

The Multi-Barrier Approach to Safe Drinking Water

Technical Brief
October 2017

Technical Brief: The Multi-Barrier Approach to Safe Drinking Water

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This document is part of a collection of resources for learning and training about household water treatment and safe storage (HWTS). To access CAWST's other HWTS resources, visit cawst.org/resources.

1 Introduction

Where does your drinking water come from, and how does it get from its source to your glass? In most communities, water goes through several steps to get from its source to a person's drinking glass. We call this combination of steps from source to sip the **water supply system**. Water supply systems range from very simple (river → bucket → user's glass) to complex (with technologies and infrastructure such as treatment systems, pumps, and piped distribution networks).

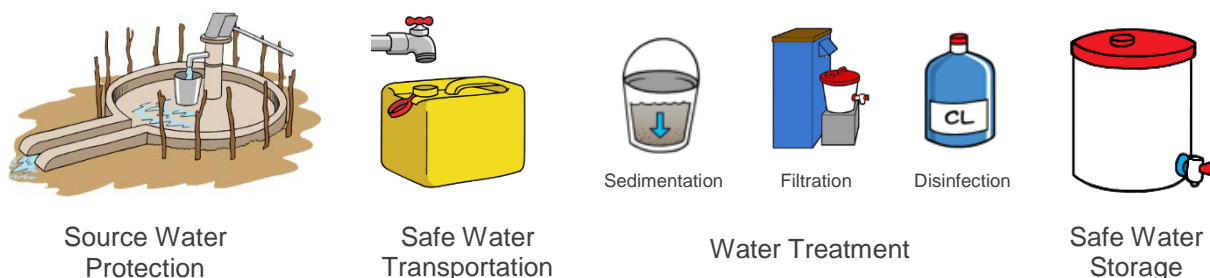
All water supply systems have multiple points at which contaminants could enter the water and make it unsafe. Using a **multi-barrier approach** is the best way to make sure water is safe when it reaches a user's glass. The multi-barrier approach uses a combination of behaviours and technologies to prevent and remove contaminants that could affect drinking water safety.

In this technical brief:

- We describe the multi-barrier approach to safe drinking water.
- We list the most common causes of drinking water contamination at the source, during transportation, and during storage.
- We describe actions you or the community you work with can take to improve drinking water safety. These include practices for source protection, safe water transportation, household water treatment, and safe water storage and handling.

Key words in this document are marked in a bold font. If you are reading this on a screen, you can go to the definition of key words by clicking on them while holding the Ctrl button. If you are reading a printed copy, please refer to Section 8: Definitions.

2 The Multi-Barrier Approach to Safe Drinking Water



The Multi-Barrier Approach to Safe Drinking Water

The multi-barrier approach uses a combination of barriers (behaviours and technologies) to:

- Protect the water source from contaminants.
- Transport the water safely to the home and within the home.

- Treat the water to remove or inactivate contaminants.
- Store and handle the water safely to prevent contamination before and after treatment.

Sometimes, these barriers occur multiple times within a given water supply system. For example, treatment can occur at the **point-of-distribution** (before transportation to people’s homes), and/or at the **point-of-use** (in a household or institution). As well, water transportation, handling, and storage may happen multiple times, before and after treatment. For each step of a water supply system, you should assess what could cause contaminants to get into the water, and use appropriate measures to keep your water safe. This process of assessing hazards and selecting appropriate barriers is also called **water safety planning**. Refer to *CAWST Technical Brief: Water Safety Planning and Household Water Treatment and Safe Storage*.



3 Source Water Protection

Source water protection involves finding the best possible water source for your household or the households you serve, and taking steps to protect it from contaminants.

3.1 Types of Water Sources

There are three types of drinking water sources: surface water, groundwater, and rainwater. Water sources are also often described as **improved** (sources that are designed to protect drinking water from fecal contamination) or **unimproved**. The following table describes and gives examples of these types of drinking water sources.

Table: Water Sources

Source Type	Description	Examples of Improved Sources	Examples of Unimproved Sources
 Surface water	Surface water is any water taken directly from a stream, river, lake, pond, or similar source on the earth’s surface. Surface water is often unsafe to drink without treatment because it is easily contaminated.	None—all surface water sources are unimproved	Rivers Streams Lakes Ponds
 Groundwater	Groundwater is the water that fills the spaces and cracks in rocks and soil beneath the earth’s surface. Groundwater quality varies from place to place, but it is often safer than surface water because it moves very slowly and filters through rocks and soil.	Borehole Protected dug well Protected spring	Unprotected spring Unprotected dug well



Rainwater

Rainwater is water that falls to earth as rain. Some people collect and store rainwater using a rooftop, ground surface, or rock catchment. The quality of rainwater collected from a rooftop is usually better than from a ground surface or rock catchment.

Rainwater (safely collected and stored)

Rainwater that runs into an open surface water source (lake, pond, reservoir)

Sometimes households collect drinking water from taps in their homes or communities, rather than directly from the source. All piped water supplies originate at a groundwater, surface water, or rainwater source. You cannot always assume that piped water is safe to drink; it depends on the quality of the source water, the level of treatment the water received before distribution (if any), and the condition of the piped network.



What is a “Safely Managed” Drinking Water Supply?

Under the **Millennium Development Goals (MDGs)**, access to safe drinking water was measured by counting the number of households with access to **improved** drinking water sources. However, people quickly recognized that this indicator did not address water safety. It is common for improved water sources to be contaminated by fecal pathogens, especially by the time water gets to people’s homes.

Now, under the **Sustainable Development Goals (SDGs)**, access to drinking water is measured based on service level, using five categories (WHO & UNICEF, 2017):

- Surface water: drinking water collected directly from a river, dam, lake, pond, or canal.
- Unimproved: drinking water from an unprotected dug well or unprotected spring.
- Limited: drinking water from an improved source, where it takes people more than 30 minutes to collect water, including round-trip travel time and waiting in line.
- Basic: drinking water from an improved source, where it takes people less than 30 minutes to collect water, including round-trip travel time and waiting in line.
- **Safely managed drinking water**: drinking water from an improved water source that is located on premises, available when needed, and free from fecal and priority chemical contaminants.

SDG 6.1 aims to achieve “universal and equitable access to safe and affordable drinking water by 2030.” Increasing access to safely managed drinking water will require a multi-barrier approach, including source protection, treatment, and safe transportation and storage.

3.2 Causes of Contamination at the Source

Different types of water sources have different contamination risks. In general, contaminants enter water sources because of:

- Poor site selection: The water source is too close to a latrine, farm, household, industry, or other source of contamination.
- Poor design or construction: The water source lacks a lining or cover (for wells), tank sealing (for reservoirs), or proper pipe connections (for piped supplies).
- Deterioration or damage to structures: Cracks in pipes, tanks, platforms, and covers allow contaminants to enter the source.
- Poor hygiene and sanitation practices: People use dirty buckets to collect water, defecate near the water source, or wash dishes and laundry in the same place they collect drinking water.
- Unsustainable land use: Land that drains into the water source is heavily used for mining, industry, or agriculture, making **erosion** and source contamination more likely to occur.



Do not site a water source downhill from, or within 30 metres of, a latrine.

Risk Assessment at the Water Source

Refer to CAWST's Sanitary Inspection Forms (available at www.resources.cawst.org) for detailed checklists you can use to assess risks of contamination at a water source. Forms are available for: boreholes, dug wells, piped water, protected springs, and rainwater harvesting tanks.



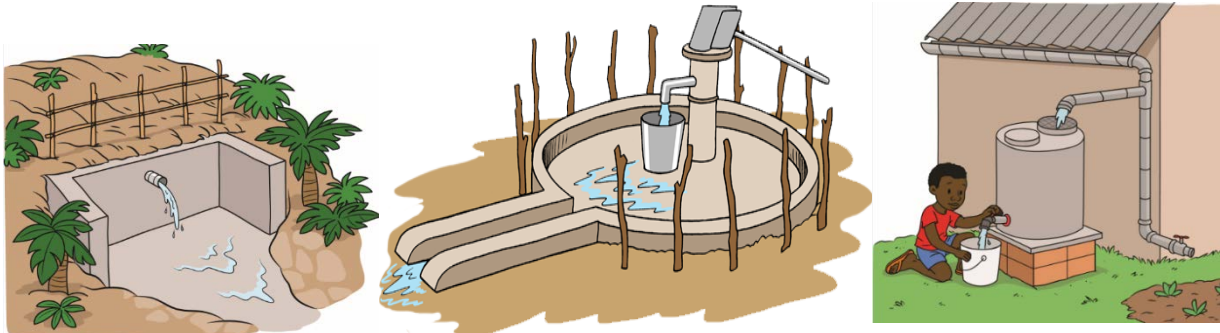
Examples of water sources at risk of contamination (from left to right): unprotected well; surface water near human activity and agriculture; borehole with cracked apron; container without lid.

3.3 Barriers to Contamination at the Source

Many different barriers can be used to protect a water source. These include changes to behaviours (such as stopping open defecation) and to infrastructure (such as installing well covers). The barriers you use should address the most critical risks identified during a sanitary inspection of the water source.

Steps you can take to protect a water source from contamination include:

- Locate latrines downhill and at least 30 metres away from the water source.
- Use fences and other physical barriers to keep animals away from the water source. Provide a place for animals to drink and bathe that is downhill from the source.
- Keep separate areas for washing clothes and watering animals. These should be downhill from where you collect water for drinking.
- Keep the area around the water source clean and free from excreta and garbage.
- Provide adequate drainage to prevent spilled water from pooling. Pools of water attract animals and allow insects to breed.
- Have a person or committee responsible as caretakers of the water source.
- Maintain and repair all constructed components (skirts, covers, drainage) to keep groundwater sources sealed from contaminated surface water.
- Monitor and keep careful records of activities around the water source and changes in drinking water quality.
- Whenever possible, eliminate or reduce contaminants from industry or agriculture that could threaten the water source.



Examples of improved water sources with barriers in place to reduce risks of contamination (from left to right): protected spring, protected borehole, and protected rainwater tank.

Constructing Improved Water Sources

When constructing a new water source, you can add barriers to protect the water from contamination. Refer to the Water, Engineering and Development Centre (WEDC) Guides (available at: <http://wedc.lboro.ac.uk/knowledge/index.html>) for details about how to construct components such as spring boxes, well linings, and impermeable aprons.

4 Safe Transportation

Safe transportation describes any actions taken to ensure that water stays safe on its journey from the source to its point-of-use. Studies have found that bacteriological contamination of drinking water often occurs during transportation and storage (Wright, Gundry, & Conroy, 2004). Without safe transportation, water from safe sources can easily become unsafe by the time it reaches people's homes.

4.1 Methods of Water Transportation

Water moves from its source to point-of-use in many different ways. Most commonly, water is transported through networks of pipes or canals, or in containers carried by humans, animals, or vehicles. Sometimes, multiple methods are used to move water from the source to users' homes. For example, water sometimes begins its journey by traveling through pipes from a source to a communal tap stand, and then is carried in buckets from the tap stand to people's homes.

4.2 Causes of Contamination during Water Transportation

4.2.1 Causes of Contamination in Containers

People often carry water from the source to their homes in containers. Sometimes they transport buckets of water by hand, and sometimes they use animals or vehicles. Along the way, contamination can occur when:

- People use dirty scoops or buckets to withdraw water from the source and pour it into their containers.
- Containers for transporting water have not been properly cleaned.
- Containers are left open during transportation, allowing contaminants to enter.
- People use dirty rags, leaves, or lids to cover their containers during transportation.
- Animals drink from the same containers used to transport human drinking water.



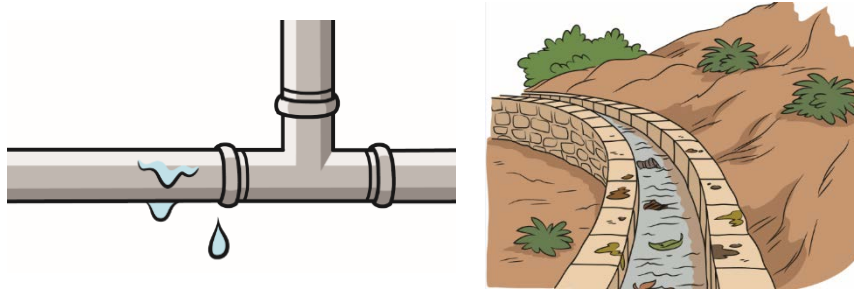
Using dirty containers or allowing animals to drink from containers can put water at risk during transportation.

4.2.2 Causes of Contamination in Pipes and Canals

Piped water systems have many advantages. They can reduce the amount of time people spend collecting water. If properly constructed and maintained, they can also protect water from contamination. However, contamination can occur in pipes and canals when:

- Chemicals or heavy metals leach from the pipes, joints, or soldering compounds.

- Contaminated water enters buried pipes because of low or variable water pressure in the pipes.
- Pipes develop leaks or holes that are not repaired quickly.
- People repair, replace, or install segments of pipe and introduce contamination.
- Pipes have dirty outlets or spouts, which contaminate water as people collect it.
- Canals are open to the environment, allowing garbage and contaminated surface water to get into the water.



Leaky pipes and unprotected canals are two examples of water transportation systems that may introduce contaminants into the water as it moves.

4.3 Barriers to Contamination during Water Transportation

4.3.1 Barriers to Contamination during Transport by Containers

Actions to protect water during transport by vehicle, animal, or by hand include:

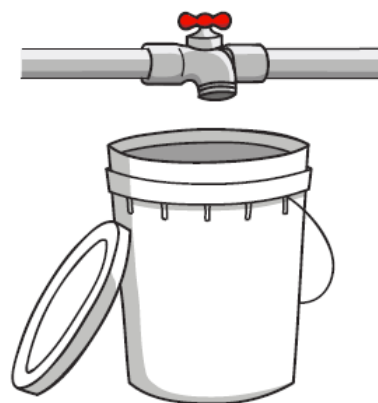
- Properly clean the container before filling it with water. Clean buckets regularly with soap or bleach to ensure they do not have microorganisms growing on them.
- If the water source does not have a tap or spout, use a clean scoop or bucket to withdraw water. If the source does have a tap or spout, make sure the spout is clean before using it to fill containers.
- Use clean lids to cover the buckets or vessels during transportation. Do not use any other materials (rags, leaves, etc) to cover buckets.
- Do not allow animals to drink from water intended for humans. Use a separate container that is clearly marked for animal use.
- When not in use, store water transportation containers in a safe location out of reach of animals and small children.



4.3.2 Barriers to Contamination during Transport by Pipes and Canals

Actions to protect water in pipes and canals include:

- Clarify roles and responsibilities for everyone involved in monitoring, record keeping, maintenance, and repairs.
- Fix leaks immediately.
- Ensure that canals are closed and protected to prevent contaminants from entering them.
- If water is treated before distribution, monitor drinking water quality at the **point-of-use** to make sure contamination is not occurring during distribution.
- If water is treated with chlorine before distribution, monitor to make sure there is an appropriate level of **free chlorine residual** (chlorine available to react with pathogens that enter the water between the treatment plant and point-of-use).



5 Water Treatment

While source protection, safe transportation, and safe storage prevent contaminants from entering the water, water treatment removes or inactivates contaminants. In this section, we discuss how to remove or inactivate pathogens through different types of treatment.

Water treatment can occur at the point-of-distribution or at the point-of-use (household or institution). There are three types of water treatment barriers: **sedimentation**, **filtration**, and **disinfection**. Most large-scale water treatment plants combine these three barriers to achieve better removal rates for microbiological contaminants. In your household or the households you serve, you can also use an appropriate combination of water treatment barriers to make your HWTS system more effective.

CAWST focuses on household-level water treatment systems. In this section, we give a broad overview of some of the household methods you can use for sedimentation, filtration, and disinfection. For detailed information about any of the options described in this Technical Brief, refer to CAWST HWTS Knowledge Base (<https://www.hwts.info/>) and *CAWST HWTS Fact Sheets*. For information about how to select appropriate HWTS options, refer to *CAWST Technical Brief: Selecting HWTS Options*. Note that centralized water treatment systems may also be appropriate for the communities you work with; such systems follow the same processes of sedimentation, filtration and disinfection but are out of the scope of this document.

5.1 Sedimentation

Sedimentation is a physical treatment process used to reduce the **turbidity** (cloudiness) of water. Sedimentation involves letting particles in water settle to the bottom of a vessel, skimming or pouring the clear water off, and leaving sediment (sand, dirt, and other particles) behind. The process can be repeated two or three times to make turbid water much clearer.

Sedimentation can rarely remove all pathogens from drinking water. However, because pathogens sometimes attach to particles in drinking water, sedimentation can remove some pathogens from your drinking water. Removal rates can exceed 90% for **protozoa** and **helminths**, but are inconsistent for viruses and bacteria (Sobsey, 2002). Sedimentation is not effective against dissolved chemicals.



Sedimentation is an important first step for water treatment when water is very turbid (cloudy). Some filters clog easily when water is turbid; using sedimentation first can improve your filter's performance. Some disinfection methods, such as SODIS (solar disinfection) and UV disinfection, are also more effective when turbidity is low.

Sometimes, people use **coagulants** (substances that cause particles to clump together) to improve the efficiency of sedimentation. Common chemical coagulants include aluminium sulphate (alum), polyaluminium chloride (also known as PAC or liquid alum), alum potash, and iron salts (ferric sulphate or ferric chloride). Certain plant products, such as moringa seed extracts and the flesh of the prickly pear cactus, can also be used as coagulants.

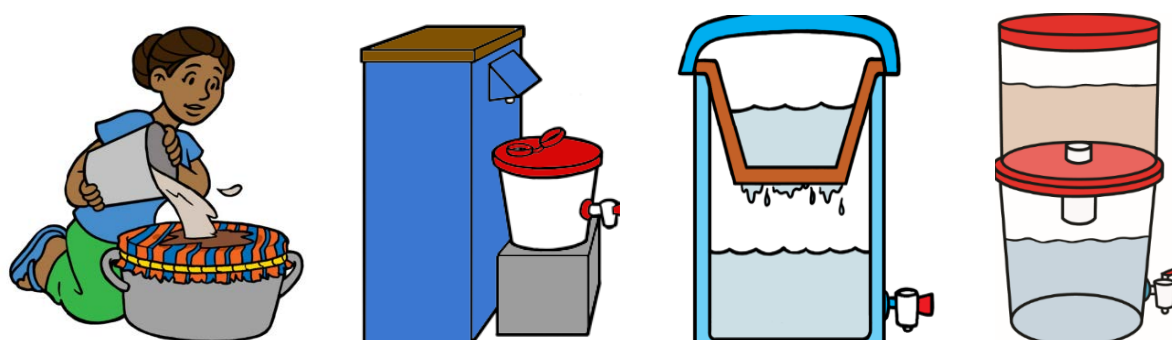


Alum and prickly pear cactus are both used as coagulants.

5.2 Filtration

Filtration is a physical process in which water passes through filter media such as sand, ceramic, cloth, or membrane. The pores of the filter media are big enough to allow water to pass through, but small enough to trap particles suspended in the water.

Filtration can be used after sedimentation to further reduce turbidity and remove pathogens. Examples of household water filters include cloth, biosand, ceramic pot, and membrane filters. Most of these are designed to remove microbiological contaminants, although some filters can also remove certain types of chemicals.

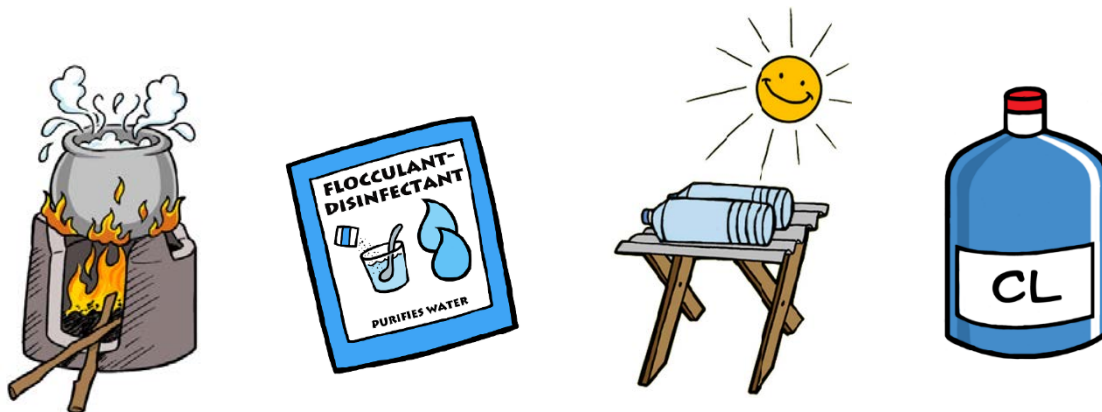


Common household filters (from left to right): cloth, biosand, ceramic pot, and membrane filters.

Household filters are highly variable in performance, durability, size, and capacity. For specific information about operation, maintenance, availability, and effectiveness of different household water filters, refer to CAWST's HWTS Knowledge Base (www.hwts.info).

5.3 Disinfection

Disinfection is a physical or chemical process that inactivates or kills pathogens in water. Examples of household disinfection methods include chlorine, solar disinfection (SODIS), ultraviolet light, pasteurization, and boiling. You can also find flocculant-disinfectant products, which include a combination of a coagulant (to cause particles to clump together and settle) and disinfectant (to inactivate remaining pathogens).



Common methods of disinfecting water at the point-of-use (from left to right): boiling, flocculant-disinfectant, SODIS (solar disinfection), chlorine.

Boiling water is the most widely-used form of household water treatment (Rosa & Clasen, 2010). Disinfection with chlorine is also very common. When using chlorine products for household water treatment, it is important to use an appropriate dose and to be aware of the shelf life of your chlorine product. Refer to *CAWST Technical Brief: Chlorine Disinfection for Household Water Treatment*.

Many disinfection methods, including SODIS, UV disinfection, and chlorination, are more effective if you have already used sedimentation or filtration to reduce the turbidity of your water. This is partly because pathogens can “hide” behind suspended particles, making it more difficult for chlorine or UV light to reach them.

Most disinfection methods are not effective at removing chemical contaminants. Boiling may cause the concentration of certain chemical contaminants to increase as water evaporates.

6 Safe Storage and Handling

Safe storage and handling describes any actions taken, before and after water treatment, to handle and store water safely. Contamination of drinking water during transportation and storage is a significant and common concern (Wright et al., 2004). Using clean, well-designed containers helps to protect drinking water (Günther & Schipper, 2013; Wright et al., 2004).

6.1 Methods of Drinking Water Storage

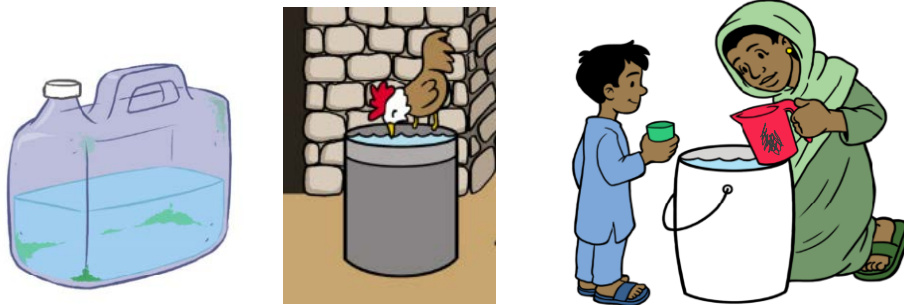
Drinking water is sometimes stored in large reservoirs or tanks that community members can access. Drinking water is also stored in people’s homes, using buckets, pots, or jerry cans. Safe drinking water storage is particularly important after treatment, to avoid

recontamination. Some household water filters, such as certain types of ceramic and membrane filters, include built-in safe storage reservoirs.

6.2 Causes of Contamination during Storage

In general, contaminants enter stored water because of:

- **Improper containers:** The storage container or reservoir is open to the environment (allowing contaminants to enter), transparent (allowing algae and other organisms to grow), or difficult to clean.
- **Dirty containers:** The storage container or reservoir is not cleaned often enough.
- **Damaged containers or reservoirs:** Cracks in tanks, containers, and covers allow contaminants to enter the stored water.
- **Poor water handling practices:** People use dirty hands or cups to scoop water from the container, allowing contaminants to get into the water. Or people use the same container to collect untreated water and to store treated water.
- **Unsafe locations:** stored water is placed where it is at risk of being bumped or contaminated by children and animals.



Examples of unsafe water storage and handling practices (from left to right): transparent container that is difficult to clean, open vessel at risk of contamination by animals, dirty scoop used to take water from the storage container.

6.3 Barriers to Contamination during Storage

Actions that can prevent contamination during water storage and handling include:

- Use a proper safe storage container. It should be durable and strong, non-transparent, and easy to clean. It should have a tight-sealing lid, and a tap for dispensing water.
- Pour drinking water out of the storage container instead of scooping it with a cup or ladle. Containers with taps make this much easier to do.
- Use different containers to store treated and untreated water.



A safe storage container with a lid and tap protects drinking water.

- Use treated water within 1-2 days after treatment.
- Store treated water off the ground in a shaded place, away from animals and small children.
- Ensure that tanks and reservoirs are regularly monitored, repaired, and covered. Fix any leaks or cracks immediately.
- Clean storage containers or reservoirs regularly with soap or chlorine.
- Consider using a residual disinfectant that can protect against recontamination during storage. Common examples include chlorine, iodine, and silver.



7 Summary

All water supply systems have multiple points at which contaminants could enter the water. It is important to be aware of the potential risks to water safety and measures you can take to protect drinking water in your community or the communities you serve.

Using a multi-barrier approach is the best way to make sure water is safe when it reaches a user's glass. The multi-barrier approach uses a combination of behaviours and technologies to:

- Protect the water source from contaminants.
- Transport the water safely to the home and within the home.
- Treat the water to remove or inactivate contaminants (using an appropriate combination of sedimentation, filtration, and disinfection).
- Store and handle the water safely to prevent contamination before and after treatment.

Source water protection, safe transportation, and safe storage and handling are preventative barriers that keep contaminants from entering water. Sedimentation, filtration, and disinfection are treatment barriers that remove or inactivate contaminants. Using an appropriate combination of preventative and treatment barriers will protect drinking water quality and human health.

8 Definitions

Coagulant: Something (often a metal salt) added to water to cause suspended particles to clump together. Coagulants cause particles to settle from water more quickly.

Disinfection: A process that inactivates or kills pathogens in water. It is the last step of the household water treatment process, after sedimentation and filtration.

Erosion: Gradual destruction of soil or rock by natural forces such as water, wind, or ice. Water sources near areas with high erosion may be more vulnerable to contamination.

Filtration: A physical process that involves passing water through filter media like sand, ceramic, cloth, or membrane. Filtration is commonly used after sedimentation to further reduce turbidity and remove pathogens. Water can pass through the pores of a filter, but particles get trapped by the filter media.

Free chlorine residual (FCR): Excess chlorine that is not consumed or combined and remains in drinking water after the contact time. FCR helps to prevent recontamination of the treated water, as it is available to kill new pathogens that enter the water.

Helminths: Also called worm or fluke. Large, multicellular organisms that are generally visible to the naked eye in their adult stages. Helminths can be either free-living or parasitic in nature. In their adult form, helminths cannot multiply in humans.

Improved Water Source: A type of water source that is likely to be protected from outside contamination, especially from feces. Examples of improved sources include boreholes, protected springs, and piped water supplies. This was an important definition for monitoring progress towards meeting the MDG target for water.

Millennium Development Goals (MDGs): Eight international development goals with specific targets for the year 2015. MDG 7 called for reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation. From 2016 onwards, the Sustainable Development Goals (SDGs) have replaced the MDGs.

Multi-barrier approach: Adding as many barriers (control measures) as possible to reduce the likelihood of drinking unsafe water. Each barrier incrementally reduces health risks.

Point-of-distribution water treatment: Water treatment that occurs at a central location (for example, at a treatment plant) before the water is distributed—usually by a piped network—to people’s homes or neighbourhoods.

Point-of-use (POU) water treatment: Water treatment in the household or institution where the water will be used. Also called Household Water Treatment.

Protozoa: Microscopic, one-celled organisms that can be free-living or parasitic in nature. They are able to multiply in humans, which contributes to their survival and permits serious infections to develop from just a single organism.

Safely managed drinking water: Under the Sustainable Development Goals, a safely managed drinking water service is defined as one that is located on premises, available when needed, and free of fecal and priority chemical contaminants.

Sedimentation: A physical water treatment process used to reduce turbidity of water. Sedimentation can be as simple as letting particles in water settle to the bottom of a bucket or tank. Sometimes coagulants are added to cause particles to clump together and settle more quickly.

Sustainable Development Goals (SDGs): Also known as the Global Goals, the SDGs build on the Millennium Development Goals, which ended in 2015. The SDGs are a series of 17 goals, each with specific targets to be reached by 2030. Goal 6 is to ensure the availability and sustainable management of water and sanitation for all.

Unimproved water source: one that does not meet the definition of an improved water source. All surface water sources are unimproved.

Turbidity: The “cloudiness” or “dirtiness” of water. Turbidity is caused by suspended solids, such as sand, silt and clay, floating in water. Light reflects off these particles, which makes the water look cloudy or dirty. Turbidity is often measured in nephelometric turbidity units (NTU).

Water safety planning: A preventative, risk-based, system-wide approach to ensuring that water remains safe from the catchment (source) to the consumer (household member).

Water supply system: The combination of practices used within a community for collection, transportation, treatment, and storage of drinking water. Water supply systems can be very diverse. Most communities have a variety of water sources, transportation practices, treatment measures, and storage practices.

9 Additional Resources

CAWST HWTS Knowledge Base. Available at www.hwts.info.

- A knowledge base for point-of-use water treatment solutions, from technology options to implementation best practices.

CAWST Education and Training Materials. Available at <https://resources.cawst.org>.

- Technical briefs, lesson plans, presentations, posters, sanitary inspection forms, and other resources for learning and training about HWTS.

World Health Organization: Publications and Documents Related to Household Water Treatment and Safe Storage. Available at: www.who.int/water_sanitation_health/water-quality/household/household-publications/en.

- Resources related to national HWTS policies, the Scheme to Evaluate Household Water Treatment Technologies, water quality guidelines, water safety planning, and more.

World Health Organization and International Water Association: Water Safety Portal. Available at: <http://www.wsportal.org/>.

- An online network to support the implementation of water safety plans, including resources, news, and events.

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Last Update: October 2017

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