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*{inquiry-ACES: Highlights of Undergraduate Research in ACES}*

## The efficiency of a Pyramid-shaped solar still

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### ABSTRACT

Clean water is essential for human life. The availability of clean water affects people worldwide. A large number of people without direct access to clean drinking water live within close proximity of an ocean, and therefore have direct access to saltwater. A low-cost, sustainable method for removing the salt from the water would have huge benefits for these people. Different types of desalination models have recently been developed to remove salt and purify the water. However, these models either have a very low yield of purified water or are cost prohibitive for most people in poor regions of the world. The objective of this study was to create a cost-efficient solar-still desalination model that can be used anywhere in the world, especially in developing countries that currently lack the infrastructure and resources to provide clean water to residents. The system designed in this study was able to effectively evaporate water in the first step of the purification process. However, only preliminary results were obtained due to time limitation and the need to make design modifications to improve the collection of the evaporated water.

## INTRODUCTION

With an increasing human population, there is also an increasing need for clean water. In dry areas of the world, the issue is finding a source of water, while in other areas the issue is treating an existing source of water and making it suitable for drinking and cooking. According to the USGS, the earth is 71 percent water. Water exists in water vapors, rivers, lakes, glaciers, in the ground as moisture, and oceans. Oceans hold about 96.5 percent of all of the Earth's water. However, only a small portion of the Earth's water is freshwater that is safe for human consumption, leaving about 748 million people without access to safe water. The lack of clean water kills about 1,400 children a day (Crowe, 2014). To look at the bigger picture, access to clean water can save lives, especially in the developing world. Creating a cost-efficient water purification system for developing countries would save lives each and every day. The clean water could be used to feed another starving mouth and hydrate a thirsty body. In third-world countries

such as Malawi and Eritrea, families spend a total of approximately \$1.60 and \$ 2.50 per day, respectively, compared to citizens in the United States that spend about \$114 per day (IMF, 2005). Bottles of water in America can cost more than \$3 dollars, so it's evident that those citizens in places like Malawi and Eritrea struggle daily for clean water and food. Between food, water, and shelter, something is missing in these poor nations. These countries are the ones that are seen on television with kids often not having shoes to walk down the street. These citizens need help, and such a low-priced and lifesaving water purification system could be one answer.

Clean water improves living conditions overall. A system that uses solar energy to purify water gives accessibility to clean water for entire communities. It will reduce long trips to travel to far regions to get clean water. Apart from drinking, clean water can be used for other purposes such as agriculture, cooking and

industrial purpose. So, clean water can also improve economies.

The use of solar water purifiers helps solve many water issues. The purification systems that are being designed and built based on solar energy can help in mitigating several environmental problems caused by other sources of energy such as fossil fuel. The purpose of the water purifiers is to use sunlight to heat the water, evaporate the contaminated water inside, and separate the clean water from the dirty source water. The trapezoidal-system selected for this study is designed in such a way that it is capable of receiving direct sunlight from all sides of the device for a large portion of the day. This system will be effective for purifying saltwater, helping regions near oceans that demand more pure water, and helping regions with contaminated water that have no other way to receive clean water. Desalination offers the potential of an unlimited source of fresh water purified from oceans with high levels of saltwater (Cooley et al., 2006). The designed purification system is an economical and more environmentally-friendly measure for water purification compared to other available options.

Although solar energy is free and the solar desalination plants are ideal, they are currently too expensive on a large scale, especially in developing countries. Therefore, smaller models are gaining popularity for desalination. California, for example, is an area that is in need of a desalination plant and is able to afford to do so. In Africa, a smaller model that can produce a few gallons per day will be more efficient than a system that costs more than a billion dollars to build. The smaller models are more convenient because they can be transported, are easy to use, and are a household item. Smaller models can be used for many purposes and in many locations, instead of a large plant that is controlled by a company or the government.

## LITERATURE REVIEW

As the world population increases, the demand for clean water also rises. Many regions of the world have access to sea and ocean water, but to purify it with conventional evaporation and condensation methods is expensive and energy intensive. Solar water distillation is a very old technology. An early solar still was built in 1872 to supply drinking water to a mining community in Chile (Bounds, 2012). Although the idea of solar desalination plants is visionary for the future, this idea also has some

drawbacks. The advantages of seawater desalination are it would be very reliable because of the necessary environmental conditions needed to effectively purify water. The process creates high quality water and removes impurities from the water. Lastly, it can be easily utilized by local residents of almost any area, allowing them to control the supply of their water. The largest disadvantage is high cost. The cost can be as high as \$2,000 per acre foot of purified water (Walsh, 2014). There is much room for improvement with the solar still system, in terms of energy efficiency, before it can be considered “green” and good for the environment. Also, there can be many environmental impacts on marine animals and plants using current desalination methods, as operations are very expensive, poorly designed, or inappropriately located (Cooley et al., 2006). California is facing one of the most extreme droughts in history, but it is one of the few locations that can potentially host such a plant and have success. Some third-world countries barely have \$15 dollars a day to spend and would not be able to pay for such a plant using currently available technology.

Many scientists have determined that creating smaller and more cost efficient models are more practical for use around the world. Solar distillation can be cost effective at a smaller scale. It starts to get very expensive and costly when used on large scales. Building plants for agriculture is a very good example. Also, agricultural water usage is not so simple, as it requires a large amount of water to be produced, eventually making the water more valuable than the actual crops (McCracken and Gordes, 1985).

During the process of solar desalination, the sun rays pass through a clear surface like glass, then inside turn into heat waves. As the water heats up, it soon starts to evaporate. The water vapors rise and leave the impurities in the original container. The purified water then condenses and gravity allows the water to run down the tilted surfaces and into a collection point to be stored and used.

The materials used for any model should have long life expectancies or be designed to allow for the convenient replacement of faulty parts. It should be sturdy and ready for weather impacts, since the model would be outside much of the time. The model should be designed for durability and easy portability. It should also be easy to operate for people with little background

knowledge on solar desalination.

The largest problem when building a model is choosing the suitable material. The type of material, durability, local availability, skill needed, cleaning, portability, and toxicity heavily affect what material is best for efficient operation of the model.

Another comparison issue comes when looking at the materials used for the sunlight to pass through. The first critical variable is the transmittance, because without that, there will not be sufficient sunlight to heat the water and cause evaporation. The cost, weight, resistance, life expectancy, wettability, solar magnification, and infrared light affect each design. This type of model has the ability to use different materials to accommodate the greatest efficiency based on the desired geographic location and environmental conditions. Every model can be different and fabricated for use in varying environments, climates and uses. The water container must keep the water safe without leaking, absorb solar energy, support and hold the water, and limit heat loss to keep the water evaporating. The profitability of the models vary by the cost of water produced, availability of sunlight, cost of local and available materials, cost of local labor and cost of important materials.

The United States has already started producing small solar desalination models called “water honchos”. The honchos produce between 1-1.5 gallons of clean water a day. The Honchos filter out radiation, fluoride, salt, and other any contaminants from any water. Even though the Honcho is one of the more efficient commercially-available systems for purifying water, the unit price is \$359 (Purest Filters, 2014). The item is made of plastic and some pipes. This Honcho would be useful to many people, but the product is cost prohibitive for many consumers. For third-world country citizens, they can barely buy a case of water for their household. The price of the Honcho is about the same price some citizens in third-world countries earn in a year. Therefore, the primary goal of this project is to develop a system for purifying water that is affordable and convenient for many people (Purest Filters, 2014).

## METHODOLOGY

All the necessary materials to build the solar still were purchased at a local store and mirror shop. Once all materials were collected, the process of building began. First, the storage containers were cut according to the

ideal design. Once cut with a utility knife, the edges were shaved and smoothed with a file. Then, the inside of the lid was chiseled and removed of all plastic blocking the flowage of water. The next step was to drill holes on one end to allow the purified water can drain into the collection container. When the model was constructed, the clear plastic wrap was placed on top of the model, black masking tape was used to secure the wrap and cover the container to trap heat inside the system. The black tape helped with trapping inside the container, which aids in expediting the evaporation process. To test the model, the aluminum pan was placed inside the model with 500 ml of water inside. The aluminum pan was wrapped in a black trash bag to increase the heat trapped from the sun waves. The model was placed on top of a cooler and sloped slightly to direct the purified water to the collection hole.

The model design can be seen in Figures 1-4. The model was cut in a triangle shape at the top, leaving the top open. The base of the model was kept solid to mount the mirrors on the side. My model was created small for experimental purposes, with the ability to increase the scale for higher demand needs.

The mirrors were used to intensify the effect of sunlight on the evaporation of water. There were three mirrors added using construction adhesive. Two were added across from each other on the sides. Another mirror was added on side perpendicular to the shorter sides. The three mirrors were used to divert most of the sun rays falling on the still into the aluminum pan. The mirrors were added close to the bottom of the model so enough sunlight could enter, and the sunlight would reflect off the mirror directly to the source of water.

**Figure 1**

Photograph showing the triangular shape of the top of the solar still.



**Figure 2**

Photograph showing the bottom (outside) of the untreated water pan covered in black tape.



**Figure 3**

Photograph showing the top (inside) of the untreated water pan that has the outside covered in black tape.



**Figure 4**

Photograph showing the whole solar desalination system during one of the experimental runs.



### *Materials*

- ✓ 29 qt storage container (plastic) 2.4 cm W x 30.4 cm D x 33 cm H
- ✓ Black masking tape
- ✓ Hammer
- ✓ Pliers
- ✓ Scissors
- ✓ Filers
- ✓ Chisels
- ✓ Ruler
- ✓ Measuring tape
- ✓ Mirror construction adhesive
- ✓ Pocket Pro Salinity Tester
- ✓ Clear plastic wrap
- ✓ Wireless thermometer
- ✓ Trash bags
- ✓ Mirrors
- ✓ Utility knife
- ✓ PVC Pipes
- ✓ PVC pipe Ratcheting pipe cutter
- ✓ Graduated Cylinders
- ✓ Aluminum baking pan

## **FINDINGS**

Due to time limitation and design flaws, it was not possible to collect the desired data for this experiment. The solar desalination design went through several iterations, requiring additional materials and construction each time. In addition, the project also relies on sunlight and heat. We experienced a very mild summer for Central Illinois, with many cloudy days, sometimes accompanied by rain. For future testing, it is recommended that a high-intensity light source be located and used to expedite heating up the inside of the solar desalination system.

The experiment was not able to reach the point of measuring the purity of the water. Only very preliminary results were obtained for estimating the amount of water that evaporated from the untreated pan. Based on the observations, it was estimated that this system can generate between 100 mL and 175 mL of evaporated water out of 500 mL water added to the pan, which would theoretically be condensed and collected at the outlet of the system. This unit measurement for the treatment of water is intended to be used as a design parameter. If the water demand is known for a household or small community, the size of the solar desalination system can be scaled accordingly to produce the desired amount of purified water based on the purification rate.

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