Solar Distillation in Rajasthan, India

Eric Spooner and Lisa VanBladeren

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Supervised by Professor Kimberly Gray

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Introduction

Background

In rural India water sources are limited. Often the only available drinking water is saline, may have an elevated fluoride concentration, and may also have a significant fecal coliform load. This poor water quality often causes sickness among villagers. Solar distillation offers an opportunity to provide a low-tech solution yielding high quality water for people living in rural Rajasthan. In this desert region there are very few overcast days outside of the monsoon season, allowing solar distillation to be viable throughout much of the year. While solar stills are able to remove salts and pathogens, their yields are relatively low and the direct ingestion of distilled water is not necessarily desirable. Instead of directly drinking the distilled water it can be blended with traditional water sources. For instance, mixing the distilled water in a 1:1 ratio with the current supply may significantly reduce deleterious health effects from dissolved salts and pathogens. The appropriate mixing ratio would need to be determined and is likely to vary over an annual cycle.

Project Goal

Design a small household solar still that can be built by villagers. This still will enable them to increase the quality and safety of their drinking water.

Objective

Designing and building a still to be used in rural Rajasthan requires overcoming a few constraints. Preliminary research identified characteristics that produce higher yields. We also wanted a design that is inexpensive and easy to build. Constructing it solely from locally sourced materials in Jodhpur, India will ensure that materials are accessible. These objectives aim to guarantee that the solar still can be easily adopted and employed.

Design Options

Many different types of solar distillation systems were researched. We considered the following types of solar stills; their rates of water production are reported in Table 1.

1. *Angle*

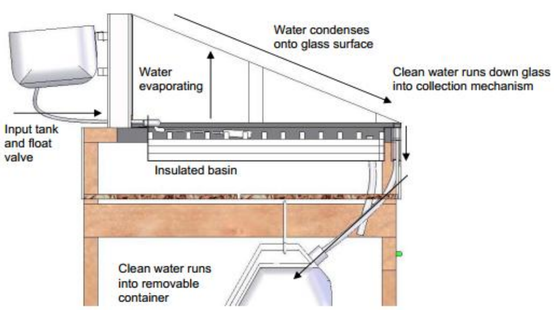
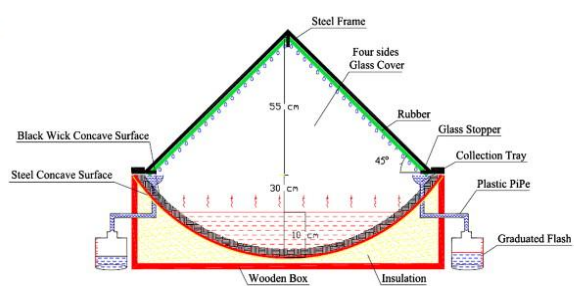


Figure 24: Design Overview

(Anburaj 2013, Coffrin et al. 2007)

2. *Pyramid Still*



(Kabeel et al. 2009)

3. Double slope

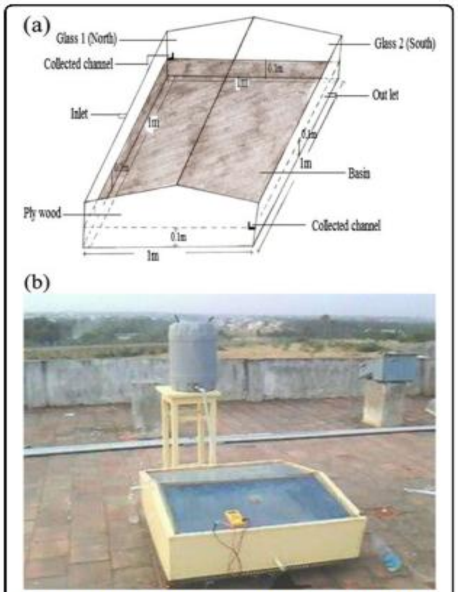
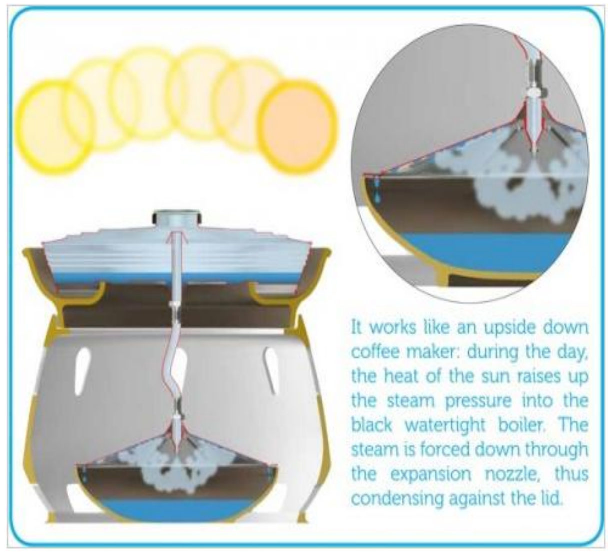


Figure 1 Schematic diagram of double-slope single-basin solar still (a) and photograph of experimental still (b).

(Kandasamy et al. 2013)

4. Eliodomestico



(Diamanti n.d.)

Table 1: Solar Still Type and Yield

Still Type	Yield (L/m^2/day)
Angle	2-4.2
Pyramid	2.8-4
Double Slope	Up to 3.2
Eliodomestico	Up to 5

After researching designs, output, and material requirements we decided that both the small angle type solar still and the eliodomestico design met all of our requirements. While the eliodomestico is potentially a high output design, there are no available studies to verify the projected output. It is also relatively expensive and made out of materials that are fragile and hard to obtain. The complexity and potential fragility of the hemispherical and pyramid designs along with their relatively low output made them poor choices. Angle type stills tend to have relatively decent outputs in the range of 2 to 4 liters a day per square meter of glass surface and are easily constructed using readily available building and plumbing materials.

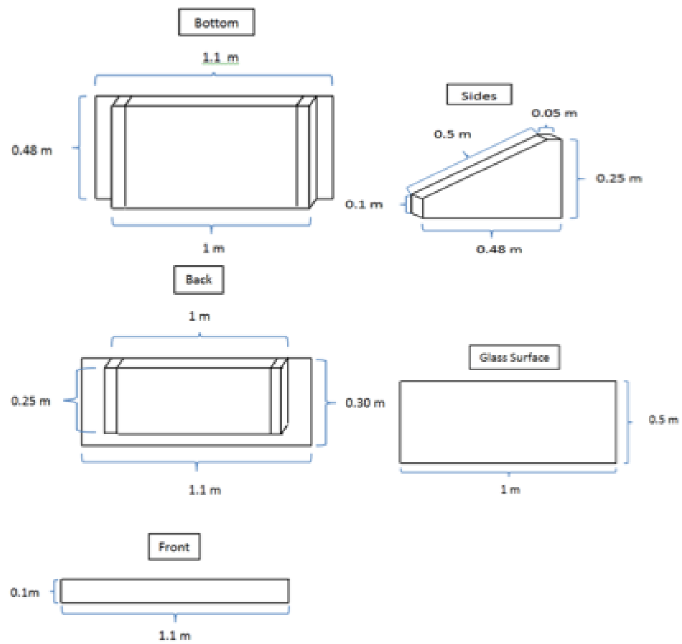
Our Design

The angle still was built using a basic metal elbow bar, plywood, glass (0.5m^2), timber 2x2's, plastic tubing, an angle bar, wood glue, nails and black waterproof caulking for coating the inside to increase the absorption of sunlight. This design allows for insulation around the water basin to retain warmth into the night when the air temperature drops and the glass cools. As the temperature differential across the glass increases, more condensation forms, potentially allowing the still to produce into the night.

The original angle still design included a float valve which regulated the water level and enabled the basin to be continually fed water while maintaining a water depth that has proven to be most efficient; 2-3cm (Coffrin et al. 2007). However, in Jodhpur we could only find large float valves that were not suitable for the scale of our still. As a result, we manually filled the still with 4 liters of water at a time. Additionally design components included a 30-degree slope of the glass surface, and space surrounding the basin for insulation. The final cost of the still was 2,512.00 Rs. as can be seen in Table 2. While this equates to roughly 42 USD, the price will make the still unobtainable for many low-income village households.

Table 2: Materials and Cost

Material	Count	Rupees
Nails		20
Screws		30
Glass (1m x 0.5m)	1	260
Caulk	4	500
Pipe Elbow	1	
Pipe Segment	1	146
Pipe Nozzle	1	
Pipe Sealant Tape	1	
Angle Bar	1	70
Wood Glue	4	200
Saw	1	100
Plywood		
- Front: 1m x .10m	1	
- Side Piece:	4	
- Bottom Inside: 0.43m x 1m	1	680
- Bottom Outside: 0.53 x 1.1m	1	
- Back Outside: 0.30m x 1.1m	1	
- Back Inside: 0.25 x 1m	1	
2x2		
- Bottom, Back: 1m	3	
- Back, side: 0.25	4	506
- Side Angle: 0.5m	2	
- Side, Bottom: 0.48m	4	
Total		2,512.00
USD (60Rs/dollar)		41.87





Materials acquisition
A primary objective when designing the solar still was to ensure that all materials and tools necessary were available locally. While we were eventually able to obtain all required materials locally it was not as easy as we had expected.

Difficulties

- Language barrier
    - Problematic when trying to explain specific materials needed
- Inexperience with local markets
    - Stores specialized to one particular material

        - Requires many different stops
        - Very time intensive to compile all materials
    - Multiple trips necessary to acquire precise materials
        - No standard cuts - every material is cut to desired length on site with very little accuracy
            - Example: angle bar was cut to requested length from long reclaimed angle bar and hammered to shape
            - Timber 2x2's cut from raw log so sides were not smooth making it difficult to create a tight seal when assembling the still
        - No small sized float valves available
            - Limited to large toilet style float valves not suitable for the scale of our solar still
    - Inflation of prices because we were foreigners

Shopping for materials in Jodhpur

Suggestions

- Markets: Local knowledge helps
    - Some stores do sell multiple items. If it is possible to locate these stores, start purchasing here
        - Finish the shopping trip with the material specific stores which tend to target larger items (i.e. glass, angle bar, wood)
    - Prepare drawings and images of each specific piece to help communicate what is needed
        - Include measurements
    - Float Valve
        - This was the only component not available at the market
        - Purchase in U.S. or order from internet prior to leaving
        - Possible to work around this constraint
- Non standardized materials
    - Allow for imprecise measurement but compensate with,
        - Extra sealant for basin
            - Our basin leaked at first due to curvature of wood structure
        - Design flexibility
            - Example: we had to construct supports for the glass that was slightly recessed in the basin
- Experience with building still
    - Building a still prior to trip is advised for future still focused projects
        - Reduces trips to the market
        - Allows for quicker assembly
            - More time for testing

Testing

When we tested our still the monsoon had just started (last week of July 2013), so there was very little bright sunlight during the day. Some modifications of the still itself could also increase efficiency. For testing, the still was filled with four liters of water obtained at the JBF headquarters. After 12 hours of daylight on an overcast day, the still produced one half liter of water. This was repeated the following day under similar weather conditions resulting in an overall yield of one liter per meter squared of glass surface.

Recent tests (November 2013) performed by a colleague (Benjamin Shorofsky) have been done with full days of sunlight and have produced up to one liter of distilled water over the same 12-hour time frame. However, in order for the household solar still to be a viable source of water the yield needs to increase. We are hoping this can be done after time is spent developing a more efficient solar still that produces more than we were able to with our design. The following design considerations and testing suggestions aim to address this issue.

Design Considerations

- Materials
  - Upon further research we do not believe silicone caulking is ok to use since water is for human consumption
    - Need a good insulating materials that is safe
- Feeding basin and float valve
  - Maintain constant water level
    - Based on research about 2-3 cm of water is most efficient
- Plug for filling hole
  - A plug was rigged, but it did not have a good seal
  - A proper plug will eliminate heat loss
- Other considerations
  - Eliodomestico style system
    - Reports good yields (5 liters per day)
      - Should be tested first hand
    - Similar cost ($50 USD)
    - Different mechanism for capture may be more efficient under the conditions in Rajasthan
    - No glass necessary
  - Wicking materials may help to enhance evaporation
    - Cotton or cloth
      - Easy to obtain in Jodhpur
  - Use reflective surfaces
    - Will concentrate sunlight to increase temperature
    - Could increase low yields
  - Evaporative cooling on glass surface
    - Has been used in other designs to increase condensation

Testing Suggestions

- More testing days
  - Time constraints only allowed us to test our still over two days
  - Ensures ample days of sunlight
    - Both of our testing days were overcast
      - Still produced distilled water but yield was low
  - Allows better approximation of yield
- Test water quality

    - Material safety
        - Caulking
            - Temperature sensitive-- could melt and contaminate water
        - Metal elbow joint and plastic tubing
            - Could contaminate water or foul over time
    - Identify contamination sources
        - Particulate matter from wind
        - Potential for microorganism growth
            - Our testing was not long enough to test for this
            - Could form on collection surfaces, piping or basin
                - Can design for cleaning - bleach widely available in region
- Test other solar still designs
    - Other designs excluded from this study cited relatively low yields but may prove to produce more under the conditions present in Rajasthan

Conclusion

The solar still that we designed and built produced roughly one to two liters of water per square meter of glass surface per day. We believe that this yield can be increased through design alterations. While the solar still alone will not produce enough water to meet the daily drinking water needs of a Rajasthani household it can be blended with current water sources to decrease negative health effects resulting from poor water quality. The materials used to build the still are available at local markets in the city of Jodhpur and are relatively inexpensive. These two parameters were important in our design because many of the Rajasthani villagers work in Jodhpur, often in construction related jobs, and therefore have the accessibility and skills to assemble a solar still. Additionally, allowing flexibility in the still design and having a well thought out plan with pictures and measurements helps streamline the materials acquisition process and minimize complications from imprecisely cut and measured materials.

Resources

Anburaj, P. et al. “Performance of an Inclined Solar Still with Rectangular Grooves and Ridges”. Applied Solar Energy Vol. 49 No. 1. pp 22-26. 2013. <http://download.springer.com.turing.library.northwestern.edu/static/pdf/738/art%253A10.3103%252FS0003701X13010027.pdf?auth66=1386896524_21a7c2649c5d4347bb1919e8f014aac8&ext=.pdf>

Coffrin, Stephen et al. “Solar Powered Water Distillation Device”. Northeastern University. Dec. 04, 2007. http://iris.lib.neu.edu/cgi/viewcontent.cgi?article=1094&context=mech_eng_capstone&sei-redir=1&referer=http%3A%2F%2Fwww.google.com%2Furl%3Fsa%3Dt%26rct%3Dj%26q%3Dlarge%2520solar%2520still%2520design%26source%3Dweb%26cd%3D13%26cad%3Drja%26ved%3D0CGkQFjAM%26url%3Dhttp%253A%252F%252Firis.lib.neu.edu%252Fcgi%252Fviewcontent.cgi%253Farticle%253D1094%2526context%253Dmech_eng_capstone%26ei%3DpMuOUfztMbOFyQGPyYFI%26usg%3DAFQjCNH2KcxZmwrpV14SzFYBHq5EM-9hUQ#search=

Diamanti, Gabriele. “Eliodomestico: How does it work?” gabrielediamanti.com <http://www.gabrielediamanti.com/projects/eliodomestico---how-does-it-work/>

Kabeel, A.E. “Performance of solar still with a concave wick evaporation surface”. Energy Vol. 34 Issue 10. Oct. 2009. pg 1504 - 1509. <http://www.sciencedirect.com.turing.library.northwestern.edu/science/article/pii/S0360544209002643>

Kandasamy, Shanmugasundaram et al. “Performance correlation for single-basin double-slope solar still”. International Journal of Energy and Environmental Engineering. Vol. 4 Issue 4. 2013. <http://download.springer.com.turing.library.northwestern.edu/static/pdf/151/art%253A10.1186%252F2251-6832-4-4.pdf?auth66=1386889608_25fab68df30f288bda15f43794c5d6c2&ext=.pdf>