Beyond the Pipes

A Guide for Communities Lacking Water and Sewage Services

September 2003

Published by the Energy Center and Center for Environmental Resource Management
at the University of Texas at El Paso

Funding provided by the Texas Comptroller of Public Accounts – State Energy
Conservation Office

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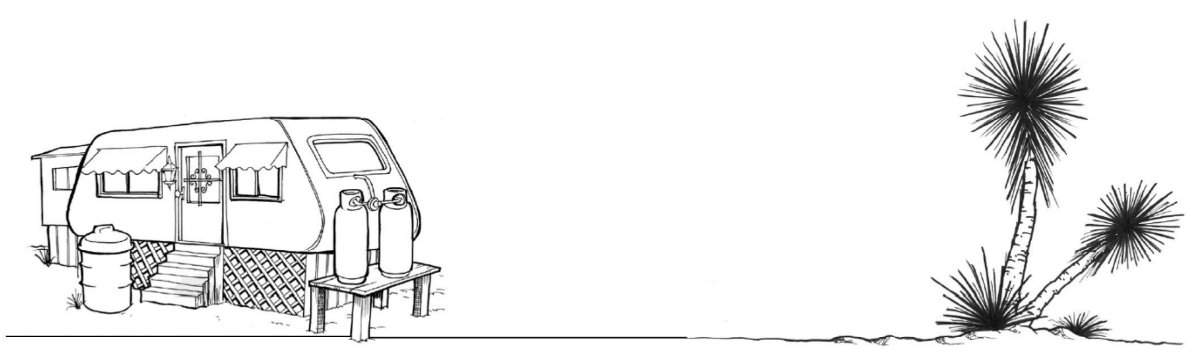
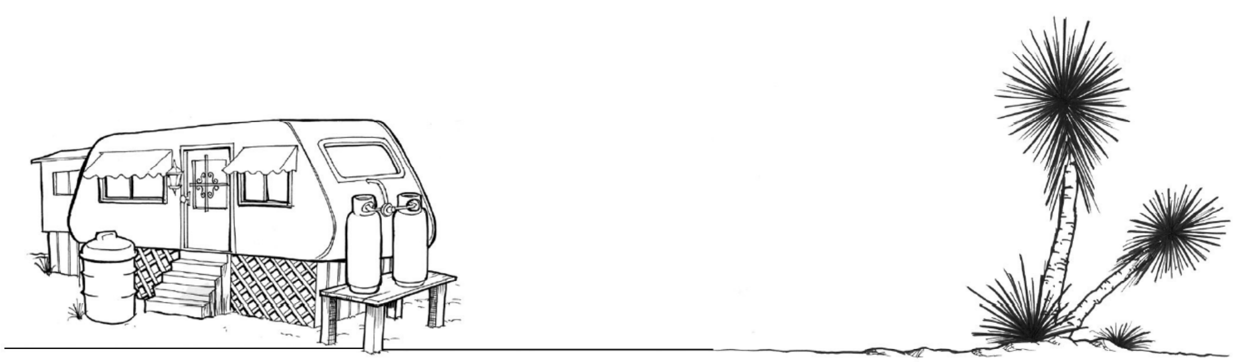




Preface

In this manual solar energy and public health are treated equally. There is advice on boiling water and chlorinating water to kill bugs. There is also advice on using solar energy to kill bugs. Either may be appropriate in certain circumstances. There is one constant: Proper sanitation, safe water storage, and hand-washing are essential in any scheme to improve public health no matter what method is chosen to purify water. Combining the best ideas from public health and solar design can produce better, integrated technologies. This goes without saying but is often missed in the narrow focus of each discipline in pursuit of specific solutions.

Conditions in Texas Colonias

Colonias in Texas are peri-urban areas that lack basic infrastructure and resources. There is a wide range of conditions for families residing in Texas colonias. As piped water has been provided to many of the colonias conditions have vastly improved. In El Paso County $250 Million dollars have been spent on water improvements for colonias.

Figure 1: This household stored water in these six open-top 55 gallon drums. Water was obtained from a neighbor 100 yards away by filling one drum at a time and pushing it in the wheelbarrow. The family recently got a 2500 gallon tank that provides indoor running water.

Some families now enjoy piped municipal water and conventional sewers. These families do not need water purification or management and have the same risk for health impacts from their water system as city dwellers. Many other families have piped water and an on-site septic system for sewage. These families are generally at low risk for health impacts but according to the El Paso City/County Health and Environmental District about 35% of on-site sewage systems are in non-compliance with one or more health codes (CH2MHill).

Some other families have a large water storage tank (2500 gallons) or private well and a septic system. The storage tank comes with a pressure pump which provides running water to the home, similar to a well system. Trucking companies deliver water to these families. Starting at this level each family must assume total responsibility for their water and wastewater. We term them as being “beyond the pipes.” These families are at a higher risk for water related illnesses. At the most severe level there are families that haul water and store it in 55 gallon drums, move it around in 5 gallon buckets and use a pit privy (outhouse) for sanitation. These families are at the greatest risk of disease from contaminating their water and from water-washed disease as well.

Within each of the categories in the hierarchy above there are many variations. For example, in the Village of Vinton a 1997 report indicated that 10% of the population uses cesspools or other unsuitable means for waste disposal. Also, among the families with large storage tanks some do not have complete kitchen or bathroom plumbing facilities inside the home and therefore do not benefit from the system. Piped water can greatly improve conditions but poverty still dictates many situations.

There are some families that will not receive piped water, many others will not be served by sewer. The cost of providing water and wastewater to some colonias is excessive (greater than $20,000 per hook-up) and has been determined to be “non-feasible.” It is this population in El Paso County and other border communities that this catalog of potential applications is directed at. We hope to start the long process of identifying and testing practical, low-cost products and technologies that may improve health and well being for colonia residents beyond the pipes. In the future some of these technologies may also be applied in urban settings to improve the sustainability of the region. That is, technology inspired by needs in today’s colonias may be applied to solve the problems of the future in urban centers.

Introduction

Beyond the Pipes is written for people working with communities lacking a safe piped water supply or good sewage disposal. The guide won't tell you what is best for your community, but will give you some of the tools you need to help make the right decision. The term "technology" is used loosely in this guide and can mean a gadget that can be purchased, something that can be constructed or occasionally behaviors like handwashing,. An evaluation (pros and cons) of many commercially available technologies is provided along with prices and where the technology can be purchased. However, after seeing some of the technologies, you may have a better idea that would fit your community's needs. Go for it and be creative but don't lose touch with the community and what they consider acceptable.

Background

Within five years, it is estimated that half of the world's population will live in cities and by 2030, the urban population will reach 4.9 billion (60% of the world's population). This growth presents difficulties not only to the city governments, unable to keep up with the growth, but also to the individuals living in the urban environment (especially in low-income countries where problems are compounded by poverty). A significant portion of the population that will migrate to cities will live in peri-urban areas similar to the colonias along the Texas /Mexico border. These families will be beyond the pipes.

"The World Health Organization (WHO) estimates that 1.1 billion individuals (worldwide) are without a safe water supply, 2.4 billion lack adequate sewage disposal, and that 3.4 million people, mostly children, die annually from water and sanitation related diseases. Alternative solutions are needed. With the migration of people to cities and the already unmet water and sanitation needs, low-cost and easily adaptable solutions that improve people's health and free-up time and energy for other activities (like going to school) are essential."

Recommended Minimun Water Requirements for Residential Use (from Gleick, 1996)

Purpose	Liter/person/day
Drinking	5
Cooking	10
Bathing	1
Sanitation	20
Total	36

Figure shows that flush toilets use 40% of the total residential demand for municipal water. If stopped using water to transport human excreta, reservoirs could be half as large and therefore much less costly. When cities were fewer and smaller and population densities lower, the cost of collecting and storing water for such purposes seemed, in financial terms, affordable. That era has long gone. Soaring costs of peri-urban land for sewage treatment and reservoirs, and the costs of involuntary resettlement make this approach less affordable. (WHO website)

The above figures are very low by U.S. standards. A comparison of some regional residential averages appears below:

Average residential water use in Fort Worth last year (2002) was 1,200 cubic feet (8,976 gallons) per month.

For 1996, the average residential water use was about 8,300 gallons per month for Dallas water utility customers.

The average residential water use in Las Cruces, NM is 13,000 gallons per month (Las Cruces Water Resource Department [LCWRD], 2002). The average daily per capita water use is 131 gallons per capita per day (gpcd) (City of Las Cruces Utility, 2003), higher than that of the national average of 75-80 gallons per capita per day (U.S. Environmental Protection Agency, 2002).

El Paso residential water use dropped to 95 gcd in 1999. (95 x 4 x30 = 11,400 gallons per month for a family of four.)

According to the AWWA, national daily indoor per capita water use in the typical single family home with no water-conserving fixtures is 74 gallons. Here is how it breaks down:

Use	Gallons per Capita	Percentage of Total Daily Use
Showers	12.6	16.8%
Clothes Washers	15.1	21.7%
Dishwashers	1.0	1.4%
Toilets	20.1	26.7%
Baths	1.2	1.7%
Leaks	10.0	13.7%
Faucets	11.1	15.7%
Other Domestic Uses	1.5	2.2%

By installing more efficient water fixtures and regularly checking for leaks, households can reduce daily per capita water use by about 30% to about 51.9 gallons per day Here's how it breaks down for households using conservation measures:

Use	Gallons per Capita	Percentage of Total Daily Use
Showers	10.0	20.1%
Clothes Washers	10.6	21.4%
Toilets	9.6	19.3%
Dishwashers	1.0	2.0%
Baths	1.2	2.4%
Leaks	5.0	10.1%
Faucets	10.8	21.9%
Other Domestic Uses	1.5	3.1%

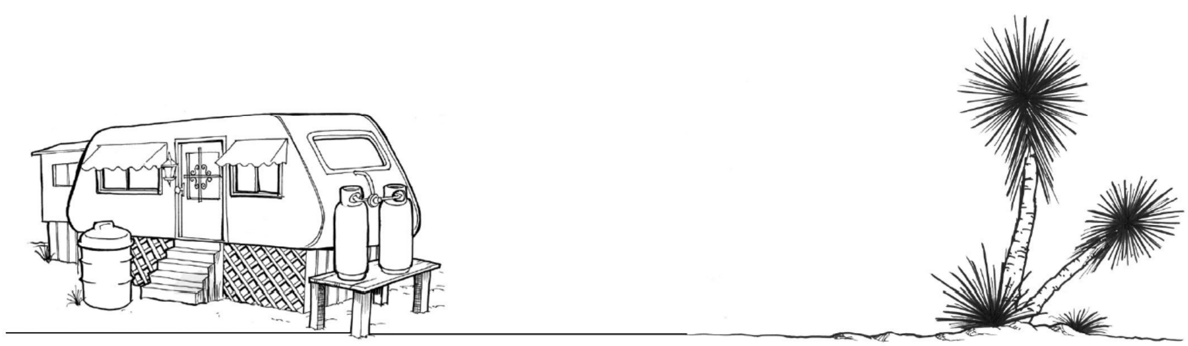
(1999 Residential Water Use Summary, American Water Works Association)

Note: 74 x 4 x 30 = 8,880 gallons per month and 51.9 x 4 x 30 = 6,228 gallons per month for a family of four.

From the American Water Works Association

Are You *Drinking Enough Water?*

-75% of Americans are chronically dehydrated
-In 37% of Americans, the thirst mechanism is so weak that it is often mistaken for hunger
-Even mild dehydration will slow down one's metabolism as much as 3%
-One glass of water shuts down midnight hunger pangs for almost 100% of the dieters studied in a University of Washington study
-Lack of water is the number one trigger of daytime fatigue
-Preliminary research indicates that 8-10 glasses of water per day could significantly ease back and joint pain for up to 80% of sufferers
-A mere 2% drop in body water can trigger fuzzy short-term memory, trouble with basic math, and difficulty focusing on the computer screen or a printed page
-Drinking 5 glasses of water per day decreases the risk of colon cancer by 45%, can reduce the risk of breast cancer by 79%, and makes one 50% less likely to develop bladder cancer



Working with communities

Communities are dynamic and there is no one correct way to work with them. However, we do recommend four basic ideas outlined in the LEAP philosophy:

Listen – Higher education and experience are helpful in community projects, but not enough to create complete success. Listening to what the community thinks (women, men and children) is important and having a true dialogue is essential before initiating a project. Sometimes their needs or ideas may not be clear, but be careful not to confuse a poorly delivered idea/need with a bad idea/need. If you don't see the community as your equal it will become evident and difficult to carry out a successful project.

Empower – Giving up authority is difficult. However, if you want something to last after you are gone or you want others to begin other improvement projects, you have to give up some of the decision making power. This does not mean you blindly hand over important tasks, but instead that you **provide training** and **support** as you slowly let people have more and more responsibility. Build confidence by demonstrating how things work and then letting people get experience through hands-on practice.

Allow mistakes – $&*@ happens! Community projects, though fun, are difficult as you often try to overcome language and cultural barriers. Try to include some room for mistakes in your projects so that you won't get too stressed when someone builds a lopsided wall or materials are delayed. This is part of the joy of letting people do something they may never have done before. Expect some crazy and funny events.

Provide alternatives – Try not to tell the community what is the best technology for them, but provide alternatives with all the pros and cons. Though you may be able to speed up the project by limiting community involvement, you'll miss out on feedback and support that are crucial for lasting success.

Selecting the right technology for your community

There are occasionally EUREKA events where you find the perfect technology that is easily adaptable to your community. However, this is the exception, not the rule. There are many factors that determine the success of a technology or behavior, so try to remember that a complex problem may need a complex solution. You may need to hold some small meetings where you demonstrate a technology and ask what people think or ask them to test the technology for a week and get some feedback. You may also have to drop the idea of the technology until the community realizes that there is actually a problem and a solution is needed.

Consider the following criteria when choosing a technology:

Functionality – Does it work and does it solve an issue that the community thinks is important?
Cost – Is it something the community can afford and do they want to spend their money on it?
Availability of materials – Can the technology be made locally or is it possible to purchase?
Acceptability by community – Does the community laugh when you show them the technology or demonstrate the new behavior?
Ease of construction – How complex is the technology and can members of the community build it?
Life of the technology – How long with the technology last before it needs to be replaced?
Maintenance – How difficult is the maintenance of the technology and can it be performed by community members?

Commonly used technologies

Boiling

How it works

Boiling is one of the simplest ways of killing bugs or microbes in water and making it safe to drink. Boiling water for **1 minute**, after you see the water bubbling, will kill almost every microbe. Some viruses and protozoans may be able to survive past 20 minutes of boiling, highlighting the need for autoclaving of surgical instruments, but reasonable protection is provided by boiling. You can boil water longer than 1 minute to be safe, but 1 minute is sufficient to greatly improve the quality of the water [Sobsey, 2002].

Amount of water that can be treated

Any amount of water is okay, but the more water you boil, the more water is likely to be sitting around. If it sits around a long time, it can easily become re-contaminated with bugs.

Conditions for appropriate use

As mentioned before, boiling is easy (a pot, some water, and a heating source). Boil water in a safe container, one that won't melt or break. Try to find a container that has a handle to avoid burns, and remember to keep children away from the heating or boiling water.

Cost of treatment

Cost varies. It depends mostly on the heating source you're using to boil the water. You may need to evaluate the availability and cost of heating water using fossil fuels, wood, or electricity versus other ways of treating your water. About 1 kilogram of wood is needed to boil 1 liter of water, so in areas where the use of wood and wood-derived fuels is a concern because of deforestation look at other alternatives.

Advantages

Boiling water is simple and well accepted.

Disadvantages

After water is boiled, it can become recontaminated. It's important to store the water in a clean container that is well covered or has a small mouth so that hands or paws can't contaminate it with microbes or bugs. Try using a covered container with a spigot instead of dipping water out with a ladle. Expense. Cost and availability of fuel may lead to intermittent use. Small batches requiring frequent, time consuming procedure.

Acceptance by users

Boiling water is a commonly accepted practice in many parts of the world. It's important to ask your community how they feel about boiling water, how expensive it is for them, how difficult it is, and if they think it's necessary.

Chemical Disinfection

Small Batch Chlorination

How it works

Chemical disinfection with chlorine is a very common and effective way to kill microbes in water. At low levels and short contact times, free chlorine generally kills 99.99% of enteric bacteria and viruses (with a few exceptions). Chlorine also has a lasting effect and can maintain its disinfectant residual.

Amount of water that can be treated

Since chlorine is so effective and relatively cheap, it is a widely accepted means for treating community drinking water supplies. Large quantities of water can be treated using chlorine, however many intervention programs have promoted in-home chlorination since households often collect and store their own drinking water supply.

Conditions for appropriate use

You basically need water, chlorine (common household bleach), and a safe container that won't allow recontamination by household members. We recommend 2 drops of bleach (5% solution) per liter. Let it sit for 30 minutes and then chug-a-lug chug-a-lug. It is much better if you can start with a relatively clear water supply free of debris. If you have a lot of debris you may let the water settle or filter it through a thin piece of cloth.

Cost of treatment

The cost varies depending upon the availability of household bleach. Bleach is readily available at reasonable cost in almost all urban and peri-urban areas. At 2 drops per liter, cost is minimal. Cost can be as low as 9 cents per cubic meter. (see chart from Burch in Appendix)

Advantages

Chlorine is great because it's easy to use, effective against most pathogens and provides lasting protection (unless it is stored too long – over 3 days).

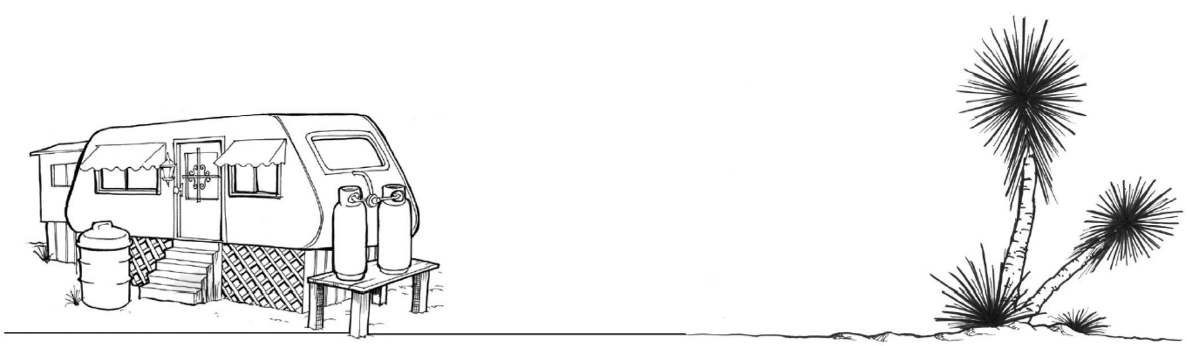
Disadvantages

Some of the disadvantages of chlorine are that it is not available worldwide and that it can react with organic material (like algae) in water forming not so healthy chemical by-products. However, many health experts believe that the health benefits of using chlorine far outweigh the health problems associated with these chemical by-products.

Acceptance by users

Some users do not like the taste and/or odor of chlorine in their water, so it's not always the best choice. You may want to do some taste tests in the community and get some feedback before promoting this as a solution.

(See http://www.cerm.utep.edu/outreach/apb/index.html and http://www.cdc.gov/safewater/default.htm)



UV Systems

Ultraviolet light can incapacitate pathogens. Both the UV-A in sunlight and the UV-C that can be produced by lamps has been employed to purify water.

SODIS (SOlar water DISinfection)

How it works

SODIS, SOlar Water DISinfection, improves the microbiological quality of drinking water. It is a simple water treatment method using solar UV-A radiation and temperature to inactivate pathogens causing diarrhoea.

"The Solar Water Disinfection (SODIS) process is a simple technology used to improve the microbiological quality of drinking water. SODIS uses solar radiation to destroy pathogenic microorganisms which cause water borne diseases."

Figure 2: Solar disinfection of water is a simple and effective technology. Since there is no indicator or water safety the procedure must be carelfully followed.

"SODIS is ideal to treat small quantities of water. Contaminated water is filled into transparent plastic bottles and exposed to full sunlight for six hours. Sunlight is treating the contaminated water through two synergetic mechanisms: Radiation in the spectrum of UV-A (wavelength 320-400nm) and increased water temperature. If the water temperatures raises above 50°C (122°F), the disinfection process is three times faster." –from the SODIS website

Amount of water that can be treated

Water is intended to be treated in re-cycled soda bottles made of PET (PVC bottles absorb or filter out more UV light). Multiple bottles of one to three liters may be used.

#1- polyethylene terephthalate (PET) sometimes PETE
soda & water containers, some waterproof packaging, tennis balls.

Conditions for appropriate use

SODIS is directed at the vast portion of world population with no access to a safe water source. It is the most basic approach utilizing the least technology at the lowest cost. It may have application for use during disaster relief in developed countries.

Cost of treatment

With re-cycled bottles it is zero.

Advantages

Lowest cost, very simple, and easy to do.

Disadvantages

May not produce desired results due to lack of adequate sunlight. There is no way to easily determine if the process worked. No indicator is available, so the user must know if the proper conditions were met.

This disclaimer appears at the SODIS website (http://www.sodis.ch/index.html):
"SODIS is used at household level under the responsibility of the user. Therefore EAWAG is not liable for any harm caused by a faulty or inadequate application of the water treatment process."

Acceptance by users

See survey in appendix. Seven of 11 agreed it cleaned the water. Only three of 11 said they would regularly use it and 5 indicated they would only use it for emergencies, when they had no other option or on camping trips. Four said it was too small.

Undersink and Countertop Ultraviolet Disinfection (UV)

This technology utilizes a small lamp to generate ultraviolet light that incapacitates pathogens. The lamp requires electricity to operate and could be powered by a conventional AC or a DC solar source. No affordable units that are PV powered have been identified. Finding DC bulbs and ballasts also proved to be difficult. This may be the case since the units need pressurized water and where there is water pressure there is almost always electricity, too. It is cheaper and easier to just plug in to the grid if available. There may be a need for a solar unit; the Energy Center will continue to search for an affordable UV-PV, family sized unit.

Technology	Pressurized water system	Electricity	Maintenance	Pretreatment required	Change in taste of water	Water quality constraints
Ultraviolet Disinfection	Required	Required	Annual bulb replacement	Depends on water quality. May require sediment filter, activated carbon, iron removal, and/or softening	No change	Water must be clear (low turbidity)

How it works

Ultraviolet (UV) disinfection is a proven technology for the destruction of pathogens in drinking water. It works by directing ultraviolet light (primarily UV-C wavelengths of 240-280nm) at the water in doses sufficient to damage the DNA of microorganisms.

Figure 3: UV treatment is simple. Water is pumped through a cartridge exposing it to UV-C radiation and then out a faucet.

Amount of water that can be treated

UV disinfection systems are customarily used with a pressurized water supply. Small-scale, batch UV disinfection systems are not widely available, if they are manufactured at all. Home UV disinfection systems may be sized to treat water from a single faucet (typical flow rate of .5 gpm to 2 gpm) or to treat water for an entire household (typically around 10 gpm). Treating a single tap is less costly but requires that the drinking water for the entire household be taken from the single tap. In addition, the quality of the untreated water must be sufficient for use in bathing and washing.

Conditions for appropriate use

The water to be treated must be clear enough to transmit UV light. This means that it must be free from both particles and dissolved substances that can reduce the clarity of water or form deposits that block light transmission. Pretreatment may be necessary to remove these substances if they are present in sufficiently high concentrations. Pretreatment commonly includes a sediment filter and activated carbon. It may also include iron removal and softening. The manufacture's guidelines should be consulted for the appropriate pretreatment required.

Figure 4: Here is a counter top version of a UV treatment device. It also includes a carbon block filter to improve taste.

Cost of treatment

The cost of treatment depends largely on the level of pre-treatment required. A simple UV unit sufficient for treating a single tap costs roughly $120-160. Systems with prefiltration and lamp monitors may cost $250-$300 or more if softening or iron oxidation is required. Treating water for the entire house, rather than a single tap, will very roughly double the initial installation costs and increase the annual lamp replacement costs by about 50%.

Operating and maintenance costs for the UV system consist largely of annual replacement of the lamp ($60-$100). Electricity costs are minimal as the wattage of the lamps is quite low (5-40 watts, depending on the size of the system). Pretreatment systems will add to operating and maintenance costs substantially. While the exact amount depends on the nature of the pretreatment required, common pretreatment, such as a sediment filter and activated carbon would roughly double annual operating costs.

If a system costs $160 and produces 3,000 per year (~8.2 gal/day) and uses 20W continuously then first year cost per gallon will be 6 cents. If a replacement lamp costs $39 and a replacement carbon block filter is $25 then second year costs drop to about

2.6 cents per gallon or about 90% less than “Windmill” bottled water.. (Based on specs for Puritec countertop model)

Advantages

This method is highly effective, does not affect the taste or odor of the water, and requires little effort or attention by the user on a daily basis.

Disadvantages

UV disinfection can not be used everywhere as it requires electricity and a pressurized water supply. It may also require pretreatment depending on water quality. Another concern is that the lamp performance declines gradually over time. While replacement is usually recommended on an annual basis, the lamps are expensive, and there are no visible signs of decreased performance by the system. These circumstance may lead users may to try to prolong the period between lamp replacements which will result in less effective disinfection by the system. The more expensive systems address this by including a UV intensity monitor to warn the user when lamp performance is declining.

Acceptance by users

User acceptance in the short term is likely to be high as this method imparts no taste or odor to the water and requires little effort by the user on a daily basis. If only a single tap is treated in a household, some minor effort will be required on the part of the users to take drinking water exclusively from that tap. In the long term, the user must maintain the device, which requires the purchase relatively costly replacement parts and adherence to a service schedule. There is little information on how well users maintain these devices over long periods of time.

Pasteurization

There are several ways to improve water quality using solar energy. Some use the sun’s energy to produce heat, some use the UV portion of the solar spectrum to incapacitate pathogens, others convert solar energy to electricity with photovoltaic cells and use the electricity to power purification devices. UV treatment is typically called disinfection while raising the temperature of water above a threshold for a period of time is called pasteurization. Distillation involves heating and vaporizing water then condensing the vapor and is targeted at removing salts from water. There are significant variations among systems of each type.

Pasteurization
Although pasteurization of milk is the mainstay of the dairy industry, it is seldom considered for water treatment. Pasteurization of water is one of the most effective methods of killing viruses, bacteria, and protozoa. In developing countries, or in disaster conditions the main recommendation of public health workers is to boil water before drinking it. While effective, boiling water is energy and labor intensive. Heating water to pasteurization temperatures (68°C or 154°F) is sufficient to kill most micro-organisms but problems in usage and the fact that illness may result from any mistakes leads authorities to recommend boiling. A major issue for solar pasteurization is knowing if the water is safe to drink after treatment. With boiling there is a visual indicator.

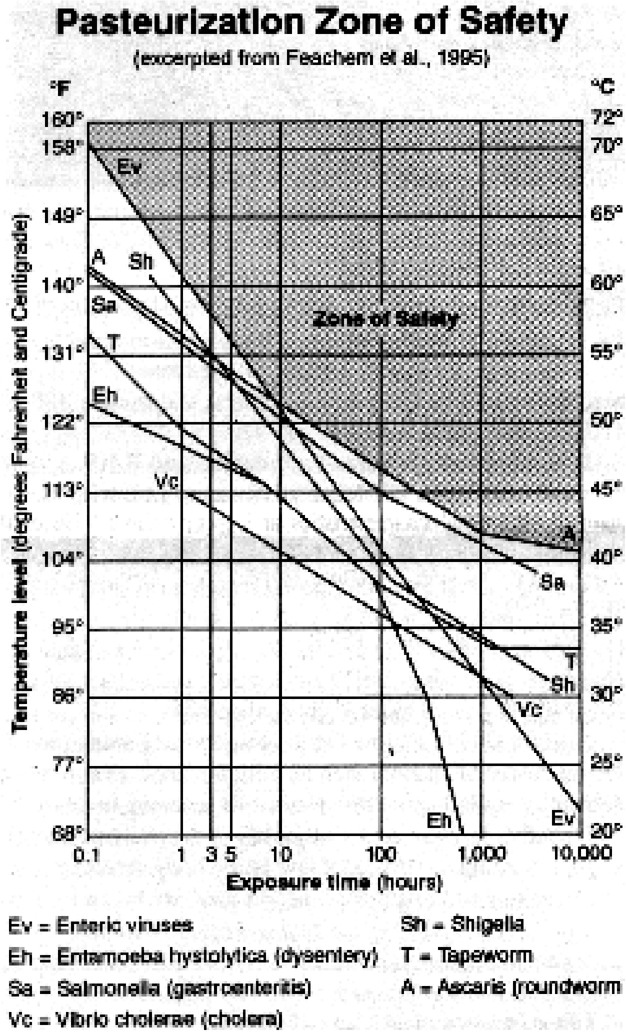


Figure 5: This chart may be used to determine if pasteurization has occurred.

A WAPI, or WAter Pasteurization Indicator, “is a plastic tube with both ends heated, pinched, and sealed, and with a particular type of soybean fat in one end that melts at 154º F (68°C). The tube itself is buoyant, but is weighted with a washer so it sinks to the bottom (coolest) part of the water, with the fat in the high end of the tube. If the fat is found in the low end of the tube at any time after, the water reached the proper temperature, even though the water may have since cooled down. A nylon string makes it easy to take the tube out without recontaminating the water. The tube is reused by flipping it over and sliding the string through the other way. This device also works with fuel-heated water. Since heating the water to the pasteurization temperature rather than the boiling point reduces the energy required by at least 50%, the fuel savings offered by this simple device alone is considerable.” (Andreatta, A SUMMARY OF WATER PASTEURIZATION TECHNIQUES, See Fig.6 - WAPI illus.)

Figure 6: The WAPI is an invaluable tool that utilizes wax as a recording thermometer substitute.

(This device works in any size water container, costs about $3, and is available from Solar Cookers International, 1724 11th Street, Sacramento, California, 95814, (916) 444-6616, http://solarcooking.org)

The solar thermal pasteurization devices are very similar to solar water heaters for domestic use. With the difference that the water must reach the Pasteurization Zone of Safety (Faechem, et.al. See Fig. #?) to ensure safety. For DHW a wide temperature range is acceptable. Batch pasteurization devices must have an indicator, such as a WAPI and flow-through pasteurizers need a control to ensure that only water that has reached sufficient temperatures is used.

*Family Sol*Saver*

How it works

This is a small scale solar batch pasteurizer that is manually filled and emptied each day. A WAPI type indicator is used to show that temperatures sufficient for pasteurization occurred. The device can be placed in a sunny spot and left all day.

Figure 7: The Family Sol*Saver is a simple water pasteurization device. At left, pasteurized water is being directly transferred to an Agua Para Beber (APB) container.

The container has a hollow molded plastic body with a polycarbonate structured sheet (PCSS) twinwall glazing cover. There are two fittings through the glazing to allow filling and draining. One of these fittings holds the WAPI like device.

Amount of water that can be treated

The FSS holds 3.5 gallons and may be re-filled on long, sunny days in summer to pasteurize additional batches.

Conditions for appropriate use

Can be used to replace boiling water when there is adequate sun for 3 to 4 hours each day. Boiling can always be used as a backup.

Cost of treatment

Initial cost of unit is high ($220) but may be recovered in fuel savings over the years.

*Advantage*s

This is a simple, effective treatment device with a pasteurization indicator. Processes 3.5 gallons in one batch. It is potentially more convenient than boiling for many families.

Disadvantages

Bulky device that requires careful handling (long dimension must be horizontal when filled). Initial cost is high. Susceptible to freezing conditions that could cause leaks or damage. Permanent, site-built batch pasteurizer combined with a WAPI may be more cost effective.

Acceptance by users

Texas Colonia residents were not very receptive since they had other easier or more desirable options available. Residents with fewer options may have more interest in the Family Sol*Saver.

AquaPak

How it works

AquaPak is a very low cost device ($19.95 retail or as low as $6 to NGOs) that looks like a solar camping shower with bubble pack material instead of clear vinyl. Typically, the unit is placed on a flat surface with the bubble side up.

Amount of water that can be treated

It holds 5 liters and can pasteurize up to 15 liters per day under ideal weather conditions.

Figure 8: A WAPI type indicator is built into the Aqua Pak. When the wax melts and runs to the low end of the tube pasteurization temperature has been reached.

Conditions for appropriate use

While this unit is not intended for use in developed countries it may have an application in some colonia households and during emergencies or disasters. If a family has an alternative such as purchasing drinking water for 25 cents a gallon at a “Windmill” dispenser they are not likely to utilize this type of water purifier.

Cost of treatment

Very low. Both initial cost and life cycle cost are very low for the Aqua Pak.

Advantages

Simple and cheap. Has an indicator to prove water reached pasteurization temperatures and is safe. In winter, additional units can be used to maintain production.

Figure 9: The Aqua Pak is a simple, low cost method of pasteurizing water that includes a thermal indicator.

Disadvantages

Designed for rural populations in developing nations. May not be considered convenient by peri-urban families with more options. Requires owner involvement.

Acceptance by users

Varies. Additional testing needed.

(see Fact Sheet for AquaPak in appendix)

*Sol*Saver*

The Sol*Saver is a solar pasteurization device designed for treating large quantities of water.

How it works

A 4x10 foot solar thermal collector heats water and releases it through a thermally activated valve and heat exchanger. Incoming water is pre-heated by the treated water to increase efficiency. A back-up wood-fired heater is provided for times when there is no sun.

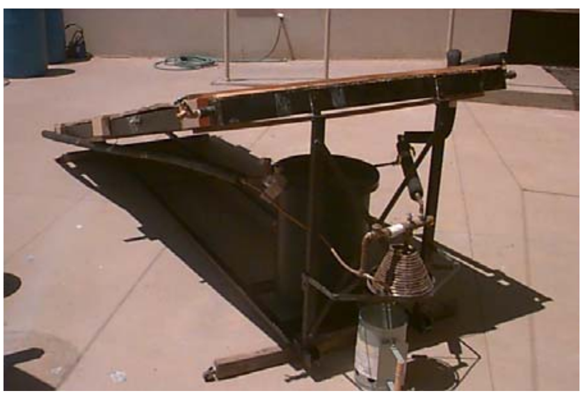


Figure 10: The Sol*Saver is large and expensive but has a high production rate and can operate automatically without any external power.

Amount of water that can be treated

Two hundred or more gallons per day can be pasteurized per day.

Conditions for appropriate use

Most suitable for a small community in a temperate climate without electricity.

Cost of treatment

Initial cost of the unit is high but the high production rate makes the unit cost effective for multiple users.

Advantages

High production rates. Can operate off grid in very remote areas with gravity fed supply.

Disadvantages

High initial cost. Not suitable for freezing climates.

Acceptance by users

Unknown.

Flow-Through Solar Water Pasteurizers

There is a definite need for a simple, rugged and low-cost flow through pasteurizer that can produce enough water for drinking and cooking for a family. Just such a device appeared to be very close to delivery to the commercial market two years ago. Unfortunately, no product has been commercialized.

How it works

A flow through pasteurizer must be able to control the production of water without allowing any contaminated water through the system. It must also incorporate a heat exchanger to boost productivity since more energy is typically realized through the heat exchange process than from solar input.

Amount of water that can be treated

Water production varies considerably based on size of unit and solar resource. A family sized unit needs to be able to supply 20 to 25 liters (5-6 gallons) per day on average. If a unit is sized to produce very large quantities of water it becomes unaffordable by a single family.

Conditions for appropriate use

Sufficient sunshine must be available to heat the water to pasteurization temperatures. A fail safe device that prevents contaminated water form being delivered is required. And, controls that negate the effects of boiling or freezing of the water are needed. The device must also be simple enough to use that a homeowner can operate and maintain it.

Cost of treatment

First cost is just as important as life cycle costs to produce water. If a family simply cannot afford the device then the cost per gallon is not important. Ideally, initial cost should be $100 to $200 dollars and cost per gallon around one cent.

Advantages

If available, the advantages would be providing an automatic device that makes safe water available using a free energy source with little owner involvement required at low cost. This would essentially be the solar equivalent of a countertop UV purifier.

Disadvantages

No product commercially available, prototypes are very expensive, prototypes are complicated and susceptible to damage.

Acceptance by users

Unknown, untested

Solar Kitchen Sink Blackwater Pasteurizer

How it works

Some authorities consider kitchen sink water to have a higher pathogen content that demands special treatment beyond that required for greywater. A basic design based on the Solar Puddle as conceived by Dale Andreatta was investigated. A simple, insulated basin covered with polycarbonate structured sheet (PCSS) and lined with silicone caulk was constructed to treat batches of kitchen sink water by raising the temperature to 158°F (70°C). This design was abandoned in favor of simple sub-surface greywater disposal.

Amount of water that can be treated

The depth of the water in a basin controls the temperature that may be reached. Varying the size of the collector and basin, virtually any amount of water may be processed.

Conditions for appropriate use

For safe re-use greywater must be treated to destroy micro-organisms or human contact must be prevented. It is much simpler and more reliable to devise a system that avoids human contact through sub-surface irrigation. As Art Ludwig states, “In a residential context, any system which uses a pump, filter or costs more than you spend on water in a year is suspect. *Disinfection is extremely suspect*.” Solar energy is capable of providing pasteurization temperatures for greywater and kitchen sink water but may prove to be more complicated and labor intensive than desired.

Cost of treatment

The device may be built at low cost but operational labor costs may be considered high by home owners.

Advantages

Uses free solar energy. Disinfects kitchen sink blackwater. Low construction cost.

Disadvantages

Other more suitable treatment methods may be more appropriate, easier, more reliable, and more cost effective. Requires significant homeowner involvement. Greywater does not store well due to odor production requiring a back-up even in very sunny climates. The pasteurizing unit must be protected from over heating between batch processes. Our conclusion is to use other simpler technologies.

Acceptance by users

Unknown. Not field tested.

Solar Distillation

How it works

In a typical basin-type single effect still, water is heated by solar radiation causing it to vaporize and condense on the glass cover. It then trickles down to a collection trough and is channeled to a storage container.

Amount of water that can be treated

Solar stills have been constructed in a very wide range of sizes. Production is limited by the efficiency of the still and the solar input. Typically, solar stills produce 1 to 2 gallons per square meter per day; more in summer and less in winter.

Conditions for appropriate use

Solar distillation is most appropriate where the salt content of water is too high for drinking. If the primary problem with water is pathogens, simpler and lower cost alternatives may be more appropriate.

Cost of treatment

Using the example of a solar still that has 18 sq.ft. of collection surface (~2sqM), costs $500, and produces on average 750 gallons (or ~2 gallons per day) per year. Costs would be 66 cents per gallon the first year but would drop to maintenance costs in subsequent years.

Advantages

Eliminates salts and many chemicals (except those with lower vapor pressure than water, e.g. gasoline) in addition to pathogens. Improves the taste of water.

Disadvantages

Relatively high initial cost. Relatively low production. Production varies seasonally with solar flux. Requires daily user interaction.

Acceptance by users

Good.

Dry Sanitation

"One flush of a standard U.S. toilet requires more water than most individuals, and many families, in the world use for all their needs in an entire day. But toilet technology has already reduced new U.S. units from the old 5–7 U.S. gallons per flush (gpf) to 1.6 or fewer, with no degradation of performance.

A more sensible design than obsolete flush toilets has been introduced by modern Swedish toilets. These feature a two-compartment bowl to separate urine, which contains most of the nutrient value in human wastes, from feces: The two leave the body separately, and should be disposed of that way. It is then a straightforward procedure to collect or sell the urine (stored in a small tank) from a tap outside the building as a valuable fertilizer, and to dry and bag, compost, or otherwise treat the 20-odd pounds of feces per person per year. In Sweden, a country noted for hygienic and aesthetic refinement, more than 50,000 such dry systems have been sold in 42 models from 22 manufacturers; they cost scarcely more to buy and can cost less to install than a nonseparating toilet plus its sewer connection. If perfected in a form attractive to the American market, separating toilets could greatly reduce toilets' water use, perhaps even to zero for dry or composting solutions. The toilets would save sewage-collection, sewage-treatment, and agricultural costs and would improve topsoil." Natural Capitalism, Hawken, Lovins & Lovins

There is an obvious advantage to dry sanitation for those living beyond the pipes. By eliminating the single largest use of household water – flushing toilets, families do not have to haul, store, and dispose of huge quantities of water. Many approaches have been tried and numerous systems are available. There is a wide variation in cost, convenience, and reliability. We will review three approaches.

Once a dry toilet is decided upon, a family must then choose a method for handling greywater from baths and laundries and a method for handling kitchen sink water since some health authorities classify it as blackwater or higher pathogen content water that requires special handling. There is the potential to save the cost of a septic tank. Most dry toilets use a composting process; others desiccate and raise the pH of the waste. The Energy Center evaluated using solar pasteurization to destroy pathogens.

Solar Assisted Composting Toilet (SIRDO)

In a project funded by Paso del Norte Health Foundation and others, CERM installed approximately 300 prefabricated, dry-composting toilets manufactured by GTA, Naucalpan, México were installed in three peri-urban communities of Cd. Juárez. These units, called SIRDOs (Sistema Integral de Reciclamiento de Desechos Orgánicos), are single-vault, self-contained, fiberglass and plastic structures that stand separate or connected to the home and serve usually a single family.

How it works

Urine, feces, toilet paper, and additive are processed in a two pile system that also incorporates an unglazed passive solar panel to add some solar heating.

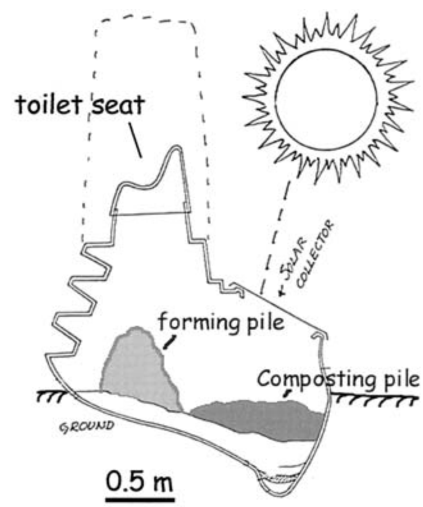


Figure 11: The SIRDO is a composting toilet that requires no water and very little space. The photo shows some units in Cuidad Juarez, Mexico.

Amount of water that can be treated

The SIRDO is sized for an individual family of 4 or 5 members.

Conditions for appropriate use

Ideal for replacing pit latrines or in areas not served by sewers. Septic tank leach fields require a large amount of space; SIRDOs do not.

Cost of treatment

Units cost $300 in Mexico. Costs are low compared to alternatives.

Advantages

Uses no water. Low cost. Saves space.

Disadvantages

The moisture level was consistently too low for efficient biodegradation, which requires moisture levels between 40-60%. High levels of multiple pathogens were found in the samples after 6 months of composting, precautionary measures should be taken during disposal of the end product. Owner involvement is required to maintain optimum moisture and to stir the pile to promote composting.

Acceptance by users

All dry sanitation system users were very satisfied with their new toilets regardless of the type. The main variables that users considered important were the absence of flies and odor. Compared to their previous system (pit latrines), the new systems had no odor and only a few flies.

Dry Lime Toilet

Figure 12: Drying waste and raising the pH level has also been shown to be effective in destroying pathogens. Above are photos of toilets installed by CERM in Cuidad Juarez, Mexico.

How it works

Lime stabilization refers to the addition of lime (calcium oxide) to waste. When the pH of the sludge is increased, usually to above 11 bacteria are killed.

The dehydrating toilets rely on desiccation and high pH (>10) for pathogen reduction. The dehydrating system had only 7% moisture at four months, which is appropriate for a desiccating system. The pH was <8 for the biodegrading system and approximately 10 for the dehydrating system. The high pH has been shown in previous studies to increase the rate of pathogen die-off. Both systems had a two-fold log reduction in fecal coliforms between two and six months. There was a major decrease in *Cryptosporidium* detected in the dehydration system compared to that of the biodegrading system, 67% to 50% positive versus 46% to 0% positive after six months. For *Giardia*, there was also a decrease but less pronounced.

Amount of waster that can be treated

Double vault toilets were built to allow additional residence time for the waste. The units are sized for a family of 4 to 5 members.

Conditions for appropriate use

A study found that pathogens were present in treated sludge that was removed from the toilets. "Based on our findings, there is the potential that viable Giardia and Cryptosporidium cysts and oocysts are still present in the composted waste. For hygienic reasons, this waste should be disposed of by burying or bagging it for transportation to a landfill to prevent future human exposure." From *Hyperendemic Cryptosporidium and Giardia in Households Lacking Municiapl Sewer and Water on the United Sates –Mexico Border* by Redlinger, et al

Cost of treatment

Low cost.

Advantages

Zero water use. Small space required. Low cost treatment.

Disadvantages

Sludge must be disposed of in landfill. Pathogens may still be present in final product. Requires homeowner involvement.

Acceptance by users

Good. Users were very happy with the units.

Texas Two Step Solar Pasteurizing Toilet

Figure 13: The collection of waste can be almost anywhere. The demonstration unit (above, left) was constructed like a pit privy but with bag collection. The pasteurizing hot box (right) is a simple, glazed and insulated box that resembles a solar cooker.

How it works

The Energy Center at CERM is investigating the practicality of pasteurizing human waste with solar energy as a means of saving water and preventing the spread of disease in border colonias. A waterless alternative to the flush toilet that utilizes the sun's power to pasteurize is being tested. It has been named the Texas Two-Step Solar Pasteurizing Toilet and the two steps are: Bag It! Bake It!

Excrement (the combination of urine and feces) and an additive such as sawdust is collected in a black polyethylene bag inside an autoclavable polypropylene bag to provide two layers of protection. (ETPA , Excrement, Toilet Paper, and Additive, is an acronym used to describe dry toilet contents.) Bagging the ETPA also makes it easier to handle, improves aesthetics and presents a uniform depth with a large solar collection area. When the inner bag is filled both are sealed and placed in an insulated box with a south sloping window that resembles a solar cooker. The goal is to achieve a temperature of 150°F (66°C) for one hour throughout the contents. This is sufficient to kill all the pathogens in the waste. One clear, sunny day during a week is needed to produce this temperature. Once pasteurization has occurred the material is considered Class A Sludge and may be composted for on-site use or sent to a landfill. Testing will be required to ensure pathogen elimination.

Figure 14: Waste is collected in a bag inside of a bucket or trash can. Access to the bag is available from inside or outside the privy. The ergonomics are tested by Jay Graham (right).

Figure 15: A later version of the pasteurizing unit features a 45 degree angle for the glazing to optimize for year round solar collection in El Paso (latitude + 15 degrees). The lightweight top simply lifts off the insulated base for loading and unloading.

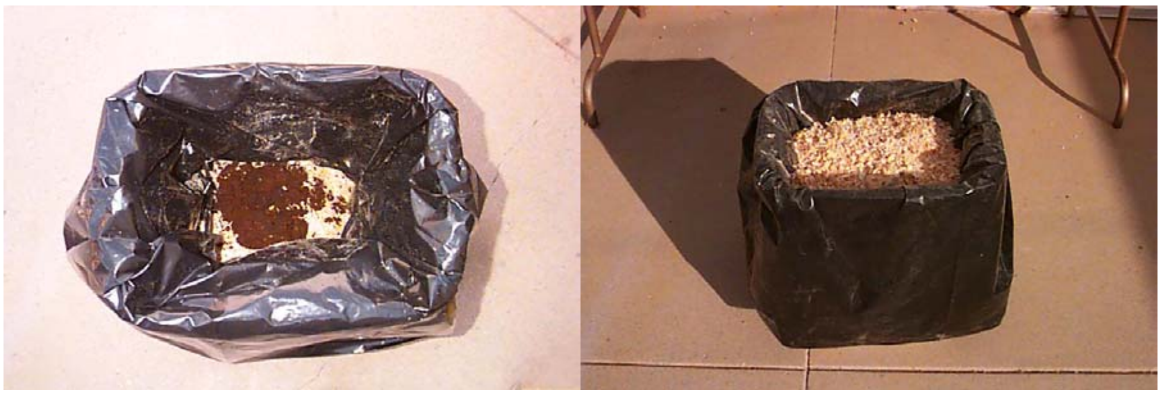


Figure 16: One week of waste collection (with urine diversion assumed) was simulated in these photos. The container is a standard 13 gallon kitchen trash can lined with a heavy duty black polyethylene bag and an autoclavable polypropylene bag. In early tests polyehtylene bags were melting at folded spots.

Figure 17: Bagging the waste minimizes the interaction of homeowners and may be more popular than stirring and shoveling the end product as in some composting designs. The bag contains 23.5 cups (.6L each) plus an equal volume of sawdust. It weighs 32 pounds.

Figure 18: Bagging the waste also allows for a large surface area for solar collection to ensure a minimal and even depth for uniform heating for pasteurization. At right, .6 liters (20.3 oz.) of simulated solid waste (cow manure) is shown.

Amount of waste that can be treated

The test unit has been sized to treat .6 liters (20.3 fl.oz.) of feces and 1.2 liters (40.6 fl.oz.) of urine per person per day with additional bulk from toilet paper and an additive to cover feces and soak up urine for four adults. The pasteurization cycle is assumed to be one week, that is, enough clear weather will occur in one week to reach pasteurization temperatures. For cloudy climates different sizing may be required. It is possible to have 2 pasteurizing units to increase residence time to 2 weeks. Typically, pasteurization temperatures are reached in a one or two day cycle. The unit is sized to achieve temperatures of 150°F (66°C) for one hour or more under the bagged waste. Initial tests indicate that the lowest temperature is at the underside of the bagged waste. This is due to the heat flow coming from solar energy on top of the bag. Testing also indicates that once the temperature under the bag reaches 150°F (66°C) it will remain there for one hour or more due to the mass effect. Additional testing is being done for feces only to simulate conditions for urine diverting toilets. The volume of treated sludge will be significantly less without urine and additive to soak it up, allowing the system to be smaller.

Conditions for appropriate use

The design is an alternative to other dry sanitation approaches or pit privies. A relatively mild, sunny climate will be the most appropriate for this design.

Cost of treatment

Costs for this design could be low to very low. Black polyethylene bags are readily available and low cost (~5 cents each) and autoclaveable bags are available for about 30 cents each. Assuming one batch per week, bags would cost $18 per year. The only other costs are for a solar pasteurizing unit, which can be constructed for less than $50, a thermal indicator to ensure pasteurization temperatures have been reached (a hi-lo reading thermometer with memory is $10-15), and wire ties (3-5 cents each) or other bag closures. There may be an additional cost for an additive like sawdust. As with other systems a major cost may be for the modified dry toilet stool, if needed. Alternatively, a privy-like arrangement to collect the waste in a bag can be built at minimal cost.

Advantages

Low Cost, requires little specialized knowledge to use, potential to close the nutrient cycle, potential to quickly and effectively neutralize pathogens,

Disadvantages

Still experimental -- requires further testing, permitting, and approvals from sanitation authorities, requires minimum solar resource, requires some homeowner involvement, requires special bags, requires additive, requires indicator of pasteurization. Potential problems include: odors developed when heating feces, expansion of gas inside bags, user resistance to bag collection.

Acceptance by users

Untested, unknown.

A Note on Urine Diversion

Processing urine and feces separately has many advantages. Since urine is typically sterile (in the absence of an infection) and contains the most nutrient value (nitrogen) it may be desirable to collect it separately for re-use. Urine also requires large amounts of additive to adequately soak it up and contributes to odor formation when combined with feces. Unfortunately, not very much work has been done on urine collection and re-use. Typically, urine diverting toilets are expensive specialty products.

"Since Thomas Crapper invented the water closet, many sanitation experts have come to view it as one of the stupidest technologies of all time: In an effort to make them "invisible," it mixes pathogen-bearing feces with relatively clean urine. Then it dilutes that slurry with about 100 times its volume in pure drinking water, and further mixes the mess with industrial toxins in the sewer system, thus turning "an excellent fertilizer and soil conditioner" into a serious, far-reaching, and dispersed disposal problem. Supplying the clean water, treating the sewage, and providing all the delivery and collection in between requires systems whose cost strains the resources even of wealthy countries, let alone the 2 billion people who lack basic sanitation. The World Health Organization has stated that waterborne sanitation cannot meet *any* of its declared objectives—equity, disease prevention, and sustainability—and suggests that only with more modern (waterless) techniques can the world's cities be affordably provided with clean water for drinking, cooking, and washing." Natural Capitalism, Hawken, Lovins & Lovins

"There is far more nitrogen present in urine than feces, which can really upset the C/N ratio … requiring far more carbon material to be added to the compost toilet than if the urine was collected separately. The addition of urine can also saturate the compost pile well beyond the desirable moisture content causing anaerobic conditions to prevail, composting to be replaced by fermentation and foul odors to persist." Composting Toilet System Book, del Porto & Steinfeld

Solar Water Heating to reduce water-washed disease

"Diarrhoea is a symptom of infection caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water. It is more common when there is a shortage of clean water for drinking, cooking and cleaning and basic hygiene is important in prevention. Water contaminated with human faeces for example from municipal sewage, septic tanks and latrines is of special concern. Animal faeces also contain microorganisms that can cause diarrhoea. Diarrhoea can also spread from person to person, aggravated by poor personal hygiene. Food is another major cause of diarrhoea when it is prepared or stored in unhygienic conditions." World Health Organization

When households lack convenient ways to shower or wash their hands gastrointestinal disease rates climb. Drinking contaminated water is one way to come in contact with pathogens another main route for fecal-oral contamination is from hands and the environment. When a mother changes the diapers of an infant and does not have a convenient method to wash her hands the family is at greater risk.

The best solution is to provide complete plumbing for kitchens and baths along with pressurized, running water. A complete plumbing system provides adequate convenience to encourage proper sanitation. Since this level of solution may be out of reach for some families the Energy Center investigated possible alternatives for use by families "beyond the pipes."

Handwashing station

How it works

A five gallon bucket is fitted with a hose bib to provide a source of water for handwashing. In households without access to running water this simple device provides an easy way to encourage sanitation behavior and reduce water-washed disease. A colorful, instructional sticker is added to the bucket to emphasize the importance of handwashing and provide instructions on how and when to wash your hands.

Amount of water that can be treated

A one gallon garden sprayer was also converted to use as a handwashing station. Although it holds much less water, it is pressurized and may be more efficient. The design was not pursued since the 5 gallon bucket is simple, low-cost, reliable, and readily available. A non-profit micro-enterprise in Cuidad Juarez, Mexico is making and selling the units.

Figure 19: The handwashing station can be used with or without solar features. For most of the year a black bucket with a clear top will provide warm to hot water.

Figure 20: A glazed, insulated cover can extend the time of year for providing warm water. Caution should be used to prevent children from using water that may be too hot.

Conditions for appropriate use

This portable unit can be placed near a dry toilet or in the kitchen area of a home without running water. It is a modified 5 gallon bucket that fits into the existing water conveyance method for most households. The graywater produced can be collected in another 5 gallon bucket and used on landscape. A solar heated version of this design may provide some additional convenience for users. The unit could be placed inside a Solar Bucket Heater (see next section) but will double the cost. Alternatively, a black plastic bucket and/or a bucket with a clear lid will produce warm water for many months of the year.

Cost of unit

Cost is very low – under $10 with a new bucket and lid and all of the hardware, including: pvc pipe, pvc fittings, hose bib, and uniseal.

Advantages

Very low technology. Encourages proper sanitation. Fits into existing water system. Low cost.

Disadvantages

Handwashing remains difficult. Some added convenience but not equal to running water. Requires homeowner involvement.

Figure 21: A one gallon garden sprayer could be adapted as a handwashing station.

Acceptance by users

Good. Units are being constructed and sold in Cuidad Juarez, Mexico.

Solar Bucket Heater

Five gallon plastic buckets are the common denominator of households without a pressurized water system. Everyone has a few 5 gallon plastic buckets around. Painting one black and simply setting it in the sun with a clear cover will heat water hotter than needed during the summer months. When ambient temperatures drop, a simple cover made of insulating foam board and plastic glazing can continue to provide bathing temperature water even on a cold, sunny day.

Figure 22: Placing a black plastic bucket inside a glazed and insulated box provides a low cost solar water heater.

How it works

Plastic buckets work about as well as metal and have the added advantage of not rusting and being available in black to eliminate the need for painting. Fill a bucket with water put a clear cap on it to help trap solar energy and prevent evaporation then set it in the sun. In winter, an insulated cover with a window on the south side is needed to get warm temperatures. The same cover can be used all year round and due to sun angles will produce about the same water temperatures. The 60 degree glazing angle is optimized for low winter sun but still allows sufficient sun in summer and screens UV radiation to prolong the life of the clear polyethylene bucket cap. (see photo) In El Paso, sunny days produce 5 gallons of 110 - 120°F water in both the summer and the winter

Amount of water that can be heated

This low-tech device is for 5 gallon buckets. Additional units may be constructed for larger capacity but more sophisticated system may be a better choice as scale increases.

Conditions for appropriate use

This system is aimed at families without pressurized or gravity-fed water systems. It is intended as a first step, least cost alternative.

Cost of heating

The most basic level of solar bucket heater is probably free or costs less than $2 for a clear top and some flat black spray paint, as many families have a bucket on hand. This heater may work 6 to 9 months of the year depending on climate. The insulated cover with PCSS glazing and a new black plastic bucket is about $10-12. The adapted pumped camp shower costs from $25 to $50 depending on the availability of surplus or retail components. Total cost is $35 to 70.

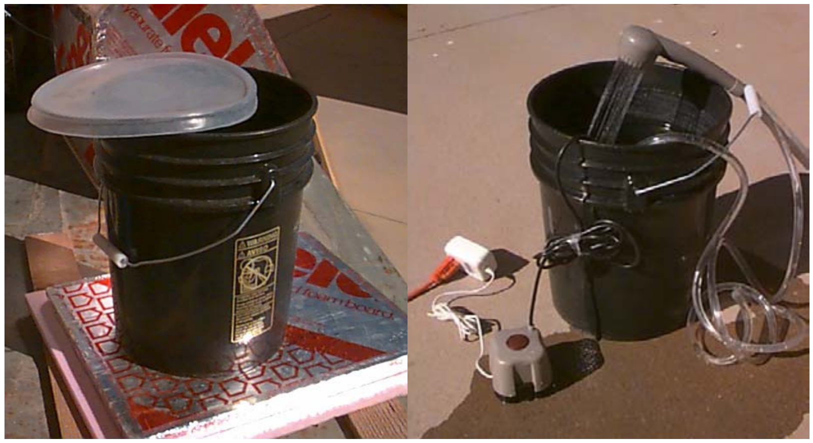


Figure 23: A black 5 gallon plastic bucket can provide hot water at a very low cost. A camping shower can be adapted to provide convenience if desired.

Advantages

One benefit is convenience. Water is heated all day long and is waiting to be used in the evening -- eliminating the need to heat water on the stove. The colonia resident brings the bucket inside, drops in the pump and is ready to shower. (Note: Water above 105 F may require mixing with cold water for comfort or to prevent scalding.) Another benefit is saving electricity or LP fuel.

Disadvantages

Small batch of water, water cools off at night if not used in time, still requires hauling water in 5 gallon bucket, must construct cover, basic knowledge of solar angles needed, dependent on solar energy, partly sunny days may require addition of some conventionally heated water, must adjust shower times based on solar heat availability

Acceptance by users

Unknown. Some positive feedback from Texas colonia residents. Additional field tests needed.
(see Fact Sheet: Solar Bucket Heater)

Passive Solar Water Heater

How it works

This is a system for families with a pressurized water system. It uses the tank from a recycled (or new) water heater that has been stripped of all the insulation and the metal cover. The bare tank is painted flat black and put into an insulated box with a south facing window to collect solar heat.

Figure 24: An old water heater tank can be converted into a passive solar water heater. In this design the weight is carried by a simple skid, allowing a lightweight insulated cover.

Amount of water that can be heated

Tank size is based on what is available. Typically tanks are 30 or 40 gallons each. They may be plumbed in series to increase capacity and to reduce mixing of incoming cold water. The amount of hot water that can be provided is expressed as the solar fraction and it varies from 50% or less to about 75%. Solar water heaters are sized based on the “average” US hot water usage of 20 gal/person/day. This can vary considerably, making sizing a family and site specific task. This type of system is usually installed as a pre-heater for an existing, conventional gas or electric water heater.

Conditions for appropriate use

The purpose of installing a solar water heater is to save money on gas or electricity bills. The heater is most appropriate where expensive fuel (electricity or LP) is used to heat water and a low-cost do-it-yourself system can be built. This solar heater is for families with “running” water. Sunny, mild climates will produce the best results but many commercial versions of this type of solar heater have been installed in very severe climates. Some owners drain the system during the 2 or 3 coldest months.

Cost

Costs vary widely depending on materials and labor costs. Commercially available systems cost $999 to $1500 for a 40 gallon unit. If a free,recycled tank and recycled patio door glass are available, the cost of the box may be as little as $50.

Advantages

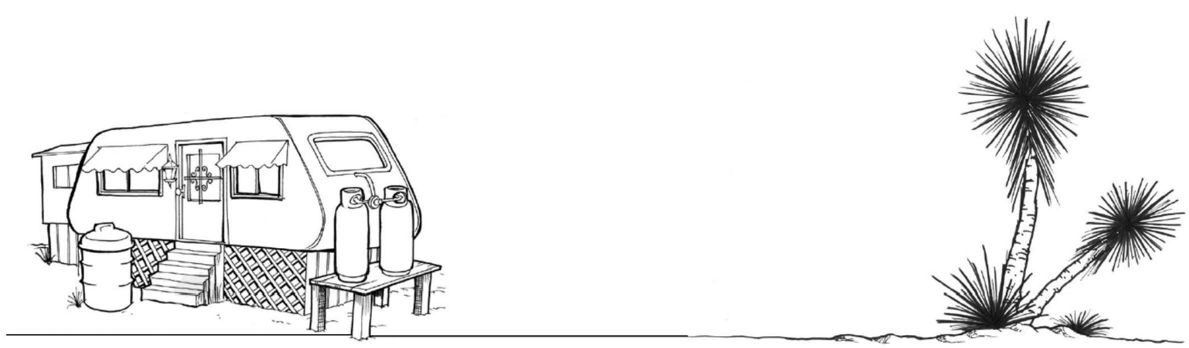
Low cost. No pumps or moving parts. Simple, owner built system. This system is designed for easy, low-cost construction by homeowners. The ground mounted design incorporates a skid to handle the heavy water tank and a minimal foam box that is easily removed to allow access to all plumbing for maintenance.

Disadvantages

Major home project. Requires knowledge and construction/plumbing skills.

Acceptance by users

Typically very well accepted since the system is low maintenance and installed as an integral part of the existing home water heating system.



Agua Para Beber APB – Drinking Water Storage

How it works

APB is a formalized small batch chlorination program. Families are provided a container that helps prevent re-contamination of drinking water; an instructional sticker is on the container. An eye dropper to properly dose the water with chlorine is provided.

Amount of water that can be treated

The APB container is 5 gallons. It is sized to provide family drinking water while the chlorine residual is still active.

Conditions for appropriate use

APB is intended to assist families without a treated water supply

Cost of treatment

Cost is very low; less than $10. Only a container, eyedropper, and chlorine are required.

Advantages

Provides instruction, a routine and a container to assist the family in maintaining a safe drinking water supply.

Disadvantages

Acceptance by users

Very good. Follow up studies have shown that families continue to use the APB method.

Drums and Buckets

Recommended systems for storage and pumping with 55 gallon drums and 5 gallon buckets.

Figure 25: A typical water storage system consists of open top recycled drums. A closed system with a pumped delivery can be assembled at a relatively low cost.

Families using 55 gallon drums for water storage are often using the only materials they can find. That is, there is no design process or thought for the system -- it is done based on what is available in the locale and without knowledge of any alternatives. A typical system consists of several recycled drums with the tops cutout. Hopefully, these drums formerly contained a non-toxic substance and are food grade. Sometimes these are covered but often remain open to contamination.

A few minimal refinements and small pieces of technology could markedly improve the system. Some that have been considered by the Energy Center are:

1.) UniSeal connections for the 55 gallon drums to link them together and make it easier to draw water from the entire stored volume.

2.) Combining closed head drums with one open head drum to allow ease in filling while keeping costs down (new closed head drums are about $10 cheaper than removable head ones)

3.) Using a siphon pump to fill 5 gallon buckets in place of dipping a bucket into a drum;

4.) Using a study plastic top that seals well on recycled drums (see photo of yellow top)

5.) Various pumping schemes

6.) Chlorine dosing at fill-up and during use

7.) Use of chlorine test strips for monitoring

For families that cannot access a 2500 gallon tank with pressure pump and tank (~$1,500), a smaller system may be affordable. A plan for what will work and how to keep it operating safely is needed. The Energy Center has devised one system that households may adapt and use as their home water system. It may be powered with a hand pump as pictured above or with an electric pump and a faucet. This basic system is a significant improvement over open-top barrels with plywood covers that require hauling water in 5 gallon buckets. A basic system with six 55 gallon drums (330 gallons) and a farm-style pitcher pump 25 feet away can be plumbed for under $300. If recycled open-top drums are used in conjunction with new lids the system could be under $150.

Figure 26: New or recycled drums can be connected with Uniseals and PVC pipe. A siphon pump allows the owner to draw water without contaminating the supply. One removable head drum makes it easier to fill the system.

Water storage options for families beyond the pipes

Gallons	Access	$ New	$/gal	$ Recycled	$/gal	Notes
55	Open Head	$45	.82	$23	.42	HDPE
55	Closed Head	$35	.64	$18	.33	HDPE
450L, 119gal	Var.Ftgs.	$75	.63	---	---	Tinaco
730L, 193gal	Var.Ftgs.	$100	.52	---	---	Tinaco,Black. ROTOPLAS
1100L, 291gal	Var.Ftgs.	$140	.48	---	---	Tinaco
2500 gal	w/Pmp&PrTnk	$1,500	.60	---	---	Black,HDPE
5 gallon	Black bucket	$4.50		---		Black, HDPE

Fig. 27: Sturdy plastic tops are available for about $6. These are much better than typical flimsy plastic lids. Recycled, closed head drums may be converted to open head drums with tops.

Note: When entire top of drum is cut away it becomes susceptible to getting "out-of-round", making rigid retrofit tops fit poorly. Solution: Leave 2 to 3 inches of top around edges in a "ring".

Costs for a basic water storage and pumping system

Number	Description	New	Recycled Drum	Total-New	Total-Recycled
6	55 gal drum	35	18	210	108
10	Uniseal	1	1	10	10
6	Drum Cover	6	6	36	36
40ft.	PVC Pipe	0.3	0.3	12	12
1	Hand Pump	25	25	25	25
				293	191

New/Gal	$0.89
Recycled/Gal	$0.58

A basic water system can be assembled for under $200 (or under $300 with all new parts). Six recycled 55 gallon drums with a capacity of 330 gallons can be covered, connected with Uniseal and PVC pipe, and plumbed to a remote hand (or small electric pump. This entry level system could provide more convenience and support sanitation behaviors.

Assorted pumps for home water systems

Pump Type	Max.Head	Max.GPM	Cost	Electrical	Notes
Siphon	N.A.	7	$9	None	US Plastic
Farm/Pitcher	18 feet	4.5	$25	None	Northern
Rule / DC	12 feet	8	$18	DC,12V-2A	Bilge pump
Submersible	23 feet	22	$40	115AC	Northern
Line / Hose			$45	115AC	Home Depot
RV Sink	?	?	$25	DC, 12V	JC Whitney
Guzzler	12 (+12 lift)	15	$45	Hand Operated	US Plastic

Large Storage Tanks

Those families that are "beyond the pipes" in border colonias frequently utilize large water storage tanks with pressure pumps and a small pressure tank to provide running water inside their homes. In El Paso colonias, 2500 gallon tanks are a common solution for the family water supply. Studies have shown that the safety of the water declines rapidly during the delivery and storage process. Families do not always adequately chlorinate their tanks.

In other border areas and in Mexico, similar plastic tanks (called "tinacos") of several sizes are often used with and without pumps. Some are installed on roofs or racks to provide gravity fed running water.

Figure 28: These 2500 gallon tanks are the solution of choice for many families living beyond the pipes.

Disaster & Emergency Water Treatment Applications

Several of the technologies investigated have potential application for families during times of emergency or when natural disasters strike. Urban households share problems of colonia residents during these times. For example, during a flood the water treatment plant may become contaminated and be unable to deliver pathogen free water. It becomes the responsibility of each family to ensure the safety of their own water supply. Proper boiling, chlorination, the use of SODIS, or solar pasteurization of water could be adapted by disaster victims.

SODIS may be the most adaptable technology and the easiest to keep on hand for use when conditions are at the very worst. If gas, water and electricity service are all interrupted, SODIS can still be used on sunny days. All that is required is a few recycled 2 liter soda bottles.

Aqua Pak is also a very simple, low-cost technology that may be used. Families could easily purchase and store one or more Aqua Paks for emergency use.

Agua Para Beber (APB or Water for Drinking) may also be easily adapted to use during emergencies. Most households could store several empty 5 gallon APB containers that could be filled when extreme weather events are expected. The chlorine and eyedropper for proper disinfection could be part of the kit.

Higher volume storage could be easily adapted as well. A 55 gallon drum and a siphon pump would provide many days of drinking water. The empty drum will take up room but is lightweight and durable. It could even serve as a support for a makeshift worktable by putting a piece of plywood on top of it.

Figure 29: An alternative to the APB container is the standard 5 gallon water bottle that is available at any Wal-Mart or K-Mart, etc. It is shown here with a convenient pump (popular in Mexico) that uses two D cells or an AC adapter. A small manual siphon pump would also work well.

As part of an emergency kit with a few cans of food, flashlight, blankets, and a first aid kit, etc., families may consider storing some recycled PET 2 liter soda bottles that have been painted on one side with flat black spray paint or an Aqua Pak. Two 2 liter bottles per family member could supply about a gallon per day. Some chlorine and an eye dropper could complete the kit that could be stowed in the garage or the top of a closet until needed.

Conclusions and Lessons Learned

- There is a need for a simple, low-cost flow-through solar pasteurizer
- Use simple greywater systems instead of solar treatment when possible
- Divert Urine and re-use if possible
- A variety of technologies may apply to "beyond the pipes" families
- A hierarchy of users exists, each level has specific needs
- There are many levels of technology and price that apply to various groups
- If a technology does not apply to certain colonia residents it may apply to others
- Good low cost water storage systems are needed
- Good low-cost water pumping and pressurization systems are needed
- Uniseals are an excellent technology (highly recommended)
- Low tech designs are often overlooked as too simple or too unsophisticated
- Matching technology to problems sometimes must be very specific

More Information

Websites, Publications, and Vendors

Vendors

W. W. Grainger http://grainger.com, With a catalog that has over 3,700 pages and 390 locations you can find many items in one spot. Wholesale only.

Associated Bag Company 1-800-926-6100, www.associatedbag.com Source for autoclavalbe bags

Northern Tool & Equiment   1-800-556-7885, http://northerntool.com, Source for farm-style pitcher pump and low cost submersible pumps

United States Plastic Corporation 1-800-537-9724, http://www.usplastic.comSource for black 5 gallon buckets, low cost siphon pumps and many other plastic items.

Consolidated Plastics Company 1-800-362-1000, www.consolidatedplastics.com

AquaPak – Solar Solutions, (858)695-3806, http://www.solarsolutions.info/aquapak/aquapak.html

SODIS www.sodis.ch/, Solar Water Disinfection, improves the microbiological quality of drinking water: It is a simple water treatment method using solar UV-A radiation and temperature to inactivate pathogens causing diarrhoea. SODIS is used at household level under the responsibility of the user. Therefore EAWAG is not liable for any harm caused by a faulty or inadequate application of the water treatment process.

Safe Water Systems http://safewatersystems.com , Sol*Saver and Family Sol*Saver

Paper Thermometer Company 1-03-547-2034, www.paperthermometer.com

Uniseal – A.G.S. Austrailian Global Services, Inc. 1-888-222-8940, http://www.aussieglobe.com/uniseal1.htm

Sundance Supply – http://www.sundancesupply.com, Polycarbonate Structured Sheet, PCSS, double wall plastic glazing.

Ohio Pure Water Company. 2003. *Ultraviolet Disinfection*, http://www.ohiopurewaterco.com/ultraviolet-disinfection.html

Pure Water Express. 2003. *Ultra Violet (UV) Stage Add-On*, http://www.purewaterexpress.com/ro.htm#2a

Puritec, 1-888-491-4100, http://www.puritec.com/residential/water/catalog.htm Countertop UV System

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Del Porto, D., D. Steinfeld, *The Composting Toilet System Book*. 1st ed. 1998, Concord, Massachusetts.: The Center for Ecological Pollution Prevention

Burch, J. and K. Thomas, An Overview of Water Disinfection in Developing Countries and the Potential for Solar Thermal Water Pasteurization. 1998, National Renewable Energy Laboratory, NREL/TP-550-23110. (http://www.nrel.gov/docs/legosti/fy98/23110.pdf)

Create an Oasis with Greywater, Builder's Guide to Greywater, and Branched Greywater System Design by Art Ludwig, Poor Richard's Press, http://oasisdesign.net

"El Paso County Comprehensive Colonia Study and Plan 2000". Martinez Engineering Group in association with Strategies & Plus, Dorado Engineering and Frontera Environmental. December 2000.

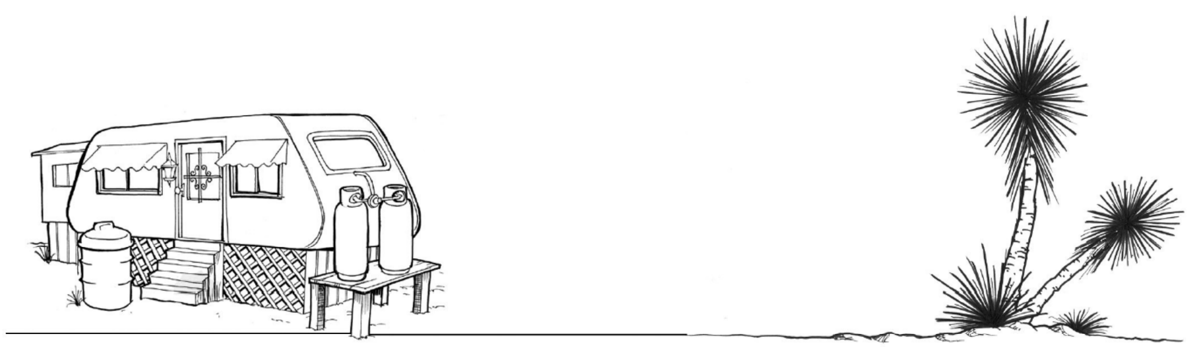
Graham, J., "The effectiveness of large household water storage tanks for protecting the quality of drinking water". School of Public Health. The University of Texas-Houston

Health Science Center. El Paso, Texas. 2000. p. 90.

"Health Benefits from Improvements in water supply and sanitation: Survey and analysis of the literature on selected diseases". United States Agency of International Development. 1990.

Laing, B. 2002. "UV disinfection for POE applications," *Water Technology*, November 2002, 33-35.

www.irc.nl/
News and information, advice, research and training, on low-cost water supply and sanitation in developing countries.



Appendix

Table 4-1. Appropriate Disinfection Technologies: Cost and Appropriateness Summary
(Labor costs included)

Technologies/Variables	Production	First Cost	Capac. Cost	LC Cost	Effectiveness[1]			Appropriateness[2]		
Units or Subcategory:	L/day	$	$/m³/day	cents/m³	res[3]	b/v[4]	p/w[5]	sup[6]	hi[7]	lo[8]
Chlorine-dosing plant	24,000	2,400	100	6	***	***	**		*	*
Chlorine (batch, average dose)	200	0	0	9	**	***	*		***	**
MOGGOD	24,000	34,472	1,436	57	***	***	***	*		**
MOGGOD/PV, 24 hr/day	24,000	48,222	2,009	73	***	***	***	*		**
Slow sand filter (low cost)	24,000	1,200	50	2		**	***	***	***	*
Roughing filter (low cost)	24,000	960	40	1			***	***	***	*
Slow sand + roughing filter	24,000	2,160	90	3		***	***	***	***	*
Household filter (low cost)	60	20	333	85		*	**	***	***	**
Sol-UV/batch: bottles	14	1	43	133		**		***	***	**
Sol-UV/flow-through	684	2,574	3,764	144		***	*	***	***	***
UV-WHI/$0.1/kWh[9]	21,600	687	32	2		***		**	**	***
UV-WHI/PV:8 hr+ roughing filter	7,200	2,366	329	14		***	***	**	**	***
UV/PV/pump (GWT)[10]	10,800	10,004	926	35		***	***	*	**	**
UV-UST200 + filter + PV (4.4 hr)	500	313	625	63		***	**	**	***	**
Water boiling, purchased fuel	20	0	0	2,083		***	***		***	*
Wood-saver (12-hour oper.)	1,361	1,236	908	190		***	***		***	*
Batch solar/Family Sol-Saver	23	78	3,425	235		***	***	***	***	***
Batch solar/SUN tube	19	143	7,537	338		***	***	***	***	***
Batch solar/solar puddle	480	34	70	70		**	**	*	***	**
Flow-through solar/Family Sol-Saver	570	2,145	3,764	144		***	***	***	***	***
Flow-through solar/trough	1,436	5,872	4,088	174		***	***	**	**	***
Flow-through solar/pot. polymer	304	84	276	19		***	***	***	***	***

Notes:

[1]Effectiveness scales: High = ***, Med = **, Low = *, None = blank.

[2]Appropriateness scales: No need = ***, Low need = **, Medium need = *, High need = blank.

[3]res = residual disinfection ability.

[4]b/v = effectiveness against bacteria and viruses.

[5]p/w = effectiveness against protozoa and worms.

[6]sup = supplies; high need = blank, no need = ***.

[7]hi = highly skilled labor; high need = blank, no need = ***.

[8]lo = low-skilled labor; high need = blank, no need = ***.

[9]WHI = Water Health International product, Section 4.3.2.2.

[10]GWT = Global Water Technologies product, Section 4.3.2.2.

Personnel

Steve Cook, PI
Jay Graham, Co-PI
Dr. Patrick Gurian
Dr. Huanmin Lu
Karl Dreher
Salvador Saenz
Veronica Corella-Barud

Students:
Jun-Young Park
Alex Reyna
Gilbert Trejo
Joel Mora