SciMedCentral
Annals of Pediatrics & Child Health

Research Article

Solar Powered Portable Culture Incubator

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Submitted: 04 March 2015
Accepted: 08 April 2015
Published: 13 April 2015

Keywords
• Solar energy
• solar culture incubator

Abstract

Background: The current rate of infant mortality in India is 40/1000, two thirds of which is due to neonatal mortality [1]. Neonatal sepsis accounts for more than 50% of the neonatal mortality in India. Ideally the prompt culture of specimens – i.e. body fluids e.g. blood, urine, cerebro-spinal fluid, etc. – would help isolate and identify microorganisms causing infection and sepsis. The results of the lab tests will help clinicians to institute timely and appropriate antibiotics to the patient. This will culminate in an overall decrease in morbidity and mortality related to sepsis/infections.

In resource-limited countries, in rural communities, there is a distinct lack of (functional) culture facilities; therefore, these specimens would require to be transported to the nearest well-equipped culture laboratory for processing, interpretation of the causative organism, and its sensitivity to antimicrobials. As the optimum temperature for bacteria culture such as the frequently used E. coli as well as mammalian cells is approximately 37° C, this is the temperature that needs to be maintained for specimens in transit from the community to the laboratory. Our main aim was to fabricate a portable culture incubator which could run on solar energy. In this paper, we highlight the benefits of the Solar Powered Portable Culture Incubator which enables the successful culture of human fluids despite unavailability of proximate laboratory facilities.

Methods: As the culture of specimens requires maintenance of the appropriate temperature in the right culture media, the Solar Powered Portable Culture Incubator is fabricated to commence the culture process of the specimen soon after collection and maintain appropriate environmental conditions whilst in transit from remote locations to a well-equipped laboratory facility. The Solar Powered Portable Culture Incubator is made of wood and can maintain a temperature of 35 ± 2° C using a battery on a dual system i.e. a battery which is charged through a solar module during daytime, and switches to normal electric power when the solar energy available is inadequate to charge the battery. During transportation the temperature within the incubator is maintained with a solar module installed on the rooftop of the vehicle.

Findings: An experiment was conducted by drawing a sample of pus from an inpatient's infected wound at a district hospital. Blood agar plates were streaked with bacteria from the sample and incubated at 37° C using the Solar Powered Portable Culture Incubator. It was found that bacteria were successfully cultured, i.e. the required quantity of bacteria grew in the incubator environment. Therefore, it was proven that the Solar Powered Portable Culture Incubator is capable of effectively transporting human fluid for culture from remote locations to better-equipped laboratory facilities.

Interpretation: The Solar Powered Portable Culture Incubator will help in establishing mobile culture facilities at the district level or the sub-district level; therefore, there is a tremendous scope for this product in our health system in rural as well as urban settings.

INTRODUCTION

An incubator is a device that is used to grow and maintain microbiological cultures or cultures for bacteria such as E. coli and mammalian cells. The device is designed to maintain optimal temperature, humidity and other conditions such as the carbon dioxide (CO_2) and oxygen content within it, for safe transportation of the sample over long distances. The simplest incubators are insulated boxes with an adjustable heater; the most commonly used temperature for bacteria and mammalian cells is approximately 37° C as these organisms grow well under such conditions. Incubators are usually run on electricity, and can vary in size from tabletop units to containers the size of small rooms.

Neonatal Mortality is defined as the number of newborns dying within 7 days (early Neonatal Mortality) to within 28 days (late Neonatal Mortality) [1]. The Registrar General of India surveyed all deaths occurring during 2001-03 in 1·1 million nationally representative homes and found that there were 10,892 neonatal deaths in the study [2]. The paper also highlighted that there were 0·27 million deaths due to neonatal infections when projected for the national population in India [2]. Many of these are avoidable as diagnoses of infections are hindered by the fact that most of the time, in rural settings, there are no culture facilities available. Therefore there is a pressing need for an innovative solution which could help in saving hundreds of thousands of lives. The Solar Powered Portable Culture Incubator addresses this need.

The Solar Powered Portable Culture Incubator is both environment-friendly and easily portable. During transportation,

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this device can operate on batteries charged with solar energy through a solar module of 5 or 10 watts installed in the rooftop of the vehicle, and will not need to rely on electric power supply. In rural areas, where power supply is erratic, and where there is plenty of sunshine, this product will help in the timely identification of neonatal infection. The blood samples could be collected from a Primary Health Centre (PHC), a Community Health Centre (CHC), or from the patients in their homes, and transported in the incubator which is connected to a solar panel on the roof of the vehicle, and the cultures could be further processed in a centrally located laboratory to isolate and identify microorganisms as well as their sensitivity to appropriate antibiotic tests. The timely use of antibiotics in neonatal sepsis will help in reducing mortality in newborns. In the world's health and medical technology literature this is perhaps the first time that anyone has used a device such as the Solar Powered Portable Culture Incubator.

Figure 1 The idea was initially tested with a thermocol and then with a wooden box in Phase-I.

Figure 2 Two Solar Powered Portable Culture Incubators were fabricated. They have cloth covers with shoulder straps.

Figure 3 The Solar Powered Portable Culture Incubator can run on AC mains whenever required through an AC battery charger 12 V, especially during the night. The voltage transformer to convert 220 V to 12 V AC is contained in a separate aluminum box.

METHODS

The idea was to connect a bulb or a heating source to a battery, a thermal regulator, and a thermostat to maintain the temperature between 35 ± 2° C inside the box. To test the idea, initially a thermocol box was used; this was subsequently replaced by a wooden box. A digital temperature indicator outside the box displayed the temperature.

In Phase-I (Figures 1a, 1b and 1c) the method involved translating the innovative idea, for which a wooden box measuring 38cm×24.5cm×19cm with a partition was prepared with the following features:

- The culture compartment was designed to accommodate blood agar plates, culture bottles, etc., on a small platform
- A geyser heating element and a thermostat were fitted beneath the platform
- An adjacent compartment housed a 12 V battery and thermo regulator
- On the front of the incubator is a digital temperature indicator, with a red light to indicate that the instrument is on and an orange light to indicate a functioning thermostat
- A portal at the back of the incubator connects either to the solar module or to a step-down transformer supplying AC current
- There are two separate lids for each of the compartments, so that the culture process can take place without interruption.

In the first step, the wooden culture incubator was adjusted to accurately maintain a temperature of 35 ± 2° C on the dual system i.e. solar module or the AC supply.

In the second step, a pair of blood agar plates, one of them streaked with microorganism was placed in the culture compartment. The incubator was tested, both in a laboratory and in a district hospital setting. It was shown that the incubator maintained the temperature during the culture period and bacterial growth was noticed in the streaked plate (confirmed by the microbiologist) after providing incubation for a total of 43 hours in one instance and 24 hours in the other; in both cases the dual system was tested as the periods spanned day as well as night times.

The cost of the culture incubator, Phase-I model, was around Rs.4,500/- (equivalent US $ 72/-)

In Phase-II (Figures 2, 3, 4, 5 and 6), the present prototype of Solar Powered Portable Culture Incubator was fabricated. It has a cloth cover with a shoulder strap to enable it to be easily carried by a field worker. The culture incubator was made of wood, measuring 29cm×24cm×21cm, and the culture compartment was made of acrylic plastic insulated by thermocol on all the sides. It had a platform to hold the culture plates. The heating wire was placed beneath the platform. The battery compartment had additional electronic items in Figure 4:

- a basic charge controller effectively cutting off the current from the solar module (or reducing it to a pulse) when the battery voltage reaches a certain level to ensure that the battery is not damaged by over-charging
- a 12 V and 7AH battery
- an automatic temperature controller
- a solid-state relay (SSR)
- a voltage transformer to convert 220 V to 12 V AC is contained in a separate aluminum box (Figure 3)
- a 10 W solar module is external to the incubator The weight of the present prototype is 6.5 kg.

The cost of the Phase-II model worked out to Rs.12,900/- (equivalent US $ 206/-). An ordinary microbiological electrical culture incubator of comparable size would cost in India US $ 800-1000/- [3].

RESULTS

Experiments have been conducted with a wooden box fabricated for the portable culture incubator

Human bodily fluid samples could easily be cultured using this dual system (providing energy to the wooden culture box using a solar module during the day; and at night, using Alternating Current (AC)). A continuous incubation was successfully carried out in a lab setting as illustrated in Figure 7.

Experiments to demonstrate that the temperature near the plate was the same as shown in the digital indicator

A thermocouple with the sensitive end placed near the culture plates, as shown in Figure 8, demonstrated that the mean ± SD° C temperature near the plates was 36·1 ± 1·10° C. The digital indicator showed 36·5 ± 1·33° C.

Experiments conducted in Palwal District Hospital (Figure 9)

Human fluid specimens were successfully cultured in a Solar Powered Portable Culture Incubator with solar power during day time and AC current at night in a district hospital in Palwal, Haryana and the portability of the system was demonstrated. The solar module was installed in the roof of the car and the culture plates were incubated during the travel time and transported from the institution in the city to the district hospital. Records

Figure 4 The present prototype of Solar Powered Portable Culture Incubator has a basic charge controller, a 12 V and 7AH battery, an automatic temperature controller, and a solid-state relay (SSR).

Figure 5 This photograph shows the portable culture incubator getting charged by a solar module of 10 watts.

Figure 6 This photograph illustrates the ease with which the portable culture incubator can be carried by field workers.

Figure 7 Two blood culture plates, A and B, were obtained. Only one of the plates was streaked with bacteria.

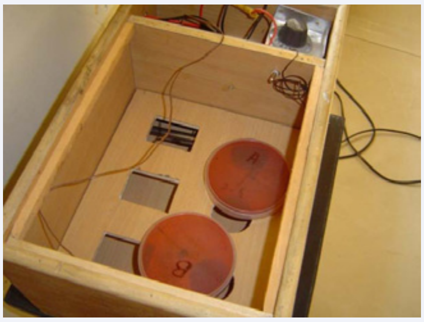

Figure 8 Thermocouple with its sensitive end near the culture plates to record temperature near the culture plates.

Figure 9 Cultured colonies were seen in plate 1 and negative in plate II (control plate) in district hospital setting.

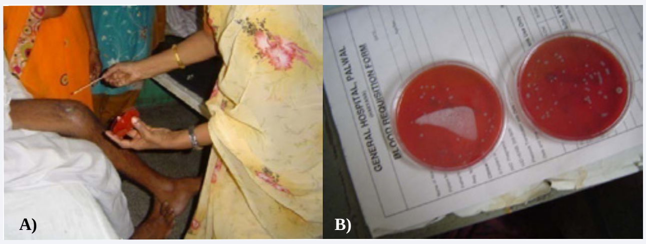

Figure 10 Two plates with bacterial colonies grown from pus obtained from a patient's infected wound at a district hospital.

show that the incubator maintained the temperature during transit and the entire culture period, and, as confirmed by the microbiologist, growth was noticed in one of the plates after an incubation of 24 hours. The culture plates which grew microorganisms (Figures 10a and 10b) were transported to the institution to identify the bacteria.

Experiments conducted with the present prototype

The present prototype is able to maintain its temperature at 37° C and similar culture plates were successfully cultured. The present prototype requires a10 watt solar module

DISCUSSIONS

To detect microorganisms in culture specimens, especially body fluids, e.g. blood, urine, cerebro-spinal fluid, etc., an appropriate and consistently maintained temperature in the right culture media is required. As the Solar Powered Portable Culture Incubator works on a dual system i.e. with electricity and with solar energy, it facilitates both the collection of specimens from remote locations *and* their transfer to a better-equipped laboratory facility for further processing and interpretation of the causative organism to establish its sensitivity to antimicrobials. The results of the culture therefore help clinicians to institute timely and appropriate antibiotics to the patient. This will result in the overall decrease of morbidity and mortality related to sepsis/infections.

Solar energy has been used in the refrigeration industry. Solar Chill aims to help deliver vaccines and refrigeration to regions of the world without electricity or with inadequate electric power supply. Solar Chill initiative has been developed under a partnership between Greenpeace International, United Nations Environment Programme (UNEP), Deutsche Gesellschaftfür Internationale Zusammenarb eit (GIZ), GmbH-Proklima, Danish Technological Institute (DTI), United Nations Children's Fund (UNICEF), World Health Organization (WHO), Programme for Appropriate Technology in Health (PATH), Danfoss, and Vestfrost over the past 10 years [4]. India's power sector continues to play an important role in the country's overall development. Central Electricity Authority statistics predict energy shortages in the coming years and therefore, developing alternative sources of energy for health care would be appropriate [5]. However, the Solar Powered Portable Culture Incubator has not been described in any literature, and such an innovation may prove very useful in improving human health, especially child health, in a resource-limited setting.

SCOPE

In this situation the Solar Powered Portable Culture Incubator will help in establishing culture facilities at the rural level. Therefore, there is tremendous scope for this product in our health system both in the rural and urban settings. Ideally each Community Health Centre could have 10 to 20 Solar Powered Portable Culture Incubators besides a large central facility

ACKNOWLEDGEMENTS

This study was funded by the Indian Council of Medical Research, New Delhi. We acknowledge the contributions of the expert committee constituted for the Solar Powered Portable Culture Incubator.

Contributors

V Thavaraj, the innovator of the product, has applied for a patent with the Indian Patent Office in 2010, applied for a grant from the Indian Council of Medical Research (ICMR), conducted all the experiments, and prepared the manuscript.

The idea initially got translated into fabrication by N Kapoor.

The product was then fabricated into the present prototype by B Vasshishth. O S Sastry facilitated the workshop for fabrication.

A Kapil provided the blinded blood agar plates.

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Cite this article

Thavaraj V, Vashishth B, Sastry OS, Kapil A, Kapoor N (2015) Solar Powered Portable Culture Incubator. Ann Pediatr Child Health 3(4): 1063.