5.0 DECIDE ON PRODUCTS

Tasks:

→ Choose a production method for disinfectant (sodium hypochlorite)
→ Choose vessel for water storage
→ Choose process or product to use if water is turbid
→ Choose bottles for disinfectant solution

A Safe Water System project enables households to disinfect and store essential quantities of household water in safe containers.

The products (“hardware”) of a Safe Water System include:
- disinfectant solution and its container
- a vessel for safe water storage in the home
- a filter, if local water is turbid

Project planners must decide how these products will be manufactured or obtained. There are a variety of ways to produce a disinfectant solution, and there are many different safe water storage vessels.
5.1 Choose a production method for disinfectant

The disinfectant should kill or inactivate pathogens that are likely to be present in the water sources of the target population. An ideal disinfectant should:

- be reliable and effective in killing pathogens under a range of conditions likely to be encountered
- provide an adequate residual concentration in the water to assure persistent disinfection during water storage
- neither introduce nor produce substances in concentrations that may be harmful to health, nor make the water unsuitable for human consumption or aesthetically unacceptable
- be safe for household storage and use
- have an adequate shelf life without significant loss of potency
- be affordable for users

There is no perfect water disinfectant that will work optimally under all circumstances. Each has advantages and disadvantages.\(^\text{15}\) However, in our experience, demonstration projects have identified chlorine, specifically 0.5% to 1% sodium hypochlorite solution, as having the best overall characteristics for both production at the local level and convenient dosing for household water disinfection. It is also extremely inexpensive to produce, making it an affordable option for economically disadvantaged populations. Sodium hypochlorite solution at this concentration is also safe, with evidence that ingestion of sodium hypochlorite at 10 times greater concentration causes no lasting damage.\(^\text{16}\)

Sodium hypochlorite has two disadvantages that must be addressed. The first is the issue of taste. Some populations object to the taste of chlorine, which may decrease use of disinfectant. Behavior change interventions should be designed to address the issue of taste (see section 7.0). In Zambia, one approach was to teach people to associate chlorine taste as an indicator of the safety of drinking water. In Bolivia, an approach was to teach people to treat water in the evening for the following day, so that the taste would dissipate. The second disadvantage is the potential for degradation of chlorine concentration during storage, particularly in hot climates. This problem can be mitigated by alkalinizing the solution and by storing it out of sunlight.
in opaque containers in the coolest possible place. In hot climates, the shelf life can be as little as 1 month, but with alkalinization, the shelf life can be increased to 4 months or more. In cool climates, the shelf life is greater than 6 months. Shelf life must be determined in each new region because of variations in source water and climate.

Another concern about chlorination of water is the health effects of trihalomethanes. Trihalomethanes are disinfection byproducts that are formed when hypochlorite is used to treat water with organic material in it. Research suggests that, over a lifetime, the risk of bladder cancer increases with chronic consumption of trihalomethanes. In populations in developing countries, however, the risk of death or delayed development in early childhood from diarrhea transmitted by contaminated water is far greater than the relatively small risk of bladder cancer in old age.

There are alternative safe and effective ways to produce sodium hypochlorite solution:
   a) local production from water and salt with a low cost hypochlorite generator that is simple to operate
   b) production by an existing local or multinational business in country

For the Safe Water System, we have decided against using dilute solution of calcium hypochlorite from High Test Hypochlorite (HTH) powder because of the caustic, hazardous nature of the highly concentrated (70%) powder. Also, in most countries, HTH must be imported, and storage can be difficult, particularly in hot, humid conditions.

Another option that is not recommended is to promote use of a locally available commercial bleach to treat water in the home because experience has shown that this approach leads to problems with acceptance. Bleach bottles often display instructions to use bleach to whiten clothes and clean toilets, which deters people from using it to treat drinking water. Another problem with commercial bleach is that it may contain additives or impurities and that concentration can vary, which makes it more difficult to provide dosing instructions. It is best to create a new product especially for treating drinking water.
Each of the preferred options for production of disinfectant solution is described below.

a) **Local production** from water and salt with a low cost hypochlorite generator that is simple to operate

Using this method, an arrangement can be made to produce hypochlorite in the community. Devices are available from several manufacturers that are designed to reliably produce hypochlorite solutions through electrolysis of ordinary salt and water (3% salt solution). Most of these devices, called hypochlorite generators, use electricity from an electrical grid, but solar powered hypochlorite generators can also be used. A suitable place is required to operate the machine and store solutions. A two-person team should be trained to operate and maintain the device and to monitor the hypochlorite concentration. (See Annex C.)

There is a range of sizes and capacities of hypochlorite generators. Different models can produce as little as 10 liters (enough for 40 families) per day up to a maximum of 400 liters (for 1600 families) per day. Running 12 hours per day, an electric-powered hypochlorite generator can produce enough disinfectant solution
to treat water for about 8,000 families (40,000 - 48,000 people) every 2 weeks.

Once production starts, the disinfectant can be produced inexpensively by a community worker. **In Zambia**, disinfectant sold for approximately $0.20 for a month’s supply for a family of 6 people. **In Madagascar**, disinfectant sold for $0.30 for 2 month’s supply, and **in Kenya**, for $0.20 for 2 month’s supply. These prices did not take into account the cost of marketing and distribution. Local production has been employed in Bolivia, Peru, Ecuador, Zambia, and Madagascar.

As the water project expands to reach additional communities, it may be necessary to obtain additional generators to meet increased demand and train more workers to produce and bottle disinfectant.

**b) Production by an existing local or multinational business in country**

With this method, a business such as a bleach manufacturer produces a disinfectant product of a specified concentration. If an existing business can produce a suitable disinfectant, the manufacturer is likely to have in place procedures for quality control, bottling, labeling, and distribution. When the project is ready to expand, the manufacturer can quickly increase production. This method has been used in Kenya.

Problems may arise, however, because the manufacturer, rather than the project administrators, will control price and production. Business usually requires a certain profit margin, which may make the disinfectant price too high for intended users. There may be increased transportation costs, depending on the distance between the manufacturing plant and the communities that purchase the product.
Figure 4: Comparison of methods for production of disinfectant solution

<table>
<thead>
<tr>
<th>Disinfectant production options</th>
<th>Cost of solution</th>
<th>Local job creation</th>
<th>Cost of transport</th>
<th>Quality control</th>
<th>Efficiency of bottling, labeling</th>
<th>Start-up costs and staff training</th>
<th>Ease of scaling up</th>
<th>Control over product price</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local production with appropriate technology</td>
<td>Low</td>
<td>Good</td>
<td>Low</td>
<td>Good</td>
<td>Good</td>
<td>High</td>
<td>Good</td>
<td>Good</td>
<td>Network must be developed</td>
</tr>
<tr>
<td>Production by existing company</td>
<td>Depends on negotiation</td>
<td>Depends on size of project</td>
<td>Higher</td>
<td>Good</td>
<td>Good</td>
<td>Lower</td>
<td>Depends on capacity of company</td>
<td>Poor</td>
<td>Existing distribution network</td>
</tr>
</tbody>
</table>
5.2 Choose bottles for disinfectant solution

Disinfectant is put into bottles that are then distributed to outlets and sold to households. There are several issues to consider in the choice and design of a bottle.

- Returnable or non-returnable bottles?

Returnable bottles can save project costs and result in a lower price for consumers. When the contents of a returnable bottle are gone, the consumer returns the empty bottle to a sales outlet and gets a discount on a new bottle. Bottles are sent back to the production point to be cleaned, relabeled and refilled. Returnable bottles reduce the likelihood that empty bottles will become solid waste (although this has not been a problem yet because people tend to reuse non-returnable bottles for other purposes when the disinfectant bottle is empty).

Non-returnable sealed bottles have been preferred by social marketing NGOs because they facilitate quality control and make operations logistically simpler.

- Color

The bottle should be opaque to extend shelf life.

- Size

The bottle should not be so small that new ones need to be bought too frequently; nor should it be so large that the supply of disinfectant lasts longer than its effective shelf life. Many projects have found that a 250 ml bottle works well, as
this is approximately the amount that an average household uses in 2 to 4 weeks. Up to 500 ml volume is satisfactory in cool climates. In hot climates, the shelf life is reduced, and 500 ml of disinfectant may begin to lose its strength before it is used up.

- Paper label to be attached or labels to be silk-screened (painted) on bottle?

The bottle must have a clear label that identifies its contents and provides instructions for use in households. Silk-screened labels wear off in time, so if bottles are to be returnable, paper labels may be more practical.

- Measuring cap

The bottle’s cap should be used to measure the correct amount of disinfectant to add to the quantity of water in the recommended water storage vessel. Therefore the size of the cap and instructions for its use must be designed with the water storage vessel in mind. The dose must be determined using the locally available disinfectant with the locally available water in the vessel recommended by the project because different waters require different doses of sodium hypochlorite for adequate disinfection. This is best accomplished via trial and error, measuring free chlorine levels one half hour after dosing. A qualified person can start by adding ½ or 1 capful, then measuring the chlorine level, and then continuing to add increments of ½ or 1 capful to the vessel until the correct chlorine level is achieved in the stored water. A free chlorine level of 0.5 to 2.0 mg/L is optimal. A cap should facilitate measuring the correct amount of disinfectant for the water storage container. For a 20-liter water vessel, the dose of disinfectant will likely be between 5 and 10 ml, so a cap size of approximately 2.5 to 10 ml will work best.

- How to produce or procure the bottle

The project may be able to use a locally produced bottle of appropriate size with an acceptable cap to which a label can be applied. However, there can be problems with locally
produced bottles. Sometimes bottles are proprietary and are therefore not available for the project. Also, available bottles may be used for other products such as chemicals, and consumers may mistake one for the other.

Another option is to manufacture a unique bottle. A unique bottle has advantages in that it can be developed to meet the exact specifications required (size, shape, cap) and consumers will come to recognize it. A mold to produce a bottle is expensive (for example, $8000 was the cost in Bolivia), but once produced, the project cost per bottle may become less expensive.

5.3 Choose a vessel for water storage in the home

Virtually every type of tank or container imaginable has been used for household water storage. Unfortunately, most do not adequately protect water from contamination. Many are open without lid or cover. Used 55-gallon oil drums and open plastic and metal buckets are commonplace.

Many people obtain or buy previously-used containers because they are cheaper. However, sometimes these containers have held poisonous substances such as pesticides. Families have become ill or have even died after drinking water stored in them.

Studies have shown that even if water is microbiologically safe when put into such containers, it can be quickly contaminated during storage and use, primarily by contact with human hands or contaminated utensils that are used to withdraw water. Dust, animals, birds and insects can also contaminate water when the vessel is inadequately covered. Under these circumstances, even when water is initially disinfected, the subsequent contamination is often so great that it nullifies the disinfectant. Water stored in wide-mouth vessels (which allow stored water to be dipped out with hands or utensils) is much more likely to be contaminated than water in vessels that must be poured. Many studies have shown the importance of a suitable household water container to prevent waterborne diseases.1, 18-21
Typical containers used for household storage that are often kept uncovered and do not adequately protect water include:

| Buckets (plastic or metal) | 55 gallon oil drums | clay pots | cooking pots |

In many countries, clay pots are popular water containers with a history of use that goes back generations. Many families prefer to use clay pots because they are porous and permit evaporative cooling. They are also accustomed to the taste of water in clay pots. In such cases, it may be difficult to convince people to change to a different type of container. In Kenya research suggested that clay pots may be reasonably effective storage containers, if kept clean, if people avoid touching water when they dip it out (in some countries, spigots are placed in clay pots to avoid this problem), and if the water is chlorinated when it is put into the pot.

Commonly used vessels for household storage which may adequately protect water if clean and used correctly include:

| Jerry cans | Plastic bottles | Picnic coolers |

CDC and PAHO have designed a 20-liter, plastic vessel with a narrow mouth, lid, and faucet. Recently, the design was improved with assistance from Procter and Gamble. This vessel has been field tested in Bolivia and Zambia with good results. PAHO Peru and PAHO Ecuador have employed containers with similar characteristics in their projects. Oxfam has designed a bucket with a tightly fitting lid, a smaller opening in the lid, and a spigot.

Below are desired characteristics of a container that will prevent
contamination of contents and facilitate disinfection of water:

1. Appropriate shape and dimensions with a volume between 10 and 30 liters so that it is not too heavy, fitted with handles to facilitate lifting and carrying, with a stable base to prevent overturning. If possible, a standard sized container should be used because then dosing can be standardized. 20 liter vessels have worked well in earlier studies. If children often carry water, the vessel will have to be smaller or the child will need to collect water in a smaller container and pour it into the safe storage container.

2. Durable material, resistant to impact and oxidation, easy to clean, lightweight, and translucent. High-density polyethylene (HDPE) is often the most appropriate material that is readily available. HDPE should be specially treated with ultraviolet absorbers, or exposure to sunlight over time will damage the plastic and vessels will crack.

3. An opening large enough to facilitate filling and cleaning but small enough that even a child cannot easily insert a hand with cup or other utensil to dip out water. The inlet should be fitted with a durable screw-on lid, preferably fastened to the container with a cord or chain. A diameter between 6 to 9 cm is optimal.

4. A durable spigot or spout for pouring that is resistant to oxidation and impact, closes easily, and can discharge approximately one liter of water in about 15 seconds.

5. Instructions for use of the container, disinfection of contents, and cleaning the interior, permanently affixed to the container on material that does not deteriorate when wet or moist.

6. A certificate that indicates the container complies with requirements of the Ministry of Health or an equivalent appropriate authority.
<table>
<thead>
<tr>
<th>Vessel</th>
<th>Lid</th>
<th>Faucet</th>
<th>Cleaning inside</th>
<th>Volume</th>
<th>Ease of dosing with disinfectant</th>
<th>Distribution costs</th>
<th>Cost</th>
<th>Ease of dosing with water (variable volume)</th>
<th>Acceptable local jerry can</th>
<th>Acceptable local jerry can (narrow mouth)</th>
<th>Orfam vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDC vessel</td>
<td>Good</td>
<td>Yes</td>
<td>Yes hand can fit in opening</td>
<td>20 liter</td>
<td>Very easy (standard volume)</td>
<td>Higher (may require import)</td>
<td>Moderate to high</td>
<td>Low</td>
<td>Moderate to high</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceptable</td>
<td>Fair</td>
<td>Yes</td>
<td>Usually do not have faucets</td>
<td>Variable</td>
<td>Can be more complicated (variable volume)</td>
<td>Lower because they are locally available</td>
<td>Low</td>
<td>Very easy (standard volume)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceptable</td>
<td>Good</td>
<td>Yes</td>
<td>Good</td>
<td>14 liter</td>
<td>Very easy (standard volume)</td>
<td>Lower (will require import)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orfam vessel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In most countries, the choice is between obtaining or manufacturing a specially designed vessel with all or most of the characteristics above or promoting use of a locally available vessel that has some of the desired characteristics.

A vessel that is already available in communities will cost less but may be less effective. A specially designed vessel will always have more of the desired characteristics.

Typically most locally available vessels lack most of the desired features. Many local vessels:
- have a mouth which is too narrow (difficult to clean)
- have no top to keep out contamination
- do not have a faucet
- are less durable
- vary in volume

Education on how to properly disinfect water is much more complicated if households have vessels of different design and volume. Mistakes adding the correct amount of disinfectant are likely. If the vessel is smaller than the standard and the dose is therefore too much, a bad taste results. If the vessel is larger and too little disinfectant is added, the water is not effectively disinfected.

Education on how to clean vessels must be tailored to the type of vessels used. If the opening of the vessel permits the entry of a hand, then the vessel can be cleaned with soap or detergent and water. If the opening is too narrow for the entry of a hand, then instructions for cleaning must be adapted to local conditions. This is one method that has been used:
- Pour 1-2 liters of water into container
- Add double the usual dose of sodium hypochlorite (e.g., 2 capfuls instead of one)
- Add detergent
- Add hard rice grains or gravel
- Agitate vigorously
- Pour out solution
- Rinse
The vessel is more suitable if it has more of the desired characteristics. Sometimes no local vessels are acceptable (only buckets are available). If only buckets or other “unacceptable” vessels are available and production or importation of a specially designed vessel is not feasible, an alternative strategy would be to locate or develop a secure cover for the bucket. Promotion and education would address keeping the bucket covered and being careful not to let anyone’s hands touch the water. In Madagascar, this situation occurred in the early stages of the project (before special vessels were obtained). Promotional material stressed the importance of keeping the buckets covered and pouring, rather than dipping, the water.

**How to assess possible household water storage vessels:**

If your project is considering recommending a local vessel, search the community for possible vessels in common sizes that are widely available and used in the area. Then assess each for the characteristics discussed above. Use a worksheet such as the one on the next page to help make a systematic comparison. There is a blank copy of this worksheet in Annex D. On the next page is an example showing how the worksheet was completed by some planners comparing a specially designed vessel and three particular vessels that are commonly available in their project area (earthenware jug, a plastic jerry can, a 10-litre bucket with lid).
Figure 6: Example Worksheet for Assessing Possible Household Water Storage Vessels

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Specially designed vessel</th>
<th>Common earthenware jug</th>
<th>Plastic jerry can</th>
<th>Bucket with lid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Easy to carry, stable</td>
<td>Familiar, difficult to carry, stable</td>
<td>Easy to carry, stable</td>
<td>Easy to carry, stable</td>
</tr>
<tr>
<td>Material</td>
<td>Plastic durable &amp; easy to clean</td>
<td>Breakable, porous, holds pathogens, durable in households that take care of them</td>
<td>Cannot see inside – gets discolored</td>
<td>Easy to clean</td>
</tr>
<tr>
<td>Inlet with screw-on lid; no access to dip with hands or cup</td>
<td>Yes</td>
<td>Some have lids placed on top. Dipping is usual practice</td>
<td>Yes</td>
<td>Usual practice is to dip</td>
</tr>
<tr>
<td>Faucet or narrow mouth to pour water</td>
<td>Faucet</td>
<td>Not usually, but in some countries clay pots are made with faucets</td>
<td>Narrow mouth</td>
<td>Wide mouth</td>
</tr>
<tr>
<td>Access to inside for cleaning</td>
<td>Yes – hand can reach in to scrub</td>
<td>Access to clean</td>
<td>Difficult to clean inside</td>
<td>Access to inside for cleaning</td>
</tr>
<tr>
<td>Device for measuring disinfectant</td>
<td>Can be designed as part of vessel or disinfectant bottle</td>
<td>Depends on site – if clay pots have a standard size, dosing will be easier; very difficult to design dosing if widely variable volumes</td>
<td>Can design as part of disinfectant bottle for two standard volumes of jerry can - - but measuring mistakes possible</td>
<td>Can design if bucket of standard size. Difficult if bucket sizes vary</td>
</tr>
</tbody>
</table>
**Figure 6: Example Worksheet for Assessing Possible Household Water Storage Vessels – continued**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Specially designed vessel</th>
<th>Common earthenware jug</th>
<th>Plastic jerry can</th>
<th>Bucket with lid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Instructions for use, disinfection and cleaning affixed</strong></td>
<td>Can be standard for standard volume; can affix before sale</td>
<td>Must provide apart from clay pot</td>
<td>Labels can be produced for households, but must be affixed by owner</td>
<td>Labels can be produced for households, but must be affixed by owner</td>
</tr>
<tr>
<td><strong>Certification of MOH</strong></td>
<td>Can be obtained and distributed with vessels</td>
<td>Difficult to certify used items already in the home</td>
<td>Difficult to certify used items</td>
<td>Not recommended for storage, therefore not certifiable</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Expensive but lasts long time</td>
<td>Cheap, already present in homes</td>
<td>Typically less expensive than special vessel; limited safe life; accessibility varies by country</td>
<td>Cheap, accessible</td>
</tr>
<tr>
<td><strong>Other comments</strong></td>
<td>Attractive, novel, status item</td>
<td>Familiar, widely available</td>
<td>Likely to be purchased used; may be unsafe—need to assure that it is not contaminated</td>
<td>Familiar, widely available</td>
</tr>
<tr>
<td><strong>Performance in field trials</strong></td>
<td>Used correctly, get improved water quality and decreased diarrhea</td>
<td>Recent studies suggest that can maintain chlorine residuals for up to 24 hours.</td>
<td>Performed OK in Zambia if had a lid</td>
<td>Not tested</td>
</tr>
<tr>
<td><strong>Overall assessment</strong></td>
<td>Best choice if can obtain for project</td>
<td>If other alternatives unfeasible, it may be possible to develop safe practices with clay pots.</td>
<td>Has drawbacks but acceptable if no other options</td>
<td>Not ideal, but acceptable if there are no other options and if a good, well-fitting lid is available</td>
</tr>
</tbody>
</table>
Whether a specially designed vessel can be used in a project depends on whether quantities of such a container are manufactured regionally or locally, and whether the project can afford to pay for them. Shipping a vessel long distances from point of manufacture to users may cost as much as the vessel itself. Therefore, local or regional manufacture of a specially designed vessel is important. Refer to the web site of the U.S. Centers for Disease Control and Prevention (www.cdc.gov/safewater) for the most current information on manufacturers of vessels and molds. In Bolivia, a specially designed vessel was manufactured for $4.00. In South Africa, the specially designed vessel sold for approximately $4.00. Oxfam sold their vessel for approximately $3.50. See section 9.0 for more information on production of vessels.

Important decisions are based on the type of vessel used. For example, the dosing of disinfectant depends on the volume of the vessel. Educational materials will need to address advantages and disadvantages of the vessel. The manufacturer’s cooperation will be important to attach promotional information to vessel surfaces and to correct any problems identified after vessels are being used.

5.4 Choose process or product to use if water is turbid

In areas where water is turbid, pretreatment to filter out sediment can improve the aesthetic quality of water and increase the efficiency of disinfection, and, in some cases, reduce the degree of microbial contamination. The simplest method is to filter water through locally available, inexpensive cloth such as sari cloth (Bangladesh), or chitenge (Zambia). To make a filter, fold the cloth over a number of times, enough to remove turbidity yet optimize flow. Do a trial with local cloth and local water. The use of the cloth will need to be added to educational messages, especially on the label of the disinfectant.

In some regions with extremely turbid water, it may be difficult to adequately filter water with cloth because the cloth can become clogged with organic material. In such regions, it may be necessary to teach people to let water settle overnight and then decant the cleared water into a new container. Alternatively, other filter systems such as slow sand filters could be considered, although cost and complexity are potential drawbacks.
Filtering Water with Cloth

Using a Settling Technique