Energy Note

Solar distillation of water

W.R. McCluney, Ph. D.
Principal Research Scientist
Florida Solar Energy Center

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Introduction

The Florida Solar Energy Center receives frequent requests for information about solar distillation for purifying water. Distillation is one of many processes available for water purification, and sunlight is one of several forms of heat energy that can be used to power that process. Sunlight has the advantage of zero fuel cost but it requires more space (for its collection) and generally more costly equipment.

To dispel a common belief, it is not necessary to boil water to distill it. Simply elevating its temperature, short of boiling, will adequately increase the evaporation rate. In fact, although vigorous boiling hastens the distillation process it also can force unwanted residue into the distillate, defeating purification. Furthermore, to boil water with sunlight requires more costly apparatus than is needed to distill it a little more slowly without boiling.

Many levels of purification can be achieved with this process, depending upon the intended application. Sterilized water for medical uses requires a different process than that used to make drinking water. Purification of water heavy in dissolved salts differs from purification of water that has been dirtied by other chemicals or suspended solids.

The present dollar cost of solar-distilled drinking water is several times that of water provided by most municipal utilities, but it costs less energy-wise. On the other hand, solar-distilled water is much less expensive than bottled water purchased in the store.

For people concerned about the quality of their municipally-supplied drinking water and unhappy with other methods of additional purification available to them, solar distillation of tap water or brackish groundwater can be a pleasant, energy-efficient option.

Solar distillation systems can be small or large. They are designed either to serve the needs of a single family, producing from ½ to 3 gallons of drinking water a day on the average, or to produce much greater amounts for an entire neighborhood or village. In some parts of the world the scarcity of fresh water is partially overcome by covering shallow salt water basins with glass in greenhouse-like structures. These solar energy distilling plants are relatively inexpensive, low-technology systems, especially useful where the need for small plants exists.

Solar distillation of potable water from saline (salty) water has been practiced for many years in tropical and sub-tropical regions where fresh water is scarce. However, where fresh water is plentiful and energy rates are moderate, the most cost-effective method has been to pump and purify.

Although Florida generally has a wealth of fresh water, growing demand and rising pollution levels demand more and more energy to pump and purify it. Critical seasonal water shortages are occurring with increasing frequency in some parts of the state. Also, natural fresh water often cannot be diverted for direct human consumption without substantial environmental damage. The economic feasibility of solar desalination of ocean water will, therefore, improve considerably as energy costs continue to escalate and population pressure exerts more stress on available fresh water supplies.

There are several acceptable designs for small solar stills for the individual Florida family; however, there is still much room for innovation and improvement. Solar desalination is particularly well-suited for backyard experimentation by individuals with little or no technical training.

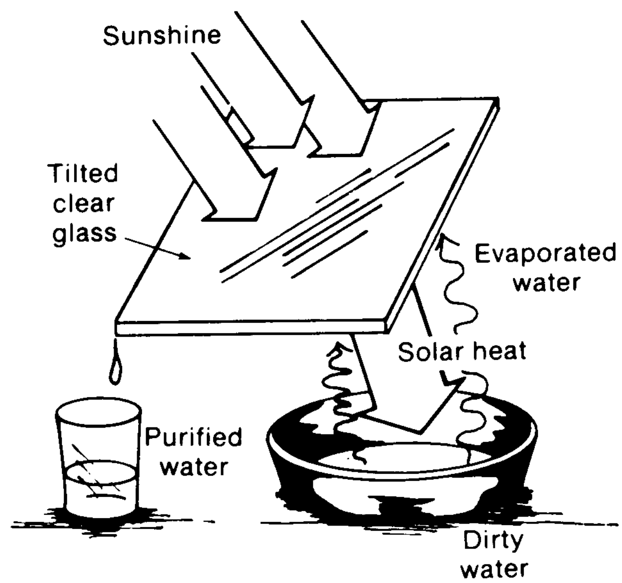

Figure 1. Basic concept of the solar distillation of water

Basic principles

The basic concept of using solar energy to obtain drinkable fresh water from salty, brackish or contaminated water is really quite simple. Water left in an open container in the backyard will evaporate into the air. The purpose of a solar still is to capture this evaporated (or distilled)water by condensing it onto a cool surface, using solar energy to accelerate the evaporation (Figure 1).

The rate of evaporation can be accelerated by increasing the water temperature and the area of water in contact with the air. A wide, shallow pan painted black makes an ideal vessel for the water. It should probably be baked in the sun for a while before it is used in order to free the paint of any volatile toxicants which might otherwise evaporate and condense along with the drinking water. The pan is painted black (or some other dark color) to maximize the amount of solar energy absorbed. It should also be wide and shallow to increase the water area exposed to air. The addition of a spongy material to the water would further increase the surface area, assuming the availability of a substance with good solar absorbing properties and durability in heated salt water. (This is a very harsh environment for materials to survive in over prolonged periods.)

To capture and condense the evaporated fresh water, we need some kind of surface close to the heated salt water which is several degrees cooler than the water. A means is then needed to carry this fresh water to a storage tank or vessel. The evaporating pan usually is covered by a sheet of clear glass or translucent plastic (to allow sunlight to reach the water) which is tilted at a slight angle to let the fresh water that condenses on its underside trickle down to a collecting trough. The glass also holds the heat inside. Figure 2 combines all these components in a single still design.

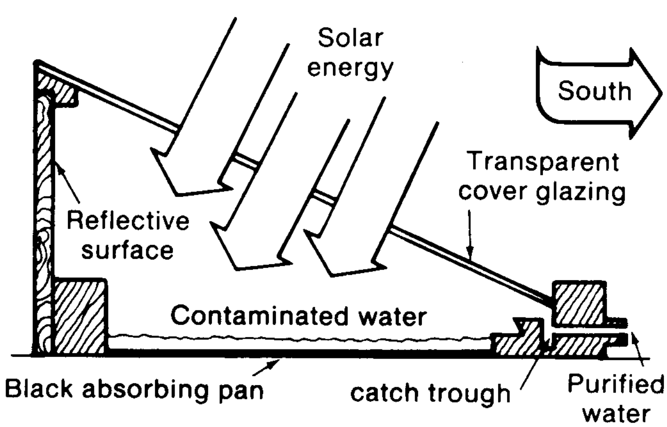

Figure 2. A simple solar still design.

Other possible configurations and materials are discussed in the **Manual on Solar Distillation of Saline Water,** available for $10.75 (using order no. PB 201 029) from the National Technical Information Service, Order Department, Springfield, VA 22161. Another excellent publication is **Solar Distillation as a Means of Meeting Small-Scale Water Demands,** published in 1970 by the United Nations. It is available for $6 from the United Nations, Publications Sales Section, Room A-3315, New York, NY 10017 (order no. E 70. 11. B. 1.).

These two publications are recommended for individuals interested in building a solar water still. In addition, the Office of Water Research and Technology, U.S. Department of the Interior, Washington, DC 20240, offers an extensive bibliography of relevant reports available from the National Technical Information Service.

An excellent review of non-solar desalination methods and economics appeared in the June 1973 issue of **American Scientist** (Vol. 61, p. 280), and an article on solar desalination methods and practices was featured in the **Sunworld** magazine published in 1979 (Vol. 3, No. 3, p. 76), by Pergamon Press (Fairview Park, Elmsford, NY 10523) for the International Solar Energy Society. Additional references are given in the bibliography at the end of this paper.

Economics

For Floridians interested in building a solar still, a good design should be capable of producing ½ to 1 gallon of fresh water per day for each square meter (10.7 square feet) of still area. Material costs generally do not exceed about $20-$30 per square meter for large solar distillation plants. For smaller, backyard models, the material costs are likely to be somewhat higher.

The per-gallon cost of solar-distilled water can be calculated as follows: (a) estimate the usable lifetime of the still; (b) add up all the costs of construction, repair and maintenance (including labor) over its lifetime; and (c) divide that figure by the still's total expected lifetime output in gallons (or liters).

Such a cost estimate is only approximate, since there are large uncertainties in both the lifetime and the yield estimates. Costs are usually considerably higher than current water prices — which explains why solar backyard stills are not yet marketed widely in Florida.

However, as times change, water prices rise. The quality of "city water" is deteriorating in many parts of Florida and some people are buying expensive water filters or drinking only bottled water. Consequently, a more favorable evaluation of solar-produced fresh water costs would involve a comparison with bottled drinking water prices. For example, a 1970 United Nations report cites costs of $3 to $6 per 1,000 gallons of solar-distilled water. Using a 10 percent annual inflation rate, this translates into about $6 to $12 per 1,000 gallons at today's prices, excluding labor costs. This can be contrasted with a price of 50¢ to $1 per 1,000 gallons for utility-supplied water, and from 50¢ to $1 per gallon for bottled water sold in supermarkets (equivalent to $500 to $1,000/1,000 gallons).

We see that the solar-distilled water costs much less than bottled water and somewhat more than utility-supplied water. Small solar stills capable of producing pure drinking water even for as much as $20 to $30 per 1000 gallons might find many Florida buyers who are unhappy with the quality of the water they are presently getting. As the cost of purifying polluted groundwater and delivering it to the home continues to rise, the solar distillation market should continue to grow significantly — especially if someone comes up with a unit that produces good drinking water at a reasonable price.

Water quality

On August 22, 1978, the St. Petersburg Times stated that published reports of impurities in some Florida water systems and national concern over carcinogens in drinking water had created a growing market for what are called "home water purifiers."

The article quoted Paige Geering of the U.S. Environmental Protection Agency as saying that "the problems they (home water purifiers) create may be far worse than the benefits".

During discussions with this author, Ms. Geering emphasized that her published comments were primarily directed at the use of the word "purifier" with home water treatment devices. She said that these products can provide some improvement in drinking water, especially if the filter is changed frequently, but that one should be cautious of manufacturers' "purity" claims.

In principle, the water from a solar still should be quite pure. The slow distillation process allows only pure water to evaporate from the pan and collect on the cover, leaving all particulate contaminants behind.

Since a clean glass cover plate and storage vessel should produce no contaminants, the catch basin, or trough, remains as the potential source of direct contamination. (If the design allows for catchment of rain, air pollutants in the rain could also be a form of contamination.)

The catch trough should be made of material unlikely to degrade water flowing through it, even at the moderately elevated temperatures which might be encountered. PVC (polyvinyl chloride) plastic plumbing pipe is commonly available at relatively low cost. Since vinyl chloride has been identified as a carcinogen potentially harmful to workers in plants manufacturing PVC products, one should be very careful about using this material in a drinking water system.

Fortunately, some PVC formulations have been designed for use in potable water systems; however, other formulations are not so-designed and could pose a problem.

An information package on PVC pipe, manufacturers, and their test methods for contaminants is available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, Michigan 48106.

Secondary potential sources of contamination include materials present in the air inside the distiller, and in the lining or coating of the evaporating pan, which might somehow find their way into the water condensing on the underside of the cover glass. There is little available information on this complex subject.

It is possible that a chemical in the feed water (or in the still itself) which evaporates along with the water could condense on the underside of the cover and be carried into the catch basin. There are several ways to minimize contamination from the materials in the still itself. Preconditioning of the distiller by "baking" it under the sun for several days may be sufficient to drive off most volatiles. Non-volatile materials left behind in the concentrate may be discarded. Avoiding use of materials containing known toxicants is another way to ensure condensate water purity.

With care in design and operation, the solar still should, therefore, be capable of producing good drinking water free of cancer-causing pollutants and other harmful substances — water that is colorless, odorless and, unfortunately, tasteless. When the minerals common to drinking water are removed, taste goes, too. One flavor recommendation is to add small amounts of minerals or salts to the distilled water — maybe a good idea, since the minerals found in water may be healthful. Lost minerals also can be replaced by trickling the distilled water through a bed of marble chips.

Summary comments

In principle, solar energy can be used to separate pure water from most of the natural contaminants, such as dissolved solids (salts) and particles (dirt and algae). Solar distillation is most economically effective when sunlight is allowed to pass through a transparent cover and into a black evaporating pan with little or no concentration of the sun's rays.

A reasonable production rate would be about one gallon of water per day per square meter (10.7 square feet) of still area. If it costs about $40-$60 per square meter to build the still and if this water is worth roughly $15 per 1,000 gallons, the still should pay for itself in 2,500 to 4,000 days, or 7 to 11 years. As the value of solar-distilled water increases, the payback time shrinks. If one values this water at 60¢ a gallon, about what distilled water costs at the supermarket, then the payback time is only 60-100 days.

Clearly, solar distillation of water is not quite competitive with utility-supplied drinking water in Florida, but it is ***highly*** competitive with bottled water. Rising energy prices seem bound to create an early Florida market for small manufactured solar water distilling units. In a few more years, large-scale solar distillation may also become economically viable for utility use in the state.

Further information

Those interested in further investigating the feasibility of solar distillation may wish to read the selected references listed on the next page. In addition, the Public Information Office of the Florida Solar Energy Center provides free copies of a comprehensive bibliography on solar distilation.

Selected references

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