SteriSol: A Solar-Powered Sterilization and Distillation Unit for Low Resource Areas

Evan Fisch, Joon Hyung Park, Anand Sastry, Ajmal Thanikkal, Rebecca Wells, Advisor: Dr. Conrad Zapanta

BIOMEDICAL ENGINEERING
Carnegie Mellon University

Sterilization in Low Resource Areas

- Surgical Site Infections (SSI) are prevalent in developing countries
  - Caused by lack of sterilization methods for surgical instruments
  - 25-40% of patients in developing countries develop SSIs[1]
  - Can cause MRSA, E. Coli infection, and pneumonia[2,3]
  - High cost of medical autoclaves
- Another issue is the lack of clean water in developing countries
  - Can cause problems such as diarrhea, intestinal worms and arsenic poisoning[4]
  - Affects 1.1 billion people worldwide[5]
- Inconsistent electricity source in developing countries
  - Devices must use renewable energy source

Our Solution

- Dual purpose sterilization/ distillation unit
- Uses a parabolic mirror to concentrate solar energy on a pressure cooker
- Sterilization mode reaches minimum conditions of 120 °C and 15 psi for 20 minutes
- Able to rotate and pitch based on the position of the sun
- Costs under $200

Figure 1: Device in distillation operation

Performance Metrics

Time to reach Sterile Conditions	31 minutes (200 mL)
Distillation Rate	5 mL/min (200 mL in 40 minutes)
Sterilization Cycle Time	51 minutes (200 mL)
Maximum Temperature	120 °C (sterilization) 95 °C (distillation)
Energy Captured	1190 W/m² from the sun
Energy Lost	740 W/m² reflected
Energy Efficiency	38%

Estimation of product costs

Component	Cost
Mirror	$ 14.00
Autoclave Unit	$ 78.32
Frame	$ 37.35
Condenser	$ 16.39
Operations/Misc.	$ 6.98
TOTAL	**$ 153.50**

Description of design

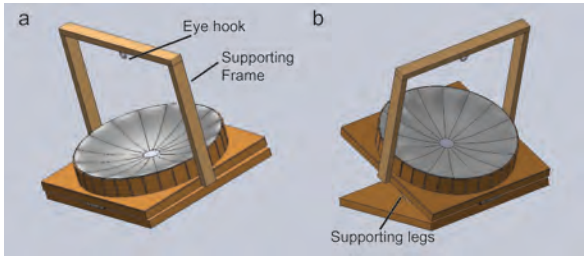


Figure 2: The mirror frame includes a tilting mechanism, as seen here. The autoclave is attached to the frame with an eye hook as shown. The frame can tilt up and is held there by supporting legs. It is also able to swivel with a lazy Susan attachment on the base.

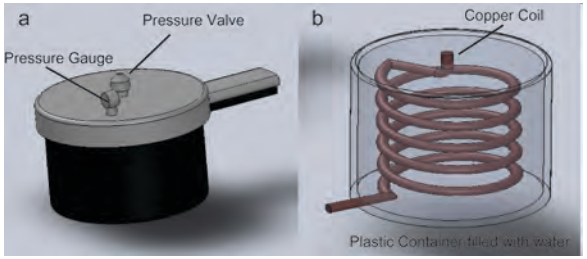


Figure 3: The autoclave chamber (a) is a pressure cooker with an attached pressure gauge, and during distillation, steam flows from the pressure valve to the condensation unit (b), which contains a copper coil in a bucket full of water to condense the steam.

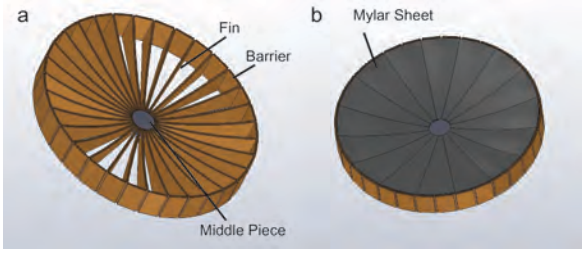


Figure 4: The base of the mirror is made of laser cut fins that are attached together (a). This is then coated with poster board and a Mylar sheet to make a reflective mirror surface (b). This surface is able to concentrate light from the sun that is directed at the autoclave to boil water.

Figure 5: Mechanism for attaining specific pitch and rotation angle for maximum sunlight

Figure 6: Autoclave suspension mechanism in sterilization cycle

Evaluation and Testing

Sterilization Test

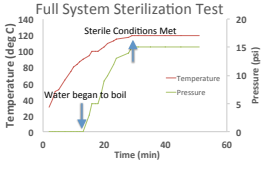
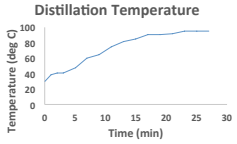


Figure 7: During the sterilization test, we reached sterilization conditions of 120 °C and 15 psi after approximately 31 minutes, and were able to maintain these conditions for an additional 20 minutes to complete the sterilization cycle.

Distillation Test



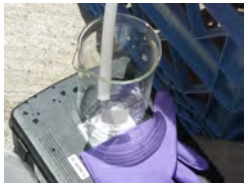
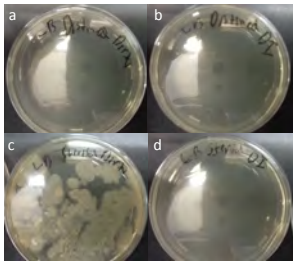


Figure 8: During the distillation test, we reached an air temperature of 95 °C in 23 minutes and distilled 200 mL of water in 40 minutes total. The water vaporizes in the pressure cooker and then travels through a system of pipes and condenses, resulting in sterile water.

Cell Culture Test



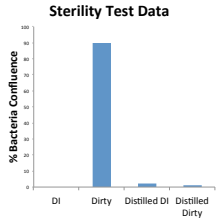


Figure 9: Results of cell culture on water swabs. (a) Distilled dirty water, (b) Distilled deionized water, (c) Original dirty water, (d) original DI water. The graph on the right shows the % bacterial confluence for the average of two plates tested.

Acknowledgements

We would like to thank Dr. Conrad Zapanta, our TA Trent Wells, and our advisor Dr. Carl Ross, for their help on this project.

References

(1) Zuniga, Nick; Tseng, Laura; and Stein, Holly. Panel Discussion. Global Health Brigades. 31 Oct. 2013.
(2) Gawande, Atul, and Weiser Thomas. World Health Organization. *WHO Guidelines for Safe Surgery*. 2008. http://gawande.com/documents/WHOGuidelinesforSafeSurgery.pdf
(3) Mawalla, Brian, Stephen E. Mshana, Phillipo L. Chalya, Can Imirzalioglu, and William Mahalu. "Predictors of Surgical Site Infections among Patients Undergoing Major Surgery at Bugando Medical Centre in Northwestern Tanzania." *BMC Surgery*. (2011): 21.
(4) *"Global Water Supply and Sanitation Assessment 2000 Report - Chapter 1." Global Water Supply and Sanitation Assessment 2000 Report.* World Health Organization. 14 Oct. 2013.
(5) World Health Organization (WHO). (2008). Safer Water, Better Health: Costs, benefits, and sustainability of interventions to protect and promote health; Updated Table 1: WSH deaths by region, 2004.