TEN YEARS OF SOLAR DISTILLATION APPLICATION ALONG THE U.S.-MEXICO BORDER

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ABSTRACT

For the past decade, solar distillation has been introduced and applied as an option for household drinking water for several colonias communities along both sides of the U.S.-Mexico border. Purifying water through distillation is a simple yet effective means of providing drinking water in a reliable and cost-effective manner. Solar stills effectively eliminate all water borne pathogens, salts, and heavy metals. Solar distillation produces an ultrapure water that is superior to most commercial bottled water sources. Three organizations have been active in promoting the use and development of solar distillation on the Border, namely the El Paso Solar Energy Association, New Mexico State University, and SolAqua. Commercial still costs were halved over the past decade due to manufacturing improvements. Over 200 Borderland families have adopted cost-shared solar distillers to meet their drinking water needs. In addition, SolAqua has worked with Sandia National Laboratories with accelerated aging and other materials testing. This paper discusses solar still performance and acceptance along the U.S. Mexico border.

1. INTRODUCTION

The arid U.S. Mexico Border faces serious water supply issues that are comparable to those found in many parts of the developing world. There is one leading solar energy technology in particular that can literally revolutionize water quality throughout the less developed world with widespread adoption: solar distillation. This technology not only purifies water sources, but also effectively desalinates.

On both sides of the U.S.-Mexico border, there are many unorganized and incorporated communities, called colonias that have limited infrastructure development, including water supply. For instance, there are over half a million people that live in colonias in the immediate Ciudad Juárez County (Chihuahua) – El Paso County (Texas)– Doña Ana County (New Mexico) tri-state/bi-national region. For many persons, safe drinking water can only be acquired at a premium price and by purchasing and hauling potable water from elsewhere. A number of Border communities, such as Palomas (Chihuahua) – Columbus (New Mexico) and Ojinaga (Chihuahua) – Presidio (Texas) municipal water supplies do not meet international drinking water standards and are laced with high arsenic and fluoride levels. Solar distillation offers a real and effective solution for Border families to clean their water supplies on-site.

Over the last decade, there has been an effort to develop solar distillation technology and apply it along the Border to meet drinking water needs. The El Paso Solar Energy Association (EPSEA) has been working with with SolAqua Inc., Sandia National Laboratories, and New Mexico State University (NMSU) to further develop the technology and demonstrate its practicality along the Border in applying an innovative, effective, simple, and decentralized on-site water treatment system that can provide safe water in a cost-effective and reliable manner. This effort began in earnest from 1994-97, originally with sponsorship from the Texas State Energy Conservation Office (SECO). An initial grant

was used to design and build a solar distiller for colonias in El Paso County. Original plans were to have families build their own stills, but most did not have the skills nor inclination to do so, athough a good construction guide for building solar stills was developed and has been disseminated around the world (1). EPSEA worked closely with NMSU during this initial pilot demonstration, where 40 pilot 3' x 8' solar distillers were built by EPSEA and distributed to colonia families and health clinics in West Texas (2).

Progress continued during 1998-99 as NMSU worked with the U.S. Economic Development Administration to test solar still effectiveness at removing contaminants. The project also included the deployment of pilot stills in Columbus, New Mexico. EPSEA built 33 stills distributed to residences in southern New Mexico. The NMSU pilot study showed that solar stills effectively eliminate all salts, heavy metals, bacteria, and microbes from contaminated water sources. Testing even reported successful removal of some pesticides (due to UV rays, high temperatures, and atmospheric venting), although recommendations remain to use a carbon filter with stills for guaranteed removal of all volatile organic compounds (3). NMSU also conducted a willingness-to-pay study along the Border to help determine a baseline for further technology commercialization.

The projects evolved to the point that solar stills could no longer be made in the garage on a one by one basis, and an El Paso solar still commercial enterprise was spun out in 1999 called SolAqua to commercialize production. SolAqua immediately began furthering the design and development of the technology with EPSEA, NMSU, and Sandia National Labs. SolAqua has made vast improvements in manufacturability and materials and received its first solar still patent in the U.S. in 2004.

Meanwhile, EPSEA continued to implement solar distillers in Texas, New Mexico, and Chihuahua. Two grants were awarded by the Border Partners in Action (BorderPACT) Network sponsored by CONAHEC to disseminate solar stills distributed to 27 Mexican families in Chihuahua (4). EPSEA also won a community challenge grant from EPA to distribute stills to 80 families in Texas and New Mexico from 2000-02. For these demonstration projects, families were asked to provide a cost-share for solar stills. In addition individual stills have been purchased directly from SolAqua by Borderland families and elsewhere on the internet. SolAqua has also provided solar distillers for a variety of water purification projects throughout the world, such as an Australian aid project on the island of Vanuato in the South Pacific, Winrock International in San Luis Potosí, Mexico, Fundación Solar in Guatemala, etc.

2. CAPABILITIES

A solar still operates using the basic principles of evaporation and condensation. The contaminated feed water goes into the still and the sun's rays penetrate a glass surface causing the water to heat up through the greenhouse effect and subsequently evaporate. When the water evaporates inside the still, it leaves all contaminants and microbes behind in the basin. The evaporated and now purified water condenses on the underside of the glass and runs into a collection trough and than into an enclosed container. In this process the salts and microbes that were in the original feed water are left behind. Additional water fed into the still flushes out concentrated waste from the basin to avoid excessive salt build-up from the evaporated salts.

A solar still effectively eliminates all waterborne pathogens, salts, and heavy metals. Solar still technologies bring immediate benefits to users by alleviating health problems associated with water-borne diseases. For solar stills users, there is a also a sense of satisfaction in having their own trusted and easy to use water treatment plant on-site.

Solar still production is a function of solar energy (insolation) and ambient temperature. Typical production efficiencies for single basin solar stills on the Border are about 60 percent in the summer and 50 percent during the winter. Single basin stills generally produce about 0.8 liters per sun hour per square meter. Measured daily solar still performance for a square meter for two days is shown in Figure 1 below:

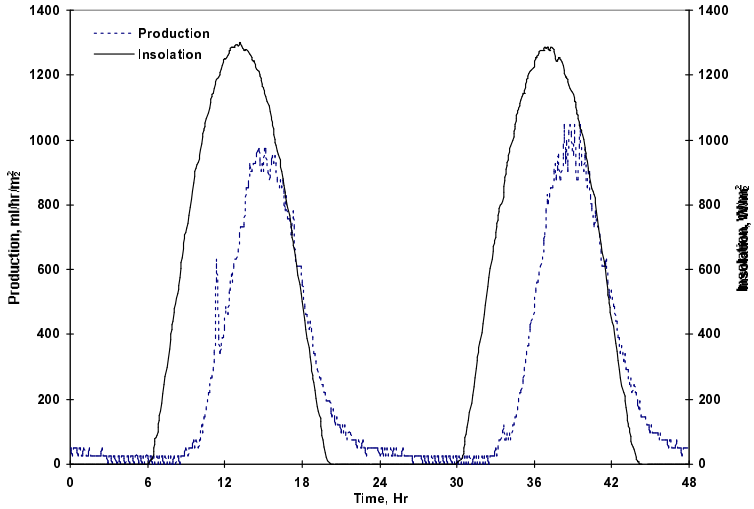

Fig. 1. Solar insolation and measured solar distillate production over 48 hours in southern New Mexico. Notice how distillate production lags insolation and continues even after sunset.

Solar stills have proven to be highly effective in cleaning up water supplies and providing safe drinking water. The effectiveness of distillation for producing safe drinking water is well established and long recognized. Distillation is the only stand alone point-of-use (POU) technology with NSF (National Sanitation Foundation) certification for arsenic removal, under Standard 62. Solar distillation removes all salts, as well as biological contaminants (e.g., *cryptosporidium, e. coli,* etc.).

TABLE 1: STILL PURIFICATION CAPABILITIES

Water	**Conductivity** µS/cm	**Hardness** ppm	**Iron** ppm
Feedwater	1180	371	0.48
Distilled Output	1.8	0.10	0.06

3. STILL OPERATION

General still operation is very simple and requires facing the still towards solar noon, putting water in the still every morning or evening to fill and flush the basin, and recovering distillate from the collection reservoir (e.g., glass bottles).. Stills are modular and for greater water production requirements, several stills can be connected together in series and parallel as desired.

As water evaporates from the solar still basin, salts and other contaminants are left behind. Over time, these salts can build to the point of saturation if the still is not properly maintained and basin flushed on a regular basis. Properly operating a still requires adding about three times as much make-up water as the distillate water produced each day (e.g., if the still produced 3 gallons of water, 9 gallons of make-up water should be added, of which 6 gallons leaves the still as excess). The excess water flushes the still basin through the overflow to prevent salt buildup. If this is done on a daily basis, the flushed water is of approximately the same quality as the original feedwater that was added to the still. The excess water is of suitable quality that it can be used to water landscaping, wash pots and pans, etc. No sediments or sludge will buildup if the still is properly operated and flushed daily at about three times daily distillate production.

There exists a misconception in some circles that drinking distilled water might be detrimental to one's health. EPSEA has now met health conscious people who have only used distilled water for over 40 years in some cases. In fact, distilled water is quite beneficial as related by Dr. Andrew Weil from the University of Arizona (5):

"I meet people who object to drinking distilled and purified water because it has been "robbed" of its mineral content. We get trace minerals from foods, especially fruits and vegetables, not from water, and the benefits of purifying drinking water are myriad. It is your best protection against ingesting a host of toxins and pollutants that are serious threats to health."

4. BORDERLANDS SOLAR STILL EVOLUTION

Solar still technology has gradually been improved over the past decade along the Border. The greatest problem for the first generation stills designed by EPSEA in the mid-1990's (an improvement on the original McCracken solar still) was that when they dried out, the inner membrane silicone lining would outgas. This in turn deposited a fine film on the underside of the glass, causing the water droplets to bead up and fall back into the basin rather than trickle down the glass to the collection trough and thus still water production drops dramatically (about 80% or more drop). The first still used a food grade silicone and were made out of plywood and concrete siding. It was found that the stills (3' x 8') were often producing far more water than the users needed, especially in the summer. As time evolved, a second generation solar still was developed made out of aluminum and smaller (3' x 6' and 3' x 3'). The still was lighter, but still expensive to build.

Fig. 2. First generation concrete sided EPSEA solar still built in 1995 that has been operational for over a decade for the Eby family in Hueco Tanks, Texas. This still uses a food grade rated silicone membrane.

Finally, a third generation still was developed by SolAqua (3' x 4') and used ABS plastic outer shell. The outgassing problem was solved using new proprietary materials for solar stills that eliminated outgassing problems while earning a NSF rating for water contact for human

consumption. These smaller stills can easily be paralleled for larger families. SolAqua was granted its first patent in July, 1999 in the U.S. on material and manufacturing techniques, and has additional patents pending in the U.S., Mexico, and Europe. The technology has now evolved to the point where with large manufacturing volumes (thousands versus hundreds of manufactured units), still costs could be greatly reduced by a factor of three or more in the future.

5. USER EXPERIENCES

Surveys were conducted by NMSU on user satisfaction with solar distillers and found that project participants receiving cost-shared solar distillers for the pilot EDA, EPA, and BorderPACT projects. Users were nearly unanimous that owning a solar still was good. Some owners prized the idea of using alternative, clean energy to achieve their purposes, while at the same time leaving only a small "footprint" on the planet. All were very enthused about the economic benefits of using a solar distiller. They found that paying a relatively low price for a still was a favorable alternative to having to buy water on a regular basis with no end in sight to this routine. Still others valued the independence and fascination they experienced from being involved in the production of their own purified water.

Many colonias residents often do not trust their local water supply. While many have noted a concern over local water supply color or odor, the overwhelming characteristic that gains their attention is poor taste. There is a good deal of concern with taste, and most of those interviewed noted that one of the reasons for wanting a water purification system was to improve the taste of their local water supply. Since many of the local water supplies are high in salts and minerals (e.g., iron or sulphur), they often have a marginal or poor taste. The solar stills were considered useful by colonia residents to improve drinking water taste.

Solar distillers were able to meet all of the drinking and cooking water needs of a household. Not all of the households receiving solar stills through the EPA pilot project had stills optimally sized to meet all of their wintertime water production needs, but about 40 percent of the households were completely satisfied with their still water production. All households had sufficient water during the high summertime production period, and it was the wintertime where some families had insufficient still water. Generally, it appears that for most Border households about one half square meter of solar still is needed per person to meet potable water needs consistently throughout the year. Most households with insufficient wintertime still water production had 0.35 m^2 or less of still area per person.

Fig. 3. Fall 2004 site visit to second generation solar distiller built by SolAqua using aluminum and water grade rated membrane at the home of July McClure in Columbus, New Mexico in operation since 2001.

Survey results clearly indicate that only about a third of colonias residents are willing or able to pay the full price of the solar still up front, because most simply could not afford the higher up-front capital cost. However, interest mounted greatly when the possibility of financing was mentioned. Thus, water districts and others interested in providing potable water to Border colonias should consider offering an option for still financing. To bolster interest, a clear, easy-to-follow breakdown of cost payback should be provided. Prospective customers interest is peaked when they realize that even at full price, the still could pay for itself in less than two years as compared to purchasing bottled water. Some prospective customers would be delighted to know that savings over a decade or more could be substantial and amount to thousands of dollars.

Almost all of those surveyed were using their solar stills regularly, thus now meeting most or all their drinking water and cooking water supply needs via solar distillation. Occasionally, still users had to supplement their still supply with store-bought water, especially in the winter, when still production decreases to about half of summertime production. Yet the need for purchasing bottled water from a store was greatly mitigated by the availability of still-produced water in the winter. Solar still savings are approximately $150 - $200 a year per household instead of purchasing bottled water.

Fig. 4. Aguilar family using third generation SolAqua solar distillers operated in parallel with water rated membrane to meet their daily drinking water needs in the Anapra colonia of Chihuahua, Mexico immediately bordering New Mexico.

Solar still users show a highly favorable attitude towards the use of solar stills. Most show a great deal of enthusiasm concerning their stills. Still users have a high level of confidence in the water produced by their stills. In all cases interviewed, users noted that they feel solar distilled water is safe to drink (6).

TABLE 2: SOLAR STILL SATISFACTION

QUESTION	YES	NO
Are you satisfied with your still?	85%	15%
Does it produce enough potable water?	40%	60%
Are you confident your still will provide years of reliable service?	75%	25%
Would you recommend a similar still to a friend or neighbor?	100%	0%
Do you feel still water is safe to drink?	100%	0%
Does your still water have a distinct odor?	0%	100%
Does your still water have a distince taste?	35%	65%

Table 2 quantifies household perceptions and overall satisfaction regarding solar still use. Most notably is the concern for health, with nearly half of those surveyed claiming that they wanted a solar still for the purpose of improved family health. Of those responding "Other," to this question, the majority desired a solar still because of their commitment to environmental issues. Responses varied from "we love solar" to "…trying to embrace permaculture." A number of households also responded that they had opted for a solar still to offset the cost of purchased drinking and cooking water (6).

TABLE 3: SELECTED USER PERCEPTIONS

QUESTION	% in range
Main reason for wanting a solar still?	
Family health	40%
Clean water	10%
Taste	20%
Other	30%
Does your still water have a distinct taste?	
Very satisfied	70%
Satisfied	25%
Mildly satisfied	5%
Not satisfied at all	0%
Taste of solar distilled water vs. other bottled waters?	
Better	60%
Same	40%
Worse	0%

6. ECONOMICS

Compared to purchasing comparable quantities of bottled water, the average return on investment on a solar still for a family is typically only a couple of years. Factoring in the health costs of contaminated water, payback for a solar still can be immediate. Solar distillation is the cheapest way to clean water for a household and is quite economical as compared to reverse osmosis and electric distillation. A square meter for a single basin solar still costs about $400. Many families in the U.S. colonias often spend from $8 to $12 per week on bottled water. Likewise, in Mexico families typically spend $3 - $5 per week on purified water. This represents an investment of anywhere from $150 to $600 per year for bottled water. Thus, simple payback on a solar still strictly compared to purchasing bottled water is typically within two to three years. The levelized energy cost of solar distilled water is about US$.03 per liter, assuming a ten year still lifetime. The first EPSEA stills have now been operating for a decade and are still going strong.

7. CONCLUSIONS

Clean drinking water remains one of the most important international health issues of today, and solar energy offers important and effective solutions in meeting potable water needs worldwide. Low cost solar stills offer an immediate and effective solution in reliably providing safe drinking water year after year. Single-basin solar stills are easy to build, inexpensive and extremely effective in distilling water with a high total dissolved salt content and in killing bacteria such as cholera and E. Coli. Single basic solar stills can use commonly available equipment, based on proven solar still

designs. Average water production is about 0.8 liters per square meter per sun hour. Solar stills can bring immediate benefits to their users by alleviating chronic problems caused by water-borne diseases. Solar stills offer the only realistic and cost-effective means to provide safe drinking for many Borderland colonias residents who have few other realistic and affordable options available. Likewise, solar stills have tremendous potential worldwide in economically addressing rural potable water needs and in saving lives.

The Borderlands solar distillation water purification projects have been an overall success. This technology calls for a different approach to providing purified water in that it only purifies the limited amounts of water that will be ingested by humans. Water used to flush the toilet, take a bath, wash clothes, etc. does not need to meet the same high level of purity as water that is ingested. As Border water supplies grow increasingly scarce and more difficult to purify (i.e., increasing salinity), solar distillation offers a practical, effective, and relatively inexpensive means for residents to purify their drinking water. It can be practically applied on a decentralized and immediate basis by any end-user around the globe.

8. ACKNOWLEDGMENTS

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