


# WATER QUALITY PROTOCOL

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Programming Guidance: Document Status		World Vision 
<b>Title</b>	Water Quality Protocol	
<b>Date</b>	January 2021	
<b>Purpose</b>	Guide WASH staff on the assessment of drinking water quality parameters at WV-constructed water supply facilities.	
<b>When Used</b>	Programme implementation and monitoring	
<b>Primary User/s</b>	Technical Programme Lead	
<b>Translations Available</b>	English	

## 1. Introduction

World Vision (WV) has been working in the area of safe drinking water supply since 1985, by providing drinking water through boreholes fitted with hand pumps, mechanised systems (including solar), and spring catchments. World Vision works to ensure every family, and especially children, has access to clean and safe water in the places where they live, work, and go to school. As WV seeks to ensure that safe drinking water is provided to communities, water quality analysis, monitoring, and treatment, as well as field water quality analytical capacity and the capacity building of staff are critical for all WASH programmes.

The WV WASH 14-Country Evaluation, conducted by the Water Institute at the University of North Carolina, noted discrepancies in the way water quality is handled among countries involved in the implementation of water supply programmes.<sup>1</sup> The assessment of water quality in these countries has shown that some water sources and/or systems contain parameters above the World Health Organization (WHO) drinking water quality guideline.

The WHO groups parameters, which include microbes, salts, and metals, into three large categories: physical, chemical, and bacteriological. Physical and chemical are often combined into one category and referred to as physico-chemical parameters. West Africa regional countries under WV's former West Africa Water Initiative (WAWI) had a protocol of systematic sampling of all constructed water facilities *before* the installation of pumping systems and the provision of water and access points to the community. The WAWI protocol was not scaled-up to other countries during the more recent expansion of WASH programmes in 2010 and 2016. In the interest of aligning all water supply programmes to a uniform process to assure water quality, the WV Global Centre has developed this protocol for implementation by all country WASH programmes.



## 2. Purpose of this Protocol

The purpose of this protocol is to provide uniform guidance to WV WASH programmes in multiple countries on the assessment of drinking water quality parameters at WV-constructed water supply facilities. This protocol is designed to be in alignment with the WHO Drinking Water Guidelines and each country's national water quality standards. The appendices of this protocol also provide guidance to evaluate possible sources of elevated water quality parameters, as well as assess potential health effects. The protocol applies to drinking water from hand pumps, mechanised water systems, spring catchments, and rainwater harvesting systems.

To minimise adverse health effects and associated risks from water supplies developed under WV WASH programmes, WHO Drinking Water Guidelines (*Guidelines for Drinking-water Quality, Fourth Edition*) should be adopted.<sup>2</sup> Future adaptations are anticipated as WHO guidelines are continuously revised into updated versions or new editions. The guidelines are based on internationally-accepted procedures for risk assessment and mitigation that have been developed by the WHO over decades. It should be understood that these publications are “guidelines”. They are neither regulations nor standards, although they are used by individual countries to develop their national standards on drinking water quality.

It should be noted that the majority of water supply facilities developed by WV WASH utilise groundwater as a primary source. While groundwater is generally considered a safer source of drinking water than surface water, it may contain naturally-occurring water quality parameters that can have either adverse or beneficial effects on human health. As described above, water quality parameters are grouped into three categories:

1 World Vision WASH 14-Country Evaluation Final Report, The Water Institute at UNC, Chapel Hill, NC, USA (November 2019)

2 [https://www.who.int/water\\_sanitation\\_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/](https://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/)

physical, chemical, and bacteriological. Physical and chemical are often combined into one category referred to as physico-chemical parameters.

Within these three categories are numerous parameters and some that gain global attention include microbes, salts, and metals such as arsenic and lead. Physico-chemical parameters include color, temperature, pH, hardness, alkalinity, and metals, as well as major and minor ions such as sulfate, chloride, sodium, and potassium. A brief summary of the categories and key parameters is given below and more detail is available in the appendices.

In this protocol, water quality challenges are defined as water supply sources where a single parameter or multiple parameters exceed the WHO guideline for drinking water. Water quality mitigation is understood to be an affordable and efficient water treatment system that either removes the exceeding parameter(s) or reduces it to below WHO guidelines. With respect to analysis of water samples, this protocol references International Organization for Standardization (ISO) certification for laboratories. ISO is an internationally-recognised standard that laboratories must hold in order to be considered technically competent. Results from either an ISO laboratory or substitute laboratory should be interpreted by professionals having the necessary knowledge, capacity, and experience, which this protocol considers to be a combination of formal education and WV training.

### 3. Protocol Essentials

The following protocols are compulsory for all WASH programmes implemented by WV staff or outsourced to a contracting company:

1. Each newly-constructed water supply source must be tested for physico-chemical parameters including major and metals, and for key bacteriological elements *after* construction and *before* installation of pumping systems.
2. Each water supply source identified with water quality challenges that cannot be mitigated must be immediately capped *after* construction and *before* installation of pumping systems.
3. Each water supply source with water quality challenges that can be mitigated must be equipped with a pumping system, yet capped until the treatment system is installed and functional.
4. All WASH programmes must follow the water quality sampling procedures as guided by this document or any accredited laboratory procedure that is prescribed by an individual country for its local context (i.e., national laboratory and national standards).
5. All WASH programmes should select ISO-certified laboratories to conduct the sample analysis. If such laboratories are not available in the country, government-accredited laboratories should be considered as substitutes, pending a reliable quality assurance management plan as well as evidence of an inter-laboratory comparison test that is carried out with at least one ISO-certified laboratory.
6. Water quality results should be interpreted and implemented by professionals having authority, knowledge, capacity, and experience. For example, a national legal authority (e.g. Ministry or Health Department) delivers a certificate of conformity stating that the tested water sample meets local standards and/or WHO drinking water quality guidelines. In cases where a guideline is not being met, the authority may make a recommendation for treatment that should be implemented by WV WASH programmes.

## 4. Methodology of Sampling

### 4.1 General Considerations

As WV does not usually conduct laboratory analysis of water samples, this protocol focuses primarily on standard sampling methods, tests conducted in the field (*in situ* or directly at the site), and an understanding of some parameters. Correct sampling methods for both field and laboratory tests is necessary to assure the accuracy of drinking water quality testing. Field tests can provide valuable, preliminary information as to water quality for drinking, which is helpful for decision-making regarding construction of supply facilities (especially before further investments in construction or equipment are made). Laboratory tests can provide more detailed information on water quality, notably for physico-chemical and bacteriological parameters that cannot be accurately assessed in the field, or cannot be assessed at all in the field. In the case of lab tests, samples may require preservation in the field. This may be as simple as refrigeration of samples in a portable cooler/ice chest or more complex acidification of samples. Therefore, the sampling method (and the quality assurance management plan provided by the lab) must be followed to avoid erroneous analytical data resulting from changes in sample composition, preservation, or potential contamination.



### 4.2 Standardised Sampling Protocol

Standardised protocols include the following:

- a. Prior to collecting samples in the field, the person responsible for collecting the samples must contact the laboratory to schedule analysis time, obtain appropriate sample containers, clarify any sample holding times or sample preservation requirements, collect chain of custody paperwork (if available), and acquire copy of the lab quality assurance management plan.
- b. Sample containers must be labeled prior to sample collection. The sample label must record: community name, the sample GPS location, borehole number (if available), date of sample, time of sample, and number and type of sample containers. Other pertinent data are recorded in a sampling log. Each water source that is tested for water quality must have a unique identifier (either an associated well number or code).
- c. A log must be recorded for each sample. The log is similar to the sample label but contains more information: community name, the sample GPS location, other specifics that identify location, borehole number (if available), date of sample, time of sample, number and type of sample containers, borehole depth, cultural features (school, market, etc.), and any other pertinent data.
- d. If multiple water sources in close proximity will be tested, then GPS coordinates of the water source must be recorded to avoid confusion of sites and related samples. If GPS coordinates cannot be recorded, or the sites are too close for accurate recording, then any other specifics which identify the sampling point must be noted. For example, “borehole closer to school” and “borehole further from school.”
- e. Samples should be collected only at the end of the required pumping test period for new boreholes and before installation of pumping systems. Exceptions can be made at existing water facilities, where samples are collected from storage tanks, at the end of long pipe runs, or after any water treatment operation.

- f. The sampling bottle(s) and sampling equipment should be rinsed with the site water before taking samples. Ideally, bottles and equipment are rinsed three times with site water (“triple-rinse”) to be free of any off-site contaminants and avoid cross-contamination between samples, especially if the sampling equipment is used at multiple well sites.
- g. The sampling depth should be measured, specifically when the construction of the borehole log shows multiple geological layers providing different waters to the same well.<sup>3</sup> Sampling depth can be obtained by a depth to water meter, if available, or from the driller’s borehole logs.
- h. For any existing well or water facility already equipped with pumping systems (hand pump or electric pump), an adequate volume of water must be flushed from the well before the sample is collected in order to ensure that the sample represents the native aquifer. Flushing 3 to 5 well casing volumes is considered adequate. This is approximately 180-400 liters of water; the time to flush will depend on pumping rate. The pH and electrical conductivity of the flushed water should be measured periodically and when the measurements are stabilised, the sample is taken. An exception is made when corrosion and contamination of pumping equipment is being assessed.
- i. Samples to be analysed for metals should be field-filtered with a 0.45 to 0.47 micron filter directly into the sample bottle prior to preservation. Do not collect an unfiltered sample in a preserved container. If preserved with acid, metals samples do not require refrigeration.
- j. All physico-chemical sample containers should be cooled on ice immediately after collection, and then transported to the laboratory while packed in a cooler/ice chest. Samples should be chilled to 4 °C to prevent degradation. The laboratory’s quality assurance management plan should detail appropriate chilling and shipping requirements.
- k. All samples requiring preservation must be preserved as soon as possible, ideally at the time of sample collection.
- l. Samples must be promptly shipped under chain of custody documentation to the appropriate laboratory to avoid violation of holding time restrictions. Holding times can be as short as six hours.
- m. The laboratory must be instructed to use detection limits that are equal to, or less than, the applicable water quality objectives/screening levels (i.e., WHO or national guidelines).

#### 4.2.1 BOREHOLE SAMPLING

##### a) New Boreholes

During the drilling process, some parameters must be tested using field testing kits. According to the availability of the kits, the following parameters should be tested *in situ*:

- Physical parameters: pH, electrical conductivity (salinity), temperature
- Chemical parameters: bicarbonate (HCO<sub>3</sub>), chloride (Cl), calcium (Ca), magnesium (Mg), Total Hardness (TH), ammonium (NH<sub>4</sub>), nitrate (NO<sub>3</sub>), nitrite (NO<sub>2</sub>), sulfate (SO<sub>4</sub>), phosphate (PO<sub>4</sub>), fluoride (F), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), turbidity, Total Alkalinity (CaCO<sub>3</sub>)
- Bacteriological parameters: fecal coliform and total coliforms

These *in situ* field tests are required for the identification of geological layers that will interfere with safe drinking water and, if possible, to isolate them from contaminating the newly drilled well. Field tests can also provide preliminary information as to quality of the water for drinking, which is helpful for decision-making

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<sup>3</sup> A single borehole can cross more than one aquifer separated by impermeable layers with different water quality signatures. The sampling depth can provide information on the type of aquifer sampled, and whether a mixture of water from different aquifers is being sampled.

regarding development of the borehole and construction of supply facilities before further investments are made. Regardless, these tests are not meant to replace lab tests.

Once drilling is completed, a pump test should be conducted on the borehole to assess borehole yield and associated aquifer characteristics. The length of time for this test is dependent on the method used. Typically, 4 to 72 hours are needed, depending on the intended use of the well. Prior to shutdown of the pump at the end of the pumping test (while pumping at a constant rate), a set of water samples should be collected in sample bottles provided by the project or by the analytical laboratory for analysis. Each bottle must be labeled and placed in a box (cooler/ice chest) and transported to the laboratory for analysis.<sup>4</sup>

“The unfiltered, unpreserved sample should typically be collected in a plastic bottle (polyethylene, polypropylene or similar). Glass is also acceptable. The bottle must be new or detergent-washed. Bottles must be [triple-rinsed and] filled completely with water from the sample point. Ensure aeration is minimised. Potential contamination of the sample by hands or other sources must be avoided. Finally, the bottle should be capped tightly. Samples for metals analysis should be filtered with a 0.45 micron membrane *in situ* before any conditioning and transportation.”<sup>5</sup>

## b) Boreholes Under Rehabilitation

In many areas where WV works, diverse stakeholders (including government entities) may have implemented water supply programmes before WV intervention. At the time of WV WASH intervention, some of these facilities may be found to be non-functional and in need of rehabilitation. It is also possible that these facilities, whether functional or non-functional, have water quality parameters above drinking water guidelines, whether naturally-occurring or anthropogenically-occurring (e.g., from local geology or corrosion of installed pumping systems). Contamination can be also caused by poor sanitary conditions around the ground surface of the borehole. When engaging in the rehabilitation of existing wells, water quality control is considered to be a key component of successful rehabilitation.

After assessing rehabilitation needs of the facility and cleaning and disinfecting the borehole, a water sample must be taken following flushing procedures and analysed at the field site for key physico-chemical parameters such as pH, conductivity, temperature, coliform bacteria, nitrates, sodium, chloride, fluoride, sulfate, iron, manganese, total dissolved solids, and hardness. Other water samples should be collected and taken to a lab for full water quality parameters analysis. Based on the field and lab results, the rehabilitation process can proceed or be abandoned if parameters are too challenging and cannot be treated. This sampling should be done before installing the rehabilitated/repaired pumping system.

If water quality results are within acceptable guidelines (or deemed treatable), the borehole should be



disinfected by using the correct dosage for chlorine (or high strength calcium hypochlorite). Subsequent to dosing, the pump should be replaced or reinstalled and operated until chlorine can be detected (smelled) in the outflow. Chlorinated water should stay in the borehole for 12 to 24 hours for disinfection before being pumped out. After that time, ensure that all chlorinated liquid has been removed until chlorine can no longer be detected in the outflow either by measurement or smell. Residual chlorine should be measured after pumping to ascertain remnant chlorine concentration. A chlorine test field kit can be

<sup>4</sup> <https://www.icrc.org/en/doc/assets/files/publications/icrc-002-4033.pdf>

<sup>5</sup> <https://www.mfe.govt.nz/publications/fresh-water/national-protocol-state-environment-groundwater-sampling-new-zealand/part-1>

used at this time to check the chlorine concentration in the water. Alternatively, it is recommended to pump the water until chlorine can no longer be smelled.

### 4.3 Lab Selection

“Water sampling and analysis should be done by ISO-certified laboratories. When local laboratories are not ISO-certified, it is advisable to assess their quality by having an ISO-certified laboratory carrying out collaborative tests to ensure that variation in the accuracy of results is sufficiently small. Unreliable results in water quality analysis can exacerbate problems of water pollution, especially when they preclude timely corrective action (often because of distance and enabling factors). Qualified technicians should carry out all sampling and monitoring tests.”<sup>6</sup>

See Section 3 (Protocol Essentials), item 5, for more information on inter-laboratory comparisons.

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<sup>6</sup> J A Sciortino, R Ravikumar. *Fishery harbour manual on the prevention of pollution*. Madras, India. Bay of Bengal Programme, 1999.

## APPENDIX I: Water Quality Parameters

### I. Water Quality Tests

Testing parameters may be grouped into physical, chemical, and bacteriological categories. Testing procedures may be grouped into field (*in situ*) or laboratory.

- Physical tests indicate properties detectable by the senses
- Chemical tests determine the amounts of mineral and organic substances that affect water quality
- Bacteriological tests show the presence of bacteria, which can be characteristic of fecal pollution

Major ions such as sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), carbonate (CO<sub>3</sub>), bicarbonate (HCO<sub>3</sub>), nitrate (NO<sub>3</sub>), sulfate (SO<sub>4</sub><sup>2-</sup>), and chloride (Cl) are measured using different methods including atomic absorption (AA) or inductively coupled spectrometry, flame spectrometer, pre-calibrated electrodes, titration, and colorimetric analysis.

Metals like iron (Fe), manganese (Mn), thallium (Tl), copper (Cu), and zinc (Zn) are analysed by voltammetry determination on pretreated by dissolution or similar methods voltammetry techniques of analysis, for example inductively coupled plasma mass spectrometry (ICPMS). The bacteriological parameters recommended for monitoring of community supplies are those that best establish the safety of the water and thus the risk (if any) of waterborne disease and infection. As per this protocol, the critical parameters of water quality are E. coli, however, thermos-tolerant (fecal) coliforms are accepted as suitable substitutes and residual chlorine (if chlorination is practiced). These should be supplemented, where appropriate, by pH (if chlorination is practiced) and turbidity (if treatment systems are in place). Turbidity values above guidelines may render chlorination to be an ineffective treatment.

### The following analyses are required for each site:

#### I.1 Physical and Aesthetic Parameters

Water temperature, color, turbidity, odour and taste, total dissolved solids, and suspended solids should be measured.

- **Temperature:** helps determine the rate of biochemical reactions in water and whether they are able to occur at all. Elevated water temperature can limit the water's ability to hold oxygen and decrease organisms' capacity to resist particular pollutants and may adversely affect the results of *in situ* field tests.
- **Color:** may be caused by the presence of minerals such as iron and manganese or by substances of organic origin such as algae and weeds. Color tests can indicate the efficacy of the water treatment system.
- **Total dissolved solids (TDS):** represents the amount of inorganic salt substances (i.e., sodium, chloride, sulfate) and small amounts of organic matter that are dissolved in the water.
- **Suspended solids:** refers to small solid particles which remain suspended in water as a colloid or due to the motion of the water. Suspended solids can be removed by sedimentation and settling because of their comparatively large size. Suspended solids is used as one indicator of water quality and defines the screen size to be used on boreholes to reduce post-construction sedimentation. Suspended solids may affect measurements of turbidity.
- **Odour and taste:** associated with the presence of living microscopic organisms; decaying organic matter including weeds, algae; or industrial wastes containing ammonia, phenols, halogens,

hydrocarbons. While chlorination dilutes odour and taste caused by some contaminants, it generates a full odour itself when added to waters polluted with detergents, algae, and some other wastes. Sodium, sulfate, and iron can also cause odour and taste.

- **Turbidity:** measures the amount of particulate matter that is suspended in the water, or more simply, how clear the water is. Turbidity may be caused by suspended solids and colloidal matter. High turbidity makes filtration expensive and renders chlorination ineffective. Pathogens may be encased in the particles and escape the action of chlorine during disinfection. Turbidity can indicate the presence of bacteria/viruses as well as other disease-causing organisms that can produce symptoms such as nausea, diarrhea, cramps, and headaches.
- **Electrical conductivity:** measures the ability of an aqueous solution to carry an electrical current. The electrical conductivity, also known as specific conductance, is related to ionic strength (salts) of drinking water. It does not, however, tell us what specific ions they are. Thus, this measurement can be a good indicator of the level of salinity, but does not indicate which ions are contributing to salinity.

## 1.2 Chemical Parameters

The parameters listed below may be measured in the field (*in situ*), or in a laboratory. Metals are often grouped into Chemical Parameters, but in this protocol they require their own consideration (see Section 1.3 of the Appendix below).

- **pH:** measures hydrogen ion concentration. It is an indicator of how basic or acidic water is; values of 9.5 and above indicate highly basic while values of 3.0 and below indicate highly acidic. Drinking water should have neutral pH values between 6.5 and 8.5, which also help in effective chlorination.
- **Total dissolved solids (TDS):** represents the amount of inorganic salt substances (i.e. sodium, chloride, sulfate) and small amounts of organic matter that are dissolved in the water.
- **Salinity:** measures the total of all non-carbonate salts dissolved in water.
- **Alkalinity:** not a chemical in water, rather, a property of water. It is the capacity of water to resist changes in pH, specifically acidification (neutralise acid). It is dependent on the presence of certain chemicals in the water, such as bicarbonates, carbonates, and hydroxides and is an important measurement for chlorination.
- **Calcium (Ca):** one of two major minerals that causes “hardness” in water. The other is magnesium (Mg).
- **Magnesium (Mg):** one of two major minerals that causes “hardness” in water. The other is calcium (Ca).
- **Sodium (Na):** one of the minerals that causes salinity and contributes to salts in water.
- **Chloride:** one of the minerals that causes salinity and contributes to salts in water.
- **Residual Chlorine:** used for the disinfection of drinking water. Free chlorine remains in the water and should be measured in the field but also in labs. Being unstable in aqueous solution, the chlorine content of water samples may decrease rapidly over time.
- **Sulfate (SO<sub>4</sub>):** one of the minerals that causes salinity and contributes to salts in water.
- **Nitrate (NO<sub>3</sub>):** a common contaminant found mainly in groundwater, originating from decaying plant materials, pollution by fertilisers, or septic contamination.
- **Phosphate (PO<sub>4</sub>):** contribute to salts in water.
- **Fluoride (F):** an ion that sometimes occurs in groundwater.
- **Hardness:** usually caused by excess amounts of the two major minerals, calcium and magnesium, in water. Hard water requires a considerable amount of soap to produce a lather and may affect plumbing.
- **Hydrogen Sulfide (H<sub>2</sub>S):** causes taste and odour problems by giving the water a characteristic “rotten egg” taste or smell. It indicates anoxic, and sometimes acidic, conditions and can be a sign of bacterial contamination.
- **Dissolved Oxygen (DO):** the amount of oxygen dissolved in water.

- **Pesticides:** in areas with intense agriculture and pesticide manufacturing, pesticides may reach the ground water through infiltration. Their presence and concentration levels may be measured in labs.

### I.3 Metals

Metals are often grouped into Chemical Parameters, but in this protocol they require their own consideration. Trace quantities of many metals are important constituents of most waters. However, many of these metals are classified as contaminants at values above WHO drinking water guidelines. The presence of any of these metals in excessive quantities will interfere with beneficial uses of the water because of their toxicity. For instance, groundwater sources are sometimes tested for:

- **Aluminum (Al):** the WHO recommended guideline is 0.09 mg/l. The long-term consumption of water above the guideline may cause adverse health effects. Between 0.1 and 0.2 mg/l, it can cause also aesthetic problem by drinking water discoloration.
- **Antimony (Sb):** the WHO recommended guideline is 0.02 mg/l. The long-term consumption of water above the guideline may cause adverse health effects (carcinogen).
- **Arsenic (As):** the WHO recommended guideline is 0.01 mg/l in drinking water. Beyond that guideline, adverse health effects are reported for both long-term and short-term consumption, depending on the amount of As in water.
- **Barium (Ba):** the WHO recommended guideline is 0.7 mg/l. The long-term consumption of water above the guideline may cause adverse health effects.
- **Beryllium (Be)<sup>7</sup>:** the WHO has not set guideline and no known adverse health effects are reported.
- **Boron (B)<sup>8</sup>:** the WHO recommended guideline is 2.4 mg/l. The long-term consumption of water above the guideline may cause adverse health effects.
- **Cadmium (Cd):** the WHO recommended guideline is 0.003 mg/l. Cadmium has a half-life of 10 to 35 years. The long-term consumption of water above the guideline is documented to have serious adverse health effects.
- **Chromium (Cr)<sup>9</sup>:** the WHO recommended guideline is 0.05 mg/l. Water with high Cr content can be a sign of industrial contamination. The long-term consumption of water is documented to have serious adverse health effects at high concentration between 1-5 mg/l).
- **Copper (Cu):** the WHO has not set a guideline and no known adverse health effects are reported. Water with high copper content may cause aesthetic problems (stains).
- **Cyanide (HCN – CN):** the WHO recommended guideline is 0.5 mg/l. Water with high CN content can be a sign of industrial contamination. The consumption of water above the guideline is documented to have serious adverse health effects.
- **Fluoride (F):** the WHO recommended guideline is 1.5 mg/l. Fluoride is an essential micronutrient, but excessive amounts are documented to have adverse health effects.
- **Iron (Fe):** the WHO has not set a guideline and no known adverse health effects are reported. However, at a concentration of more than 0.3 mg/l laundry may have stains (aesthetic).
- **Lead (Pb):** the WHO recommended guideline is 0.01 mg/l. The consumption of water above the guideline is documented to have serious adverse health effects, especially for children.
- **Manganese (Mn):** the WHO has not set a guideline. However, beyond 0.4 mg/l, water can stain laundry; Mn causes undesirable taste to beverages posing some aesthetic problems and health discomfort.
- **Mercury (Hg)<sup>10</sup>:** the WHO recommended guideline is 0.006 mg/l. Water with high Hg content can be a sign of industrial contamination. The consumption of water above the guideline is documented to have serious adverse health effects, including poisoning and death.

<sup>7</sup> [https://www.who.int/water\\_sanitation\\_health/dwq/chemicals/beryllium\\_in\\_drinking2.pdf](https://www.who.int/water_sanitation_health/dwq/chemicals/beryllium_in_drinking2.pdf)

<sup>8</sup> [https://www.who.int/water\\_sanitation\\_health/dwq/boron.pdf](https://www.who.int/water_sanitation_health/dwq/boron.pdf)

<sup>9</sup> [https://www.who.int/water\\_sanitation\\_health/dwq/chemicals/chromium.pdf](https://www.who.int/water_sanitation_health/dwq/chemicals/chromium.pdf)

<sup>10</sup> [https://www.who.int/water\\_sanitation\\_health/dwq/chemicals/mercuryfinal.pdf](https://www.who.int/water_sanitation_health/dwq/chemicals/mercuryfinal.pdf)

- **Molybdenum (Mo)**<sup>11</sup>: the WHO recommended guideline is 0.07 mg/l. The long-term consumption of water above the guideline may cause adverse health effects.
- **Nickel (Ni)**<sup>12</sup>: the WHO recommended guideline is 0.07 mg/l. The long-term consumption of water above the guideline may cause adverse health effects.
- **Selenium (Se)**: the WHO recommended guideline is 0.04 mg/l. The long-term consumption of water above the guideline may cause adverse health effects.
- **Silver (Ag)**: the WHO has not set a guideline. Ag is rarely present, because it is naturally insoluble in water. Thus, health effects are difficult to determine.
- **Uranium (U)**: the WHO recommended limit is 0.03 mg/l. The consumption of water above the guideline has been documented to cause serious adverse health effects.
- **Zinc (Zn)**: the WHO has not set a guideline and no known adverse health effects are reported. Water with high Zn content may be associated with pipe corrosion or industrial contamination. High Zn content is associated with some aesthetic issues, but mostly the taste of drinking water.

#### I.4 Bacteriological and Viral Parameters

Bacteria and viruses are "indicators" that may cause diseases at higher concentration. More commonly-occurring ones are listed below.

- **Total Coliform**: bacteria naturally present in the environment and used as indicators that other possibly harmful bacteria may be present in drinking water.
- **E. coli and fecal coliform**: bacteria whose presence can indicate water contaminated by human or animal wastes, causing short-term health effects, and in some cases even death. Viruses, algae and protozoa may be present in groundwater but their occurrence is less frequent than those mentioned above.

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<sup>11</sup> [https://www.who.int/water\\_sanitation\\_health/dwq/chemicals/molybdenum.pdf](https://www.who.int/water_sanitation_health/dwq/chemicals/molybdenum.pdf)

<sup>12</sup> [https://www.who.int/water\\_sanitation\\_health/gdwqrevision/nickel2005.pdf](https://www.who.int/water_sanitation_health/gdwqrevision/nickel2005.pdf)

## APPENDIX II: WHO Guideline Values for Drinking Water Quality (4th Edition – 2017)

SOURCE	PARAMETER	SYMBOL	GUIDELINE (mg/l)		REMARKS
			HEALTH	AESTHETIC	
Naturally Occurring	Hydrogen Sulfide	H <sub>2</sub> S	-	0.05-0.1	Odour
	Chloride	Cl <sup>-</sup>	-	250	Taste
	Hardness		-	100–300	Taste, scaling
	Iron	Fe	-	0.3	Stain laundry
	Manganese	Mn	-	0.2	Stain laundry (0.4 mg/l-health)
	pH		-	6.5-8.5	Taste, metal dissolution
	Potassium	K	-	-	Taste
	Sodium	Na	-	200	Taste
	Sulfate	SO <sub>4</sub> <sup>2-</sup>	-	250	Taste
	TDS		-	600	Taste / scaling
	Zinc	Zn	-	4	Taste
	Color		-	15 TCU	Sight
	Turbidity		-	5 NTU	Sight, effective chlorination
	Aluminum	Al	0.9	0.1–0.2 mg/l	Health (deposits)
	Molybdenum	Mo	0.07	-	Health
	Arsenic	As	0.01	-	Health
	Barium	Ba	0.7	-	Health
	Boron	Bo	2.4	-	Health
	Chromium	Cr	0.05	-	Health
	Fluoride	F	1.5	-	Health
Selenium	Se	0.04	-	Health	
Uranium	U	0.03	-	Health	
Agriculture Industry	Beryllium	B	-	0.012	Health
	Cyanide	CN <sup>-</sup>	0.5	-	Health
	Cadmium	Cd	0.003	-	Health
	Mercury	Hg	0.006	-	Health

SOURCE	PARAMETER	SYMBOL	GUIDELINE (mg/l)		REMARKS
			HEALTH	AESTHETIC	
	Ammonia	NH <sub>3</sub>		1.5	Odour
	Nitrate	NO <sub>3</sub> <sup>-</sup>	50	-	Health
	Nitrite	NO <sub>2</sub> <sup>-</sup>	3	-	Health
Disinfectant	Silver	Ag	-	-	Health (no data)
	Chlorine	Cl	5	-	Health
Water Treatment	Copper	Cu	-	2	Staining
	Antimony	Sb	0.02	-	Health
	Lead	Pb	0.01	-	Health
	Nickel	Ni	0.07	-	Health

## APPENDIX III: Sampling Methods for Physico-Chemical and Bacteriological Testing

Parameters	Unit	Test Remarks	Methods
<b>Physical &amp; Chemical:</b>			
Color	Pt. Co scale	3	Colorimetric
Odour	Pt. Co scale	negative	Organoleptic
pH	Pt. Co scale	6.5	Electrometric, litmus paper
Taste	Pt. Co scale	normal	Organoleptic
Turbidity	NTU/FTU	1	Turbidity meter
Alkalinity	mg/l		Titration
Aluminum	mg/l	below 0.20	AAS/ICPMS
Copper	mg/l	below 0.03	AAS/ICPMS
Iron	mg/l	below 0.04	AAS/ICPMS
Manganese	mg/l	0.06	AAS/ICPMS
Sodium	mg/l	96.93	AAS/ICPMS
Zinc	mg/l	0.047	AAS/ICPMS
Chloride	mg/l	140.41	Argentometric/IC
Fluoride	mg/l	0.09	Colorimetric/IC
Nitrate	mg/l	below 0.11	Colorimetric/IC
Nitrite	mg/l	0.96	Colorimetric/IC
Sulfate	mg/l	below 0.94	Turbidimetric/IC
Arsenic	mg/l	below 0.001	AAS/ICPMS
Barium	mg/l	below 0.10	AAS/ICPMS
Cadmium	mg/l	below 0.005	AAS/ICPMS

Parameters	Unit	Test Remarks	Methods
Cyanide	mg/l	below 0.01	Colorimetric
Chromium (Hexavalent)	mg/l	below 0.006	Colorimetric
Lead	mg/l	below 0.01	AAS/ICPMS
Mercury	mg/l	below 0.001	AAS/ICPMS
Selenium	mg/l	below 0.007	AAS/ICPMS
Organic Matter by KMnO <sub>4</sub>	mg/l	3.06	Permanganantometric
Dissolved Solid	mg/l	43 l	Gravimetric
Hydrogen Sulfide	mg/l	below 0.01	Colorimetric
Total Hardness	mg CaCO <sub>3</sub>	95.49	AAS/IC
Total Bacteria	per ml	6.9 x 10 <sup>2</sup>	Pour Plate
Coliform	per 100 ml	nil	Filtration/Plate count
E. Coli	per 100 ml	nil	Filtration/Plate count
Salmonella	per 100 ml	negative	Filtration/Plate count

### **References & Links**

[https://www.who.int/water\\_sanitation\\_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/](https://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/)

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