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Design, Fabrication and Performance Evaluation of Portable Incubator

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Abstract

For rural water supply system, microbiological parameter such as Escherichia coliform needs to be monitored frequently to ensure safe water. Lack of portable incubator made difficulties in monitoring the water quality in remote areas. Difficulties in carrying and unreliable power sources are some of the existing challenges. Thus, the research focused on design, fabrication and performance evaluation of the portable incubator and performed validation of the setup. Experimental research methodology was performed for the research where data were collected from various testing setup without and with 16 nos. of test plates of incubator using 12V DC bulb as heating source. The power supply for the setup was battery powered by solar PV setup, as well as AC-DC charger connected to a grid line. A 20Wp solar with 20Ah battery setup meets the requirements of the power. Bulb Incubator consumed 0.620A current and 7.44W power. It requires 17.36Wh energy to perform one cycle of incubation and heating cycle operated for 14 times. The total operation hours for one complete incubation cycle in 24 hours was 2.33 hours. AVC -144 vaccine box of 1.4L capacity with inbuilt PU insulation of 40mm thick as an incubator casing has effectively prevented from the heat loss and is also portable.

Keywords

Incubator, Portable, Heat loss, microbial

1. Introduction

Safe water is the basic need of human. Poor quality of water has significant impact on human health, exposing them to waterborne diseases. Microbial water quality is one of the key indicators to be properly diagnosed so that effective water treatment methods could be implemented to ensure safe water for all. However, rural water supply system located far from the urban settlement has challenges to monitor the microbiological parameter such as Escherichia coliform frequently to identify the status of safe water[1]. Lack of access to established laboratory and rough geographical terrain has increased difficulties in monitoring the water quality of different sources. Similarly, time constraints required to collect the samples followed by difficulties on timely delivery of these samples to the nearest existing laboratory have negative consequences in microbial testing of water. On the other hand, reliable power sources to operate the devices is another problem in remote context. Thus, it can be noted that, the assessment in poor resource settings has limited availability of proper sets of devices required to carry out the tests. These issues could be addressed by selecting lower- cost alternatives instead of standard equipment which could significantly save cost of equipment as well as the testing could be possible[2]. Therefore, equipment needed for microbial test could be further breakdown and developed locally with easy handling and portability. National Drinking Water Quality Standards, 2005 [1] provides the framework for the collection and processing of sample as shown in the figure 1.

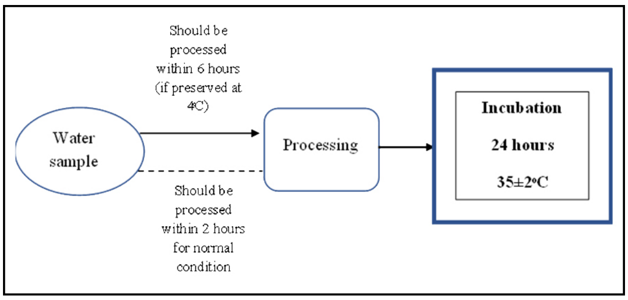

Figure 1: Need of incubator

As presented in the figure 1, it can be observed that the water samples for tests might be collected from various sources, but the crucial part is processing and incubating the test plates for the prescribed time and environment[1]. In the remote settings, where these incubators could not be operated- the incubation process is conducted in an unreliable a way, or by using the body warmth or conventional approach leading to poor diagnosis of microbial growth and measure the risk in the water. Consequently, exposure to risk of microbial disease increases as well as adoption of treatment methods is also forced for implementation.

Thus, in order to fill the gap of required portable setup of incubation, the study focused to design, fabricate and carry out the performance evaluation of the portable incubator setup which could steadily maintain a standard incubation temperature of 35±2°C.The study further carried out performance evaluation of power consumption and temperature variation in the incubator to ambient conditions. The setup was further validated by conducting microbial growth in comparisons with the available standard incubator.

2. Literature review

Surveillance and monitoring of water samples for bacterial contamination are critical for public health for water consumption, recreation, and sanitation, however conducting these tests in remote locations poses many challenges[3]. The document further suggests that samples processed after 24 hours of collection poorly represent bacterial loads and gives inconsistent, and unreliable results leading to false conclusions. Microbial test is one of the major indicators to diagnose the quality of water and conduct the treatment process to avoid waterborne disease. However, the need of water quality testing within 2 hours of collection in normal conditions requires better access to the water quality laboratory or portable incubator[4]. Also, available portable incubators are expensive and needs to be imported.

Incubator could be constructed by structuring the setup in four components: first- by the assembly of the heating core; second-by the assembly of the controlling unit; third- by the assembly of the incubator power supply; and fourth- by the assembling these in the incubator casing which includes all the above three components as well as provide space for the test plates.

3. Methodology

Experimental setup of the incubator with 5W DC LED bulb as heating core to provide heat with an operating voltage of 12V, axial fan for air circulation and temperature sensor were installed in a vaccine box of 1.4L capacity. A w1209 temperature controller to control the temperature variation is connected to control the power supplied to the axial fan and bulb. Poly-crystalline solar panel with Lead-acid battery was used as a power the testing of the setup. Meanwhile, AC-DC charger was also used to ensure that the setup could be operated from main grid line. The Hobo data logger with four ports was used to collect all the temperature data from various points. Data logger was calibrated in the Nepal Bureau of Standards and Metrology before collecting the data. Measurement of the voltage and current was done by using the AMprobe multimeter. PVsyst 7.2 was used for designing and selecting the solar PV setup. The petri-dishes were used to prepare media (HI Agar) and 0.45 micrometer filter paper was used to filter the water from the filtration unit. 100ml of water sample was collected for processing the test. The test specimen for the incubator is made of Borosilicate glass; it has two components; top and the bottom part. The outer diameter of the top part is 53.5mm with 2mm thickness and height of 16.5mm. The total weight of the setup combining both top and bottom part with agar is 62.97gm. The designed setup include 16 nos. of these test plates for tests in one cycle. Thus, these test plates used for the growth of the microbial were prepared and incubated in the designed and fabricated setup as well as in an incubator of the Faithful(45 litre) for the validity.Data from the setup were collected, analyzed and documented by using MS excel.

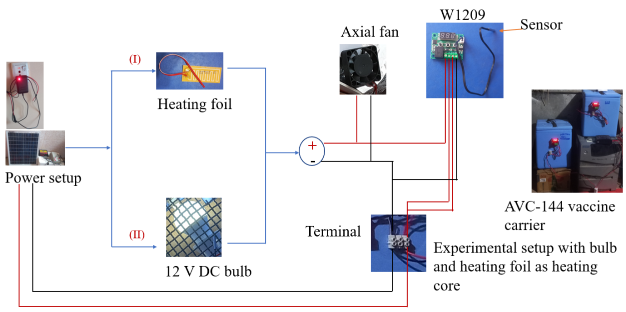

Figure 2: Wiring setup including both heating core

The connection of the bulb and fan with the power was carried out as show in the figure 2. Here for this setup w1209 is connected in such a way that it controls the power supply of both heating unit and fan for cut off and on of the setup.

4. Results and discussion

The heating core setup with bulb has been placed in the base made of plywood and vertical supporting wall for the bulb and axial fan. The axial fan was placed adjacent to the bulb so that the heat generated from the bulb could circulate throughout the inner surface.

4.1 Calibration of data logger

The key element was temperature measurement, thus the data logger was calibrated by Government of Nepal, Nepal Bureau of Standards and Metrology to ensure the accuracy and reliability. The calibration of the data logger was carried out in water bath at an ambient temperature of 25°C.

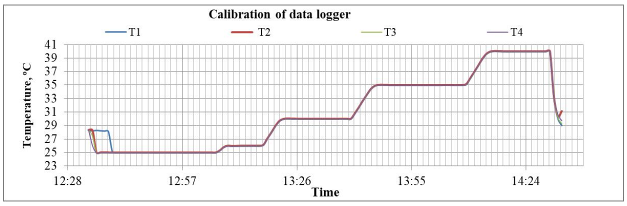

Figure 3: calibration of four sensors of data logger

The calibration of the data logger was carried for four different temperature points. There is a drop in temperature at the end because of the sensor was taken out of the water bath, but the rest of the curve in figure 3 shows the uniformity of the temperature at 25°C, 26°C, 30°C, 35°C and 40°C, ensuring exact temperature readings.

4.2 Details of setup

The heating core used 5W 12V DC bulb. 5mm thick plywood was used as base and supporting wall for the bulb and fan. The details of the casing used (AVC-144) in a schematic way is presented in figure 4.

Insulator of 40mm placed in between the outer and interior wall plays a crucial role to prevent the loss of heat from inner to outer wall.

4.2.1 Bulb based heating core setup

The heating core setup by using 12V DC bulb is presented in the figure 5. One of the issue with this setup was the size of the bulb which occupied half of the space of the inner chamber. Also, the setup needed

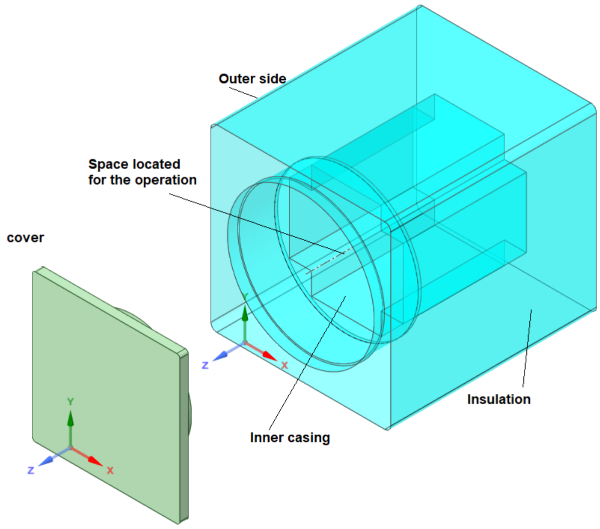

Figure 4: Incubator casing made up of AVC-144

an extra vertical supporting plate to hold the bulb itself.

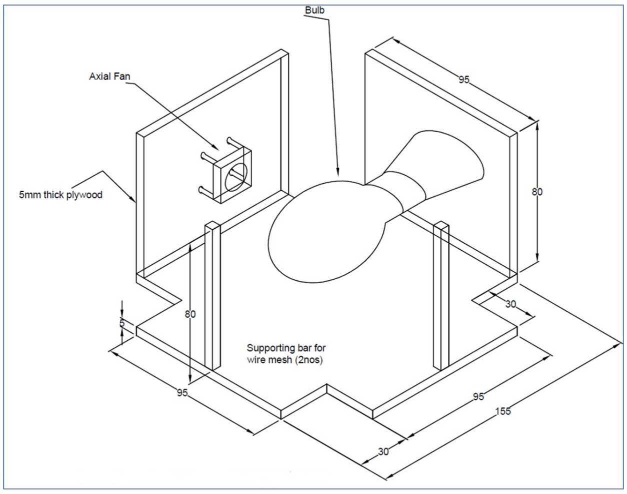

Figure 5: Setup of incubator using bulb as a heating source

4.3 Layout of the test plates

The estimated weight of the total test specimen inside the incubator was 1007.5 gm including the filter membrane and wrapping papers. The lower portion is filled with media and the upper portion is used to cover the lower portion.

For stacking and incubating the setup, a metal wire mesh has been selected to separate the incubating chamber with the heating core region.

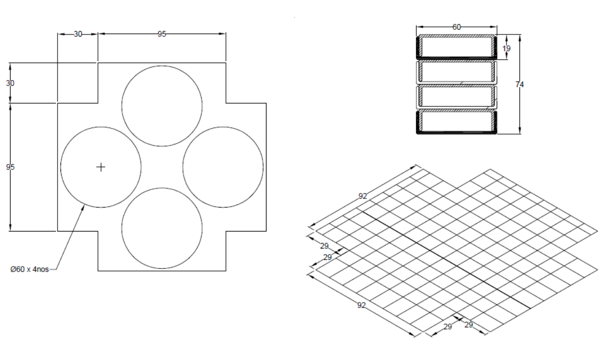

Figure 6: Layout of the test plates and stacking setup

4.4 Heat calculation of the incubator casing

The heat calculation of the study was mainly carried out by calculating the heat required for 16 nos. of samples that could be tested in a day- in the context of remote areas.

Thus, on the basis of the size of petri-dishes and stacking capacity of 4 and in 2x2 matrix, the volume needed for placement of the plates was finalized. Based on the size and insulation material; AVC -144 as incubator casing of 1.4L capacity was selected. The weight of the empty vaccine box is 2.2kg. The external Surface material is made up of HDPE (High Density PE) and the internal lining material is made up of HIPS (High Impact PS). 40 mm thick insulation material made up of CFC free PU is inbuilt in the casing. The thermal resistance (Rth) of the casing calculated is 2.01 K/W.

Heat transfer was calculated in order to select the size of the heater for raising the internal temperature of 35ºC. The total area of the interior casing is 0.0204 sq.m with the volume of 0.00343 cu.m with the height of 168mm. The designed height for the electric core was considered of 84mm considering the significant space between the test specimen and the heating unit[5].

The amount of heat required to achieve 35°C from 25°C is 10.9kJ. Thus, 5W of the bulb was selected to generate the needed amount of heat. Also, this frequent operation of the bulb will allow the axial fan to operate and circulate air around the test plates removing stagnant air within the incubator.

4.5 Performance evaluation of the incubator setup

The major element for the performance evaluation is the uniformity of the temperature at the inner surface. Thus, measurement of the temperature within the surface was carried out for 24 hours under different conditions and the data collected from the setup was in an interval of 1 minute.

4.5.1 Operation of the setup without test plates

The fixed temperature in w1209 of the bulb incubator was set on 35ºC with the correction factor of -2.1ºC in the device. The range of data collected for 24 hours in day/night setup showed, that the variation of the temperature from the core to the outer wall of the casing.

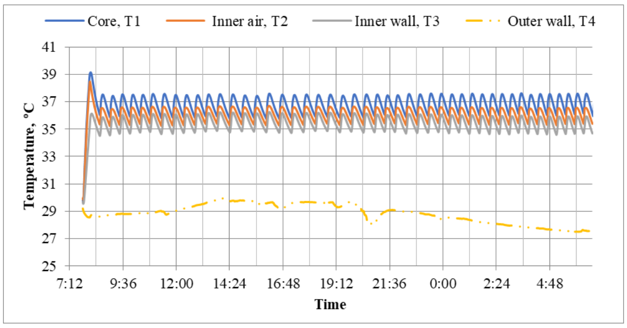

Figure 7: Operation of the setup without test plates

From the experimental data as presented in figure 7, it is observed that the initial period of the heating by the bulb rises to the maximum point, where the most energy is consumed by the setup. Contrary, to this situation the energy consumed by the setup during regular operation in afterwards cycle is more uniformly balanced where the core temperature is in the range of 37-38ºC and the inner temperature is in the prescribed range of temperature in a permissible and uniform range.

4.5.2 Operation of the setup with test plates

The temperature for the bulb based incubator casing was set on 35ºC with the correction of -2.1ºC in the device. The range of data collected for 12 hours in night for the setup shows the variation of the temperature from in core to the external casing. 16 nos. of test plates were used in the test setup.

Similar pattern as in the setup of test without test plates was observed. A continuous temperature drop from inner air to inner wall was observed indicating that the plates are properly absorbing heat as presented in figure 8.

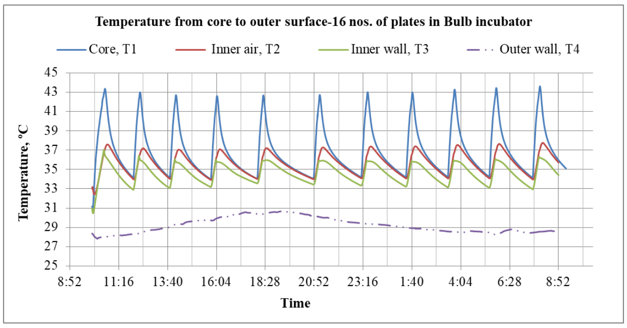

Figure 8: Operation of the bulb incubator with 16 nos. of test plates

4.5.3 Inner side wall temperature measurement of the bulb based incubator casing

The temperature of four inner walls were monitored by using data logger in order to figure out either the setup is maintaining the temperature properly or not.

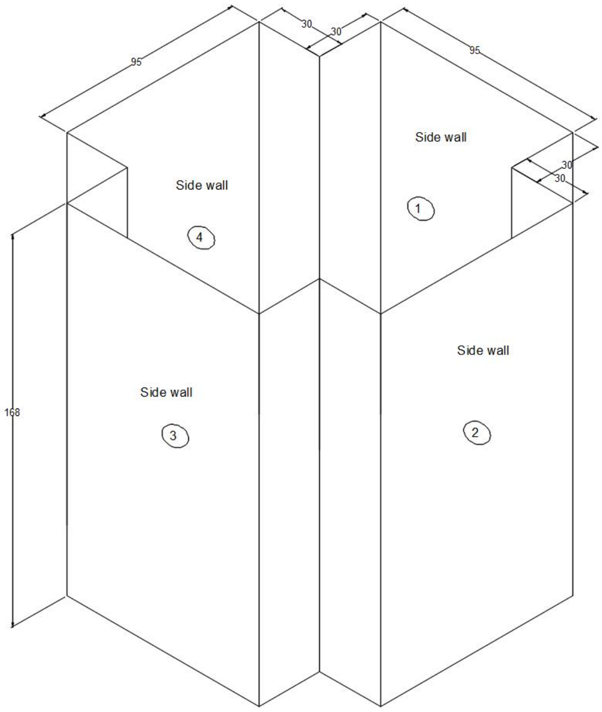

Figure 9: Position of data logger point for measurement of temperature

The temperature measured in four side wall as shown in figure 9 indicates that the range of temperature variation in these four inner side wall lies within the permissible range. Temperature sensors were placed in the upper side wall are where the test plates are placed, so measurement of the temperature around these side wall provides the suitable to place the plates platform and ensure that the temperature variation within these side walls are in permissible range. Also, prescribed temperature zone is maintained within each region.

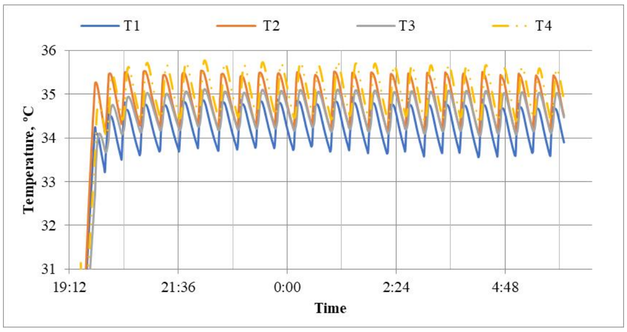

Figure 10: Temperature profile of inner sidewall of the incubator casing without test plates

The inner side wall temperature with no test plates is shown in figure 10 where the temperature is maintained at specified temperature range. The slight increase in the temperature at T4 region was observed and the cause could be the bulb facing that side wall.

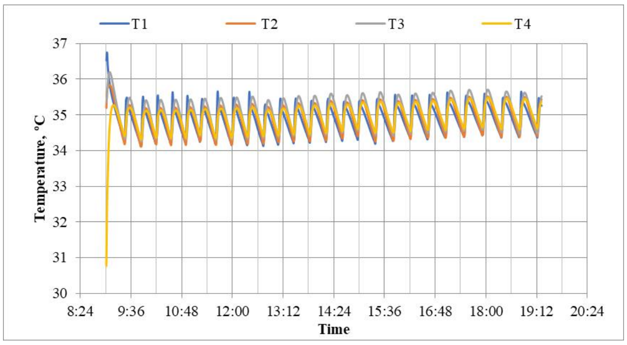

Figure 11: Temperature profile of inner sidewall of the incubator casing with 16 test plates

The inner side wall temperature with 16 test plates as shown in figure 11 could be seen in a proper range, however first cycle reached to a temperature peak. Here, the inner space are occupied by the test plates and has limited space that might have created balance of heat around the four side walls.

4.6 Heat loss from the incubator setup

As the incubator casing selected was vaccine carrier box which is insulated by CFC free 40mm thick PU insulator material. Following figure12 provides the loss of heat from the setup.

From the figure 12 it has been found that the heat transfer from the setup took place through convection-core to inner air, convection-inner air to inner wall, conduction-inner wall to outer wall and convection-outer wall to ambient condition[5].

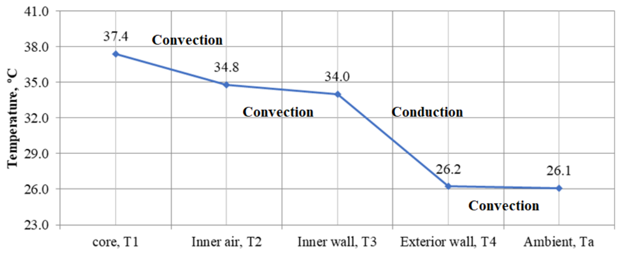

Figure 12: Heat transfer from the setup

In the figure 13, it was found that the setup maintained uniform temperature in the inner region of the incubator, which indicates that the favorable temperature as permitted has been maintained in the setup.

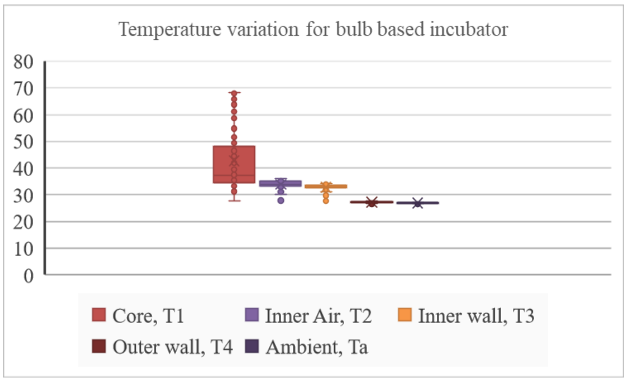

Figure 13: Heat balance in the setup

The figure 13 shows that the core temperature of the bulb has crossed 48°C only on rare event, but most of the period the temperature lied in the range below 42°C. Similarly, the inner air temperature with inner wall temperature are in the permissible range of set temperature. The outer wall temperature measured was close to the ambient temperature illustrating that the setup is suitable for the ambient of temperature of 25°C.

4.7 Estimation of the load and other parameters

The solar PV set is mainly considered for the power supply. The voltage variation during the operation of the setup for 24 hours is presented in the figure below. From the figure 14, it has been found that the for an incubation cycle of 24 hours the sun rise from 6:00am has increased the charging of the battery.

Also,the operation of the fan and bulb under heating cycle are observed in long. Contrary, the frequency of operation of the setup from 18:00 to 6:00 is in short span presenting that the power consumption by the

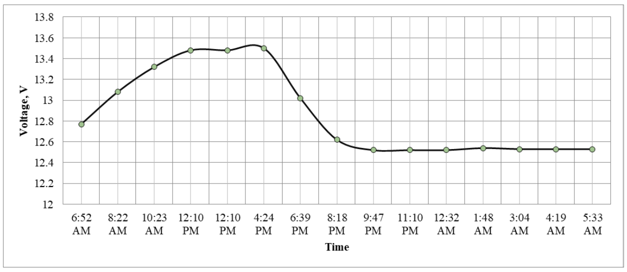

Figure 14: Voltage variation of battery in Solar PV setup

setup is high during the night hours. Also, during this period, voltage of the battery kept discharging.

5. Conclusion

Thus from the experimental based research, it was found that using available materials, such as w1209 temperature controller, AVC-144 vaccine carrier and other basic materials- a portable incubator could be constructed. From the findings of the experimental setup, temperature controller used in the setup has maintained the permissible range of temperature for allocated hours of incubation. The power required for the setup could be a solar PV powered battery or AC-DC charger connected to a grid line. Based on the operating hours and power consumption pattern- a 20Wp solar with 20Ah battery setup could meet the requirements of the power needed for the operation of the setup.

The capacity of the incubator designed is for the 16 nos. of petri dishes and 16 nos. of compact dry plates. The incubator itself weighs 2.3kg at empty and 3.3 kg when filled with the petri dishes. The bulb-based setup incubator draws 0.620A current to operate the system. The power consumed by the incubator for an hour of operation is 11.76Wh and total power consumption in 24 hours is 17.36 Wh/day which in minimal compared to another setup. The cost of the setup is NPR 6900 without battery. Overall, the total cost of the setup including the solar power setup it would be in the range of NPR 24400 which is way economic compared to imported standard incubator that cost NPR 45000 for similar capacity without any power supply.

Validation of the setup was carried out by preparing and incubating 10 nos. of duplicates of samples collected from the same sources. Microbial processing was carried out by filtration method using 0.45 micrometer filter paper and placed in an agar filled petri-dishes (as test plates). These 10 nos. of each plates were placed in standard and bulb based incubator for 24 hours at prescribed temperature. The result from the experiment showed that there was uniform growth of the Escherichia coliform in these 10 plates which were placed in both incubator were in same range and also countable. Similarly, all the data collected from the data logger under various experimental setup lies in the acceptable range.

Also, it was found that bulb incubator operated heating cycle for 14 times during the 24 hours of incubation period. The total operation hour for one complete incubation cycle was 2.33 hours for bulb incubator.

Acknowledgments

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