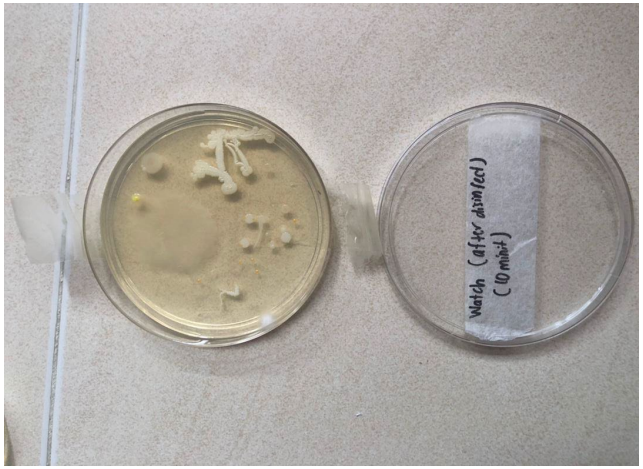
Disinfection time (minute)	Procedure
0	1. Take the sterile cotton swab stick and rub it on the surface of smartphone and smartwatch to collect the bacteria. 2. Lightly rub the swab across the surface of the agar in a zigzag pattern turning the Petri dish a few times for maximum coverage. This must be down swiftly after removing the cover of petri dish. After that, close the lid. 3. Label each dish and kept in a dark place with room temperature for 4 days such as inside a box for 4 days to observe the growth of bacteria. 4. Observe and record the result after 4 days.
3,8 and 10	1. Put the smartphone and smartwatch in the Disinfection Box. 2. Switch ON the Disinfection Box and close the lid. Leave the smartphone for 3,8 and 10 minutes until the disinfection process is over. 3. Take the sterile cotton swab stick and rub it on the surface of smartphone and smartwatch to collect the bacteria. 4. Lightly rub the swap across the surface of the agar in a zigzag pattern turning the Petri dish a few times for maximum coverage. This must be down swiftly after removing the cover of petri dish. After that, close the lid. 5. Label each dish and kept in a dark place with room temperature for 4 days such as inside a box for 4 days to observe the growth of bacteria. 6. Observe and record the results after 4 days.

Table 3 - The growth of bacteria on the agar in Petri dish based on different disinfection time

Disinfection time (minute)	Device	Bacteria growth on agar in Petri dish	Observation after 4 days
0	Smartphone		From the visual observation, the growth of bacteria on the agar is massive which can be seen from the high density of small and round bacteria colonies. Therefore, it is shown that the smartphone is contaminated with bacteria before the disinfection process takes place.
	Smartwatch		From the visual observation, the growth of bacteria on the agar is not as massive as on the smartphone which can be seen from the low density of small and round bacteria colonies. Thus, it is shown that the smartwatch is also contaminated with bacteria before the disinfection process takes place.

3	Smartphone		From the visual observation, there is a growth of bacteria colonies on the agar in Petri dish. However, the density is low. Therefore, it is shown that the smartphone is still contaminated with bacteria within 3 minutes of disinfection time.
	Smartwatch		From the visual observation, there is a growth of bacteria colonies on the agar in Petri dish. However, the density is lower than the bacteria colonies on smartphone. Therefore, it is shown that the smartwatch is still contaminated with bacteria within 3 minutes of disinfection time.

8	Smartphone		From the visual observation, there is still a growth of bacteria colonies but not as dense as the bacteria colonies within 3 minutes disinfection time. Thus, it is shown that there is reduction of bacteria growth within 8 minutes of disinfection time.
	Smartwatch		From the visual observation, there is still a growth of bacteria colonies but not as dense as the bacteria colonies within 3 minutes disinfection time. In addition, the amount of bacteria colonies on the smartwatch is less dense as compared to the smartphone. Thus, it is shown that there is reduction of bacteria growth within 8 minutes of disinfection time.

10	Smartphone		From the visual observation, the growth of bacteria colonies on the agar is greatly reduced as compared to the 3 minutes and 8 minutes' disinfection time based on less density of bacteria colonies on the agar. Therefore, it is shown that the 10 minutes disinfection time is sufficient to disinfect the smartphone. This is consistent with the fact that bacteria could not be completely eliminated from any surfaces [6].
	Smartwatch		From the visual observation, there is a massive reduction in the growth of bacteria colonies on the agar as compared to the 3 minutes and 8 minutes disinfection time. In addition, the amount of bacteria colonies on the smartwatch is greatly reduced as compared to the smartphone**.** Therefore, it is shown that the 10 minutes disinfection time is sufficient to disinfect the smartwatch. On top of that, it is also shown the smartwatch is less contaminated as compared to smartphone. This can be attributed to the fact that smartwatch are used or touched less frequently and for a shorter period of time as compared to smartphone.

4. Conclusion

A Portable IoT-based Disinfection Box has been designed and developed in this work. The Disinfection Box consists of a Controlling Unit and Disinfection Box itself which is connected via connecting wires. The UV-C LED strip light is utilized in the box to disinfect small electronic devices with 360˚ wide angle for optimum disinfection and the time to complete the disinfection process is set to be 10 minutes. Effectiveness of the UV-C LED light strip in disinfecting small electronic devices are observed based on the bacteria colonies on the agar in Petri dish at different disinfection time of 3, 8 and 10 minutes. It is shown from the experimental procedures that 10-minute disinfection time provided by the Disinfection Box is sufficient to disinfect small electronic devices such as smartphone and smartwatch. This is based on the great reduction of bacteria colonies on the agar in Petri dish after being kept in a dark place with room temperature for 4 days.

Acknowledgement

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