National Drinking Water Quality Management Framework for Ghana

"Prevention is better than cure"

Ministry of Water Resources, Works and Housing
Government of Ghana

June 2015

FOREWORD

The Government of Ghana recognizes access to safe drinking-water as a basic human right and essential to protect public health. Over the past decade, significant progress has been made to raise the proportion of the population with access to improved water sources in the country. However, it is generally recognised, that access to improved sources of drinking water do not necessarily imply access to safe water. In that regard, a rapid assessment of the status of the quality of drinking water and the way it is managed in Ghana was conducted as a basis for the formulation of a National Drinking Water Quality Management Framework.

The National Drinking Water Quality Management Framework has been developed through a consultative and participatory process involving key stakeholders at all levels. The Framework is based on the World Health Organisation's recommended risk-based approach in the management of drinking water quality, which focuses on systematic identification of risks, implementation of Water Safety Plans, effective monitoring and evaluation, regulation and coordination of roles and responsibilities of all relevant actors. This would ensure that multiple barriers are put in place from the Catchment to the Point-of-Use, to effectively manage the risk associated with the exposure of contaminated drinking water to the public and thereby protecting public health.

This Framework aims at providing a guide to all water supply agencies on effective drinking-water quality management and public health protection. It covers all aspects of drinking water supply i.e. urban, peri-urban and rural settings; private and vendor water supplies. It also provides clarification on the roles and responsibilities of the stakeholders involved in drinking water quality management and the mechanisms for effective coordination and collaboration in its implementation.

I wish to express my sincere appreciation to UNICEF, the European Union and other stakeholders who have played various roles in the development of this Framework.

Hon. Dr. Kwaku Agyemang-Mensah

Minister for Water Resources, Works and Housing

List of Abbreviation

µg/l	Microgram per litre
CCP	Critical Control Points
CONIWAS	Collation of NGOs in Water and Sanitation
CSIR	Council for Scientific and Industrial Research
CWSA	Community Water and Sanitation Agency
DALYs	Disability Adjusted Life Years
DA	District Assembly
DWST	District Water and Sanitation Team
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
FDA	Food and Drug Authority
GHS	Ghana Health Service
GLSS	Ghana Living Standards Survey
GSA	Ghana Standards Authority
GSS	Ghana Statistical Service
GWCL	Ghana Water Company Limited
HACCP	Hazard Analysis and Critical Control Points
HWTS	Household Water Treatment and Storage
LMS	Limited Mechanized System
MDG	Millennium Development Goal
mg/l	Milligram Per Litre
MLGRD	Ministry of Local government and Rural Development
MMDA	Metropolitan, Municipal and District Assemblies
MOH	Ministry of Health
MWRWH	Ministry of Water Resources, Works and Housing
NADMO	National Disaster Management Organization
NDPC	National Development Planning Commission
NGOs	Non-Governmental Organizations
PURC	Public Utilities Regulatory Commission
UNICEF	United Nations Children's Fund
WRC	Water Resources Commission
WRI	Water Research Institute
WSP	Water Safety Plan
WHO	World Health Organization

CONTENTS

List of Table

List of Figures

1. INTRODUCTION

1.1 Background

The Ministry of Water Resources, Works and Housing (MWRWH) recognizes access to safe drinking-water as basic human right and essential to protect public health. In the recent decade significant progress has been made to raise the proportion of population with access to improved water sources in the country. However, research studies and national surveys found a number of drinking water quality parameters do not conform the national water quality standards. In addition, water related diseases are also prevalent in the country which is a threat to public health. In recognition of the importance of safe drinking water to public health, the MWRWH with the support of UNICEF has carried out a detail assessment of the existing drinking-water quality management system. The objective was to identify the challenges and gaps in the existing water quality management system and make recommendations to address those challenges. The assessment process has followed a participatory approach with active involvement of stakeholder's and comprehensive consultations. Key findings of the assessment includes;

- Bacteriological contamination of drinking-water is widespread in the country; in many instance chemical constituents, notably, fluoride, iron, manganese, arsenic and salinity of drinking-water also doesn't conform to the national standards; and water related diseases are prevalent in the country.
- District Assemblies are responsible for inspection, monitoring and regulation of drinking water quality in the districts with support from regional and national relevant organizations. PURC has the responsibility to monitor drinking water of GWCL only. Water quality of self-supplies, vendors and tankers water suppliers are not monitored.
- There are Disaster Management Plans at district level in place but not regularly updated and DAs doesn't have the necessary emergency supplies in place.
- The roles and responsibilities to manage drinking-water are not well coordinated among the sector organizations.
- The national drinking-water quality standards does not require water service providers to use a risk-based approach or maintain water safety from catchment to consumer applying risk management approach.
- Distinct and consistent guidelines for drinking-water quality management is lacking throughout the drinking water supply sector.
- The overall drinking-water quality management follows traditional compliance monitoring approach where action is taken based on the results of water quality tests. A major limitation of this traditional approach is that water quality results are only available after exposure has taken place, also water volumes tested are not statistically representative and has limited capability to detect short term fluctuations.

The findings of the assessment's report has informed the formulation of National Drinking-Water Quality Management Framework to guide all water supply agencies on effective drinking-water quality management and public health protection. Its covers all aspects of drinking water supply i.e. urban, peri-urban and rural settings; private and vendor water supplies. The Framework also provides clarification on roles and responsibilities of the stakeholders involved in drinking water quality management and mechanisms for effective coordination and collaboration.

1.2 Introduction to the Framework

This chapter introduces the National Drinking-Water Quality Management Framework (NDWQMF) and describes its purpose, benefits and structure. It outlines how the Framework can be applied and explains the importance of various agencies working in partnership with drinking water suppliers to apply the framework successfully.

1.2.1 Approach (Preventive strategy from catchment to consumer)

The National Drinking-Water Quality Framework for Ghana is based on a preventative risk management approach from catchment to consumer. This approach promotes an understanding of the entire water supply system, the events that can compromise drinking water quality and the operational control necessary for optimizing drinking water quality and protection of public health. Globally in drinking-water supply systems, the risk management approach has gained success and is increasingly being used as a means of assuring drinking water quality by strengthening the focus on more preventive approaches.

The WHO guidelines for drinking-water quality (WHO, 2011) provides the recommendations of the World Health Organization for managing the risk from hazards that may compromise the safety of drinking water and discourages the traditional approach of reliance on water quality determination alone. The WHO framework provides generic requirements for organizations undertaking a diverse range of activities. The Framework is adapted into the local context to guide the design of a structured and systematic approach for the management of drinking water quality from catchment to consumer, to assure its safety and reliability.

1.2.1 Structure of the Framework

The Framework has six components which are considered good practice for drinking water supply system management. General description is illustrated in Table 1 and further detail description is outlined in Table 2.

Table 1 General description of the framework

Components	Purpose	Example
(Component-1) Commitment to drinking water quality management. Health based target,	Setting up the realistic national health based targets in line with national health policy and existing water supplier risk management capacity.	Long term evaluation of monitoring results support establishment of realistic health based targets and incremental improvement over the time.
Regulatory and formal requirement,	To Ensure responsibilities are understood by water service provider and communicated to its employees.	Documentation and identification of all regulatory and formal requirements e.g. National Water Policy, Water Quality Standards etc.
Engaging stakeholders	To Identify all stakeholders who could affect, or be affected by, decisions or activities of the drinking water supplier and to enlist commitment and support from key stakeholders.	Coordinate and agree on collaboration with WRC and EPA for water catchment management, FDA for packaged water, DAs/PURC for regulations etc.
Drinking-water quality policy	To formalize the level of service to which the water supplier is committed.	Formulate in-house drinking water quality policy, endorsed by senior executive, to be implemented throughout the water supply organization.
(Component-2) Water supply system analysis and management (Water Safety Plans)	To minimize risk to water quality by quantify the risks to water quality from source to the consumer end, the likelihood and impact on public health; what measures are needed to reduce or control the risks? Are the existing control measures are working? How is the quality of water at the point of drinking?	Risk from agro-chemicals, industries, geology at catchment, risk of bacteriological contamination, treatment failure, faulty and leaking distribution, un-hygienic handling at household etc. Review of existing preventive measures for each significant hazard or hazardous event. Monitor water quality data to validate and verify for short term that the preventive measures are working and what is needed for further improvement.
(Component-3) Review, audit, evaluation and continual improvement	The long-term evaluation of water quality monitoring results and audit of drinking water quality management to determine whether preventive strategies are effective and whether they are being implemented appropriately and help to identify opportunities for improvement.	The systematic review of monitoring results over an extended period (typically the preceding 12 months or longer) to assess overall performance against numerical GSA standards values, regulatory requirements or agreed levels of service, identify emerging problems and trends and to assist in determining priorities for improving drinking water quality.
(Component-4) Application to specific water sources Specific water sources: small community water supplies, point water sources, self-supplies, tanker waters and packaged water	Together with WSP and Hazard Analysis and Critical Control Point (HACCP) approaches, another simple and practically applicable approach of sanitary risk assessment is introduced to manage water quality of small water supplies.	Greater attention is given to physical inspections of the water sources for risks from animal and human waste, structural integrity and baseline water quality characteristics. Emphasis on protection through maintaining hygienic environment and household water treatment and safe storage.
(Component-5) Management of incidents and emergencies	To guide on identification of potential incidents and emergencies related to water quality, response plans preparation and how to communicate it with community.	Review of the hazards and events that can lead to emergency situations, Every water supply agency must have in advance a set of procedures to follow in the event of incidents leading to emergencies.
(Component-6) Supporting programs	To clarify the needed support for effective implementation of all the 5 components.	Comprehensive water supply agency employee awareness and training, community involvement and awareness, research to fill the knowledge gap and appropriate documentation and reporting mechanism.

Table 2 Detail outline of the framework

Component of the Framework	Sub-components
1-Commitment to risk-based management and multi-stakeholder involvement	**1-Commitment to risk-based drinking-water quality Management** Health based target, Regulatory and formal requirement, Engaging stakeholders and Drinking-water quality policy
2-Water supply system analysis and management (Water Safety Plans)	**1-Assessment of the drinking water supply system** Water supply system analysis, assessment of water quality data, hazard identification and risk assessment(Annexure 7.4) **2-Preventive measures for drinking water quality management** Preventive measures and multiple barriers, critical control points **3-Operational procedures and process control** Operational procedures, operational monitoring, corrective action, equipment capability and maintenance, materials and chemicals **4-Verification of drinking water quality** Drinking water quality monitoring, consumer satisfaction, short-term evaluation of results, corrective action
3-Validation & verification of WSP	**1-Evaluation and audit** Long-term evaluation of results, audit of drinking water quality management **2-Review and continual improvement** Review by senior executive, drinking water quality management improvement plan
4-Application to specific water sources	**1-Specific water sources** Management of small systems, vended, self-supplies, packaged water
5-Water quality incidence and emergencies	**2-Management of incidents and emergencies** Incident and emergency response and communication protocols
6-Supporting programs	**1-Employee awareness and training** Employee awareness, involvement and training **2-Community involvement and awareness** Community consultation and adequate communication **3-Research and development** Investigative studies & research monitoring, validation of processes, design of equipment **4-Documentation and reporting** Management of documentation, records and reporting mechanism

Although listed as distinct components, all of them are interrelated and each supports the effectiveness of the others. To assure a safe and reliable drinking water supply, these components need to be addressed together because most water quality problems are attributable to a combination of factors. A schematic representation showing the key linkages within the Framework is presented as *Annexure 7.3.*

The Framework outlines principles of management applicable to all water supply systems regardless of size and system complexity (i.e. both small and large supplies, individual point water sources and water vendors). To reflect the diversity of individual water supplies and the varying institutional arrangements (e.g. urban, rural, vended, packaged and self-supplies), the Framework is flexible. It provides generic guidance and the content should not be regarded as being prescriptive or exhaustive.

1.2.2 Advantages of the Framework

Management of drinking water quality through a comprehensive preventive strategy benefits the water supply agencies by providing an overall framework that:

- Promotes public health by assuring safer drinking-water for consumers.
- Enables an in-depth systematic evaluation of water systems, the identification of hazards and the assessment of risks and promotes a holistic approach to management of drinking-water quality.
- Stresses prevention of risks from hazards and places water testing in an appropriate verification role.
- Introduces a consistent approach of applying water safety plans that minimize the chance of failure through oversight or management lapse. It also provides contingency plans to respond to system failures or unforeseeable hazardous events. Water safety plans can be developed generically for small supplies rather than for individual supplies.
- Provides the opportunity for various agencies and stakeholders to identify their areas of responsibility and become involved, and offers the outcome of a cooperative and coordinated approach with improved understanding of the responsibilities of all parties.
- Provides a framework for communication with the public and with employees.
- Contribute to the debate on setting regulations and standards relevant to public health and the water quality.

1.2.3 The need for multi-agency involvement

In a water supply system from catchment to consumers end, many aspects of drinking-water quality management often fall outside the direct responsibility of the single organization. The Framework covers the water supply chain from catchment to consumer and addresses inter-agency involvement. Drinking water suppliers are responsible for the quality of drinking water delivered to consumers and accordingly must show leadership in application of the Framework; however, implementation will generally require coordination and consultation with other agencies for various components of drinking-water quality management, such as, catchment management, independent monitoring and reporting requirements, emergency response plans and communication strategies. The sector organizations include Water Resource Commission, Environmental Protection Agency, Food and Drug Authority, Ghana Standards Authority, Water Service Providers, Agriculture Departments, Local Government Authorities, National

Development Planning Commission, Ghana Health Service and community-based interest groups and organizations.

Even where commitments and partnership agreements with other agencies are difficult to establish, the Framework should still be implemented. Gradually, as partnerships with other agencies are established, the Framework can be further improved and a more integrated approach developed.

1.2.4 Applying the Framework

The framework is not intended to be applied as standards but rather to be considered as the best practices to safely manage drinking water. In determining how the framework is applied, water supply operators, regulators and relevant organizations e.g. Ghana Standards Authority should consider costs and benefits of these actions before making it as a requirement as well as developing an appropriate implementation timetable. The timetable should allow smooth shift from the traditional approach to risk-based approach with establishment of mechanisms to ensure continual improvement. It is pertinent to determine and agree on how the framework will be monitored, audited and reported. These aspects need clarification to ensure effective, unambiguous implementation. Effective management systems are not static and must be capable of accommodating change such as catchment developments, emerging issues, advances in technology or new institutional arrangements. Development should be an ongoing and iterative process whereby performance is continually evaluated and reviewed.

Application of the Framework will vary depending on the arrangements for water supply within urban and rural areas; for example, in urban areas, water supply is managed by Ghana Water Company Limited, whereas in rural areas it is managed locally by District Assemblies either through private operators/contractors or identified community management groups. This is likely to affect the manner and degree to which the Framework is implemented. However, all water suppliers and relevant government agencies should still be encouraged to use the Framework as a model for best practice.

How the Framework is applied will depend on the needs of the organization and most importantly the regulatory requirements. Each organization should develop an internal plan for implementing the Framework in a manner that suits its particular circumstances. The Framework can be applied as a stand-alone drinking water quality management system or can be integrated with an existing management system.

The time and resources required to implement the framework will depend on how many features of the Framework are already being practiced. Current water quality management applied by most drinking water suppliers already incorporate many of the components specified in the Framework. In many instances, all that may be needed is to review, document and formalize these practices and address any areas where improvements are required.

The first step in initiating a drinking water quality management system based on the Framework is to identify appropriate personnel with defined roles and responsibilities. Establishing a core group with the necessary skills will help to ensure consistency throughout the implementation. District Works Department (DWD) and the District Water and Sanitation Teams (DWST) already exist in rural areas to lead the implementation of the framework in the district. Within GWCL the water quality assurance department together with production department may establish such water quality committee with responsibility for the implementation and ongoing management of the overall water supply system. Some components of the Framework will require more effort than others, and improvements may need to be prioritized and implemented sequentially. To assist with implementation additional guidance on those components such as assessment of water supply system, water quality monitoring, sanitary risk assessment surveys etc. is provided in the Appendix.

The most important step in getting started is to document the current practice along the water supply chain from catchment to source to consumers. This should make maximum use of existing documentation where that is adequate. A manual should be developed to provide an overview of the system and a summary of all relevant documentation. The Framework is not intended to duplicate or replace management systems that are adequately working; rather, it is intended to be compatible and complementary. The Framework, which is based on WHO guidelines is sufficiently flexible to allow implementation to be built on programs and systems already existing in an organization. However, the relationships between the Framework and these systems should be understood.

Training personnel, including senior executives, in basic water quality and risk management approach may assist in the development and implementation of a drinking water quality management system. Some staff of the Community Water Sanitation Agency (CWSA), Ghana Water Company Limited (GWCL) and Public Utility Regulatory Authority (PURC) has already been trained on the risk-based approach and water safety planning and could be used as resource persons to facilitate trainings of further staff in District Assemblies and GWCL and implementation of the Framework.

Component-1

Commitment to Drinking WQ Management

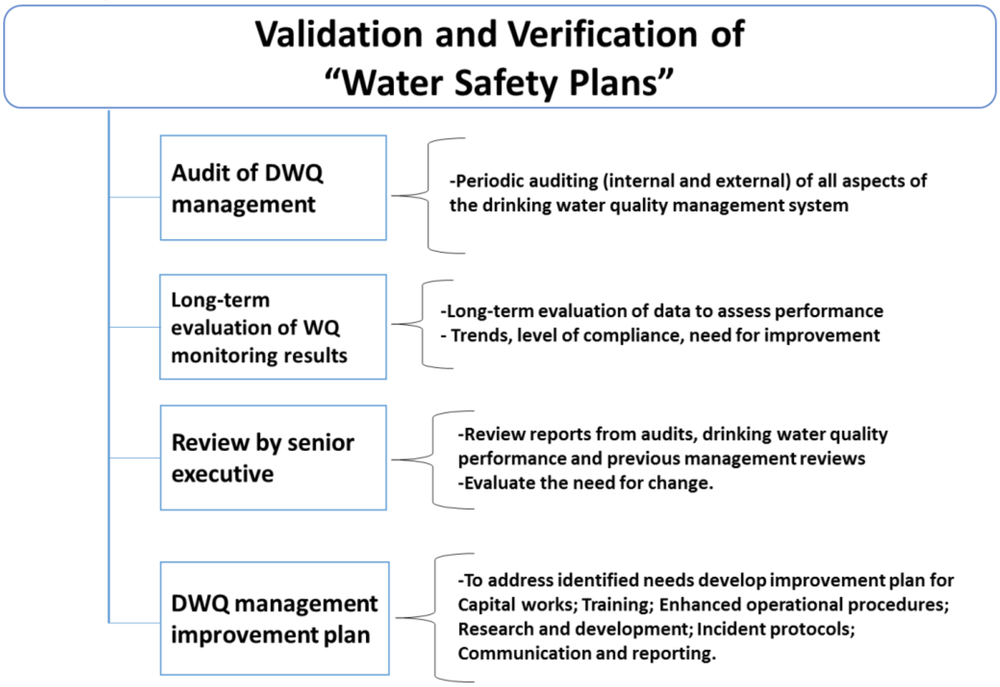
- **Health-based Standards**
  - Establishment of National Standards based on evaluation of health concerns.
  - Types of health-based targets
- **Collaboration with stakeholder**
  - Identify all stakeholders
  - Develop appropriate documentation for stakeholder commitment and involvement.
  - Regularly update the list of relevant agencies.
- **Policy and regulatory requirement**
  - Identify and document all relevant regulatory and formal requirements.
  - Ensure responsibilities are understood and communicated to employees.
  - Review requirements periodically
- **In-house organizational drinking WQ policy**
  - Formulate in-house drinking water quality policy
  - Ensure that the policy is visible and is understood and implemented by employees.

Component-2

Water supply system analysis and management "Water Safety Plans"

- **Assessment of water supply system**
  - Analysis of WSS, team- flow diagram
  - Assessment of water quality data
  - Hazard identification and risk assessment
- **Preventive measures**
  - Identify existing preventive measures for identified hazard and additional if required
  - Evaluating whether the preventive measures are effective in reducing risk to acceptable levels
- **Operational procedures and process control**
  - Identify procedures required for operational procedures
  - Operational monitoring and corrective action;
  - Treatment equipment and chemicals used in treatment
- **Verification of drinking water quality**
  - Drinking-water quality monitoring
  - Consumer satisfaction
  - Short-term evaluation of results to assess safety
  - Corrective actions

Component-3


Validation and Verification of
"Water Safety Plans"
Audit of DWQ management
-Periodic auditing (internal and external) of all aspects of the drinking water quality management system
Long-term evaluation of WQ monitoring results
-Long-term evaluation of data to assess performance
- Trends, level of compliance, need for improvement
Review by senior executive
-Review reports from audits, drinking water quality performance and previous management reviews
-Evaluate the need for change.
DWQ management improvement plan
-To address identified needs develop improvement plan for Capital works; Training; Enhanced operational procedures; Research and development; Incident protocols; Communication and reporting.

2. NATIONAL DRINKING WATER QUALITY MANAGEMENT FRAMEWORK

This chapter details the first three components that make up the National Drinking Water Quality Management Framework (the framework). Each component includes an introduction and a list of the sub-components, which are then described in further detail. A 'What needs to be done' box heads each component, providing an overview of the steps involved in implementation. Additional information and guidance are also provided for some areas of the framework in Appendix.

2.1 Commitment to water quality management (Component-1)

Organizational support and long-term commitment by senior executive is the foundation to implementation of an effective system for drinking water quality management. Senior executive should ensure that its actions and policies support the overall national policies and goals through effective management of drinking water quality (e.g. appropriate staffing, training of employees, provision of adequate financial resources, active participation and reporting to the sector stakeholders). Commitment to drinking water quality management consist of following four sub-components;

1) Health based targets
2) Collaboration with stakeholder
3) Policy and regulatory requirement
4) Individual organizational drinking water quality policy

2.1.1 Health based targets

Health-based targets are measurable health, water quality, or performance objectives that are established based on a judgment of safety and on risk assessments of waterborne hazards. World Health Organization recommends National drinking water standards must underpin such targets as benchmark for water suppliers and regulators to confirm the adequacy of existing water supply systems or the need for improvement to protect and improve drinking-water quality and consequently, human health. Where required, health based targets can be used to support incremental improvement by marking out milestones to guide progress towards water safety and public health goals. This normally requires periodic review and updating of priorities and targets. In turn, National standards should also be periodically updated. Health-based targets assists in determining specific interventions appropriate to delivering safe drinking water, including control measures such as source protection and treatment processes. Following are the four distinct types of health based targets, applicable to all types of hazards and water supplies:

1. health outcome targets (e.g. tolerable burdens of disease);
2. water quality targets (e.g. numerical standards values for chemical hazards such as arsenic, fluoride etc.);
3. performance targets (e.g. log-reductions of specific pathogens); and
4. specified technology targets (e.g. application of defined treatment processes).

Section 2.1.1.2 provide further details on each type of health based targets.

2.1.1.1 Setting health based targets

To ensure effective health protection and improvement, targets need to be realistic, measurable and should be in line with overall national public health policy and goals, taking into account public health status and trends and the contribution of drinking water to the transmission of infectious disease and to overall exposure to hazardous chemicals.

While water can be a source of microbial, chemical or radiological hazards, it is by no means the only source. In setting targets, consideration needs to be given to other sources, including food, air, person-to-person contact, consumer products, as well as poor sanitation and personal hygiene. Where the overall burden of disease from multiple exposure routes is very high, there is limited value in setting strict targets for drinking water. For example there is limited value in establishing a strict target for a chemical hazard if drinking-water provides only a small proportion of total exposure. For some pathogens and their associated diseases, interventions in water quality may be ineffective and may therefore not be justified. This may be the case where other routes of exposure dominate.

Meeting health based targets should be viewed in the context of broader public health policy including initiatives to environmental protection, improve sanitation, waste disposal, personal hygiene and public education on ways to reduce both personal exposure to hazards and reducing impacts of personal activity on water resources. Improved public health, reduced carriage of pathogens and reduced human impacts on water resources all contribute to drinking-water safety. Public health prioritization normally indicate that the major contributors to disease should be dealt with preferentially taking account of the costs and impacts of potential interventions.

An important concept in the allocation of resources to improving water safety is the possibility of establishing less stringent transitional targets supported by water safety plan implementation in order to encourage incremental improvements to the quality of drinking water. In this regard, health based targets can be used as the basis for supporting and measuring incremental progress in water quality. Improvements can relate to progression through increasingly tighter targets or evolution through target types that more precisely reflect the health protection goals (e.g. from specified technology targets to performance targets). It is pertinent to evaluate whether the benefit resulting from the adoption of any of the health based targets justifies the cost involved in achieving the target.

The processes of formulating, implementing, communicating and evaluating health based targets provide benefits to the overall preventive management of water quality as outlined in Table 3.

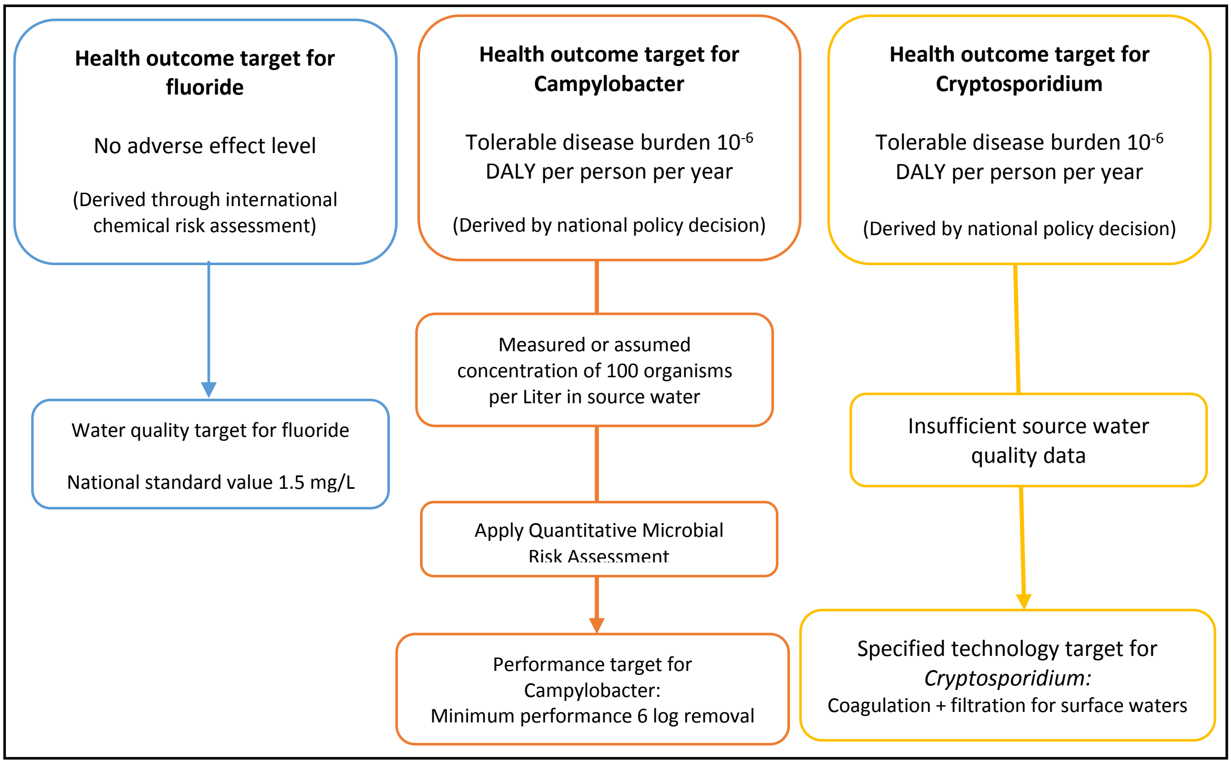
Table 3 Benefits of health based targets

Target development stage	Benefits
Formulation	Provides insight into the health of the population; reveals gaps in knowledge; supports priority setting; increases the transparency of health policy; promotes consistency among national health programs; and stimulates debate
Implementation	Inspires and motivates collaborating authorities to take action; improves commitment; fosters accountability; and guides the rational allocation of resources.
Evaluation	Supplies established milestones for incremental improvements; provides opportunity to take action to correct deficiencies and/or deviations; and identifies data needs and discrepancies

Table 4 Nature and application of health based targets

Type of target	Nature of target	Typical applications	Remarks
Health outcome	Defined tolerable burden of disease	High-level policy target set at national level, used to inform derivation of performance, water quality and specified technology targets	WHO Guidelines define a tolerable burden of disease of 10^{-6} DALYs per person per year (for details on DALY see box 14, Section 6.11)
	No adverse effect or negligible risk	Chemical or radiological hazards	Derived from international (e.g. WHO) chemical or radionuclide risk assessments
Water quality	Standards values	Chemical hazards	Based on individual chemical risk assessments
		Microbial water quality targets are not normally applied	*E. coli* is used as an indicator of fecal contamination and to verify water quality
		Radiological water quality targets are not normally applied	Radiological screening levels are applied
Performance	Specified removal of hazards	Microbial hazards (expressed as log-reductions)	Specific targets set by water supplier based on Quantitative Microbial Risk Assessment and health outcome targets, or generic targets set at national level.
		Chemical hazards (expressed as percentage removal)	Generic targets set at national level
Specified technology	Defined technologies	Control of microbial and chemical hazards	Set at national level Based on assessments of source water quality, frequently underpinned by established/validated performance of the specified technology (e.g. requirement of filtration for surface water, water with high fluoride, iron, manganese etc.)

Figure 1 Examples of how to set health based targets for various hazards



2.1.1.2 Types of health based targets

The nature and typical application of targets are presented in Table 4. They differ considerably with respect to the amount of resources needed to develop and implement the targets and in relation to the precision with which the public health benefits of risk management actions can be defined. The most precise are health outcome targets which underpin the derivation of the remaining targets as shown in Figure 1. Target types at the bottom of Table 4 require least interpretation by practitioners in implementation but depend on a number of assumptions. The targets towards the top of the table require greater scientific and technical inputs to overcome the need to make assumptions and are therefore more precisely related to the level of health protection. The framework supports incremental improvement in that critical data for applying the next stage of target setting may not be available, and a need to collect additional data may become obvious (e.g. in applying specified technology targets in the absence of sufficient data to apply performance targets for microbial pathogens).

In order to minimize the likelihood of outbreaks of disease, care is required to account of performance both in steady state, during periods of short-term water quality deterioration (e.g. following heavy rain, flood) and during maintenance. Both short-term and catastrophic events can result in periods of very degraded source water quality and greatly decreased efficiency in many processes, both of which provide a logical and sound justification for the long-established "multiple-barrier principle" in water safety. This is particularly important in applying performance and specified technology targets.

For chemical hazards such as fluoride, arsenic, health based targets most commonly take the form of water quality targets, using the National standard values. Performance targets expressed as percentage removals or specified technology targets can also be applied to chemical hazards.

For microbial hazards, health based targets usually take the form of performance or specified technology targets. The choice of target will be influenced by the amount of data available on source water quality with performance targets requiring greater information. Water quality targets are typically not developed for pathogens, because monitoring finished drinking water for pathogens is not considered a feasible or cost effective option. Concentrations of pathogens equivalent to a health outcome target of 10^{-6} DALYs per person per year are typically less than 1 organism per 10^{-4} to 10^{-5} liters. Therefore, it is more feasible and cost-effective to monitor for indicator organisms such as *E. coli*.

In practice, risks to public health from drinking water are often attributable to a single hazard at a time; therefore, in deriving targets the reference level of risk is applied independently to each hazard.

2.1.1.2.1 Health outcome targets

The most direct descriptions of drinking water safety are health outcome targets such as upper limits on frequencies of diarrheal disease or cancer incidence. These upper limits represent tolerable burdens of disease and are typically set at national level. They underpin the derivation of water quality, performance and specified technology targets (Figure 1). WHO Guidelines define a tolerable burden of disease of 10^{-6} DALYs per person per year. For threshold chemicals the health outcome target is based on no adverse effect levels. Health outcome targets must be translated into water quality, performance or specified technology targets in order to be actioned by the water supplier as part of the water safety plans.

2.1.1.2.2 Water quality targets

Water quality targets are the most common form of health based target applied to chemicals that may be found in drinking water. The standard values for individual chemicals described in the GSA water quality specification provides water quality targets that can be used to verify that WSPs have been effective in managing risks from chemicals in drinking water.

Example to establish National Health based Water Quality Target

The standards values for water quality target are mostly established on the basis of international risk assessments of the health effect from the chemical in water. Exposure from chemicals in drinking water is typically minor in comparison to other sources (e.g. food, consumer products and air) with a few important exceptions (e.g. arsenic and fluoride). This may lead to national targets that differ appreciably from the WHO guidelines or other international guideline values.

The WHO recommended health based target for fluoride in drinking water is 1.5 mg/liter, with a comment that "Volume of water consumed and intake from other sources should be considered when setting national standards." Thus in a country like Ghana with a warm year-round climate and where water sources having high fluoride is the preferred source of drinking-water, authorities may select a health-based target for fluoride that is lower than this guideline value, as water consumption is expected to be higher. Health based target should also be reviewed in terms of its impact on the most vulnerable section of the population.

Where water treatment processes have been put in place to remove or reduce specific chemicals (e.g. arsenic, fluoride) water quality targets should be used to determine appropriate treatment requirements.

It is important that water quality targets are established only for those chemicals that, following rigorous assessment, have been determined to be of health concern or of concern for the acceptability of the drinking water to consumers. There is little value in undertaking measurements for chemicals that are unlikely to be in the system that will be present only at concentrations much lower than the standards value or that have no human health effects or effects on drinking-water acceptability.

Water quality targets are also used in the certification process for chemicals that occur in water as a result of treatment processes or from materials in contact with water. In such applications, assumptions are made in order to derive standards for materials and chemicals that can be employed in their certification. Generally, allowance must be made for the incremental increase over levels found in water sources. For some materials (e.g., domestic plumbing), assumptions must also account for the relatively high release of some substances for a short period following installation.

E. coli remains an important indicator of fecal contamination for verification of water quality but measurements of *E. coli* do not represent a risk-based water quality target.

2.1.1.2.3 Performance targets

Although performance targets can be applied to chemical hazards the most common application is for control of microbial hazards in piped supplies. Performance targets assist in the selection and use of control measures that are capable of preventing pathogens from breaching the barriers of source protection, treatment and distribution systems or preventing growth within the distribution system.

Performance targets define requirements in relation to source water quality. Ideally this should be based on system specific data but more commonly targets will be specified in relation to broad categories of source water quality and type. The derivation of performance targets requires the integration of factors such as tolerable disease burden (acceptable risk), including severity of disease outcomes or Quantitative Microbial Risk Assessment. It is not realistic or desirable to derive performance targets for all potentially waterborne pathogens because data is insufficient and resources are limited. The practical approach is to derive targets for reference pathogens representing groups of pathogens (e.g. bacteria, viruses and protozoa). Selection of reference pathogens should take into account variations in susceptibility to treatment as well as local conditions, including prevalence of waterborne transmission and source water characteristics.

The most common application of performance targets is in identifying appropriate combinations of treatment processes to reduce pathogen concentrations in source water to a level that will meet health outcome targets and hence meet the requirements for water safety.

Performance targets can be applied to catchment controls which are aimed at reducing pathogen concentrations through preventive measures and to measures to prevent ingress of contamination through distribution systems. Performance targets are also important in certification of point-of-use devices and specified technologies used for drinking-water treatment.

Performance targets can be applied to chemical hazards. In comparison to targets for microbial hazards they are typically applied to specific chemicals with performance measured in terms of percentage reduction e.g. for fluoride, iron and manganese treatment

2.1.1.2.4 Specified technology targets

Specified technology targets typically take the form of recommendations concerning technologies applicable in certain circumstances (e.g. filtration and disinfection of surface water). Selection of technologies is usually based on qualitative assessments of source water type and quality (e.g. impacted surface water, protected groundwater). Specified technology targets are most frequently applied to small community supplies and to devices used at household level. They can be applied to both microbial and chemical hazards.

Smaller municipal and community drinking-water suppliers often have limited resources and ability to develop individual system assessments and health based targets. National regulatory agencies (e.g. Ghana Standards Authority and Community Water Sanitation Agency) may therefore directly specify technology requirements or approved options. This may include, for example: specific and approved treatment processes in relation to source types and characteristics providing guidance on requirements for protection of well heads and, requirements for protection of drinking-water quality in distribution systems.

It is important to review specified targets on a regular basis to ensure that they are kept up to date in terms of the prevailing scientific knowledge about the technology and its application.

2.1.2 Stakeholders collaboration

What needs to be done

1. *Identify all stakeholders who could affect, or be affected by, decisions or activities of the drinking water supplier.*
2. *Develop appropriate mechanisms and documentation for stakeholder commitment and involvement.*
3. *Regularly update the list of relevant agencies.*

Several aspects of drinking water quality management require involvement with other organizations. For example, collaboration with the appropriate agency is necessary where catchments and source waters are beyond the drinking water supplier's jurisdiction. Similarly, consultation with relevant health and other regulatory authorities is necessary for establishing many elements of drinking water quality management, such as monitoring and reporting requirements, emergency response plans and communication strategies.

The range of organizations involved in individual water supply systems will vary depending on local organizational and institutional arrangements. Agencies may include:

- Health and environment protection authorities such as Ghana Health Service and Environmental Protection Agency (EPA)
- Catchment and water resource management (Water Resource Commission)
- Local government and planning authorities (District Assemblies)
- Non-government organizations (NGOs)
- Community-based groups (WSMTs, WATSAN committees, care takers etc.)

An integrated management approach with collaboration from all relevant organizations is essential for effective drinking water quality management. All major stakeholders that could affect (e.g. regulators, catchment basins) or be affected by (e.g. consumers, industry) decisions or activities of the drinking water supplier should be identified. The list of major stakeholders in water sectors with mandated roles and responsibilities is presented in Annexure 7.2. The list of stakeholders should be regularly updated.

The various agencies involved should be encouraged to define their accountabilities and responsibilities to support the drinking water supplier and, where appropriate, to coordinate their planning and management activities. Appropriate mechanisms and documentation should be established for stakeholder commitment and involvement. This may include establishing working groups, committees or task forces, with appropriate representatives, and development of partnership agreements, including signed memoranda of understanding.

2.1.3 Policy and regulatory requirement

What needs to be done

1. *Identify and document all relevant regulatory and formal requirements.*
2. *Ensure responsibilities are understood and communicated to employees.*
3. *Review requirements periodically to reflect any changes.*

Drinking water quality management may be subject to a range of regulatory and other formal requirements such as:

- National legislation and regulation;
- Operating licenses and agreements;
- Contracts and agreed levels of service;
- Memoranda of understanding among organizations

All relevant regulatory and formal requirements should be identified and documented (e.g. existing MoU between WRC and EPA on water quality monitoring of basins and data sharing). Individual drinking water suppliers need to understand their responsibilities in supplying water to their particular jurisdictions.

Relevant information should be communicated to employees and a registry of relevant regulations and other requirements should be readily accessible for reference. This registry should be regularly reviewed and updated as necessary to reflect any changes.

2.1.4 Organizational drinking water quality policy

What needs to be done

1. *Formulate in-house drinking water quality policy, endorsed by senior executive, to be implemented throughout the organization.*
2. *Ensure that the policy is visible and is communicated, understood and implemented by employees.*

Development of an in-house drinking water quality policy is an important step in formalizing the level of service to which the drinking water supplier is committed and in increasing focus on water quality management throughout the organization. The policy provides the basis on which all subsequent actions can be judged. It should define the organization's commitments and priorities relating to drinking water quality management.

The drinking water quality policy should provide a basis for detailed implementation strategies. As such, it should be clear and concise, and should address broad issues and requirements of the organization's commitment and approach to drinking water quality management. The policy may cover issues such as:

- Commitment to drinking water quality management;
- The level of service provided and the involvement of employees;

- Compliance with relevant regulations and other requirements;
- Liaison and cooperation with relevant agencies including health departments and other regulators;
- Communication with employees and the public;
- Intention to adopt best practice management and multiple barriers;
- Continual improvement in the management of drinking water quality.

In developing the drinking water quality policy, the opinions and requirements of employees, consumers and other stakeholders should be considered. Management should ensure that the policy is highly visible, continually communicated, understood and implemented by all employees of the organization. It is the responsibility of all employees to support this commitment. Box 1 provides an example of a generic drinking water quality policy.

Box 1 Example of a drinking water quality policy

The organization is committed to managing its water supply effectively to provide a safe, high-quality drinking water that consistently meets the National water quality standards, and consumer and other regulatory requirements.

To achieve this, in partnerships with stakeholders and relevant agencies, the organization will:

- Manage water quality at all points along the delivery chain from source water to the consumer end;
- Use a risk-based approach in which potential threats to water quality are identified and balanced;
- Integrate the needs and expectations of our consumers, stakeholders, regulators and employees into our planning;
- Establish regular monitoring of the quality of drinking water and effective reporting mechanisms to provide relevant and timely information, and promote confidence in the water supply and its management;
- Develop appropriate contingency planning and incident response capability;
- Participate in appropriate research and development activities to ensure continued understanding of drinking water quality issues and performance;
- Contribute to the debate on setting regulations and guidelines, and other standards relevant to public health and the water supply systems;
- Continually improve our practices by assessing performance against corporate commitments and stakeholder expectations.

The organization will implement and maintain a drinking water quality management system consistent with the Ghana Standards Authority (GSA) standards to manage effectively the risks to drinking water quality.

All managers and employees involved in the supply of drinking water are responsible for understanding, implementing, maintaining and continuously improving the drinking water quality management system.

2.2 Water supply system analysis and management "Water Safety Plans" (Component-2)

This section describe the water safety plans i.e. water supply system analysis and management which is made up of following four sub-components:

1) Assessment of the drinking water supply system
2) Preventive measures for drinking water quality management
3) Operational procedures and process control
4) Verification of drinking water quality

Detail elaboration of each sub-component is given below;

2.2.1 Assessment of the drinking water supply system

Assessment of the drinking water supply system includes drinking-water supply system analysis, assessment of water quality data, hazard identification and risk assessment. The drinking-water supply system is defined as everything from the point of water source to the consumer and can include:

- Catchments, including surface and ground water systems, points source, rain water harvesting system;
- Storage reservoirs, water impoundment for treatment systems;
- Service reservoirs and distribution systems;
- Household reservoirs and handling of water in household.

Water supply systems includes all type of water supply scheme ranging from households point source e.g. dug-well or hand-pump to a large water supply such as GWCL water supplies and small town water supplies.

Water supply system assessment is an essential prerequisite for subsequent steps in which effective strategies for prevention and control of hazards are planned and implemented. This includes understanding the characteristics of the drinking water system in three ways;

What can go wrong? Identify hazards and hazardous events; *Are control suitable and effective?* Determine and validate the existing control and measures; *How important are the risks?* Access and prioritize risk to public health.

Water quality can be affected at each of these points and because they are all interrelated, integrated management is essential. Generally, a drinking water supplier is only responsible for delivery of water to the consumer. However, although it is not possible to control consumers' actions, suppliers should consider through relevant organization how drinking water quality may be affected during handling and storage at households and provide appropriate information to consumers to maintain water safety and protect health. Additional guidance and information on water supply assessment of common water supply system is provided in the Appendix 6.1.

2.2.1.1 Analysis of water supply system:

What needs to be done

1. *Assemble a team with appropriate knowledge and expertise.*
2. *Construct a flow diagram of the water supply system from catchment to consumer.*
3. *Assemble pertinent information and document key characteristics of the water supply system.*
4. *Periodically review the water supply system analysis.*

Effective system management requires, first and foremost, an understanding of the water supply system from catchment to consumer. Each element of the water supply system should be characterized with respect to drinking water quality and the factors that affect it. This characterization promotes understanding of the water supply system, and assists with identification of hazards and assessment of risks to water quality.

Assemble team: A team with appropriate knowledge and expertise should be assembled to carry out the analysis. In case of big water supply schemes such as some of GWCL and small town water supply systems, the team should include management and operations staff from the drinking water supplier as well as representatives from relevant agencies. In most cases, consultation with Water Resource Commission and Environmental Protection Agency, Local Authorities will be required for the analysis of catchments, which should include the potential impacts of land uses on water quality and stream and river flows. Health and other regulatory agencies should also be involved.

***Flow diagram*:** A generalized flow diagram should be constructed describing the water supply system from catchment to consumer. The diagram should:

- Outline all steps and processes, whether or not they are under control of the drinking water supplier;
- Summarize the basic characteristics of each component;
- Make explicit any characteristics that are unique to the system;
- Be verified by field audits and checked by those with specific knowledge of the system.

The water supply system analysis should be reviewed periodically to incorporate any changes that occur, for example in land use, industrial activity, treatment processes or consumer distribution lines.

2.2.1.2 Assessment of water quality data

What needs to be done

1. *Assemble historical data from source waters, treatment plants and finished water supplied to consumers.*
2. *List and examine exceedances of the characteristics.*
3. *Assess data using tools such as trends analysis to identify trends and potential problems.*

A review of historical water quality data can assist in understanding source water characteristics and system performance both over time and following specific events such as heavy rainfall or extended drought. This can help in identifying hazards and aspects of the drinking water system that need improvement.

Where available, water quality data should be assessed from monitoring of source waters, the operation of treatment processes, and drinking water as supplied to consumers. Trends analysis can be valuable tools for recognizing potential problems or hazards and the accumulation of any gradual changes or cumulative effects.

2.2.1.3 Hazard identification and risk assessment

What needs to be done

1. *Define the approach and methodology to be used for hazard identification and risk assessment.*
2. *Identify and document hazards, sources and hazardous events for each component of the water supply.*
3. *Estimate the level of risk for each identified hazard or hazardous event.*
4. *Evaluate the major sources of uncertainty associated with each hazard and hazardous event and consider actions to reduce uncertainty.*
5. *Determine significant risks and document priorities for risk management.*
6. *Periodically review and update the hazard identification and risk assessment to incorporate any changes.*

Effective risk management requires identification of all potential hazards, their sources and hazardous events, and an assessment of the level of risk presented by each. A structured approach is important to ensure that significant issues are not overlooked and that areas of greatest risk are identified.

The distinction between hazard and risk is important (see Box 2), attention and resources need to be directed to actions selected primarily on the basis of level of risk, rather than just the existence of a hazard. Realistic expectations of hazard identification and risk assessment are important. Rarely will enough knowledge be available to complete a detailed quantitative risk assessment. Hazard identification and risk assessment are predictive activities that will often include subjective judgments, and will inevitably contain uncertainty. Given these inherent limitations, flexibility is vital, to ensure an effective response when the unexpected occurs. Staff should have a realistic understanding of the limitations of these predictions.

Box 2

A hazard *is a biological, chemical, physical or radiological agent that has the potential to cause harm.*

A hazardous event *is an incident or situation that can lead to the presence of a hazard (what can happen and how).*

Risk *is the likelihood of identified hazards causing harm in exposed populations in a specified timeframe, including the severity of the consequences.*

Example: *The protozoan parasite Cryptosporidium partum is a hazard; failure at a water treatment plant leading to Cryptosporidium partum passing into the distribution system is a hazardous event; and the likelihood of the organism being present in source water and passing through the treatment plant in sufficient numbers to cause illness is a risk.*

A consistent methodology should be established for both hazard identification and risk assessment.

The methodology needs to be transparent and fully understood by everyone involved in the process. Staff should be included and need to be aware of the outcomes of the risk assessment.

Hazard identification: Hazardous agents include microbial, chemical, physical and radiological agents. All potential hazards, sources and events that can lead to the presence of these hazards (what can happen and how) should be identified and documented for each component of the water supply system, regardless of whether or not the component is under the direct control of the drinking water supplier. This includes point sources of pollution (e.g. human, animal and industrial waste discharges, illegal mining's) as well as diffuse sources (e.g. those arising from agricultural and animal husbandry activities). Continuous, intermittent or seasonal pollution patterns should also be considered, as well as extreme and infrequent events such as droughts or floods.

The hazard identification and risk assessment should be reviewed and updated periodically because changing conditions may introduce important new hazards or modify risks associated with identified hazards.

Risk assessment: Once potential hazards and their sources have been identified, the level of risk associated with each hazard or hazardous event should be estimated so that priorities for risk management can be established and documented. Although there are numerous contaminants that can compromise drinking water quality, not every potential hazard will require the same degree of attention.

The level of risk for each hazard or hazardous event can be estimated by identifying the likelihood of occurrence (e.g. certain, possible, rare) and evaluating the severity of consequences if the hazard were to occur (e.g. insignificant, major, catastrophic). The aim should be to distinguish between very high and low risks.

An example of an approach to estimating the level of risk is provided in Tables 5-7. These tables have been adapted from WHO guidelines (WHO, 2011), and can be modified to meet the needs of an organization. A likely outcome of risk assessment is the identification of specific areas where further information and research is required.

Table 5 Qualitative measures of likelihood of risk and impact

Qualitative measures of likelihood	Qualitative measures of consequence or impact
Almost certain: it is expected to occur in most circumstances	**Insignificant:** Insignificant impact, little disruption to normal operation, low increase in normal operation costs
Likely: it will probably occur in most circumstances	**Minor:** Minor impact for small population, some manageable operation disruption, some increase in operating costs
Moderate likely: it might occur or should occur at some time	**Moderate:** Minor impact for large population, significant modification to normal operation but manageable, operation costs increased, increased monitoring
Unlikely: it could occur at some time	**Major:** Major impact for small population, systems significantly compromised and abnormal operation if at all, high level of monitoring required
Rare: it may occur only in exceptional circumstances	**Catastrophic:** Major impact for large population, complete failure of systems

Table 6 Example of a simple scoring matrix for ranking risks

Likelihood	**Severity of consequences**				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	5	**10**	**15**	**20**	**25**
Likely	4	8	**12**	**16**	**20**
Moderately likely	3	6	9	**12**	**15**
Unlikely	2	4	6	**8**	**10**
Rare	1	2	3	4	5

Table 7 Risk scoring and risk rating

Risk score	**<6**	**6-9**	**10-15**	**>15**
Risk rating	**Low**	**Medium**	**High**	**Very high**

Risk prioritization: Based on the assessment of risks, priorities for risk management and application of preventive measures can be established. Risk should be assessed at two levels:

- Maximum risk in the absence of preventive measures; and
- Residual risk after consideration of existing preventive measures.

Assessing maximum risk is useful for identifying high priority risks, determining where attention should be focused and preparing for emergencies. Residual risk provides an indication of the need for additional preventive measures.

Unforeseen and rare events: In well-managed water supply systems, problems should be rare, making them more challenging to anticipate and possibly to counter. This highlights the need to learn constructive lessons from the experiences of other international drinking water suppliers and water agencies. Many problems are triggered by short periods of sudden change, such as heavy rainfall or equipment failure. There are many sets of reports on waterborne disease outbreaks and the events that caused them. Some of these events should have been foreseeable while others have been attributable to more unusual or rare events. Maintaining awareness of such incidents can enable preventive measures to be implemented, to safeguard against similar occurrences (see Box 4, Section 2.2.3).

Uncertainty: There will always be uncertainty associated with hazard identification and risk assessment. Uncertainty can be caused by a lack of knowledge or by variability in parameters. While variability can only be better understood (e.g. by improved characterization of a hazard), uncertainty due to lack of knowledge can be reduced through better measurement and research. For example, uncertainty in our ability to identify the source, human infectivity or infectious dose of *Cryptosporidium* oocysts can be addressed through increased research.

Investigative studies and research monitoring can often provide further information for the risk assessment process and help to reduce uncertainty (see Section 5.3.)

2.2.2 Preventive measures for drinking water quality management

This consist of preventive measures, multiple barriers and critical control points. Prevention is an essential feature of effective drinking water quality management. Preventive measures are those actions, activities and processes used to prevent hazards from occurring or reduce them to acceptable levels.

Hazards may occur or be introduced throughout the water system and preventive measures should be comprehensive, from catchment to consumer. Many preventive measures may control more than one hazard, while, as prescribed by the multiple barrier approach, effective control of some hazards may require more than one preventive measure.

Planning of preventive measures should always be based on system-specific hazard identification and risk assessment. The level of protection to control a hazard should be proportional to the associated risk. Assessment of preventive measures involves;

- Identifying existing preventive measures from catchment to consumer for each significant hazard or hazardous event;
- Evaluating whether the preventive measures, when considered together, are effective in reducing risk to acceptable levels (i.e. Section 2.2.1.3);
- If improvement is required, evaluating alternative and additional preventive measures that could be applied.

If additional measures are required, factors such as level of risk, benefits, effectiveness, cost, community expectations and willingness to pay should be considered. Preventive measures often require considerable expenditure, and decisions about water quality improvements cannot be taken in isolation from other aspects of water supply that compete for limited financial resources. Priorities will need to be established and many improvements may need to be phased in over time.

All preventive measures are important and should be given ongoing attention. However, some can significantly prevent or reduce hazards and are agreeable to greater operational control than others. These measures could be considered as critical control points (see Section 2.2.2.2).

Additional detail guidance on preventive measures for drinking water quality management is provided in the section 6.1.2.

2.2.2.1 Preventive measures and multiple barriers:

What needs to be done

1. *Identify existing preventive measures from catchment to consumer for each significant hazard or hazardous event and estimate the residual risk.*
2. *Evaluate alternative or additional preventive measures where improvement is required.*
3. *Document the preventive measures and strategies into a plan addressing each significant risk.*

Identifying and implementing preventive measures should always be undertaken within the context of a multiple barrier approach, so that failure of one barrier will be compensated by effective operation of the remaining barriers. This minimizes the likelihood that contaminants will pass through the entire treatment system to be present in sufficient amounts to cause harm to consumers. Traditional preventive measures are incorporated in the multiple barriers, including:

- Catchment management and source water protection;
- Detention in protected reservoirs and storages;
- Extraction management;
- Coagulation, flocculation, sedimentation and filtration;
- Disinfection;
- Protection and maintenance of the distribution system
- Household water treatment and safe storage

The types of barriers required and the range of preventive measures employed will be different for each water supply and will generally be influenced by characteristics of the source water and surrounding catchment (see below Box 3). Selection of appropriate barriers and preventive measures will be informed by hazard identification and risk assessment.

Box 3 Examples of multiple barriers

Most parts of rural areas are supplied with ground-water source such as dug-well or bore-well fitted with hand pump or small mechanized pump. District Water Sanitation Teams focuses much of its attention and resources on maintaining prevention of contamination during distribution and handling of water. The series of barriers for the majority of such water supply system include:

- Protection of well surrounding
- Improved distribution system
- Household water treatment such as boiling, use of bleach and safe storage at residence

In contrast, most Urban areas are supplied with surface water derived from multi-use catchments and the rivers, where there is limited control over activities with potential impacts on water quality. As a result, the barriers applied are heavily weighted towards water treatment and downstream control to remove turbidity and microorganisms. Barriers include the use of multiple storage reservoirs, coagulation, flocculation, sedimentation, filtration and disinfection with long contact times before supply. Provision of residual disinfectant through large parts of the distribution system is also an important barrier for such systems.

2.2.2.1.1 Catchment management and source water protection

Catchment management and source water protection provide the first barrier for the protection of surface water quality. Where catchment management is beyond the jurisdiction of drinking water suppliers, the planning and implementation of preventive measures will require a coordinated approach with relevant agencies such as Water Resource Commission and Environmental Protection Authority. Effective catchment management and source water protection include the following elements:

- Developing and implementing a catchment management plan which includes preventive measures to protect surface water and groundwater;
- Ensuring that planning regulations include the protection of water resources from potentially polluting activities and are enforced (e.g. buffer zone policy);
- Promoting awareness in the community of the impact of human activity on water quality.

Whether water is drawn from surface catchments or underground sources, it is important that the characteristics of the local catchment or aquifer are understood, and the scenarios that could lead to water pollution are identified and managed. The extent to which catchment pollution can be controlled is often limited in practical terms by competition for water and pressure for increased development in the catchment or presence of geogenic contaminants.

Effective catchment management has additional benefits. By decreasing contamination of source water, the amount of treatment and quantity of chemicals needed is reduced. This may lead to health benefits through reducing the production of treatment by-products, and economic benefits through minimizing operational costs.

In surface water catchments, preventive measures can include:

- Selection of an appropriate source water (where alternatives exist);
- Exclusion or limitations of uses (e.g. restrictions on human access and agriculture);
- Protection of waterways (e.g. fencing out livestock, management of buffer zones);
- Use of planning and environmental regulations to regulate potential water-polluting developments (e.g. urban, agricultural, industrial, mining and forestry);
- Regulation of community and on-site wastewater treatment and disposal systems;

Groundwater from depth is generally microbiologically safe and chemically stable; however, shallow or unconfined aquifers can be subject to contamination from discharges or seepages associated with agricultural practices (pathogens, nitrates and pesticides), septic tank discharges (pathogens and nitrates) and industrial wastes. Preventive measures for groundwater supplies should include protecting the aquifer and the local area around the bore-head from contamination and ensuring the physical integrity of the bore (surface sealed, casing intact etc.).

2.2.2.1.2 Detention in reservoirs or storages

Detention of water in reservoirs can reduce the number of fecal microorganisms through settling and inactivation, including solar (ultraviolet) disinfection. Most pathogenic microorganisms of fecal origin do not survive indefinitely in the environment. Substantial die-off of enteric bacteria will occur over three to four weeks. Enteric viruses and protozoa will survive for longer periods (weeks to months). Detention also allows suspended material to settle, which makes subsequent disinfection more effective and reduces the formation of disinfection by-products.

Other preventive measures in reservoirs and storages include:

- Reservoir mixing or destratification to reduce growths of cyanobacteria (taste, odor and toxin production);
- Excluding or restricting human, domestic animal and livestock access;
- Diversion of local storm water flows.

2.2.2.1.3 Extraction management

Where a number of water sources are available, there may be flexibility in the selection of water for treatment and supply. In such a situation it may be possible to avoid taking water from rivers and streams when water quality is poor (e.g. following heavy rainfall) in order to reduce risk and prevent problems in subsequent treatment processes.

Within a single water body, selective use of multiple extraction points can provide protection against localized contamination, either horizontally or vertically through the water column (e.g. algal blooms).

2.2.2.1.4 Water treatment

Coagulation, flocculation, sedimentation (or flotation) and filtration remove particles, including microorganisms (bacteria, viruses and protozoa). It is important that operations are optimized and controlled to achieve consistent and reliable performance. As an alternative to conventional media-based processes, membrane filtration provides a direct physical barrier and generally achieves a greater removal of microorganisms.

Care should be taken in the selection and use of water treatment chemicals as they may contain undesirable contaminants. In addition, there can be variation in performance of the same chemical obtained from different sources.

Disinfection: The most commonly used disinfection process is chlorination, but ozone, ultraviolet irradiation and chlorine dioxide could also be used. These methods are very effective in killing bacteria and can be reasonably effective in inactivating viruses (depending on type) and many protozoa, including *Giardia. Cryptosporidium* is not inactivated by the concentrations of chlorine that can be safely used in drinking water, and the effectiveness of ozone and chlorine dioxide is limited with this organism. However, there is some evidence that ultraviolet light might be effective in inactivating *Cryptosporidium*, and that combinations of disinfectants can enhance inactivation.

Storage of water after disinfection and before supply to consumers can improve disinfection by increasing contact times. This can be particularly important for microorganisms, such as *Giardia* and viruses.

Providing a disinfectant residual throughout the distribution system can provide protection against contamination and limit regrowth problems; however, the issue of disinfection by-products needs to be considered.

2.2.2.1.5 Protection and maintenance of the distribution system:

Water distribution systems should be fully enclosed and storages should be securely roofed with external drainage to prevent contamination. Backflow prevention policies should be applied and monitored. There should also be effective maintenance procedures to repair faults and burst mains in a way that will prevent contamination. Positive pressure should be maintained throughout the distribution system. Appropriate security needs to be put in place to prevent unauthorized access to, or interference with, water storages.

Corrosion of pipes, including those on customer premises, can result in leaching of metals, with implications for public health (e.g. copper, cadmium and lead) or aesthetic quality (e.g. copper, iron and zinc). This should be monitored. Growth or persistence of biofilms should be minimized to reduce aesthetic problems, including unacceptable tastes, odors and staining.

Adequate training of maintenance workers, including contractors, care taker, WATSAN committee and WSMT responsible for the distribution system is essential because of the potential for contamination during repairs and new installations.

2.2.2.2 Critical control points

What needs to be done

1. *Assess preventive measures from catchment to consumer to identify critical control points.*
2. *Establish mechanisms for operational control (see Section 2.2.3).*
3. *Document the critical control points, critical limits and target criteria.*

A critical control point is defined as an activity, procedure or process at which control can be applied and which is essential to prevent a hazard or reduce it to an acceptable level and ensure that the health-based targets are met.

From among the preventive measures, critical control points should be identified for those hazards that represent a significant risk and require elimination or reduction to assure supply of safe drinking water. Not all preventive measures are feasible to selection as critical control points. A critical control point has several operational requirements, such as;

- Operational parameters that can be measured and for which critical limits can be set to define the operational effectiveness of the activity (e.g. chlorine residuals for disinfection);
- Operational parameters that can be monitored frequently enough to reveal any failures in a timely manner (online and continuous monitoring is preferable);
- Procedures for corrective action that can be implemented in response to deviation from critical limits.

Critical limits are performance criteria that separate acceptability from unacceptability in terms of hazard control and water safety. They should be chosen carefully and should not be confused with target criteria (see Section 2.2.3.2). Critical limits may incorporate a numerical value as well as a consideration of time (e.g. failure to provide a minimum chlorine residual for a specified time).

Deviation from critical limits indicates loss of control of the process or activity and should be regarded as representing a potentially unacceptable health risk. Such events should result in immediate notification of the appropriate health regulator. Discussion of target criteria and critical limits is included in Section 2.2.3.2, and more detailed explanation of critical control points and their requirements is provided in Section 6.2.5.2 of the Appendix.

2.2.3 Operational procedures and process control

The effectiveness of preventive measures is highly dependent upon the design and implementation of associated process control programs. To consistently achieve a high-quality water supply it is essential to have effective control over the processes and activities that govern drinking water quality. Operational procedure and process control consist of;

- operational procedures and process control programs;
- operational monitoring;
- corrective action;
- treatment equipment capability and maintenance; and
- materials and chemicals used in treatment

Periods of sudden change and sub-optimal performance in the drinking water supply system can represent a serious risk to public health (see Box 4). Therefore, it is vital to ensure that all operations are optimized and are continuously controlled, and that barriers are functional at all times.

Process control programs support preventive measures by detailing the specific operational factors that ensure that all processes and activities are carried out effectively and efficiently. This includes a description of all preventive measures and their functions, together with:

- Documentation of effective operational procedures, including identification of responsibilities and authorities;
- Establishment of a monitoring protocol for operational performance, including selection of operational parameters and criteria, and the routine review of data;
- Establishment of corrective actions to control excursions in operational parameters;
- Use and maintenance of suitable equipment;
- Use of approved materials and chemicals in contact with drinking water.

Effective implementation of these programs relies on the skills and training of operations staff. Operators should be proficient, have the ability to interpret the significance of changes in water quality and treatment, and be able to respond appropriately in accordance with established procedures (see Section 5.1).

Process control programs should be documented in operations manuals, with controlled copies readily accessible to all appropriate personnel. One option is to organize each manual into sections dealing with the individual components of the water supply system. Documentation should include a description of:

- Preventive measures and their purpose;
- Operational procedures for relevant activities;
- Operational monitoring protocols, including parameters and criteria;
- Schedules and timelines;
- Data and records management requirements;
- Corrective actions to be implemented and maintenance procedures;
- Responsibilities and authorities;
- Internal and external communication and reporting requirements.

Box 4 Examples of outbreaks resulting from sub-optimal performance

1-Walkerton outbreak (O'Connor, 2002)

A public inquiry into the outbreak and its implications for the safety of drinking water in Ontario Canada reported over 2000 cases of illness and seven deaths. Public health investigations confirmed that the most severe illnesses were caused by *Escherichia coli* 0157 and *Campylobacter*. The shallow groundwater supply appears to have been contaminated by cattle waste following heavy rains and localized flooding. A large number of faults have been proposed as potential contributing factors to the outbreak, including:

- Reliance on bores subject to the direct influence of surface run-off, with only chlorination for treatment;
- Operation and monitoring on the assumption that the bores were secure, deep groundwater sources;
- Inadequate protection of surface catchments near the water supply bores;
- Deficient chlorination practice;
- Inadequate regulatory oversight;
- Unreliable chlorine residual monitoring;
- Failure to respond to the detection of contamination;
- Failure to communicate the results to regulatory authorities;
- Inadequate operator training and corporate commitment.

Box 4 Examples of outbreaks resulting from sub-optimal performance *(Continue)*

2-Milwaukee outbreak (MacKenzie WR, 1994)

An assessments in 1994 into outbreak in Milwaukee (USA) indicated that over 400,000 illnesses were caused, including 4400 hospitalized. The source of the contamination was not identified but it is considered that increased flows in rivers supplying Lake Michigan could have carried oocysts from livestock wastes or human sewage. Turbidity of the water taken from the lake deteriorated in the weeks preceding the outbreak.

Operation of one of the treatment plants supplying Milwaukee was not under optimal control. Although coagulant doses were adjusted, this did not prevent turbidity fluctuations in filtered water produced at one filtration plant (0.1–2.7 nephelometric turbidity units). Inexperience with the use of polyaluminium chloride, which had been a recent introduction, could have been a contributing factor. In addition, monitors intended to optimize coagulant doses during changes in water quality were not being used due to improper installation, and filtered water turbidity meters were not being used. Turbidity measurements were being taken every eight hours.

Recycling of backwash water through the filtration process could also have had an impact on the numbers of oocysts passing through the plant. Other water treatment deficiencies associated with outbreaks of cryptosporidiosis have included:

- Failure to respond to deterioration in source water quality;
- Poor coagulation;
- Poor monitoring of chemical dosing;
- Inadequate flocculation;
- Filters brought on line without backwashing.

2.2.3.1 Operational procedures and process control

What needs to be done

1. *Identify procedures required for processes and activities from catchment to consumer.*
2. *Document all procedures and compile into an operations manual.*

The proper maintenance and operation of water supply, treatment and distribution systems are essential to ensure the provision of consistently good quality water. Detailed procedures are required for the operation of all processes and activities from catchment to consumer, including preventive measures, operational monitoring by trained staff and regular inspection of facilities, maintenance requirements. Procedures are most effective when operations staff are involved in their development, documentation and verification.

2.2.3.2 Operational monitoring

What needs to be done

1. *Develop monitoring protocols for operational performance of the water supply system, including the selection of operational parameters and criteria, and the routine analysis of results.*
2. *Document monitoring protocols into an operational monitoring plan.*

Operational monitoring are planned observations or measurements to assess whether the control measures in a drinking-water system are operating properly. In most cases, operational monitoring will be based on simple and rapid observations or tests, such as turbidity, residual chlorine, pH or structural integrity, rather than complex microbial or chemical tests. Observations could include activities such as regular inspections of the catchment (e.g. for integrity of fences), plant equipment, wellhead protection areas, storage reservoirs and tanks. Data from operational monitoring can be used as triggers for immediate short-term corrective actions to improve drinking water quality. The general intent of operational monitoring is different from that of drinking water quality monitoring (see Section 2.2.4.1).

Key elements of operational monitoring include:

- Development of operational monitoring plans from catchment to consumer, detailing strategies and procedures;
- Identification of the parameters and criteria to be used to measure operational effectiveness and, where necessary, trigger immediate short-term corrective actions;
- Ongoing review and interpretation of results to confirm operational performance.

Further guidance on operational monitoring is provided in section 6.3.

Operational parameters: Operational parameters should be selected that reflect the effectiveness of each process or activity, and provide an immediate indication of performance. Typically, operational monitoring should focus on parameters that can be readily measured and enable a rapid response. To fulfil these requirements, indicators are often used as operational parameters rather than direct measurement of the hazards themselves. For example, turbidity may be used as an indicator for *bacteriological contamination*. More detail on surrogates is provided in section 6.2.5.1.

Operational parameters should be monitored with sufficient frequency to reveal any failures in good time. Online and continuous monitoring should be used wherever possible, particularly at critical control points.

Target criteria and critical limits: Once operational parameters are identified, target criteria (performance goals) should be established for each preventive measure. These criteria can be quantitative (numerical) or qualitative (descriptive). Any deviation of performance from established targets should be regarded as a trend towards loss of control of the process, and appropriate action should be taken to resolve potential problems.

For preventive measures identified as critical control points for the water supply system, critical limits must also be defined and validated. A critical limit is a prescribed tolerance that distinguishes acceptable from unacceptable performance at a critical control point. When a critical control point is operating within the prescribed limits, performance in terms of hazard removal is regarded as being acceptable. While, exceedance of or deviation from a critical limit represents loss of control of a process and indicates an unacceptable health risk. Corrective actions should immediately be instituted to resume control of the process, and the health regulator should be notified.

Setting target criteria that are more stringent than critical limits at critical control points will enable corrective actions to be instituted before an unacceptable health risk occurs. Exceedance of a target criterion at a critical control point would generally not require that the health regulator be notified, providing corrective action successfully prevented deviation from a critical limit. Section 6.2.5.2 provides more explanation of target criteria, critical limits and monitoring at critical control points.

Analysis of results: Results must be reviewed frequently to confirm that records are complete and accurate, and that there are no deviations from critical limits or target criteria. Where results indicate that control has been lost, appropriate corrective actions and process adjustments should be instituted to maintain quality. Those responsible for interpreting and recording operational results should clearly understand how the results should be assessed.

A system should be established for regular reporting of operational monitoring results to relevant staff and departments. Methods such as graphs or trend charts can be used to facilitate the interpretation of operational monitoring results. More guidance on short-term evaluation of results for assessing drinking water safety is provided in section 6.8.1.

2.2.3.3 Corrective action

What needs to be done

1. *Establish and document procedures for corrective action to control excursions in operational parameters.*
2. *Establish rapid communication systems to deal with unexpected events.*

Procedures should be developed for immediate corrective action to re-establish process control following failure to meet target criteria or critical limits. Adoption of internal operating standards that are more stringent than the Ghana Standard Authority (GSA) Drinking-Water Quality Standards and acting when these internal standards have been exceeded, will reduce the chances of exceeding GSA limits in the final waters. Operating procedures should be documented and include instructions on required adjustments and process control changes and should clearly define responsibilities and authorities including communication and notification requirements.

Examples of possible corrective actions for which operational procedures should be documented include:

- Selection of an alternative raw water source if available;
- Altering the plant flow rate (e.g. reducing loading);
- Jar testing for coagulant control and optimization;

- Altering the mixing intensity;
- Changing treatment chemicals;
- Using auxiliary chemicals such as coagulant aids, flocculants aids, filtration aids;
- Adjusting pH;
- Varying chemical feed rates and feed points;
- Adjusting filtration loading rate or operation;
- Increasing disinfectant dose;
- Secondary or booster disinfection;
- Mains flushing, cleaning and localized disinfection.

After implementing a corrective action, its effectiveness will need to be verified. This usually requires additional monitoring. Secondary impacts of the corrective action, and whether adjustments or action is needed further along in the supply system, should also be considered.

Where possible, the underlying cause of a problem should be identified and measures implemented to prevent future occurrences. An analysis of the causes may identify some solutions such as modifying an operating procedure, process control adjustments and operator training. Finally, details of the incident should be recorded and reported.

While advance planning is important, it will not always be possible to anticipate every type of event. Rapid communication systems should be established to deal with these events. Incident and emergency responses should be prepared for times when normal corrective actions cannot re-establish operational performance quickly enough to prevent drinking water of unacceptable quality from reaching consumers. Section 6.8.1 provides more discussion of corrective actions.

2.2.3.4 Water supply equipment capability and maintenance

What needs to be done

1. *Ensure that equipment performs adequately and provides sufficient flexibility and process control.*
2. *Establish a program for regular inspection/maintenance of all equipment, including monitoring equipment.*

The capability of equipment is an important consideration in maintaining process control. Equipment and infrastructure in a drinking water supply system need to be adequately designed and of sufficient capacity (size, volume, detention times) to handle all flow rates (peak and otherwise) without limiting performance. Processes should not be hydraulically overloaded or subjected to rapid changes in hydraulic loading, as these conditions may compromise performance. Ideally the design features that can improve performance and process control include:

- Online measuring devices that monitor operational parameters continuously;
- Automated responses to changes in water quality;
- 24-hour monitored alarm systems that indicate operational failure;
- Backup equipment, including power generators;
- Variable control of flow rates and chemical dosing;
- Effective mixing facilities.

Design of new equipment and processes should undergo validation through appropriate research and development (see Section 5.3).

Equipment used to monitor process performance should also be selected carefully. Monitoring equipment needs to be sufficiently accurate and sensitive to perform at the levels required. Wherever possible, monitoring should be online and continuous, with alarm systems to indicate when operational criteria have been exceeded. Monitoring failures should not compromise the system and in some cases, particularly at critical control points, backup equipment should be considered. Staff should understand the operation of monitoring equipment so that causes of spurious results can be recognized and rectified.

Regular inspection and maintenance of all equipment from catchment to consumer is required to ensure continuing process capability. A maintenance program should be established and documented, detailing:

- Standards operational procedures and records for the maintenance of equipment, including the calibration of Monitoring equipment;
- Schedules and timelines;
- Responsibilities;
- Resource requirements.

2.2.3.5 Water treatment materials and chemicals

What needs to be done

1. *Ensure that only approved materials and chemicals are used.*
2. *Establish documented procedures for evaluating chemicals, materials and suppliers.*

The selection of materials and chemicals used in water supply systems is an important consideration as potentially they may have an adverse effect on drinking water quality. Chemicals added to water include disinfectants, oxidants, coagulants, flocculants, algicides, antioxidants and chemicals for softening, pH adjustment and scale prevention.

All chemicals used should be evaluated for potential contamination. General considerations include data on impurities, chemical and physical properties, maximum dosages and behavior in water. In addition, the potential impact of water treatment chemicals on materials used in treatment plants needs to be considered. For example, ferric chloride used as a coagulant is extremely corrosive and can have severe effects on commonly used grades of stainless steel. Contaminants may also be introduced when water comes into contact with materials such as filter media, protective coatings, linings and liners, joining and sealing products, pipes and fittings, valves, meters and other components. Chemical suppliers should be evaluated and selected on their ability to supply product in accordance with required specifications for drinking water use. Documented procedures for the control of chemicals, including purchasing, verification, handling, storage and maintenance, should be established to assure the quality of the chemicals at the point of application.

2.2.4 Verification of drinking water quality

It includes drinking-water quality monitoring, consumer satisfaction, short-term evaluation of results and corrective actions. Verification of drinking water quality provides an assessment of the overall performance or compliance of the system and the ultimate quality of drinking water being supplied to consumers. This incorporates monitoring drinking water quality as well as assessment of consumer satisfaction. It provides indication of problems within the water supply system (particularly the distribution system) and the necessity for any immediate short-term corrective actions or incident and emergency response; and confidence for consumers and regulators regarding the quality of the water supplied. Section 6.3 provides more information on verification of drinking water quality.

2.2.4.1 Drinking water quality monitoring (Compliance Monitoring)

What needs to be done

1. *Determine the characteristics to be monitored in the distribution system and at consumer end.*
2. *Establish and document a sampling plan for each characteristic, including the location and frequency of sampling.*
3. *Ensure monitoring data are representative and reliable.*

Drinking water quality monitoring is a wide-ranging assessment of the quality of water in the distribution system and, importantly, as supplied to the consumer. It includes regular sampling and testing to assess whether water quality is meeting the National standards and any regulatory requirements or agreed levels of service.

Monitoring of drinking water quality should be regarded as the final check by the water supply agency that, overall, the barriers and preventative measures implemented to protect public health are working effectively. The purpose of drinking water quality monitoring is different from that of operational monitoring and the two types of monitoring also differ in what, where and how often water quality characteristics are measured. Although demonstrating compliance with regulatory limits is necessary as verification, it should be recognized that monitoring of drinking water quality is only one aspect of an overall preventative strategy to assure a safe and reliable drinking water supply. Monitoring for drinking water quality should never be used as a replacement for any of the barriers or as a reason for removing them.

As it is neither physically nor economically feasible to test for all drinking water quality parameters equally, monitoring effort and resources should be carefully planned and directed at significant or key characteristics.

Key characteristics related to health include:

- Microbial indicator organisms;
- Disinfectant residuals and any disinfection by-products;
- Any health-related characteristic that can be reasonably expected to exceed the National standards value, even if occasionally;

- Potential contaminants identified in analysis of the water supply system (Section 2.2.1.1) and hazard identification (Section 2.2.1.3).

In addition to characteristics related to health, those with significant aesthetic impact (e.g. taste, odor) may also need to be monitored.

Sampling locations will depend on the water quality characteristic being examined. Sampling at the treatment plant or at the head of the distribution system may be sufficient for characteristics where concentrations do not change during delivery; however, for those that can change during distribution, sampling should be undertaken throughout the distribution system, including the point of supply to the consumer.

Frequency of testing for individual characteristics will depend on variability, and whether the characteristics are of aesthetic or health significance. Sampling should be frequent enough to enable the monitoring to provide meaningful information. Sampling and analysis are required most frequently for microbial constituents, and less often for organic and inorganic compounds. This is because even brief episodes of microbial contamination can lead to immediate illness in consumers, whereas, in the absence of a specific event (e.g. chemical overdosing at a treatment plant), episodes of chemical contamination that would constitute an acute health concern are rare.

Once parameters and sampling locations have been identified, these should be documented in a consolidated monitoring plan. Monitoring data should be representative, reliable and fully validated. Section 6.3.2 provides more information on the monitoring of drinking water quality.

2.2.4.2 Consumer satisfaction

Monitoring of consumer comments and complaints can provide valuable information on potential problems that may not have been identified by performance monitoring of the water supply system.

Consumer satisfaction with drinking water quality is largely based on a judgment that the aesthetic quality of tap water is ‘good’, which usually means that it is colorless, free from suspended solids and has no unpleasant taste or odor.

Changes from the norm are particularly noticeable to consumers, who may interpret aesthetic problems as indicating health risks. A consumer complaint and response program operated by appropriately trained personnel should be established. Response targets should be set and regularly reviewed. Complaints and responses should be recorded and, in the longer term, the types, patterns and changes in numbers of complaints received should be evaluated. Sections 6.3.1 and 6.8.2.4 provides additional information on consumer satisfaction.

2.2.4.3 Short-term evaluation of results

Short-term performance evaluation entails the daily reviewing of drinking water quality monitoring data and consumer satisfaction to verify that the quality of water supplied to consumers conforms to National standards. If the quality does not conform, then immediate corrective actions and/or incident and emergency response should be implemented.

Those responsible for interpreting and recording results should clearly understand how results should be assessed and, if required, how and where they should be communicated. Monitoring results should be reviewed within appropriate timeframes, and compared with previous results, established standard values, and any regulatory requirements or agreed levels of service. Procedures for performance evaluation and recording of results should be established and documented. Mechanisms and responsibilities should be identified for the reporting of results internally within agency and to the senior executives as well as externally, where required, to stakeholders such as regulators and consumers (see Section 5.4.2). Section 6.8.1 provides further discussion on short-term evaluation of results.

2.2.4.4 Corrective action

If the short-term evaluation of drinking water quality monitoring data indicates non-conformance with standard values or other requirements, an investigation should be initiated and, if necessary, corrective action taken as quickly as possible. Failure to take prompt and effective action may lead to the development of a more serious situation, which could require incident and emergency response protocols to be instituted. Corrective action could also be required in response to consumer feedback.

Corrective actions should be developed in consultation with relevant regulatory authorities and other stakeholders. Examples include:

- Disinfection of tanks;
- Flushing and maintenance of the distribution system;
- Temporary shutdown of a treatment plant if adequate storage is available;
- Increased booster or secondary disinfection;
- Enhanced filtration;
- Investigative or sanitary surveys of distribution systems;

Significant system failures that could pose a health risk or adversely affect water quality for an extended period require an immediate response and should also be reported to the relevant health authority (see Section 4).

Corrective actions should be documented, responsibilities and authorities clearly defined, and staff trained in appropriate procedures. Section 6.8.1 provides further discussion on response to monitoring results that are outside specification.

2.3 Validation and Verification of Water Safety Plans (Component-3)

Validation and verification of water safety plans includes;

1. Long-term evaluation of water quality monitoring results,
2. Audit of drinking water quality management
3. Review by senior executive
4. Drinking water quality management improvement plan

The long-term evaluation of water quality monitoring results and audit of drinking water quality management to determine whether preventive strategies are effective and whether they are being implemented appropriately. These evaluations and validation enable performance to be measured against objectives and help to identify opportunities for improvement.

Senior executive support, commitment and ongoing involvement are essential to the continual improvement of the organization's activities relating to drinking water quality. Senior executive should regularly review its approach to drinking water quality management, develop action plans, and commit the resources necessary to improve operational processes and overall drinking water quality performance.

2.3.1 Long-term evaluation of results

What needs to be done

1. *Collect and evaluate long-term data to assess performance and identify problems.*
2. *Document and report results.*

The systematic review of monitoring results over an extended period (typically the preceding 12 months or longer) is needed to:

- Assess overall performance against numerical standards values, regulatory requirements or agreed levels of service;
- Identify emerging problems and trends;
- Assist in determining priorities for improving drinking water quality.

There will certainly be occasions of non-conformance with operational criteria or numerical standard values. Each event will need to be assessed and responses determined.

Mechanisms for evaluation of results should be documented, with responsibilities, accountabilities and reporting requirements defined. Useful tools to enhance the interpretation of data sets include statistical evaluation of results and graphs or trend charts. Evaluation of results should be reported internally to senior executive, and externally to consumers, stakeholders and regulatory authorities in accordance with established requirements (see Section 5.4.2). Providing assurance that data are reviewed regularly and that improvements are made in response to identified problems will contribute to consumer confidence. Section 6.8.2 provides further more guidance on assessing long-term system performance.

2.3.2 Audit of drinking water quality management

What needs to be done

1. *Establish processes for internal and external audits.*
2. *Document and communicate audit results.*

Auditing is the systematic evaluation of activities and processes to confirm that objectives are being met. It includes assessment of the implementation and capability of management systems. Auditing provides valuable information on those aspects of the system that are effective, as well as identifying opportunities to improve poor operational practices.

Periodic auditing of all aspects of the drinking water quality management system is needed to confirm that activities are being carried out in accordance with defined requirements and are producing the required outcomes.

Internal audits are important for maintaining a functional drinking water quality management system and for identifying areas for improvement. Internal audits will involve trained staff and should include a review of the management system and associated operational procedures, monitoring programs, and the records generated. The aim is to ensure that the system is being implemented correctly and is effective. The frequency and schedule of audits should be defined, as should the responsibilities, requirements, procedures and reporting mechanisms. The audit process can take place over time but it should be comprehensive.

Drinking water agencies should consider mechanisms for establishing external auditing. Such auditing can be useful in establishing credibility and maintaining consumer confidence. External auditing could be achieved by peer review or be undertaken by an independent third party. External audits should focus on confirming implementation and results of internal audits.

External audits could be conducted on:

- The management system;
- Operational activities;
- Drinking water quality performance;
- The effectiveness of incident and emergency response or other specific aspects of drinking water quality management.

Audit results should be documented and communicated to management and personnel responsible for the department or function being audited. Results of audits should also be considered as part of the review by senior executive (see next section). Section 6.8.2 provides additional information on review and continual improvement.

2.3.3 Review by senior executive

What needs to be done

1. *Senior executive review of the effectiveness of the management system.*
2. *Evaluate the need for change.*

In order to ensure continual improvement, the highest levels of the organization should maintain oversight of the effectiveness of the drinking water quality management system and evaluate needs for change.

Senior executive should review reports from audits, drinking water quality performance and previous management reviews. The review should also consider concerns of consumers, regulators and other stakeholders, and evaluate the suitability of the drinking water quality policy, objectives and preventive strategies in relation to changing internal and external conditions such as:

- Changes to legislation, expectations and requirements;
- Changes in the activities of the organization;
- Advances in science and technology;
- Outcomes of drinking water quality incidents and emergencies;
- Reporting and communication.

The review by senior executive should be documented.

2.3.4 Drinking water quality management improvement plan

What needs to be done

1. *Develop a drinking water quality management improvement plan.*
2. *Ensure that the plan is communicated and implemented, and that improvements are monitored for effectiveness.*

An improvement plan should be developed to address identified needs for full implementation of the drinking water quality management system. The improvement plan should be endorsed by senior executive. Improvement plans may encompass a wide range of issues such as:

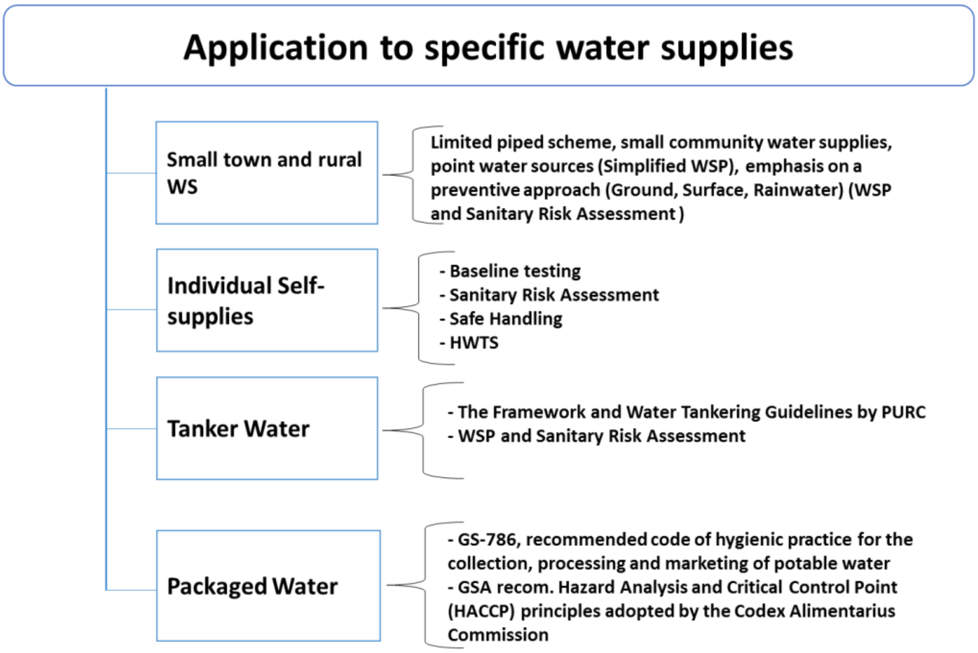
- Capital works;
- Training;
- Enhanced operational procedures;
- Research and development;
- Incident protocols;
- Communication and reporting.

Improvement plans can include short-term (e.g. one year) or long-term programs. Short-term improvements might include actions such as enhanced mains flushing programs, increased staffing, and the development of community awareness programs. Long-term capital works projects could include covering of water storages or enhanced coagulation and filtration.

Improvement plans should include objectives, actions to be taken, accountability, timelines and reporting. They should be communicated throughout the organization and to the community, regulators and other agencies.

Implementation of improvement plans will often have significant budgetary implications and therefore may require detailed cost–benefit analysis and careful prioritization in accord with the outcomes of risk assessment (see Section 2.2.1.3). The organization should adequately budget for and mobilize resources/funds for the implantation of the improvement plan. Implementation of plans should be monitored to confirm that improvements have been made and are effective.

Component-4


Application to specific water supplies
Small town and rural WS
Limited piped scheme, small community water supplies, point water sources (Simplified WSP), emphasis on a preventive approach (Ground, Surface, Rainwater) (WSP and Sanitary Risk Assessment)
Individual Self-supplies
- Baseline testing
- Sanitary Risk Assessment
- Safe Handling
- HWTS
Tanker Water
- The Framework and Water Tankering Guidelines by PURC
- WSP and Sanitary Risk Assessment
Packaged Water
- GS-786, recommended code of hygienic practice for the collection, processing and marketing of potable water
- GSA recom. Hazard Analysis and Critical Control Point (HACCP) principles adopted by the Codex Alimentarius Commission

3. APPLICATION TO SPECIFIC WATER SUPPLIES (Component-4)

3.1 Introduction

The Framework provides applicable approach to ensuring the safety of drinking-water supplied through specific water supplies such as;

1. Limited piped scheme, small community water supplies, point water sources;
2. Individual household supplies;
3. Rainwater harvesting;
4. Packaged water supply (bottled water, sachet water);
5. Vended Water supply (tankers, donkey cart or push cart).

The sources of these supplies can include groundwater, surface water and rainwater. This section is not intended to stand alone, and reference is made to more comprehensive supporting principles from the preceding chapters that provide detailed guidance. In all the specific small water supplies described above the principles enshrined in water safety plans (WSPs) apply. However, the WSP should be tailored to the type of supply in each circumstance; for example, routine chemical and microbiological monitoring of rainwater may not be feasible at a household level, but preventive barriers are both applicable and achievable.

The WSP approach emphasizes preventive risk management. It requires that risks to drinking-water safety are identified, prioritized and managed to protect drinking-water quality before problems occur. This approach draws on the methodology of sanitary inspection (see Section 6.10), which offers quick results and clearly identifies action points for improvements. The aim of employing a WSP approach is to consistently ensure the safety and acceptability of a drinking-water supply in a practical manner. Where all risks cannot be immediately minimized because of, for example, limited resources, a WSP is implemented to make prioritized, incremental improvements over time. For small water supplies, it may not be economically feasible or practical to carry out all the recommendations of the Framework; however, there is a range of basic measures that can be implemented to provide reasonable assurance of safety.

3.1.1 Applying the Framework

The Framework for management of drinking water quality is based on a preventive, risk management approach. Those responsible for small water supplies should adhere to this approach as far as possible; however, it may not be practical or necessary to implement all aspects of the Framework. One of the major difficulties for small communities, particularly those in remote areas, is the implementation of regular monitoring programs (both in terms of cost and the practicalities of transporting samples to testing laboratories). The Framework provides guidance on methods that are suited to small communities and that should give an adequate degree of confidence that safe water is being supplied. The advantage of the Framework is that it places emphasis on a preventive approach to managing water quality, with less reliance on water testing.

The principal risk to human health from drinking water is the presence of pathogenic microorganisms. Thus, to ensure safe water, the focus in small supplies should be on regular inspection of the system to check for any direct or potential sources of contamination, and on the use of a clean and unpolluted water source. The following sections explain how these requirements for small water supplies can be achieved in the context of the Framework.

3.2 Assessment of the small drinking water supply

Analysis of the water supply system, identification of potential hazards and risk assessment (described in detail in Section 2.2) are essential for good management of all water supplies.

In the case of small water supplies, initial steps would be to develop a simple flow diagram of the main features of the system (water sources, treatment or disinfection, service tanks and major piping) and to determine basic water quality characteristics. If groundwater is the source of supply, then baseline chemical quality should be assessed as a priority. In some parts of Ghana, concentrations of naturally occurring elements such as fluoride, arsenic, iron and manganese; and nitrates from agricultural land uses, may exceed safe levels.

The water system should be inspected to identify likely sources of hazards. The greatest sources of microbial hazards are human and livestock wastes, and water systems should be inspected to determine the likelihood that this type of contamination will affect water quality. The discharge of septic waste and access of livestock to watercourses, or the proximity of either to bore wells, are likely sources of contamination.

Potential sources of hazards for water supplies can include:

- Septic waste from on-site or communal wastewater systems;
- Animal feces or dumped animal carcasses;
- Effluent from factories, milking sheds and urban storm-water drains (which may contain partially treated gray-water and toilet wastes);
- Leakage or seepage from rubbish tips and landfill sites;
- Agricultural pesticides and fertilizers;
- Naturally occurring elements;
- Mining industry wastes.
- Small scale textile industries

Risk assessment, described in detail in Section 2.2.1.3, involves estimating the likelihood that a hazard will occur and the consequences if it does. The aim is to distinguish between high and low risks so that attention and resources can be directed towards those hazards that are most threatening. The risks associated with all hazards identified for a small water supply system should be assessed.

3.2.1 Preventive measures for drinking water quality management

Where there are hazards that represent high risks (described in detail in Section 2.2.2), preventive measures will be required to remove the hazard or to reduce it to an acceptable level. The effectiveness of existing measures should also be assessed, but if these are not sufficient, alternative measures will need to be identified. With all type of water supply systems, assessment of preventive measures should include consideration of the important principle of the multiple barrier approach. The types of barriers and the preventive measures required will depend on the characteristics of the source water and the associated catchment.

3.2.1.1 Preventive measures for ground-water sources

In most cases, contamination of groundwater supplies can be prevented by a combination of simple measures. Groundwater in confined or deep aquifers will generally be free of pathogenic microorganisms and, provided the water is protected during transport from the aquifer to consumers, microbial quality should be assured. The local vicinity of the well-head should be protected from livestock access, and buffer zones should be established between the well and disposal or discharge of septic wastes. Boreholes should be encased to a reasonable depth and bore-heads should be sealed to prevent ingress of surface water or shallow groundwater.

Once the groundwater is pumped out of the aquifer, protection can be achieved by delivering the water through enclosed water systems. Storage tanks should be roofed, pipelines should be intact and cross-connections should be protected by the installation of backflow prevention devices. More details is provided in Section 6.1.2.

3.2.1.2 Preventive measures for Rainwater

Rainwater can provide an important source of drinking-water in some circumstances as well as a useful source of water for blending with other sources to reduce the levels of contaminants of health concern, such as fluoride and arsenic. The development of formal WSPs at the household level may not always be practical, but promotion of sanitary inspection with simple good practice is important. Well-designed rainwater harvesting systems with clean catchments, covered cisterns and storage tanks, and treatment, as appropriate, supported by good hygiene at point of use, can offer drinking-water with very low health risk.

Health risks associated with rainwater: Rainwater is initially relatively free from impurities, except those picked up by the rain from the atmosphere. However, the quality of rainwater may subsequently deteriorate during harvesting, storage and household use. Wind-blown dirt, leaves, fecal droppings from birds and other animals, insects and litter on the catchment areas, such as roofs and in cisterns, can contaminate rainwater. Regular cleaning of catchment surfaces and gutters should be undertaken to minimize the accumulation of debris.

Materials used in the catchment and storage tank should be approved for use in contact with drinking-water and should not leach contaminants or cause taste, odor or discoloration. As rainwater is slightly acidic and very low in dissolved minerals, it can dissolve metals and other impurities from materials of the catchment and storage tank, resulting in unacceptably high concentrations of contaminants in the water.

Most solid roofing materials are suitable for collecting rainwater, but roofs with bitumen-based coatings[1] are generally not recommended, as they may leach hazardous substances or cause taste

[1] Concise international chemical assessment document 59, ASPHALT (Bitumen), WHO, 2005

problems. Care should be taken to ensure that lead-based paints are not used on roof catchments. Thatched roofs can cause discoloration or deposition of particles in collected water.

Un-hygiene water storage practices and abstraction from storage containers or at the point of use can also represent a health concern, but risks can be minimized by good design and practice. Fecal contamination is quite common, particularly in samples collected shortly after rainfall, but can be minimized by good practice. Higher microbial concentrations are generally found in the first flush of rainwater, decreasing as the rain continues; therefore, microbial contamination is less in rainy seasons when catchments are frequently washed with fresh rainwater. A system to divert the contaminated first flow of rainwater from roof surfaces is necessary, and automatic devices that prevent the first flush of runoff from being collected in storage are recommended.

If diverters are not available, a detachable downpipe can be used manually to provide the same result. Storage tanks can present breeding sites for mosquitoes, including species that transmit dengue virus. Covers discourage mosquito breeding and help to prevent fecal contaminants and sunlight, which will promote algal growth, from reaching the water. Covers should be fitted, and openings need to be protected by mosquito-proof mesh. Cracks in the tank can result in contamination of stored water, whereas water withdrawal using contaminated containers is a potential cause of both fecal and chemical contamination. Storage containers should preferably be fitted with a mechanism such as a tap or outlet pipe that enables hygienic abstraction of water.

Further household water treatment at the point of consumption may be applied to ensure better quality of drinking-water and reduce health risk. Solar water disinfection and point-of-use chlorination are examples of low-cost disinfection options for the treatment.

3.2.1.3 Preventive measures for surface water

Assurance of quality from surface water sources is more difficult than from most groundwater or rainwater systems. In general, surface waters will require at least disinfection, and in some cases filtration, to assure microbial safety. However, as for groundwater systems, the first barrier is to prevent contamination at source by minimizing contamination from human waste, livestock and other hazards as discussed above. The greater the degree of protection of the water source, the less the reliance on treatment and disinfection. After treatment or disinfection, water should be protected during delivery to consumers in the same manner as groundwater. More details is provided in Section 6.1.2.

3.2.2 Implementation of operational procedures and process control

Section 2.2.3 provides a detailed description of the implementation of operational processes and process control.

3.2.2.1 Operational procedures

Operational procedures should be developed and clearly documented. The procedures should provide clear protocols for activities and processes such as:

- Regular inspections of raw water sources and storages for sources of contamination (animals, birds, drainage inflows);

- Checking the integrity of groundwater boreholes and protection of boreholes from surface contamination;
- Inspection and cleaning of rainwater catchments and tanks;
- Inspection and maintenance of all equipment and plant,
- Water collection, storage and handling at household

3.2.2.2 Operational monitoring

Operational monitoring includes both regular inspections and testing. In small and remote systems, greater attention should be given to inspections of systems (see section 6.10), to check that the preventive measures used to protect water supplies (e.g. denying livestock access, keeping out human waste) are functioning. The frequency of sanitary inspections of a catchment will depend on the characteristics of each site, the source of raw water, the time the water remains in storage, and the subsequent treatment that is provided. As well as regular inspections in the immediate vicinity of the off-take site, every catchment where there is habitation or free public access should be comprehensively inspected at least once a year for potential sources of pollution. Wherever possible, measurements should be undertaken at the site. Test kits are available for a range of parameters, including disinfectant residuals and pH. Where catchments and supplies are beyond the water supplier's jurisdiction, exchange of information and collaborative assessment of the quality of source waters is encouraged.

3.2.2.3 Corrective action

Where problems occur, corrective action should be taken as quickly as possible. Potential impacts on water quality will need to be assessed and, where necessary, discussed with the local health authority.

If health risks are considered unacceptable, responses could include using an alternative source of water (if available), or issuing advice to the public to either to boil water before consumption (in the case of microbial contamination) or avoid use (in the case of chemical contamination). In the latter case, arrangement for alternative water supply will be needed.

3.2.2.4 Equipment capability and maintenance

The equipment and plant incorporated in the water supply system should be maintained in good condition. In particular, equipment used in water treatment (e.g. for disinfection or microfiltration) should be inspected regularly and should be adequately maintained.

3.2.2.5 Materials and chemicals

Materials and chemicals used in water systems should be suitable for use with drinking water. Chemicals such as disinfectants and coagulants should be evaluated for suitability. Where expertise is limited, small communities are encouraged to seek advice from regional and national water supply organizations through District Water Sanitation Team (DWST). For further details see Section 2.2.3.5.

3.2.3 Verification of drinking water quality

Verification of drinking water quality is described in detail in Section 2.2.4. Testing of water in small and remote supplies can present both economic and logistic difficulties, particularly for microbial samples that need to be transported to testing laboratories within 12–24 hours of collection. Application of the Framework decreases reliance on drinking water quality testing; however, testing is still important as a means of verifying that, overall, the barriers and preventive measures implemented to protect public health are working effectively.

Small systems should be monitored on the basis that it is more effective to test for a narrow range of characteristics as frequently as possible than to analyze comprehensively less often. Microbial quality is the most important factor in determining the ongoing safety of water supplies for human consumption. Therefore, wherever possible, a regular testing program should be instituted for the indicator *E. coli.* As stated in section 6.3.2.2.1 a minimum of one microbial sample per month is generally recommended for small water supplies; however, in small systems this is not always practical. Where sampling is less frequent than recommended, sanitary inspections should be more frequent to provide assurance on the integrity and normal operation of the system.

In systems where disinfection is used, evidence of continuous operation is very important in providing assurance of microbial quality. Disinfection is very effective against bacterial pathogens but less so against viruses and enteric protozoa (e.g. *Giardia* and *Cryptosporidium*). The presence of viruses and protozoa can be minimized by protecting water supplies from human and livestock waste.

If chlorination is used, the presence of a free chlorine residual in the distribution system provides evidence of initial disinfection and protection against recontamination from backflow, pipeline breaks or other causes. The amount of chlorine required varies with the flow rate, the quality of the raw water and other factors. Generally, a free chlorine residual of between 0.2 and 0.5 mg/L is adequate. At least daily testing of chlorine residuals should be carried out to check the effectiveness of the disinfection system. This can be done using a simple diethyl-phenylenediamine (DPD) color comparator.

3.3 Individual household supplies

An individual household drinking-water supply is a stand-alone system that is not connected to a community drinking-water supply. For an individual household supply, the emphasis should be on selecting the best quality source water available, and on protecting its quality by the use of barrier systems and maintenance programs.

Whatever the source (ground, surface or rainwater tanks), householders should assure themselves that the water is safe to drink. Generally, surface water or shallow groundwater should not be used as a source of drinking water without household water treatment. Information on the quality of surface and groundwater could be obtained from relevant District Assembly offices. Alternatively, an individual household should consider having the water tested for any key health characteristics identified as being of local concern, for example fluoride in Northern Region.

Greater attention should be given to inspections of systems, to check that the preventive measures used to protect water supplies (e.g. denying livestock access, keeping out human waste) are functioning. The frequency of sanitary inspections of a catchment will depend on the characteristics of each site, the source of raw water, the time the water remains in storage, and the subsequent treatment that is provided (see Section 6.10.4). The immediate vicinity of the off-take site, every catchment where there is habitation or free public access should be comprehensively inspected at least once a year for potential sources of pollution.

It is possible to assess the likelihood of fecal contamination of water sources through a sanitary inspection. Sanitary inspection and water quality testing are complementary activities; the findings of each assists the interpretation of the other. Where water quality analysis cannot be performed, sanitary inspection can still provide valuable information to support effective decision-making. A sanitary inspection makes it possible to see what needs to be done to protect the water source. Further guidance on Sanitary Risk Assessment is given in Section 6.10.

3.4 Vended water supplies

Vended water is commonly used in many parts of the Ghana. Water vending implies private vending of drinking-water including water trucking, water carts, but does not include bottled or packaged water (which is considered in section 3.5).

Water vending in Ghana is done mostly through a registered associations called Private Water Tanker Operators Association (PWTOA) and informal water carts. In urban areas, the water typically comes from treated utility supplies or registered sources and is supplied in tankers or from standpipes and water kiosks. Informal suppliers tend to use a range of sources, including untreated surface water, dug wells and boreholes, and deliver small volumes for domestic use, often in containers loaded onto small carts or tanker trucks.

3.4.1 Applying the framework

The principal risk to human health from vended water supplies is the presence of pathogenic microorganisms. Thus, to ensure safe water, the focus in vended water should be on regular inspection of the system to check for any direct or potential sources of contamination, and on the use of a clean and unpolluted water source for filling. The Framework can be applied as a stand-alone drinking water quality management system or can be integrated with an existing management system (e.g. Water Tankering Guidelines by PURC). The framework recommends implementation of water safety plans for vending water supply that incorporate all components of water vending, including sources, methods of abstraction and transport. Where vendors are registered or have a contract with a water utility, implementation and operation of the WSP should be regularly checked by the regulatory organization (e.g. District Assembly and PURC). WSPs and the operation of water vendors should also be subject to independent surveillance as described in Section 2.3.

3.4.1 Management of Vended water supply

Effective management of drinking water quality requires appropriate attention to system analysis and system management. The objectives are to increase understanding of:

- the entire water supply system from water source to consumer.
- the hazards, sources and events that can compromise drinking water quality before filling, at filling, during transportation and at delivery
- the preventive measures needed to effectively control hazards, including the application of multiple barriers to reduce exposure to hazards.

Water safety plans for vended water supplies are required to document water supply system assessment and operational monitoring requirements associated with abstraction, transport and delivery of water. Procedures associated with performing and monitoring these tasks need to be included. For example, procedures for cleaning and disinfection of hydrants, hoses and bulk water tankers should be documented. A brief detail on risk assessment, operational monitoring and surveillance is provided in the following sections.

3.4.1.1 Vended water supply risk assessment

In undertaking a risk assessment of vended water supplies, a range of issues should be considered, including:

- the nature and quality of source water should be assessed and the likelihood of contamination occurrence (surface water and some dug wells water is not recommended to use compared to boreholes or standpipes associated with piped water supplies);
- control measures, including protection of source waters and treatment. In case of untreated sources the risks associated with human and animal excreta and domestic, industrial and agricultural chemicals;
- mechanisms for abstraction and status and integrity of storage, including hoses, hydrants and pipework.
- design and characteristics of containers used to transport and deliver water (e.g. containers should be dedicated to transport of drinking-water and made of suitable material)

More details on risk assessment and preventive measures is provided in Section 6.1 and guidance on sanitary risk assessment for vended water is given in Section 6.10.

3.4.2 Operational monitoring

Vendors have a responsibility for ensuring that control measures operate effectively. Operational monitoring of control measures could include:

- sanitary surveys of source water, abstraction devices and hoses for protection from external sources of contamination;
- integrity, cleanliness and maintenance of equipment and devices such as hydrants, standpipes, backflow preventers, storages, hoses, containers and bulk water tankers;
- monitoring of disinfectant residuals and pH;
- performance and maintenance of tanker filters;

Further guidance on operation monitoring see Section 6.2.5.

3.4.3 Surveillance

Independent surveillance is an important element of ensuring that vended drinking-water is safely managed. One of the barriers to effective surveillance can be a lack of records and documentation identifying water vendors. Implementation of registration systems by District Assemblies (bye laws) has already been considered. Surveillance should include:

- Inspection of vendor's registration/licensing
- periodic audit and/or direct assessment of water quality;
- review of WSPs and auditing of its implementation;
- sanitary surveys of source waters, abstraction and delivery systems;
- investigating and providing advice on receipt of reports of significant incidents.

Surveillance should include an assessment of household storage practices and the effectiveness of hygiene education programs. Where consumers carry vended water home, hygienic practices associated with the collection and transport of water should be assessed.

3.5 Packaged drinking-water

Bottled water and water in containers particularly in plastic sachets are widely used in Ghana. The number of packaged water producers in the country are in thousands. Consumers purchase packaged drinking-water for reasons such as taste, convenience and quality.

3.5.1 Applying the Framework

In applying the framework to packaged waters management, certain chemical constituents may be more readily controlled than conventional water supplies as stricter standards are provided by Ghana Standards Authority, the Water Quality – Specification for drinking water (FDGS 175-1:2013). In case of packaged water the GSA standards focus on the product and its compositional and quality factors, including prescribed treatments, limits for certain chemicals, hygiene, packaging and labelling, storage and an associated code of practice (e.g. GS 786, recommended code of hygienic practice for the collection, processing and marketing of potable water).

To manage quality of packaged water, the Ghana Standards Authority specification for drinking water (FDGS 175-1:2013) encourages packaged water producers on applying procedure or procedures based on the Hazard Analysis and Critical Control Point (HACCP) principles adopted by the Codex Alimentarius Commission[2]. The HACCP system (Maskeliunas, 2011), which is science-based and systematic, identifies specific health related hazards and measures for their control to ensure the safety of packaged water. This should provide the basis for determining the appropriate combination of control measures to reduce, eliminate or prevent, as necessary, hazards (microbiological, chemical and radiological) for the production of safe packaged water. Similar to risk-based approach of water safety plans, HACCP is a tool to assess hazards and

---

[2] The Codex Alimentarius Commission was created in 1963 by Food and Agricultural Organization (FAO) and World Health Organization (WHO) two specialized agencies in the United Nations system to develop food standards, guidelines and codes of practice under the Joint FAO/WHO Food Standards Programme, http://www.codexalimentarius.org/about-codex/en/

establish control systems that focus on prevention rather than relying mainly on end-product testing.

The principal risk to human health from drinking packaged water is the presence of pathogenic microorganisms. Thus, to ensure safe water, the focus in packaged water industry should be on regular inspection of the system to check for any direct or potential sources of contamination, the water processing and on the use of a clean and unpolluted water source. The following sections explain, how these requirements for packaged water industry, can be achieved in the context of the Framework.

3.5.2 The HACCP principles

a. The identification of any hazards that must be prevented, eliminated or reduced to acceptable levels;
b. The identification of the critical control points at the step or steps at which control is essential to prevent or eliminate a hazard or to reduce it to acceptable levels;
c. The establishment of critical limits at critical control points which separate acceptability from unacceptability for the prevention, elimination or reduction of identified hazards;
d. The establishment and implementation of effective monitoring procedures at critical control points;
e. The identification of corrective actions to be taken when monitoring indicates that a critical control point is not under control;
f. The identification of procedures, which shall be carried out regularly, to verify that the measures outlined in subparagraphs (a) to (e) are working effectively;

Detail description of Hazard Analysis and Critical Control Point (HACCP) principles and processes involved to implement in packaged water industry is provided in Appendix 6.9.

Component-5

Management of WQ incidents and emergencies

Incidence and Emergency Response Planning

- Define potential incidents and emergencies, document procedures and response plans
- Train employees
- Investigate any incidents and revise protocols as necessary.

Communication protocols

- Define communication protocols, contact list
- Develop a public and media communications strategy.

Documentation and Reporting

- What was the initiating cause of the problem?
- How the problem was first identified?
- What were the most critical actions required?
- What communication problems arose?
- What were the immediate and longer-term consequences?
- How well did the protocol function?

4. MANAGEMENT OF INCIDENTS AND EMERGENCIES (Component-5)

This section outline the communication protocols and incident, emergency response planning and reporting related to drinking water quality incidence and emergencies.

Although preventive strategies are intended to prevent incidents and emergency situations from occurring, some events cannot be anticipated or controlled, or the probability of their occurring is so low that providing preventive measures would be too costly. Such events includes natural disasters such as floods, drought, earthquake, and accidental failure of water supply system, and man-made incidents, for example catchment chemical spills and bacteriological contamination, can significantly disrupt and impact on the quality of water services thus posing a significant health risk to consumers. For such incidents, there must be an adaptive capability to respond constructively and efficiently. Emergency protocols and communication planning are therefore critical in minimizing public health risks associated with drinking water failure.

Wherever possible, emergency scenarios should be identified, and incident and emergency protocols, including communication procedures, should be planned and documented. Establishing procedures 'on the run' is a recipe for inefficiency, lack of coordination, poor response times and potential loss of public confidence.

4.1 Incidence and Emergency Response Planning

What needs to be done

1. *Define potential incidents and emergencies and document procedures and response plans with the involvement of relevant agencies.*
2. *Train employees and regularly test emergency response plans.*
3. *Investigate any incidents or emergencies and revise protocols as necessary.*

As indicated in National Water Policy, potential incidents and emergencies should be defined and response plans should be developed and documented in advance to respond to these events. Plans should be developed in consultation with relevant regulatory authorities and other key agencies, and should be consistent with existing government emergency response arrangements for example "The National Water, Sanitation & Hygiene (WASH) Emergency Preparedness and Response Plan (EPRP)".

The development of appropriate plans involves a review of the hazards and events that can lead to emergency situations, such as:

- Non-conformance with water quality standards values and other requirements;
- Accidents that increase levels of contaminants (e.g. spills in catchments, incorrect dosing of chemicals, major main breaks);
- Equipment breakdown and mechanical failure;
- Prolonged power outages;
- Extreme weather events (e.g. flash flooding, cyclones, drought);

- Natural disasters (e.g. fire, earthquakes, lightning damage to electrical equipment);
- Human actions (e.g. serious error, sabotage, strikes resulting in lack of control of the treatment plant).

Every water supply agency must have a set of procedures to follow in the event of incidents leading to emergencies. These procedures should be in place well in advance of any event. Plans should cover above mentioned incidents that could potentially affect drinking water quality.

Emergency plans should include clear procedures for the remediation of the situation and communication with appropriate authorities. A coordinated emergency response strategy should be developed to identify clear roles and interrelated response mechanisms.

Actions and protocols should be developed in consultation with relevant regulatory authorities and other key agencies. It is vital that protocols are developed prior to the occurrence of any incident or emergency to enable efficient, effective and rapid response that will minimize the impacts on the community. Incident and emergency response protocols must be communicated to all relevant personnel and copies of documented procedures must be available.

Key areas to be addressed in water quality incident and emergency response plans include clearly specified:

- Response actions, including increased monitoring;
- Responsibilities and authorities of internal parties;
- Responsibilities and authorities of parties external to the organization;
- Plans for emergency water supplies;
- Communication protocols and strategies, including notification procedures (internal, regulatory body, media and public);
- Mechanisms for increased health surveillance.

Personnel should be trained in emergency response to ensure that they can manage any potential incidents or emergencies effectively. Incident and emergency response plans particularly communication protocols should be regularly reviewed and updated. This improves preparedness and provides opportunities to improve the effectiveness of plans before an emergency occurs.

4.2 Communication protocols

What needs to be done

1. *Define communication protocols with the involvement of relevant agencies and prepare a contact list of key people, agencies and businesses.*
2. *Develop a public and media communications strategy.*

Effective communication is vital in managing incidents and emergencies. Clearly defined protocols for both internal and external communications should be established in advance, with the involvement of relevant agencies, including health and other regulatory agencies. These protocols should include a contact list of key people, agencies and businesses, detailed notification forms, procedures for internal and external notification, and definitions of responsibilities and authorities. Contact lists should be regularly updated (e.g. six-monthly) to ensure they are accurate, It must have a review date and responsibility for review assigned on the document or file.

Maintaining consumer confidence and trust during and after an incident or emergency is essential, and this is largely determined by how incidents and emergencies are handled. A public and media communication strategy should be developed before any incident or emergency situation occurs.

Draft public and media notifications should be prepared in advance and formatted for the target audience. An appropriately trained and authoritative contact should be designated to handle all communications in the event of an incident or emergency. All employees should be kept informed during any incident, because they provide informal points of contact for the community.

Consumers should be told when an incident has ended and be provided with information on the cause and actions taken to minimize future occurrences. This type of communication will help allay community concerns and restore confidence in the water supply.

4.3 Documentation and Reporting

Appropriate documentation and reporting of the incident and emergency should also be established. The water supply agencies should learn as much as possible from the incidents to improve preparedness and planning for future incidents. Review of the incident may indicate necessary amendments to existing protocols.

Following any incident or emergency situation, an investigation of the incident or emergency should be undertaken and all involved staff should be debriefed to discuss performance and address any issues or concerns. The investigation should consider factors such as:

- What was the initiating cause of the problem?
- How the problem was first identified or recognized?
- What were the most critical actions required?
- What communication problems arose and how were they addressed?
- What were the immediate and longer-term consequences?
- How well did the protocol function?

Component-6

SUPPORTING PROGRAMS

WS employee awareness

- Develop mechanisms and communication procedures to increase employees' awareness
- The organization's drinking water quality policy
- Characteristics of the water supply system,
- Preventive strategies in place throughout the system;
- Regulatory and legislative requirements;
- Roles and responsibilities of employees and departments;
- How their actions can impact on water quality and public health.

Trainings

- Employees and contractors appropriate experience and qualifications.
- Identify training needs & resources to support training programs.
- Document training & maintain records of all employee training.

Community involvement and awareness

- Assess requirements for effective community involvement.
- Develop a strategy for community consultation.
- Develop two-way communication program to inform consumers and promote awareness of drinking water quality issues.

Research and development

- Establish programs to increase understanding of the water supply system.
- Use information to improve management of the water supply system
- Validate processes and procedures to ensure that they are effective in controlling hazards.
- Revalidate processes periodically or when variations in conditions occur.
- Validate the selection and design of new equipment and infrastructure

Documentation and reporting

- Document information pertinent to all aspects of WQ management.
- Develop a document control system to ensure current versions are in use.
- Establish a records management system and ensure that employees are trained to fill out records.
- Periodically review documentation and revise as necessary.
- Establish procedures for effective internal and external reporting.
- Produce an annual report and sharing with stakeholders.

5. SUPPORTING PROGRAMS (Component-6)

Supporting programs are the actions that contribute indirectly to drinking water safety. These include basic elements of good practice to ensure that the system is sustainable and has the capacity to operate optimally and adapt to meet the challenges. Supporting programs includes;

1. Water supply agency employee awareness and training
2. Community involvement and awareness
3. Research and development
4. Documentation and reporting

5.1 Water supply agency employee awareness and training

The knowledge, skills, motivation and commitment of employees and contractors ultimately determine a drinking water supplier's ability to operate a water supply system successfully. It is vital that awareness, understanding and commitment to performance optimization and continuous improvement are developed and maintained within the water supply organization. Specific details with focus on water supply employees are given below.

5.1.1 Water supply agency employee awareness and involvement

What needs to be done

1. *Develop mechanisms and communication procedures to increase employees' awareness of and participation in drinking water quality management.*

An understanding of drinking water quality management is essential, to enable and motivate employees to make effective decisions. All employees of the drinking water supplier should be aware of:

- The organization's drinking water quality policy (see Section 2.1.4);
- Characteristics of the water supply system and preventive strategies in place throughout the system;
- Regulatory and legislative requirements;
- Roles and responsibilities of employees and departments;
- How their actions can impact on water quality and public health.

Mechanisms and communication procedures should be developed to ensure awareness of employees throughout the water supply organization. Methods to increase employee awareness can include employee education and induction programs, newsletters, guidelines, manuals, notice boards, seminars, briefings and meetings. The participation and involvement of employees in decision making is an important part of establishing the commitment necessary for the continuous improvement of drinking water quality management. Open and positive communication is a foundation to creating a participatory culture, and employees should be encouraged to discuss issues and actions with management. Employees should be encouraged to participate in decisions that affect their jobs and areas of responsibility. Such participation provides a sense of ownership for decisions made and their implications.

5.1.2 Water supply authority employee training

What needs to be done

1. *Ensure that employees, including contractors, maintain the appropriate experience and qualifications.*
2. *Identify training needs and ensure resources are available to support training programs.*
3. *Document training and maintain records of all employee training.*

Employees and water supply contractors must be appropriately skilled and trained in the management and operation of water supply systems, as their actions can have a major impact on drinking water quality and public health (see below Box 5).

Employees should have a sound knowledge base from which to make effective operational decisions. This requires training in the methods and skills required to perform their tasks efficiently and competently, as well as knowledge and understanding of the impact their activities can have on water quality. For example, treatment plant operators should understand water treatment concepts and be able to apply these concepts and adjust processes appropriately to respond to variations in water quality.

Appropriate training to address specific needs should be identified and adequate resources made available to support appropriate programs. Examples of relevant areas to address includes general water chemistry (chemical and microbiology) and;

- Coagulant control testing;
- Proper filtration operation;
- Disinfection techniques and related system operation;
- Pipe network management;
- Sampling, monitoring and analysis;
- Interpretation and recording of results;
- Calibration and maintenance of equipment.

Employees should also be trained in other aspects of drinking water quality management, including incident and emergency response, documentation, record keeping, reporting, and water quality related research and development.

Commonly used training techniques and methods include formal training courses accredited by a national training body such as GWCL training schools, School of Hygiene, Institute of local government studies, in-house training, on-the-job experience, workshops, demonstrations, seminars, special courses and conferences. Training programs should encourage employees to communicate and think critically about the operational aspects of their work.

Training should be documented, and records maintained of all employees who have participated in training.

Mechanisms for evaluating the effectiveness of training should also be established and documented. Training is an ongoing process and requirements should be regularly reviewed to ensure that employees maintain the appropriate experience and qualifications. For those activities that have a significant impact on drinking water quality, periodic verification of the capability of operations staff is necessary. Where possible, accredited training programs and certification of operators should be employed.

Box 5 Water Supply Contractors

Currently there is considerable reliance on contractors to undertake work for drinking water suppliers and regulators. These include contractors for construction, operations and maintenance treatment and distribution systems, water treatment supplies, and water sampling and water testing.

Contractors need to have the same awareness, training and culture as the water supplier and regulator's employees. Requirements for contractor acceptability should be established, and contractors should be evaluated and selected on the basis of their ability to meet the specified requirements.

A drinking water supplier should ensure that contractors are qualified and have undergone appropriate training related directly to their task or role. When contracting services, provisions should be made within the organization to conduct the necessary education and training of contractors on the requirements for adherence to the organization's policy and protocols.

5.2 Community involvement and awareness

It includes community consultation and communication with communities.

Community consultation, involvement and awareness can have a major impact on public confidence in the water supply and the water supply organization's reputation. A communication program is a long-term commitment, including both consultation and education, and should be designed to provide an active, two-way exchange of information. This will help to ensure that consumers' needs and expectations are understood and are being satisfied.

5.2.1 Community consultation

What needs to be done

1. *Assess requirements for effective community involvement.*
2. *Develop a comprehensive strategy for community consultation.*

Decisions on drinking water quality made by a drinking water supplier and the relevant regulatory authorities must be aligned with the needs and expectations of consumers. Therefore, the community should be consulted and involved during decision-making processes with special consideration to involve women as they are mostly taking responsibility for household drinking water needs.

Discussions should include the establishment of levels of service, costs, existing water quality problems, and the options for protection and improvement of drinking water quality, including constraints on land use and changes in treatment or infrastructure. Consumers should also be consulted on monitoring requirements and mechanisms for public reporting of system performance. For example, one community may choose to tolerate aesthetic problems, while another may choose to pay for treatment to bring water quality within commonly accepted limits.

Priorities will depend on the impact of water quality improvements on public health and on aesthetic considerations (taste, color and odor). Public health should take a higher priority than aesthetics.

Assessing what is required for effective community involvement can be a complex task, depending on the issues and the community involved. Developing a community consultation strategy entails:

- Defining the scope of the issue and the potential links with wider issues or problems. This will provide an indication of the extent of consultation or education required;
- Identifying specific interest and stakeholder groups that may be affected, and their needs, existing level of knowledge and attitudes on the issues. All groups should be able to participate in the consultation process irrespective of barriers of language, distance, level of education, technical knowledge or lack of resources;
- Presenting factual information to the community, consumers and groups in a form that is accessible, understandable and suitable as a basis for informed discussion;
- Providing adequate time for consultation. The community should understand and agree to the process proposed for the consultation;
- Identifying or developing measures to evaluate the effectiveness of the community consultation process.

Community consultation might include:

- Briefings targeted to specific groups with interests or responsibilities;
- Workshops or seminars on key issues or for special groups;
- Focus groups and market research or surveys to determine community views, knowledge and attitudes;
- Customer councils or customer panels;
- Informative media programs targeting print media, radio and television;
- Community education or information exchange programs;
- School programs;
- Preparation of technical issues papers;
- Media advertising of activities and available papers;
- Public hearings for major and controversial initiatives.

5.2.2 Communication with community

It involves to develop an active two-way communication program to inform consumers and promote awareness of drinking water quality issues. Effective communication to increase community awareness and knowledge of drinking water quality issues and the various areas of responsibility is essential. Communication helps consumers to understand and contribute to decisions about the service provided by a drinking water supplier or land-use constraints imposed in catchment areas.

Effective communication is particularly important in the event of an incident or emergency (see Section 4.2).

A coordinated consumer information program should include:

- Discussion of issues on drinking water quality, public health and risk assessment, cost of treatment, and levels of service;
- Details of the water supply system and the drinking water quality management system;
- Incident and emergency response plans, including procedures for notification when drinking water quality poses a health risk;
- Consumer responsibilities beyond the tap as how drinking water quality may be affected in household distribution and handling before drinking (e.g. education on household water treatment and safe storage);
- The role and responsibility of the community in protecting water supply catchments and water conservation;

Although a drinking water supplier is generally responsible only for delivery of water. However collaboration and coordination with relevant organizations should inform consumers about how drinking water quality may be affected in household distribution, storage and handling.

Procedures should be established for disseminating information to promote awareness of drinking water quality issues to the community targeting both male and female members. Possible methods include annual or other periodic water quality reports, newsletters, notices in bills, workshops, seminars or briefings, media programs targeting radio and television, websites, treatment plant tours, and school education programs. Additionally, mechanisms such as a service line or complaint handling system should be established to provide opportunities for consumers to communicate their needs and expectations.

5.3 Research and development

Research and development encompass investigative studies and research monitoring, validation of processes and design of equipment.

A corporate commitment to conduct and participate in research and development activities on drinking water quality issues is important. Such a commitment helps to ensure continual improvement and the ongoing capability to meet drinking water quality requirements. Applied research and development may be directed towards:

- Increasing the understanding of a water supply system and potential hazards;
- Investigating improvements, new processes, emerging water quality issues and new analytical testing methods;
- Validation of operational effectiveness of new products and processes;
- Increasing the understanding of the relationship between public health outcomes and water quality.

Research at a local level increases understanding of the specific characteristics of individual water supply systems. Local research could include, for example, detailed analysis of temporal and spatial variations in source water quality parameters (e.g. arsenic and fluoride in ground-water). Research and development activities should also investigate mechanisms to improve and evaluate treatment processes (including the validation of critical limits and target criteria) and design new equipment. These activities should be carried out under controlled conditions by qualified staff, and all protocols and results should be documented and recorded.

Additionally, participation in research and development activities through partnerships and industry-wide cooperation can be a cost-effective way to address broader issues associated with water quality and treatment, including the development and evaluation of new technologies. Opportunities for collaboration and initiation of joint research and development projects should be identified. Partnership organizations may include health and environment agencies, industry associations, other drinking water suppliers, water research institutions and university departments.

5.3.1 Investigative studies and research monitoring

What needs to be done

1. *Establish programs to increase understanding of the water supply system.*
2. *Use information to improve management of the water supply system.*

Investigative studies and research monitoring include strategic programs designed to increase understanding of a water supply system, to identify and characterize potential hazards, and to fill gaps in knowledge. Improved understanding of the factors affecting water quality characteristics allows suppliers to anticipate periods of poor water quality and respond to them effectively. Examples could include:

- Baseline monitoring of parameters or contaminants or testing of potential new water sources to identify water quality problems;
- Source water monitoring to understand the temporal and spatial variability of water quality parameters;
- Developing early warning systems to improve the management of poor water quality;
- Event-based monitoring to determine the magnitude of impacts (duration and maximum concentrations);
- Examining mixing effects within a water storage;
- Evaluating characteristics of an aquifer through pumping tests and analyses;
- Studying the Environmental impact on water bodies

In addition, monitoring could provide input into predictive modelling of source water quality or assist in the selection of management and treatment approaches.

5.3.2 Validation of processes

What needs to be done

1. *Validate processes and procedures to ensure that they are effective in controlling hazards.*
2. *Revalidate processes periodically or when variations in conditions occur.*

Validation involves evaluating the scientific and technical information that is available on processes and then, where necessary, undertaking further investigations, in order to validate system-specific operational procedures, critical limits and target criteria. The aim of process validation is to ensure effective operation and control. Historical data and operational experience can also be useful sources of information.

Processes should be revalidated on a regular basis or when variations occur (e.g. seasonally). Any new processes should be tested using benchtop, pilot-scale or full-scale experimental studies to confirm that the process and operational criteria produce the required results under the conditions specific to the individual water supply system.

Section 6.5 provides more information on validation of processes.

5.3.3 Design of equipment

What needs to be done

1. *Validate the selection and design of new equipment and infrastructure to ensure continuing reliability.*

Research and development should be undertaken to validate the selection and design of new equipment and infrastructure, or to confirm design changes necessary to improve plant performance and control systems. New technologies require pilot-scale research and evaluation before full-scale implementation.

Design specifications should be established to ensure that new equipment will be able to meet the intended requirements and provide necessary process flexibility and controllability (see Section 2.2.3.4).

Other considerations for ensuring the reliability of water treatment systems include designing equipment and facilities to withstand natural disasters (e.g. earthquakes and flooding) and providing backup systems for emergency use (e.g. alternative power generation). Consideration of these factors during the design phase will reduce the risk that equipment failures will cause major disruptions in service.

5.4 Documentation and reporting

Appropriate documentation provides the foundation for the establishment and maintenance of effective drinking water quality management systems. Documentation should:

- Demonstrate that a systematic approach is established and is implemented effectively;
- Develop and protect the organization's knowledge base;
- Provide an accountability mechanism and tool;
- Facilitate review and audits by providing written evidence of the system;
- Establish due diligence and credibility.

Documentation provides a basis for effective communication within the organization as well as with the community and various stakeholders. A system of regular reporting, both internal and external, is important to ensure that the relevant people receive the information needed to make informed decisions about the management or regulation of drinking water quality.

5.4.1 Management of documentation and records

What needs to be done

1. *Document information pertinent to all aspects of drinking water quality management.*
2. *Develop a document control system to ensure current versions are in use.*
3. *Establish a records management system and ensure that employees are trained to fill out records.*
4. *Periodically review documentation and revise as necessary.*

Documentation pertinent to all aspects of drinking water quality management is required. Documents should describe activities that are undertaken and how procedures are performed. They should also include detailed information on:

- Preventive measures;
- Critical control points, including specific operational procedures and criteria, monitoring and corrective actions;
- Incident and emergency response plans;
- Training programs;
- Procedures for evaluating results and reporting;
- Communication protocols.

Documentation should be visible and readily available to employees. Mechanisms should be established to ensure that employees read, understand and adhere to the documents.

Operation of systems and processes leads to the generation of large amounts of data that need to be recorded. Efficient record keeping is an essential tool for indicating and forewarning of potential problems, and providing evidence that the system is operating effectively.

Activities that generate records include:

- Operational and drinking water quality monitoring;
- Corrective actions;
- Incident and emergency responses;
- Training;
- Research and development;
- Assessment of the water supply system (flow diagrams, potential hazards etc.);
- Community consultation;
- Performance evaluations, audits and reviews.

Documentation and records systems should be kept as simple and focused as possible. The level of detail in the documentation of procedures should be sufficient to provide assurance of operational control when coupled with a suitably qualified and competent operator. Retention of corporate memory should also be considered in documentation of procedures.

Mechanisms should be established to review documents periodically and, where necessary, to revise them to reflect changing circumstances. Documents should be assembled in a way that will allow any necessary modifications to be made easily. A document control system should be developed to ensure that current versions are in use and obsolete documents are discarded.

Records of all activities pertaining to the performance of drinking water quality management should be stored so that they can be easily accessed and reviewed. Storage should provide protection against damage, deterioration or loss. A system should be in place to ensure that employees are properly trained to fill out records, and that records are regularly reviewed by a supervisor, signed and dated.

Documents and records can be stored in a variety of forms, such as written documents, electronic files and databases, video and audiotapes, and visual specifications (flow charts, posters etc.). Computer-based documentation should be considered to allow for faster and easier access as well as to facilitate updating.

5.4.2 Reporting

What needs to be done

1. *Establish procedures for effective internal and external reporting.*
2. *Produce an annual report to be made available to consumers, regulatory authorities and stakeholders.*

Reporting includes the internal and external reporting of activities pertinent to drinking water quality management.

Internal reporting supports effective decision making at the various levels of the organization, including operations staff and management, senior executive and the board of directors. It also provides a way to communicate information on decisions to employees throughout the organization.

Internal reporting requirements should be defined and a system developed for communication between the various levels and functions of the organization. Documented procedures (including definition of responsibilities and authorities) should be established for regular reporting (daily, weekly, monthly etc.).

These reports should include summaries of monitoring data, performance evaluation and significant operational problems that occurred during the reporting period. Results from audit and management reviews should also be communicated to those within the organization responsible for performance.

External reporting ensures that drinking water quality management is open and transparent. It includes reporting to regulatory bodies, consumers and other stakeholders in accordance with requirements.

External reporting requirements should be established in consultation with consumers and the relevant regulatory authorities; procedures for information dissemination should also be developed.

Agreement should be reached with health and other relevant regulators on requirements for:

- Regular reports summarizing performance and water quality data;
- Event reports on significant system failures that may pose a health risk or adversely affect water quality for an extended period (see Section 4.1).

Reports should be provided to regulatory authorities on incidents defined in agreed incident and emergency response protocols. If necessary, the health authority can then ensure that public health concerns are reported to the community.

An annual report should be produced and made available to consumers, regulatory authorities and stakeholders. The annual report should:

- Summarize drinking water quality performance over the preceding year against numerical standard values, regulatory requirements or agreed levels of service, and identify water quality trends and problems;
- Summarize any system failures and the action taken to resolve them;
- Specify to whom the drinking water supplier is accountable, statutory or legislative requirements, and minimum reporting requirements;
- Indicate whether monitoring was carried out in accordance with standards set by Ghana Standards Authority or the regulator and any requirements contained in agreed levels of service.

Annual reports should contain sufficient information to enable individuals or groups to make informed judgments about the quality of drinking water and provide a basis for discussions about the priorities that will be given to improving drinking water quality. The annual report represents an opportunity to canvass feedback, and it should therefore encourage consumers and stakeholders to provide comment.

6. APPENDIX

6.1 Additional guidance on Assessment of the water supply system and Preventive measures for water quality management

This appendix provides additional guidance on Assessment of the drinking water supply system (2.2.1) and Preventive measures for drinking water quality management (2.2.2) of the Framework. It should be read in conjunction with section (2.2), which provides a more comprehensive overview.

Effective management of drinking water quality requires appropriate attention to system analysis and system management. The objectives are to increase understanding of:

- the entire water supply system from catchment to consumer,
- the hazards, sources and events that can compromise drinking water quality,
- the preventive measures needed to effectively control hazards, including the application of multiple barriers and the establishment of critical control points to reduce exposure to hazards.

Figure 2 provides a suggested roadmap to assist in the application of these aspects of the Framework. Further guidance on implementing these aspects is offered in the following sections.

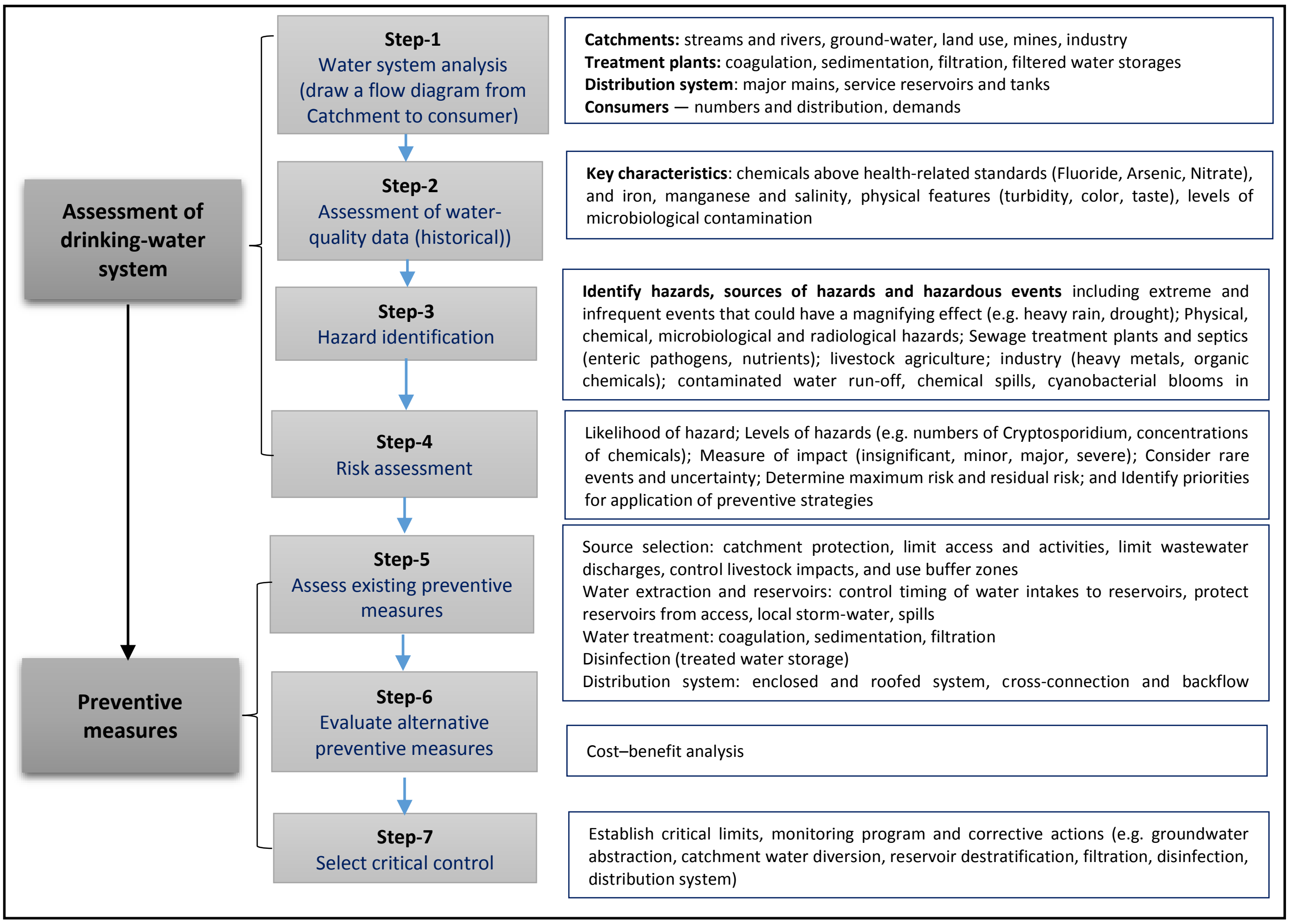


Figure 2 Step involved in assessment of water supply system and preventive measures identification

6.1.1 Water supply system analysis

What needs to be done

1. *Assemble a team with appropriate knowledge and expertise.*
2. *Draw a flow diagram of the water supply system from catchment to consumer.*
3. *Assemble pertinent information and document key characteristics of the water supply system to be considered.*
4. *Periodically review the water supply system analysis*

Assessment of the drinking water system provides an important information base and is a prerequisite for subsequent steps in which strategies for prevention and control of hazards are planned and implemented. The purpose of assessment is to develop a broad overview and basic understanding of the water supply system. It is not intended to be an extensive data collection exercise; rather, it is the characterization of the system at an appropriate level of detail to provide a useful information base from which to make effective decisions.

Characterization of the water supply system should be fully documented and should be a collaborative effort between relevant organizations. Characterizations will be specific for each system but should include, where appropriate, consideration of the catchment area, source water, groundwater system, reservoirs and raw water transport, treatment systems, distribution system and consumers.

Table 8 provides examples of some key characteristics to be considered in assessing drinking water supply systems from catchment to consumer. Seasonal characteristics, as well as extreme and infrequent events such as droughts or floods, should also be considered.

Much of the necessary information may be available in existing documentation from studies carried out previously or from external organization such as Water Resource Commission and Environmental Protection Agency. Sources of useful information can include:

- land use surveys and catchment maps;
- sanitary surveys;
- surveys of major streams and rivers e.g. water quality index of rivers;
- research and investigative monitoring ;
- employee knowledge;
- records from local authorities (e.g. locations of septic tanks, animal feedlots, drainage and sewage treatment plants);
- community surveys such as Ghana health survey, living standards survey, multiple indicator cluster survey;
- public and consumer complaints.

General information and key characteristics of the water supply system are illustrated in table 8 below;

Table 8 Key characteristics of the drinking water supply system

Catchment	▪ Geology and soils ▪ Topography and drainage patterns (hydrology) ▪ Meteorology and weather patterns ▪ (climatic and seasonal variations) ▪ Riparian conditions ▪ Vegetative cover ▪ General catchment and river health ▪ Historical contaminated sites ▪ Land irrigation practices ▪ Future planning activities ▪ Recreational activities	▪ Nature and intensity of development and land-use activities: ▪ Agricultural, dairy and animal husbandry ▪ Land clearing ▪ Forestry ▪ Mining ▪ Industrial ▪ Rural and urban development / residential ▪ Sewage treatment works and septic tanks
Source water	▪ Surface water (river, reservoir, dam) ▪ Groundwater (dug-well, deep well) ▪ Rain Water ▪ Flow and reliability of source water ▪ Seasonal and event changes (including infrequent events such as droughts or floods)	▪ General and unique constituents (physical, chemical, microbial): ▪ Major ions and pH, turbidity ▪ iron, manganese, arsenic, fluoride ▪ salinity, hardness ▪ bacteria, viruses and protozoa ▪ naturally occurring organics
Ground water systems	▪ Geology, homogeneity ▪ Confined or unconfined aquifer ▪ Depth to water table ▪ Flow rate and direction	▪ Dilution characteristics ▪ Recharge area ▪ Well-head protection ▪ Depth of casing
Storage reservoirs and intakes	▪ Detention times ▪ Reservoir design: size, materials, storage capacity, depth of storage ▪ Seasonal variations: stratification, algal blooms ▪ Treatment efficiencies (microbial removal) ▪ Recreational or human activity	▪ Protection (e.g. covers, enclosures, access) ▪ Intake location and operation ▪ Bulk transport: pipeline material, length, flow rate and changes in flow rate, cleaning systems
Treatment systems	• Treatment processes (including optional processes) • Treatment configuration • Equipment design: size, materials, peak flow rates, process change control, backup systems ▪ Monitoring equipment and automation	• Water treatment chemicals used: coagulant, filtration aids, fluoride, powdered activated carbon, disinfectant • Treatment efficiencies • Disinfection log removals of pathogens ▪ Disinfection residual and contact period
Service reservoirs and distribution systems	• Reservoir design: size, materials, storage capacity, depth of storage ▪ Detention times (stratification) ▪ Protection (e.g. covers, enclosures, access) ▪ Distribution system design: size, network, pipe materials, pipe age	▪ Hydraulic conditions (e.g. detention times, flows) ▪ Backflow protection ▪ Secondary disinfection practices ▪ Disinfectant residuals ▪ Disinfection byproducts
Consumer end	▪ Consumer distribution ▪ (industry, bodies corporate, general community, schools and health facilities) ▪ Drinking water handling practices	▪ Water demand and patterns of drinking water consumption (diurnal and seasonal variations) ▪ Internal plumbing and water storage

6.1.1.1 Assessment of water quality data

What needs to be done

1. *Assemble historical data from source waters, treatment plants and finished water supplied to consumers (over time and following specific events).*
2. *Assess data using tools such as control charts and trends analysis to identify trends and potential problems.*

A review of historical data from source waters, treatment plants and finished water supplied to consumers can assist in understanding drinking water system characteristics and the identification of hazards.

Water quality data should be reviewed both over time and following specific events (e.g. heavy rainfall, extended drought) to identify those aspects of the system that require improvement. Water quality parameters that can provide useful information include:

- Turbidity, color and taste
- microbial quality
- chemical quality (health-based parameters e.g. arsenic, fluoride, lead, nitrates) and salinity, iron and manganese level
- naturally occurring organic matter
- pH
- disinfectant residuals
- disinfection by-products.

In some cases, awareness of potential problems or hazards can be difficult because events occur gradually or result from cumulative effects. Trends analysis can be a valuable tool for recognizing the accumulation of gradual changes and for predicting where things may be going wrong.

6.1.1.2 Hazard identification

What needs to be done

1. *Define the approach and methodology to be used for hazard identification. Devise an evaluation team with appropriate representatives.*
2. *Review hazardous agents in drinking water and ensure that their link to public health is understood.*
3. *Identify and document hazards, sources and hazardous events for each component of the water supply system (see Tables 9 and 10).*
4. *Periodically review and update the hazard identification to incorporate any new hazards.*

Adoption of a risk-based approach that includes the identification of hazards from catchment to consumer and the assessment of the potential impact on drinking water quality and human health (i.e. risk) is essential to effective water supply system management. Hazard identification and risk assessment are useful for understanding the vulnerability of a drinking water supply and planning effective risk management strategies to assure drinking water quality and safety. The purpose is to identify and document all potential hazards and the hazardous events and sources that might give rise to the presence of these hazards.

A structured approach is important to ensure that significant issues are not overlooked and that areas of greatest risk are identified. There is no single right way to perform these activities; however, the process should involve a structured and comprehensive evaluation of the water supply system.

For each component of the water supply system, all hazards and hazardous events and sources that might affect drinking water quality and safety (what can happen and how) should be identified and documented. Table 9 provides examples of various pollution sources and the potential hazards they produce.

All potential hazards, hazardous events and sources should be included in the assessment, regardless of whether or not they are under the direct control of the drinking water supplier. Continuous, intermittent or seasonal pollution patterns should also be considered as well as extreme and infrequent events such as droughts or floods. Table 10 provides examples of potential sources and hazardous events, from catchment to consumer, to be considered.

Table 9 Examples of sources and potential hazards

Potential sources	Potential hazard
Septic tanks	Pathogens, nitrates/nitrites
Animal husbandry	Pathogens, nutrients, turbidity, color
Rural storm-water	Pathogens, turbidity, color
Forestry	Pesticides, turbidity, color
Agricultural activity	Pesticides, nitrates/nitrites, turbidity, color
Industry	Heavy metals, organic chemicals including halogenated organics; specific industries can be associated with specific types of contaminants (e.g. arsenic and copper associated with wood preserving, gold refining, cadmium and chromium with electroplating and chromium with leather tanning).
Mining	Acid mine wastes from pyrites tailings can release and transport metals such as aluminum, iron and manganese; other naturally occurring metals such as cadmium and copper can also be leached; arsenic can be associated with goldmine areas, particularly with illegal mining "The galamsay".
Urban storm-water	Lead and zinc from roads, turbidity, color, petrol/oil products, microorganisms from pets (lower range of pathogens than from humans or livestock waste).
Storm-water/sewer overflows	Pathogens, nutrients, turbidity, color

Table 10 Examples of hazardous events and their potential sources

Catchments and groundwater systems	
▪ Rapid variations in raw water quality ▪ Sewage and septic system discharges ▪ Industrial discharges ▪ Chemical use in catchment areas (e.g. use of fertilizers and agricultural pesticides) ▪ Major spills and accidental spillage ▪ Public roads ▪ Human access (recreational activity) ▪ Inadequate buffer zones ▪ Surrounding land use (e.g. animal husbandry, agriculture, forestry, industrial area, waste disposal, gold mining) ▪ Changes in surrounding land use ▪ Poorly vegetated riparian zones, failure of sediment traps and soil erosion ▪ Storm-water flows and discharges	▪ Existing or historical waste-disposal or mining sites/contaminated sites and hazardous wastes ▪ Unconfined and shallow aquifers (nitrates and nitrites) ▪ Groundwater under direct influence of surface water ▪ Inadequate well-head protection and unhygienic practices ▪ Uncased or inadequately cased bores ▪ Saline intrusion of coastal aquifers ▪ Contaminated aquifers (iron, manganese, arsenic and fluoride) ▪ Climatic and seasonal variations (e.g. heavy rainfalls, droughts) ▪ Bushfires, natural disasters, sabotage ▪ Unrestricted livestock
Storage reservoirs and intakes	
▪ Open reservoirs and aqueducts, uncovered storages ▪ Human access/absence of exclusion areas around shorelines ▪ Animal access including birds and vermin ▪ Short-circuiting of reservoir ▪ Depletion of reservoir storage ▪ No selective withdrawal ▪ No alternative water sources ▪ Unsuitable intake location	▪ Cyanobacterial blooms ▪ Stratification ▪ Soil erosion ▪ Inadequate buffer zones and vegetation ▪ Climatic and seasonal variations (e.g. heavy rainfalls, droughts) ▪ Public roads / accidental spillage ▪ Failure of alarms and monitoring equipment ▪ Bushfires and natural disasters and Sabotage
Treatment systems	
▪ Significant flow variations through water treatment system ▪ Incapable equipment or unit processes ▪ Inadequate backup ▪ Inappropriate treatment processes ▪ Process control incapability or operational inflexibility ▪ Use of unapproved or contaminated water treatment chemicals and materials ▪ Chemical dosing failures ▪ Inadequate mixing ▪ Failure of dosing equipment ▪ Inadequate filter operation and backwash recycling ▪ Ineffective disinfection ▪ Equipment malfunctions ▪ Poor reliability of processes ▪ Failure of alarms and monitoring equipment ▪ Sabotage and natural disasters ▪ Formation of disinfection byproducts ▪ Service reservoirs and distribution systems ▪ Open reservoirs and aqueducts/uncovered storages and unprotected pipe system ▪ Human access, absence of exclusion areas around shorelines, Animal access	▪ Short-circuiting of reservoir, stagnation zones ▪ Buildup of sediments and slimes ▪ Inappropriate materials and coatings or material failure ▪ Aged pipes, infrastructure ▪ Corrosion of reservoirs and pipe system ▪ Mixing of different source waters ▪ Infiltration and ingress of contamination from cross-connections, backflow (soil and groundwater) ▪ Biofilms, regrowth ▪ Pipe bursts or leaks ▪ Inadequate repair and maintenance, inadequate system flushing and reservoir cleaning ▪ Commissioning new mains ▪ Inadequate disinfection after construction, repairs ▪ Flow variability, inadequate pressures ▪ Treatment dosing failure ▪ Inadequate maintenance of chlorine residual ▪ Formation of disinfection byproducts ▪ Failure of alarms and monitoring equipment ▪ Sabotage and natural disasters, power failures
Consumers	
▪ Potential consumer misuse of water ▪ Inappropriate plumbing and construction materials	▪ Leaching of metals ▪ Unsafe storage and unhygienic handling of water

6.1.1.3 Risk assessment

What needs to be done

1. *Define a consistent approach to be used for risk assessment.*
2. *Evaluate the major sources of uncertainty associated with each hazard and hazardous event and consider actions to reduce uncertainty.*
3. *Determine significant risks and establish and document priorities for risk management (based on assessment of maximum and residual risk).*
4. *Periodically review and update the risk assessment.*

The objective of risk assessment is to distinguish between very high and low risks so that priorities for risk management can be established. Once potential hazards and their sources and events have been identified, the level of risk associated with each hazard or event needs to be estimated. Not all hazards will require the same degree of attention, and risk estimation assists in directing attention and resources to those hazards that are most threatening.

In some instances, an initial screening-level risk assessment may be useful to identify broad issues and show where to focus efforts for a more detailed assessment.

An example of an approach to estimating the level of risk is provided in Tables 2 to 4 2.2.1.3.

These tables have been adapted from WHO guidelines on *Risk Management* and can be modified to meet the needs of an organization. Using these tables to guide a risk assessment will quickly reveal the need to define the level of detail required and format to be used for classifying events. Events may arise along a continuum from commonly recurring incidents of minor consequence to rarer incidents with more serious consequences.

In some cases, variations of the same type of event can appear at both ends of the spectrum. For example, 'loss of disinfectant residual in the distribution system' can have distinctly different meanings. A slight reduction or a loss in parts of a system may be fairly common and have limited health consequences; a total loss of disinfection should be rare but could have potentially severe consequences. There is no set of rules to be followed in using these tables; rather, they are offered as a general guide for the development of a consistent methodology that will be relevant for the water system under study.

Based on the assessment of risk, priorities for risk management should be determined. Maximum risk in the absence of preventive measures should first be determined to identify high-priority risks and provide an indication of worst-case scenarios in the event of failures. Residual risk, determined in conjunction with evaluation of existing preventive measures, should also be assessed to provide information on the effectiveness of existing strategies and the need for improvements.

6.1.2 Preventive measures and multiple barriers

What needs to be done

1. *Identify existing preventive measures from catchment to consumer for each significant hazard and event.*
2. *Determine the residual risk.*
3. *Evaluate alternative and additional preventive measures where improvement is required.*
4. *Document the preventive measures and strategies addressing each significant risk into a plan.*
5. *Establish mechanisms to ensure cooperation and development of action plans with external agencies.*

The identification, evaluation and planning of preventive measures should always be based on system specific hazard identification and risk assessment. The level of protection used to control a hazard should be proportional to the associated risk.

The multiple barrier principle should be employed and preventive measures should be comprehensive from catchment to consumer. Wherever possible, the focus of these measures should be to prevent contamination in the catchment rather than to rely on downstream control. Box 6 provides further information on catchment management and source water protection. Examples of preventive measures and management strategies from catchment to consumer are provided in Table 11.

Once preventive measures addressing each significant risk have been identified, the strategies should be documented into a plan. Any new preventive measures to be implemented over the longer term, such as covering water storages or the introduction of filtration, should be incorporated into an improvement plan (see Section 2.3.4). Where responsibility for preventive measures lies outside the direct control of the drinking water supplier (i.e. with external agencies), mechanisms for communication to ensure cooperation and development of action plans should be established (see Section 2.1.2).

***Box 6** Catchment management and source water protection*

Catchment management and source water protection provide the first barrier for the protection of water quality. Catchment management usually involves a coordinated approach to develop short-term and long-term plans to enhance water quality and eliminate or control any potential sources of pollution.

Whether water is drawn from surface catchments or underground sources, it is important that the local catchment or aquifer is understood, and that the activities that could lead to water pollution are identified and managed. Effective catchment management and source water protection include development of a catchment management plan with the commitment of land use planning authorities to prevent inappropriate development and to enforce relevant planning regulations.

Catchment management plans

A comprehensive catchment management plan should be developed and implemented to mitigate any existing and potential future risks, and where practical, aim to improve the quality of water harvested over time. The plan should include, where appropriate, the following elements:

- a policy statement identifying the protection of water quality as an explicit objective of local legislation

- preparation and review of land use planning controls jointly with the planning authority
- establishment of agreed processes and criteria for managing development applications
- a clear statement of responsibilities of different organizations and agreed coordination processes
- identification of water quality hazards, estimation of risks and planning of relevant management strategies
- a monitoring program to identify pollution sources, maintain quality control, and collect long-term data to determine trends
- regular documented inspections to monitor catchment conditions and land use changes
- a community awareness program, including strategies for working with landowners to support the catchment management plan
- agreed and tested emergency response plans with relevant emergency services for responding to major pollution events such as spillages or contamination.

The extent to which catchment pollution can be controlled or remediated is often limited in practical terms wherever there are competing water uses and pressure for increased development in the catchment. In devising catchment management plans, it may be necessary or useful to divide large catchments into smaller, more manageable units (e.g. sub-catchments). Where this is done, it is important to ensure that, in combination, the various plans provide an integrated approach across the entire catchment. For large river systems protection may be possible only over limited reaches in the vicinity of the raw water off-take or reservoir inlet.

Planning controls

Well-designed planning regulations are a critical component of sound catchment management and protection of water quality. Where possible, protection of water resources should be included as a principal objective in planning policies.

Planning regulations should address management and control of high-risk development in catchments and aquifer intake areas (e.g. intensive animal feedlots) and should also address the issue of long-term incremental development. Urban development, agroindustry and gold mining industry should be carefully scrutinized to ensure that they will not impact on water resources. On site waste treatment and disposal systems should be permitted only where sites are suitable and there is minimal risk to the water supply. Such systems should be designed, installed and maintained correctly, and inspected regularly. Defects should be reported and rectified.

Responsibility for the development and implementation of planning strategies and regulations is generally shared between central and district government agencies. It is important that drinking water suppliers and environment and health authorities establish strong links with planning agencies and take an active role in:

- the development or amendment of these planning strategies and regulations
- the evaluation of individual development proposals with respect to potential impacts on water quality or quantity.

Community awareness

Community awareness programs should be developed to promote the protection of water quality. Diffuse sources of pollution arising from illegal gold mining, agricultural and animal husbandry activities are difficult to manage but their effect on water quality can be minimized by the use of best practice management such as fencing of streams, management of buffer zones. Landowners can be encouraged to protect stream banks and provide buffer strips through community awareness programs and by subsidizing tree planting and fencing works.

Table 11 Examples of preventive measures from catchment to consumer

Source water and catchments	
▪ Use of an appropriate source water ▪ Ownership and control of catchment area ▪ Designated and limited uses ▪ Registration of chemicals used in catchments ▪ Control of human activities within catchment boundaries ▪ Control of wastewater effluents ▪ Participation of community and landowners within the catchment area	▪ Involvement in land use planning procedures ▪ Regular inspections of catchment areas ▪ Protection of waterways (fencing out livestock, buffer zones, management of riparian zones) ▪ Runoff interception ▪ Use of planning and environmental regulations to regulate potential water polluting developments ▪ Use of industry codes of practice and best practice management
Water extraction and storage systems	
▪ Control of water extraction ▪ Alternate selection of water source ▪ Use of available water storage for periods of heavy rainfall ▪ Appropriate location and protection of intake ▪ Proper well construction including casing, sealing and well-head security ▪ Proper location of wells in aquifer ▪ Water storage systems to maximize detention times ▪ Infiltration wells	▪ Enclosed water storages ▪ Prevention of unauthorized access ▪ Destratification of water storage ▪ Diversion of storm-water downstream from intake ▪ Roofed storages and reservoirs with appropriate ▪ Storm-water collection and drainage ▪ Securing tanks from access by animals ▪ System maintenance (reservoir cleaning or scouring, pipeline flushing, fittings maintenance)
Water treatment system	
▪ Coagulation or flocculation and sedimentation ▪ Alternative treatment ▪ Use of approved water treatment chemicals and materials ▪ Control of water treatment chemicals ▪ Regular assessment of hazards and risks ▪ Use of skilled and trained operators	▪ Process controllability of equipment ▪ Availability of backup systems ▪ Water treatment process optimization, including (chemical dosing, filter backwashing, flow rate, minor infrastructure modifications ▪ Use of tank storage in periods of poor-quality raw water
Distribution systems	
▪ Distribution system maintenance ▪ Availability of backup systems (power supply) ▪ Maintaining an adequate disinfectant residual ▪ Cross-connection and backflow prevention	▪ Fully enclosed distribution system and storages ▪ Secondary disinfection in distribution main pipes ▪ Appropriate repair procedures, including subsequent ▪ Maintaining adequate system pressure
Monitoring	
▪ Quality assurance and validation procedures for sampling and testing	▪ Calibration and maintenance of field and lab equipment
Consumers	
▪ Information dissemination ▪ Responsibilities relating to drinking water quality ▪ Plumbing and appliances	▪ Backflow prevention ▪ Household water treatment and safe storage and hygienic handling of water

6.2 Monitoring overview

Drinking-water quality monitoring is meant to confirm the effectiveness of the preventive measures and barriers to contamination, and to enhance understanding of system performance. This is achieved through the collection of data that increase understanding of the entire water supply system, including the hazards and risks that are present, the performance of treatment barriers, the integrity of the distribution system and the consumer satisfaction.

The Framework encourages a considered, overall strategy for monitoring that includes:

- **operational monitoring** in the source/catchment, through the treatment process, and in the distribution system, to ensure that processes and activities are functioning optimally to achieve safe drinking water;
- **verification of drinking water quality**, which consists of:
  - drinking water quality monitoring in the distribution system to verify the quality of treated water as supplied to the consumer; and
  - consumer satisfaction monitoring to assess consumer comments and complaints;
- **investigative studies and research monitoring** (including baseline monitoring where new water sources are going to be used to supply drinking water) to identify and characterize hazards, and increase understanding of a water supply system;
- **validation monitoring** is to monitor the effectiveness new operational processes and barriers;
- **incident and emergency response monitoring**, it is undertaken in response to incidents or emergencies.

Each type of monitoring supports the others in the overall understanding and management of a water supply system, and in interpreting the monitoring data that are generated.

The overall goal of monitoring is to provide a high level of public health protection by minimizing the risk of supplying contaminated drinking water. Water suppliers therefore need to ensure that monitoring attention and resources are directed to those aspects that provide the greatest assurance of drinking water quality. Monitoring programs that focus primarily on the quality of treated drinking water do not effectively guarantee the supply of safe drinking water.

6.2.1 Monitoring priorities

While the potential contaminants of drinking water supplies are many. The most significant contaminants are waterborne microbial pathogens which represent the clearest and most acute risk to drinking water safety, and they can cause outbreaks of illness that affect a high proportion of the community.

Chemical contamination does occur but such contamination typically arises from specific natural local conditions like fluoride in Northern Regions or from site-specific contamination by humans (illegal gold mining activities, distribution cross-connections). Priority chemicals (arising primarily from natural contamination) include arsenic, fluoride, nitrates and lead. Iron and manganese and high salinity are also identified as frequent sources of aesthetic water quality problems.

Chemicals used in water treatment may pose a risk because of the potential for unintentional contamination, and they should be monitored accordingly. By-products of disinfection should also be monitored, because of the possible adverse health effects from chronic exposure to these chemicals.

Most other chemicals, including pesticides and other trace organics, do not warrant the same level of monitoring attention as microbial pathogens or the chemicals of main concern, unless there is evidence or reasonable inference of their potential presence, as determined through site-specific investigation and analysis of the water supply system. Box 7 summarizes monitoring priorities based on health risk.

Box 7 Monitoring priorities based on health risk

Key characteristics related to health include:

- microbial indicator organisms and disinfectant residuals;
- any known characteristics that can be reasonably expected to exceed the standards value, even if occasionally;
- any chemicals used in treatment processes and any by-products that may result from their use;
- any potential contaminants identified through the water supply system analysis (see Section 2.2.1.1) and hazard identification (see Section 2.2.1.3), even if undetected.

Some characteristics not related to health, such as those with significant aesthetic impacts, should also be monitored. Where aesthetic characteristics (e.g. taste and odor) are frequently unacceptable, further investigation may be needed to determine whether there are problems with significance for health.

6.2.2 Principles of monitoring frequency

The frequency of monitoring of each water quality parameter depends on the hazard and risk profile of the parameter as identified through analysis of the water supply system. In general, parameters that pose a high level of risk require more monitoring, while those posing a low risk require less monitoring. Typically, the most frequent monitoring is for microbial safety, followed by known or identified high priority parameter, with less frequent monitoring for any parameters that are not likely to present a risk.

Operational monitoring of preventive measures and barriers throughout the water supply system should be carried out with sufficient frequency to reveal any challenges or failures promptly, so that corrective actions can be taken. Continuous monitoring should be used wherever possible, particularly for essential processes identified as critical control points, such as disinfection and filtration (see Sections 2.2.2.2 and 6.2.5.2).

Depending on the historical data available and the present understanding of source water characteristics, a baseline investigation of contaminants in a water supply is essential to assess hazards and their risk levels.

Disease outbreaks associated with drinking water supplies are often linked to unusual events. Such events should therefore be recognized as potential triggers for increased challenges and potential suboptimal performance, and should alert water managers to the potential for problems and the need for increased monitoring of performance throughout the system. Unusual events include any sudden or extreme change in weather, flow or water quality, as well as power outages, treatment variations, and maintenance and repairs. The increased monitoring frequency should be maintained until there is confidence that water quality is back within specification.

The risk of contamination of water supplies with microbial pathogens is always present. While safeguards and multiple barriers may be in place, the historical absence of waterborne outbreaks in a water system is no guarantee that one will not occur in the future unless the effectiveness of the barriers is continuously maintained and verified. Constant vigilance and effective monitoring programs that support understanding of a water supply system, its challenges and capabilities are of paramount importance in assuring the safety of drinking water. More detailed discussion on specific sampling frequencies within the water supply system is provided in Section 6.2.5.4.

6.2.3 Catchment-to-consumer monitoring

An integrated approach to monitoring incorporates all aspects of the water supply system, including catchment and source water, treatment processes, the distribution system and consumers, to provide key information on system management and operation.

6.2.3.1 Source water

Effective system management requires knowledge of the source water (surface, ground or sea water) and the characteristics of the associated catchment area. Source water monitoring assists a water supplier in understanding what hazards are possible and the contamination challenge (i.e. the level of risk) they present. Where a new drinking water source is to be brought on line (either adding to an existing water supply system, or as part of a new one), a range of monitoring and other background investigations are needed to inform hazard identification and risk assessment for the supply system. Monitoring requirements will be influenced by the characteristics of the water source and catchment. Types of monitoring to be considered include:

- microbiological monitoring based on potential sources of fecal contamination (e.g. sewage and septic waste, livestock);
- microbiological and chemical monitoring to assess intermittent or seasonal pollution patterns;
- chemical monitoring based on identified geology, agricultural, mining and industrial pollution sources;
- identification of existing land uses and planned developments.

6.2.3.2 Water treatment plant

Monitoring of treatment processes and barriers is fundamental to a preventive strategy for drinking water safety. The advantage of monitoring treatment performance is that, if set up correctly, ineffective treatment processes (e.g. inadequate disinfection, degraded filtered water quality) can be identified and acted upon in close to real-time, to prevent potentially contaminated water from reaching consumers. To help ensure that unsafe water is not delivered to consumers, monitoring results need to be promptly evaluated and reported and, where appropriate, corrective actions need to be implemented immediately.

If the source water challenge and water treatment capabilities are understood, if attention is focused on understanding treatment performance, and if performance is monitored continuously, this provides a high level of assurance of drinking water safety.

6.2.3.3 Distribution system

Monitoring the integrity of the distribution system, and the quality of water supplied to consumers, is necessary to confirm that drinking water quality is maintained. Efficient design, management and integrity of distribution systems are essential for maintaining water quality. Monitoring programs should consider the potential for stagnation and ingress of contamination through faults in the distribution system. Stagnation and growth of biofilms can occur in poorly designed and operated distribution systems, while ingress of contamination can occur through tanks, reservoirs and pipes, cross-connections to the pipe network, and poor control of repairs or installation of new mains.

6.2.3.4 Consumers

Monitoring consumer satisfaction is another important surveillance mechanism. Consumers are located throughout distribution systems and their feedback can be directly related to the quality of drinking water supplied. They can provide timely information on potential problems, particularly within the distribution system, that may otherwise go unidentified.

6.2.4 Developing a monitoring program

Monitoring is an integral component of risk management. Because it is not possible to monitor for all things at all times, the monitoring program for a particular water supply system must be structured so that it enhances system knowledge and feeds into decision-making processes. The monitoring program should be designed by personnel who understand the water supply system, the assessment of water quality, and the preventive management approach detailed in the framework. Monitoring program may be developed in consultation with water supply system operators, planners and health regulators, or authorities responsible for auditing the performance of the drinking water supply system. The monitoring program should address four broad questions:

- What are the hazards and risks of concern, what are the sources and what data exists? (i.e. investigative studies and research, including baseline monitoring or historical water quality data)
- Are the barriers sufficient to manage the hazards and risks? (i.e. validation monitoring)
- Are the preventive strategies working now? (i.e. operational monitoring)
- Did the preventive strategies work? (i.e. verification of drinking water quality)

Once the objective and purpose of a monitoring activity is defined, the following questions could be used to determine the specifics:

- What data can be collected to provide the needed information?
- Is this the most effective way to generate this information? What alternatives are available for achieving the desired objective?
- How will the data be collected?

- Where will the data be collected?
- When will the data be collected?
- What will be done with the information? How will the data be used?
- How will the data be interpreted and evaluated?
- How will the data be responded to, and who should be notified?

Analysis of this type will help to generate data that are meaningful and useful. Monitoring activities relate not only to the collection of samples for laboratory analysis, but also to observations, field measurements. All monitoring activities, and their bases, need to be documented into a comprehensive monitoring program that supports an integrated and comprehensive understanding of the water supply system, including the rationale for the monitoring decisions.

All monitoring data should be subject to short-term evaluation. In addition, monitoring data collected over the long-term should also be reviewed periodically and linked back into the system analysis and risk assessment. The aim is to assess whether there have been any significant changes to key characteristics or levels of challenge that warrant changes to system management, including the monitoring strategy.

6.2.5 Operational monitoring

Preventive measures and barriers to contamination should be applied from catchment to consumer in accordance with the multiple barrier approach, and these measures and barriers should be regularly monitored to assure their ongoing effectiveness. Operational monitoring includes a planned sequence of measurements and observation throughout the water supply system to ensure and confirm performance of preventive measures and barriers to contamination. To be effective, operational monitoring is needed at those points within the water supply system, including critical control points (see Section 2.2.2.2) such that if an adverse result is obtained, corrective action can be triggered to ensure that unsafe water does not reach the consumer.

Developing a protocol for monitoring operational performance of a water system requires the following steps:

- Identify preventive measures (see Section 2.2.2).
- Select operational characteristics and associated operational objectives to be used to assess the operational process or activity.
- Establish corrective actions to address any deviation in operational characteristics from defined objectives.
- Include frequent, routine monitoring of operational characteristics and ongoing analysis of monitoring results.

6.2.5.1 Operational characteristics

The characteristics selected for operational monitoring should provide useful information concerning operational activities and performance. It is common, particularly in monitoring the operation of treatment processes, to use surrogates or indicators for water quality characteristics when direct testing is difficult, time-consuming or expensive e.g. pH, turbidity, color, electrical conductivity, total coliform. Routine observational monitoring should be in place from catchment to consumer to identify and confirm, for example:

- the general level of activity in the catchment and/or reservoir, any illegal activities and sources of contamination, and the effectiveness of preventive measures such as gates, fences and signs;
- the security of the water treatment plant and chlorination facilities;
- that the chemicals used in water treatment are appropriate
- the integrity of dosing equipment;
- the performance of treatment processes such as effective folk formation, bubbling in granular filters, membrane integrity;
- the integrity of service tanks or reservoirs and the pipe network; and
- that routine preventive maintenance is undertaken throughout the water supply system.

6.2.5.2 Critical limits at critical control points

A critical limit is a prescribed tolerance that distinguishes acceptable performance from unacceptable performance at a critical control point in terms of hazard removal or attenuation. Breaching a critical limit represents loss of control of the process and the existence of a health risk, either directly through the supply of unsafe water, or indirectly, where multiple critical control points exist, by exceeding the capacity of subsequent processes. Such events should result in immediate corrective actions to re-establish operations within specification, and notification of the health regulator. Setting target criteria that are more stringent than the critical limits at critical control points will enable corrective actions to be instituted before an unacceptable health risk occurs. Exceeding a target criterion at a critical control point would generally not require that the health regulator be notified, providing corrective action successfully prevents deviation from a critical limit. Box 8 provides an example of setting operational requirements for filtration as a critical control point.

Box 8 Target criteria and critical limits for filtration

Where drinking water is sourced from multi-use surface water with risk of contamination by *Cryptosporidium*, filtration is often the primary barrier to these chlorine-resistant protozoan pathogens. It is critical that filter performance be optimized and continuously monitored to ensure that the required pathogen removal is achieved and safe drinking water provided at all times.

Whilst not a perfect measure of performance, continuous monitoring of filtered water turbidity is currently the best practical alternative for assessing filter performance. It is strongly recommended that continuous on-line turbidity meters be installed on the outlet of each individual filter, as monitoring only at the combined filter outlet may fail to detect poor performance of an individual filter. With filtration defined as a critical control point, a **critical limit** is set to define unacceptable performance contributing to a significant health risk (e.g. 0.5 NTU). Measured turbidities above this limit indicate loss of control of the process and compromised pathogen removal. To ensure critical limits are not breached, **target criteria** should also be established. A target criterion for filtration may be to achieve <0.2 NTU.

6.2.5.3 Corrective action

Where monitoring results indicate a deviation from target criteria or critical limits, appropriate corrective actions and process adjustments should be instituted to maintain water quality. Examples of corrective actions are:

Additional monitoring will be required throughout the system to verify the effectiveness of any corrective actions.

- repairing fences;
- removing dead animals from catchment areas;
- increasing catchment controls;
- inspecting the water supply system for faults;
- altering the flow rate of the water treatment plant to reduce loading;
- manual backwashing of filters;
- inspecting and calibrating monitoring equipment;
- engaging back-up equipment;
- adjusting pH;
- selecting an alternative water source, if available;
- increasing disinfection dose;
- booster disinfection;
- flushing of mains; or
- increasing monitoring and observation.

6.2.5.4 Operational monitoring frequency

Operational characteristics throughout the system should be monitored often enough to reveal any failures and trigger a response within a timeframe that is appropriate to how critical the monitored activity or process is. This applies to both measurements and observational monitoring. Online and continuous monitoring should be used wherever possible, particularly at critical control points. For operational characteristics that are deemed less critical or are more stable, grab samples or regular inspections may be sufficient.

Frequency of observations may be increased at times of increased risk; for example, inspections of reservoirs for algal blooms may be more frequent during summer, or folk blanket observations during the coagulation process may be increased when there are higher flow rates through the treatment plant.

Operational monitoring requirements and frequency of monitoring will vary for each water supply, depending on the key characteristics identified through analysis of the water supply system and risk assessment. Table 12 provides an example of how selected operational characteristics can be used within a catchment-to-consumer operational monitoring program.

Table 12 Example of an operational monitoring program (characteristics and frequencies)

Location	Characteristic	Monitoring frequency	Rationale
Catchment			
General catchment	Rainfall	Daily	Understand impact of rainfall on water quality – to help predict challenge under range of rainfall intensity.
	Inspection	Monthly to Daily Frequency depends on level of access and use permitted in catchment.	Detect human and animal activities that could cause contamination; confirm that fences and signs are effective.
Feeder streams in catchment	Turbidity, color, *E. coli*	Monthly plus events	Early warning of changes to raw water quality to allow timely changes to treatment processes. Detect local contamination and disturbances.
	Cryptosporidium	Risk-based	Assess if treatment barriers are needed to effectively remove or inactivate cryptosporidium.
Source Water			
Storage dam or raw water reservoir	Temperature and Dissolved oxygen profile	Monthly to weekly	Information for management of water quality in storage with existing or new management systems.
	General water quality profile	Weekly to event based	Allow best quality water to be selected for supply.
	Inspection	Weekly	Detect human and animal activities that could cause contamination.
	Cryptosporidium	Risk-based	Information for changes to water treatment processes in order to maintain optimal *Cryptosporidium* removal.
	Turbidity *Color*	Continuous Weekly to event based	Information for changes to water treatment processes in order to maintain optimal turbidity and color removal.
River intake	*Rainfall*	Daily	Understand impact of rainfall on water quality to help predict challenge under range of rainfall intensity.
	Turbidity Color	Continuous Weekly to event based	Inform changes to water treatment processes in order to maintain optimal turbidity and color removal.
	Iron, Manganese	Weekly (risk-based)	Inform changes to water treatment processes in order to maintain optimal iron and manganese removal; forewarn of water quality that may cause customer complaints.
	Cryptosporidium	Risk-based	Inform changes to water treatment processes in order to maintain optimal *Cryptosporidium* removal.
	Turbidity,	(Rainfall-related monitoring)	Understand rainfall effects
	E. coli Cryptosporidium	Risk-based	Identify high challenge periods and forewarn downstream processes; identify local point source of contamination. Intervene in catchment before reservoir affected.
	Pesticides and color		Feedback to industry and source of contamination

Table 12 Example of an operational monitoring program (characteristics and frequencies) (continue)

Location	Characteristic	Monitoring frequency	Rationale
Treatment Processes			
Coagulation (inlet to flocculation tank)	pH	Daily to Continuous	Optimize pH for effective coagulation of selected coagulants when raw water quality changes. Provide alarm if pH is outside set limits.
Flocculation (last compartment)	Flock characteristics	Daily toEvent based	Optimize flock characteristics for effective clarification or filtration when changes occur to raw water quality or operating conditions.
Clarifier (clarified water outlet)	Turbidity Color Visual observation of flock or flock blankets	Daily to Continuous Daily to Event based Daily to Event based	Confirm coagulant dose, pH correction, flocculation and clarifier operations are optimized when changes occur to raw water quality or operating conditions. Provide alarm if turbidity is above set limit. Assess if adjustment needed to process to improve stability of clarification process.
Filtration (Individual or combined filtered water)	Turbidity Filter Headloss	Continuous Continuous	Provide alarm if filtrate turbidity is above set maximum. Trigger for initiating filter cleaning. Trigger for initiating filter cleaning to avoid turbidity breakthrough.
Filtration (Combined filtered water post pH correction)	pH	Continuous	Confirm target pH range is maintained. Provide alarm if pH is outside target limits for effective disinfection and corrosion control.
	Aluminum (If aluminum-based coagulant used)	Weekly	Assess inadvertent carry-over of aluminum from sub-optimal flocculation pH.
Chlorine Disinfection	Free chlorine residual	Continuous	Provide alarm if chlorine residual is outside set limits for maintaining integrity of water quality during reticulation and for reticulation hygiene.
UV Disinfection	UV dose rate	Continuous	Confirm UV system is operating satisfactorily. Provide alarm if below minimum set dose.
Distribution System			
Disinfection (At various locations in the reticulation system selected by careful monitoring design)	Chlorine residual	Continuous to Daily	Confirm total chlorine target or free chlorine residual target range are achieved.
Service Reservoirs and tank	Integrity from contamination	1 to 5 yearly	Confirm roof/hatches are effective against ingress of contaminants.
Consumers	Customer complaints	Ongoing	Clusters of complaints of turbidity, objectionable taste and odor, illness allow investigation to identify cause(s) of water quality problems.

6.3 Verification of drinking water quality

Verification of drinking water quality provides an assessment of the quality of drinking water being supplied to consumers. It incorporates monitoring drinking water quality in the distribution system and assessing consumer satisfaction.

Verification of drinking water quality provides an important link back to the operation of the water supply system and additional assurance that the preventive measures and treatment barriers in the water supply system have worked, and are working, to supply safe drinking water. This information helps in assessing long-term system performance and identifying any trends or problems within the water supply system that may have gone unrecognized, and it provides confidence to consumers and regulators regarding the quality of water supplied.

6.3.1 Monitoring consumer satisfaction

Monitoring consumer satisfaction can provide valuable and timely information on potential problems that may go unidentified by performance monitoring. Changes from the norm are particularly noticeable to consumers, who are often the first to identify something unusual about the water delivered to their tap.

In addition, because consumers are located throughout distribution systems, they offer a wide-ranging source of information on potential contamination, compared to limited monitoring in the distribution system. An effective consumer complaint and response system that is operated by trained personnel and closely linked to the operation of the water supply system is an important component of any preventive strategy for drinking water safety. The types of complaints that could signal potential contamination include objectionable taste, odor, high turbidity, unusual color, reduced water pressure, water supply interruption, suspicious activity, or illness. All complaints need to be investigated and documented, including the associated responses. Complaints of illness warrant particular attention and should be reported to the health authority for joint investigation.

Clearly, water suppliers would like to operate in a manner such that consumers will never need to complain. Nevertheless, to maximize the ability to detect contaminated water and respond to problems effectively, a water supplier should ensure that consumers are educated on what to expect in relation to the quality of their water (what is normal) and are encouraged to inform the supplier of any water-related concerns, including symptoms of illness.

6.3.2 Monitoring water quality

Drinking water quality monitoring is used to provide assurance that the quality of drinking water in the distribution system, as supplied to the consumer, is meeting national standards limits, agreed levels of service, and/or any regulatory requirements. It can provide an additional means of detecting any unrecognized problems that may be occurring upstream or within the distribution system, and can trigger the necessary corrective actions.

Drinking water quality monitoring cannot prevent unsafe water being supplied to consumers, as results are typically not available for days to weeks after collecting the sample, so that any corrective actions occur after the water has been supplied. Drinking water quality monitoring therefore, should not be used in place of or as a substitute for operational monitoring.

As it is neither physically nor economically feasible to test for all drinking water quality characteristics equally, monitoring effort and resources should be directed at significant or key characteristics that is, those characteristics identified in the water supply system specific hazard identification and risk assessment process as likely to be present. These key characteristics require more frequent monitoring. Characteristics that the risk assessment shows are unlikely to be present, or pose a low risk, are monitored very infrequently, or may not need to be included in the drinking water quality monitoring program.

Generally, sampling and analysis are required most frequently to assure microbial safety and less often for chemical and radiological compounds. This is because of the acute and almost universal health risk posed by waterborne microbial pathogens, whereas the standard values for most (but not all) chemical characteristics are based on lifetime exposure. In the absence of a specific event (e.g. spills, chemical overdosing at a treatment plant), episodes of chemical contamination that would constitute an acute health concern are rarer.

6.3.2.1 Sampling locations of water quality monitoring

Drinking water quality monitoring confirms the final quality of water that is supplied to consumers. As such, it needs to be undertaken throughout the distribution system at point representative of the quality of water supplied to consumers' properties.

The location and number of sampling points within a distribution system are determined by the complexity of the water supply system. For purposes of management, monitoring and reporting, large and complex distribution systems should be divided into discrete water quality monitoring zones.

As the priority for monitoring drinking water quality is to confirm microbial safety, the design of the microbiological sampling program often dictates the location of sampling points. Sampling points are normally placed well into the distribution system to be representative of what most consumers have received. They should also be spread geographically to give coverage across the water supply system or zone.

Circumstances where microbial quality has the potential to change within a distribution system need to be considered. This is most likely where the system is depressurized, increasing the chance for ingress (e.g. at a service tank). Sample points should, therefore, be included downstream of any tanks even though the source water may be unchanged.

Samples for physical and chemical quality monitoring can usually be taken from the sample points used for microbiological monitoring. Since physical and chemical quality monitoring requires many fewer samples in a given period, a decision must be made on whether to rotate sampling around all the sample points within a zone (providing an indication of performance across the zone) or to use only one or two fixed sample points (providing an opportunity to plot trends).

For chemical characteristics that are more stable and unaffected by the distribution system, sampling can occur at the entry point to the distribution system.

Operational monitoring such as chlorine residual monitoring is typically also carried out simultaneously at these sample points, as well as at other strategic locations within the distribution system, such as entry points (e.g. outlets of service reservoirs/tanks), trunk mains, and dead ends.

6.3.2.2 Sampling frequency of water quality monitoring

It is not practicable to prescribe a standard frequency of sampling without taking into consideration all the variables associated with a water supply, which include effects on the water from climatic, human and industrial activities, the volume of water processed, the population served, the area of reticulation and the capabilities of the analytical facility (both in terms of capacity and in terms of analytical performance). For this reason, Ghana Standards Authority (GSA) water quality standards for water quality sampling program suggest to establish a sampling program that takes into consideration appropriate international recommendations. In the absence of a formally established sampling program, GSA standards suggested minimum sampling frequency given in Table 13 could be used as an interim measure for drinking water in the distribution system.

Table 13 Minimum sampling frequencies for drinking water in distribution

Population served	Samples to be taken monthly
Less than 5000	1 sample
5001 – 100,000	1 sample per 5000 population
More than 100,000	1 sample per 10,000 population plus 10 additional samples

6.3.2.2.1 Microbial quality – sampling frequency

The more frequently the water is examined for fecal indicator organisms, the more likely it is that contamination will be detected. Routine monitoring for specific microbial pathogens is not recommended as it is usually complex, expensive and time-consuming, and may fail to detect their presence. Rather, globally the recommendation is to monitor for the microbial indicator bacterium *E. coli* as a marker for the presence of fecal contamination and the possible presence of microbial pathogens as it is currently the best verification indicator available for fecal related microbial quality. Whilst there are limitations to the use of *E. coli* as an indicator of fecal contamination of water supplies (e.g. *Cryptosporidium* oocysts may survive chlorine disinfection and may be present in the absence of *E. coli*), therefore water without *E. coli* should be seen as low-risk, rather than completely safe.

The recommended minimum monitoring frequency for *E. coli,* based on World Health Organization recommendations, is detailed in Table 14. Samples should be collected at points within the distribution system that are representative of the quality of water supplied to consumers.

Table 14 Recommended minimum frequency of *E. coli* monitoring

Type of water supply and population in monitoring zone	Minimum number of samples
Point sources	Progressive sampling of all sources over 3 to 5 years cycle (maximum)
Piped supplies	
<5000	One sample per month. Where the water supply in this category is remote, the recommended sampling frequency needs to be balanced against the logistics of collecting the samples, the risk profile for the supply, and the risk mitigation processes that are operating on the supply. With remote water supply systems, regular physical inspections and operational monitoring are more beneficial to ensuring water quality than infrequent *E. coli* sampling.
5000-100,000	One sample per month per monitoring zone of 5000 population
>100,000-500,000	One sample per month per monitoring zone of 10,000 population plus 10 additional sample per month per monitoring zone of 10, 000 population.
>500, 000	One sample per month per monitoring zone of 50,000 population plus 50 additional sample per month per monitoring zone of 50, 000 population.

Sampling should normally be random but should be increased at times of epidemics, flooding or emergency operations or following interruptions of supply or repair work. More frequent sampling should also occur at sample points where previous results have indicated potential problems. Operational monitoring such as disinfectant residuals, temperature and turbidity are often taken alongside with *E.coli* to provide complementary evidence of system status and enhance interpretation of data.

The results of the *E. coli* monitoring program will not prevent unsafe water being supplied to consumers, hence drinking water quality monitoring should not be substituted for or used in place of a well-constructed operational monitoring program. For systems serving small communities, regular physical inspections of the water supply system, and the monitoring of critical processes and activities, such as sanitary inspection and chlorination, yield more information than infrequent sampling (see Annexure 6.10).

6.3.2.3 Drinking water quality monitoring sampling frequency (non-microbial)

Monitoring requirements for non-microbial characteristics will vary for each water supply system, depending on the key characteristics identified through water supply system analysis and risk assessment. In general, characteristics that pose a high level of risk require more frequent monitoring, while those posing a low risk require less monitoring. The closer the mean value of a characteristic is to the water quality standards value, and/or the greater its variability, the more frequent the monitoring needs to be. Those characteristics that are deemed, on the basis of a thorough analysis of the catchment and water supply system, unlikely to be present will typically require very infrequent monitoring, or no monitoring at all.

Table 15 provides a generic guide to monitoring frequency for drinking water quality characteristics. Monitoring frequencies and characteristics for individual systems should be adjusted as needed, based on the ongoing review of the water supply system and risk assessment of historical water quality data.

Table 15 Recommended minimum frequency for water quality monitoring (non-microbial)

Characteristics	Frequency of water sampling				
	Weekly	Monthly	Quarterly	Annually	Comments
Physical characteristics	pH, Temperature Total dissolved solids*	Color, Turbidity, Dissolved oxygen Hardness**		Taste and odor	*If reverse osmosis used, or there are known salinity issues, otherwise quarterly **If water is treated for hardness
Water treatment related chemicals (if used)	Aluminum* Chlorine Copper (seasonal)		Any related organic contaminants, e.g. acrylamide, carbon tetrachloride, epichlorohydrin		*Aluminum not likely to be present if no alum-based coagulant is used.
In-organics	Iron and Manganese		*Arsenic, nitrate, *fluoride, selenium, lead, Ammonia, cadmium, chromium, nickel, zinc, copper, hydrogen sulfide	Tin, silver beryllium, uranium, iodide, molybdenum, boron, barium	*Quarterly sampling for groundwater sources, more frequent monitoring when arsenic and fluoride detected at elevated concentrations in surface or ground water sources; otherwise sampling reduced to annually, seasonally or event-related (e.g. storm events, spills).
Pesticides and organic toxicants		If detected or potential presence		If not detected	Monthly or quarterly sampling for pesticides/organic toxicants previously (or potentially) detected; seasonally annually, or event-related (e.g. storm events, spills) for other pesticides/organic toxicants.
Radiological				Radionuclides	New supplies should be assessed quarterly for one year, then every 2 years (groundwater) or 5 years (surface water). Increase frequency to quarterly if standard screening levels exceeded.

6.4 Investigative studies and research monitoring

Investigative studies and research monitoring can be used to increase understanding of a water supply system, identify and characterize potential hazards, fill gaps in knowledge, and inform targeted capital expenditure, system augmentation and operational improvements. By improving understanding of the factors affecting water quality characteristics, such monitoring allows suppliers to anticipate periods of poor water quality and respond to them more effectively. Investigative studies and research monitoring can often also be used to provide further information for the risk assessment process and reduce uncertainty. Examples include:

- baseline monitoring of characteristics or contaminants in potential new water sources, to identify water quality problems (see Box 9);
- source water monitoring, to understand the temporal and spatial variability of water quality characteristics;
- event-based monitoring in source water and catchment areas, to determine the magnitude of impacts (duration and maximum concentrations);
- developing early warning systems, to improve the management of poor water quality;
- examining mixing effects within a water storage;
- evaluating characteristics of an aquifer through pumping tests and analyses;
- examining backwash return water and its effect in increasing microorganism load;
- examining the effects of natural events that affect drinking water quality, such as bushfires or floods.

Box 9 Baseline monitoring of new drinking water sources

Baseline monitoring of raw water quality should be carried out for all new water supplies being considered, as well as any poorly characterized existing systems. Baseline monitoring informs the hazard identification and risk assessment process, and the development of effective ongoing monitoring regimes, by identifying major water quality problems and the key characteristics that should be routinely measured. This characterization of the water supply also establishes a base for assessing long-term trends and changes in water quality over time, and provides information to compare and select source waters for future supply.

The extent of sampling and the timeframe required for a baseline assessment will depend on land use in the catchment, levels of pollution found, and variability or trends in water quality. A land-use survey of the catchment should be carried out to identify any important features likely to affect water quality. Where catchments and supplies are beyond the water supplier's jurisdiction, exchange of information and collaborative assessment of the quality of source waters is strongly recommended e.g. with Water Resource Commission and Environmental Protection Agency.

The baseline water quality and potential levels of risk should be periodically assessed to identify any significant changes in water quality arising from changed land-use practices or the impacts of water abstraction (particularly from unconfined aquifer systems), as well as longer-term natural variability in water quality that may not have been evident from initial baseline monitoring.

6.5 Validation of barrier performance

Typically, validation monitoring is required where new treatment processes or significant operational changes are being implemented. Validation monitoring involves identifying the operational requirements that should be used to ensure that processes reduce risk to an acceptable level on an ongoing basis. In some cases, validation can be completed entirely using desktop assessment based on existing evidence; in other cases, objective empirical evidence from monitoring is needed. One of the most common applications of *in situ* validation monitoring is during or just after commissioning of new unit processes. Once the process is considered to be operating as intended, but before it is brought on line to supply water to consumers, microbial and/or chemical characteristics should be assessed in samples taken before, during or after the unit process to confirm that it can reduce the concentration of substances to the extent required.

Many drinking water treatment plant manufacturers, or suppliers of treatment processes, will undertake such tests on modular units and then market those units as being pre-validated. Some examples of where validation monitoring should be undertaken include:

- monitoring microbial indicator and particle count concentrations pre and post a media-based filtration plant, to check its pathogen-reduction capability;
- monitoring arsenic and/or fluoride concentrations pre and post treatment plant, to check its removal capability.

Once a unit process has been validated, ongoing monitoring of the unit is needed to ensure that it is operating correctly. This ongoing monitoring will form part of the operational monitoring program for the water supply system.

6.6 Incident and emergency response monitoring

General aspects of incident and emergency response are discussed in Chapter 4. Any emergency or incident is likely to trigger an increase in monitoring frequency. The increase in testing frequency for grab samples should reflect the risk that the incident poses to consumers and the characteristics being monitored. The increase in testing frequency should continue until water quality is confirmed as being back within specification.

Emergency incident plans need to take into consideration the capability and availability of operational and laboratory personnel. Experience shows that overwhelming laboratories with samples during incident conditions can cause major problems for laboratory quality control and can lead to adverse outcomes. It is important to maintain the quality of laboratory analysis regardless of the urgency of testing.

6.7 Reliability of monitoring data

6.7.1 Sample integrity

If the data collected as part of a monitoring program are to be meaningful, the samples need to be collected from appropriate locations, by trained personnel, working to a predetermined plan, and the procedures employed in the collection, preservation and transport of samples to the laboratory should be chosen with regard to the characteristics being measured.

6.7.2 Testing Methods

It is important that the results obtained in analyses are valid. If analysis of water supplies is to be useful, methods must yield consistent results; however, different methods of analysis can in some cases give different results on the same water sample. To ensure consistency, the GSA recommended method should be used, as it is well recognized, readily available and is widely used by most water testing laboratories. If other methods are to be used, it is important that they give results that are consistent with the standard methods.

Whatever analytical technique is used, it must give a result that can be compared to the listed health and aesthetic standards values. This is especially true in relation to the limit of detection for the method. Wherever possible, the method used should have a limit of detection that is less than the standards value. The whole analytical process, from sampling through to presentation of results, needs to be managed in accordance with sound quality assurance principles and should include quality control checks as part of the quality assurance process. Wherever possible, analyses should be undertaken at GSA attested laboratories.

6.7.3 Measurement uncertainty

There is an inherent level of uncertainty associated with the measurement of water quality characteristics, in addition to the uncertainty arising from sampling. This inherent uncertainty arises from a number of sources, but it primarily relates to the accuracy of the laboratory equipment used to produce a result, and various measurement errors that may be introduced through the analytical process.

In some cases, the level of uncertainty will be insignificant relative to the quoted result; in other cases, however, it can be quite significant. Organizations performing water quality testing are encouraged to certify the laboratories for ISO/IEC 17025—2005 “General Requirements for the Competence of Testing and Calibration Laboratories". This will promote an appreciation of the variability in the analytical data being received.

6.7.4 Field testing

Field testing can be used for operational monitoring of drinking water supplies, and its use is encouraged, particularly for small and remote systems where access to laboratory-based testing is difficult. Some tests, including those for temperature, residual chlorine, turbidity are always undertaken in the field. Sample storage times and conditions affect results such that unless analysis can be undertaken within a short time of sampling, field testing is the only method of deriving representative results.

Beyond those tests which must be done in the field, it is possible to acquire, at reasonable cost, basic chemical test kits for common physical and chemical characteristics, including pH, dissolved oxygen, electrical conductivity, color, iron, manganese, turbidity, chlorine and fluoride. These test procedures are well within the capabilities of trained treatment plant operators and system caretakers. The test results should generally, however, be regarded as indicative only, and should complement, but not replace, more reliable laboratory tests.

Recent advances in field tests for indicator microorganisms, such as total coliforms and *E. coli*, are making such tests feasible as part of drinking water quality monitoring in small and remote locations where it may not be possible to get samples to laboratories within the timeframe required for accurate analysis, or the costs of doing so are prohibitive. Furthermore, such kits enable many tests to be performed in the field, thus avoiding the need to preserve and transport samples to a laboratory.

In all cases where field testing is undertaken, it is essential that those doing the testing are appropriately trained, that analyzers are calibrated as per the manufacturers' specifications, and that an audited quality assurance program, ideally including proficiency testing, is in place to monitor testing performance. The extent to which a monitoring program relies on the results of field kits should be discussed with the relevant health regulator.

6.7.5 Monitoring advice for small, remote or community-managed water supplies

While small, remote water supplies are typically managed by a community group or a small private operator, some are managed by water utilities.

The same general principles apply for such supplies as for any other, with decisions on monitoring informed by risk assessment, and operational monitoring taking a higher priority. For example, tests of microbial quality of drinking water are a valuable adjunct to, but not a substitute for, assessing source water protection, treatment, and the integrity of treatment barriers through to the consumer's tap. Given the limitations in the ability of indicators to predict health risk accurately, it is essential to maintain effective barriers to fecal contamination.

Operational monitoring of small supplies will typically include a greater focus on observational monitoring, including regular inspections using the sanitary risk assessment surveys (preferably weekly) that generally includes:

- local source water catchment or recharge areas and source water reservoirs;
- bore-heads, to ensure that they are sealed and secure;
- fences and enclosures around bores, tanks and other infrastructure;
- tank roofs and above-ground pipes and valves, to ensure that integrity is maintained, roofs are intact and there are no breaks or leaks; and
- drainage at bore sites, air valve pits and scour valve pits.

Contamination events are often associated with extreme events, and observational monitoring should be undertaken to assess impacts of heavy rainfall, flooding and storms on infrastructure.

The most common form of treatment in small supplies is disinfection. Where applied, it will always be a critical control point. It should be monitored frequently. If other treatment processes are applied such as MACAFE for Iron and Manganese removal, then appropriate operational monitoring will be needed e.g. level of iron-manganese in treated water.

In general, drinking water quality monitoring of small water supplies should be based on the principle that it is much more effective to test for a narrow range of key characteristics as frequently as possible, than to conduct comprehensive but lengthy (and possibly largely irrelevant) range of analyses less often.

Key characteristics to be monitored as part of drinking water quality monitoring should include those with the potential to present significant risks and for which reliable verification of safety is required.

As discussed in Section 6.2.1, priority chemicals particularly for groundwater supplies include arsenic, fluoride, nitrate, lead and uranium. Iron, manganese, total dissolved solids and hardness can be sources of aesthetic water quality problems.

If data are not available, testing should be undertaken to determine background concentrations of key health-related hazards. This should be informed by a risk assessment, taking account of local geology, potential sources of chemicals (e.g. illegal gold mining) and known problems in the area identified by testing of nearby water supplies. Initially, quarterly monitoring is recommended, to include consideration of any seasonal influences.

Further testing should be based on mean concentrations and variability. In general, the closer the mean value of a characteristic is to the standard value, or the greater its variability, the more frequent the monitoring needs to be (for these characteristics, the suggested frequency is annual). Those characteristics that, based on risk assessment, are not likely to be present or have been shown to be present in concentrations well below standard values typically require monitoring very infrequently (e.g. every two years) or not at all.

Observational monitoring should be used to supplement the chemical testing program; for example, checking for chemical spillage and appropriate application, uses and storage of fertilizers and pesticides.

The monitoring program (and the available results) should be discussed with the regulator who has responsibility for the oversight of drinking water quality, to determine an appropriate sampling frequency.

Frequent testing for aesthetic characteristics is generally not justified once concentrations are established unless variability is expected or specific controls are introduced (e.g. desalination, pH correction, filtration of surface waters).

While monthly an *E. coli* testing is recommended in Table 14, there can be practical difficulties in performing microbial testing for small remote communities. The recommendation to collect weekly samples needs to be balanced against the logistics of collecting, preserving and transporting the samples, the risk profile for the supply, and the risk mitigation processes that are operating on the supply. Alternatives can include less frequent testing or the use of field kits.

6.8 Evaluation of monitoring data

Results from both operational monitoring, field measurements, observational activities and verification of drinking water quality should be evaluated over both the short and long term.

In the short term, monitoring results should be reviewed promptly to assess performance against target criteria and critical limits, national standards values, or agreed levels of service. Where results indicate that established criteria, such as critical limits, have been exceeded or deviated from, or control of the process has been lost, immediate corrective action is required.

> **Box 10**
> **Short-term evaluation** of monitoring date refers to the routine review of a single monitoring result, or a time-limited (for example, 24 hours) review of daily operational monitoring data.
> Short-term evaluation of monitoring data is meant to assess safety.
>
> **Long-term evaluation** of monitoring data refers to the review of data and the assessment of performance over a time period, typically over a year.
> Long-term evaluation of monitoring data is meant to assess performance.

The objective of the long-term review of monitoring data is to look at overall system performance in order to enhance understanding of recognized problems, identify any emerging problems and trends, and evaluate the risk to public health and the need for water quality improvement projects. Long-term evaluation of monitoring data can provide confirmation of the hazard identification and risk assessment process, and it assists in corroborating or modifying the assumptions made in the previous risk assessment, as well as increasing system knowledge.

6.8.1 Short-term evaluation of monitoring data

In the short term, monitoring results should be reviewed promptly to assess performance against target criteria and critical limits, national standards values, or agreed levels of service. Where results indicate that established criteria, such as critical limits, have been exceeded or deviated from, or control of the

Monitoring results should be reviewed promptly and assessed against specified operational criteria, standard values, agreed levels of service, or previous results, to ensure that preventive measures are functioning effectively and the drinking water quality supplied to consumers is acceptable. Monitoring results that fail to meet established criteria indicate a potential break in process control, and corrective actions are required to resolve the issue and regain control.

Those responsible for interpreting monitoring results and activities should have a sound understanding of the assessment process and the necessary responses, and should be familiar with any communication protocols. A considered approach to responding to potential failures should be developed and documented in advance, and should include any instructions on system investigation, additional monitoring, required adjustments upstream or downstream, and process control changes. The objective of the response is to re-establish the system within operating specification as rapidly as possible.

Immediate response and notification of the relevant health authority is required if there is a significant system failure that could pose a health risk or seriously affect water quality (e.g. non-conformance with critical limits, positive detections of *E. coli* within the distribution system, health-related chemical detections above the relevant standards value). Incident and emergency response plans should be developed to deal with these failures. These plans will be particularly important for times when normal corrective actions cannot re-establish operational performance quickly enough to prevent drinking water of unacceptable quality from reaching consumers (see Section 4.1).

A process should be established for documenting and evaluating an event or incident, in order to identify opportunities for improvement. As necessary, the incident should also trigger further investigation, including a long-term review of relevant characteristics, to identify the underlying nature of any problems.

The following sections provide guidance on evaluating and responding to monitoring results from critical control points and other operational monitoring, as well as microbial, chemical and physical monitoring of the quality of drinking water as supplied to consumers.

6.8.1.1 Short-term evaluation of operational monitoring

Operational monitoring is carried out throughout the water system, including source water and catchment, treatment processes, and the distribution system. All operational monitoring results should be promptly reviewed against any established criteria, objectives and previous results to assess whether the water supply system is operating under normal conditions or whether there is an increase in the level of challenge, or the preventive measures and barriers are not performing effectively.

When target criteria and/or critical limits (for critical control points) have not been met, operational staff need to remain aware that the water supply system may not be functioning effectively, and assess the immediate or future risk of supplying unacceptable and possibly unsafe water to consumers.

Critical control points (CCPs): Of all operational monitoring, monitoring at critical control points is the most critical for assuring drinking water safety. Monitoring at CCPs should occur frequently, preferably continuously, using online analyzers, and these analyzers should be alarmed at both the target criteria and the critical limits, so that operational staff are alerted promptly of adverse results and effective operational control can be maintained.

Target criteria breach: Any breach of target criteria should be regarded as a warning or indication of a change in system status and possibly the start of a trend towards loss of control of the process, which may ultimately result in a breach of a critical limit. Investigation and appropriate corrective actions to resolve any potential problems should immediately be undertaken to ensure a critical limit is not breached.

Possible corrective actions for deviations from target criteria at CCPs include:

- inspection of the water supply system for faults;
- manual backwashing of filters;
- alteration of plant flow rate to reduce loading;
- use of an alternative raw water source;
- increasing disinfectant dose;

- adjusting process control;
- inspection and calibration of monitoring equipment;
- engagement of backup equipment;
- increased monitoring and observation.

Box 11 provides an example of the short-term evaluation of filtration performance and the corrective action that should be taken when the target criterion for turbidity has not been met.

Box 11 Short-term evaluation of filtration performance

For the filtration critical control point example detailed in Box 6, the target criterion for turbidity at each filter was set at <0.2 NTU and a critical limit for turbidity was set at 0.5 NTU.

If the turbidity from an individual filter has exceeded 0.2 NTU continuously for longer than the pre-determined delay period, an alarm should alert the operator that the target criterion has been breached and target filtration performance is not being achieved. The operator should promptly assess the filtration process and investigate the cause of the alarm. If the exceedance is during normal operation, immediate corrective actions should be implemented to achieve target performance. This may include:

- visual inspection of the filter to identify abnormalities;
- reviewing turbidity trends for all individual filters;
- confirming that upstream processes (e.g. coagulation) are operating normally;
- assessing raw water quality for unusual loadings;
- checking filter flow rates;
- manual backwashing of the filter; and
- reducing the hydraulic load on the filter.

If the exceedance of the target criteria is the result of a backwash event, the operator should keep the filter performance under close surveillance to confirm that plant operation returns to normal as expected, and ensure that the critical limit of 0.5 NTU is not breached. If an alarm indicates that the critical limit is exceeded, this should result in the filter being immediately taken off line until operation is satisfactorily back within specification.

After corrective action has been taken, its effectiveness needs to be verified. This usually entails additional monitoring. Secondary impacts of the corrective action, and the need for adjustments or additional action further along in the water supply system, should also be considered.

Exceedance of, or deviation from, a target criterion at a critical control point would not generally require notification of the health regulator, provided the corrective action successfully prevents a breach of a critical limit.

Critical limit breach: Breaching of a critical limit indicates that control of a process has been lost, probably resulting in an unacceptable health risk. The health regulator should be notified without delay, corrective action should be taken immediately to resume control and normal operation of the process, and implementation of an emergency response plan should be considered. The emergency plan may include:

- plant shutdown;
- immediate collection and review of all relevant results (e.g. if filtered water turbidity exceeds limits, this should include source water quality operation of downstream disinfection plants);
- water diversion and/or reliance on an alternative supply;
- reduction in flow and the holding of unsafe water in pipelines for disposal;
- additional treatment elsewhere in the system (e.g. secondary disinfection, spot dose, booster disinfection);
- mains flushing, cleaning and localized disinfection;
- increased sampling and monitoring of relevant operational and drinking water quality characteristics downstream throughout the distribution system;
- implementation of a boil-water advisory in consultation with the relevant health regulator, if microbial contamination is suspected.

Critical operational processes with online, continuous monitoring of performance is suggested to use as it can be equipped with alarm systems set at critical limits which, when breached, trigger an automatic immediate shutdown of the treatment plant. This mitigates the risk of producing water with an unacceptable level of associated health risk (e.g. supply of un-disinfected water) to consumers. Where possible, the water transfer system may also be shut down or diverted, to ensure that unsafe water is not supplied to consumers.

When any critical limit is breached, rapid response and investigation are essential to ensure that consumer's health is protected and supply is maintained. It may also be necessary to issue a public advisory, depending on available knowledge of the situation, the rapidity and effectiveness of the actions taken in response to the breach, and whether drinking water of unacceptable quality has been or will be supplied to consumers. This decision will be made in consultation with the relevant health regulator.

When the system is back under control, the root cause of the barrier breach should be investigated and improvements made, based on the outcome of the investigation.

6.8.1.2 Other operational monitoring – catchment to consumer

In addition to evaluating data at critical control points, results from other operational monitoring activities throughout the system should also be promptly reviewed against established target criteria and objectives, and previous results, to assess whether:

- the system is operating under expected normal conditions or there is an increase in the level of challenge;
- the preventive measures and barriers are performing effectively; and/or
- the monitoring results indicate a trend in performance that may be associated with; (poor maintenance; insufficient backwashing; clogging of filters; increased chlorine demand; or poor calibration of monitoring equipment.

Results from observational monitoring activities would also be assessed. Any reports of barrier breaches, such as damage to tank roofs, backflow or cross-connections, are significant and require immediate attention. Other observations of concern, such as increased human activity in a catchment, "boiling" in filter beds when backwashing, reduction in chlorinator maintenance, or failure to meet targets for testing of backflow prevention devices, while they may not have an immediate impact on water quality, should nevertheless be addressed promptly to bring performance back to established requirements and target criteria.

The potential impact of poor performance or failure of an upstream barrier on the performance or integrity of downstream barriers should also be assessed.

6.8.1.3 Short-term evaluation of drinking water quality monitoring

Water supply agencies should always aim to supply drinking water that complies with the health-related and aesthetic standards values (GSA Standards 7.1).

If the results of drinking water quality monitoring within the distribution system show that the water being supplied to consumers does not comply with the relevant health-related and/or aesthetic standard values, then corrective action should be taken, as detailed in the following sections.

Evaluating short-term microbial quality: The short-term performance measure for microbial quality (*E. coli*) within the distribution system is detailed below;

Water suppliers should take all reasonable actions to meet the standards limits for *E. coli*, which is that *E. coli* should not be detected in a minimum 100 mL sample of drinking water. In practice, *E. coli* may occasionally be present in drinking water in the absence of any identifiable source of fecal contamination. Nevertheless, if samples taken are found to contain *E. coli*, the response to each detection should be rigorous:

- Action should be taken urgently to identify and rectify any barrier breaches, and ensure that all the barriers are working continually and the system is safe. This should include checking disinfectant residuals.
- Further samples should be collected to confirm the presence of *E. coli* and determine possible sources and distribution. This should include a repeat sample from the point where the nonconforming sample was collected and, as appropriate, an upstream sample (e.g. a service reservoir or system entry point) and a downstream or adjacent sample (e.g. a nearby sampling location).
- An investigation should be initiated immediately to identify the underlying cause of any barrier breaches or unexplained results, and put in place corrective actions to prevent future fecal contamination and detection of *E. coli.*
- Further sampling should be undertaken to verify that the corrective actions have been effective.
- All actions taken in relation to the detection should be documented.

If any of the repeat samples returns a positive result for *E. coli*, the response needs to be escalated. Depending on the circumstances, the escalation may involve:

- additional water treatment, including increased disinfection and spot dosing with chlorine;
- provision of an alternative water supply;

- issuing of a boil-water advisory (based on advice from, or done in consultation with, the relevant health regulator).

Additional, more widespread monitoring of the supply system should also be undertaken to determine the extent of contamination. Procedures on reporting and responding to *E. coli* detections should be established with the relevant health regulator, and should be included in incident protocols. The procedures should include agreement on the requirements to be met before an incident is deemed to be closed. Detection of *E. coli* in the drinking water system is a serious issue. At the conclusion of any incident, a debrief should be held to assess the problem and response, and agree to any short- and long-term actions needed to prevent a recurrence. Responsibility for undertaking those actions should be clearly established. If no identifiable source of contamination is determined, a long-term review of microbial system performance should be triggered to look for any emerging problems or trends. Box 12 provides an example of a response protocol for *E. coli* detections.

Box 12 Example response protocol for *E. coli* detections

- Notification of the health regulator and immediate implementation of measures to render the water supply safe, as a priority. For chlorinated systems, establishing a free chlorine residual throughout the distribution system provides a high level of assurance that bacterial contamination will be inactivated. Actions that can be taken to increase residuals in the water supply system include increasing disinfection (e.g. chlorine dose rate), tank disinfectant dosing, mains flushing, and localized disinfection.
- Chlorine residuals should be frequently monitored to provide assurance that this barrier to contamination is being continually maintained in the distribution system during the incident. This may be achieved by grab sampling or, preferably, installation of mobile chlorine monitors.
- A repeat sample for *E. coli* should be taken from the same sample point within 24 hours of the initial *E. coli* detection, to assess the effectiveness of remedial actions.
- Rapid investigation from catchment to tap to identify the contamination source or reason for the barrier breach. This includes gathering relevant information on water treatment performance and other operational data, including any consumer complaints, and initiating surveillance in the catchment/reservoirs, treatment plant and distribution system to assess any non-routine or unusual activities that may have occurred or are occurring.
- *E. coli* samples should also be concurrently taken from all other sample points within the supply zone, e.g. at the reservoir/tank outlet, downstream and adjacent points in the distribution. The purpose is either to confirm that the supply zone is free of contamination or to indicate the extent of any contamination.
- Outcomes of the repeat samples should be immediately reported to the health authority. If any repeat samples are positive, then further actions to protect public health will be determined.
- Two more sets of repeat samples from all sample points in the zone should be taken over the following week to provide assurance that the system has returned to operating within specification.
- Conduct a rapid investigation from catchment to tap to identify the contamination source or reason for the barrier breach. This includes gathering relevant information on water treatment performance and other operational data including any consumer complaints, and initiating surveillance in the catchment/reservoirs, treatment plant, and distribution system to assess for any past or present activities that are non-routine or unusual.

- Investigation should also include possibility of sample errors or sample contamination as a result of sampling conditions or transport, as well as laboratory quality assurance and possible analytical issues.
- Short-term corrective actions to eliminate any identified source of contamination or reasons for the positive result.

Close liaison should be maintained with the health regulator and local authorities throughout the incident. The health regulator will determine the need to initiate emergency response plans, including issuing a public advisory, depending on the individual circumstances, the location of the sample and the investigation outcomes, and whether the sample represents a significant health threat to consumers.

Evaluating short-term health-related chemical quality: The short-term performance measure for health-related chemical characteristics within the distribution system is given below

- Chemical characteristics should not be detected in drinking water at concentrations above the relevant health-related national standards value.
- If a chemical characteristic is detected at a concentration above the relevant health-related standard value, follow-up action must be taken.

Water suppliers should take all reasonable actions to ensure that drinking water does not contain any chemical characteristic in excess of a health-related standards value. With a few exceptions (e.g. nitrate, copper, sulfate, fluoride), all health-related standard values relate to lifetime exposure e.g. arsenic, such that a single result above the standards value is unlikely to present an immediate health risk. Nonetheless, each result above a health-related standards value should be investigated to ensure that it does not pose any short-term acute effects or represent an emerging issue. Such results may at least indicate that a problem has occurred somewhere in the system with respect to barrier performance, and this should be investigated.

The recommended response to any detection of a chemical characteristic at concentrations above the relevant health-related standard value is as follows:

- The detection is to be reported to the relevant health regulator, following established reporting protocols. Any health implications of the exceedance or non-conformity should be quickly assessed in relation to any short-term acute effects of the chemical in question, as this will influence the response.
- The water supply system should be inspected, and treatment records should be reviewed to ensure that if treatment barriers have been applied to manage the particular chemical characteristic (e.g. arsenic or fluoride removal), they have not been compromised.
- Further sampling should be undertaken to verify the persistence and extent of the contamination.
- Sampling should also be undertaken to verify that corrective actions have been effective. The additional sampling should include a repeat sample from the point where the non-conforming sample was collected and, as appropriate, samples from source waters, upstream points (e.g. a service reservoir or system entry point) and a downstream or adjacent location (e.g. a nearby sampling point).
- All actions taken in relation to the detection should be documented.
- A public advisory would not normally be required unless the concentrations found are so high that an acute health impact is possible. However, if any of the follow-up samples

return a result above the relevant health-related standards value, the issue needs to be discussed with the relevant health regulator.

Depending on the circumstances, the discussions may result in:

- additional, more widespread monitoring of the supply system to improve understanding of the problem;
- operational changes to reduce the exposure;
- provision of an alternative water supply;
- longer-term improvements (e.g. additional treatment); and issuing of public advice.

Evaluating short-term aesthetic quality: The short-term performance measure for aesthetic and physical characteristics is detailed below;

- Aesthetic and physical characteristics should not be detected in drinking water at levels outside relevant aesthetic standard values.
- If an aesthetic or physical characteristic is detected at a level outside relevant standard values, follow-up action should be taken.

Whilst not presenting a health risk, the aesthetic standard values ensure that drinking water is aesthetically pleasing and pleasant to drink. Many customers equate aesthetics with the safety of drinking water, so every effort should be made to meet the aesthetic standard values. The recommended response to any detection of a characteristic outside the relevant standard value is as follows:

- Inspect the water supply system and review treatment records to ensure that barriers have not been compromised.
- Undertake further sampling to verify the persistence and extent of the issue. Sampling should be from the point where the non-conforming sample was collected plus, as appropriate, an upstream sample (e.g. a service reservoir or system entry point) and a downstream or adjacent sample (e.g. a nearby sampling location).

It should be noted that some aesthetic characteristics, such as pH and turbidity, have an association with the safety of drinking water supplied as they affect treatment effectiveness. Some water supply systems may consistently not meet an aesthetic standard value because of the nature of the source water (e.g. high total dissolved solids). In these specific cases, investigating the reason for each elevated result is not recommended; rather, a normal operating limit or range should be established based on historical data. Any monitoring results outside these limits would then be assessed as unusual and would indicate a change in system operation that requires further investigation.

6.8.2 Long-term evaluation of monitoring

The evaluation of monitoring results against the standards values, regulatory requirements or agreed level of service over an extended period of time (annually) provides important information regarding the effectiveness of preventive measures and identifies opportunities for improvement. The long-term evaluation of microbial, health-related chemical and aesthetic performance includes the assessment of all available monitoring information from catchment to consumer, including observational activities. Useful tools to facilitate analysis of data sets include graphs, trend charts and, where appropriate, statistical evaluation.

The results from the long-term evaluation of performance should form an input to the senior management review. Some aspects will be reported externally to consumers, stakeholders and regulatory authorities as appropriate.

6.8.2.1 Long-term evaluation of microbial performance

The long-term evaluation of microbial performance is a system-wide assessment that includes a performance evaluation of microbial monitoring data for the distribution system, including the point of supply to consumers, over a defined period, supplemented by all available operational monitoring data relevant to microbial system performance, from catchment to consumer. The purpose is to confirm the robustness of the system to deliver, reliably and continuously, drinking water that is free of microbial contamination.

Assessment of long-term microbial performance of the water supply system is undertaken to understand microbial challenges, and assess the effectiveness of preventive measures and barrier performance and whether they are being implemented appropriately. Any unacceptable increase in risk to consumers from changes in microbial challenge, barrier performance and/or system operation should be mitigated through short- and long-term improvements as necessary.

6.8.2.2 Long-term evaluation of health-related chemical performance

The long-term evaluation of health-related chemical performance is a system-wide assessment that includes evaluation, against standards values, of chemical monitoring data for the distribution system, including the point of supply to consumers over a period, supplemented by all available operational, investigation and validation monitoring data from catchment to consumer. The objective of the long-term evaluation is to understand system performance and confirm the robustness of the system to deliver drinking water reliably with concentrations of chemicals below the recommended maximum concentrations. The long-term evaluation of chemical performance, with inputs from drinking water quality monitoring data and any associated operational data, should increase understanding of overall system performance and provide input to any short- and long-term improvements to improve the management of any risk of exceeding health-related standard values.

6.8.2.3 Long-term evaluation of aesthetic and non-health-related chemical performance

The long-term evaluation of aesthetic and non-health-related chemical is also important to understand system performance, identify any trends that may be developing and the actions required to prevent exceedance from the standards values. An important consideration is to assess if the overall performance of any aesthetic characteristic is likely to be associated with an adverse effect on the safety of the water supplied to customers (e.g. pH can affect chlorination effectiveness and the corrosiveness of the water). Typically this requires evaluating the aesthetic monitoring data in conjunction with other data, such as microbial monitoring data. If the safety of drinking water is unacceptably affected, then corrective actions should be included in the water quality improvement plan. If there is uncertainty about whether these characteristics are affecting system performance, additional operational monitoring should be planned.

6.8.2.4 Long-term evaluation of consumer satisfaction

From the consumer's point of view, changes from the norm are particularly noticeable. The objective of the long-term evaluation of consumer satisfaction is to confirm that the complaint handling system is effective for picking up complaints, and particularly any clusters of complaints, related to water quality, and that action plans are adequate and linked suitably to operations.

Drinking water quality complaints by type (e.g. alleged illness, taste and odor, dirty water, stained laundry) should be reported over the period and evaluated against any internal or external performance targets (e.g. fewer than x complaints per 1000 households per year), noting any potential trends of concern. Investigations and response actions should be reviewed to ensure the actions were satisfactory, particularly with respect to any complaints of alleged illness, and that staff are adequately trained to respond effectively.

6.8.2.5 Improvement plan

Any actions identified in the long-term review of performance that are needed to improve system management and overall drinking water safety and consumer satisfaction should be documented and incorporated into an improvement plan. Actions may apply in the short-term (e.g. enhanced mains flushing programs, provision of alarms on critical control points), or may be longer-term capital works projects (e.g. covering water storages, upgrading treatment).

The implementation of corrective and preventive actions will often have significant budgetary implications and may therefore require detailed evaluation and careful priority setting. Implemented actions should be documented and methods for monitoring the improvements should be developed, carried out, and subsequently reviewed for overall effectiveness and improvement.

6.8.2.6 Performance reporting

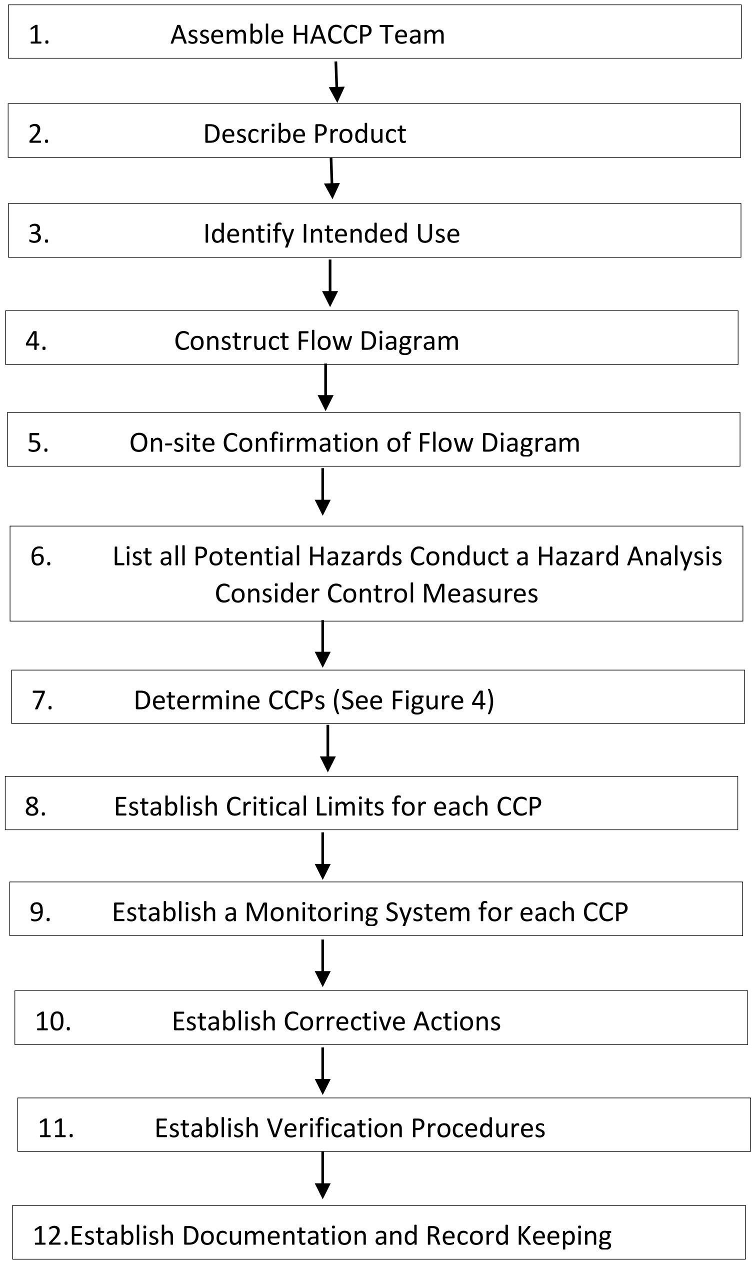
Performance assessment, based on the long-term review of monitoring data, should be reported internally to relevant staff and departments, as well as to senior management.

Performance reporting on water supply systems is also an important issue for health and regulatory authorities, and for consumers. Providing assurance that performance is reviewed regularly and that improvements are made in response to identified problems contributes to confidence in the water supplied and the water supply organization. External reporting ensures that system management and drinking water quality performance remains open and transparent. External reporting may be done through an annual report.

6.9 Hazard Analysis and Critical Control Point (HACCP)

The successful application of HACCP requires the full commitment and involvement of management and the work force. It also requires a multidisciplinary approach as detailed in Section 2.1.2. Figure 3 shows steps involved in application of HACCP principle to manage packaged water industry.

Figure 3 Logical sequence for application of HACCP



6.9.1 Preliminary Steps involved in HACCP approach

After obtaining the management commitment, the packaged water producer shall implement the following preliminary five steps:

6.9.1.1 Assemble HACCP team (Step-1)

The water filling operation shall ensure that the appropriate product specific knowledge and expertise is available for the development of an effective HACCP plan. This should be accomplished by assembling a HACCP trained multidisciplinary team.

Where such expertise is not available on site, expert advice should be obtained from other sources (e.g. HACCP literature and HACCP guidance including existing national sector-specific HACCP guides from Food and Drug Authority and Ghana Standards Authority).

The full scope of the organisation's activities, from receipt of raw materials to product consumption, shall be included in the HACCP plan and all the general classes of hazards have to be addressed: microbiological, chemical and physical health-related hazards.

6.9.1.2 Describe product (Step-2)

A full description of the product shall be drawn up, including relevant safety information such as:

- Raw materials: water, CO2 and added minerals (As may be added to drinking water for remineralisation purposes)
- Authorised water treatments
- Product contact materials
- Durability, storage conditions and methods of distribution.

6.9.1.3 Identify intended use (Step-3)

The intended use shall be based on the expected uses of the product by the end user or consumer. In specific cases, vulnerable groups of the population (e.g. infants, special diets) should be considered.

An example of a product description and intended use sheet is given in the table 16 below and its examples of associated questions should be considered when developing the product description.

6.9.1.4 Construct flow diagram (Step-4)

The flow diagram shall be constructed by the HACCP team and shall be specific to the water filling operation. The flow diagram shall cover all steps in the operation for a packaged water in a given packaging material. Example of generic on-site flow diagram is given in Figure 4.

The same flow diagram may be used for a number of products that are manufactured using similar processing steps (e.g. the same product with two different labels or grouping).

When applying HACCP to a given operation, consideration should be given to steps preceding and following the specified operation.

6.9.1.5 On-site confirmation of flow diagram (Step-5)

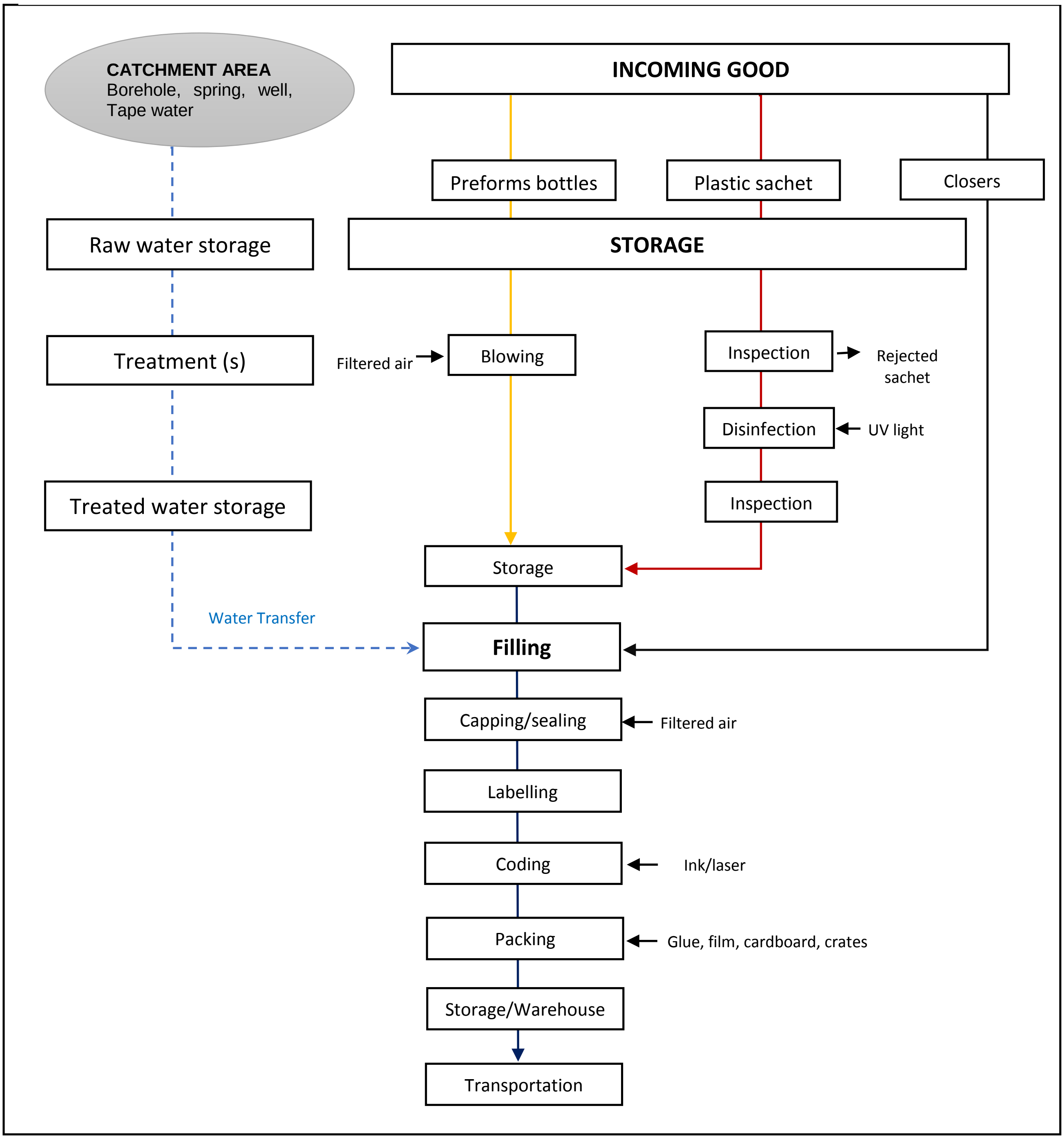
Action shall be taken to confirm the processing operation against the flow diagram during all stages and hours of operation and amend the flow diagram where appropriate.

The confirmation of the flow diagram should be performed by a person or persons with sufficient knowledge of the processing operation. The flow diagram shall be kept up-to-date to reflect any change in the product and operations.

Table 16 Example of packaged water product description

Topics to be considered	Examples of questions needing to be answered
Product name	▪ Common Name? ▪ Natural Mineral Water? ▪ Spring water? ▪ Processed/Prepared Water?
Sales description	▪ Mountain Spring Water? ▪ Well Water? ▪ Carbonated Water
Intended use	▪ Drinking as such? ▪ Drinking after carbonation? ▪ Drinking after sweetening? ▪ Cooking?
End users	▪ General population? ▪ Infants? ▪ Vulnerable groups? ▪ Specific groups?
Product specifications	▪ Chemical and physico-chemical water parameters? ▪ Allowed applied water treatments? ▪ Carbone Dioxide level, type and origin? ▪ Added Minerals?
Packaging	▪ Size and volume of packaging? ▪ Type of primary container (e.g. glass, plastic, metal, paper, bulk)? ▪ Type of closure (e.g. plastic, aluminum)? ▪ Type of secondary packaging (e.g. crates, boxes, packs)? ▪ Type of tertiary packaging (e.g. pallets, wrapping)?
Labelling	▪ Type of labels (e.g. paper, Polypropylene) and glue specifications? ▪ Regulatory requirements?
Product shelf life	▪ Shelf life Duration? ▪ Coding description? ▪ Type of coding (e.g. ink, laser)?
Storage and Distribution	▪ Conditions Internal storage? ▪ External storage? ▪ Range of temperature storage?

Figure 4 Example of on-site confirmation of flow diagram



6.9.2 The HACCP principles

The HACCP principle described in Section 3.5.2 consist of the following.

6.9.2.1 Hazards Identification

It consist of identifying any hazards that shall be prevented, eliminated or reduced to acceptable levels. The HACCP team shall list all of the hazards that may be reasonably expected to occur at each step according to the scope from primary production, processing, manufacture, and distribution until the point of consumption. Each process step identified in the flow diagram (see steps 4 & 5 above) shall be assessed for the introduction or presence of a hazard.

The HACCP team shall next conduct a hazard analysis to identify for the HACCP plan, which hazards are of such a nature that their elimination or reduction to acceptable levels is essential to the production of safe packaged water.

In conducting the hazard analysis, wherever possible the following shall be included:

- the likely occurrence of hazards and severity of their adverse health effects in view of risk evaluation
- the qualitative and/or quantitative evaluation of the presence of hazard survival or multiplication of microorganisms of concern
- production or persistence in water of toxins, chemical or physical agents
- conditions leading to the above

Consideration shall be given to what control measures, if any exist, can be applied to each hazard. More than one control measure may be required to control a specific hazard(s) and more than one hazard may be controlled by a specified control measure.

Detail description of hazard identification and risk evaluation is provided Section 2.2.1.3, table 5-7. The HACCP team could decide that the hazards with a low risk number are not significant and do not need specific control measures.

6.9.2.2 Critical Control Points (CCP)

It includes identifying the critical control points at the step or steps at which control is essential to prevent or eliminate a hazard or to reduce it to acceptable levels.

The determination of a CCP in the HACCP system can be facilitated by the application of the following decision tree (Figure 5) which indicates a logic reasoning approach.

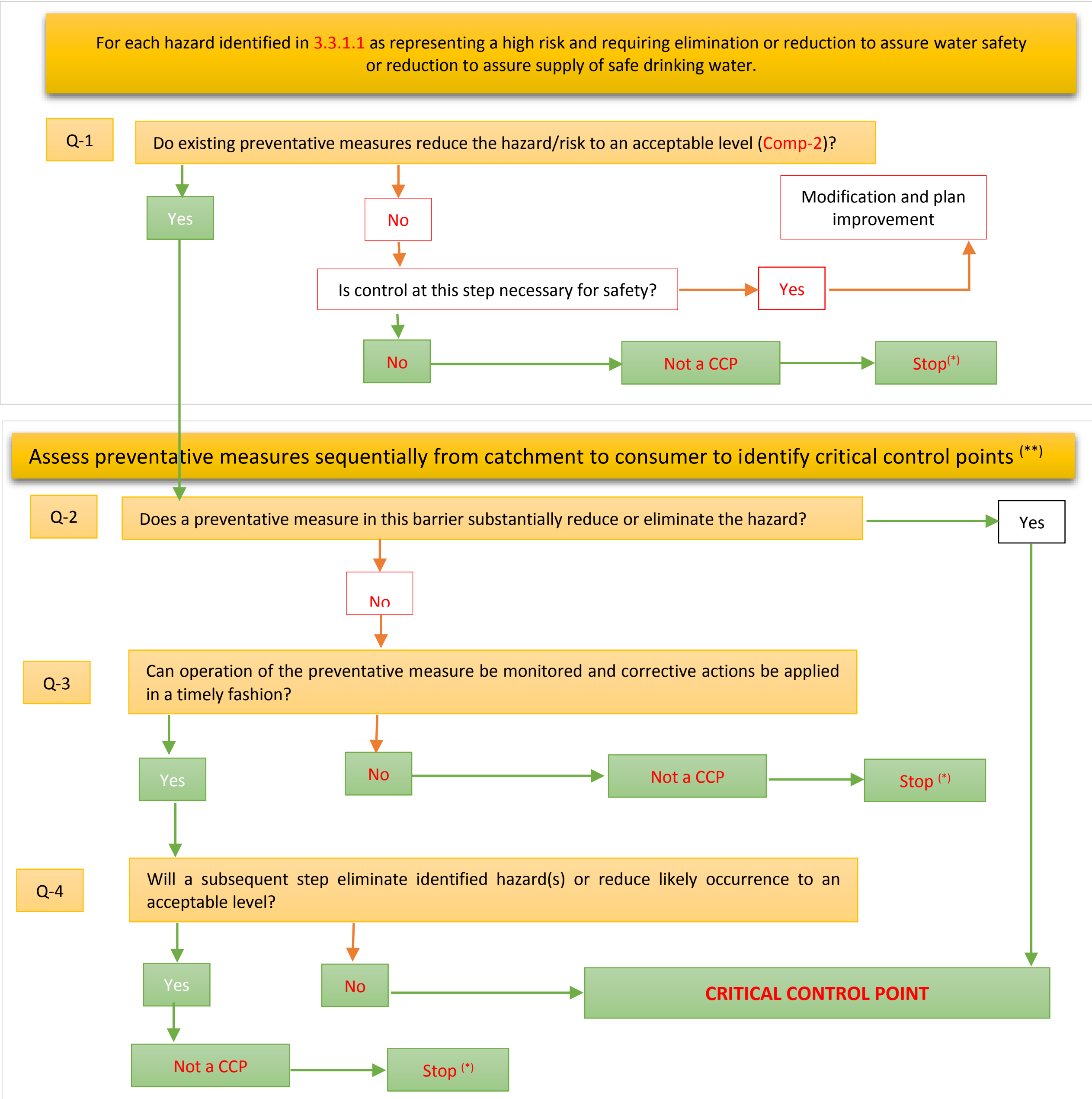
Application of a decision tree should be flexible and should be used for guidance when determining CCPs. There may be more than one CCP at which control is applied to address the same hazard.

6.9.2.3 Establishing critical limits at critical points

Establishing critical limits at critical points is essential which separate acceptability from unacceptability for the prevention, elimination or reduction of identified hazards.

Critical limits shall be specified and validated for each Critical Control Point. Details of the establishment of critical limits shall be recorded. These critical limits shall be measurable. In some cases more than one critical limit will be elaborated at a particular step.

Figure 5 Decision tree for the determination of critical control points (CCPs)



(*) Proceed to the next identified hazard and repeat the same above question.
(**) Acceptable and unacceptable levels need to be defined within overall objectives in identifying the CCPs of HAACP

6.9.2.4 Operational monitoring

It includes establishing and implementing effective monitoring procedures at critical control points. Operational monitoring is the scheduled measurement or observation of a CCP relative to its critical limits. The monitoring procedures shall be able to detect loss of control at the CCP.

Further, monitoring should ideally provide this information in time to make adjustments to ensure control of the process to prevent violating the critical limits. Where possible, process adjustments should be made when monitoring results indicate a trend towards loss of control at a CCP. The adjustments should be taken before a deviation occurs.

Data derived from monitoring shall be evaluated by a designated person with knowledge and authority to carry out corrective actions when indicated. If monitoring is not continuous then the amount or frequency of monitoring shall be sufficient to guarantee the CCP is in control.

Most monitoring procedures for CCPs will need to be done rapidly because they relate to online processes and there will not be time for lengthy analytical testing. Physical and chemical measurements are often preferred to microbiological testing because they may be done rapidly and can often indicate the microbiological control of the product.

All records and documents associated with monitoring CCPs shall be signed by the trained person(s) doing the monitoring and by a responsible reviewing official(s) of the industry. Records are used to demonstrate that a CCP is under control.

6.9.2.5 Establishing corrective actions

Establishing corrective actions is essential when monitoring indicates that a critical control point is not under control. Specific corrective actions shall be developed for each CCP in the HACCP system in order to deal with deviations when they occur.

A corrective action plan shall be designed to bring a non-conforming situation back into Control. The actions shall ensure that the CCP has been brought under control. Actions taken shall also include proper disposition of the affected product.

Corrective action may also include review of control options, review of standards, and increased frequency of monitoring and retraining. Deviation from CCP and product disposition procedures shall be documented in the HACCP record keeping.

6.9.2.6 Verification and audit

Verification and auditing methods, procedures and tests, including sampling and analysis, should be used to determine if the HACCP system is working correctly. The frequency of verification should be sufficient to confirm that the HACCP system is working effectively.

Verification should be carried out by someone other than the person who is responsible for performing the operation monitoring and corrective actions. Where certain verification activities cannot be performed in house, verification should be performed on behalf of the business by external experts or qualified third parties.

Examples of verification activities include:

- review of the HACCP plan and its records
- review of finished products' microbiological data
- review of deviations and product dispositions
- confirmation that CCPs are kept under control

6.9.2.7 Establishing documents and records

Efficient and accurate record keeping is essential to the application of a HACCP system. HACCP procedures shall be documented. Documentation and record keeping should be appropriate to the nature and size of the operation and sufficient to assist the business to verify that the HACCP controls are in place and being maintained.

Expertly developed HACCP guidance materials (e.g. sector-specific HACCP guides) may be utilized as part of the documentation, provided that those materials reflect the specific food operations of the business.

Documentation examples are, but not limited to:

- hazard analysis
- CCP determination
- critical limit determination

Record examples are, but not limited to:

- CCP monitoring activities
- deviations and associated corrective actions
- verification procedures performed
- modifications to the HACCP plan
- HACCP related staff training records

The record keeping system may be integrated into existing operations and may use existing paperwork, such as delivery invoices and checklists to record, for example, product temperatures.

6.10 Sanitary Inspection of Water Supply Systems

6.10.1 Introduction

Sanitary inspection is a powerful on-site fact-finding activity that can strongly support water safety plan implementation. It is the physical/visual assessment component of the water supply assessment step and can be particularly useful in systematically identifying potential hazards and hazardous events, thus informing the risk assessment process. Sanitary inspection specifically:

- assists in identifying potential contamination sources that could be missed by water quality analysis alone;
- supports adequate interpretation of water quality laboratory results;
- provides information about known, immediate and ongoing contamination;

- provides a longer-term perspective on causes of contamination;
- enhances knowledge of the water supply system;
- evaluates the effectiveness of operation and maintenance procedures.

Sanitary inspection not only identify system deficiencies i.e. sources of actual contamination but also inadequacies and lack of integrity in the system that could lead to contamination. In small communities. In remote areas where official visits by the local government staff are infrequent, it is essential that responsible community members are trained on how to conduct the inspection independently.

6.10.2 Sanitary inspection forms

Sanitary inspection typically makes use of standardized "sanitary inspection forms" containing a systematic checklist of a limited number of specific questions (often not more than 10 or 12 per form), which can be answered by the assessor using a mixture of visual observation and interviews onsite. An important feature, and benefit, of this approach is that it both gives a score related to risk and makes it apparent what improvements could be made to reduce that score, and hence reduce the risk. Sanitary inspection tools are available for a variety of situations and water supplies (see examples below). Sanitary inspection forms should be designed to match local circumstances (e.g. localized inspection forms in local languages).

The World Health Organization (WHO) developed sanitary inspection forms for conducting a sanitary inspection of small scale water systems. For different water supply systems and local environment, the situation and risks can be different, and therefore, other aspects have to be considered. Generic forms[3] for the basic and most general hazards to different small scale water supplies are given in section 6.10.5.

6.10.3 How to conduct sanitary risk inspection

A sanitary survey can be done by people who are able to read and write and that had a basic training on the survey. After the survey has been done results should be analyzed and at wells that show a high risk of contamination a follow up action will be required. Well users should be made aware of the findings of the survey. Each question answered with "yes" represents a risk. The total score of "yes" answers and the related level of risks for the water system are presented at the bottom of the form. Positive results of a sanitary inspection may "not guarantee" for safe drinking water. Groundwater and spring sources can be influenced by contaminants and geology, which infiltrated the source many kilometers away from the point of abstraction. This happens in mountainous areas.

From case to case, it may be concluded that not all the questions of the form have the same level of risks. For example, in example-1. "risk assessment of dug well or borehole", questions 1 and 2 (Is there a latrine, animal breeding etc. within 30m of the well or borehole?) could be more important than question 6. (Is the fence missing or faulty?). It is also very important to note that (it remains important to critically look at each question of the sanitary survey and examine the

---

[3] Sanitary inspection tools are available for a variety of situations and water supplies. (WHO, 1997), available at http://www.who.int/water_sanitation_health/dwq/2edvol3h.pdf.

real risk of each question e.g. if the only identified problem is a crack in the apron and one can see that waste water can directly flow back into the well the contamination risk is still very high even though the survey might indicate a low risk). Furthermore, possible risks of water contamination related to, for example, the mining of minerals and geogenic conditions are not considered in the sanitary inspection surveys. Still carrying out a risk assessment by using the sanitary inspection forms is an excellent tool for learning more about the possible risks of the water system and raising awareness on possible sources of pollution particularly microbiological contaminations.

6.10.4 Timing and frequency of sanitary inspections

Sanitary inspections should be undertaken on a regular basis, World Health Organization[4] has recommended ideally at the frequencies indicated in Table 17.

Table 17 Suggested minimum annual frequency of sanitary inspections

Source and mode of supply	Community [a]	Water-supply agency [b]	Surveillance agency [a,b,c]
Dug well (without windlass)	6	-	1[d]
Dug well (with windlass)	6	-	1[d]
Dug well with hand-pump	4	-	1[d]
Shallow and deep tube-well with hand pump	4	-	1[d]
Rainwater catchment	4	-	1[d]
Gravity spring	4	-	1[d]
Piped supply: groundwater sources (springs and wells), with and without chlorination	-	1	1

a-For family-owned facilities (e.g. dug wells with or without hand-pumps), the family will conduct inspections, with support from the environmental health unit of relevant District Assembly.
b-All new community water sources should be inspected before commissioning.
c-Under emergency conditions, such as onset of epidemic diseases, inspection should take place immediately.
d-Where it is impractical to inspect all such facilities, a statistically significant sample should be inspected.

4 http://www.who.int/water_sanitation_health/dwq/2edvol3c.pdf

6.10.5 Generic example of sanitary inspection form

Example-1: Sanitary survey form for boreholes and hand dug wells with hand pump

1-General information:

Community name: District: Region:
Number of users:

2-Date of inspection:

Sr #	Specific Diagnostic Information for Assessment Risk	Yes	no	remarks
1	Is there a latrine within 20 meters of the well			
2	Is the latrine on higher grounds than the well			
3	Is there any other source of pollution within 10 meters			
4	Is there ponding/stagnating water around the well			
5	Is the drainage channel broken/cracked or overflowing within the first 2 meters from the apron?			
6	Is there adequate fencing around the well (preventing animals to come near the well)			
7	Is the apron radius less than 1 meter around the well			
8	Is there ponding/stagnating water at the apron			
9	Are there any cracks in the wells apron			
10	Is the hand pump loose at the point of attachment			
11	Is the well likely to be properly sealed (lined) within the first 3 meters below ground level?			
12	If there is a cover on the well is it properly sealed and no water can flow into the well			
13	Is the hand pump broken?			
	The number of yes scores or total risk score is			

Contamination risk score:
6-13 (very) High
2-5 Medium
0-2 Low

The following important points of risk were noted:……………………………………………………………………………………….

Recommendations for further action;

1. <u>Wells with a high risk score:</u>
   Water of this well is not safe to use for consumption, treatment is required and improvements of the well are needed to protect the well. A bacteriological test is not needed as water is most probably contaminated.
   Preferred options to treat the water are **a)** House Hold Water treatment (e.g. ceramic pot filter, household chlorination, boiling of water) **b)** chlorination of water vessels at the well site **c)** Daily well chlorination followed up by residual chlorine monitoring.
2. <u>Wells with medium risk score:</u>

Water from this well is possibly not safe for consumption and improvements of the well are needed to protect the well. A bacteriological test can confirm safety.

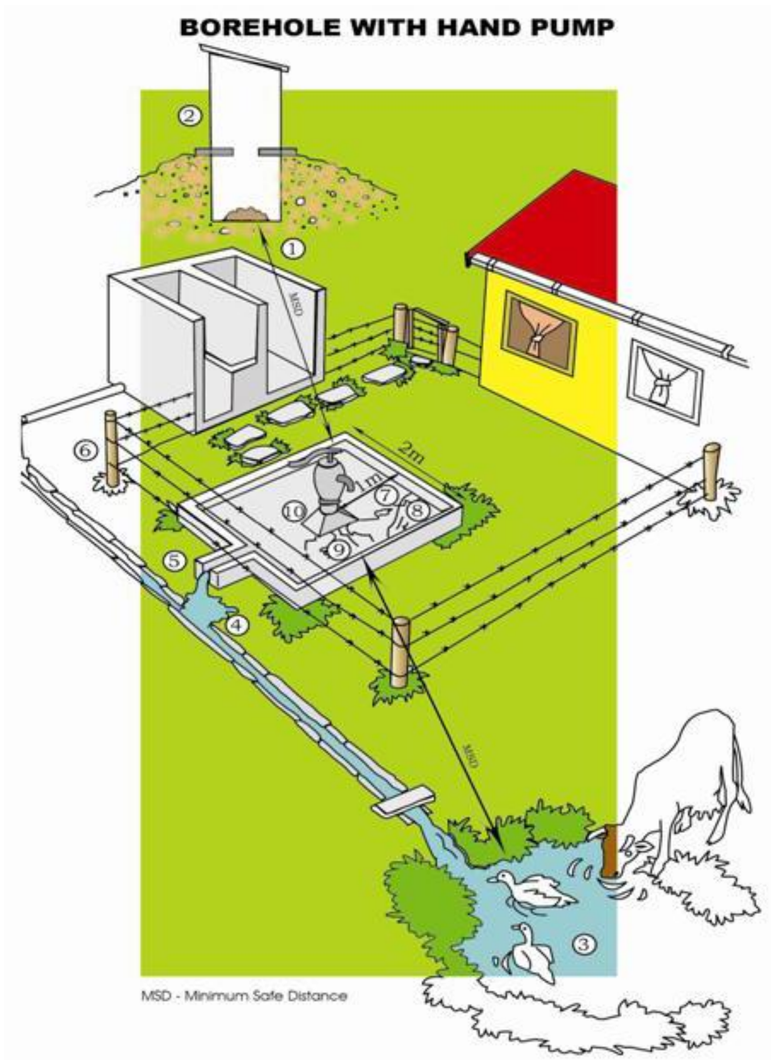
It is advisable to treat the water, possible ways to treat water are; **a)** House Hold Water treatment (e.g. ceramic pot filter, household chlorination, boiling of water) **b)** chlorination of water vessels at the well site **c)** Daily well chlorination followed up by residual chlorine monitoring.

3. Wells with a low risk score:

   Water of this well is likely to be safe for consumption; a bacteriological test can confirm this.

   To ensure a safe water chain it remains advisable to promote House Hold Water Treatment and Safe storage or alternatively chlorination at the well can be considered.

Figure 6 View of boreholes and hand dug wells with hand pump



Example-2 Sanitary survey form for open well

1 General information:

Community name: District: Region:

Number of users:

2 Date of inspection:

Sr #	Specific Diagnostic Information for Assessment Risk	Yes	no	remarks
1	Is there a latrine within 20 meters of the well			
2	Is the latrine on higher grounds than the well			
3	Is there any other source of pollution within 10 meters			
4	Is there ponding/stagnating water around the well			
5	Is the drainage channel broken/cracked or overflowing within the first 2 meters from the apron?			
6	Is there a well wall which will prevent spillage water to flow back into the well			
7	Is the apron radius less than 1 meter around the well			
8	Is the well properly sealed (lined) within the first 3 meters below ground level?			
9	Are there any cracks in the wells apron			
10	Are ropes and bucket possibly contaminated when used (e.g. been put on the ground)			
11	Is there adequate fencing around the well (preventing animals to come near the well)			
12	Do people use their own rope and bucket when fetching water			
13	Is the well open when not in use			
	The number of yes scores or total risk score is			

Contamination risk score

6-13 (very) High
2-5 Medium
0-2 Low

The following important points of risk were noted:……………………………………………………………………………….

Recommendations for further action;

1. <u>Wells with a high risk score:</u>

   Water of this well is not safe to use for consumption, treatment is required and improvements of the well are needed to protect the well. A bacteriological test is not needed as water is most probably contaminated.

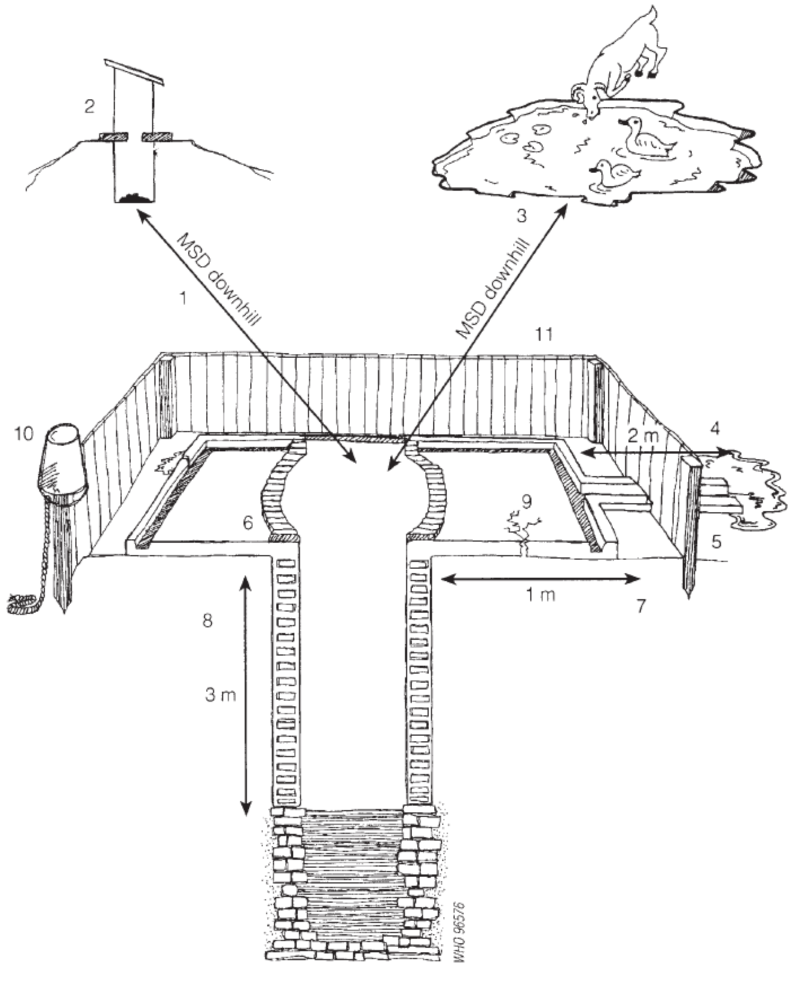
   Preferred options to treat the water are **a)** House Hold Water treatment (e.g. ceramic pot filter, household chlorination, boiling of water) **b)** chlorination of water vessels at the well site **c)** Daily well chlorination followed up by residual chlorine monitoring.

2. <u>Wells with medium risk score:</u>

Water from this well is possibly not safe for consumption and improvements of the well are needed to protect the well. A bacteriological test can confirm safety.
It is advisable to treat the water, possible ways to treat water are; **a)** House Hold Water treatment (e.g. ceramic pot filter, household chlorination, boiling of water) **b)** chlorination of water vessels at the well site **c)** Daily well chlorination followed up by residual chlorine monitoring.

3. Wells with a low risk score:
   Water of this well is likely to be safe for consumption; a bacteriological test can confirm this.
   To ensure a safe water chain it remains advisable to promote House Hold Water Treatment and Safe storage or alternatively chlorination at the well can be considered.

Figure 7 View of open well and surroundings



Example-3: Sanitary survey form for filling station, tanker trucks and household drums

General information:

1- Community name: District: Region:
Number of users:
2- Date of inspection:

Sr #	Specific Diagnostic Information for Assessment Risk	Yes	No	remarks
Tanker filling station				
1	Is the chlorine level at the filling station less than 0.5 mg/liter?			
2	Is the filling station excluded from routine quality control program of water supply agency?			
3	Is the discharge pipe is dirty?			
Tanker trucks				
4	Is the tanker ever used for transporting other liquids besides drinking water?			
5	Is the filter hole dirty or is the lid missing?			
6	Is the delivery hole dirty or stored unsafely?			
Household drums				
7	Can contaminants (e.g. soil, leaves or other rubbish) enter the drum during the filling?			
8	Does the drum lack cover or cap?			
9	Does the drum need a tap for withdrawal of water?			
10	Is there stagnant water around the drums?			
	The number of yes scores or total risk score is			

Contamination risk score:

6-10 (very) High
2-5 Medium
0-2 Low

The following important points of risk were noted:…………………………………………………………………………………

Recommendations for further action;

1. Tanker water with a high risk score:

   Water of this tanker is not safe to use for consumption, treatment is required and improvements of this tanker water supply is needed to protect the water quality. A bacteriological test is not needed as water is most probably contaminated.

   *Preferred options to treat the water are **a)** House Hold Water treatment (e.g. ceramic pot filter, household chlorination, boiling of water) **b)** chlorination of water vessels at the filling site **c)** Daily tanker chlorination followed up by residual chlorine monitoring.*

2. Tanker with medium risk score:

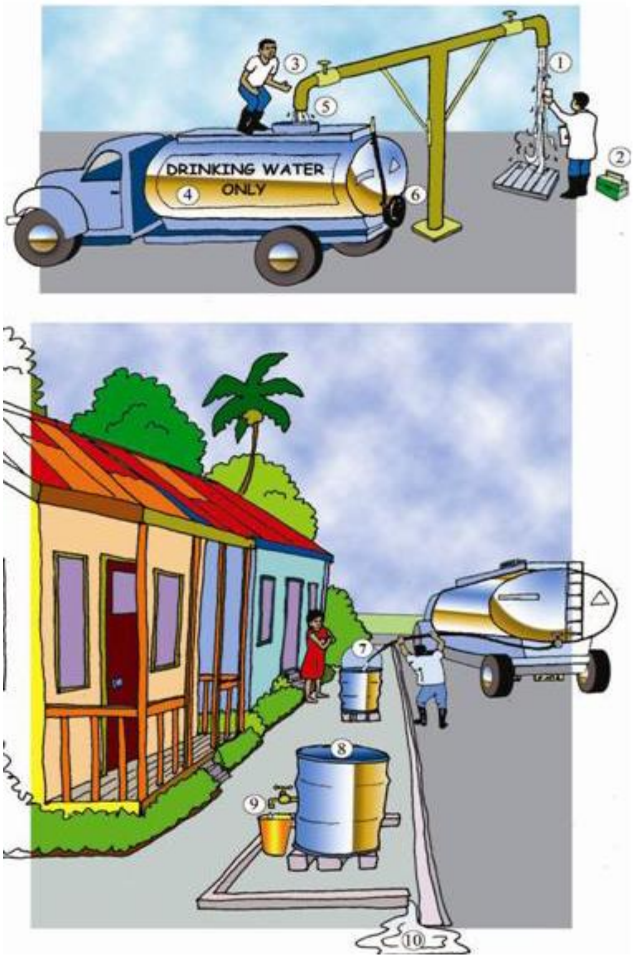
   The Water is possibly not safe for consumption and improvements of the system is needed to protect water quality. A bacteriological test can confirm safety.

*It is advisable to treat the water, possible ways to treat water are; **a)** House Hold Water treatment (e.g. ceramic pot filter, household chlorination, boiling of water) **b)** chlorination of water vessels at the filling site **c)** Daily tanker chlorination followed up by residual chlorine monitoring.*

3. Tanker with a low risk score:

   Water of such tanker is likely to be safe for consumption; a bacteriological test can confirm this. To ensure a safe water chain it remains advisable to promote House Hold Water Treatment and Safe storage or alternatively chlorination at the tanker can be considered.

Figure 8 View of filling station, tanker trucks and household drums



6.11 Disability adjusted life years (DALYs)

At a national level, decisions about risk acceptance and tolerable burdens of disease are complex and need to take account of the probability and severity of impact in addition to the environmental, social, cultural, economic and political dimensions that play important roles in decision-making. Negotiations play an important role in these processes, and the outcome may very well be unique in each situation. Notwithstanding the complexity of these decisions, definitions of tolerable burdens of disease and reference levels of risk are required to provide a baseline for the development of health based targets and as a departure point for decisions in specific situations.

Box 13 Definition of DALYs

DALYs: DALYs are used to convert the likelihood of illness into impacts or burdens of disease. The advantage of using DALYs is that the metric recognizes that not all pathogens cause the same level or severity of disease. Some like Cryptosporidium cause mild diarrhea in the general population while others such as *E.coli* 0157 and Rotavirus can result in death.

Disease burden is the impact of a health problem as measured by financial cost, mortality, morbidity, or other indicators. It is quantified in terms of disability adjusted life years (DALYs), which quantify the number of years lost due to disease.

One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability (Prüss-Üstün & Corvalán, 2006).

Descriptions of tolerable burdens of disease relating to water are typically expressed in terms of specific health outcomes such as maximum frequencies of diarrheal disease or cancer incidence. However, these descriptions do not consider the severity of the outcomes. The various hazards that may be present in water are associated with very diverse health outcomes with different impacts ranging from mild diarrhea to potentially severe outcomes such as typhoid, cancer or skeletal fluorosis.

"Tolerable burden of disease" represents an upper limit of the burden of health effects associated with waterborne disease that is established by national policy-makers. *"Reference level of risk"* is an equivalent term used in the context of quantitative risk assessments (see section 2.2.1.3).

A common "metric" is needed that can be used to quantify and compare the burden of disease associated with different water-related hazards, taking into account varying probabilities, severities and duration of effects. Such a metric should be applicable regardless of the type of hazard (microbial, chemical or radiological) to enable a consistent approach to be applied to each hazard. The metric used in the WHO Guidelines (WHO, 2011) is the DALY (See Box 13).

A key advantage of using DALYs is its aggregation of different impacts on the quality and quantity of life and that it focuses attention on actual outcomes rather than potential risks and hence supports rational public health priority setting. DALYs can be used to define tolerable burden of disease and the related reference level of risk. The tolerable burden of disease is defined as an upper limit of 10^{-6} DALYs per person per year (WHO, 2011). This upper limit DALY is approximately equivalent to a 10^{-5} excess lifetime risk of cancer (i.e. 1 excess case of cancer per 100,000 people ingesting drinking water at the water quality target daily over a 70 year period), which is the risk level used in these Guidelines to determine guideline values for genotoxic carcinogens.

Expressing health based target targets for chemical hazards in DALYs has the advantage of enabling comparisons with microbial risks. However, use of the DALY approach for chemicals has been limited in practice due to gaps in knowledge.

The 10^{-6} DALY tolerable burden of disease target may not be achievable or realistic in some in the near term. If the overall burden of disease by multiple exposure routes (water, food, air, direct personal contact, etc.) is very high, setting a 10^{-6} DALY per person per year level of disease burden from waterborne exposure alone will have little impact on the overall disease burden. Setting a less stringent level of acceptable risk, such as 10^{-5} or 10^{-4} DALY per person per year, from waterborne exposure may be more realistic yet still consistent with the goals of providing high-quality, safer water.

Box 14 Disability Adjusted Life Years, tolerable disease burdens and reference levels of risk

The various hazards that can be present in water can have very different health outcomes. Some outcomes are mild (e.g. diarrhea,) while others can be severe (e.g. cholera, hemolytic uremic syndrome associated with *E.coli* 0157, or cancer); some are acute (e.g. diarrhea) while others are delayed (infectious hepatitis, cancer); some especially relate to certain age ranges and groups (skeletal fluorosis in older adults often arises from long term exposure to high levels of fluoride in childhood; infection with hepatitis E virus has a very high mortality rate among pregnant women). In addition, any one hazard may cause multiple effects (e.g. gastroenteritis, Guillain-Barre syndrome, reactive arthritis and mortality associated with *Campylobacter*).

Disability Adjusted Life Years (DALYs) metrics, if applied to all types of hazard, taking into account different health outcomes including probabilities, severities and duration of effects, supports public health priority setting.

The basic principle of the DALY is to weight each health impact in terms of its severity within the range of 0 for good health to 1 for death. Severities for outcomes of microbial infection include:

- 0.02 – 0.12 for mild diarrhea
- 0.21 for reactive arthritis
- 0.23 for severe diarrhea
- 1 for death

The severity is then multiplied by duration of the effect and the relative frequency of occurrence in those who become ill. In the case of death, duration is regarded as the years lost in relation to normal life expectancy (e.g. Life expectancy at birth for Ghana is 61 years (Bank, 2014)).

Hence, DALYs = YLL (years of life lost) + YLD (years lived with a disability/illness)
In this context disability refers to conditions that detract from good health.

Calculation of DALYs
Infection with rotavirus (in developed countries), for example, causes:

- mild diarrhea (severity rating of 0.1) lasting 7 days in 97.5% of cases
- severe diarrhea (severity rating of 0.23) lasting 7 days in 2.5% of cases
- rare deaths of very young children in 0.015% of cases (a death at < 1 years of age means a loss of up to 61 years of life)

The DALY per case then = (0.1 x 7/365 x 0.975) + (0.23 x 7/365 x 0.025) + (1 x 70 x 0.00015)
= 0.0019 + 0.0001 + 0.0105 = **0.0125**

Infection with *Cryptosporidium* can cause watery diarrhea (severity weighting of 0.067) lasting for 7 days with extremely rare deaths in 0.0001 % of cases. This equates to a DALY per case of 0.0015.

Further information on the use of DALYs in establishing health based targets is available in *Quantifying Public Health Risk in the WHO Guidelines for Drinking-water Quality*. http://www.who.int/water_sanitation_health/dwq/rivmrep.pdf?ua=1

7. ANNEXURE

7.1 Water Quality – Specification for drinking water FDGS 175-1:2013

The Ghana Standard specifies the requirements for drinking water obtained from “prepared waters[5]” or “waters defined by origin[6]”. The standard also applies to packaged/bottled drinking water but not packaged/bottled natural mineral water[7].

Table 18 Physical requirements

Sr No.	Parameter	Requirement
1	Turbidity	Shall not exceed 5 Nephelometric Turbidity Units (NTU)
2	Apparent color	Shall not exceed 5 Hazen Units
3	Odor and taste	Shall not be objectionable to most consumers
4	Temperature	Shall not be objectionable to most consumers
5	Total Suspended Solids/Matter	Shall not exceed zero (0 mg/L) in packaged water

Table 19 Chemical requirements

Sr No.	Parameter	Requirement
1	Aluminum, (as Al), max	0.2 mg/L
2	Chloride (as Cl), max	250 mg/L
3	Iron (as Fe), max	0.3 mg/L
4	Manganese (as Mn), max	0.4 mg/L
5	pH	6.5 – 8.5*
6	Total dissolved solids	1000 mg/L
7	Sulphate (SO4), max	250 mg/L
8	Total hardness, max	500 mg/L
9	Arsenic (as As), max	0.01 mg/L
10	Residual free Chlorine*, max	0.2 mg/L
11	Cyanide (as CN), max	0.07 mg/L
12	Fluoride (as F), max	1.5 mg/L
13	Nitrite (as NO2), max	3.0 mg/L
14	Nitrate (as NO3), max	50.0 mg/L
*For effective disinfection, there should be a residual concentration of free chlorine of ≥ 0,5mg/L after at least 30min contact time at pH < 8,0		

[5] Prepared waters: water that may originate from any type of water supply

[6] Waters defined by origin: waters that come from underground or from the surface (specific environmental resources) without passing through a community water system

[7] Natural mineral water: microbiologically wholesome water originating in an underground water table or deposit and emerging from a spring tapped at one or more exits and packed at source. It is clearly distinguished from ordinary drinking water by its natural (mineral content and trace elements) by its original state. It is bottled or packaged at source and is recognized as a natural mineral water as specified in GS 220.

Table 20 Bacteriological requirements

Sr. No.	Determinants	Requirement
1	Total viable count, at 37˚C for 48h	500 count/ml
2	Total viable count, at 22˚C for 72hrs	50 count/ml
3	*E. coli*, count/100ml	Not detected
4	Total coliform, count/100 ml	Not detected
5	Clostridium, count/100 ml	Not detected
6	Streptococcus, count/100 ml	Not detected
7	Pseudomonas, count/100 ml	Not detected

Virological quality
All drinking water shall be free of human enteroviruses to ensure negligible risk of infection.
Note:
1. Virological studies have indicated that drinking water treatment can reduce the levels of viruses but may not eliminate them completely from very large volumes of water. Virological, epidemiological and risk analysis have provided some important information, although it is still insufficient for deriving quantitative and direct virological criteria. Such criteria cannot be given for routine use because of the cost, complexity and lengthy nature of virological analysis and the fact that they cannot detect the most relevant viruses.

2. Ground water obtained from a protected source and documented to be free from fecal contamination from its zone of influence, the wells, pumps and delivery system can be assumed to be virus-free. However, when such water is distributed, it is desirable that it is disinfected and that a residual level of disinfectant is maintained in the distribution system to guard against contamination.

It is recommended that in addition to the requirements given in Table 18 and 19, assessment of the parameters given in table 20-26 should be undertaken at least once a year.

Table 21 Chemical Constituents

Determinant	Requirement
Inorganic	
Copper (as Cu), max	2.0 mg/L
Sulphide, max.	0.05 mg/L
Dissolved oxygen	**
Organic	
Toluene, max.	0.7 µg/L***
Xylene, max.	0.5 µg/L***
Ethyl benzene, max.	0.3 µg/L ***
Styrene, max.	0.02 µg/L***
Monochlorobenzene, max.	10 – 120 µg/L
1,2-Dichlorobenzene, max.	1.0 µg/L
1,4-Dichlorobenzene, max.	0.3 µg/L
Trichlorobenzene (total), max.	5 – 50 µg/L
2-Chlorophenol, max.	0.1 – 10 µg/L
2,4-Dichlorophenol, max.	0.3 – 4.0 µg/L
2,4,6-Trichlorophenol, max.	2 – 300 µg/L
** The dissolved oxygen content shall not be substantially less than the saturation concentration. *** Concentrations of this substance at or below this health-based value may affect the appearance, taste or odor of the water, leading to consumer complaints.	

Table 22 Inorganic constituents of health significance

Constituent	Requirement
Barium (as Ba), max	0.7 mg/L
Boron (as B), max	0.5 mg/L
Cadmium (as Cd), max	0.003 mg/L
Chromium (hexavalent), max	0.05 mg/L
Lead (as Pb), max	0.01 mg/L
Manganese (as Mn), max	0.4 mg/L*
Mercury (total as Hg), max	0.001 mg/L
Molybdenum, max	0.07 mg/L
Nickel (as Ni), max	0.02 mg/L
Selenium (as Se), max	0.01 mg/L
Antimony (as Sb), max	0.005 mg/L
*The concentration of the substance at or below this value may affect the appearance, taste or odor of the water leading to consumer complaints	

Table 23 Organic constituents of health significance

Constituent	Requirement
Chlorinated Alkanes	
Carbon tetrachloride max	4 µg/L
Dichloromethane, max	20 µg/L
1,2 -Dichloromethane, max	40 µg/L
1,1,1-Trichloroethane, max	2000 µg/L
Chlorinated Ethenes	
Vinyl chloride, max	5 µg/L
2-Dichloroethane, max	50 µg/L
1,1-Dichloroethane, max	30 µg/L
Trichloroethane, max	70 µg/L
Tetrachloroethane, max	40 µg/L
Chlorinated Benzenes	
Monochlorobenzene, max	300 µg/L *
1,2 -Dichlorobenzene, max	1000 µg/L *
1,4 -Dichlorobenzene, max	300 µg/L *
Trichlorobenzene (total), max	20 µg/L *
Aromatic Hydrocarbons	
Benzene, max	10 µg/L
Toluene, max	700 µg/L
Ethylbenzene, max	300 µg/L *
Styrene, max	20 µg/L *
Benzo [α] pyrene, max	0,7 µg/L *
Miscellaneous	
Di (2-ethylhexyl) adipate, max	80 µg/L
Di (2-ethylhexyl) phthalate, max	8 µg/L
Acrylamide, max	0,5 µg/L
Epichlorohydrin, max	0,4 µg/L
Hexachlorobutadiene, max	0,6 µg/L
Eidetic acid (EDTA), max	200 µg/L
Nitrilotriacetic acid, max	200 µg/L
Tributylin oxide, max	2 µg/L
*Note that concentrations of these substances at or above the health value may affect the appearance, taste or odor of the water.	

Table 24 Chemical constituents of health significance – Pesticides*

Constituent	Requirement
Aldicarb, max	10 µg/L
Aldrin / dieldrin, max	0,03 µg/L
Atrazine, max	2 µg/L
Carbofuran, max	5 µg/L
DDT, max	1.0 µg/L
1,2-dibromo-3-chloropropane, max	1.0 µg/L
Heptachlor & heptachlor expoxide, max	0.03 µg/L
Lindane, max	2 µg/L
Methoxychlor, max	20 µg/L
Metolachlor, max	10 µg/L
Molinate, max	6 µg/L
Permethrin, max	20 µg/L
Propanil, max	20 µg/L
*These pesticides are being used currently in Ghana. The probability that they would contaminate drinking water sources is rather high.	

Table 25 Chemical constituents of health significance – Pesticides**

Constituent	Requirement
Alachlor, max	20 µg/L
Bentazone, max	30 µg/L
Chlordane, max	0.2 µg/L
Chlorotoluron, max	30 µg/L
1,2-dichloropropane, max	20 µg/L
1,3-dichloropropene, max	20 µg/L
Hexachlorobenzene, max	1 µg/L
Isoproturon, max	9 µg/L
4-chloro-2-methyl phenoxy-acetic acid (MCPA), max	2 µg/L
Pendimethalin, max	20 µg/L
Pentachlorophenol, max	9 µg/L
Periodate, max	100 µg/L
Simazine, max	2 µg/L
Trifluralin, max	20 µg/L
2,4-DB, max	90 µg/L
Dichlorprop, max	100 µg/L
Fenoprop, max	9 µg/L
Mecoprop, max	10 µg/L
**These pesticides are known to be present in drinking water in other countries. There is no evidence of their presence in Ghana now. The limits stated are guidelines values. When evidence of their existence is established, appropriate limits would be set.	

Table 26 Disinfectants and disinfectant by-products of health significance

Constituent	Requirement
Trihalomethanes	
- Bromoform, max	100 µg/L
- Dibromochloromethane, max.	100 µg/L
- Bromodichloromethane, max.	60 µg/L
- Chloroform, max.	200 µg/L
Chlorite, max	700 µg/L
Cyanogen chloride, max	70 µg/L
2,4,6-trichlorophenol, max	200 µg/L
Di-and trichloroamine+	-
Iodine+	-
Chlorate	-
2-Chlorophenol+	-
Monochloroacetic acid+	-
2,4-dichlorophenol+,µg/L,max	-
Monochloroacetic acid+, µg/L, max.	-
Chloroacetone+	-
Chloropicrin+	-
Chlorine dioxide++	-
+There is no adequate data to permit recommendation of a health guideline value. ++No limit has been established for this compound because of the rapid breakdown of chlorine dioxide and because the chlorite value is adequately protective for potential toxicity from chlorine dioxide.	

7.2 Role and Responsibilities of drinking-water sector organizations

The roles and responsibilities of the drinking water sector organisations are described below.

7.2.1 Policy Planning and Coordination

Ministry of Water Resources Works and Housing (MWRWH): It is the principal water sector ministry responsible for the overall policy formulation, planning, coordination and harmonization, monitoring and evaluation of programs for the water supply and water resources. The ministry performs these tasks through its Water Directorate (WD), established in 2004. The key agencies of MWRWH carrying out the ministry's water resources management and drinking water programs are the Water Resource Commission (WRC), Ghana Water Company Limited (GWCL) and Community Water and Sanitation Agency (CWSA).

The Ministry of Water Resources, Works and Housing (formerly Ministry of Works and Housing) derives its mandate of existence from the enactment of the Civil Service Law (PNDCL 327 of 1993), the Government guidelines formulated by the Public Administration Restructuring Decentralization and Implementation Committee and other laws, including the Local Government Act 462. These legal instruments grant all the Ministries, Departments and Agencies (MDAs) including the Ministry of Water Resources, Works and Housing, the authoritative function of initiating and formulating policies, coordination, budgeting, monitoring and evaluation to ensure the efficiency and performance of its specific sector. The Executive Instrument, E.I. 6 Civil Service (Ministries) (Amendment) Instrument, 2005, gazette on 25th November, 2005 is the latest instrument that changed the name of the ministry from Ministry of Works and Housing to the Ministry of Water Resources Works and Housing.

Ministry of Local Government and Rural Development: The ministry sets the policy framework for the development of local communities and oversees the performance of local administration –Metropolitan, Municipal and District Assemblies (MMDAs). The MLGRD is responsible for environmental sanitation after the environmental health and sanitation unit was ceded to her in 1995 from the Ministry of Health. The Environmental Health and Sanitation Directorate (EHSD) of the MLGRD, is responsible for coordinating the activities of all the key sector institutions involved in the sanitation sector. According to the revised Environmental Sanitation Policy (GOG/MLGRD, 2010) all environmental sanitation tasks within MMDAs comprising the public health management functions (covering food hygiene, environmental sanitation education, inspection and enforcement of sanitary regulations) shall be carried out by Environmental Health and Management Departments of Metropolitan, Municipal and District Assemblies, with private sector inputs where appropriate. Furthermore, the Sanitary inspectors cover some aspect of water quality monitoring (limited largely to visual inspection), as part of implementing Expanded Sanitary Inspections and Compliance Enforcement (MLGRD, 1999).

Local Government Service Secretariat: The Local Government Service Secretariat (LGSS) was established by the Local Government Service Act, 2003, Act 656 (GOG, 2003) to ensure the effective administration and management of local government structures. One of the functions of the Service in clause 4 is the provision of technical assistance to the Regional Co-ordinating Councils and District Assemblies in the performance of their functions under the Local Government Act, 1993, Act 462 (GOG, 1993). The sanitary inspectorate division formerly under EHSD is now under Local Government Service (LGS).

Ghana Health Service (GHS)/Ministry of Health (MOH) have responsibilities for ensuring good public health to the people of Ghana. The GHS/MOH role covers Advocacy, Advisory, Monitoring of Water related diseases.

National Development Planning Commission: The National Development Planning Commission is established by the National Development Planning Commission Act, 1994 (Act 479) to be responsible for broad policy formulation on which MDAs formulate their sectoral policies (GOG, 1994a). Act 479 requires NDPC is to advise the President of the Republic of Ghana (and Parliament upon request) on development policy and strategy, to prepare and ensure the effective implementation of approved national development plans and strategies and coordinate economic and social activities country wide in a manner that will ensure accelerated and sustainable development of the country and improvement in the standard of living for all Ghanaians. NDPC is the national coordinating body for Decentralized Development Planning System in Ghana according to the National Development Planning (System) Act, 1994 (Act 480).

Ghana Standards Authority (GSA): Ghana Standards Authority (GSA) is established by the Standards Authority Act, 1973 NRCD 173 to provide for promulgation of standards, for ensuring high quality of goods and for related matters. With respect to drinking water GSA is responsible for setting drinking water standards in Ghana. The most recent standards for drinking water are the Ghana Standards FDGS 175-1:2013.

7.2.2 Facilitation and Regulation

Water Resources Commission (WRC) (Water Resources Commission) is established by the Water Resources Commission Act 522**Invalid source specified.** to be responsible for the regulation and management of the utilization of water resources and for the co-ordination of any policy in relation to them. With respect to water quality their remit is on the raw water –surface and ground water- quality monitoring and surveillance. The responsibilities of WRC are to:

- propose comprehensive plans for the utilization, conservation, development and improvement of water resources;
- initiate, control and co-ordinate activities connected with the development and utilization of water resources;
- collect, collate, store and disseminate data or information on water resources in Ghana;

- require water user agencies to undertake scientific investigations, experiments or research into water resources in Ghana;
- monitor and evaluate programmes for the operation and maintenance of water resources;
- advice the Government on any matter likely to have adverse effect on the water resources of Ghana;
- advise pollution control agencies in Ghana on matters concerning the management and control of pollution of water resources; and
- perform such other functions as are incidental to the foregoing

Food and Drug Authority: Public Health Act 851,**Invalid source specified.** mandates Food and Drugs Authority (FDA) to enforce standards for the sale of food (includes packaged water) and to monitor through the District Assemblies. FDA's Public analysts[8] of each district shall submit a quarterly report on the number of food products which they have analyzed and to forward copies of the report to the relevant Metropolitan, Municipal and District Assemblies. FDA authorizes food products sale in market. The authorization process complete in three stages, which involved 1-Pre-Licensing (The premise inspection is to ascertain the company's level of compliance with Good Manufacturing Practices), 2-Registration (The registration of the product involves testing of the product, packing and labeling) and 3-Post Market Surveillance (involves inspecting products in trade and handling information of the transport and storage facilities). Market surveillance occurs mostly on receipt of consumer complaints and results are sometimes shared with public as alert through public notice.

Community Water and Sanitation Agency: Community Water and Sanitation Agency (CWSA) is established by the Community Water and Sanitation Agency Act, 1998 Act 564 to facilitate the provision of safe water and related sanitation services to rural communities and small towns. CWSA provides support to District Assemblies in promoting the development and sustainability of safe water. The functions of CWSA are to:

- Provide support to District Assemblies to promote the sustainability of safe water supply and related sanitation services in rural communities and small towns;
- Formulate strategies for the effective mobilization of resources for the execution of safe water development and related sanitation programmes in rural communities and small towns.
- Prescribe standards and guidelines for safe water supply and provision of related sanitation services in rural communities and small towns and support the District Assemblies to ensure compliance by the suppliers of the services;

---

[88] "public analyst" means a person appointed by the Minister for each district to act as an analyst for the purposes of FDA functions.

Environmental Protection Agency (EPA) is established by the Environmental Protect Agency Act, 1994 Act 490 (GOG, 1994c) and mandated to:

- Advise the Minister on the formulation of policies on the environment and in particular to make recommendations for the protection of the environment;
- Co-ordinate the activities of bodies concerned with the technical or practical aspects of the environment and serve as a channel of communication between those bodies and the Ministry;
- Co-ordinate the activities of the relevant bodies for the purposes of con-trolling the generation, treatment, storage, transportation and disposal of industrial waste;
- Secure by itself or in collaboration with any other person or body the control and prevention of discharge of waste into the environment and the protection and improvement of the quality of the environment;

Public Utilities Regulatory Commission: Public Utilities Regulatory Commission (PURC) is an independent body set up by the Public Utilities Regulatory Commission Act 1997, 538 to regulate and oversee the provision of utility services by public utilities to consumers and to provide for related matters. According the Act 538, the functions of the Commission are to provide guidelines on rates chargeable for provision of utility services; to examine and approve rates chargeable for provision of utility services; to protect the interest of consumers and providers of utility services; to monitor standards of performance for provision of services; to initiate and conduct investigations into standards of quality of service given to consumers; to promote fair competition among public utilities; to conduct studies relating to economy and efficiency of public utilities; to make such valuation of property of public utilities as it considers necessary for the purposes of the Commission; to collect and compile such data on public utilities as it considers necessary for the performance of its functions; to advise any person or authority in respect of any public utility; and to maintain a register of public utilities.

District Assemblies (DAs) are responsible for rural and small town water service delivery. The Local Government Act 462, 1993 gives the District Assemblies the mandate to initiate programs for the development of basic infrastructure and provide municipal works and services in the district. The Local Government (Departments of District Assemblies) (Commencement) Instrument, Legislative Instrument 1961 made DAs responsible for overall inter-sectorial coordination, collaboration, planning and overseeing water supply in their districts. In DAs the Department of Works[9] has responsibility to facilitate the provision of adequate and wholesome supply of potable water for the entire district. The District Department of Health, consisting of the District Medical Officer of health and the Environmental Health unit, is responsible to facilitate collection and analysis of data on health, assist in regular inspections of the district to detect nuisances that are injurious to human health, and facilitate supervision and control of the manufacture of foodstuffs

[9] A merger of former Public Works Department, Department of Feeder Roads and District Water and Sanitation Unit, Department of Rural Housing and the Works Unit of the Assembly

including packaged water. The DAs also play roles as regulators, for example, approving tariffs and ensuring drinking water quality. Water and Sanitation Management Teams (**WSMT)** are responsible for the management of water and sanitation facilities. The Department of Health at the District Assembly level, which consists of the office of the District Medical Officer of Health and the Environmental Health Units have the following functions related to water quality:

- facilitate and assist in regular inspection of the district for detection of nuisance of any condition likely to be offensive or injurious to human health;
- assist to establish, install, build and control public latrines, lavatories, urinals and wash places;
- facilitate supervision and control of the manufacture of foodstuffs and liquids of whatever kind or nature intended for human consumption;
- facilitate the prevention and dealing with the outbreak and prevalence of any diseases;

According to the Environmental Sanitation Policy (Revised 2010), the functions of the Environmental Health Management in Metro/Municipal include Food and Water Hygiene. In their organogram water quality control is explicit under food and water hygiene.

7.2.3 Service Providers

Ghana Water Company Limited: Ghana Water Company Ltd. (GWCL) was established by the Ghana Water and Sewerage Corporation Act of 1965, Act 310 to provide, distribute and conserve water for domestic, public and industrial purposes GWCL has a responsibility to deliver water quality that meets the Ghana Standards. In the years between then and 1994, it had responsibility for both urban and rural water supplies. GWCL has since 1999 been operating as a limited liability company following the enactment of the Statutory Corporations (Conversion to companies) Act 1993 (Act 461) (GOG, 1993a). GWCL operates 87 systems in Ghana.

Private Sector Operators: Tankers, Self-suppliers etc.: There are other service providers such as tanker operators, self-suppliers, sachet water producers' etc. due to lack of access from the formal service providers. The Ghana Living Standards Survey VI report, 28% of the Ghanaian population drink sachet water (44.5% in urban areas and 71% in Accra) and 0.4% of the population drink from tanker water suppliers. Another 18.9% of the urban population drinks from Wells (boreholes and hand dug wells).

National Disaster Management Organization: The National Disaster Management Organization (NADMO) was established by the National Disaster Management Organization Act 517 of 1996 to manage disasters and similar emergencies (GOG, 1996). It was structured and placed under the ministry of the interior, to enable it coordinate all the relevant civil authorities at the national, regional and district levels. The mission of NADMO is to manage disasters by co-ordinating the resources of government institutions and non-governmental agencies, and developing the capacity of communities to respond effectively to disasters and improve their livelihood through social mobilization, employment generation and poverty reduction projects. NADMO works through its head office in Accra and secretariats in the regions and Metropolitan, Municipal and District (MMDAs to strengthen Disaster Prevention and Response Mechanisms.

During emergency situations NADMO plays a key role to ensure that affected populations needs with respect to WASH are met. According to the National Water, Sanitation & Hygiene (WASH) Emergency Preparedness and Response Plan, in case of a crisis, the Water Directorate of the MWRWH and the Environmental Health and Sanitation Directorate of MLGRD , co-leading the National WASH in Emergency Technical Working Committee [10]—will activate WASH sector emergency coordination at national level and prompt WASH emergency coordination at regional and district level as appropriate, in order to ensure that WASH partners[11] provide quick and concerted response to affected population needs (GOG, 2014). Consequently, lead agencies at national, regional and district level—in consultation with WASH partners—will define coordination priorities and frequency of meetings based on the scale and nature of the disaster and the number of actors involved in the response.

7.2.4 Other organisations: Universities, Researh Institutes and NGOs

Universities and Training Institutions: A number of universities such as Kwame Nkrumah University of Science and Technology (KNUST), University of Cape Coast (UCC), University of Ghana (UG) conducts research and provides training in the areas of water supply. KNUST has two postgraduate, MSc programmes in Water Supply and Environmental Sanitation Project (WSESP) and Water Resources Engineering and Management (WREM). UCC has a course in Water and Sanitation at the BSc degree level. In addition, there are other tertiary institutions such as three schools of hygiene under the Ministry of Health that trains the Environmental Health Officers. The universities and training institutions provide manpower for the Water, Sanitation and Hygiene (WASH) sector. The research findings for the institutions also serve the sector.

The Water Research Institute: Water Research Institute (WRI) one of the institutes of the Council for Scientific and Industrial Research (CSIR) was formed in 1996 from the merge of Institute of Aquatic Biology and the Water Resource Research Institute, both of the Council for Scientific and Industrial Research (CSIR), which were created in 1965 and 1982, respectively. CSIR was re-established by the Council for Scientific and Industrial Research Act, 1996, Act 521 to promote, encourage and regulate research and the application of science and technology in development and to provide for related matters (GOG, 1996). Some of the functions of CRIS include the following:

---

[10] At all time, one of the two agencies will lead the WinE TWG and the other co-lead. MWRWH WD and the MLGRD EHSD will periodically review co-leadership arrangements to share responsibilities.

[11] Government institutions, NGOs, Red Cross, UN agencies, donors and other organizations implementing WASH related activities.

- To advise the Minister on scientific and technological advances likely to be of importance to national development.
- To encourage coordinated employment of scientific research for the management, utilization and conservation of the natural resources of the republic in the interest of development.
- To cooperate and liaise with international and local bodies and organizations, in particular universities and the private sector on matters of research

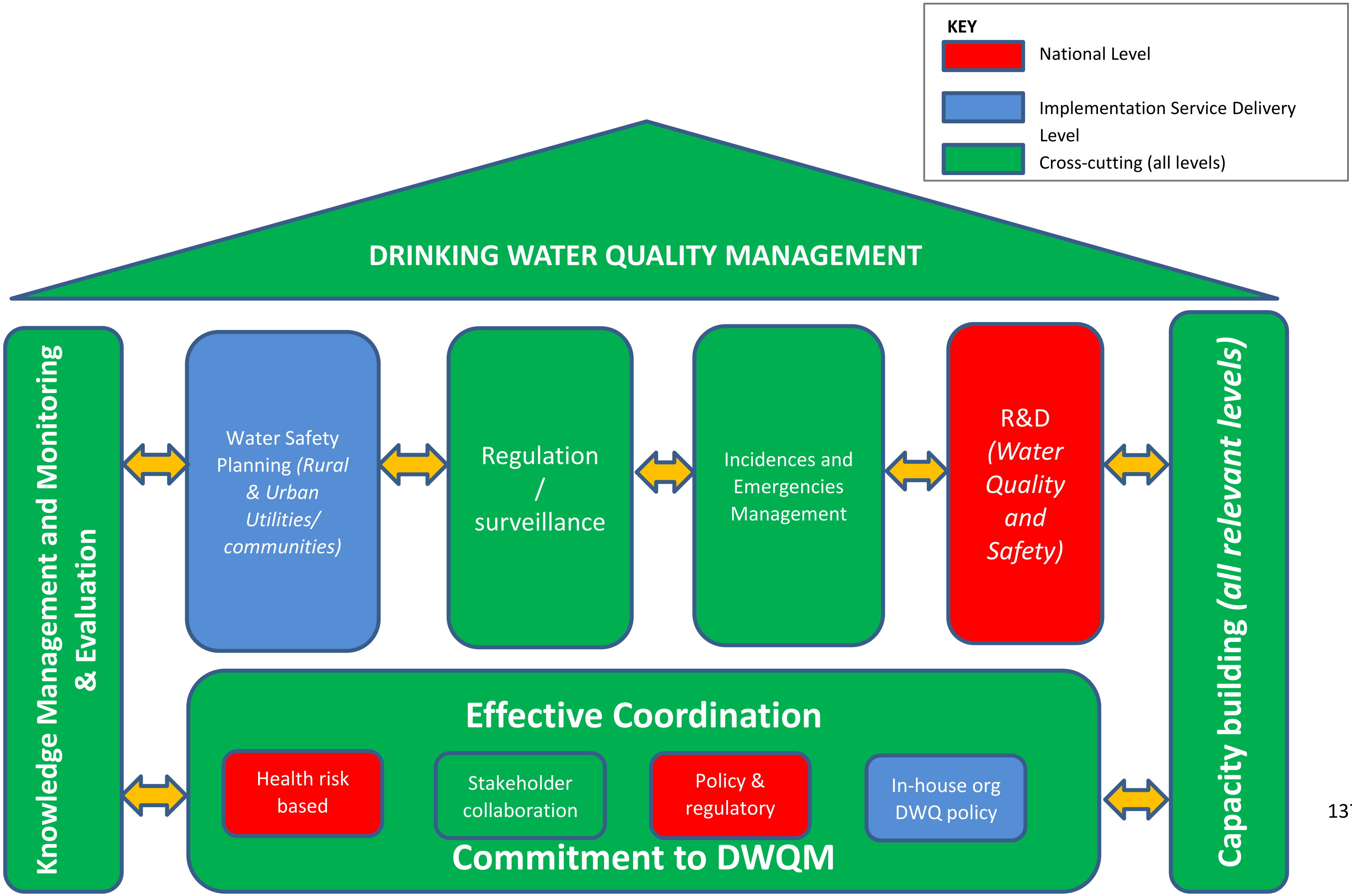
WRI has the mandate to conduct research into water and related resources (both living and non-living) in order to provide scientific and technical information and services as well as strategies for the sustainable development , utilization and management of such resources for the socio-economic advancement of the country. The functions and roles of the institute are as follows:

- Generate, develop and transfer appropriate technologies, information and services for sustainable development, utilization and management of surface water resources
- Generate, process and disseminate information on the availability of ground water, rate and volumes to be abstracted for various uses as well as the reliability and sustainability of its recharge
- Generate, process and disseminate water and waste water quality information to end users
- Enhance public health status of the Ghanaian populace through environmental management water pollution control strategies and disease control and preventive strategies.
- Increase local fish program through participatory research and technology transfer in aquaculture and sustainable management strategies in inland and coastal water in Ghana

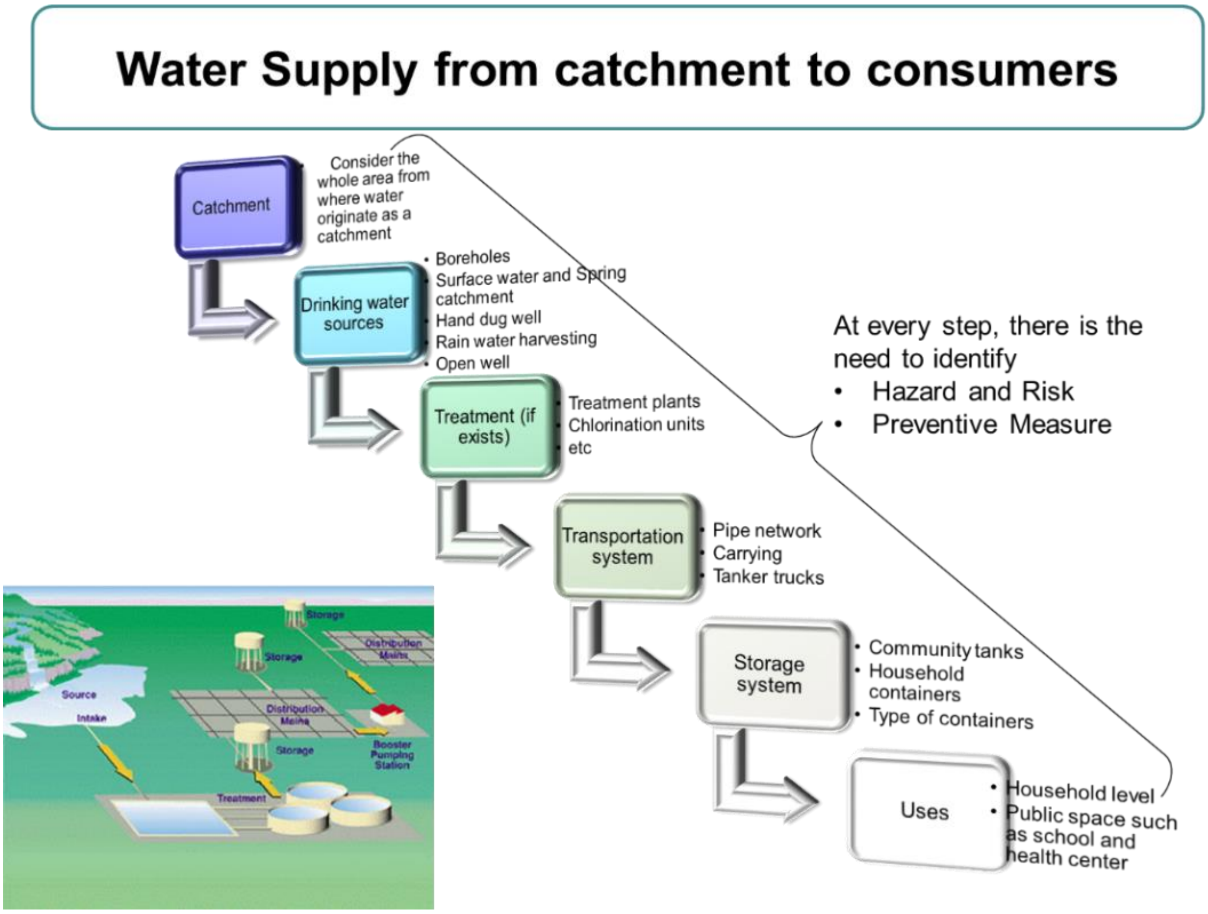
The Water Research Institute has laboratories are equipped to undertake water quality assessment and monitoring of water resources (Surface, ground water, wastewater, treated water).

NGOs: There are several NGOs active in the sector. International NGOs such as WaterAid, World Vision International, Plan International and others are providing support to WASH delivery, either directly or through partner organizations. These NGOs have formed an association known as Coalition of NGOs in Water and Sanitation (CONIWAS), which has the basic objective of promoting the role of NGOs in the delivery of WASH services.

7.3 Schematic of National Drinking Water Management Framework



7.4 Schematics of Water System Operational Procedures and Process Control and Verification of Drinking Water Quality



8. REFERENCES

Bank, W. (2014). *World Development Indicators: Ghana Mortality.* Retrieved from http://wdi.worldbank.org/table/2.21

MacKenzie WR, H. N. (1994). A massive outbreak in Milwaukee of cryptosporidium infection transmitted through the public water supply. *331*(3), 161-167.

Maskeliunas, J. (2011). Codex Alimentarius: Code of Hygienic Practice For Bottled/Packaged Drinking Waters (Other Than NMW), CAC/RCP 48-2001. In Codex, *RECOMMENDED INTERNATIONAL CODE OF PRACTICE, GENERAL PRINCIPLES OF FOOD HYGIENE CAC/RCP 1-1969.*

O'Connor. (2002). *Report of the Walkerton Inquiry, Part 1. The events of May 2000 and related issues and Part 2. A strategy for safe drinking water.* The Attorney General of Ontario, Toronto, The Walkerton Inquiry.

Prüss-Üstün, A., & Corvalán, C. (2006). *Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease". Quantifying environmental health impacts.* World Health Organization. Retrieved from http://www.who.int/quantifying_ehimpacts/publications/preventingdisease.pdf

WHO. (2011). *Guidelines for drinking water quality .* (4th, Ed.)