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

UNC Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC

Zachary Mangel¹, Michael Fisher, PhD¹,², Emily Concepcion¹, Timothy Purvis, MSPH¹,², Amanda Northcross, PhD¹

¹ECUIPP Laboratory, Department of Environmental Science and Engineering, UNC Gillings School of Global Public Health, ²The Water Institute at UNC

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
  \[
  \text{Heat loss} = \frac{\text{Surface Area} \times \text{Temperature Gradient}}{R} = \text{value}
  \]
  Where temperature gradient = \( T_{\text{outside}} - T_{\text{inside}} \) 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 1-31°C, 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

- 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°C where 40W on for 75% of time is too warm, but 50% is too cold.
- Issues may also arise at -3.2 – -1°C, 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.

Discussion

- 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 and Contact Information

Special thanks goes to the University of North Carolina at Chapel Hill and the generous donors who support the ECUIPP Laboratory