TECHNICAL GUIDE

Understanding and Testing Water Quality

As mentioned in *Assessing Communities, Institutions, and Existing Infrastructure*, all existing water sources are identified as part of the assessment phase. Some of these sources will be good, potential sources for a safe water project, while others will not. There are many factors that can make a water source viable or not, including yield, location, community access, and land ownership. One of the most important factors is water quality. The quality of the water source will directly impact the treatment method. Choosing a source with relatively good water quality could mean a less intricate water treatment process to produce safe water.

Water Mission has always stressed the importance of ensuring that water is accessible, sustainable, and safe. Safe water is defined by the World Health Organization (WHO) as water that "*does not represent any significant risk to health over a lifetime of consumption*" (2011). This applies to the more delicate stages of life too, such as infancy or aging, when one may be more vulnerable to contaminants.

The presence of contaminants in water is not always obvious. A clear glass of water can be deceptive. Nearly half of the groundwater samples we have taken from drilled boreholes have tested positive for fecal contamination, even though the water appears clear. Not all water contaminants can be seen. Even from sources that are assumed to be protected, consistent and reliable water quality requires testing and treatment. This is why every Water Mission project begins by testing water quality to determine the presence of contaminants and the best treatment method.

There are two main categories of contaminants found in water: suspended and dissolved. Suspended contaminants include material that exists in a suspended (i.e. insoluble) form in water and may settle out, while dissolved contaminants are material that is dissolved as part of water and cannot settle out. Figure 1 has a summary of different contaminants and common solutions used to make water safe.

WHAT'S IN THE WATER?

There are 2 types of contaminants in water.

	Contaminant	Description	Solution
1	**Suspended Contaminants**	• Dirt and debris that make water appear cloudy and dirty • Or microbial contaminants (disease-causing microorganisms that pose a serious health risk if consumed), primarily: – Bacteria that cause illnesses like cholera, typhoid, diarrhea, and dysentery – Viruses like rotavirus and hepatitis A – Protozoa like ***cryptosporidium*** and ***giardia***	Sedimentation, filtration, or disinfection
2	**Dissolved Contaminants**	Minerals, metals, and organic compounds such as pesticides	More complicated to remove and may require chemical reaction, reverse osmosis, distillation, or ion exchange

Figure 1 - What's in the Water?

Understanding Water Contaminants

Suspended Contaminants

Microbial Contaminants

Microbial contaminants (or “pathogens”) are disease-causing microorganisms that can pose serious health risks. Illness is a common result of consuming pathogens, and for children, the elderly, or immune-compromised people, these illnesses can be serious or even life-threatening.

The most common source of waterborne pathogens is fecal contamination from human or animal waste entering a water source. Pathogens are almost always found in open surface waters where it is easy for contaminated run-off to flow into the source. Groundwater sources may become contaminated through floods, disasters, or poorly constructed wells. Even if pathogens are not present in a water source or immediately after treatment, they may enter a water system in the pipeline, at the tap stand, or in collection containers. For these reasons, microbial contaminants must be addressed when designing a system to ensure water remains safe all the way to consumption. More information on effective removal of pathogens can be found in *Understanding and Selecting Water Treatment Solutions*.

There are three major types of waterborne pathogens: viruses, bacteria, and protozoa.

Viruses are very small microbiological entities, ranging in size from 0.01-0.1 microns. Viruses commonly cause gastrointestinal and respiratory illnesses. Due to their small size, some viruses may pass through water filters. However, viruses are very susceptible to chlorine disinfection.
Examples of viruses: poliovirus, hepatitis, rotavirus, and Ebola.

Bacteria range in size from 0.5-1.0 microns. Coliforms are a specific type of rod-shaped bacteria found in the digestive tract of humans and animals. One coliform of significant concern is *Escherichia coli*, more commonly known as *E. coli*. Some strains of *E. coli* aid in food digestion and are normally present in the intestines of humans. However, when certain strains of *E. coli* enter other parts of the body, it can cause serious diseases. Different strains cause different reactions, but results can include urinary tract infections, bacteremia (i.e. bacteria in the blood), meningitis, and diarrhea. Some bacteria can be removed by certain filtration technologies based on size-exclusion and most are susceptible to chlorine.
Examples of bacteria-caused diseases: cholera, typhoid fever, and salmonella.

Protozoa are the largest of the three pathogens, ranging from 2-50 microns. Protozoa are single-celled organisms found in most habitats worldwide. Depending on the species, protozoa infections range from asymptomatic (i.e. no noticeable symptoms) to life-threatening. Due to their large size, protozoa are removed by most filters. This is beneficial because protozoa that form cysts, like *Cryptosporidium parvum*, are chlorine resistant in the cyst stage. Therefore, both filtration and disinfection are required for water sources suspected to contain protozoa, including all surface waters.
Examples of protozoa: *Cryptosporidium parvum*, *Giardia lamblia*, *E. histolytica*, and helminths.

Unfortunately, viruses and protozoa are very difficult to detect or quantify in water. Coliform bacteria, however, are more readily detected and are consistently present with viruses and protozoa. This means that the presence of coliforms in water also indicates the presence of viruses and protozoa. Therefore, coliforms are often used as an “indicator organism”. The number of coliforms in a water source is measured as colony forming units (CFU) and reflects the extent of microbial contamination.

Suspended Solids

Suspended solids are particles, such as dirt and debris, that originate from eroding soil or decaying organic matter. Like microbial contaminants, solids are most often found in open surface waters, but can leach into unprotected groundwater sources. Suspended solids make water cloudy and hazy (see Figure 2) and provide a surface for microbial growth. This means that not just suspended solids are carried into water with dirt and debris, but microbial contaminants as well. Additionally, solids can negatively impact disinfection by consuming chlorine or shadowing the UV light needed to kill pathogens. Filtration is the most common method of removing suspended solids from water.

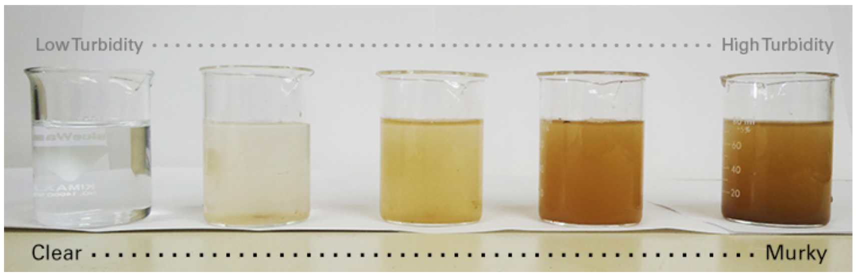

Figure 2 - Visual Effects of Turbidity

Turbidity is the measurement of suspended solids in a water source. Turbidity itself does not pose adverse health risks. However, as mentioned above, it can be a surface for microbial growth and interfere with disinfection. Turbidity is measured in nephelometric turbidity units, or “NTU”.

Dissolved Contaminants

Dissolved contaminants (or “dissolved solids”) include any minerals, salts, metals, or ions that are dissolved in water. This includes anything that is not a suspended solid or pure water. Dissolved solids come from many sources, including rocks or soil, the insides of pipes, and run-off from urban areas or agricultural fertilizers.

In addition to the actual dissolved contaminants, there are several parameters that are either caused or affected by dissolved solids. These are related to the type and quantity of dissolved solids in a water source. Examples include total dissolved solids, alkalinity, conductivity, hardness, and pH.

Alkalinity is a measure of water’s ability to neutralize an acid. In other words, it reflects how much acid must be added to water to cause a significant change in pH. Alkalinity is caused by dissolved carbonates from soil or rock (e.g. limestone). There are no adverse health effects associated with alkalinity. Low alkalinity (< 150 mg/L) may lead to corrosion if pH is also low. High alkalinity (> 200 mg/L) may contribute to scale buildup in pipes. When measured as calcium carbonate (mg/L $CaCO_3$), the alkalinity should be near 75-100% of the hardness (Mechenich & Andrews, 2004). Alkalinity can also affect coagulation and subsequent chlorine disinfection.

Ammonia (NH_3) is a colorless, pungent gas that is soluble in water. In nature, ammonia is produced by decaying organic matter. It can also seep into surface or groundwater through discharge from industrial processes containing ammonia or fertilizers. There are no health-based concerns for ammonia at the concentrations naturally found in water (WHO Ammonia, 2003). However, high levels may cause aesthetic concerns, such as taste (> 35 mg/L) or odor (> 1.5 mg/L) (WHO, 2011). Additionally, ammonia reacts with chlorine to form chloramine, which reduces free chlorine (i.e. limits disinfection).

Arsenic (As^{3-}) is an element found in rocks and soil that can seep into groundwater as a negatively-charged ion (known as an "anion"). Arsenic does not affect the aesthetics of water (e.g. color, taste, smell), but even small amounts (> 0.01 mg/L) cans pose serious health concerns (EPA Primary, 2018). In severe cases, it can cause cancer. The greatest threat to public health from arsenic is contaminated groundwater. While not a problem everywhere, the WHO has identified high levels of arsenic in the groundwater in Argentina, Bangladesh, Chile, China, India, Mexico, and the US (WHO Arsenic, 2018).

Chloride (Cl^-) is present in water when salts (e.g. NaCl, KCl, $MgCl_2$) dissolve, forming the anion (Cl^-) and cations (e.g. Na^+, K^+, Mg^{2+}). Intrusion from salt water or hot spring and leaching from rocks or soil are common sources of chloride in water. There are no health-based concerns for chloride at the concentrations naturally found in water (WHO, 2011). The standard for chloride (< 250 mg/L) is based on aesthetics due to the salty taste of water with high chloride (EPA Secondary, 2017). If the chloride level is high enough, it may also cause corrosion to metal pipes and fittings.

Chlorine is commonly used as a disinfectant to kill harmful pathogens in water. Chlorine in water can be measured as total or free chlorine. Total chlorine includes all the chlorine in a sample, including what is already combined with contaminants and is no longer available to disinfect. Free chlorine includes only the chlorine that has not combined with contaminants and is still available (or "free") for disinfection. Chlorine dosages must be carefully monitored to ensure the proper amount is being added. For treated drinking water, it is recommended to have a free chlorine concentration of 0.2-0.5 mg/L at the point of distribution to make sure the water remains safe until consumption (WHO, 2011). Excessive chlorination (> 4.0 mg/L total) may irritate or damage the skin, mouth, and digestive tract (EPA Primary, 2018). Common aesthetic complaints about chlorinated water are the smell and taste of chlorine.

Conductivity measures the ability of water to carry electrical current. This is impacted by the number of dissolved ions in the water – the more ions, the higher the conductivity. High conductivity is associated with dehydration and salty tasting water.

Copper (Cu^+, Cu^{2+}) can leach into water as a positively-charged ion (known as a "cation") from corroding pipes and fittings, or from rocks and soil. For human health, copper is an essential and vital element. However, consuming high levels (> 1.3 mg/L) can cause nausea or illness and prolonged exposure can lead to kidney and liver damage (EPA Primary, 2018). Aesthetically, water contaminated with copper (> 1.0 mg/L) may have a metallic taste and/or cause blue or green staining (EPA Secondary, 2017).

Fluoride compounds are salts that form when the element, fluorine, combines with minerals in soil or rocks. These compounds can easily dissolve into groundwater and with excessive consumption (> 4.0 mg/L) can cause bone disease (EPA Primary, 2018). Children under the age of eight are particularly at risk as their teeth are still developing. Tooth discoloration may occur at lower concentrations (> 2.0 mg/L) for all ages (EPA Secondary, 2017). The WHO has identified the highest disease burden related to fluoride in China, Eritrea, Tanzania, Ethiopia, Kenya, South Africa, and India (Bartram *et. al.*, 2007). The WHO recommends a maximum concentration of 1.5 mg/L for drinking water (WHO Fluoride, 2004).

Hardness reflects the amount of dissolved multivalent cations in water and is caused by the leaching of magnesium and calcium ions from rocks or soil. Hardness is not a health concern at the levels found naturally in drinking water. High levels of hardness (> 200 mg/L) (i.e. "hard" water) can scale to build up in pipes and soaps to be less effective, while low hardness (< 100 mg/L) (i.e. "soft" water) could lead to corrosion if the pH and alkalinity are also low (WHO, 2011).

Hydrogen Sulfide (H_2S) is a gas produced by sulfate-reducing bacteria. Inhaling the gas directly can cause nausea, illness, and even neurological damage. However, the levels found naturally in water are very low and it is unlikely that anyone could consume a harmful dose from drinking water. Even though there is low health risk for the levels found naturally in water, hydrogen sulfide should never be detectable in drinking water by taste or smell. Hydrogen sulfide may cause a rotten egg smell or taste in water at concentrations as low as 0.05 mg/L (WHO, 2011).

Iron (Fe^{2+}, Fe^{3+}) is part of a normal diet and does not pose a danger to human health in drinking water (WHO, 2011). Iron may be present in water due to leaching from rocks and soils, or from corroding pipes. High iron (> 0.3 mg/L) may cause an undesirable rusty color, staining, flecks, or a metallic taste (EPA Secondary, 2017). It may also promote the formation of "iron bacteria", which leaves a slimy coating inside pipes or a film on top of the water.

Manganese (Mn^{2+}, Mn^{4+}) is also part of a normal diet and is one of the most common metals in the Earth's crust. It leaches into water from rocks or soils. High manganese (> 0.05 mg/L) may cause black- or brown-colored water, staining, flecks, or a metallic taste (EPA Secondary, 2017). Particularly high levels can also lead to neurological damage if consumed over an extended time. However, the levels of manganese required for this are well above the concentrations normally found in water (WHO, 2011).

Nitrate (NO_3^-) is a naturally occurring form of nitrogen found in soil and is very common in groundwater sources. It may also be introduced to surface water through run-off from agricultural fertilizers or fecal waste. Nitrate is an important nutrient for plants, but can be poisonous for humans. The toxicity of nitrate to humans is mainly attributed to its reduction to nitrite. Nitrate is considered high when it exceeds 10 mg/L when measured as nitrogen (N) (or 50 mg/L when measured as nitrate) (WHO, 2011).

Nitrite (NO_2^-) is formed by the reduction of nitrates after they enter the body. Nitrites disrupt the ability of blood to carry oxygen throughout the body. High nitrites lead to a serious and sometimes fatal condition called methemoglobinemia (or "blue baby syndrome"), which can affect any age group, but is a particular risk for infants and unborn children. Nitrites in drinking water are considered high when they exceed 1 mg/L when measured as nitrogen (or 3 mg/L when measured as nitrite) (WHO, 2011).

pH measures the concentration of hydrogen ions in water. It is affected by the decomposition of organic matter and leaching from rocks or soil. Safe water, ideally, has a neutral pH value of 7. Water with a higher pH is considered "basic" and lower pH values are "acidic". Basic conditions (> 8.5) cause scaling of pipes and a sour taste, while acidic conditions (< 6.5) cause pipe corrosion and a metallic taste (EPA Secondary, 2017). These conditions can also reduce the effectiveness of chlorination and coagulation. Extreme pH (>10, < 4) may irritate the eyes, skin, mouth, or stomach (WHO pH, 2003).

Phosphate (PO_4^{3-}) is introduced into water through run-off from agricultural fertilizers or fecal waste. Extremely high levels of phosphate can cause digestive problems. Phosphate in water can also indicate the presence of dangerous agricultural pesticides. Therefore, further tests for pesticides should be performed to avoid adverse health effects from any potentially present pesticides.

Sulfate (SO_4^{2-}) is a naturally occurring ion that enters water by leaching from rocks or soil, or intrusion from hot springs or volcanoes. There are no health-based concerns for sulfate at the concentrations naturally found in water (WHO, 2011). Its presence can cause a noticeable salty taste (> 250 mg/L) (EPA Secondary, 2018). Very high levels (> 1,000 mg/L) can cause nausea or a laxative effect, especially for those who are unaccustomed to drinking water with sulfate (WHO Sulfate, 2011).

Total Dissolved Solids (TDS) is comprised of the total amount of charged ions in water. This includes minerals, salts, or metals that have been dissolved in a water source. There are no health concerns directly from TDS at the levels found naturally in water (WHO, 2011). However, TDS is a good indicator of overall water quality because more dissolved ions may mean more contaminants. Aesthetically, high levels of TDS (> 500 mg/L) can cause a salty taste, colored water or staining, or scaling in pipes (EPA Secondary, 2017).

Water Quality Standards

Water quality standards vary depending on the governing agency. However, there is some overall agreement that can help define good water quality. For example, the Environmental Protection Agency (EPA) sets enforceable, nation-wide water quality standards for the United States. These standards are divided into two categories: primary and secondary. Primary standards cover water quality risks that cause adverse health effects, while secondary standards deal with aesthetic concerns such as odor, taste, or appearance of the water. Additionally, the WHO provides guidelines for international water development projects. While these guidelines are not enforceable, they do act as reliable information and suggestions that countries can use to set their own standards.

It is important to note that not all countries mandate water quality standards. This means that many of Water Mission's safe water projects are not in locations with government-enforced regulations. Therefore, Water Mission, taking both the EPA and WHO guidelines into consideration, has developed standard guidelines for use in its development projects (see Table 1). If a project does happen in a location where there are government regulations, then the government regulations will be respected. If a local government regulation differs from a Water Mission guideline, then the more conservative value will be implemented.

Water Quality in Disaster Relief Work

It is important to note that standards may change in disaster relief efforts. This is because it can take significant time to design and implement water treatment systems that meet every guideline listed in Table 1. However, in disaster situations, the need for water is often immediate. Additionally, some of the contaminants will not cause serious health impacts, especially if consumed for only a short duration. Therefore, water quality guidelines may be adjusted to provide quicker relief **as long as doing so does not impose additional health risks**.

One example is turbidity. Ideally, drinking water has a turbidity less than 1 NTU. However, Sphere recognizes that up to 5 NTU is acceptable when responding to disasters (2011). Remember that turbidity itself is not hazardous to health, but it is a medium for microbial growth. Subsequently, a higher free chlorine concentration of 0.5-1.0 mg/L is also recommended. The higher chlorine residual accounts for increased contamination or dirty collection containers that may be used in the disaster situation.

While some guidelines may be adjusted for disaster relief, the standards for bacteria will not change. It is important to stress that the Water Mission standard is **zero fecal coliforms per 100 milliliters of water at the point of delivery** in both disaster relief and development work.

Table 1 - Water Mission Water Quality Guidelines

Parameter	Units	WM Recommendations		If Outside Recommended Range			
		Acceptable	Ideal	Causes in Water	Health Impacts	Aesthetic or Other	Treatment
Alkalinity	mg/L	N/A	150-200**	Dissolved carbonates	None	Possible corrosion (low); scaling (high); affects coagulation and chlorination	Best solution is another source; otherwise neutralizing filters or chemicals, or reverse osmosis*
Ammonia	mg/L	< 35[iii] (taste)	< 1.5[iii] (odor)	Decaying organics; runoff from industrial processes or fertilizers	None for concentrations found naturally in water	Taste; odor; reacts with chlorine (limits disinfection)	Best solution is another source*
Arsenic	mg/L	< 0.01[i]	0[i]	Erosion of natural deposits	Skin damage; complication of the circulatory system; cancer	None	Best solution is another source
Bacteria, Fecal Coliforms	CFU/100 mL	0[i]	0[i]	Pathogenic bacteria from fecal waste contamination	Gastrointestinal illness (diarrhea, vomiting)	None	Filtration and/or disinfection
Bacteria, Total Coliform	CFU/100 mL	0[i]	0[i]	Pathogenic bacteria from natural contamination	Possible gastrointestinal illness (diarrhea, vomiting)	None	
Chloride	mg/L	< 250[ii] (taste)	0	Intrusion from sea water or hot springs; leaching from rocks or soil; evaporation exceeding precipitation	Dehydration	Salty taste; corrosive to metal piping	Best solution is another source; otherwise reverse osmosis, distillation, or ion exchange
Chlorine, Free	mg/L	< 4.0[i]	0.2-0.5[iii] (treated water)	Over-chlorination during the disinfection process	Possible irritation and damage to the skin, mouth, and digestive tract	Chlorine smell and taste	Reduce the amount of chlorine addition during disinfection
Chlorine, Total	mg/L	< 4.0[i]	N/A				
Conductivity	µS/cm	< 2,000	< 1,000	Intrusion from sea water or hot springs; leaching from rocks or soil;	Possible dehydration	Salty taste; corrosive to metal piping	Best solution is another source; otherwise reverse osmosis or distillation
Copper	mg/L	< 1.3[i]	< 1.0[ii] (taste/staining)	Leaching from rocks, soil, or corroded piping	Nausea or illness; possible liver or kidney stones	Metallic taste; blue or green staining	Best solution is another source; otherwise ion exchange, distillation, reverse osmosis, and/or remove corroded piping
Fluoride	mg/L	< 1.5[iii]	0	Leaching from rocks or soil; runoff from agricultural fertilizers	Possible risk of bone disease (tenderness or joint pain); pitting of teeth in children	Discoloration of water, skin, or teeth	Best solution is another source; otherwise distillation, ion exchange, or reverse osmosis
Hardness	mg/L	< 250**	< 80**	Leaching of multivalent cations (e.g. Ca^{2+}, Mg^{2+}) from rocks or soil	None for concentrations found naturally in water	Scaling (high); possible corrosion (low)	Best solution is another source; otherwise lime-soda softening, ion exchange, or reverse osmosis*

i EPA Primary Drinking Water Regulations
ii EPA Secondary Drinking Water Regulations (aesthetic concern)
iii WHO Guidelines for Drinking Water (aesthetic concern)
* Treatment required only if aesthetic effects are present and unacceptable
** measured as calcium carbonate ($CaCO_3$)

water mission

Parameter	Units	WM Recommendations		If Outside Recommended Range			
		Acceptable	Ideal	Causes in Water	Health Impacts	Aesthetic or Other	Solution
Hydrogen Sulfide	mg/L	< 10	0	Sulfate-producing bacteria	Inhalation of gas at high levels can cause nausea, illness, or neurological damage	Discolored water; rotten egg odor and/or taste	Best solution is another source; otherwise aeration or chlorination followed by filtration, or carbon filter
Iron	mg/L	< 0.3[ii] (color/taste)	0	Leaching from rocks, soil, or corroded piping	Part of a normal diet; no adverse health impacts under normal conditions	Rust-colored water; metallic taste; red or orange staining	Aeration or chlorination followed by filtration, reverse osmosis, and/or remove corroded piping
Manganese	mg/L	< 0.05[ii] (color/taste)	0	Leaching from rocks or soil	Part of a normal diet; no adverse health impacts under normal conditions	Black- or brown-colored water; metallic taste; black staining	Aeration or chlorination followed by filtration, or reverse osmosis
Nitrate	mg/L	< 10[i] **	0	Runoff from agricultural fertilizers or fecal waste	High levels are poisonous and can be fatal for infants	None	Best solution is another source; otherwise ion exchange, reverse osmosis, or distillation
Nitrite	mg/L	< 1.0[i] **	0				
pH	-	6.5-8.5[ii]	7.0	Decomposition of organic material; leaching from rocks or soil	Possible irritation to eyes, skin, mouth, or stomach (extreme high or low)	Metallic taste and corrosion (low); sour taste and scaling (high); limits chlorination and/or coagulation	Best solution is another source; Otherwise neutralizing filter or chemical addition
Phosphate	mg/L	< 10	0	Runoff from agricultural fertilizers or fecal waste	Indicates possible presence of dangerous pesticides in the water	Algae growth; blue- or green-colored water	Test water for pesticides; best solution is another source; otherwise reverse osmosis
Sulfate	mg/L	< 250[ii] (taste)	0	Intrusion from sea water, hot springs, or volcanoes; leaching from rocks or soil	Possible nausea or illness (extreme high)	Salty taste	Best solution is another source; otherwise ion exchange, reverse osmosis, or distillation
TDS	mg/L	< 500[ii] (color/taste)	N/A	Intrusion from sea water or hot springs; leaching from rocks or soil;	Possible dehydration	Salty taste; colored water; staining; scaling; corrosive to metal piping	Best solution is another source; otherwise reverse osmosis or distillation
Turbidity	NTU	< 5.0[iii] (treated water)	< 1.0[iii] (treated water)	Suspended particles from eroding soil and decaying organic matter	No direct impacts	Provides surface for microbial growth; limits disinfection	Coagulation, sedimentation, and/or filtration

i EPA Primary Drinking Water Regulations
ii EPA Secondary Drinking Water Regulations (aesthetic concern)
iii WHO Guidelines for Drinking Water (aesthetic concern)
** measured as nitrogen (N)

Water Quality Testing

The only way to know what water contaminants are present is to test the water. Water quality testing is an important part of every Water Mission project, starting at the initial assessment and continuing throughout the ongoing operation and maintenance. Simple tests are available to evaluate water quality in the field. Table 2 shows the testing methods used by Water Mission along with where to find the corresponding instruction manuals. See the training presentation *How to Test Water Quality* for more information and video instructions on testing water quality.

Table 2 - Methods for Water Quality Testing

Parameter	Test Method	Test and Care Instructions
Alkalinity	Hach Alkalinity or 5-in-1 Test Strips	See instructions on test strip bottle
Ammonia	Hach Nitrogen Test Strips	See instructions on test strip bottle
Arsenic	Arsenic Test Kit	Arsenic Test Kit Manual
Bacteria, Fecal and Total	Membrane Filtration	Hach Membrane Filtration Manual
Chloride	Hach Chloride Test Strips	See instructions on test strip bottle
Chlorine, Free and Total	Hach Colorimeter DR890 (prgm 9)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 80)	Hach DR900 Manual
	Hach Chlorine Test Kit	Hach Chlorine Test Kit Manual
	Hach 5-in-1 Test Strips	See instructions on test strip bottle
Conductivity	Hach Pocket Pro+	Hach Pocket Pro+ Manual
Copper	Hach Colorimeter DR890 (prgm 20)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 135)	Hach DR900 Manual
	Hach Copper Test Strips	See instructions on test strip bottle
Fluoride	Hach Colorimeter DR890 (prgm 27)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 195)	Hach DR900 Manual
Hardness	Hach Hardness or 5-in-1 Test Strips	See instructions on test strip bottle
Hydrogen Sulfide	Water Works Hydrogen Sulfide Test Strips	See instructions on test strip bottle
Iron	Hach Colorimeter DR890 (prgm 33)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 265)	Hach DR900 Manual
	Hach Iron Test Strips	See instructions on test strip bottle
Manganese	Hach Colorimeter DR890 (prgm 41)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 295)	Hach DR900 Manual
	Hach Manganese Test Strips	See instructions on test strip bottle
Nitrate	Hach Colorimeter DR890 (prgm 51)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 355)	Hach DR900 Manual
	Hach Nitrate Test Strips	See instructions on test strip bottle
Nitrite	Hach Colorimeter DR890 (prgm 60)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 371)	Hach DR900 Manual
	Hach Nitrite Test Strips	See instructions on test strip bottle
pH	Hach Pocket Pro+	Hach Pocket Pro+ Manual
	Hach pH or 5-in-1 Test Strips	See instructions on test strip bottle
Phosphate	Hach Colorimeter DR890 (prgm 79)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 490)	Hach DR900 Manual
	Hach Phosphate Test Strips	See instructions on test strip bottle
Sulfate	Hach Colorimeter DR890 (prgm 91)	Hach DR890 Manual
	Hach Colorimeter DR900 (prgm 680)	Hach DR900 Manual
	Hach Sulfate Test Strips	See instructions on test strip bottle
TDS	Hach Pocket Pro+	Hach Pocket Pro+ Manual
Turbidity	Hach 2100P Turbidimeter	Hach 2100P Manual
	Hach 2100Q Turbidimeter	Hach 2100Q Manual

Water Sampling

Collecting a good, representative water sample is an essential step in water quality analysis. Water quality is a major factor in determining the usability of a potential water source, the type of treatment required, and the ongoing operation and maintenance.

In general, there are two categories of water samples: grab samples and composite sample. A grab sample gives a snapshot of the water quality at a specific time and place. A composite sample consists of multiple samples taken over a period of time or at regular intervals. Most of Water Mission water quality testing consists of grab samples. However, if a water course is seasonal or varies throughout the year, a grab sample may not reflect those variances. A composite sample taken at different points throughout the year would be more appropriate to determine the overall water quality. Talking with community leaders and members during assessment is the best way to determine if there are seasonal changes in a water source and if a composite sample will be required.

It is important to retrieve a water sample from a location that is representative of the water source or distribution point being assessed. The following are guidelines for where and how to collect the water sample based on the sample collection point.

For sampling open water sources like rivers or lakes: Collect water samples from a location that provides a representative sample. This is usually towards the middle of the water source and about mid-depth. For lakes and collection tanks, be sure to avoid collecting the water sample from any sources that feed into the area such as streams, springs, or inlet pipes.

For sampling valves or tap stands: Open the valve or and allow the water to run for 5-10 seconds to flush the valve. This allows for a more accurate and representative sample of the water.

For sampling from a borehole: it is important to collect a water sample that is representative of the groundwater at a given location. If water has been stagnant inside the borehole for some time, it may not be representative of the groundwater held in the surrounding subsurface strata. For this reason, an existing borehole with a handpump or submersible pump should be pumped long enough for the dynamic water level to be achieved before taking a water sample. For a new borehole, the water sample should be taken after the borehole has been flushed or developed. This allows time for the turbidity level in the borehole to drop so that a reliable water sample can be taken. Typically, this water sample can be taken at the end of the yield test so that the water quality tests analyze water taken while the borehole is in a stable state at its dynamic water level.

For sampling existing water systems: If sampling is to be taken from existing water infrastructure, such as an old distribution system or raw water storage tank, a water sample should be taken at the source and the end point of the existing system such as a tap or collection point. This will help to determine the effect the existing system has on the water quality.

Sampling Containers and Volumes

Each water quality testing method has a different sampling container and sample volume required (see Table 3). When performing tests in the field, make sure to use the correct container and volume for each test. See the manuals listed in Table 2 or the training presentation *How to Test Water Quality* for more information.

For water samples being transported out of the field for testing, make sure an adequate amount of water is collected to run all the necessary tests at the office Most general testing containers come in a variety of sizes (e.g. 500 milliliters, 1 liter, 2 liters, 20 liters). For example, jar tests require several liters of water, so a 20-liter container is recommended. Water samples being transported to test for turbidity or dissolved contaminants can be collected in a clean, general container – it does not need to be sterile, but it should be free of dirt or other sources of contaminants that could affect the test results. Rinsing general testing containers before collecting the final sample is good practice to make sure the water sample is not impacted by any substances in the container. Samples that will be tested for microbial contaminants (i.e. bacteria) should always be collect in sterile Whirl-Pak container.

Table 3 - Water Sample Containers and Volumes

Whirl-Pak (microbial)	Hach Pocket Pro	Hach Turbidimeter	Hach DR900	Hach Chlorine Test	General (non-microbial)
100 mL	9 mL	10 mL	5 or 10 mL	5 or 10 mL	Volume varies
					

Using Whirl-Paks: Whirl-Paks are sterilized, sealed bags containing a 25-milligram tablet of active sodium thiosulfate. This tablet is necessary for treated (i.e. chlorinated) water samples. The sodium thiosulfate neutralizes chlorine, providing results that reflect the water at the time of collection. Sodium thiosulfate tablets will affect the dissolved solids in water. For example, samples collected in Whirl-Paks will show higher conductivity and salt levels due to the sodium thiosulfate. Therefore, it is not recommended to use Whirl-Paks for any tests other than microbial.

Figure 3 - Best Practices for Using Whirl-Paks (from Whirl-Pak)

Figure 3 show best practices for using Whirl-Paks to get accurate microbial test results. Due to the sodium thiosulfate tablet and the risk contamination, do not rinse Whirl-Paks before collecting samples. Be careful when opening the Whirl-Pak to not introduce contamination from hands or other sources. Use care when pulling off the seal and use the plastic pull tabs to open the Whirl-Pak – touching the rim or opening can contaminate the water sample. Depending on the water source, water samples can either be poured into the Whirl-Pak or the Whirl-Pak can be submerged in the water (e.g. lake, river). Fill the Whirl-Pak between the "100 mL FILL LINE" and the "4 oz FILL LINE". Each microbial test requires a 100-milliliter sample. Underfilling will result in an insufficient water sample for accurate results, and overfilling could lead to spilling and possible contamination. If multiple microbial tests will be run, make sure to collect a separate Whirl-Pak sample for each test.

General Water Sampling Procedure

Whether testing for microbial contaminants, turbidity, or dissolved solids, the following are general water sample collection procedures for Water Mission staff. More detailed instructions for each test can be found in the manuals listed in Table 2.

1. Ensure that all water quality testing equipment has been properly calibrated. It is recommended that water quality testing procedures are done on a sample blank from a reputable bottled water source to serve as a quality check a few times a year and in training new staff.
2. Put on protective equipment such as gloves and eyeglasses when appropriate.
3. Table 2 lists some of the most common collection containers used in Water Mission water quality analysis. For all containers except the Whirl Pak, rinse each container two to three times with the sample water before filling it with the final sample. For water samples collected for jar tests, make sure to completely fill the containers so that there is no air in them and transport them as gently as possible. This will help to reduce oxidation and preserve the visual characteristics of the sample as best as possible.
4. For the most accurate results, water quality tests should be performed immediately after sampling. If microbial tests cannot be performed within an hour, the sample should be refrigerated as soon as possible. If possible, bring coolers filled with ice or freezer packs to the field and place samples inside until testing. All microbial tests should be done within 24 hours for accurate results. Make sure a Portable Incubator is available for incubation (see the *Portable Incubator Manual* for instructions).
5. All water samples being transported back from the field need to be clearly labeled and placed in a secure location where they will not spill or leak. Water samples must be labeled with the following information, as seen in Figure 4:
    a. Community Name
    b. Water Source
    c. Date
    d. Collection Time
6. Log all water quality test results in the appropriate Field Activity Form (e.g. *Assessment Form*, *Commissioning Form*, *Follow-up Form*).

Figure 4 -
Sample Labeling

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