



INTRODUCTION TO
DRINKING WATER QUALITY TESTING

Quality Control in Drinking Water Quality Testing





Goal 6 of the 2030 United Nations Development Programme (UNDP) Agenda for Sustainable Development aims to “ensure availability and sustainable management of water and sanitation for all” and includes targets for universal access to safe drinking water (Target 6.1). Despite some progress, the world is not on track to achieving target 6.1, and according to the WHO/UNICEF Joint Monitoring Programme for Water Supply report (JMP 2021), meeting this effort will require a quadrupling of current rates of progress in safely managed drinking water services.

Monitoring drinking water quality plays an important role in the effort to ensure availability of safe drinking water. CAWST (Centre for Affordable Water and Sanitation Technology) has developed introductory information and resources on eight key drinking water quality topic areas intended for water, sanitation and hygiene (WASH) practitioners in developing countries where there is limited access to resources:

- Sanitary Inspections
- Aspects of Drinking Water Quality
- Water Sampling
- Testing for Microbiological Aspects in Drinking Water
- Quality Control in Drinking Water Quality Testing
- Testing for Acceptability Aspects in Drinking Water
- Testing for Chemical Aspects in Drinking Water
- Interpreting and Reporting Drinking Water Quality Test Results

LEARNING AND TRAINING RESOURCES

This document is part of a collection of resources for learning and training about introductory drinking water quality testing. To access CAWST’s other water, sanitation and hygiene resources, visit cawst.org/resources.

**TECHNICAL BRIEF:
QUALITY CONTROL IN DRINKING WATER QUALITY TESTING**

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1 INTRODUCTION

Quality assurance and quality control (QA/QC) procedures are very important for water quality testing, especially when using field methods and testing for microorganisms. There exists the possibility of contamination in every step of the sampling and testing procedures. This brief provides you with useful information on how to ensure that your water quality testing produces reliable, accurate and precise results.

2 QUALITY ASSURANCE AND QUALITY CONTROL

The subject of quality assurance and quality control can be confusing. Different people may use different words to describe the same thing or the same word to describe different things. The following are some definitions of words that we use in this brief.

Quality assurance

Aims to prevent errors by focusing on the processes used for water quality testing. The objective is to have clear and concise documentation of all sampling and testing procedures that can be monitored to ensure quality is maintained. Quality assurance is a proactive process.

Quality control

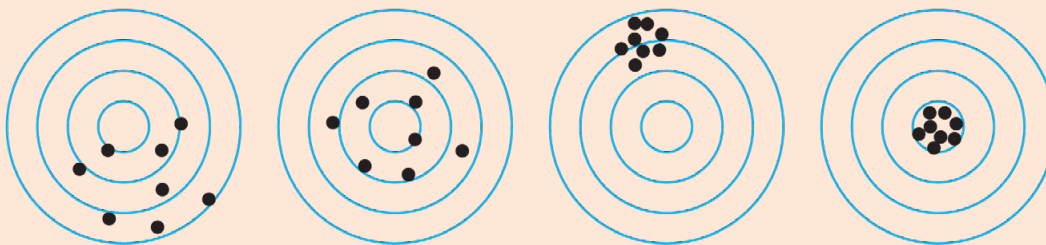
Aims to find and eliminate causes of quality problems by checking products and equipment. Quality control is a reactive process.

Accurate

How close a measured value is to the actual (true) value.

Precise

How close the measured values are to each other. Precision depends primarily upon the test equipment and method, but also on the technician and quality control procedures.



Not precise, not accurate

Not precise, more accurate

Precise, not accurate

Precise and accurate

Scientific research studies often explain the level of precision of water quality testing, including statistical analysis that was conducted on the results. Statistical analysis of test results is a complex subject and falls outside the scope of this brief. This section only presents a simplified discussion of the most important aspects of quality assurance and control.

When you carry out repeated tests many times on the same sample of water, you will rarely get the same results each time. Measurements and observations are always subject to some error. These errors can be caused by people, equipment, supplies, test methods and/or environmental conditions (e.g., humidity, light).

Regardless, if you are doing field or laboratory testing, a QA/QC system should be designed in the planning stage to help reduce errors. Your system will be simpler for field testing, but it should have a basic set of procedures necessary to remove or reduce errors.

A quality assurance system documents all water quality testing procedures to help ensure reliable results. In general, a quality assurance system should include the following elements:

- Management – staff organization, job descriptions and responsibilities
- Standard Operating Procedures – documents describing in detail all procedures for water quality testing, including sampling, transportation, analysis, use of equipment, quality control, calibration and report writing
- Training – for anyone taking water samples or conducting tests (e.g., Community Health Promoters, Water Quality Technicians)
- Equipment – maintenance and calibration
- Record keeping – sampling records and test results
- Clear reporting of results

A quality control system helps to find and eliminate causes of quality problems by checking products and equipment. The following checklist and sections provide further information about how to ensure the quality and reliability of your test results.

Checklist for Ensuring Quality Control

Items	Checks
Calculation and records	<ul style="list-style-type: none"> • Check math calculations for mistakes • Confirm that results have been recorded in the proper units and that any transfer of data from one record to another has been made correctly
Standard solutions	<ul style="list-style-type: none"> • Check the standard solutions used for calibrating equipment (old solutions may have deteriorated and errors may occur) • Check on storage conditions, the age of solutions and their expected shelf-life
Reagents	<ul style="list-style-type: none"> • Check whether old reagents have deteriorated • Check fresh reagents to ensure they have been properly prepared • Check the storage conditions of reagents, especially those that must be stored at specific temperatures or away from light • Check the expiry date of reagents and discard any that are outdated or have been improperly stored
Equipment	<ul style="list-style-type: none"> • Check calibration records and maintenance records for all equipment • Check and recalibrate equipment such as scales, incubators and digital meters • Check that equipment is being properly used

(Adapted from UNEP/WHO, 1996)

The following sections describe more specific actions you can do to help ensure quality control and reliable test results.

2.1 SELECTING EQUIPMENT AND PRODUCTS

There are several different types of equipment and products available in the commercial market for water quality testing. All have their own advantages and limitations. Some are easy to operate, but may lack in precision. Others are accurate, but may be difficult to read. Similarly some are unable to measure a small quantity of your water sample. Therefore, selecting the appropriate equipment and products is important to meet your testing objectives.

2.2 EQUIPMENT CALIBRATION

It is important to calibrate equipment according to the manufacturer's specifications to get good results. Most electronic equipment will require some sort of calibration. Commonly used water quality testing equipment that requires calibration include incubators, pH meters, turbidimeters, colorimeters and photometers. Manufacturers will give the instructions for calibration when you buy a piece of equipment.

2.3 QUALITY OF PRODUCTS

Most consumable products have a shelf life and should be used before they expire. Some need to be stored in a refrigerator, while others need to be kept in a cool and dry place. Follow the manufacturer's instructions to protect the life of the products and their effectiveness.

The reliability of the reagents and culture media used for microbiological testing is especially important. Large projects should monitor the quality of reagents and culture media on a regular basis. Whenever you need to order new products, it is a good idea to compare them with those currently in use. You may also want to test them with a known level of contamination to see if you get valid results.

You should check the following prior to using reagents and culture media:

- Expiry date
- Date manufactured
- Condition upon delivery
- Manufacturer's instructions for storage and use

2.4 UNEQUAL DISTRIBUTION OF MICROORGANISMS IN A WATER SAMPLE

One factor that can significantly affect microbiological test results is the uneven distribution of microorganisms in a water source and even within a water sample. This happens because microorganisms like to clump together and may also stick to the sides of your sample container.

It is not uncommon for independent tests performed from a single water sample, and using the same test method, to produce slightly different results. Test results are most variable when microorganisms are present in very low concentrations.



Note: Thoroughly shake any water sample for at least 10 seconds before testing to help ensure an even distribution of microorganisms throughout the water.

2.5 SECONDARY CONTAMINATION

Water samples need to be handled carefully to avoid secondary contamination. This is especially important for microbiological testing since unwanted microorganisms from your hair and skin, as well as from unclean work surfaces and equipment, can contaminate your water samples if you are not careful. Using aseptic techniques helps to prevent contact with microorganisms and eliminates secondary contamination. As well, using aseptic techniques helps to protect the environment and people who are doing the testing, ensures valid test results and can save time and resources by not having to repeat tests.

Basic sanitary methods to use when working with microorganisms include the following:

Personal Preparation (avoid contamination from bacteria on skin, hair and personal items)

- Tie back long hair
- Wash hands with soap and water and/or use hand sanitizer
- Cover cuts with waterproof plasters or bandages; or use disposable gloves
- Secure loose clothing and jewelry (e.g., neckties, flowing sleeves, necklaces)
- Wear personal protective equipment such as a lab coat and eye protection if possible
- Roll down sleeves and button up lab coat to protect normal clothes from accidental spills

Preparation of Work Space (avoid contamination from work surfaces and equipment)

- Choose a smooth, non-absorbent work bench for microbiological testing to prevent contamination if there is a spill
- If necessary, cover the work bench with heavy plastic
- Disinfect the work bench with commercial disinfectant (e.g., Dettol or Lysol) or alcohol (e.g., ethanol or isopropyl alcohol) before setting up
- Place testing implements (e.g., pipettes, forceps, media bottles, testing equipment) on clean paper towels and replace when spillage occurs
- Clean and sterilize testing equipment and sample containers (see instructions below)
- Minimize air flow in the testing area by not using fans and open windows since many contaminants are spread by dust particles that land on sterile surfaces

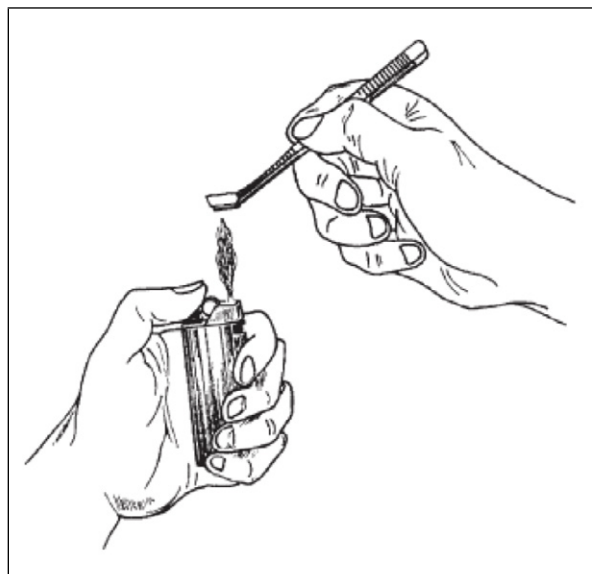
Sanitary Methods for Microbiological Testing (avoid contamination from careless handling and poor technique)

- Do not touch the inside of the membrane filter equipment
- Do not touch the inside of sample containers, Petri dishes, lids or caps

- Do not have food or drinks in the testing area
- Do not leave Petri dishes open when they are not being used
- Use a butane or propane flame to sterilize forceps between uses
- Cover your nose and mouth when sneezing or coughing
- Test the least contaminated samples first (e.g., test filtered water first, then storage water and finally, source water)
- Test blank samples to detect secondary contamination (one for every 10-20 samples)
- Do not use fingers or objects to aid in bacterial colony counting (especially objects that are used for other purposes such as pens or pencils)
- Clean and disinfect the workspace before moving to a different task
- Dispose of waste properly
- Clean and disinfect equipment before storing
- Store testing equipment in a clean and secure place

All reusable equipment must be cleaned and sterilized thoroughly before each use to avoid secondary contamination and ensure good results. Manufacturers usually include instructions on how to sterilize their equipment. Some methods for sterilizing equipment are:

- **Flaming:** The flame from a cigarette lighter, for example, can be used to sterilize forceps used for holding filter paper. It must be a butane or propane gas lighter, not matches or a lighter that uses gasoline or similar liquid fuel, which would blacken the forceps and leave a residue.



Sterilizing forceps using a cigarette lighter

(WHO, 2007)

- Sterilizing forceps using a cigarette lighter (WHO, 2007)
- Formaldehyde: This gas is a powerful bactericide. It is generated by the combustion of methanol (but no other alcohol) in a closed space where oxygen becomes depleted. In the field, this is a convenient way to disinfect the membrane filtration equipment between uses. Manufacturers usually include instructions on how to sterilize their membrane filtration equipment using this method.
- Conventional oven: Heat at 180°C for 30 minutes (WHO, 2012)
- Boiling: Boil for 10 minutes (CDC, 2010 and WHO, 2012)
- Autoclave: Heat at 121°C for 20 minutes (WHO, 1997)
- Pressure cooker: Heat for at least 30 minutes (WHO, 1997)

Never use bleach, chlorine or disinfectants on equipment that may leave a residue without properly rinsing (with distilled water) or boiling the equipment afterwards. The residue may affect your results by inhibiting or killing the bacteria you are trying to test for.

2.6 DUPLICATE SAMPLES

Duplicate samples are independent samples taken from the same location at approximately the same time. There is normal variability in the microbiological concentration between one sample and the next from the same water source. By taking duplicate samples, you can check the reliability of your testing procedures and average two samples to get more accurate results.

Ideally, all water samples should be duplicated, but this can be expensive and is not feasible for most projects. Depending on your resources, you should try to duplicate at least 10% of your samples (CDC, 2010).

Example of duplicate sampling at 10%

A rate of 10% duplicate samples means you need to duplicate one in every 10 samples. So, if you plan to test 50 samples of water, you will need to take a duplicate sample of sample number 10, 20, 30, 40 and 50. So you will end up with five more samples to test. It is important that you collect the duplicate in a different container, as this will help identify possible errors in sample collection.

2.7 CONTROLS: BLANK SAMPLES AND TRUE POSITIVES

Blank samples help with quality control to make sure there is no secondary contamination. You test the blank the same as your field samples, but use clear boiled water for microbiological testing and deionized or distilled water for physical or chemical testing. If the blank sample shows any results

from the test, then you know there was secondary contamination during your sampling and testing procedure. One blank sample should be completed for every 10-20 samples (CDC, 2010).

A true positive sample is the opposite of a blank sample. You use (or create) a sample that you are certain has fecal contamination. A long stick in a pit latrine or any other method should help you create the sample (1 gram of feces contains billions of coliform bacteria). Be careful not to cross-contaminate your other samples with this highly contaminated sample. Make sure to filter this sample last. If no growth occurs in this sample, then there may be a problem with your culture media or incubator.

3 HEALTH AND SAFETY

It is important to work safely and avoid injuries while carrying out water quality testing. Water quality testing staff may come across a range of hazards in the course of their work. For example, water sources may be highly contaminated with feces or chemicals, access to sampling stations may involve crossing dangerous terrain, and wading in streams carries the possibility of slipping. Field staff should be trained to recognize and deal with as many hazards as possible that they are likely to encounter (UNEP/WHO, 1996).

It is the responsibility of the project implementer to provide training to anyone involved in water sampling and testing. As a minimum, training should include water safety and first aid. In addition, project staff should understand any special hazards and risks associated with handling specific chemicals (such as arsenic and methanol) and follow the safety precautions.

It is also the responsibility of the project implementer to provide safety equipment, but it is the responsibility of each individual to use the equipment properly and to request equipment if it is not available. Safety equipment such as fire extinguishers, safety glasses, gloves and first-aid kits should be suitably located and readily available. Safety equipment should be routinely checked and all staff should be trained in their use. It is also important to make sure everyone knows who to call in an emergency.

During water sampling, a basic first-aid kit should be carried at all times and should not be left in the transport vehicle if staff need to move far away from it. Where there is a risk of infection from contact with water (as in the case of schistosomiasis, for example), suitable protective clothing, such as rubber gloves, should be provided and used by staff (UNEP/WHO, 1996).

Samples and any waste generated during testing may contain pathogens or chemicals that may be harmful to health and must be properly and safely disposed.



Make sure everyone knows where the FIRST AID KIT is located.

At the very least, the kit should contain bandages, gauze and disinfectants.



Make sure everyone knows WHO TO CALL in an emergency.

4 KEY POINTS

- There is an inherent variability associated with all analytical techniques. Therefore, the result of a single water quality test is only a best estimate or approximation of the true value of what is being measured.
- Regardless, if you are conducting portable or laboratory testing, a quality assurance and quality control system should be designed to help reduce errors.
- It is not uncommon for independent tests performed from a single water sample, and using the same test method, to produce slightly different results. Test results are most variable when microorganisms are present in very low concentrations.
- It is the responsibility of the project implementer to provide safety equipment and training to anyone involved in water sampling and testing.

5 GLOSSARY

Aseptic technique	Techniques and practices that prevent contact with microorganisms.
Bacteria	Single-celled microorganisms, typically a few micrometres (µm) in length. They can live in water, soil, in animals and on plants. Bacteria are usually too small to see with the human eye.
Community water supply	The management and administration of the water supply usually handled by the local community. Community water supplies may include simple piped water systems, boreholes with mechanized or hand pumps, dug wells and protected springs.
Contamination	Pollution of water due to human or natural causes.
Deionized water	Deionization is a chemical process that removes the minerals from water. However, deionization does not significantly remove pathogens (e.g., viruses, bacteria).
Disinfection	A process that removes, deactivates, or kills pathogens in water or on surfaces. Disinfection is less lethal than sterilization because it destroys most pathogens, but not necessarily all of them (e.g., bacterial spores).
Distilled water	Water that has many of its chemical, physical and microbiological impurities (e.g., minerals, turbidity, pathogens) removed through distillation. Distillation involves boiling the water and then condensing the steam into a clean container, thus leaving all of the impurities behind.
Equipment	The permanent hardware that is usually purchased one time for water quality testing (e.g., incubator, scale, digital meters).
Fecal bacteria	Bacteria found in the feces of humans or warm-blooded animals. Their presence in water indicates fecal contamination and the possible presence of pathogens.
Microbiological contamination	Pathogens in water that can make you sick. Microbiological contamination can come from human and animal feces, garbage, or from the environment.
Microorganism	A tiny living thing, including protozoa, bacteria and viruses. Most are too small to see with the human eye. Microorganisms, also called microbes, can live in water, soil, in animals or on plants.

Pathogen	Any living microorganism that causes disease. Pathogens commonly found in drinking water include bacteria, viruses, protozoa and helminths.
Precision	How close the measured values are to each other.
Protozoa	Multi-celled microorganisms, often with a hard shell. Protozoa can live in water, soil, in animals and on plants. They are very small, but some protozoa can be seen with the human eye.
Quality assurance	Aims to prevent errors with a focus on the process. It is a proactive quality process.
Quality control	Aims to identify errors in the finished product. It is a reactive process.
Reagent	A chemical or biological substance that is needed to do a particular water quality test. A reagent can be used to detect or measure a contaminant or prepare a product like culture media.
Risk	The likelihood of a hazard causing harm to exposed populations in a specific time frame and the magnitude and/or consequences of that harm.
Shelf life	The length of time that something may be stored and still be good to use before the expiration date.
Standard solutions	A standard solution is any chemical solution that has a precisely known concentration. They are often used when calibrating equipment.
Sterilize	To kill all microorganisms – whether pathogenic or not – and their spores present on a surface or object. Sterilization is more lethal than disinfection.
Virus	Single-celled microorganisms. A virus can live in water, soil, in animals and on plants. Viruses are too small to see with the human eye.

6 ADDITIONAL RESOURCES

CAWST: Wash Resources: Aseptic Practices for Water Sample Collection: Available at: <https://washresources.cawst.org/en/resources/76682d73/aseptic-practices-for-water-sample-collection>

An eLearning module about best practices and sanitary methods that limit errors and prevent secondary or cross contamination when collecting water samples for testing.

7 REFERENCES

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CAWST, the Centre for Affordable Water and Sanitation Technology, is a nonprofit organization that provides training and consulting to organizations working directly with populations in low and middle income countries who lack access to clean water and basic sanitation.

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