

USAID AFRICA BUREAU

WATER QUALITY ASSURANCE PLAN (WQAP): GUIDANCE NOTE

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# Contents

This Water Quality Assurance Plan (WQAP) guidance note will facilitate the completion of WQAPs prior to implementation of USAID-funded water projects. In order to develop a high quality WQAP, please read the WQAP guidance note, which provides instructions, and example language, during completion of the [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx).

[Water Quality Assurance Plan Guidance Note](#_Water_Quality_Assurance)

[Water Quality Assurance Plan Africa BureauTemplate](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx)

USAID/Africa Bureau

# Water Quality Assurance Plan Guidance Note

25 April 2018

**DISCLAIMER**

The authors’ views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the U. S. Government.

# Introduction:

USAID’s Water and Development Implementation Plan (2018-2022) emphasizes providing safe drinking water as part of U.S. Government international policy and practice.

*“Achieving safely managed water services requires an increased emphasis on water quality at the point of supply, as well as the reliability of services and the sustainability of raw water supplies. Ultimately, a sustained high level of water quality is the responsibility of the local service provider and regulator. USAID will work with these entities to develop, test, and scale up water quality testing and water quality improvement programs, leveraging private sector capacity when feasible.”*

The United Nations Sustainable Development Goal 6 (SDG-6) for water and sanitation emphasizes sustainable access to safely managed drinking water supply. To track progress toward achieving SDG 6 the Joint Monitoring Program (JMP) implemented by the World Health Organization (WHO) and UNICEF has developed a classification system ([Drinking Water Ladder](https://washdata.org/monitoring/drinking-water)) that classifies drinking water sources into five categories (surface water, unimproved, limited, basic and safely managed). According to this system, the 2015 JMP baseline estimates that 57% of the rural population in Sub-Saharan Africa (SSA) does not have access to a basic water source (an improve water source with a collection time of 30 minutes or less), and over 40% of the rural population relied upon an unimproved drinking water source (i.e. surface water source or an open well that is exposed to environmental contamination); while a meta-analysis of improved water sources, water supply systems that by design have the potential to deliver safe drinking water, found that 38% of these water sources in low to middle income countries had fecal contamination.[[1]](#footnote-2) This data implies that the majority of the rural population in SSA (both communities relaying on open water sources and those with access to an improved source) could be routinely exposed to fecal contamination through drinking water supplies.

In light of these challenges, improving drinking water quality remains a long term development challenge that requires systematic improvements that gradually move communities up the drinking water ladder. USAID’s policy and programmatic commitment, as outlined in the USAID Water and Development Implementation Plan, is to increase access to safely managed drinking water sources that meet basic water quality standards. The WQAP Guidance Note is a tool intended to help USAID move in that direction, while serving as a minimum recommended standard for water supply projects.

As an important step to improving drinking water quality, the Africa Bureau recommends that new Initial Environmental Examinations (IEEs) for drinking water provisioning activities within the region require Implementing Partners (IPs) to develop, implement, and report on a WQAP. The WQAP is a tool designed for monitoring water quality in small scale drinking water systems primarily in rural settings. The WQAP may not be the best tool or may be inadequate for managing water quality risks associated with large scale activities in urban settings, other tools, including water safety plans or environmental assessments, may be better suited to meet challenges in such systems. Within the environmental regulatory framework, the WQAP will be Africa Bureau recommended approach to meet the water quality monitoring conditions of water supply projects, where the IEE resulted in a negative determination with conditions. The WQAP is not presently in use by other regions outside the Africa Bureau, and this guidance note is therefore only applicable to IPs working on drinking water provision within the region. The WQAP should be considered as supplemental to the Environmental Mitigation and Monitoring Plan (EMMP). The EMMP will continue to be necessary to address the siting, construction, maintenance and operation of water supply activities, as well as the many associated WASH activities. Within the WQAP and EMMP framework the IP is free to propose additional measures or tools that may be better suited to reduce water quality risks within the local context.

See [Annex 5](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_5_Suggested_Language.docx) for example IEE language requiring the WQAP and [Annex 6](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_6_Illustrative_Procurement_Language.docx) for example procurement language for the WQAP. Both annexes can be accessed here: <http://www.usaidgems.org/wqap.htm>.

The goal of the WQAP is to provide a framework by which the quality of the drinking water supply is improved or maintained by:

1. Identifying potential water quality issues,
2. Implementing, in advance, practical measures to prevent adverse impacts, and,
3. Responding to these issues by implementing corrective measures in accordance with well-developed procedures.

Through a WQAP, IPs will meet minimum water testing requirements within the USAID environmental compliance framework, reduce risks associated with contaminated drinking water during the life of the project, and ensure that the project meets applicable partner-country water quality guidelines given project implementation conditions.

This WQAP guidance note, with the associated [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx), will facilitate the completion of WQAPs by USAID IPs prior to the implementation of USAID-funded water activities. This package, including the WQAP guidance note and the [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx), provides instructions, and example language for developing high quality WQAPs.

Implementation of the WQAP is just one element of the larger framework of the sustainable development of safe drinking water supplies in USAID partner countries. The focus of the WQAP on compliance with regulatory standards (22 CFR 216 and host country regulations) at the initial commissioning phase of the drinking water project is critical; however, over the long term, the WQAP should be integrated into a risk based framework of continuous improvement such as the [Water Safety Plan (WSP)](http://www.who.int/water_sanitation_health/water-quality/safety-planning/en/) approach promoted by the World Health Organization (WHO).

This current version of the WQAP Guidance Note was written and intended specifically for Africa Bureau programming to assist in WQAP development.

# Implementation: Additional Resources

Overview: [This template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx) and [example WQAP](http://gemini.info.usaid.gov/repository/internal/39306-2461.pdf) are provided on the GEMS website, and should be used by IPs to become familiar with the application of WQAPs to USAID water provisioning projects. Developing a WQAP may require consulting additional resources, some of which are listed below.

WASH Sector Environmental Guideline: The Water Supply, Sanitation, and Hygiene (WASH) Sector Environmental Guideline (SEG) provides a broad overview of the types of WASH projects typically funded by USAID, with a particular focus on environmental and social impacts, mitigation measures, and environmentally sound design and management (ESDM) best practice for those activities. The SEG is intended to support ESDM of these activities, regardless of the specific environmental requirements or regulations that apply, if any. However, the *WASH Sector Environmental Guideline* document directly supports environmental compliance by providing: information essential to assessing the potential impacts of activities, and to the identification and detailed design of appropriate mitigation and monitoring measures. Thus the document is intended to help USAID Missions comply with Section 117 of the Foreign Assistance Act (FAA) and Regulation 216, which require that environmental impact assessments be conducted and appropriate measures be implemented to mitigate environmental and social impacts for all USAID projects, to help USAID partners and staff design WASH activities that minimize vulnerability to climate change, and maximize the potential for USAID WASH projects to improve human well-being and health.

[Water Safety Planning for Small Community Water Supplies (WHO 2012a):](http://apps.who.int/iris/bitstream/10665/75145/1/9789241548427_eng.pdf) In this guidance document, pp. 27-42, the WHO describes the process by which a water quality monitoring plan should be developed. This guidance makes a distinction between operational and verification monitoring. Operational monitoring is often completed on a frequent basis (e.g., daily) by the person responsible for O&M of the facility, and includes monitoring of system components in addition to water quality testing. If the monitored parameter does not fall within the proper range, then an action is required by the operator to correct the issue. Verification monitoring on the other hand includes compliance monitoring, auditing and checking consumer satisfaction. Compliance monitoring in the WSP process is similar to the process described in this WQAP. The WHO document can thus be useful to consult, both for perspectives on operational monitoring and responses to exceedances, for compliance monitoring guidelines, and for guidance on overall risk management approaches to drinking water quality.

[Guidelines for Drinking-Water Quality, Fourth Edition (WHO, 2017):](http://apps.who.int/iris/bitstream/10665/75145/1/9789241548427_eng.pdf) The [WHO guidelines](http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/) provide recommendations for managing water quality risks and builds upon the foundation laid in three prior versions of the guidelines. The WHO has provided and published international standards for drinking water since 1958, which have often been adapted or incorporated directly into drinking water regulations in developing countries globally.

# Overview: Key Elements of The WQAP process

The WQAP process typically includes three key elements:

1. Research and Analysis
2. Documentation
3. Implementation

**Research and Analysis:** Developing a WQAP requires completing research on: (1) the regulatory context (including the applicable international guidance and host country regulatory requirements), (2) the available resources and capacity of your technical team and host country laboratories to collect, transport and analyze water quality samples, and (3) prevalent water quality issues and potential sources of contamination identified within the community and surrounding area. Understanding the regulatory context, the host country water quality monitoring system and capacity, and potential risks to water quality will enable the IP to identify and select critical parameters of concern, establish guideline values, and delineate corrective actions that will be taken if water quality contaminant levels are exceeded.

**Documentation:** A WQAP must include thorough documentation of the research and analysis steps above. This documentation ensures that the stakeholders and implementers have a clear understanding of the requirements for implementation of the WQAP. This documentation includes describing in detail the international (e.g. World Health Organization [WHO]) and host country water quality requirements and guidelines for drinking water that are applicable to the project. In addition, documentation includes a detailed inventory of the resources and capacity of the implementing team to identify and resolve potential gaps to ensure proper implementation.

**Implementation:** The above actions support correct and complete implementation of the WQAP. Implementation includes engagement and handover to the community or local authorities to ensure that water quality monitoring continues after the life of the project.

This WQAP guidance note and [template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx) provides the IP with instructions and additional resources to help create a quality WQAP. The WQAP guidance note instructions are structured to match the sections of the WQAP [template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx):

* 1. Introduction;
	2. Assessment of Applicable Water Quality Standards and Criteria;
	3. Resources for Sample Collection and Laboratory Analysis;
	4. Sustainability and Operational Factors Affecting Water Quality; and,
	5. Corrective Measures.

**Annexes**: The following annexes can be found in the WQAP section of the GEMS website: <http://www.usaidgems.org/wqap.htm>

Annexes 1 and 2 are critical supplemental documents to the WQAP:

* [Annex 1: WQAP Record and Compliance Template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_1_WQAP_Record_of_Compliance_Template.docx)
* [Annex 2: Investigation of Potential Sources of Contamination](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_2_Investigation_of_Potential_Sources_of_Contamination.docx)

Annexes 3 through 7 are supporting documents for the completion of the WQAP or for addressing water quality concerns more generally:

* [Annex 3: Suggested Approaches for Resolution of Water Quality Contamination](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_3_Approach_to_Resolution.docx)
* [Annex 4: Standard Text for Description of WHO Guidance for Section II, 3.](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_4_Standard_Text.docx)
* [Annex 5: Suggested IEE Language on Water Quality Monitoring](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_5_Suggested_Language.docx)
* [Annex 6: Illustrative Procurement Language on Drinking Water Quality](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_6_Illustrative_Procurement_Language.docx)
* [Annex 7: Standard Operating Procedures for Field Measurements and Sample Collection](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_8_Example_Water_System.docx)

# WQAP Guidance Note Contents

[WQAP Guidance Note Contents vi](#_Toc511820716)

[Guidance Note: Step by Step Instructions for Developing the WQAP 1](#_Toc511820717)

[I: WQAP Introduction 1](#_Toc511820718)

[II: Assess Potential Parameters of concern and Applicable Water Quality Standards 1](#_Toc511820719)

[III: Assess and Document Resources for Sample Collection and Laboratory Analysis 8](#_Toc511820720)

[IV: assess and document Implementation of the Water Quality Assurance Plan 13](#_Toc511820721)

[V: Assess and document Corrective Measures 14](#_Toc511820722)

[References: 16](#_Toc511820723)

# Guidance Note: Step by Step Instructions for Developing the WQAP

## I: WQAP Introduction

In the introduction, the IP should describe the characteristics of the drinking water provisioning program so that the WQAP can be properly developed and implemented. The introduction should be approximately one page in length, and should contain the following descriptions:

**Paragraph 1:** Describe the existing water system(s) or typical water system(s) being constructed or rehabilitated, current issues and needs. Include the setting (urban, peri-urban or rural) of the service area, the size and density of the population(s) served, the condition (i.e., water quality) of the source water, and setting of the catchment/watershed (if different from the service area).

**Paragraph 2**: Describe the key characteristics of the project and the number and type of components of the proposed drinking water systems.

**Paragraph 3**: List key assumptions regarding the WQAP process.

**Paragraph 4**: Describe potential issues or barriers to implementing the project/program and strategies to overcome these barriers. Examples may include lack of trained technicians or certified laboratories, or a limited budget for monitoring.

**Paragraph 5**: Describe the general organization of this document, its intended purpose and audience.

## II: Assess Potential Parameters of concern and Applicable Water Quality Standards

In the second step of the WQAP process, the IP should complete an assessment of the applicable water quality parameters, guideline values or standards, and the criteria and analysis used for selecting them for monitoring in the project. This assessment includes three parts; (1) research on the relevant local and international regulatory requirements and guidelines, and local parameters of concern for the particular water system and location, and (2) selection of the most appropriate water quality parameters, guideline values, standards and criteria for monitoring, based on the specific conditions of the project.

### A) Research Regulatory Requirements and potential contaminants of concern

In order to select the appropriate parameters and standards for assessing water quality, the IP must conduct research on the regulatory framework for the specific drinking water provisioning project. The regulatory framework will necessarily include USAID guidance in the [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx), international standards and guidance (e.g., WHO guidance values) and host country requirements and regulations.

The IP should document the research for each set of regulations and guidance from USAID, the host country, and the WHO. The [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx) provides example descriptions for USAID recommended water quality parameters, which should be adapted to the project’s site-specific conditions.

A site sanitary inspection or survey should yield data on site-specific issues. Sanitary inspections should be performed prior to installation of the water provisioning system and at regular intervals throughout the life of the project to ensure that potential sources of contamination are identified and are minimized or eliminated. The initial sanitary survey prior serves to identify the potential contaminants of concern in the raw source water, in addition to identifying sources to be removed or minimized.

[Annex 2](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_2_Investigation_of_Potential_Sources_of_Contamination.docx) of the [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx) includes an example sanitary survey checklist for borehole projects. (Annex 2 can be found here at: <http://www.usaidgems.org/wqap.htm>) (Additional guidance for surveys for surface water, and spring water projects, amongst others, is provided in the WHO Fact Sheet 2.1, entitled “Sanitary Inspections,” available online at: <http://www.who.int/water_sanitation_health/sanitation-waste/fs2_1.pdf?ua=1>)

Additional parameters should be identified by completing a desktop study of existing land use within the source water catchment, by performing a source water assessment based on field surveys, by consulting community stakeholders and the review of water quality measurements taken from nearby drinking water sources, by performing a sanitary survey, or by performing an assessment using a combination of these methods. The methodology depends on the scale of the drinking water system and the needs of the beneficiaries.

Additional water quality parameters should be included in the WQAP based on nearby domestic, commercial, industrial, or agricultural activities and facilities in the region. The implementing partner should therefore consult with the local community and host government officials to determine what livelihood activities are present in the area, and if any special considerations should be given to specific potential contaminants. Historical water quality issues affecting surrounding communities should also be investigated to determine if there are naturally occurring contaminants of concern prevalent in the region. This research is then documented and used to justify the selection of water quality parameters included in the WQAP.

#### USAID Recommended Water Quality Parameters

In this section, the IP should include the eight key drinking water quality parameters recommended by USAID for the general assessment of water quality. Additional water quality parameters should be included based on site-specific considerations or issues and the IPs research on local potential natural sources of contaminants. The eight parameters and associated guidance values are based on USAID staff experience and a review of USEPA and WHO guidance documents.

The USAID-recommended eight key drinking water quality parameters consist of four health related parameters -- arsenic, fecal coliform, fluoride and nitrate -- and four operational parameters -- electro-conductivity, total dissolved solids (TDS), pH, and turbidity. The four health-related parameters were selected based on prevalence globally, potential for contaminating drinking water sources, and severity of illness as a result of exposure. The four operational parameters were selected based on ease of measurement, the potential to indicate the presence of other health related contaminants in a given water sample, and the potential to identify needed adjustments to water treatment procedures based on the measured values. The IP should consider these eight key parameters as a minimum, best practice, and should include other parameters based on site-specific or regional considerations. A broader range of chemical and biological contaminants and/or more frequent measurements might be considered if the scale of the intervention serves a larger community or population, as in the case of piped water distribution networks.

#### A justification for including each of the eight drinking water contaminants is outlined in the Table 1 below.

|  |
| --- |
| Table 1. Justification for key drinking water quality parameters |
| Water quality parameter | Justification for inclusion  |
|  |  |
| Arsenic (As) | Arsenic is a naturally-occurring metalloid found in many parts of the world. Consumption of arsenic at high concentrations can lead to death, while long-term exposure at lower concentrations through drinking water sources can lead to a severe chronic illness called arsenicosis. Long-term exposure can result in thickening of the skin, darker skin, abdominal pain, diarrhea, heart disease, numbness and cancer. Following the discovery of several cases of arsenicosis as a result of USAID-funded water supply programs in the 1990’s, the Agency now requires the testing of arsenic in all water supply programs.  |
| Fecal coliform | According to the WHO, the greatest risk to human health associated with drinking water is contamination by animal and human waste, which can lead to outbreaks of waterborne diseases. Therefore, the ‘first priority in developing and applying controls on drinking-water quality should be the control of such outbreaks.’ In general, the WHO has determined that the risk of contamination of water supplies with pathogens, particularly if they are from excreta, is far greater than the risk associated with chemical contamination. Fecal coliform, specifically Escherichia coli (E. coli), is a waterborne pathogen commonly linked to diarrheal disease, and is associated with both human and animal waste. The WHO estimates that diarrheal disease causes 1.5 million deaths annually, affecting mainly children in developing countries. Approximately 58% of these deaths are attributable to unsafe water supply, sanitation and hygiene. Other diseases that can be transmitted by microbial-contaminated water include typhoid fever, cholera, salmonellosis, dysentery, and botulism, as well as viral diseases including SARS, Hepatitis A, and Polio.  |
| Fluoride (F-) | Fluoride is a naturally-occurring anion of fluorine which occurs in minerals and fluoride salts. In small quantities, fluoride can be helpful to human health and protect from tooth decay. However, in higher concentrations (above several parts per million), fluorides can cause pitting of teeth and skeletal problems including crippling fluorosis, anemia and stiff joints. Heavy concentrations of fluoride can be found naturally throughout northern Africa, the Middle East and central Asia. |
| Nitrate (NO3-) | Nitrate (NO3-) is an inorganic compound that is both produced synthetically and occurs naturally. Although nitrate does occur naturally in surface and groundwater, high levels of nitrate contamination in drinking water is most often due to improper treatment of animal wastes, leaching of septic or wastewater systems into drinking water sources, and excess fertilizer application with its subsequent infiltration or runoff into source waters. The consumption of high concentrations of nitrate (greater than 50 mg/L of NO3-) and the subsequent reduction of nitrate to nitrite (NO2-) can lead to methemoglobinemia in infants. The presence of nitrite in the blood converts hemoglobin to methemoglobin, which cannot carry oxygen, and can lead to brain damage or death at high enough concentrations. This process is often complicated by the presence of microbial contamination and subsequent gastrointestinal infection.  |
|  |  |
| Electro-conductivity | Conductivity is a measure of the ability of water to pass an electric current, and is influenced primarily by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Healthy freshwater systems have a range of 150 and 500 µhos/cm (microsiemens per centimeter), but the value may vary greatly depending on the geology and mineral deposits. Sharp changes to electro-conductivity from baseline condition can indicate an influx of wastewater from industrial or agricultural activity. For this reason elevated electro-conductivity values may indicate the need for additional testing.  |
| Total Dissolves Solids (TDS) | TDS is closely related to conductivity and is a measure of all ion particles that are smaller than 2 microns (0.0002 cm). Thus TDS is a close approximation of salinity (although dissolved organic matter and other compounds may be included in the TDS measurement). High TDS can also indicate high alkalinity or hardness. Sharp changes in TDS indicate changes to the overall water quality. Water hardness can influence the effectiveness of water treatment, and thus is useful to monitor in order to inform effective water treatment. |
| pH | pH is a measure of the balance between hydrogen ions (H+) and hydroxide ions (OH -), with a pH of 7.0 being neutral. Surface water sources normally range from a pH of 6.5 to 8.5, while groundwater sources can range from 6 to 8.5. In general, water with higher acidity (pH < 6.5) could be corrosive and contribute to elevated levels of metals (iron, manganese, copper, lead, and zinc) as a result of leaching from the aquifer substrate, plumbing fixtures, and piping. Waters with higher alkalinity (pH > 8.5) indicate hardness (high concentration of dissolved minerals, particularly calcium and magnesium) and could contribute to mineral deposits along the water supply network. Although hardness is not a health concern, it can be distasteful.  |
| Turbidity | Turbidity is a measure of the clarity or cloudiness of water and could be caused by silt, sand, mud, chemical precipitates, algae, bacteria, and other microscopic organisms. Turbidity is easy to measure and can be an indicator of contaminant loading. Further testing will be required to determine specific contaminant loading.  |

Other potential water contaminants of concern include heavy metals including iron, cadmium, mercury, lead, and chromium as well as pesticides and industrial chemicals, all of which can be found in drinking water sources, and can lead to a variety of health risks. Heavy metals are often present in drinking water sources as a result of mining operations or other industrial activities, while agricultural chemicals can be transported in runoff in rural areas or infiltrate into groundwater sources. USAID recommends an investigation of potential sources of contamination at each project site, in order to determine the relative risks and identify contaminants that should be monitored during the project implementation phase.

#### Host Country Regulatory Requirements

In this section the IP reviews and describes the host country’s regulatory requirements. The usefulness of any regulatory requirements in protecting human health depends on the capacity and transparency of the host country environmental and water resources regulatory program. Typically, the host country will provide a definition of “potable” water in a descriptive narrative or as a water quality profile (e.g. list of limits for certain water quality parameters). The regulations may also include water quality limits by water use category (e.g. industrial or agricultural uses) and scale (e.g. population served). It is critical that the IP understand which regulations apply to their specific conditions. Consultation with the relevant host country regulatory agency is recommended to ensure that the applicable water quality requirements are understood and described here. The narrative in this section should include the list of regulations reviewed, their relevance to planned project activities, and the specific water quality parameters and standards evaluated. From these relevant water quality regulations, the IP will select the applicable water quality standards and criteria listed in Section B, and included in Tables II-A and II-B.

**Resources:**

* Guidance on the water sector regulatory framework in developing countries (in English) can be found on the Rural Water Supply Network (RWSN) internet platform which includes regulatory information for countries in sub-Saharan Africa (e.g. Chad, Ethiopia, Ghana, Uganda, Zambia), the Commonwealth of Independent States (e.g. Moldova and Ukraine), and Latin America (e.g., Bolivia, Columbia, Honduras, Nicaragua). The resource is available at: <http://www.rural-water-supply.net/en/region-and-countries>
* Guidance on the water sector regulatory framework for developing countries (in French) can be found on the Programme Solidarité Eau (PS-Eau) internet platform which includes regulatory information for Benin, Burkina Faso, Cambodia, Haiti, Lebanon, Madagascar, Mali, Morocco, Mauritania, Niger, West Bank and Gaza, and other countries. This is available at: <http://www.pseau.org/fr/pays>
* EPA Quick Reference Guides on Drinking Water Rules: Available online at: <https://www.epa.gov/dwreginfo/drinking-water-rule-quick-reference-guides>.
* USEPA National Primary Drinking Water Regulations: available online at: <https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants#Inorganic>

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#### WHO Guidance

The WHO provides some of the most comprehensive information about drinking water quality that is available and relevant in the development context. The WHO drinking water quality guidelines were updated in 2017, and are used in many countries worldwide as the basis for drinking water quality regulations. The IP should thus review the WHO drinking water quality guidelines to inform the evaluation and selection of drinking water parameters and associated guideline values to be incorporated into the WQAP. Illustrative language, describing the WHO regulations on USAID’s eight key quality parameters, is included in Annex 4 of this guidance note. (Please see Annex 4 at: <http://www.usaidgems.org/wqap.htm>.) This illustrative language can be used by the IP as a basis for writing this section. The selection of the relevant water quality parameters should be carefully evaluated in consultation with local and USAID staff that have expertise in drinking water quality and knowledge of the local context.

**Resources:**

* WHO. 2017. Guidelines for Drinking-Water Quality. Fourth Edition Including the First Addendum. Available online at: <http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/>.
* WHO. 2016. Nitrate and Nitrite in Drinking-Water. Available online at: <http://www.who.int/water_sanitation_health/dwq/chemicals/nitrate-nitrite-background-jan17.pdf?ua=1>.
* WHO. 2011. Arsenic in Drinking-Water. Available online at: <http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/arsenic.pdf?ua=1>.
* WHO. 2007. pH in Drinking-Water. Available online at: <http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/ph_revised_2007_clean_version.pdf?ua=1>.
* WHO. 2004. Fluoride in Drinking-Water. Available online at: <http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/Fluoride_in_drinking_water_3.pdf?ua=1>
* WHO. 1996. Total Dissolved Solids in Drinking Water. Available online at: <http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/tds.pdf?ua=1>

### B) INVENTORY of Selected Water Quality ParAmeters, Standards and Criteria used for selection

The IP must document, in narrative form, and in Tables II-A and II-B included in the [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx), the water quality parameters to be monitored, the frequency of monitoring, the applicable guideline values or standards the project will follow, and the criteria used to select these parameters and standards (this should link directly to the research completed in Section A above). The [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx) includes an introductory narrative describing the selected drinking water quality standards and summary tables for human health-related (Table II-A) and operational-related parameters of concern (Table II-B). The IP must modify this illustrative language and each tabular summary of the water quality standards based on the site-specific conditions of the project, by (1) including any additional applicable host country and WHO water quality standards or guideline values, and (2) complying with the host country required limits and collection frequency for each parameter.

The determination of the sample frequency for a given parameter of concern typically depends on the regulatory requirements of the host country, USAID recommendations in this guidance document, and site-specific conditions. If the host country specifies the sampling frequency for the selected parameters, then that frequency should be used at a minimum, unless site-specific conditions warrant using a more frequent interval. Sampling frequency should be based on the relative health risks posed by the potential pollutant or contaminant; the population served or volume of water supplied by the drinking water system; and the rate at which a contaminant concentration may change over time (WHO, 2017). The frequency of sample collection may also be influenced by the practical limits of the capacity of local resources. Qualified laboratories may not be available or accessible to complete the analysis, and the use of field test kits may not be possible.

#### Rationale for Selection of Site Specific Water Quality Parameters

In this section, the IP must clearly describe in the narrative how and why the water quality parameters of concern, and the frequency for monitoring, were selected from those presented in Section A, based on site-specific conditions. This narrative (3 to 5 paragraphs) should provide backup support for the values listed in Tables II-A and II-B. This rationale should include additional water quality parameters which were selected based on site-specific conditions including nearby activities, as suggested above.

**Resources:**

* **2017 WHO Guidelines for Drinking-water Quality, Fourth Edition:** This is the most up-to-date guidance document on drinking water standards and discusses microbial, chemical and radiological aspects of water quality. The document presents a risk based approach drinking-water quality that includes water safety plans, surveillance, and a conceptual framework for implementing and applying the guidelines under a range of circumstances. (<http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/>)
* **1997 WHO Guidelines for Drinking-water Quality, Second Edition, Volume 3 Surveillance and control of community supplies:** This document specifically focuses on the unique problems of small-community water supplies in developing countries. It describes the methods employed in the surveillance of drinking-water quality, outlines the strategies necessary to ensure that surveillance is effective, and discusses the linkage between surveillance and remedial actions that should be taken. (http://www.who.int/water\_sanitation\_health/publications/small-water-supplies-guidelines/en/)
* **2007 WHO Chemical Safety of Drinking Water: Assessing Priorities of Risk Management:** In this comprehensive guidance document, WHO describes the process by which risks and specific contaminants of concern can be identified and prioritized. It notes that prior to implementing water quality testing, the implementer should consider the following questions:
	+ “What is the extent of the problem – is there strong evidence that the chemicals are present in water sources or are likely to be present?
	+ What is the relevant contribution from drinking-water sources compared with other sources (e.g. food)?
	+ How severe is the potential health concern in the context of other health problems?”

The guidance provides lists of potential parameters of concern in drinking water, based on risks from certain land use and activity. Of note are the following tables:

* + Table 4.1 “Environmental factors affecting the distribution of naturally occurring toxic chemicals in water and soil,”
	+ Table 6.1 “Chemicals derived from human settlements,”
	+ Table 7.1 “Chemical contaminants of extractive industry wastewaters,” and,
	+ Tables A1.1 “Chemicals considered for health based guideline values” and Table A1.2 “Chemicals that may give rise to consumer complaints.”
	+ **WHO Environmental Fact Sheet 2.29, Water Quality Monitoring**: In this brief fact sheet, WHO provides guidance on the critical water quality parameters to sample, and the frequency of sample collection depending on the nature of the project, and is available online at: <http://www.who.int/water_sanitation_health/publications/envsanfactsheets/en/index1.html>

##

## III: Assess and Document Resources for Sample Collection and Laboratory Analysis

The third step in the WQAP development process is assessing the resources available to collect and analyze the water samples. This step ensures not only that the field collection will be completed according to defined procedures, but also that the analyses will be performed according to standard analytical protocols.

In each subsection, the IP must describe how and where samples will be collected, how and where field measurements will be performed, and how and where laboratory analysis will be completed. The available resources must be documented in this section of the WQAP, in table or brief narrative form. In addition, the resources must be documented by completing or expanding Table III-A in Section III C to capture all the information gathered.

**Resources:**

* World Health Organization, 1997. Guidelines for drinking-water quality: Volume 3 Survaillance and control of community supplies, Chapter 4, Water Sampling and Analysis?

http://www.who.int/water\_sanitation\_health/publications/small-water-supplies-guidelines/en/

* June 2009, Centre for Affordable Water and Sanitation Technology (CAWST) Training Manual – Introduction to Water Quality Sampling: Sections 2.1.5, 2.16, 2.17, and 2.1.8 describe the planning process, and Sections 3.3, 3.4 and 3.7 describe sample collection and analysis steps, available online at: <http://www.sswm.info/sites/default/files/reference_attachments/CAWST%202009%20Introduction%20to%20Drinking%20Water%20Quality%20Testing.pdf>
* November 2015, USEPA, Quick Guide to Drinking Water Testing, available online at: [https://www.epa.gov/sites/production/files/2015-11/documents/drinking\_water\_sample\_
collection.pdf](https://www.epa.gov/sites/production/files/2015-11/documents/drinking_water_sample_collection.pdf)
* New Hampshire Sample Collection and Preservation Manual for Drinking Water (2011), available online at: <http://des.nh.gov/organization/commissioner/pip/publications/co/documents/r-co-01-5.pdf>

### Sample Collection and Field Measurement

In this subsection, the IP describes the staff, equipment and other resources that are available to collect samples for further laboratory analysis and to perform field measurements for the parameters outlined above. A brief narrative should be included here for each section outlined below to provide the detail necessary to support the data summarized in Table III-A in Section III C.

#### Availability of Trained Personnel

The IP should include a brief narrative addressing the following items:

* Available qualified technicians from local health clinics, government offices, or local water management committees who can perform sample collection and field measurement.
* Qualifications for each technician.
* Local beneficiaries who can be trained to perform these tasks.
* Additional training, if any, required for these technicians to perform the sample collection and field measurement task.

#### Availability of Appropriate Equipment

The IP should include a brief narrative that:

* Identifies and describes the sampling equipment, including consumables (i.e. bottles or containers), PPE, bailers, coolers to be used.
* Describes its applicability to the task, and include the inventory of available equipment.
* Describes available refrigeration or ice making equipment for preserving samples.
* Identify location where an office, or clean area is available, where samples can be processed.
* Describes portable test kits to be used. Describe the conditions under which their use is proposed and whether they are suitable. (Please see below, Field Analysis using Portable Test Kits, in Section B. Laboratory Analysis.)
* Identifies and describes other technologies that can be used to measure field parameters.

Examples of the necessary sampling equipment and supplies may include:

* Meter for field measurements
* Spare parts (e.g. backup meter and electrodes)
* Batteries
* Standard buffer solutions for meter calibration (note expiration date)
* Deionized water
* Paper towels, tissues, or lab wipes
* Germicidal wipes or dilute bleach solution (1:6)
* Sample containers with labels
* Log book or computer
* Chain of custody forms
* Ziploc bags
* Strapping tape
* Cooler(s) with ice
* Sterile gloves
* Safety glasses
* Other safety equipment as needed
* Wrench or other tool to remove a cap, cover or enclosure
* Equipment to take sample safely, such as sampling pole with clasp for bottles, or sampling pump or bailer for wells.

Sample bottles, including any preservatives and labels, can be ordered from the laboratory performing the analysis. Miscellaneous, expendable sampling supplies (e.g., ice, coolers, markers, calibration standards) may have to be purchased by the IP and the sample collection team.

The IP should consult the laboratory or host country regulations to determine the necessary sample containers and required analyses for each water quality parameter. The following table, based on USEPA requirements, is a useful reference on sample bottle type, preservative, and holding time for an example list of water quality parameters. Information for other water quality parameters can be found in the international standard analytical methods referenced in this document.

|  |
| --- |
| Table 2. Sample Bottle Requirements for Example USEPA Mandated Analyses |
| Contaminant | Analytical Method | Bottle Type | Bottle Size | Preservative | Holding Time |
| Coliform | SM9223 | Plastic | 125 mL | thiosulfate (if chlorinated) | 24 hours |
| Arsenic | EPA 200.8 | Plastic | 500 mL/250 mL | EDTA/acetic acid | 6 months |
| Metals | EPA 200.8 | Plastic | 500 mL/250 mL | nitric acid/unpreserved | 6 months |
| Nitrate/nitrite | EPA 300.0 | Plastic | variable | None | 48 hours |
| Nitrate/nitrite | EPA 353.2 | Plastic | variable | sulfuric acid | 28 days |

#### Procedures and protocols for collection, MEASUREMENT, SAMPLE preservation and transport to laboratories.

In this section, the IP should include a brief narrative addressing the following items:

* Protocols or standard operating procedures (SOPs) developed and provided to the personnel performing these tasks.
* Recordkeeping tools, including logs, chain of custody forms available to these personnel.

Examples of typical SOPs for collecting water samples and taking field measurements are provided in [Annex 7.](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_8_Example_Water_System.docx) (Please see Annex 7 at: <http://www.usaidgems.org/wqap.htm>.)These SOPs are included for illustration only. It is expected that the IP will review and select similar SOPs developed for project specific parameters, local conditions, and in the language of the sample collection team.

### Laboratory Analysis

In this section, the IP must describe the resources available to receive and store samples collected in the field, to perform the analysis according to standard protocols, to perform standard QA/QC, to report the analytical results, and to complete field testing using portable test kits, for the parameters selected above. A brief narrative or table, similar to Table 2 must be included here to document the analytical methods or field measurements for each water quality parameter.

#### Location of Nearest Qualified Laboratory

In this section, the IP must identify one or more qualified laboratories located within a reasonable distance to receive and process samples for the selected parameters. Information can be summarized in a table or brief narrative. Describe the length of time it will take to transport the samples to the lab. If qualified labs are not available, describe other available options for measurement/analysis, i.e., verified test kits. (Please see below, Field Analysis using Portable Test Kits, in Section B. Laboratory Analysis.) The following example table is provided to illustrate how the locations of qualified labs can be documented.

|  |
| --- |
| Table 3. Example List of Qualified Laboratories |
| Name of Laboratory | Type of Analyses | Physical Address and Phone Number | Laboratory Manager | Comments |
| XYZ Limited | Chemistry, Microbiology | Jones StreetP.O Box 12345Mombasa, 80100+254 20 123 1234  | Mr. John Doe | Distance from location = 100 kmCertified by the Government Accreditation Service |
| State National Microbiology Reference Laboratory | Microbiology | Jones TowersMountain AvenueNeighborhoodNairobi, 12345 | Ms. Julie DoePh: 0123-324-678Email: juliedoe@XYZY.or.ba | Distance from location = 200 km,Certified by the Government Accreditation Service |

#### Availability of Proper Analytical Equipment

In this section, the IP must describe in a brief narrative or summary table the resources available at the selected laboratory to document that they have the proper equipment for:

* Receiving/storing (refrigeration) the samples.
* Analysis of the samples for the parameters of concern.
* Disposal of reagents, chemical waste.

This information can be summarized in a table similar to the example shown below.

|  |
| --- |
| Table 4. Example Laboratory Resources Table |
| *Laboratory: (Name)* |
| Water Quality Parameter | Analytical Method | Instrument Make and Model | Receiving Protocol | Disposal Practices for Consumables |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

#### Availability of Trained Personnel

In this section, the IP should include a brief narrative addressing the following items:

* Identification of qualified, trained technicians and managers at the lab.
* Description of their capacity and availability to process the number of samples planned for this program.

An example summary table describing the laboratory capacity is provided below:

| Staff Position | Qualifications | Comments |
| --- | --- | --- |
| Lab Manager | B.S. Medical Laboratory Science, Methodist University.Higher National Diploma, Medical Laboratory Sciences (Bacteriology), Medical Training College (MTC). | Lab capacity to process 500 samples per week, available 5 days a week. Sampling program will generate 100 samples per collection round. |
| Deputy Lab Manager | Higher Diploma, Medical Virology (KMTC)Diploma, Medical Laboratory Sciences (KMTC). |
| Quality Assurance Officer | B.S. Medical Laboratory Science, Kenya Methodist University. |
| Lab Technicians | Diploma, Medical Laboratory Sciences (KMTC). | 30 technicians |

#### Reporting and QA/QC of Data

In this section, the IP should include a brief narrative addressing the following items:

* How the lab quantifies and reports the uncertainty of its analytical results.
* The lab’s quality assurance plan and its quality control procedures covering the specific analyses required by the project.
* How the laboratory identifies the activities and personnel responsible for ensuring policies are followed.

The IP should contact the laboratory or view its website, if available, to review the QA/QC program at the facility. Typically, the lab QA/QC program includes (UC Davis, 2016):

1. Quality Assurance (QA) - the system used to verify that the entire analytical process is operating within acceptable limits; and,
2. Quality Control (QC) - the mechanisms established to measure non-conforming method performance.

The program can be documented in a QA/QC manual and a quality policy statement. Two examples of these documents, one from the University of California - Davis (UC Davis) Analytical Lab, and one from the Kenya National Microbiology Reference Laboratory (NMRL), can be found online at these websites:

1. UC Davis Analytical Lab QA/QC Program: <http://anlab.ucdavis.edu/qa-qc>
2. Kenya NMRL,
* Description: <http://nmrl.nphls.or.ke/>
* Laboratory Handbook: <http://nmrl.nphls.or.ke/wp-content/uploads/2015/08/Revised-laboratory-hand-book-Nov-11.-2014.pdf>

#### Field Analysis using Portable Test Kits

In this section, the IP should include a brief narrative that:

* Describes the portable test kits which are available for testing the parameters of concern.
* Describes the process by which the accuracy of the test kits has been verified and the test kits specified range.
* Identifies the field staff trained in the use of the test kits.
* Inventories supplies and test kits available in the field use.
* Obtains approval of the selected test kits from USAID MEO, REA or BEO.

Note: It is the responsibility of the implementing partner to demonstrate to the appropriate USAID Environmental Officer that the use of a particular portable test kit produces data that is replicable and capable of accurately detecting contaminants at or below the standard contaminant limit identified during the IPs research on applicable standards.

**Resources:**

* + **2008 UNICEF Handbook on Water Quality:** In addition to a comprehensive description of water quality issues, this guidance provides an excellent description of field test kits for inorganic parameters including arsenic, fluoride and nitrates. See Section 3.2.2, Chemical Analyses, pp. 61- 68, available online at: <https://www.unicef.org/wash/files/WQ_Handbook_final_signed_16_April_2008.pdf>
	+ **2009 Centre for Affordable Water and Sanitation Technology (CAWST) Training Manual – Introduction to Water Quality Sampling**: Appendix 1 of this manual contains descriptions of field test kits, costs and suppliers, available online at: <http://www.sswm.info/sites/default/files/reference_attachments/CAWST%202009%20Introduction%20to%20Drinking%20Water%20Quality%20Testing.pdf>
	+ **2006 Oxfam Technical Bulletin 3: Water quality analysis in emergency situations:** This guidance bulletin provides a comprehensive review of test kits for inorganic and microbiological drinking water parameters, available online at: <http://policy-practice.oxfam.org.uk/publications/water-quality-analysis-in-emergency-situations-126714>

### Documentation of Availability of Resources

This section includes completion of Table III-A to document the available resources for the program. The IP should be as specific as possible by, for example, listing equipment models and protocol references. If additional detail is required to support and provide background on the data in the table, please expand the table, or include additional tables, as necessary or provide this information.

## IV: SUSTAINABILITY AND OPERATIONAL FACTORS AFFECTING Water Quality

Monitoring and testing for specific water quality parameters should only be one part of a more comprehensive water quality management system and operations and maintenance plan. As a matter of policy, the USAID Water and Development Plan emphasizes programming to promote the long-term sustainability of water systems and the continual improvement of water quality. The WQAP and associated water quality monitoring actions represents a check on such a system, as it is intended to help ensure the system is being maintained, drinking-water is being properly treated, and public health is being protected during the life of USAID and IP involvement and beyond. This section of the [WQAP template](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Africa_Bureau_WQAP_Template_Final.docx) is where the IP describes aspects of the project that will lead to management of risks to water quality over the longer-term, and how the WQAP or similar compliance monitoring program will be transferred to the local relevant authority after a project ends.

Planning

In this section, the IP should describe aspects of the planning phase of the water project that will contribute to the delivery of safe water quality for project beneficiaries.

Design and Construction

The IP should describe the specific standards (both local and international) used for the design of the proposed water supply infrastructure. In addition, the IP should describe the specific activities to be performed to ensure that the water system is constructed and operated to ensure that water quality is maintained. The specific roles and responsibilities for each of the stakeholders in the areas of construction project management, supervision and monitoring should be described.

Source Protection

The IP should evaluate and describe specific plans to protect the integrity of source water from contamination. Source protection measures may include delineation/mapping of the area to protect (e.g. the sub-watershed), the construction/installation of physical barriers (e.g. fences) to prevent entry, and the engagement of a ranger or guard to ensure that the measures are enforced and implemented. The specific roles and responsibilities for each of the stakeholders should be described.

Operational Sustainability

In this section, the IP should describe the activities and roles/responsibilities of organization(s) and other stakeholders that will ensure the long-term operation and sustainability of the water system (e.g., water management committees or other similar entities). This section should describe the organization and financial structure of the water management committee. It should specifically describe each of the operation and maintenance (O&M) and monitoring activities, who will be responsible for performing them, and how they will be financed routinely and over the long term. Finally, this section should describe how and what training should be delivered to ensure that drinking water managers have the capacity to perform their duties, especially prior to handover of the water infrastructure.

Stakeholder Participation

In this subsection, the IP should describe the process by which stakeholders will be engaged to ensure that the proposed water system meets community needs. Specific outreach actions to engage all stakeholders, including community leaders and beneficiaries should be described. The plan for transferring the water supply infrastructure and monitoring functions to the relevant authorities (e.g. a water management committee, local or central government) should be explicated described here.

Routine Operation and Maintenance

In this subsection, the IP should describe which stakeholders are responsible for routine and long term O&M and at what frequency they will be conducting these activities.

Routine Monitoring and Testing

In this subsection, the IP should describe which stakeholders are responsible for routine monitoring and testing and at what frequency they will be conducting these activities.

Training

In this subsection, the IP should describe how and what training should be delivered to ensure that local system managers have the capacity to perform their duties prior to handover of the water infrastructure. Training should include the following topics:

* Operation and Maintenance
* Financial Management

##

## V: Corrective Measures

In this section, the IP should describe the response(s) or corrective measure(s) to be taken in the event of a water quality test that exceeds the guideline value and/or standard noted in Tables II A and IIB, including when and how local authorities and USAID staff will be notified and consulted when such guideline values are exceeded.

For guidance on the resolution of water quality contamination, please see [Annex 3: Approach to Resolution of Water Quality Contamination](http://www.usaidgems.org/Documents/WQAPTemplateFiles/Annex_3_Approach_to_Resolution.docx), which can be accessed here: <http://www.usaidgems.org/wqap.htm>.

Annex 5 includes narrative descriptions of the corrective measures to be included in the WQAP. The IP should update and adapt this language, as appropriate, to the local context and other portions of the WQAP (corrective measures for the site-specific or host country-specific water quality parameters should also be included in this section).

***Approach to Resolution of Water Contamination.*** The selection of corrective measures to implement when the water quality guidance levels are exceeded depends on a variety of factors, most of which depend on potentially unique site characteristics. The two most important issues to consider prior to implementing a corrective response are:

* Does the exceedance present an immediate health risk to consumers?
* Are there alternative water sources, which are accessible and safe?

In all cases, the implementing partner should notify and consult with the relevant USAID MEO, REA, or BEO regarding the exceedance and appropriate responses.

**Resources:**

* **WHO. 2012b. Rapid Assessment of Drinking-Water Quality.** A Handbook for Implementation. Available online at: <https://www.wssinfo.org/fileadmin/user_upload/resources/RADWQHandbookv1final.pdf>
* **Centers for Disease Control and Prevention (CDC) Drinking Water Advisory Communication Toolbox. 2013.** Available online at: <https://www.cdc.gov/healthywater/pdf/emergency/drinking-water-advisory-communication-toolbox.pdf>.
* **CDC Emergency Water Supply Preparation.** Available online at: <https://www.cdc.gov/healthywater/emergency/drinking/emergency-water-supply-preparation.html>.
* **2008 UNICEF Handbook on Water Quality:** In addition to a comprehensive description of water quality issues, this guidance provides a description of emergency water treatment techniques, though targeted at disaster response. See Section 5.3.4, Water Treatment in Emergencies, pp. 124- 128. The document can be found online at: <https://www.unicef.org/wash/files/WQ_Handbook_final_signed_16_April_2008.pdf>
* **CDC (2001). Safe Water Systems Manual.** Atlanta: Centers for Disease Control, available online at: [www.cdc.gov/safewater](http://www.cdc.gov/safewater).
* **IRC (2002). Small community water supplies.** Technical paper no. 40. The Hague: IRC International Water and Sanitation Centre.
* LeChevallier, M.W. & Au, K.-K (2004). **Water treatment and pathogen control: Process efficiency in achieving safe drinking water.** Geneva, World Health Organization. [www.who.int/water\_sanitation\_health/dwq/9241562552/en/](http://www.who.int/water_sanitation_health/dwq/9241562552/en/)

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National Research Council (NRC). 2005. Public Water Supply Distribution Systems: Assessing and Reducing Risks -- First Report. The National Academies Press. Available online at: <https://www.nap.edu/catalog/11728/drinking-water-distribution-systems-assessing-and-reducing-risks>.

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Rural Community Assistance Corporation (RCAP). 2012*. Protecting Water Quality by Optimizing the Operations and Maintenance of Distribution Systems.* Washington DC: Rural Community Assistance Partnership, Inc.

UNICEF. 2008. *Handbook on Water Quality*. Available online at: <https://www.unicef.org/wash/files/WQ_Handbook_final_signed_16_April_2008.pdf>

WHO. 2017. *Drinking Water Guidelines*. Available online at: <http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/>

WHO. 2012b. *Rapid Assessment of Drinking-Water Quality. A Handbook for Implementation.* Available online at: https://www.wssinfo.org/fileadmin/user\_upload/resources/RADWQHandbookv1final.pdf

WHO. 2012a. *Water safety planning for small community water supplies: step-by-step risk management guidance for drinking-water supplies in small communities.* Geneva: World Health Organization.

WHO. 2007. Terrence Thompson et al. Chemical Safety of Drinking Water: Assessing Priorities for Risk Management. Available online at: http://apps.who.int/iris/bitstream/10665/43285/1/9789241546768\_eng.pdf?ua=1

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