Development and Evaluation of Low-Cost Incubator for Testing Microbial Contamination of Private Well Water

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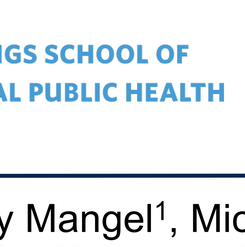
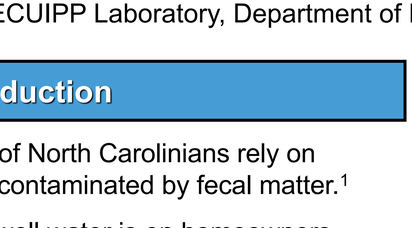
Introduction

- ~15% of Americans and 25% of North Carolinians rely on private wells, which are often contaminated by fecal matter.[1]
- The burden of testing private well water is on homeowners, which is a financial barrier for low-income households.[1]
- *E. coli* is an indicator of fecal contamination in drinking water.[3]
- Low-cost indicator tests for *E. coli* contamination require incubation between 30-44.5°C for approximately 24 hours.[9-14]
- A cost-effective incubator can be implemented in K-12 schools to provide free testing to residents.
- Incubation too malodorous to be implemented indoors.

Methods

- Constructed incubator using Styrofoam cooler, 40W incandescent light bulb, 96-setting low-cost outlet timer, and data-logging thermocouples
- Built on work making functional indoor incubator
- Used data from incubation indoors to create mathematical model of heat loss for outdoor use.
- Equation 1: Heat loss in an incubator





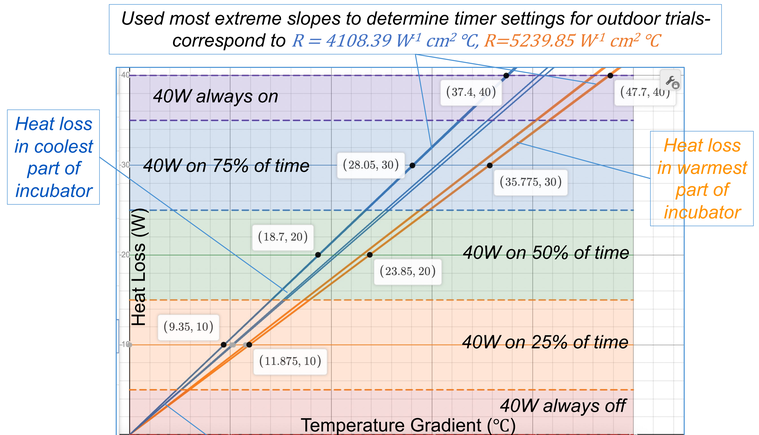
$$Heat\ loss = \frac{Surface\ Area \times Temperature\ Gradient}{R - value}$$

Where temperature gradient = $T_{inside\ incubator} - T_{ambient}$ and "R-value" is an empirical constant that consolidates unchanging variables such as thickness of box, volume of air in box, and heat lost due to box modifications.

- Validated model over various 24-hour incubation trials, testing outdoor temperatures 1-31ºC, wind speeds 0-14mph, and keeping all other conditions as constant as possible.
- Compared performance of *E. coli* compartment bag tests incubated using experimental vs. commercial incubator.

Results

Figure 1: Mathematical Model for Heat Loss in Incubator



Heat loss in incubator according to slopes created by various "R-values." These were calculated at different points in trials when there was a steady state (constant heat loss) with a known temperature gradient.

Figure 2: Outdoor Trials of Incubator Using Model (All in °C)

Timer settings based on model predictions used in outdoor trials. Examples below:

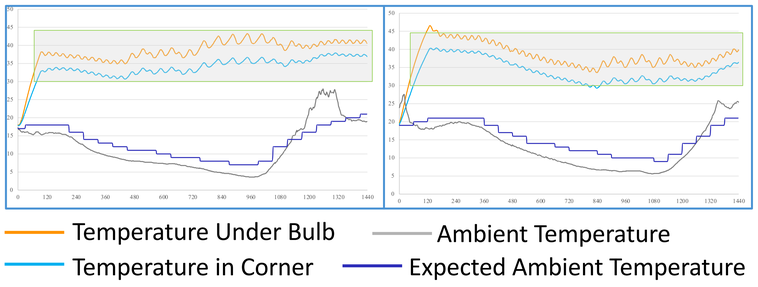
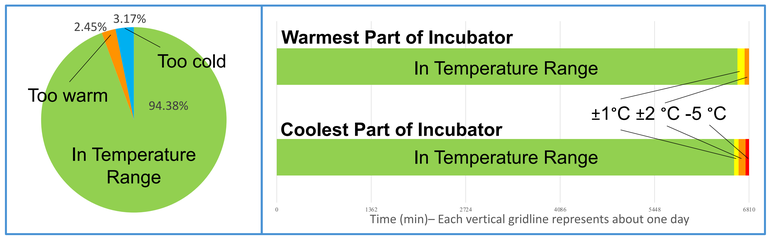


Figure 3: Performance of Mathematical Model Across 5 Trials



Discussion

- Incubator was constructed using only accessible and safe materials with an estimated retail cost of around $25.
- Incubator stays in desired temperature range over 94% of the time using timer settings predicted by mathematical model.
- Key challenges arise at crossover points of ambient temperature 9-11℃ where 40W on for 75% of time is too warm, but 50% is too cold.
- Issues may also arise at -3.2 – 1ºC, but not able to test due to warm ambient temperatures in Chapel Hill.
- Other challenges include large discrepancies between forecasted (used to predict temperature gradient) and actual temperature, and heating too much or little at beginning of trial.

Conclusion and Next Steps

- The incubator is able to maintain temperature range most of the time with a specific Styrofoam cooler and heat source.
- Trialing is needed to determine how much time can be spent outside the temperature range while maintaining *E. coli* growth, as well as to determine what is irredeemably hot and cold.
- Additional work needed to determine whether incubator can be modified to accommodate different conditions, such as more wind, a different Styrofoam box, or other tests with different temperature ranges.
- Piloting program and stakeholder engagement activities to determine the best way to adapt for K-12 use.

References, Contact Information, and Acknowledgements

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