A low cost incubator to support microbiological analysis in developing countries

Robert Matthews, Stephen Gundry
Water and Health Research Centre, University of Bristol

Background

The idea for a phase change incubator originated from the Aquatest project (www.bristol.ac.uk/aquatest), the goal of which is to develop a new, low cost, easy to use field test to monitor microbiological contamination of drinking water. The Aquatest device detects *Escherichia coli*, an indicator of faecal contamination in water (WHO, 2004). Aquatest has the potential to bring substantial benefits to developing countries; governments and regulatory bodies will be able to conduct a much higher volume of testing then at present and communities and individuals will be empowered to conduct their own testing programs.

The Aquatest device is completely self contained; it can be used by relatively unskilled hands and in field settings. However, as with most microbiological tests, it requires a period of incubation at a controlled temperature. This is a problem in a low resource setting not only because the capital cost of a conventional incubator is often prohibitively high, but the unreliable power supply that is endemic across most low resource areas means that a typical electrical incubator will not function correctly (Sanghvi, 1991). Only a relatively few better equipped laboratories with backup power supplies can achieve reliable incubation. To address this problem a low cost phase change incubator that does not require an electrical power supply has been developed. Although the phase change incubator has been designed with microbiological water testing in mind, in particular in conjunction with Aquatest, it has potential to be applied to many other fields, including clinical microbiology, environmental monitoring and sample transport.

The Phase Change Incubator

The phase change incubator (Figure 1) makes use of the combination of a vacuum flask to provide a high level of insulation and a phase change material (PCM) to store energy in the form of latent heat. To use the incubator, the incubation chamber is filled with 500ml boiling water. Energy is transferred from the water to the PCM, causing it to melt. This takes a minimum of 30 minutes but the incubator can be left in the filled state for up to 6 hours without excessive heat loss to the environment. It is envisaged that the tester will fill the incubator before setting out to conduct the test. When the test is ready, the water can be emptied and the test inserted, which will then be kept at incubation temperature for 24 hours. Design criteria for the phase change incubator are shown in table 1:

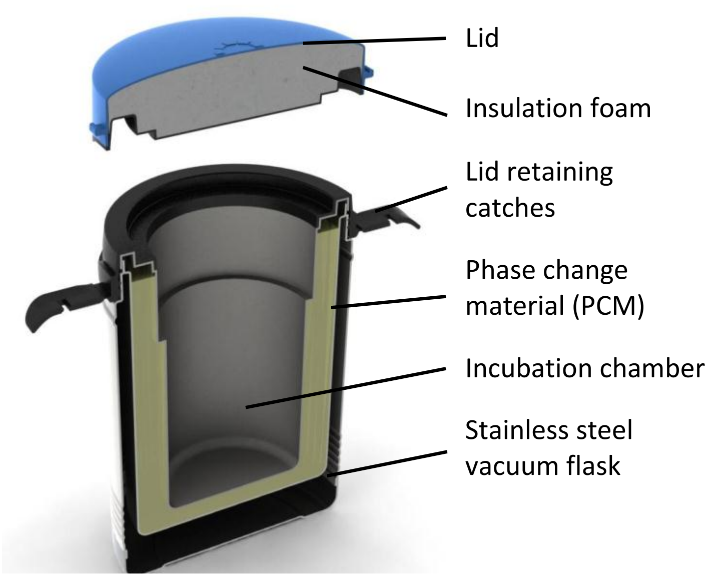

Figure 1: The components of the phase change material incubator

Table 1: Design criteria for the phase change incubator

Technically capable	Heat a 100ml water test to incubation temperature within 1hr Incubation temperature to be maintained for 24hrs Temperature of test must not exceed *E. coli* growth temperature
Reliable operation	Independent from unreliable resources, especially mains electricity In a wide ambient temperature range, proposed 10°C to 40°C Outdoors, in-home, in-vehicle, in-laboratory
Affordable	Target less than $20
Ease of use	Suitable for use by unskilled operators Intuitive operation by design Low maintenance
Portable	Can be easily carried by one person
Rugged	Resistant to harsh operating environment Misuse and forceful operation

Incubation Temperature

E. coli tests are commonly used worldwide, but discrepancies in protocol exist when it comes to incubation temperature. For example in the UK and much of Europe it is standard practise to incubate at 37°C ± 1°C whereas in the US the regulations state 35°C ± 0.5°C (Standing Committee of Analysts, 2009, APHA, 2005). Detail of the incubation temperature is not of great concern when a standard laboratory incubator is used, although many are not accurate to 0.5°C. However a less stringent incubation temperature requirement has significant potential benefits for the phase change incubator, as less energy storage requires less PCM, leading to reduced size and cost of the incubator. To this extent a significant part of the development of the phase change incubator has been establishing exact incubation temperature requirements for an *E. coli* test, thereby defining a performance envelope for the phase change incubator.

E. coli in the natural environment may be subject to stress due to conditions such as low temperatures, exposure to oxidising agents (such as chlorine) and nutrient deprivation. It is important for an *E. coli* test to recover injured organisms to ensure that they are detected; as these are more sensitive to incubation temperature than healthy *E. coli,* this will determine the temperature requirement of the phase change incubator.

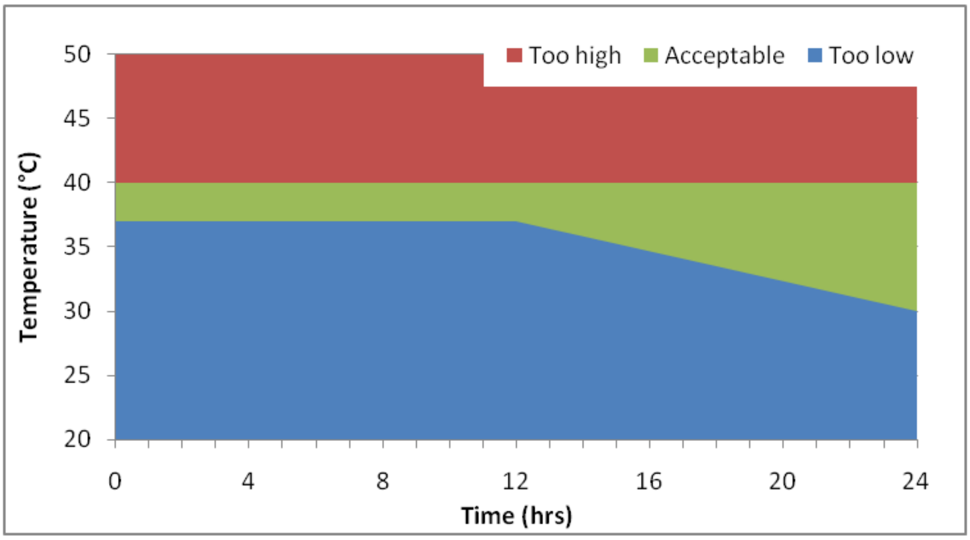

Figure 2: Incubation temperature range that does not affect the recovery of chlorine injured *E. coli*

Error! Reference source not found. Figure 2 shows the acceptable incubation temperature range determined for the recovery of chlorine injured *E. coli*[1]. Using this data the performance of the phase change incubator can be demonstrated. The prototype incubator has been tested for its ability to keep warm a 100ml water sample in a range of simulated conditions. These include hot, cold and fluctuating ambient temperature, cold sample starting temperature and different lengths of charging time. Examples of response to challenging ambient temperatures are given in figures 3 and 4.

Unlike a conventional incubator, the performance of the phase change device is dependant on the ambient temperature, because the amount of energy stored within the system is fixed. However, also unlike a conventional incubator, it has the ability to protect the sample against excessive high temperature spikes.

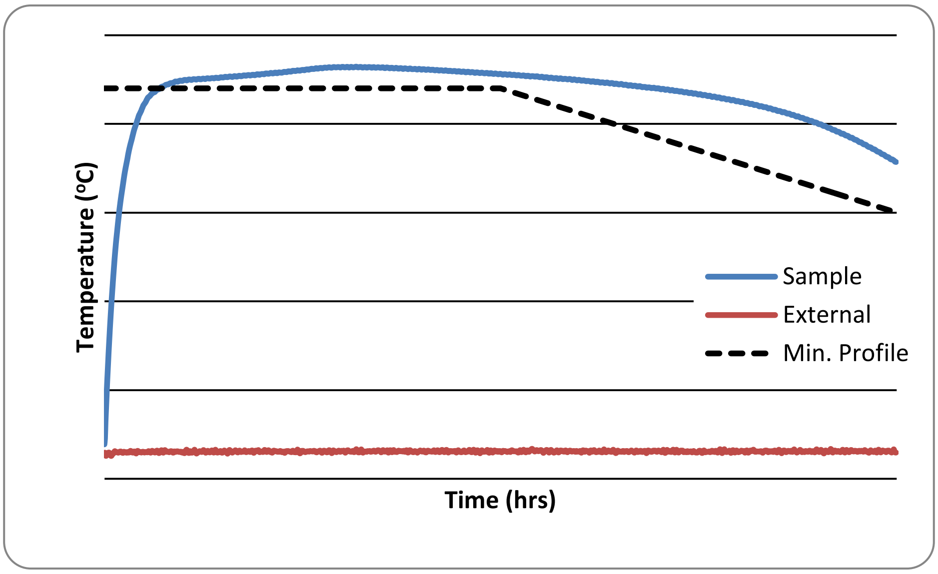

Figure 4: Performance of the phase change incubator in a cold environment with reference to minimum acceptable temperature profile

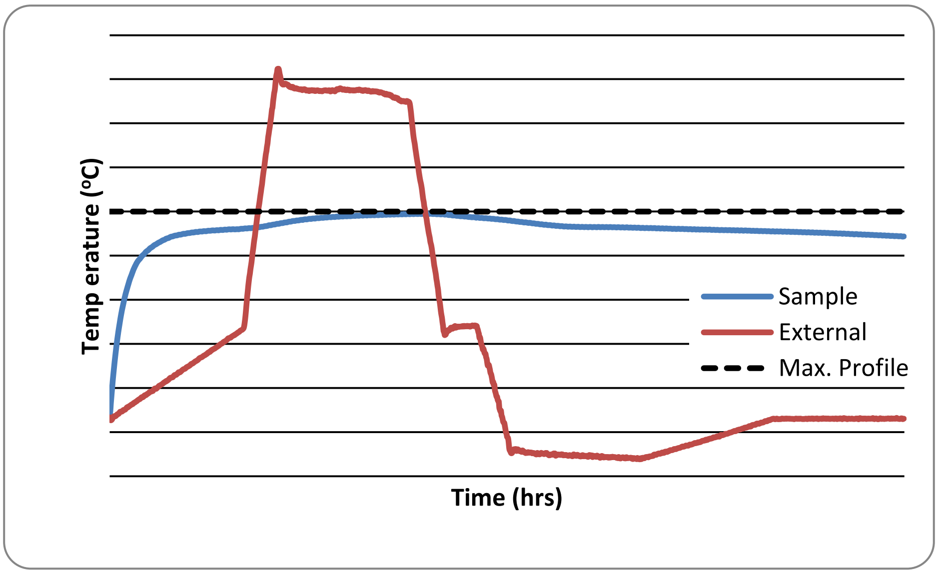

Figure 3: Acceptability of the incubator to protect against spikes in ambient temperature with reference to maximum acceptable temperature profile.

[1] It should be emphasised that this is preliminary data only and this work is still underway

Further Research

To date the incubator has been developed primarily for microbiological water testing. To support trials of the Aquatest device, an initial batch of 1000 is due to be produced for field testing next year. Application of the phase change incubator concept to clinical microbiology or other fields still needs investigation to establish user and technical requirements for specific tests, as described above for an *E. coli* test. This work is currently in the planning stage and is due to start, with the assistance of the Fiona and Nicholas Hawley Environmental Engineering Award, in 2011.

Acknowledgement of Funding

This work was funded by the Bill and Melinda Gates Foundation as part of the Aquatest 2 project.

References

APHA (2005) *Standard Methods for the Examination of Water and Wastewater,* Washington, DC.

SANGHVI, A. P. (1991) Power shortages in developing countries - Impacts and policy implications. *Energy Policy,* 19**,** 425-440.

STANDING COMMITTEE OF ANALYSTS (2009) The microbiology of drinking water (2009) - Part 4 - Methods for the isolation and enumeration of coliform bacteria and Escherichia coli. *Methods for the Examination of Waters and Associated Materials.* Bristol, Environment Agency.

WHO (2004) *Guidelines for drinking water quality. Third edition. Volume 1: Recommendations,* Geneva, World Health Organisation.