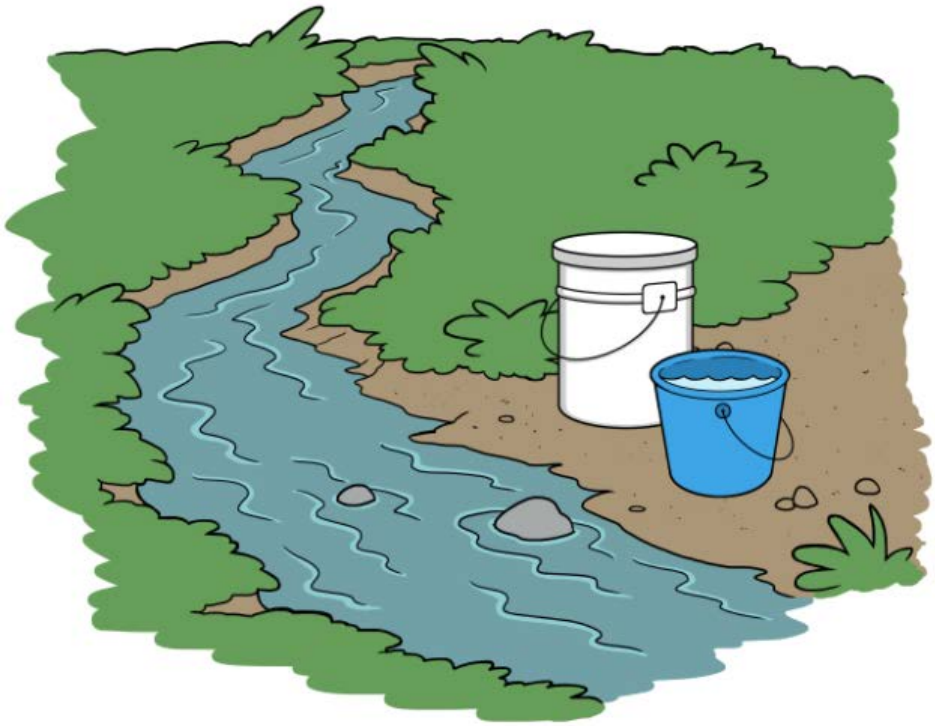


Introduction to Drinking Water Quality for Household Water Treatment Implementers

Technical Brief

October 2017

CAWST
Centre for Affordable Water and Sanitation Technology

Technical Brief: Introduction to Drinking Water Quality for HWTS Implementers

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

If you want to improve the safety of drinking water through **household water treatment and safe storage (HWTS)**, it helps to understand the most common factors that affect drinking water quality.

In this technical brief:

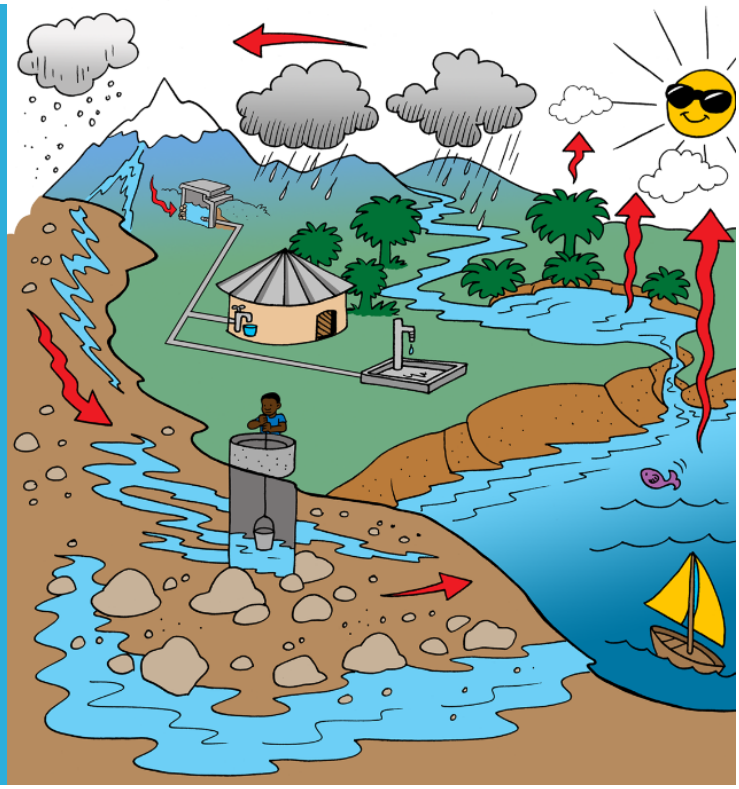
- We describe where drinking water comes from and how natural and human processes can affect its quality.
- We summarize four aspects of drinking water quality: microbiological, chemical, radiological, and acceptability.
- We give an overview of the sources, impacts, and household-level treatment options for common chemical and microbiological contaminants.
- We discuss factors that influence the acceptability (taste, smell, and appearance) of drinking water.

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 6: Definitions.

2 Where does Drinking Water Come From?

Water is constantly moving on, above, and below the earth's surface through the water cycle.

The sun causes water to evaporate from oceans and lakes into the atmosphere. From there, water vapour moves through the atmosphere, condenses into clouds, and falls back to the earth as rain or snow. Run off from rain and melting snow replenishes lakes, rivers, and other surface water sources. It also infiltrates through soil to replenish groundwater sources.



Most water on Earth is salt water found in oceans, and only 2.5% of Earth's water is freshwater. Most freshwater is frozen in ice and snow. This means that for our drinking water, we rely on the very small fraction of Earth's water that is liquid, accessible, and not salty.

There are three common types of drinking water sources:

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.

Groundwater is the water that fills the spaces and cracks in rocks and soil beneath the earth's surface. Groundwater depth and 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. Over half of the world's population gets their drinking water from groundwater sources such as wells and springs (Smith, Cross, Paden, & Laban, 2016).

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.

Water quality varies greatly between different water sources. As well, water quality at the same source may be different from year to year or between rainy and dry seasons.

3 What is Safe Drinking Water?

As it moves through the water cycle, water picks up many things along its path. Even water that looks clear may contain different chemicals, microorganisms, and particles. Some of these substances are harmless, while others can affect human health. Some substances come from natural sources, while others come from human activities, such as open defecation, waste disposal, agriculture, industry, and unsafe handling and storage of drinking water.

The World Health Organization (WHO) defines **safe drinking water** as water that "does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages" (2017a). The WHO **Guidelines** and countries' national **standards** for drinking water quality set limits for microbiological and chemical parameters. These limits help to determine if water is safe for drinking. Usually, safe drinking water contains some substances other than water, but these are at low enough concentrations that they are unlikely to harm people's health.

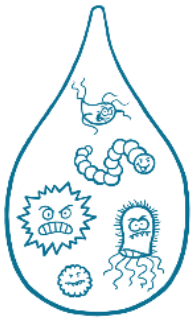
Guidelines and Standards for Drinking Water Quality

The WHO Guidelines for Drinking Water Quality are recommendations, not mandatory limits (World Health Organization, 2017a). Many countries have developed their own national standards. These standards are sometimes different from the WHO Guidelines.

Water quality can change between the source and a user's glass; in many communities, there are multiple points at which contaminants may enter drinking water during collection, transportation, and storage. Keeping water safe requires a **multi-barrier approach**: the use of an appropriate combination of behaviours and technologies to protect the water source, transport water safely, treat water, and store water safely. For more information about safe drinking water, the multi-barrier approach, and the role of HWTS, refer to *CAWST Technical Brief: Introduction to Household Water Treatment and Safe Storage.*

4 Aspects of Drinking Water Quality

There are four aspects of drinking water quality (World Health Organization, 2017a):



1. *Microbiological Aspects*: this refers to microorganisms in water. There are four types of microorganisms often found in water: **bacteria**, **viruses**, **protozoa**, and **helminths** (worms). Not all microorganisms are harmful to human health. Microorganisms that cause disease are called **pathogens**.
2. *Chemical Aspects:* this refers to natural or human-made elements or compounds in water. Examples include nitrogen, pesticides, heavy metals, salts, and pharmaceutical drugs. Water usually contains some chemicals, and many are not harmful to human health at concentrations commonly found in drinking water. However, some chemicals can cause serious health problems over time.
3. *Radiological Aspects:* this refers to radioactive substances, which may come from natural sources like rocks and soil, or from human sources like industrial or medical facilities. Generally, the amount of radiation people consume in their water is tiny compared to their radiation exposure from other sources, such as the sun. Therefore, the health risks from radioactive substances in water are typically very small. We do not focus on radiological aspects of drinking water quality in this Technical Brief.
4. *Acceptability Aspects:* this refers to factors that influence the appearance, smell, and taste of water. Substances that affect the acceptability of water include suspended solids, certain chemicals, and organic material. It is important to consider acceptability aspects of your drinking water. If people think water tastes, smells, or looks unappealing, they may decide to use water from other sources that could be more harmful to their health.

When a substance in drinking water can cause harm to human health or to the environment, we refer to it as a **contaminant**. Microbiological contaminants (pathogenic bacteria, viruses,

protozoa, and helminths) cause many of the most common diseases related to drinking water quality, including many diarrheal diseases. In 2012, unsafe drinking water caused an estimated 502,000 deaths from diarrhea (Prüss-Ustün et al., 2014). Some chemical contaminants, such as fluoride, arsenic, and nitrate, can also cause widespread health effects (WHO, 2017).

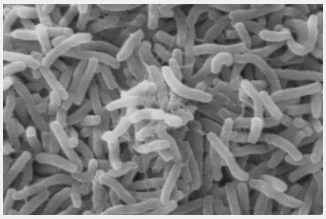
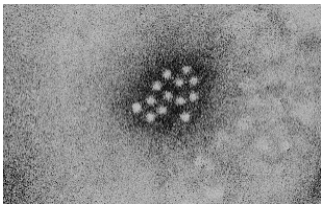
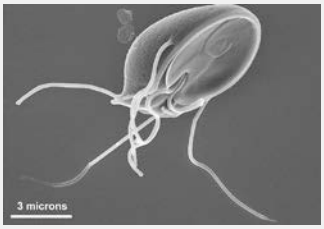
4.1 Microbiological Aspects of Water Quality

Most microorganisms are harmless or even beneficial. When microorganisms in water are harmful and could make people sick, we refer to them as pathogens or microbiological contaminants.

4.1.1 Types of Microorganisms in Water

The following table describes the four groups of microorganisms that can be found in water: bacteria, viruses, protozoa, and helminths.

Table: Types of Water-Related Microorganisms

Microorganism Type	Description	Size	Water-Related Disease Examples
Bacteria  Bacterium that causes cholera ("REMF Image Index," n.d.)	Bacteria are tiny, single-celled organisms, found almost everywhere on earth, and very common in human and animal feces. This is a very diverse group of organisms.	0.2–10 microns	The most common water-related diseases caused by pathogenic bacteria have diarrhea as a symptom. These diseases include cholera, shigellosis (also known as bacillary dysentery), and typhoid. Cholera outbreaks are a major public health concern in many countries.
Viruses  Electron micrograph of the Hepatitis A virus (CDC, n.d.)	Even smaller than bacteria, these tiny microorganisms are unable to reproduce by themselves and must invade another living host to reproduce.	0.03–0.2 microns (100x smaller than bacteria)	Hepatitis A, Hepatitis E, and rotavirus are diseases caused by viruses that can be found in water. Dengue Fever, Japanese Encephalitis, and West Nile Fever are diseases caused by viruses that are spread by mosquitoes, which breed or live in water.
Protozoa  *Giardia muris*, a protozoan, causes the disease giardiasis (CDC, 1999/Dr. Stan Erlandsen)	Protozoa are a diverse group of single-celled organisms. Some protozoa are parasites that need a living host to survive. Others, such as cryptosporidium, form cysts that help them survive harsh environments without a host.	2–150 microns Cysts: 2–50 microns	Amoeba, cryptosporidium, and giardia are some of the pathogenic protozoa found in water, mainly in tropical countries. Malaria is caused by protozoa that are transmitted by mosquitoes.

Helminths  Electron micrograph of an adult male Schistosoma parasite worm.	Helminths are worms. Pathogenic helminths are often passed through feces. Some enter the body when people ingest contaminated food or water. Others enter through the skin. Many helminths can live in people's bodies for several years. Some spend part of their life in other animal hosts.	Often 40–100 microns. Some can grow to over 100 cm long.	Common types of helminths that cause illness are round worms, pin worms, and hook worms. Schistosomiasis, also known as bilharzia, is a disease caused by the trematode flatworm. Dracunculiasis is a disease caused by the Guinea Worm, a type of round worm.

(Baron, 1996; World Health Organization, 2017a)

4.1.2 Microbiological Contaminants and Human Health

Water-related pathogens can enter the body and cause diseases in different ways, as shown in the following table.

Table: How Water-Related Pathogens Cause Disease

Disease Class	How Microorganism Enters the Body	Pathogen Examples	How to Prevent Disease
Waterborne	Ingestion: Pathogens enter the body when a person drinks or eats contaminated water or food.	Bacteria: *E. coli*, *Shigella* species, *Vibrio cholerae*, *Salmonella enterica*. Viruses: Hepatitis A and E viruses, Rotavirus, Adenoviruses, Enteroviruses. Protozoa and Helminths: Cryptosporidium, Guinea worm (Dracunculus), Giardia, Tapeworms.	Improve drinking water quality through treatment to remove or kill pathogens. Carefully wash food with treated drinking water and cook food properly.
Water-washed (water-access related)	Contact: Pathogens enter through the skin or eyes because of a lack of safe water and good hygiene to wash away pathogens.	Bacteria: *Chlamydia trachomatis, Treponema pertunue.* Mite: *Sarcoptes scabei* (scabies).	Provide enough safe water for basic hygiene. Improve basic hygiene practices.
Water-based	Contact: Pathogens enter through the skin, wounds, or other bodily membranes when people bathe or walk in contaminated water.	Bacteria: *Leptospira*, *Mycobacteria* (non-tuberculosis) Protozoa: *Acanthamoeba* Helminths: *Schistosoma*, some hookworms.	Do not bathe or swim in water that is known to be contaminated. Improve water quality by removing or killing pathogens or their hosts.
Water-insect vector	Insect Bite: Pathogens grow in water-breeding insects such as mosquitos and enter the human body when the insect bites the human.	Virus: Dengue virus, Japanese Encephalitis virus Protozoa: *Plasmodium* (malaria), *Trypanosoma*	Prevent insects from breeding in water. Use pesticides to control insects. Prevent insects from biting by using bed nets and wearing long clothes.

(Adapted from Bartram, 2015; World Health Organization, 2017)

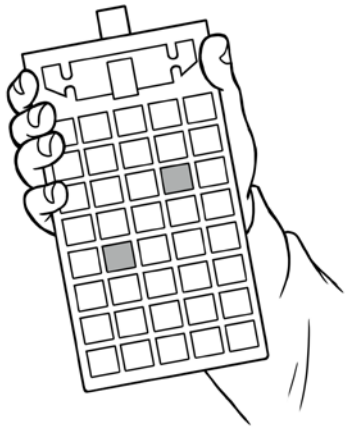
The probability of becoming sick after pathogens enter your body depends on:

- How many pathogens entered your body (dose).
- How easily the pathogen can cause disease in people (virulence). Different pathogens vary in their ability to invade the human body, multiply, and make you feel sick.
- How well your body can protect against the pathogen (immune status). Young children, the elderly, people with HIV/AIDs, and pregnant women are often at greater risk of becoming ill because their immune systems are not as strong.

  (World Health Organization, 2017a)

4.1.3 Measuring Microbiological Contaminants and Assessing Risk

Testing for every possible pathogen in water would be time consuming, complicated, and expensive. Often you can test for **indicator organisms** as a way of assessing the microbiological safety of drinking water. For example, *Escherichia coli* and thermotolerant coliforms are often used as indicator organisms for fecal pathogens. When these microorganisms are present in water, fecal contamination is likely. Refer to *CAWST Drinking Water Quality Testing Manual* for more information about testing for indicator bacteria.



Test tray for estimating the most probable number (MPN) of indicator bacteria in a sample.

The WHO Guidelines state that safe drinking water should have no *E. coli* or thermotolerant coliforms detectable within a 100 mL sample (World Health Organization, 2017a). This can be a difficult target to achieve, and some countries have created standards that are not as strict.

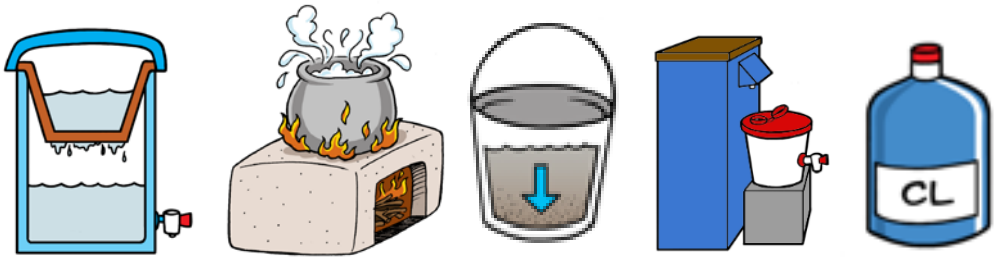
You need to be careful when interpreting results from tests for indicator organisms. Water that has no indicator bacteria may still contain protozoa or viruses. For example, treatment with chlorine is more likely to inactivate indicator bacteria than certain protozoa and viruses. In addition, filters often remove bacteria more effectively than viruses, which are much smaller. For these reasons, you cannot always assume that water without indicator bacteria is completely safe.

Testing for pathogens is important, but is a **reactive** approach to risk assessment, meaning that you will only identify pathogens after they have entered the water and potentially made people sick. In addition to water quality testing, communities should take **proactive** measures to identify potential sources of pathogens and to reduce the likelihood of pathogens entering their drinking water. **Water safety planning** is one approach used to assess and prevent risks to water safety. Refer to *CAWST Technical Brief: Water Safety Planning and Household Water Treatment and Safe Storage*.

4.1.4 HWTS Options for Microbiological Contaminants

Most HWTS systems are designed to remove or inactivate microbiological contaminants. However, different HWTS options vary in their ability to remove different pathogen types. For an overview of how effectively different HWTS methods remove or inactivate pathogens, refer to *CAWST Technical Brief: Introduction to Household Water Treatment and Safe Storage.* Also, refer to *CAWST HWTS Fact Sheets* and online HWTS Knowledge Base for detailed

information about the effectiveness of specific HWTS options. Remember that multiple methods—for example, an appropriate combination of sedimentation, filtration, and disinfection—can be combined to add extra protection against pathogens.



Examples of HWTS options: ceramic pot, boiling, settling, biosand filter, and liquid chlorine.

4.2 Chemical Aspects of Water Quality

Water often contains chemicals. Some occur naturally in certain water sources (for example, arsenic, fluoride, sulphur, magnesium, salts). Human activities such as agriculture and industry add other chemicals to water (for example, nitrates, some heavy metals, pesticides).

Most chemicals in drinking water do not pose threats to human health at normal concentrations. A few chemicals, however, have the potential to cause serious health problems and occur over widespread areas. These include arsenic, fluoride, and nitrate/nitrite (World Health Organization, 2017a). Other common chemicals such as iron, manganese, sulphur, certain minerals, and salts may or may not affect water's safety but can change its colour, taste, or smell. These acceptability factors are important because they influence whether or not people will drink the water.

Unlike microbiological contaminants, which tend to cause disease outbreaks very quickly, chemical contaminants often go unnoticed until disease occurs due to **chronic** (repeated or continued) exposure. The WHO Guidelines provide health-based limits to help you understand when a given concentration of a chemical in water could be harmful to human health over a lifetime of consumption.

4.2.1 Types of Chemicals in Drinking Water and their Impacts

The table below summarizes key information about common chemical parameters that could affect your drinking water quality. For more information, refer to *CAWST Chemical Fact Sheets* and the resources by the World Health Organization and by the US Environmental Protection Agency listed under Additional Resources in Section 7.

Table: Chemicals that Commonly Affect Drinking Water Quality

Chemical Parameter	Description and Source	WHO Guideline Concentration	Potential Impacts
Arsenic	Arsenic is a naturally occurring chemical that comes from mineral and sedimentary deposits. It is found most often in groundwater but can also be found in some surface water. High concentrations of arsenic are found in water from deep wells in over 70 countries. This is a chemical contaminant of great concern in certain regions including parts of India, Bangladesh, Nepal, Argentina, and the United States.	0.01 mg/L (10 µg/L)	Long-term consumption of arsenic in drinking water is associated with increased risk of cancer of the skin, lungs, bladder, and kidney. It often causes people to develop skin bulges (keratosis) on their palms and feet.
Disinfection By-Products (DBPs)	When chemical disinfectants (such as chlorine or bromine) are used for water treatment, some by-products are usually formed. This is a broad category of chemicals formed by the interaction between disinfectants and substances in the water.	Variable. Refer to the WHO Drinking Water Quality Guidelines (2017)	Some DBPs may be carcinogenic. The best way to reduce DBP formation if you are treating water with chlorine or bromine is to remove organic substances from the water before disinfection. In most cases where HWTS is applied, the health risks from drinking untreated water are far greater than the potential health risks from DBPs.
Fluoride	Fluoride is a naturally occurring chemical that can be found in groundwater and some surface water. There are certain regions where fluoride in drinking water often exceeds the WHO Guideline value. These include parts of India, China, Central Africa, and South America.	1.5 mg/L	A low concentration of fluoride in water (0.7 mg/L) is good for strengthening people's teeth. However, consuming water with high concentrations of fluoride over time can cause damage to teeth and bones. Infants and young children are most at risk.
Hardness	Hardness in water is caused mainly by ions of calcium and magnesium. Natural waters have a wide range of mineral content and hardness.	No guideline	There are no major health concerns from drinking hard water. Calcium and magnesium are important minerals and should be in people's diets. However, hardness may affect the taste of the water and may cause mineral build-up on pots and kettles.
Iron	Iron occurs naturally in certain groundwater and surface water sources where rocks and sediment are high in iron. Iron can also enter water from rusting steel or iron pipes.	No guideline	Drinking water with high concentrations of iron will not make people sick. Iron affects the taste of water and makes it appear reddish in colour. This makes it less appealing to drink and more likely to stain clothing.
Lead	Lead usually enters water due to the corrosion of lead pipes, fittings, or service connections in piped water systems. Manufactured materials that are not disposed of properly, such as lead-acid batteries, leaded paint, or fuel with lead additives, can also contribute to lead contamination. The use of lead in many of these products is no longer as common as it was in the past.	0.01 mg/L (10 µg/L)	Exposure to lead is associated with neurological and developmental problems, impaired kidney function, reduced fertility, impaired development of the fetus, and increased blood pressure.

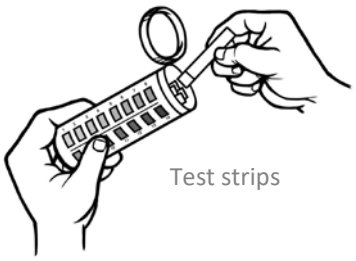
Chemical Parameter	Description and Source	WHO Guideline Concentration	Potential Impacts
Manganese	Manganese often occurs naturally in groundwater and surface water, usually with iron. Human activities also cause manganese contamination in some areas. Manganese can occur in two forms in water: dissolved and suspended. If groundwater comes from a deep tube well, the manganese may be dissolved and not visible. Water with high levels of suspended manganese usually has a black colour or black flakes in it.	0.4 mg/L	People need small amounts of manganese for their health, but most people get this from food. There could be health impacts from drinking water with high manganese concentrations. This does not occur very often because people will choose not to drink the water (manganese makes water taste bad and appear black when above 0.1 mg/L. Water with a high concentration of manganese may stain laundry or form coatings on water pipes.
Nitrate and Nitrite	Nitrate and nitrite are naturally occurring chemicals in the environment. Nitrate (NO_3^-) is an important plant nutrient commonly used in agricultural fertilizers. Nitrate in groundwater and surface water is normally low in concentration. It can reach high levels if there is leaching or run off from fertilizers or feces. Nitrite ($N0_2^-$) is formed as a result of microbial activity in soil or water, and its levels in water can vary.	Nitrate: 50 mg/L nitrate ion Nitrite: 3 mg/L nitrite ion WHO Guidelines also list a combined limit.	Methemoglobinemia, or blue baby syndrome, occurs in infants who are bottle fed with formula prepared using water high in nitrate and nitrite. Affected babies have difficulty breathing, and their skin sometimes turns blue from a lack of oxygen. Babies with methemoglobinemia often also have diarrhea at the same time. This is because high nitrate levels are usually associated with higher levels of microbiological contamination.
pH	pH is a parameter used to indicate how basic or acidic a solution is. It is measured on a logarithmic scale from 0 to 14, in which a one unit decrease (for example, from pH 7 to 6) represents a 10x increase in hydrogen ion concentration. Water is considered acidic if pH is below 7, and basic if pH is above 7. pH can be affected by factors such as mining, industrial activity, acid rain, accidental spills, cement linings, and acidic or alkaline rocks and soil. pH is often considered an acceptability aspect of drinking water quality.	No health-based guideline. Typically, optimum pH for drinking water is between 6.5–8.5.	pH should be below 8 for optimal disinfection with chlorine. Higher pH may lead to incomplete disinfection. Low pH (acidic water) can lead to corrosion of water mains and pipes and can accelerate the leaching of heavy metals.
Total dissolved solids (TDS)	Total dissolved solids (TDS) describes the concentration of dissolved inorganic salts and organic material in water. TDS may come from natural sources (for example, rocks and minerals) or human sources (for example, run off from agriculture or roads). Therefore, it can vary depending on geology and human activity. TDS is sometimes considered an acceptability aspect of drinking water quality.	No guideline	There are no proven health problems from consuming water with high TDS, but people may find it less acceptable to drink. Water with a TDS concentration greater than 1000 mg/L is usually not acceptable due to taste.

Adapted from: World Health Organization Drinking Water Quality Guidelines (2017) and US Environmental Protection Agency Table of Regulated Drinking Water Contaminants (US EPA, n.d.)

4.2.2 Testing Chemical Aspects of Water Quality

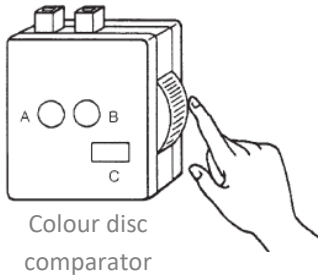
It is expensive and difficult to test every chemical parameter. Generally, you should focus on chemicals that are known to be an issue in the region where you work. If you know very little about chemical water quality in your region, three parameters you can prioritize for testing are arsenic, fluoride, and nitrate. These chemicals are found in many regions and have negative effects on human health. You may also want to test parameters that affect the acceptability of water, such as TDS, manganese, and iron.

Usually, you will get the most accurate results by sending your water samples to a certified lab for testing. If you choose to do your own testing, some simple portable methods for testing chemical parameters include:



Test strips

- *Test strips*: these are small strips containing a **reagent** that reacts in the presence a specific chemical and changes colour. You compare the colour on the test strips to a colour chart to estimate the chemical concentration. People often use test strips to estimate parameters such as pH, chlorine, iron, and nitrate.



Colour disc comparator

- *Colour disc comparators*: these are portable devices for estimating concentrations. To use one, you add a provided reagent to a sample and wait for the sample to change colour as the reagent reacts with chemicals in the water. Then you place the sample in the comparator, and visually match the colour of the sample to a colour on a disc.

Photometer

- ***Colorimeters*** *and* ***photometers***: these are digital instruments that measure the amount of coloured light absorbed by a sample. These are more expensive and require calibration and a power source. However, they are also more accurate than test strips and comparators, which rely on visual colour assessments.

Digital pH meter

- *Digital meters*: these are electronic devices you use by inserting a probe or electrode into the sample to take digital concentration readings. People often use digital meters to measure pH and TDS. They are easy to use, but require calibration using standard solutions, which must be purchased separately.
- *Portable test kits*: Some parameters, such as arsenic, are difficult to measure at low concentrations without laboratory equipment. Now you can purchase test kits with all the reagents and equipment required to test for a particular chemical parameter. Often you will need basic laboratory skills to use these kits.

For details about testing for specific chemical contaminants, refer to *CAWST Chemical Fact Sheets* and *CAWST Drinking Water Quality Testing Manual*.

4.2.3 HWTS Options for Chemical Contaminants

Most HWTS systems are designed to remove or inactivate pathogens, not chemicals. However, some HWTS systems can remove specific chemical contaminants. For example:

- Certain oxidation and sorption methods can remove arsenic from water (refer to *CAWST Factsheets: Household Water Treatment for Arsenic Removal*).
- Some sorption and precipitation methods can remove fluoride from water (refer to *CAWST Factsheets: Household Water Treatment for Fluoride Removal)*.
- Solar or heat-based distillation can remove most chemical contaminants, but often produces only a small volume of water (Cardoso da Silva et al., 2014).
- Activated carbon (present in the core of many ceramic candle filters) removes a range of organic compounds, including compounds causing taste and smell issues, and some pesticides. Researchers are experimenting with biochar filters for the same purpose.
- Aeration followed by filtration or settling can remove iron and manganese.

Note: Boiling is not effective against many chemical contaminants. As water evaporates out of the pot or kettle, the concentration of many chemical contaminants will increase.

4.3 Radiological Aspects of Water Quality

Some chemical elements found in soil and water are naturally radioactive. Radiation can also come from human sources, such as health clinics that use radiation to diagnose or treat illnesses. Most of the time, the amount of radiation you are exposed to from drinking water is very small and is not a significant health risk. For this reason, we do not focus on radiological contamination when we consider household-level water quality testing and treatment. To learn more about radiological aspects of water quality, refer to the *World Health Organization's Drinking Water Quality Guidelines* (World Health Organization, 2017a).

4.4 Acceptability Aspects of Water Quality

Certain factors can alter the appearance, taste, or smell of water. We call these acceptability aspects of water quality, because they affect how consumers feel about drinking the water. Acceptability aspects include turbidity, colour, taste, and smell. For some water sources, acceptability aspects also include factors listed in the chemical parameters table above, such as pH, TDS, manganese, and iron.

4.4.1 Turbidity

Turbidity is a measure of the cloudiness of water. High turbidity is caused by silt, clay, and other suspended particles in water. Water appears clear if turbidity is below 1 NTU, and becomes visibly cloudy at 4 NTU (World Health Organization, 2017b). Turbidity is an acceptability aspect of water quality because if people see that their water is very cloudy, they often do not want to drink it.

The particles that cause turbidity are usually not harmful by themselves, but microbiological contaminants often attach to these suspended particles and can make water unsafe. High

turbidity sometimes indicates that water quality is poor, or that a treatment system is not working properly. As well, high turbidity can make certain water disinfection methods, such as UV or solar disinfection (SODIS), less effective.

The WHO Guidelines (World Health Organization, 2017a) recommend that large municipal supplies should produce water with no visible turbidity (less than 4 NTU) and ideally should be able to reach less than 0.5 NTU before disinfection. For small water supply systems with limited resources, and for household water treatment systems, reaching turbidity levels this low may not be possible (World Health Organization, 2017b).

There are several different ways to measure turbidity, ranging from a simple estimate by looking through a plastic bottle to a more accurate measurement with a digital turbidimeter. For more information about methods for measuring turbidity, refer to *CAWST Drinking Water Quality Manual*, and the turbidity resource by the World Health Organization listed under Additional Resources in Section 7.

4.4.2 Colour

Sometimes, the colour of water may indicate a contaminant you want to avoid. More often, coloured water is not dangerous, but it may cause people to look for other water sources because they prefer colourless water.

Here are some examples of substances that can make water coloured:

- Vegetation and other organic materials can cause dark brown or yellow colour.
- Silt and clay often cause a brown or red colour.
- Iron can cause a reddish (orange to brown) colour.
- Manganese can cause a black colour and staining.
- Algae can make water look bright green or blue-green. Some algae produce toxins that could be harmful.
- Bacterial growth can also turn water black (or other colours).

4.4.3 Taste and Smell

Most people prefer water that tastes and smells good. Such preferences may lead them to choose a water source that is less safe. Beyond preferences, though, a bad taste or smell may indicate contamination, especially if it changes suddenly. Here are some examples of tastes and smells that may occur in drinking water:

- Algae and some bacteria may cause unpleasant tastes or smells.
- High sulphate concentrations may cause a bitter taste. Some bacteria can convert sulphate to hydrogen sulfide (H_2S), which smells like rotten eggs.
- Iron in water may cause it to taste bad.
- Hardness and TDS can affect the taste of water.
- In some communities, people dislike the taste and smell of chlorinated water.

5 Summary

There are four aspects of drinking water quality:

1. Microbiological aspects are any microorganisms in water. Pathogenic microorganisms make people sick, and the priority of most HWTS systems is to remove these contaminants from drinking water.
2. Chemical aspects are any natural or human-made elements or compounds in water. Many chemicals are harmless, but some can lead to chronic health effects when present above guideline concentrations.
3. Radiological aspects are any radiological substances in water. Most of the time, the amount of radiation in drinking water is very small and is not a significant health risk.
4. Acceptability aspects are any factors that affect water's appearance, taste, or smell. Acceptability aspects are important to consider because they determine how likely people are to drink the water instead of finding a different, possibly less safe, source.

6 Definitions

Bacteria: Tiny single-celled organisms, found almost everywhere on earth, and very common in human and animal feces.

Chronic: Refers to health problems that persist over a long period of time. Opposite of acute.

Colorimeter: Digital instrument that measures the amount of coloured light absorbed by a coloured solution.

Colour disc comparator: A portable device for comparing the colour of a solution with colours on an interchangeable disc of standards.

Contaminant: A microorganism or chemical in drinking water that can cause harm to human health or to the environment.

Groundwater: The water that fills the spaces and cracks in rocks and soil beneath the earth's surface.

Guideline: A recommended limit that should not be exceeded. See the WHO Drinking Water Quality Guidelines (2017a).

Hardness: The traditional measure of how well water can react with soap. Hard water requires more soap to produce a lather, and can cause deposits to build on pots and kettles when water is boiled. Hardness in water is caused mainly by ions of calcium and magnesium.

Helminths: Parasitic worms.

Household water treatment and safe storage: Activities by which household members treat and store water in their homes. Also called managing water at the point-of-use (POU).

Indicator organism: Microorganisms whose presence in water indicates the likely presence of fecal contamination.

Multi-barrier approach: Adding as many barriers (control measures) as possible to reduce the likelihood of drinking unsafe water. Each barrier adds an incremental health risk reduction.

Pathogen: An organism that causes disease.

Photometer: A device for measuring the intensity of light. Photometers can be used to measure the absorption of light by a coloured solution, to calculate the concentration of a chemical.

Proactive: Taking action in anticipation of potential risks or future challenges.

Protozoa: A diverse group of single-celled organisms. Some protozoa are parasites that need a living host to survive. Others, such as cryptosporidium, are able to form cysts that help them survive harsh environments without a host.

Rainwater: Water that falls to earth as rain.

Reactive: Taking action in response to a problem after it arises.

Reagent: A substance used to test for the presence of another substance by causing a chemical reaction with it.

Safe drinking water: Water that does not represent any significant risk to health over a lifetime of consumption.

Standard (for drinking water quality): A mandatory limit that must not be exceeded. Standards often reflect a legal duty or obligation.

Surface water: 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.

Total dissolved solids (TDS): The concentration of dissolved inorganic salts and organic material in water. TDS may come from natural or human sources (for example, rocks and minerals, run off from agriculture or roads), and can vary depending on geology and human activity.

Turbidity: A measure of the cloudiness of water. High turbidity is caused by silt, clay, and other suspended substances in water, which reflect light and make it difficult to see through the water.

Viruses: Even smaller than bacteria, tiny microorganisms that are unable to reproduce by themselves and must invade another living host to reproduce.

Water cycle: The continuous movement of water on, above, and below Earth's surface.

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

7 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, and other resources about HWTS, drinking water quality testing, and other topics.

US Environmental Protection Agency. *Table of Regulated Drinking Water Contaminants [Overviews and Factsheets].* Available at: https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants

- Detailed information about contaminants in drinking water, including microoganisms and chemicals.

World Health Organization (2017). *Turbidity: information or regulators and operators of water suppliers.* Available at: www.who.int/water_sanitation_health/water-quality/household/household-publications/en

- Provides information on the use and significance of turbidity as a measure of water quality.

World Health Organization. (2017). *Guidelines for drinking-water quality: fourth edition incorporating the first addendum.* Available at: http://apps.who.int/iris/handle/10665/43428

- Detailed information about the WHO's water quality guidelines, aspects of drinking water quality, and specifics about many different contaminants.

8 References

Baron, S. (Ed.). (1996). *Medical Microbiology* (4th ed.). Galveston (TX): University of Texas Medical Branch at Galveston. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK7627/

Bartram, J. (2015). *Routledge Handbook of Water and Health*. Routledge.

Cardoso da Silva, M. C., Sens, M. L., Soares, C., & de Andrade Neto, C. O. (2014). Water purification by direct solar distillation process in isolated households - doi: 10.4025/actascitechnol.v36i1.18737. *Acta Scientiarum. Technology*, *36*(1), 75–80.

CDC. (n.d.). Public Health Image Library (PHIL). Retrieved January 4, 2017, from https://phil.cdc.gov/phil/details.asp?pid=2739

Prüss-Ustün, A., Bartram, J., Clasen, T., Colford, J. M., Cumming, O., Curtis, V., … Cairncross, S. (2014). Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. *Tropical Medicine & International Health*, *19*(8), 894–905. https://doi.org/10.1111/tmi.12329

REMF Image Index. (n.d.). Retrieved January 4, 2017, from http://remf.dartmouth.edu/imagesindex.html

Smith, M., Cross, K., Paden, M., & Laban, P. (Eds.). (2016). *Spring: managing groundwater sustainably*. International Union for Conservation of Nature and Natural Resources. Retrieved from https://portals.iucn.org/library/sites/library/files/documents/2016-039.pdf

US EPA. (n.d.). Table of Regulated Drinking Water Contaminants [Overviews and Factsheets]. Retrieved February 14, 2017, from https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants

World Health Organization. (2017a). *Guidelines for drinking-water quality: fourth edition incorporating the first addendum.* Retrieved from http://apps.who.int/iris/handle/10665/43428

World Health Organization. (2017b). Water quality and health-review of turbidity: information for regulators and water suppliers. Retrieved from http://www.who.int/entity/water_sanitation_health/publications/turbidity-information-200217.pdf

Calgary, Canada | www.cawst.org | support@cawst.org

Last Update: October 2017