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Safe water guide for the Australian aid program 2005

A FRAMEWORK AND GUIDANCE FOR MANAGING WATER QUALITY

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Cover photo: A woman collects arsenic-free water from a rainwater tank funded through AusAID in the Manikganj District, Bangladesh. Rainwater harvesting is one way of providing safe drinking water. Photo: Simon Buckley.

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Acknowledgments

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Abbreviations and acronyms

AAS	atomic absorption spectroscopy
ADD	activity design document
AusAID	Australian Agency for International Development
DWQRCG	Drinking Water Quality Review Coordinating Group
EC	electrical conductivity
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
GCMS	gas chromatography – mass spectrophotometry
ICPMS	inductively coupled plasma mass spectrometry
mg/L	milligrams per litre
NGO	non-government organisation
NHMRC	National Health and Medical Research Council (Australia)
NRMMC	Natural Resources Management Ministerial Council
PHAST	participatory hygiene and sanitation transformation
POPs	persistent organic pollutants
ppm	parts per million
ppt	parts per trillion
QA/QC	quality assurance and quality control
TCE	trichloroethene or trichloroethylene
TDS	total dissolved solids
THMs	trihalomethanes
UNICEF	United Nations Children's Fund
UV	ultraviolet

VOCs	volatile organic compounds
WASH	'Water, Sanitation and Hygiene for all' campaign
WHO	World Health Organization
WQMP	water quality management plan
WSH	water, sanitation, health

Glossary

The following terms are used generally in the water industry.

Acute effects	Effects that arise quickly and have a relatively short and severe impact on humans.
Acidification	Change in an environment's natural chemical balance caused by an increase in the concentration of acidic elements.
Aquifer	Subsurface layer or layers of earth, gravel or rock of sufficient porosity and permeability to allow storage and either a significant flow of groundwater or the abstraction of significant quantities of groundwater from the aquifer.
Bacteria	Simple single-celled prokaryotic organisms of many different species. Some species can be pathogenic, causing disease in larger, more complex organisms and these are the ones of concern in water quality. Many species of bacteria play a major role in the cycling of nutrients in ecosystems through aerobic and anaerobic decomposition.
Bancroftian filariasis	Filarial infection with the nematode parasite *Wuchereria bancrofti*. Adult worms usually reside in the large lymphatics of the human host. Often known as elephantiasis.
Blue baby syndrome	Methaemoglobinemia is a blood disorder caused when nitrate interacts with the haemoglobin in red blood cells. This reduces the oxygen available in the bloodstream causing an infant to go blue. Methaemoglobinemia is rare among adults.
Catchment	An area of land in which precipitation drains to a particular stream, river, lake, etc. Sometimes it is called the river or lake basin.
Chronic effects	Lingering, severe effects that tend to build up over time and have ongoing impacts on humans.
Contaminant	Any impurity or substance that pollutes another; an agent of contamination accidentally or inadvertently introduced to food, water, soil or air that may be harmful or potentially poisonous.

Cumulative effects	Defined as effects of an activity that may increase when considered with other reasonably foreseeable activities in the surrounding area. Alternatively, cumulative effects may be caused by the continuous intake of a substance over time, causing accumulation in the human body.
Dengue	An infectious disease of the tropics transmitted by mosquitoes and characterised by a flu-like illness with rash and aching head and joints.
Diarrhoea	Frequent and watery bowel movements; can be a symptom of infection, food poisoning, colitis or a gastrointestinal tumour.
Dissolved oxygen	The oxygen dissolved in water from the atmosphere and photosynthesis; the amount of oxygen freely available in water and necessary for healthy aquatic life and the oxidation of organic materials.
Distillation	A two-stage water treatment. The liquid is boiled, producing water vapour, and the vapour is condensed, leaving most contaminants behind. Can be used to remove inorganic chemicals, some non-volatile organic chemicals, and bacteria.
Electrical conductivity	A measure of the total dissolved ions in a substance, which indicates the material's ability to conduct electricity. The soil's EC is determined from distilled water extracts of saturated soil pastes. In water supplies it is a measure of salinity in the water.
Environmental sanitation	The promotion of hygiene and the prevention of disease and other consequences of ill health relating to environmental factors.
Faecal coliform	Aerobic bacteria found in the colon or faeces. Its presence is often used as an indicator of faecal contamination from humans and animals.
Filtration	The process of passing water through a porous substance to remove solids in suspension.
Gas chromatography	An analytical separation technique whereby the minor components of a mixture of gases are separated and resolved into individual components.
Guinea worm	Contracted by drinking stagnant water contaminated with Guinea worm larvae that can mature inside a human's abdomen causing painful and debilitating effects until the worms emerge through painful blisters in the person's skin.
Groundwater bore	A narrow lined hole drilled to monitor or withdraw groundwater from an aquifer.
Hookworm	Parasitic blood-sucking roundworms with hooked mouthparts that fasten to the intestinal wall of human and other hosts. Eggs are passed in faeces of animals and enter humans/animals from eating contaminated food. Can also enter the body when people walk barefoot on faecal contaminated soil.
ICPMS	Ionisation of elements in a high temperature plasma.

Malaria	An infectious disease caused by a parasite that is transmitted by the bite of infected mosquitoes. It is characterised by recurring chills and fever, and is common in tropic countries.
Nephelometric turbidity units	A measure of turbidity – made with an instrument called a nephelometer, which measures the suspended particles in a liquid. Turbidity in excess of 5 NTU is just noticeable to the eye of an average person.
Parasite	A plant or animal that lives, grows and feeds on or within another living organism.
Pathogens	A bacterium, virus or parasite that causes or is capable of causing disease. May contaminate water and cause waterborne disease.
pH	Measure of the relative acidity or alkalinity of water. Defined as the negative log (base 10) of the hydrogen ion concentration. Pure water has a pH of 7; acidic solutions have lower pH levels and alkaline solutions higher pH levels in the range from 1 to 14.
Precipitation	All forms of water particles that develop in a saturated atmosphere and fall to the ground.
Protozoa	Small, usually single-celled, non-photosynthetic micro-organisms that live in the soil and feed on dead or live bacteria and fragments of organic matter.
Ringworm	A fungal skin infection characterised by ring-shaped, red, scaly or blistery patches.
Roundworm	Long, spaghetti-like worms that live in the human intestine.
Scabies	An infestation of mites in the skin characterised by small pimples that itch.
Schistosomiasis	An infestation with or a resulting infection caused by a parasite of the genus *Schistosoma*. Symptoms depend on the part of the body infected. It is common in the tropics and most of the developing world.
Secchi disc	A 20 cm diameter disc used to measure transparency of water.
Tapeworms	Tapelike, many jointed cestode of genus *Taenia*, parasitic in alimentary canal in man and most vertebrates.
Titration	A laboratory technique in which the concentration of an unknown reagent can be determined by mixing it with a known quantity of a standard concentration of another reagent.
Toxic	Relating to the harmful effect of a poisonous substance on the human body caused by physical contact, ingestion or inhalation.
Triazines	A group of herbicides that are considered to be of low toxicity to humans.
TCE	A contaminant that is a component of cleaning solvents. Commonly found at air force bases as a result of cleaning aircraft and equipment.

Typhoid fever	Contracted when people eat food or drink water that has been infected with bacillus salomonella enterica typhi. It is recognised by the sudden onset of sustained fever, severe headache, nausea and severe loss of appetite, sometimes accompanied by a hoarse cough and constipation or diarrhoea.
Viruses	The smallest life forms known that are not cellular in nature. They are made up of a chromosome surrounded by a protein shell. They live inside the cells of animals, plants and bacteria and may cause disease.
Volatile organic compounds	Organic compounds that vaporise (become gas) at normal room temperature.
Water quality parameter	Chemical or biological constituents in water. If particular constituents in water exceed certain guideline levels the water may be harmful to humans if consumed.
Water source	The water in its natural environment. Common water sources are groundwater, surface water, spring water and rainwater.
Water supply system	A means of providing water to a household, village or large urban population. For the purpose of this guide it includes the collection of water at the source and the transfer system, which encompasses treatment, storage and distribution (includes hardware such as a rain water pot) and usage points.
Whipworm	A common worldwide parasitic infection of the large intestine that primarily affects children, who may become infected if they ingest food or water contaminated with whipworm eggs. The ingested eggs hatch, and the whipworm embeds in the wall of the large intestine (caecum, colon, rectum).

Purpose and format of the guide

The *Safe water guide* provides an overview of the approach that AusAID has adopted for managing water quality in activities implemented under the Australian aid program. That approach is based on managing risks. The guide outlines the steps that may need to be taken when designing, implementing, monitoring and evaluating water-related activities, particularly the provision of safe drinking water supplies. It provides guidance on the procedures for identifying and managing existing and potential water quality problems.

The guide provides practical advice to AusAID staff, contractors, NGOs, development partners and other parties involved in water-related activities.

The guide provides practical advice to AusAID staff, contractors, non-government organisations (NGOs), development partners and other parties involved in water-related activities funded through AusAID.

Although the guide will assist all parties involved in development activities to identify key issues in managing water quality, it is not designed to be a comprehensive reference for all water quality issues. Detailed information can be sought from other suggested references and/or water quality experts as required. If there is uncertainty about a particular situation it is best to seek professional advice.

This guide is not a comprehensive reference. If there is uncertainty about a particular situation, seek professional advice.

The guide contributes to addressing the critical development issues of access to water and sanitation that were identified in *Australian aid: investing in growth, stability and prosperity*, the 11th statement to the Australian Parliament on overseas aid.[1]

1 AusAID, *Australian aid: investing in growth, stability and prosperity, Eleventh statement to Parliament on Australia's Development Cooperation Program, the Hon Alexander Downer MP, Minister for Foreign Affairs, September 2002*, Australian Agency for International Development, Canberra, September 2002, viewed 22 October 2004 <www.ausaid.gov.au/publications/>.

It also forms an important part of the foundation work for the Australian Water Research Facility.[2] This facility is one of the strategies developed to achieve the aim of Australia's water-related development assistance, which is to 'help reduce poverty and raise living standards in developing countries through promoting the efficient, equitable and sustainable use of water resources'.[3] The facility aims to identify and commission applied research into water-related issues affecting developing countries in the Asia-Pacific region, thereby supporting the effective implementation of Australia's policy on water assistance, which is outlined in *Making every drop count: water and Australian aid*.[3]

The guide consists of three parts – framework, guidelines and supporting guidance.

The guide consists of three parts.

Part 1, 'Framework for managing water quality', describes the general procedures that may need to be followed during the various stages of water-related activities funded through AusAID – procedures to ensure the best outcome for water quality in the development context. It outlines the steps involved and the roles and responsibilities of AusAID staff, contractors, NGOs and other parties, and how the framework relates to the activity cycle.

Part 2, 'Guidelines for managing water quality', includes advice on:

- assessing water quality
- identifying risks to water quality
- appropriate treatment and risk reduction methods
- developing management plans
- practical indicators for water quality in field situations, and
- indicative sampling and analysis techniques.

Part 3, 'Supporting guidance', provides, as attachments, more detailed information. The supplement to AusAID's gender guideline and AusAID's specific guide for managing arsenic in water supplies are included. This guidance was current at 28 February 2005.

Each subsequent part provides more technical or specific information to assist in managing water quality.

2 See <www.ausaid.gov.au/hottopics/topic.cfm?Id=9039_5385_2163_8128_5932>.

3 AusAID, *Making every drop count: water and Australian aid*, Australian Agency for International Development, Canberra, March 2003, p. 11, <www.ausaid.gov.au/publications/>.

Part 1
Framework for managing water quality

Introduction

Managing water resources and supplying safe water are two of the greatest challenges for the present generation. Over the past twenty years there has been growing global recognition of the decline in readily accessible, good quality water resources and of the increasing impacts of both water extraction and effluent discharge on the environment and downstream communities. In 2003, around 1.1 billion people did not have access to clean drinking water and 2.4 billion people lacked adequate sanitation. Only 5 per cent of the world's wastewater was treated.

In 2003, 1.1 billion people did not have access to safe water and 2.4 billion lacked adequate sanitation.

APPROACH OF THE FRAMEWORK

AusAID's framework for managing water quality incorporates best practice principles for safe water from the *Australian drinking water guidelines 2004*, the WHO *Guidelines for drinking-water quality* (3rd edn), and AusAID's *Environmental management guide for Australia's aid program 2003*.[4] The framework has been designed to suit the practical needs of AusAID-funded activities in developing countries.

AusAID's framework for managing water quality incorporates best practice principles for safe water.

The framework outlines the steps that may need to be taken by AusAID activity managers, individuals and organisations when designing, implementing, monitoring and evaluating water-related activities in the Australian aid program, particularly the provision of safe drinking water supplies. It provides processes for identifying potential problems and managing risks to water quality in a developing country context throughout the Asia-Pacific region. (These are supported by technical advice for on-the-ground operations in Part 2, 'Guidelines for managing water quality'.)

4 National Health and Medical Research Council (NHMRC) in collaboration with Natural Resource Management Ministerial Council (NRMMC), *Australian drinking water guidelines 2004: national water quality management strategy*, Canberra, 2004, viewed 16 December 2004 <www7.health.gov.au/nhmrc/publications/synopses/eh19syn.htm>; WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>; AusAID, *Environmental management guide for Australia's aid program 2003*, Australian Agency for International Development, Canberra, 2003, viewed 22 October 2004 <www.ausaid.gov.au/publications/>.

Safe water at a glance

WATER QUALITY MANAGEMENT STEPS	AusAID RESPONSIBILITIES FOR WATER-RELATED ACTIVITIES DESIGNED THROUGH AusAID PROGRAMS	ACTIVITY CYCLE
STEP 1 Understand the policy and legal setting	AusAID needs to ensure that the team(s) responsible for identifying an activity and preparing the activity design: > understand Australia's development cooperation policies > become familiar with the international health and water quality guidelines > understand partner government water policies.	**ACTIVITY DESIGN**
STEP 2 Assess water quality and outline the management plan	AusAID needs to include the following tasks when activities are being identified and initially assessed: > identify country-specific water quality standards and guidelines > collect regional and/or country level water quality data > identify key water quality issues to be considered when developing water supply activities in the country/region > summarise water quality issues that need to be addressed when the full activity design is being prepared.	> activity identification
	AusAID needs to include the following tasks when the activity design is being prepared: > identify water source options, water demands, and options for water supply systems > conduct an initial assessment of water quality – identify potential problems associated with water source options, sanitation facilities and hygiene practices – identify risks associated with supply system options, including storage, treatment and distribution issues	> design preparation
	> document findings and prepare an outline for the water quality management plan (WQMP) that: – addresses the issues identified and specifies who is responsible for managing them – considers water supply systems, sanitation facilities and hygiene practices as a package. AusAID needs to ensure that: > the outline for the WQMP is independently appraised for its suitability for the activity design > the outline for the WQMP is included in the activity design document.	> appraisal and approval for implementation

WATER QUALITY MANAGEMENT STEPS	AusAID RESPONSIBILITIES FOR WATER-RELATED ACTIVITIES DESIGNED THROUGH AusAID PROGRAMS	ACTIVITY CYCLE
STEP 3 Implement the provisions for managing water quality	AusAID needs to ensure that the activity's delivery organisation: > reviews the initial water quality assessments and the outline for the WQMP > conducts a more detailed water quality risk assessment of specific water sources and supply systems, including treatment, storage, distribution and usage points > based on findings, identifies appropriate management strategies and develops a comprehensive WQMP, which includes a monitoring program for water quality > obtains agreement for the proposed WQMP with the partner government > implements the agreed WQMP.	**ACTIVITY IMPLEMENTATION** > mobilisation of activity
STEP 4 Monitor and evaluate water quality management	AusAID needs to ensure that: > the activity's monitoring plan and the WQMP are being implemented and are effective > the monitoring encompasses any water-related work that arises during activity implementation but was not identified during activity design.	> monitoring of activity
STEP 5 Review water quality management in AusAID	After the activity is completed, AusAID reviews the effectiveness of water quality management when assessing the effectiveness of the activity's overall implementation. For selected activities, AusAID subsequently evaluates the effectiveness of water quality management and draws lessons about the activity design and the suitability of the management and the water quality principles and practices that were followed. The results and lessons of these processes are fed into the periodic reviews of AusAID's water quality management principles and practices – and drive the updating of the *Safe water guide* – to continuously improve water quality management in activities funded through AusAID.	**ACTIVITY COMPLETION AND EVALUATION**

CONTINUOUS IMPROVEMENT

The framework provides guidance on water quality management issues that need to be considered throughout the activity cycle.

The framework also includes an approach for reviewing the framework's effectiveness and AusAID's success in managing water quality so that water quality objectives can be met.

While this framework is applicable to a range of water supply activities – from small-scale village supply schemes, to humanitarian relief, to broad-based capacity building, to funding for large-scale programs administered by multilateral agencies – it provides guidance to non-technical people on water quality management issues that need to be considered throughout the activity cycle. It is envisaged that large water supply activities would involve professionals with the required water expertise. In the future, more detailed guidance for large, technical and institutional activities may be developed.

The framework has five steps:

1. Understand the policy and legal setting
2. Assess water quality and outline the management plan
3. Implement the provisions for managing water quality
4. Monitor and evaluate water quality management
5. Review water quality management in AusAID

These steps reflect the framework and principles embodied in the *Australian drinking water guidelines*. Each step identifies the key tasks involved in managing water quality and who is responsible for undertaking the work.

The relationship between the steps of the framework and AusAID's activity cycle is broadly illustrated in 'Safe water at a glance' (pp. 4–5).

LINKS TO *AUSGUIDE*

There are numerous references within *AusGuide* that should be consulted when managing water quality.

AusGuide, including the associated AusGuidelines, is the basic reference used within AusAID for managing activities designed and delivered through the Australian aid program. It provides an operational framework for AusAID officers, as well as useful information for implementers and stakeholders involved in development activities.

There are numerous references within *AusGuide* that should be consulted when managing water quality. These relate largely to the broader goals of reducing poverty and achieving sustainable development. Therefore, this framework works in parallel to *AusGuide*.

It is important to use agency guidelines when identifying and assessing aid initiatives as they flag issues that could arise when activities are being implemented and affect the long-term success of the activities. If water quality issues are identified early in the development of activities it is more likely that they will be effectively managed.

Stage 1 of the AusAID activity cycle, which relates to the initial identification and assessment of aid initiatives, provides criteria for assessing proposed activities.[5] This is a crucial stage when any impact that an activity might have on water quality is initially considered. Water quality issues common in the country or region may assist in identifying water quality parameters that need to be considered. Previous experience in managing water quality during an activity's implementation is another source of valuable information.

Efforts need to be made during different stages of the activity cycle to ensure that water quality issues are identified and managed in a sustainable manner.

At the next stage of the activity cycle – preparing a full activity design – the AusGuideline on preparing activity design documents outlines the types of issue that AusAID considers when developing an activity. Under AusAID principles, the activity's design should identify existing and potential water quality issues that will need to be managed. This is when the framework and the associated guidelines should be used.

A key task undertaken when designing activities is an assessment of the likely sustainability of their benefits. The AusGuideline on promoting practical sustainability focuses solely on sustainability issues. It provides guidance on analysing sustainability when identifying and designing activities so that sustainability strategies can be developed. The key point stressed is that any AusAID or other donor activity should be implemented to maximise the flow of benefits after the activity itself has been completed.

The principles of sustainability outlined in the AusGuideline apply to water quality, and efforts need to be made during each stage of the activity cycle to ensure that water quality issues are identified and managed in a sustainable manner.

The benefits of activities are generally maximised when stakeholders in the partner country actively participate in and assume ownership of the activities. One of the best ways of achieving this is to link water-related activities to partner government policies as much as possible. This assists in filtering the benefits of these activities through the different levels of government and down to the community level. Where appropriate policies do not exist, a component of the activities may be to assist the government to develop those policies.

5 See <www.ausaid.gov.au/ausguide/>.

Current versions of the relevant parts of *AusGuide* and the relevant AusGuidelines can be accessed on AusAID's website.

A point highlighted in the AusGuideline on sustainability that is particularly applicable to safe water supplies is the need for the partner country to meet the ongoing operation and maintenance costs of the supply system. Historically, such costs have not been well handled by the donor community. Mechanisms for meeting these costs need to be an integral part of any water supply activity. The AusGuideline on sustainability provides a sample sustainability strategy for asset maintenance.

It is recognised in this AusGuideline that sustainability objectives need to be realistic and this also applies to water-related activities. In many instances longer term assistance may be required to achieve the ultimate objectives of activities. This AusGuideline provides detail on assessing sustainability and how to integrate it into the activity cycle.

AusGuide, including the associated AusGuidelines, is revised when appropriate as part of the process of continuously improving activity management. Current versions of the relevant parts of *AusGuide* and the relevant AusGuidelines can be accessed on AusAID's website <www.ausaid.gov.au/ausguide/>.

Step 1

UNDERSTAND THE POLICY AND LEGAL SETTING

THE AUSTRALIAN AID PROGRAM'S DEVELOPMENT COOPERATION POLICIES

The Australian aid program has three main policies that explicitly refer to the provision of safe water and sanitation.

The Australian aid program works with partner countries to help address their water challenges.

Reducing poverty: the central integrating factor of Australia's aid program (2001)[6] recognises the links between the environment and poverty. It stresses that preventing environmental degradation is essential to reducing poverty and ensuring development is sustainable. The degradation of water resources and water quality contributes to ongoing poverty.

Australian aid: investing in growth, stability and prosperity (2002) is a key overarching policy document for the Australian aid program. It reinforces the essential policies established in *Better aid for a better future*[7] in 1997 and the policy framework that has evolved since then. It guides the Australian aid program in a rapidly changing international and regional environment. The document identifies the importance of safe and accessible water.

Making every drop count: water and Australian aid (2003) further elaborates on the aid priority of safe water and sanitation. It articulates how the Australian aid program works with partner countries to help address their water challenges. The policy emphasises the fundamental importance of good governance in sustainably managing the use of water and draws attention to the need to improve the efficiency of existing water supply systems. Increases in efficiency can lead to sustained improvements and better access to water and sanitation services. This policy was further endorsed in *Australian aid: an integrated approach, Thirteenth annual report to Parliament on Australia's aid program* (2005).[8]

***Making every drop count* is the Australian Government's policy on water-related development assistance.**

6 AusAID, *Reducing poverty: the central integrating factor of Australia's aid program*, Canberra, 2001, viewed 10 December 2004 <www.ausaid.gov.au/publications/>.

7 AusAID, *Better aid for a better future: Seventh annual report to Parliament on Australia's Development Cooperation Program and the Government's response to the Committee of Review of Australia's Overseas Aid Program*, the Hon Alexander Downer MP, Minister for Foreign Affairs, AusAID, Canberra, 18 November 1997, viewed 22 October 2004 <www.ausaid.gov.au/publications/>.

8 AusAID, *Australian aid: an integrated approach, Thirteenth annual report to Parliament on Australia's aid program*, Australian Agency for International Development, Canberra, 2005, viewed 13 March 2005 <www.ausaid.gov.au/publications/>.

AusAID addresses rural development, infrastructure, governance, health and education in the Australian aid program, taking into account the crosscutting issues of gender and the environment when implementing the program. The availability of safe water directly influences health and development in rural areas, and indirectly influences AusAID's other key development areas, as well as the delivery and sustainability of all activities.

AUSTRALIAN ENVIRONMENT LEGISLATION

The EPBC Act is particularly relevant to the construction of water supply and sanitation systems.

AusAID-funded projects are subject to Australian environment legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth). Under the EPBC Act, as it is commonly known, any aid activity that has, may have or is likely to have a significant impact on the environment anywhere in the world is subject to approval by the Minister for the Environment and Heritage. The EPBC Act is particularly relevant to the construction of water supply and sanitation systems. It may also be relevant to other AusAID activities that have the potential to contaminate water supplies. For specific advice on the EPBC Act as it relates to Australian aid activities refer to the *Environmental management guide for Australia's aid program 2003*.

AusAID AND PARTNER GOVERNMENT REQUIREMENTS

A key purpose of this guide is to ensure that the Australian Government's commitment to providing safe water, as well as the requirements of the partner governments, can be met.

AusAID's water-related policies and documents aim to establish the link between poverty reduction, water, the environment and health. Without a safe water supply community health deteriorates, which ultimately reduces economic activity. So safe water is essential for a viable and sustainable community. But there is no common definition of 'safe water'. AusAID refers to the WHO *Guidelines for drinking-water quality* and the *Australian drinking water guidelines* for information on the requirements for safe water.

When identifying and assessing aid initiatives, a clear understanding of those guidelines is vital. Of equal importance is an understanding of the legislation, regulations, policies and guidelines that govern the management and supply of drinking water in the partner country. Such understanding should ensure that the Australian Government's commitment to providing safe water, as well as the requirements of the partner government, can be met.

When determining the water quality objectives of an activity it is important that comprehensive discussions are held with the counterpart water, health and environment agencies. Issues that need to be considered are whether one set of guidelines and requirements relating to water quality are more stringent than the other, whether they are comprehensive and whether they are enforceable.

Although water supply activities aim to supply water that can be considered safe in terms of international guidelines (particularly the WHO guidelines), meeting those guidelines is usually the long-term goal. It should be recognised that it may not be possible to fully comply with the guidelines in a single step and that the practical application of guidelines will call for some judgment of what are acceptable as interim water quality standards. In such situations the activity managers, partner governments, NGOs and other stakeholders should negotiate and agree on the standards to be met, and document the decision-making process and outcome. If interim quality standards are adopted, these must not pose a serious risk to human health.

While the focus of this framework is to ensure that water for drinking is safe, water for other uses such as irrigation, bathing and washing clothes, cooking, sanitation and recreation also needs to be safe. The same principles used in managing the quality of drinking water can be applied to water for these other uses.

INTERNATIONAL GOALS

The objectives of AusAID's water-related policies align with broad international goals of providing better access to safe water supplies and sanitation for the world's poor.

Better access to safe water supplies and sanitation for the world's poor are key international development goals.

The United Nations Millennium Development Goals were agreed in New York at the Millennium Summit in 2000. World leaders committed to reduce by half, by the year 2015, the proportion of people who are unable to reach, or to afford, safe drinking water. And at the World Summit on Sustainable Development in Johannesburg in 2003, a complementary target was adopted – a commitment to halve the proportion of people without access to basic sanitation services, also by 2015. The United Nations has since proclaimed 2005–2015 as the International Decade for Action, 'Water for Life'.

There are many agencies worldwide, including WHO, that are assisting national governments and contributing to the achievement of these goals. AusAID is one of them.

Step 2

ASSESS WATER QUALITY AND OUTLINE THE MANAGEMENT PLAN

The Australian aid program delivers activities, many with a water component, in a variety of ways. They are delivered using a range of mechanisms that cater to the individual circumstances of developing countries. When water quality is being assessed and its management is being planned, the differences in delivery mechanisms and partner country conditions must be taken into account, but without compromising AusAID's legal and policy requirements or imposing an unnecessary administrative or technical burden on the partner country.

Differences in delivery mechanisms and partner country conditions must be taken into account.

Water quality assessment and management planning are most effective when started early in the activity cycle and conducted iteratively during the design of the activity. The indicative tasks in this assessment and planning step are to:

> conduct a preliminary assessment of water quality

> identify and assess water quality problems and risks

> prepare an outline for the water quality management plan (WQMP), and

> appraise the water quality assessment and initial management planning.

Water quality assessment and management planning are most effective when started early in the activity cycle.

When undertaking the assessment and management planning for an activity it is important the work involved is proportionate to the level of risk associated with providing water of a certain quality. Box 1 gives an insight into the development of risk-based water quality management.

The assessment and planning required at the different stages of the activity cycle are illustrated in 'Safe water at a glance' (pp. 4–5).

BOX 1: THE DEVELOPMENT OF THE RISK-BASED APPROACH TO MANAGING WATER QUALITY

Over the past decade it has become increasingly evident that the delivery of safe and aesthetically acceptable drinking water cannot be assured if the water's quality is based on only measurements of water quality and/or the performance of a water filtration plant. For example, in some incidents of waterborne disease it was found that the treated water generally complied with microbiological requirements.

Further, the significance of non-compliance with microbiological requirements is not always well defined. For example, the *Cryptosporidium* incident in Sydney, Australia, in 1998[1] shows that detection of *Cryptosporidium* does not always produce a high-risk outcome in terms of effects on human health. However, other waterborne disease incidents such as the one in Walkerton, Canada, in 2000[2] show that non-compliance can result in significant illness. The Walkerton incident highlights the importance of effective risk assessment, documentation of the treatment facility's performance, external auditing and proper training of operations staff to avoid criminal charges.

In response to these uncertainties and the practical difficulty in monitoring the quality of treated water, Australian regulatory authorities now require a risk-based approach to managing the quality of drinking water. Examples of this are the new *Safe Drinking Water Act 2003*[3] in Victoria, and the requirements for risk management in the operating licences for the Sydney Catchment Authority and the Sydney Water Corporation.

Water quality guidelines are also being expanded to include not only guidance on the acceptable levels of contaminants, but also risk-based approaches to system management. Examples of this are the 2004 *Australian drinking water guidelines*[4] and the third edition of the WHO *Guidelines for drinking-water quality*.[5]

A key advantage of a risk-based approach is in avoiding the costs associated with installing inappropriate systems of delivering water.

References: **1** See <http://water.sesep.drexel.edu/outbreaks/Sydney_1.htm>.
2 See <www.ene.gov.on.ca/water.htm>. **3** See <www.waterquality.crc.org.au/hsarch/HS30f.htm>.
4 See <www7.health.gov.au/nhmrc/publications/synopses/eh19syn.htm>.
5 See <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

CONDUCT A PRELIMINARY ASSESSMENT OF WATER QUALITY

A preliminary water quality assessment aims to identify the range of water quality problems and risks that need to be managed in the partner country or that could result from development activities. As part of the assessment, relevant policies, strategies and program planning should be reviewed in order to put water quality issues into context.

In general, a preliminary water quality assessment should:

> inform decision-makers of key water issues

> facilitate activity design, plans, work programs and sustainable outcomes

> consider the range of water quality issues that could arise, including those that could arise from the cumulative impacts of proposed development activities, and

> help in the later, more significant task of identifying and assessing water quality problems and risks.

The preliminary assessment should be undertaken as early as possible in the activity formulation process. It involves assessing broad water quality issues and can help to identify the links between access to safe water and poverty reduction at the regional, country or program level. The assessment of water-related impacts on the poor should be an integral part of the poverty analysis.

A preliminary water quality assessment should be undertaken as early as possible in the activity formulation process.

The preliminary assessment should be undertaken in conjunction with the partner government, who should be introduced to the framework for managing water quality. It provides an important opportunity for building the capacities of the health, water and sanitation agencies of the partner government.

For an activity focused on capacity building and broader reform within an institution, the preliminary water quality assessment is likely to be all that is needed to ensure that the institution understands the water quality concepts and issues it should consider in its policies, strategies and plans. Only if specific water sources are being considered for development and management by the institution would the subsequent tasks in assessing water quality and outlining a management plan be required.

An overview of the current, common water quality problems in many of the countries in which AusAID-funded activities are undertaken is given in Table 1.

Water has many constituents. Some of these are of natural origin, and some are man made and present as contaminants.

Water has many constituents. Some of these are of natural origin, and some are man made and present as contaminants. Some can give rise to serious health effects, and some will give rise to only aesthetic characteristics, such as an unpleasant taste or colour. Some are more common in particular regions. Box 2 puts pathogens – by far the most common and widespread health risk associated with drinking water – into perspective.

Information on water quality issues for specific countries and regions can be found in WHO publications and national government publications.

Table 1: Common water quality problems in countries in which AusAID-funded activities are undertaken[a]

Pathogens are by far the most common and widespread health risk associated with drinking water.

PROBLEM	CONTAMINATION POTENTIAL
Pathogens	Widespread; most significant risk to water quality.
Metals (eg arsenic)	Confined to certain geographic areas, catchment types and groundwater.
Pesticides	Found only in individual supplies or localised areas of pesticide use.
Algal toxins	Widespread in stagnant or slow moving surface water.
Nitrates	Widespread in groundwater.
Fluoride	Confined to certain areas and groundwater.
Organic compounds (eg POPs)	Found only in individual supplies or localised areas.

a Based on common experience in Bangladesh, Viet Nam, Cambodia, Lao PDR, China, Pacific island countries, Indonesia and India.

Note: It is possible to find examples of other problems in particular countries, including more serious problems than may be inferred in Table 1. As such, the summary must not be relied on for characterisation of water supplies. It serves only as a basis for initial assessment.

IDENTIFY AND ASSESS WATER QUALITY PROBLEMS AND RISKS

Existing and potential water quality problems for a specific water source or supply system are identified and assessed in the partner country by the activity design team or the NGO that will implement the activity. These teams should include members with appropriate water quality skills, and should consult with counterpart organisations and all relevant stakeholders. Stakeholders include the affected community, the partner government and/or local government, the water, environment and health agencies, and local villagers. It is vital that all communities expected to be affected by the proposed development actively participate in this process.

Existing and potential water quality problems are identified and assessed in the partner country.

BOX 2: PATHOGENS IN PERSPECTIVE

Although heavy metals, particularly arsenic, are very dangerous to human health, pathogens are by far the most common and widespread health risk associated with drinking water.

Pathogens are found in water contaminated either directly or indirectly by excreta and the micro-organisms contained in human or animal faeces. One gram of faeces can contain 10 000 000 viruses, 1 000 000 bacteria, 1000 parasite cysts and 100 parasite eggs.[1] On average every year 2.2 million people die from diarrhoeal diseases,[2] mostly caused by contaminated food or water.

Worldwide there are millions deaths a year from gastrointestinal diseases caused by poor water quality, poor hygiene and the lack of adequate sanitation. It is estimated that 4 billion people a year suffer from diarrhoea related to gastroenteritis.[2]

According to some estimates, in Bangladesh between 28 and 35 million people consume drinking water with elevated levels of arsenic.[3] Some predict that 1 in 100 people who drink water containing 0.05 mg of arsenic per litre may eventually die from arsenic-related cancers.[4] These figures illustrate the seriousness of arsenic contamination but microbial contamination affects far more people than arsenicosis and is far more widespread.

References: 1 B Appleton and C van Wijk, *Hygiene promotion – thematic overview paper*, IRC International Water and Sanitation Centre, Delft, Netherlands, February 2003, viewed 22 October 2004 <www.irc.nl/page.php/16>. **2** See <www.who.int/water_sanitation_health/diseases/diarrhea/en>. **3** G Howard, *Arsenic, drinking-water and health risk substitution in arsenic mitigation: a discussion paper*, A report prepared for the Arsenic Policy Support Unit, Local Government Division, Government of Bangladesh, World Health Organization, Geneva, 2003, viewed 5 January 2005 <www.who.int/water_sanitation_health/dwg/wsh0306/en>. **4** See <www.who.int/water_sanitation_health/diseases/arsenicosis/en>.

The design team or NGO may already be familiar with the risk assessment principles applied in such programs as WSH,[9] PHAST[10] and WASH[11] and other hygiene-related initiatives. Although the approach taken here to assessing the risks to water quality is slightly different, identifying the risks and determining how to manage those risks is not new.

Tasks include gathering information, inspecting systems and identifying problems and risks.

Guideline 1, 'Identifying water quality problems and assessing risk to a water supply', in Part 2 of this guide lists tasks involved in, for example, gathering information on water sources, inspecting a water supply system, identifying existing and potential water quality problems, and assessing how aware the community is of water quality issues.

The problems and risks for drinking water quality and appropriate treatment are related to the water source.

The guideline presents the tasks separately according to the water source (surface water, deep groundwater, shallow groundwater, spring water and rainwater) as the problems and risks for drinking water quality and appropriate treatment are related to the water source. If more than one source or supply system is involved in an activity, each will need to be separately assessed. The guideline also includes the tasks involved in identifying and treating problems associated with storage, distribution and usage points, which are common to all water sources.

For small-scale activities, particularly those delivered by NGOs, Guideline 1 provides guidance on issues that need to be considered for small water supply systems, including household systems. The terms of reference for delivery organisations responsible for such activities should require them to identify water quality problems and assess the risks to water quality. This work should be done in consultation with local counterparts.

Similarly, for a major activity, the design team should identify and assess water quality problems and risks. The nature and size of the water-related components of such an activity are likely to make such tasks much more comprehensive than for a small NGO activity, but also make technological solutions feasible and affordable. For an activity being prepared by AusAID, the results should be incorporated into the activity design document (ADD), either in the problem analysis or setting sections or as a separate annex. All potential negative outcomes for water quality and intended outcomes that may not be achieved should be addressed in the risk matrix of the ADD. See the AusGuideline on preparing activity design documents for more detail.

9 See <www.who.int/water_sanitation_health/about/en/>.

10 See <www.afro.who.int/wsh/phast.html>.

11 See <www.wsscc.org/index2.cfm?CFID=441739&CFTOKEN=64717014>.

Prioritise the issues to be addressed.

By identifying and assessing water quality problems and risks it is possible to prioritise the issues to be addressed. This enables a strategic, staged approach to be taken to maximise the benefits from available resources.

In practical applications, WHO gives priority to addressing water quality problems in the following way.[12]

1. Ensure an adequate supply of microbiologically safe water.
2. Maintain the acceptability of drinking water to prevent consumers seeking other potentially less microbiologically safe supplies.
3. Manage key chemical contaminants known to affect the health of people.
4. Address other chemical contaminants.

Table 2 provides a summary of the key parameters of water quality, their potential sources, the effects of exposure to them, and the level of risk that common contaminants pose in drinking water supplies.

It should be recognised that the effects of exposure to contaminated drinking water can be diverse:

- cumulative – accumulate in the body
- non-cumulative – pass through the body
- acute – cause immediate adverse effects
- chronic – give rise to problems after long-term continued exposure.

Such effects are used in prioritising the issues that need to be managed.

In some cases water that is not suitable for drinking purposes may be able to be used safely for other purposes such as bathing, clothes washing or irrigation.

12 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Table 2: Key parameters of drinking water quality and their health effects

PARAMETER	POTENTIAL SOURCES	EFFECTS OF EXPOSURE
Pathogens (bacteria, viruses and protozoa): extreme risk		
The most common and widespread health risk associated with drinking water is contamination – either directly or indirectly – by excreta and the micro-organisms (pathogens) in human or animal faeces. If contamination was recent, and those who contributed to it included carriers of communicable enteric diseases (diseases of the gut) – ie people and domesticated animals – some of the micro-organisms that cause these diseases may be present in the water. Drinking the water or using it in food preparation may cause new cases of infection. Most but not all pathogens are removed by common treatment methods (eg boiling).	Common in all water supplies, even those from 'protected' catchments. Sources include septic tanks, sewage treatment plants, farm animals, rural stormwater, sewer overflow, and urban stormwater.	Gastroenteritis (ranging from mild to severe), diarrhoea, dysentery, hepatitis, cholera and typhoid fever. Those at greatest risk of infection are infants and young children, people whose immune systems are suppressed (eg HIV/AIDS patients), the sick and the elderly.
Algal toxins: high risk		
Algae are common in open, surface water bodies when warm temperatures, sunlight (for photosynthesis), nutrients and stagnant or slow-moving water are available. Some algae species (eg blue-green algae) generate toxins harmful to humans. Algal cells are readily removed by treatment such as filtration, but toxins are dissolved and are not removed by simple treatment methods. Many algal species, including blue–green algae, also generate offensive taste and odour in the water, which are not removed by common treatment methods.	Algal growth is typically triggered by elevated nutrients in the water body. Sources of nutrients can be natural (eg from rotting vegetation and recycled nutrient-rich sediments) or from organic matter from sewage treatment plants and overflows, septic tanks, stormwater and fertilisers used in agriculture (phosphorous, nitrogen).	Liver damage and effects on the nervous system.
Parasites: high risk		
Mosquitos	Stagnant water in streams, drains and uncovered storage or drinking vessels.	Malaria and dengue fever from the bites of infected mosquitos.
Worms (hookworms, etc)	Contaminated land and water.	Intestinal ailments.
Treatments for parasites include water source management and medication if illness occurs.		
Nitrate: medium risk		
A common contaminant in groundwater. Concentrations that exceed acceptable levels for children, particularly bottle-fed infants, are moderately common. Not removed by common treatment methods.	Particularly associated with wastewater (sewage treatment plants and septic tanks), livestock facilities and fertilised croplands.	Blue baby syndrome. Unlikely to be at concentrations that will adversely affect adults.

(Continued on next page)

Table 2: Key parameters of drinking water quality and their health effects (continued)

PARAMETER	POTENTIAL SOURCES	EFFECTS OF EXPOSURE
Heavy metals: medium risk		
Some heavy metals, such as arsenic,[13] are moderately common in groundwater supplies. They are not commonly seen in surface water supplies because they oxidise in air to an insoluble form and settle out. Some metals used in plumbing and pipe solders (eg lead, copper and zinc) can also contaminate water supplies. The maximum allowable concentrations of these metals are very low. The metals can occur in dissolved form, be complexed with organic compounds, or be adsorbed on suspended material such as clays or metal precipitates. Generally metals are at least partially removed by common treatment, although the effectiveness depends on the chemical form of the contaminant.	Natural leaching from mineral deposits into source waters – ie where the rock hosting the aquifer has naturally occurring arsenic and other heavy metals. Leaching from the host rock and mobilised in water where mining has taken place and there are sulphidic ore bodies. Corrosion of pipes and fittings. Wastes from industrial operations, particularly those involving metal plating and cleaning.	Lead, mercury and cadmium affect the central nervous system. Arsenic, a cumulative poison, commonly gives rise to black pigmentation of the skin (melanosis, keratosis), and less commonly to other more severe effects such as cancer and effects on the nervous system.
Fluoride: medium risk		
Moderately common natural constituent of groundwater in certain regions. Present as the soluble fluoride ion. Common treatment may achieve some reduction.	Natural mineralisation present in certain regions. Added to water supplies to protect teeth from decay.	Mottling of the teeth and bones. Disease of the bones at high concentrations. Has beneficial effect in preventing dental cavities at concentrations of less than 1 mg/L.
Organic chemicals: medium–low risk		
Commonly used in industry and transport. The most common are petroleum hydrocarbons. Include aromatic and aliphatic hydrocarbons and phenols, and chlorinated solvents (eg TCE) common in dry cleaning. Not removed by common treatment methods.	Discharges from large manufacturing industry of significant loads to surface waters and groundwater. Stormwater contaminated by industrial wastewater or fuel leaks.	The aromatic hydrocarbons are the most toxic, and some can be carcinogenic. Usually the non-chlorinated and non-aromatic compounds have a relatively low toxicity.

(Continued on next page)

13 See the attachment ‘Managing arsenic in water supplies: interim AusAID guidelines and operating procedures’ in Part 3 of this guide.

Table 2: Key parameters of drinking water quality and their health effects (continued)

PARAMETER	POTENTIAL SOURCES	EFFECTS OF EXPOSURE
Pesticides: low risk		
Commonly used in agriculture and forestry. Includes agricultural chemicals such as insecticides, herbicides, nematicides, rodenticides and miticides. Generally found at low concentrations in water supplies. Common treatment may achieve some reduction.	Agricultural and forestry industries. May be found in groundwater (eg the triazines) or in surface water after spraying. The phenoxyacetic acid herbicides (eg 2,4 D) now in common usage breakdown rapidly. Use in warfare has left areas where herbicides can enter water supplies (Viet Nam, Lao PDR, Cambodia).	Bioaccumulation, particularly associated with body fat. Effects vary; some can be neurotoxins, and some may be carcinogenic.
Salts: low risk		
All naturally occurring water has some level of salt so it is a very common water parameter. Desalination plants, membrane filtration, distillation or ion exchange are available for removal of high levels of salt but these units are expensive and energy intensive.	Land uses in catchments that exacerbate natural processes such as the mobilisation of salts, including saltwater intrusion.	Most salts are of low toxicity to humans, but can give rise to a salty taste and may cause temporary gastrointestinal upset.
Aesthetic indicators: low risk		
True colour (ie the colour that remains after any suspended particles have been removed). Turbidity (the cloudiness caused by fine suspended matter such as soil particles). Peculiar taste, odour and 'feel' problems usually due to total dissolved solids (either high or very low). Treatments for aesthetic parameters include filtration, coagulation and membrane filters.	Animal husbandry, horticulture, rural stormwater, forestry, urban stormwater, stormwater and sewer overflows, and algal blooms.	Water's odour, taste and appearance govern perception of its quality and may lead to water being judged unpalatable. Less palatable water can be safer to drink than apparently 'cleaner' but contaminated water.
Radiological and disinfection by-products: low risk		
The by-products cannot be treated. Operational strategies need to be put in place to minimise disinfection by-products.	Radiation associated with natural radioactivity of minerals. Formed when the disinfection product (ie chlorine or bromine) combines with other matter in the water such as soils and humic substances.	Increased incidence of cancer.

The water supply system used to get water from its source to households influences the contaminants that may be found in water. The system, which includes water collection at its source, treatment, storage, distribution and usage points, may serve an individual dwelling, a small settlement, a village of a few hundred people, a town or a city. So it can vary greatly in size and include a well, rainwater tank, filter, rainwater pot, a small chemical treatment system for a household, a small reticulated village system, a large urban system, or formal or informal tanker deliveries.

The water supply system influences the contaminants that may be found in water.

As already noted, Guideline 1 highlights the risks to water quality generally associated with key water sources, as well as the transfer system. If there is uncertainty about the risks associated with different types of supply system, further advice should be sought from experts.

PREPARE AN OUTLINE FOR THE WATER QUALITY MANAGEMENT PLAN

After identifying and assessing the water quality problems and risks, and prioritising the issues to be addressed, the design team or NGO should document its findings and prepare an outline for the WQMP, which will be fully developed later by the activity's delivery organisation.

The water quality management plan is the key tool for ensuring that water quality problems and risks are managed during the activity's implementation.

The WQMP is the key tool for ensuring that the water quality problems and risks are managed during the implementation of the activity. The purpose of the plan is to avoid or minimise the activity's negative impacts on water quality and maximise its positive impacts. The requirement for such a plan should be included in the delivery organisation's scope of services or terms of reference.

Traditionally WQMPs have focused on protecting water sources. However, water that is safe at its source is in constant danger of being contaminated during storage, distribution or consumption. Often water is contaminated by faeces because storage and distribution systems are poorly maintained or hygiene practices are poor. These issues reinforce the importance of working with communities to increase their awareness of sound maintenance practices and good hygiene standards.

The plan's outline should clearly indicate that the water supply system, sanitation facilities and hygiene are parts of an integrated system required to produce safe water. Most of the health benefits of water supply activities stem from changes in hygiene practices. By integrating hygiene, environmental sanitation and water supply systems it is possible to break the contamination–transmission cycle. This can involve providing effective community-based education on hygiene (see Box 3) and introducing and promoting safe water storage and distribution.

The water supply system, sanitation facilities and hygiene are parts of an integrated system required to produce safe water.

BOX 3: KEY MESSAGES ABOUT HYGIENE

UNICEF's 'Facts for Life' campaign aims to make life-saving knowledge available to everyone and includes seven key messages about hygiene.

1 All faeces should be disposed of safely. Using a toilet or latrine is the best way.

2 All family members, including children, need to wash their hands thoroughly with soap and water or ash and water after contact with faeces, before touching food, and before feeding children.

3 Washing the face with soap and water every day helps to prevent eye infections. In some parts of the world, eye infections can lead to trachoma, which can cause blindness.

4 Only use water that is from a safe source or is purified. Water containers need to be kept covered to keep the water clean.

5 Raw or leftover food can be dangerous. Raw food should be washed or cooked. Cooked food should be eaten without delay or thoroughly reheated.

6 Food, utensils and food preparation surfaces should be kept clean. Food should be stored in covered containers.

7 Safe disposal of all household refuse helps prevent illness.

Source: UNICEF, 'Hygiene', *Facts for life*, 3rd edn, UNICEF, New York, 2002, pp. 96–7.

Most of the health benefits of water supply activities stem from changes in hygiene practices.

The key ways of preventing the spread of water and sanitation-related diseases are presented in Table 3. Further information is available from the International Water and Sanitation Centre.[14]

The outline should describe how the plan's implementation and effectiveness will be monitored and reported on.

The outline should also include how the plan's implementation and effectiveness will be monitored and reported on. This will ensure that problems and risks are properly managed and will enable early detection and response to any unexpected water quality problems or emergencies. To facilitate monitoring and reporting, the final plan should include indicators of effective water quality management.

The plan also needs to take into account any plan the partner government has for safeguarding or improving water quality. If the partner government's plan is used it is important to ensure that a systematic approach was taken to developing the plan and to properly identifying all problems and risks.

14 See B Appleton and C van Wijk, Hygiene promotion – thematic overview paper, IRC International Water and Sanitation Centre, Delft, Netherlands, February 2003, viewed 22 October 2004 <www.irc.nl/page.php/16>.

Table 3: Major preventive measures for the spread of water and sanitation-related diseases

INFECTION	MAJOR PREVENTIVE MEASURES							
	SAFE WATER	SAFE EXCRETA DISPOSAL	PERSONAL HYGIENE	DOMESTIC HYGIENE	FOOD HYGIENE	WATER HYGIENE	DRAINAGE OF WATER	SAFE DISPOSAL OF WASTEWATER
Diarrhoea	✓	✓	✓	✓	✓	✓		✓
Guinea worm	✓	✓				✓		✓
Hookworm		✓						✓
Ringworm			✓	✓				✓
Round and whipworm		✓	✓	✓	✓			✓
Tapeworms		✓			✓			
Bancroftian filariasis		✓		✓			✓	
Dengue				✓			✓	
Malaria				✓			✓	
Scabies			✓	✓				
Schistosomiasis		✓	✓	✓				
Typhoid	✓	✓	✓	✓	✓	✓		✓
Trachoma and conjunctivitis		✓	✓	✓				
Yaws			✓	✓				
Yellow fever				✓			✓	

Source: Based on B Appleton and C van Wijk, *Hygiene promotion – thematic overview paper*, IRC International Water and Sanitation Centre, Delft, Netherlands, February 2003.

For a large water-related activity prepared by AusAID the outline of the WQMP can be in a separate section of the ADD or as an annex to the ADD. But it is most effective when integrated with the activity's overall key management tools, including the logframe, risk management framework, and monitoring plan (see the AusGuidelines on the logical framework approach and on risk for information on logframes and the risk management framework).

For a small NGO activity the WQMP can be part of a simple activity brief.

The main elements required for a WQMP can be found in Guideline 2, 'Developing a water quality management plan', in Part 2 of this guide.

APPRAISE THE WATER QUALITY ASSESSMENT AND INITIAL MANAGEMENT PLANNING

Significant water quality problems or risks need independent appraisal.

If the activity design team or NGO identified significant water quality problems or risks, there should be an independent review of the report produced and the management planning aspects of the ADD or activity brief.

For an activity prepared by AusAID, such an independent appraisal is usually undertaken by an AusAID technical adviser or a water quality expert. The appraisal is important, as the AusAID ADD or activity brief is normally AusAID's main opportunity to ensure that the planned water quality management and the activity design are adequate to meet AusAID's requirements.

The appraiser evaluates the potential for the activity to give rise to significant water quality problems, as well as to sustainable activity outcomes.

An important task of the appraiser is to evaluate the potential for the activity to give rise to significant water quality problems, and to recommend any improvements to the design to avoid this.

Another important task of the appraiser is to assess the sustainability of the intended activity outcomes and to make suggestions for improving the activity design to increase the likelihood of sustainable outcomes. These suggestions may include increasing the activity's focus on building the capacity of communities to manage their water supply, and on ensuring that institutions are able to deliver safe water in the long term. Developing and implementing plans for operating and maintaining water supply systems is a key to ongoing supplies of safe water. The appraiser should also assess the likelihood of the activity being replicated elsewhere.

Step 3

IMPLEMENT THE PROVISIONS FOR MANAGING WATER QUALITY

The key responsibilities for managing water quality during implementation need to be allocated to clearly identified partners in implementation.

The management arrangements of the activity should allocate clear responsibilities for fulfilling the requirements of the framework for managing water quality.

For a water-related activity funded through AusAID, AusAID should ensure that the management arrangements of the activity allocate clear responsibilities for fulfilling the requirements of the framework for managing water quality among the partners in activity implementation, such as AusAID, the delivery organisation, the counterpart agencies and other involved parties. This is needed to ensure that AusAID fulfils its policy and duty-of-care requirements.

It may also be necessary to introduce the partner government to the principles of the framework for managing water quality so that government staff understand the risk management approach to securing safe water. If so, the implementation arrangements for the activity should allocate this responsibility to a suitably qualified organisation or individual.

The delivery organisation fully develops the water quality management plan at the beginning of implementation in conjunction with local counterparts.

Because the delivery organisation (usually a managing contractor or an NGO for a small water supply activity) is responsible for implementing the Australian Government's contribution to an activity, it has responsibility for fully developing the WQMP. It does this at the beginning of the implementation process in conjunction with local counterparts, which builds their capacity to manage water quality and ensure its sustainability. Ideally these activity implementers would consult relevant stakeholders.

The full plan will address the water quality problems and risks already identified and assessed (step 2). It will also describe the actions required to manage (that is, avoid or mitigate) each identified issue and specify who is responsible for carrying out these actions.

WHO has developed the concept of the 'water safety plan' (WSP), which incorporates similar principles to those in WQMPs.[15] Box 4 describes briefly the history of the WHO guidelines and the development of WSPs.

15 WHO, 'Water safety plans', chapter 4 in Guidelines for drinking-water quality, 3rd edn, vol. 1, Recommendations, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_hea>.

BOX 4: WHO GUIDELINES AND WATER SAFETY PLANS

The World Health Organization published the first edition of the *Guidelines for drinking-water quality* in 1983–84. The guidelines were successors to the WHO International Standards, which focused on numerical values for allowable concentrations of potential contaminants. The guidelines are kept current by a process of rolling revision and the 3rd edition of the *Guidelines for drinking-water quality,* volume 1, *Recommendations,* was published in 2004. This latest edition is a major advancement from previous versions in that it moves away from prescriptive standards for water quality and focuses on managing water quality through a risk-based guideline approach.

The WHO guidelines (3rd edn) recommend the use of water safety plans as an effective means of ensuring the safety of drinking water by integrating a risk assessment and risk management approach that covers all stages in a drinking water supply from catchment to consumer in a sustainable way. A water safety plan has three key components: a supply system assessment, effective operational monitoring, and management. These components also form part of AusAID's framework for managing water quality and are referred to in this guide as a water quality management plan.

The objectives of water safety plans are to minimise contamination of source water, treat the water effectively, and prevent contamination during storage and distribution to consumers. These objectives are equally applicable to large piped systems, small community systems and household systems.

There is great commonality in the concept of a water safety plan and the AusAID framework for managing water quality. The principles in each are the same. However, while the *Safe water guide* sets out a water quality management system for organisations that deliver water supply activities funded through AusAID, a water safety plan is established for a specific water enterprise, community supply or government department to monitor, manage and sustain water quality for the future.

Chapter 4, 'Water safety plans', of the 3rd edition of the WHO *Guidelines for drinking-water quality* can be used as a reference to assist agency staff, managing contractors, NGOs and partner governments in developing a water quality management plan.

For activities managed under contract with AusAID, the managing contractor and the partner government or counterpart agency should sign off on the WQMP.

Guideline 2, 'Developing a water quality management plan', in Part 2 of this guide indicates the typical tasks involved in developing such a plan. These include gaining a commitment by the village or relevant water authority to manage water quality, defining the water supply system, identifying problems and risks, identifying suitable preventive measures, developing operational procedures, verifying water quality, and providing or organising training.

Information on how to sample and quantify water quality is provided in Guideline 3, 'Sampling and analysing water quality'.

The delivery organisation is responsible for ensuring that the provisions for managing water quality specified in its scope of services or terms of reference are met. It is also responsible for implementing the activity in a cooperative manner with counterparts. This cooperative approach is required to ensure that counterparts understand the principles of the framework for managing water quality. It is also important in developing the ability and desire of counterparts to continue to meet the requirements of the WQMP, so as to ensure the sustainability of safe water.

The delivery organisation and other partners should ensure that the activity's provisions for managing water quality are implemented.

The delivery organisation is also required to comply with all relevant standards, laws and regulations of the partner country, which should have been included as part of the provisions in its scope of services or terms of reference.

Step 4

MONITOR AND EVALUATE WATER QUALITY MANAGEMENT

The performance of an activity with respect to water quality management is assessed through monitoring and evaluation. Its performance is measured against the WQMP and the water quality provisions in the delivery organisation's scope of services or terms of reference. The monitoring and evaluation help AusAID to comply with its policy and duty-of-care requirements during the implementation of an activity.

A program for monitoring water quality should have been prepared when the activity was being designed.

A program for monitoring water quality should have been prepared when the activity was being designed, and a set of performance indicators should have been included in the WQMP to assist in evaluating water quality management.

MONITORING PERFORMANCE – RESPONSIBILITIES AND CAPACITY BUILDING

The delivery organisation is responsible for monitoring water quality management.

Monitoring water quality management against the performance indicators should be part of the activity monitoring plan, and the results of this monitoring should be included, as appropriate, in the agreed activity reporting. The delivery organisation is responsible for monitoring the performance of the activity in terms of its water quality management. The managing contractor or other delivery organisation should be able to assure AusAID that:

> the risks associated with water quality are being properly managed

> the WQMP has been implemented, and

> the activity's water quality outcomes are as specified in its scope of services or terms of reference.

If the delivery organisation or another implementation partner lacks the capacity to address an issue that arises about water quality or its management, it should seek assistance. Technical advisory groups and activity monitoring groups are used as part of AusAID's normal monitoring process and can be used to assess water-related issues. For a major water-related activity delivered under an AusAID contract, the terms of reference of such groups should include monitoring the WQMP and its success.

If a delivery organisation has not complied with the provisions for managing water quality included in its scope of services or terms of reference, the activity manager will need to arrange for AusAID to take corrective action. Advice should be sought from AusAID's Contract Services Group.

The responsibility for monitoring water quality should be progressively handed over to the partner government, counterpart agency and/or village as they gain capacity.

The responsibility for monitoring water quality and adhering to the requirements of the WQMP should be progressively handed over from the delivery organisation to the partner government, counterpart agency and/or village as they gain the required knowledge and capacity.

If ongoing technical monitoring is required and it is determined that the partner government or counterpart agency does not have the staff to carry out that monitoring, it may be necessary for the activity to include training and accreditation of water quality managers to carry out this function. In general, including such capacity building in the activity design promotes sustainability beyond the completion of the activity, and is desirable. However, capacity building may be feasible in only certain cases, such as urban water supplies.

EVALUATING MANAGEMENT – RESPONSIBILITIES AND LESSONS LEARNED

The effectiveness of the WQMP and the potential for water quality problems should be externally evaluated at least annually. This evaluation should include assessing the effectiveness of the systems that have been put in place and noting any response to unexpected non-compliance with water quality targets.

The 'lessons learned' guide improvements in the sustainability of activity outcomes.

In selected cases, the longer term effectiveness of an activity's water quality management should be identified in an activity evaluation undertaken by AusAID or the partner government after the activity has finished. Such evaluations contribute the 'lessons learned' that guide improvements in the level and sustainability of activity outcomes.

Step 5

REVIEW WATER QUALITY MANAGEMENT IN AusAID

AusAID will ensure that the guide for managing water quality remains relevant and appropriate.

AusAID will review and update the *Safe water guide* periodically to ensure that the framework for managing water quality, the associated guidelines and the supporting guidance remain relevant and appropriate in the developing country contexts (at the household, village and urban levels).

AusAID will draw on the experiences of and lessons learned by:

> AusAID staff (desk and post), technical advisers, key contractors and NGOs applying the guidelines, and

> partner governments that are using and/or attempting to institutionalise the framework for managing water quality.

The review approach will create a demand-driven process for maintaining the guide's relevance in a rapidly changing environment. Sources of information for this process will include:

> key activity monitoring reports

> AusAID's simplified monitoring toolkit and NGO monitoring briefs

> reports from activity monitoring groups and technical advisory groups

> reports from activity coordination meetings

> mid-term reviews

> activity completion reports

> program audits or cluster evaluations

> ex-post evaluations

> ex-post environmental reviews.

Further guidance will be developed and added to future editions of the guide as priority topics are identified on the basis on users' needs.

The review process will assist in strengthening and improving AusAID's approach to water quality management.

Part 2
Guidelines for managing water quality

Introduction

Part 2 of *Safe water guide for the Australian aid program 2005* provides the following guidelines:

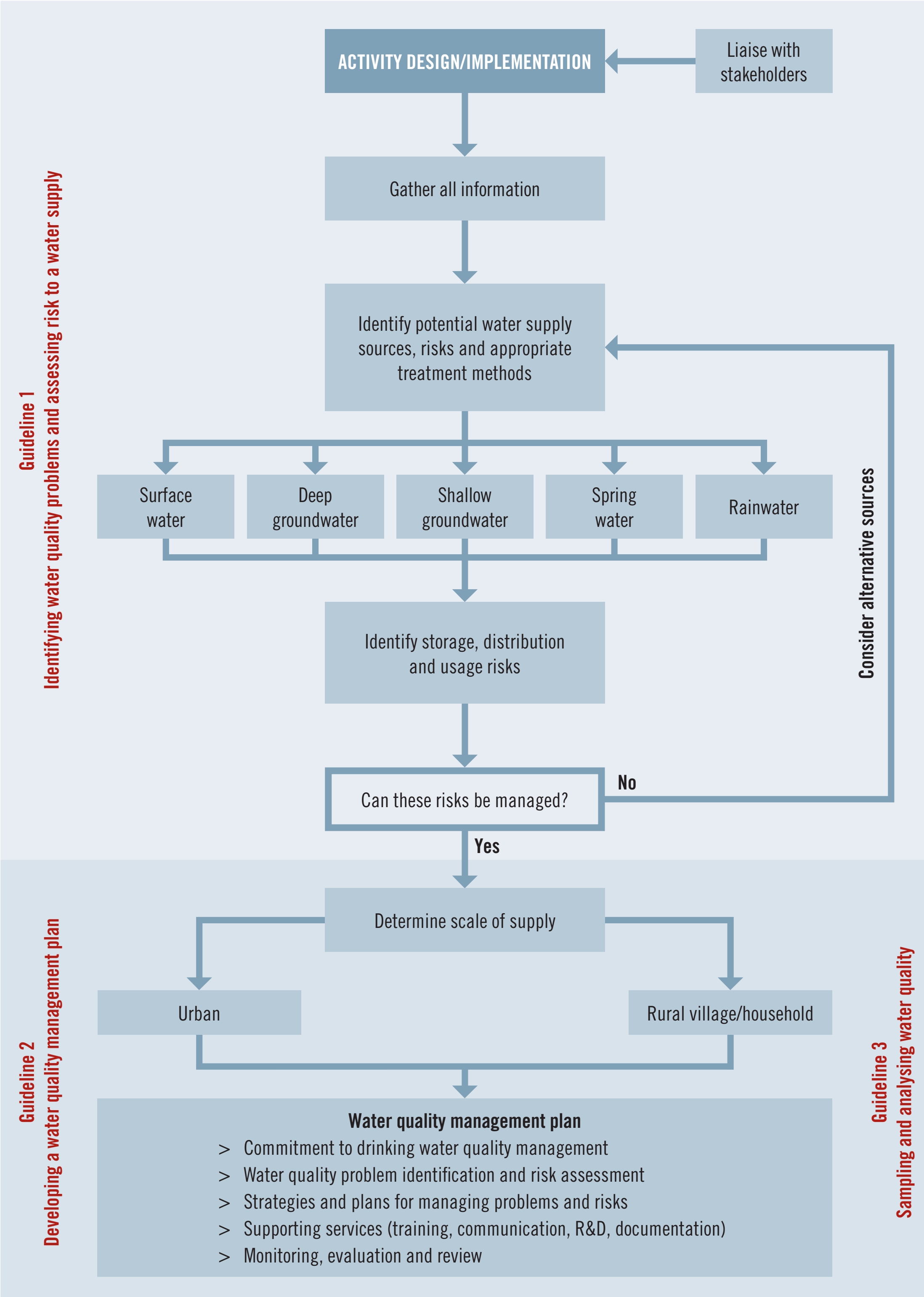
Guideline 1	Identifying water quality problems and assessing risk to a water supply
Guideline 2	Developing a water quality management plan
Guideline 3	Sampling and analysing water quality

These guidelines should be used in conjunction with Part 1, 'Framework for managing water quality', which describes the steps that may need to be taken in designing, implementing, monitoring and evaluating water-related activities funded through AusAID, and the roles and responsibilities of those involved.

The guidelines are intended to be used by AusAID staff, managing contractors, non-government organisations, development partners and other parties when designing, implementing and monitoring water-related activities. They are particularly relevant to those working in partner countries on the provision of safe drinking water supplies.

They are not intended to be comprehensive but to guide the user in identifying water quality problems and risks, in avoiding high-risk delivery systems in specific circumstances, and in managing water quality, particularly in small water supplies. Professional water quality expertise may be required to supplement these guidelines. If there is uncertainty about a particular situation it is best to seek professional advice.

Figure 1: Overview of guidelines on managing water quality



Guideline 1

IDENTIFYING WATER QUALITY PROBLEMS AND ASSESSING RISK TO A WATER SUPPLY

All water supplies have risks associated with them that need to be managed properly if the water is to be safe. In selecting a particular water source, there are inherent risks and a number of treatment technologies and risk reduction strategies that will be appropriate to that source. And in different parts of the water supply system there are risks that are important to understand.

This guideline is designed to assist the design team or NGO when in the partner country to identify and assess existing and foreseeable water quality problems for water supply initiatives.

It provides guidance on the tasks involved in, for example:

- gathering information on water sources
- inspecting the water supply system
- identifying potential water quality problems, and
- assessing how aware the community is of water quality issues.

The guideline considers the common types of water source – surface water, deep groundwater, shallow groundwater, spring water and rainwater. The characteristics of each of these sources are outlined, together with the potential water quality problems and the effectiveness of treatment methods commonly applied to address these problems.

The examples included in the tables should be used only as a guide.

Common to all water supplies are the requirements for storage, distribution and usage points. Water quality problems associated with these parts of the water supply system are addressed separately in the final section of this guideline, 'Storage, distribution and usage points'.

The examples included in the tables should be used only as a guide.

Surface water source

Surface water sources include rivers, lakes or ponds.

1. GATHER INFORMATION

- [ ] a) Undertake a desktop review of existing information on water quality in the area or region and of water activities that have been or are being undertaken and identify any regional issues for water quality that could occur in the water supply of interest.
- [ ] b) Speak to relevant stakeholders – all communities affected or likely to be affected, local government officials, local villagers, the water, environment and health agencies, local university/laboratory that may be a source of water quality or health data, and other aid agencies working on water supplies in the area, country and region.
- [ ] c) Gather available water quality data. This information may be anecdotal and collected from the relevant stakeholders listed above.
- [ ] d) Collect aerial photographs, maps, planning scheme, land use map and policy documentation.
- [ ] e) Identify known water quality problems in the region that could occur in the water supply of interest.
- [ ] f) Find out future development plans (urban, industrial and agricultural) for the area.
- [ ] g) Identify how the water is used in the area and obtain a breakdown of usage.
- [ ] h) Investigate known health problems in the community or region and whether they could be related to water quality.

2. INSPECT THE WATER SUPPLY AND IDENTIFY WATER QUALITY PROBLEMS

While undertaking the tasks listed below (a to e):

> photograph the entire water supply and the potential causes of water quality problems in the catchment, collection, treatment, storage and distribution to consumers (be aware of local cultural issues with photography)

> prepare a schematic (diagram) of the water supply (catchment to consumer), clearly indicating water quality problems, and

> use Table 1.1 as a guide to the causes of typical water quality problems and their potential impact on consumers, Table 1.2 as a guide to the types of activity or practice that can pose high risks to water quality, Table 1.3 as a guide to characteristics the water may exhibit, Table 1.4 as a guide to the implications for water quality of some parameters, and Table 1.5 as a guide to the effectiveness of various treatment options for particular water quality problems.

Undertake the following tasks to identify risks to surface water supply systems:

a) Inspect the water currently being used and ask local people about its taste, odour and appearance. ☐

b) Inspect the transfer system, which encompasses the storage and distribution systems and end-use points (tanks, pipelines, taps, water tankers) (see the final section of this guideline, 'Storage, distribution and usage points', for specific risks). ☐

c) Assess the appropriateness or deficiencies of any existing treatment and infrastructure, given the water quality problems identified. ☐

d) Inspect the source or offtake point and the catchment immediately upstream. ☐

e) Review the whole catchment, preferably by including a field inspection but at least by reviewing maps and talking to local people. Find out whether the water quality varies after storms or events such as a bushfire, landslide or industrial spill. Identify seasonal issues that affect water quality (eg pesticide use during the crop-growing season or variable discharge from industry). ☐

3. ASSESS COMMUNITY AWARENESS OF WATER QUALITY ISSUES

☐ a) Assess the level of awareness of water quality issues in the community. For example, determine whether local people know the source of their drinking water, what activities can affect water quality and what controls are in place to protect the water supply.

☐ b) Ask for historical 'stories' or anecdotes about water quality and appearance, illnesses in the community and activities in the catchment that may affect water quality.

4. PRODUCE MATERIAL FOR THE WATER QUALITY MANAGEMENT PLAN

☐ a) A summary of available water quality data and graphs of water quality parameters against time.

☐ b) A photographic journal of the water source and supply system (catchment to consumer), identified water quality problems and any general features that may give rise to problems, and general water use in the community.

☐ c) A flow diagram or map of the water source and supply system (catchment to consumers), identifying all infrastructure and indicating where water quality problems may arise.

☐ d) A risk assessment that covers key existing and potential water quality problems, existing controls and their effectiveness in managing risk for consumers.

5. RECOMMEND WAYS TO MANAGE OR IMPROVE WATER QUALITY

Based on the information gathered and the risk assessment, recommend an option or options for a safe water supply. For example:

☐ a) Protect the water source from contamination and remove the causes of water quality problems at their source if possible.

☐ b) Provide additional treatment as required.

☐ c) Minimise the potential for contamination in the collection, treatment, storage and distribution systems (see the final section of this guideline, 'Storage, distribution and usage points').

☐ d) Seek an alternative source if the risks are too high or management options are too expensive and/or not feasible.

☐ e) Ensure that users are aware of water quality problems and the requirements for good hygiene and safe water.

Table 1.1: Surface water: typical water quality problems, their causes and their potential impact on consumers

<table>
<tr><th>QUALITY PROBLEM</th><th>CAUSES OF WATER QUALITY PROBLEMS</th><th>IMPACT ON CONSUMERS</th></tr>
<tr><td>Pathogens</td><td>Faecal matter entering the water supply.

Recontamination of water from tap to mouth due to poor sanitation and hygiene practices.</td><td>Impact can vary from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera or typhoid fever.</td></tr>
<tr><td>Nutrients, algae and algal toxins</td><td>Nutrients, particularly nitrogen and phosphorus, from urban activities and fertilisers, which increase the likelihood of algae in water.

Some algae, which generally grow in still water in the presence of sunlight and make the water look green, produce toxins that are harmful to people and animals.</td><td rowspan="4">Exposure to algal toxins, and organic and inorganic chemicals can have a range of effects – generally classified into:
> organ-specific diseases
> neurological or behavioural disorders
> reproductive or developmental diseases and disorders
> carcinogenic or mutagenic diseases.

Impact may be acute (short term or sudden) or chronic (exposure over a long period) and the nature, severity and incidence will generally increase as dose or exposure increases. (Refer to the WHO Guidelines for drinking-water quality for further details.)</td></tr>
<tr><td>Metals</td><td>Leaching from mineral deposits, mine tailings, processing industry discharges and fertilisers.

Corroded pipelines (copper, lead).</td></tr>
<tr><td>Pesticides, herbicides and insecticides</td><td>Primarily from intensive agricultural industries such as horticulture, cropping, forestry, feed lots and intensive grazing and from weed spraying along water courses.</td></tr>
<tr><td>Industrial chemicals, fuels and organic compounds</td><td>Wastewater discharges and spills from industries, and leakage from fuel storage tanks.

Small-scale and informal industry with minimal controls over discharges.

Disinfection by-products resulting from the use of chlorine as a disinfectant (but these are secondary to achieving good disinfection).</td></tr>
<tr><td>Aesthetic parameters
> turbidity
> colour
> salt (TDS or EC)
> temperature/pH
> hardness/ alkalinity
> iron, manganese or aluminium</td><td>A wide range of sources, both natural and from human activities. For example, high levels of turbidity may result from soil erosion within the catchments, particularly after rain, colour may result from vegetation and naturally present iron and manganese, and salt may result from salinisation. However, even apparently clear water can contain iron, manganese or salt at concentrations of concern.</td><td>These hazards generally affect the taste, odour, appearance or ‘feel’ of the water. While high salt content or colour may make the water unpalatable, neither necessarily makes it unsafe to drink. Some aesthetic parameters can affect the ‘treatability’ of the water, reduce the effectiveness of disinfection or result in by-products formed during treatment. For example, turbidity may make disinfection less effective and, colour may give rise to higher concentrations of disinfection by-products such as trihalomethanes.</td></tr>
</table>

Table 1.2: Surface water: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS[a]	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Swimming and washing (people and clothing)	✓	✓				
Sewage discharge (even if treated)	✓	✓				
Houses/dwellings with domestic waste entering the waterways	✓	✓	✓			
Storms in the catchment that wash faecal matter and other contaminants into waterways	✓	✓				✓
Intensive agricultural industries (eg feed lots, abattoirs and dairies)	✓	✓		✓		
Recontamination prior to use (eg during storage and distribution)	✓					
Domesticated animals and animal husbandry	✓	✓				
Stagnant water		✓				✓
Chemical processing industry and fuel storage			✓		✓	
Stormwater from villages (particularly where wastewater capture, treatment and sanitation are poor)	✓					
Weed spraying along water courses				✓		✓

a Generally unlikely to have algal toxins unless the water visually contains algae (water is green or there is scum on the downwind shoreline) and has some taste and odour.

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.3: Surface water: characteristics that indicate the presence of potential water quality problems

Guidance in the absence of water quality data

CHARACTERISTIC	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Turbid, cloudy or dirty, particularly after storms	✓					✓
Colour and/or organic odour		✓	✓			✓
Salty taste						✓
Bitter taste			✓		✓	✓
Difficulty forming lather with soap						✓
Blue stains (corroded copper pipes)			✓			
Rotten egg smell – sulphide[a]						✓
Scaling on pots or kettles (indicator of hardness)						✓

a Possible indicator of contamination by organic matter causing reducing conditions (ie absence of oxygen).

Table 1.4: Surface water: some basic quality parameters to consider

PARAMETER[a]	IMPLICATION FOR WATER QUALITY
E. coli (*Escherichia coli*)	Indicates faecal contamination of the water supply and that pathogens are likely to be present.
Coliforms	Generally should not be present after treatment (disinfection). Their presence after treatment can indicate that disinfection was ineffective and that there is a risk of pathogens.
Turbidity	Can interfere with disinfection if above about 1 NTU (ie may be slightly cloudy in a glass).
Colour	Generally indicates organic material in the water, which can interfere with disinfection and produce harmful disinfection by-products. May also indicate the presence of iron or manganese.
Salt (TDS or EC)	Generally makes the water unpalatable or unpleasant to drink.
Hardness	Can affect treatability of the water and the ability of the water to lather.
pH	Should be in the neutral range (6.5–8.5). If above 8, effectiveness of chlorine disinfection decreases. At higher pH, scaling may occur if hardness is high. If below 6.5, water can be corrosive and attack metals.
Metals – iron or manganese	Can cause brown or black water, staining and colouration of laundry and baths/sinks and an iron or bitter taste.

a High levels of any of these parameters can be problematic or can be an indicator of other related problems.

Surface water **almost always** requires some treatment for pathogens regardless of how protected or pristine the catchment is or how clear the water looks. Usually boiling or disinfection is required as a minimum.

The treatment options in Table 1.5 are relevant to a range of water supplies – from an individual dwelling to a major urban area. Seek expert assistance as required to determine the appropriate level of treatment for each type of supply. Refer to the WHO Guidelines for drinking-water quality (3rd edn)[16] for further information.

A tick in Table 1.5 indicates that the treatment improves water quality and may be applied to correct the particular water quality problem. Further investigation (including testing) may still be required to determine whether the water is safe to drink. If the water is unsafe, additional treatment may be required.

Table 1.5: Surface water: a guide to the effectiveness of various water treatments and risk reduction measures

TREATMENT OR RISK REDUCTION MEASURE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Boil water	✓					✓[a]
Coagulate and filter water	✓	✓	✓	✓	✓	✓
Disinfect (chlorine or UV)[b]	✓	✓				
Seek an alternative water source	✓	✓	✓	✓	✓	✓
Avoid use of water if contamination is likely (eg after storm)	✓	✓				✓
Store water for >4 weeks in sunlight (UV irradiation)	✓					
Shift water source offtake upstream of contamination source	✓	✓	✓	✓	✓	✓
Use activated carbon filter		✓		✓	✓	✓

a Boiling and settling water over night can reduce turbidity.

b Most harmful pathogens in source water are inactivated through disinfection with an appropriate chlorine dose. However, there are some pathogens, particularly *Cryptosporidium* and *Giardia*, that are resistant to chlorine. Harmful *Cryptosporidium* and *Giardia* are generally found only in faeces from people and domesticated animals, particularly cattle and calves. Other forms of treatment are required to remove or inactivate *Cryptosporidium* and *Giardia*. These may include coagulation and filtration or UV irradiation. UV irradiation is not effective if water has high turbidity or iron.

16 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Deep groundwater source

Deep groundwater is accessed by bores that are typically more than 50 metres deep and may draw water from below a separate shallow aquifer. The recharge area for a deep groundwater bore can be located a significant distance from the bore site.

1. GATHER INFORMATION

a) Undertake a desktop review of existing information on water quality in the area or region and of water activities that have been or are being undertaken and identify any regional issues for water quality that could occur in the water supply of interest. ☐

b) Speak to relevant stakeholders – all communities affected or likely to be affected, local government officials, local villagers, the water, environment and health agencies, local university/laboratory that may be a source of water quality or health data, and other aid agencies working on water supplies in the area, country and region. ☐

c) Gather available water quality data. This information may be anecdotal and collected from the relevant stakeholders listed above. ☐

d) Collect geological map of the recharge area, topographical maps, aerial photographs, planning scheme, land use map and policy documentation. ☐

e) Identify known water quality problems in the region that could occur in the water supply of interest. ☐

f) Find out future development plans (urban, industrial and agricultural) for the area. ☐

g) Identify how the water is used in the area and obtain a breakdown of usage. ☐

h) Investigate known health problems in the community or region and whether they could be related to water quality. ☐

2. INSPECT THE WATER SUPPLY AND IDENTIFY WATER QUALITY PROBLEMS

While undertaking the tasks listed below (a to e):

- photograph the entire water supply and the potential sources of water quality problems in the recharge area, collection, treatment, storage and distribution to consumers (be aware of local cultural issues with photography)
- prepare a schematic (diagram) of the water supply (from recharge area to consumer), clearly indicating water quality problems, and
- use Table 1.6 as a guide to the causes of typical water quality problems and their potential impact on consumers, Table 1.7 as a guide to the types of activity or practice that can pose high risks to water quality, Table 1.8 as a guide to characteristics the water may exhibit, Table 1.9 as a guide to the implications for water quality of some parameters, and Table 1.10 as a guide to the effectiveness of various treatment options for particular water quality problems.

Undertake the following tasks to identify risks to groundwater supply systems:

☐ a) Inspect the water currently being used and ask local people about its taste, odour and appearance.

☐ b) Inspect the transfer system, which encompasses the storage and distribution systems and end-use points (tanks, pipelines, taps, water tankers) (see the final section of this guideline, 'Storage, distribution and usage points', for specific risks).

☐ c) Assess the appropriateness or deficiencies of any existing treatment and infrastructure, given the water quality problems identified.

☐ d) Inspect the groundwater bore and the immediate surrounding area.

☐ e) Review the recharge area, preferably by including a field inspection but at least by reviewing maps and talking to local people. Find out whether the water quality varies after events such as a landslide or industrial spill. Identify seasonal issues that affect water quality (eg pesticide use during the crop-growing season or variable discharge from industry).

3. ASSESS COMMUNITY AWARENESS OF WATER QUALITY ISSUES

a) Assess the level of awareness of water quality issues in the community. For example, determine whether local people know the source of their drinking water, the location or direction of the recharge area, what activities can affect water quality and what controls are in place to protect the water supply. ☐

b) Ask for historical 'stories' or anecdotes about water quality and appearance, illnesses in the community and activities in the recharge area that may affect water quality. ☐

4. PRODUCE MATERIAL FOR THE WATER QUALITY MANAGEMENT PLAN

a) A summary of available water quality data and graphs of water quality parameters against time. ☐

b) A photographic journal of the water source and supply system (recharge area to consumer), identified water quality problems and any general features that may give rise to problems, and general water use in the community. ☐

c) A flow diagram or map of the water source and supply system (recharge area to consumers), identifying all infrastructure and indicating where water quality problems may arise. ☐

d) A risk assessment that covers key existing and potential water quality problems, existing controls and their effectiveness in managing risk for consumers. ☐

5. RECOMMEND WAYS TO MANAGE OR IMPROVE WATER QUALITY

Based on the information gathered and the risk assessment, recommend an option or options for a safe water supply. For example:

a) Protect the water source from contamination and remove the causes of water quality problems at their source if possible. ☐

b) Provide additional treatment as required. ☐

c) Minimise the potential for contamination in the collection, treatment, storage and distribution systems (see the final section of this guideline, 'Storage, distribution and usage points'). ☐

d) Seek an alternative source if the risks are too high or management options are too expensive and/or not feasible. ☐

e) Ensure that users are aware of water quality problems and the requirements for good hygiene and safe water. ☐

Table 1.6: Deep groundwater: typical water quality problems, their causes and their potential impact on consumers

QUALITY PROBLEM	CAUSES OF WATER QUALITY PROBLEMS	IMPACT ON CONSUMERS
Pathogens[a]	Contaminated water containing faecal matter entering the aquifer or the groundwater bore. Recontamination of water from tap to mouth due to poor sanitation and hygiene practices.	Impact can vary from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera or typhoid fever.
Metals	Leaching of metals (eg arsenic, mercury) from natural rock formation. (Toxic chemicals, eg fluoride, may also be leached.) Seepage from industrial waste dumps and processing industries. Corroded pipelines (copper, lead) as a result of naturally corrosive groundwater.	Exposure to organic and inorganic chemicals can have a range of effects – generally classified into: > organ-specific diseases > neurological or behavioural disorders > reproductive or developmental diseases and disorders > carcinogenic or mutagenic diseases. Impact may be acute (short term or sudden) or chronic (exposure over a long period) and the nature, severity and incidence will generally increase as dose or exposure increases. (Refer to the WHO *Guidelines for drinking-water quality* for further details.)
Pesticides, herbicides and insecticides	Seepage into bore or recharge area of surface water affected primarily by intensive agricultural industries such as horticulture, cropping, forestry, feed lots and intensive grazing and by weed spraying.	
Industrial chemicals, fuels and organic compounds	Wastewater discharges and spills from industries, and leakage from underground fuel storage tanks seeping into the aquifer. Small-scale and informal industry with minimal controls over discharges. Disinfection by-products resulting from the use of chlorine as a disinfectant (but these are secondary to achieving good disinfection).	
Aesthetic parameters > turbidity > colour > salt (TDS or EC) > temperature/pH > hardness/ alkalinity > iron, manganese or aluminium	A wide range of sources, both natural and from human activities. Turbidity levels should be low (not visible in a glass) in a well-built and maintained bore. Colour may result from naturally present iron and manganese, and salt may result from salinisation. However, even apparently clear groundwater can contain iron, manganese or salt at concentrations of concern.	These hazards generally affect the taste, odour, appearance or 'feel' of the water. While high salt content or colour may make the water unpalatable, neither *necessarily* makes it unsafe to drink. Some aesthetic parameters can affect the 'treatability' of the water, reduce the effectiveness of disinfection or result in by-products formed during treatment. For example, colour may give rise to higher concentrations of disinfection by-products such as trihalomethanes.

a The primary pathogen risk is from surface water contamination entering a poorly constructed bore or contamination of the bore site. Generally properly constructed deep bores have limited potential for pathogen contamination from surface water or sewage ingress.

Table 1.7: Deep groundwater: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Poor groundwater bore construction or maintenance, allowing seepage of contaminated water from a shallow aquifer into the deep aquifer below	✓	✓	✓	✓	✓
Incorrect or inadequate construction of the groundwater bore, allowing surface water ingress down the outside of the well casing	✓	✓	✓	✓	✓
Leaching of metals (eg arsenic, mercury) from natural rock formation in the groundwater recharge area		✓			
Leaks from underground fuel storage tanks in the recharge area				✓	
Sewage discharge (even if treated) in the bore recharge area	✓				
Houses/dwellings with domestic waste seepage in the groundwater recharge area	✓	✓			
Intensive agricultural industries (eg feedlots, abattoirs and dairies) in the groundwater recharge area	✓		✓		
Recontamination prior to use (eg during storage and distribution)	✓				
Domesticated animals and animal husbandry around the bore site	✓				
Seepage from chemical processing industry waste dumps in the groundwater recharge area		✓		✓	
Stormwater from villages (particularly where wastewater capture, treatment and sanitation are poor) overflowing and entering the bore	✓				

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.8: Deep groundwater: characteristics that indicate the presence of potential water quality problems

Guidance in the absence of water quality data

CHARACTERISTIC	PATHOGENS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Turbid, cloudy or dirty	✓				✓
Colour and/or organic odour		✓			✓
Salty taste					✓
Bitter taste		✓		✓	✓
Difficulty forming lather with soap					✓
Blue stains (corroded copper pipes)		✓			
Rotten egg smell – sulphide[a]					✓
Scaling on pots or kettles (indicator of hardness)					✓

a Possible indicator of contamination by organic matter causing reducing conditions (ie absence of oxygen).

Table 1.9: Deep groundwater: some basic quality parameters to consider

PARAMETER[a]	IMPLICATION FOR WATER QUALITY
E. coli (*Escherichia coli*)	Indicates faecal contamination of the water supply and that pathogens are likely to be present.
Coliforms	Generally should not be present after treatment (disinfection). Their presence after treatment can indicate that the disinfection was ineffective and that there is a risk of pathogens.
Turbidity	Can interfere with disinfection if above about 1 NTU (ie may be slightly cloudy in a glass).
Colour	Generally indicates organic material in the water, which can interfere with disinfection and produce harmful disinfection by-products. May also indicate the presence of iron or manganese.
Salt (TDS or EC)	Generally makes the water unpalatable or unpleasant to drink.
Hardness	Can affect treatability of the water and the ability of the water to lather.
pH	Should be in the neutral range (6.5–8.5). If above 8, effectiveness of chlorine disinfection decreases. At higher pH, scaling may occur if hardness is high. If below 6.5, water can be corrosive and attack metals.
Metals – arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc	Can be harmful to humans and animals if consumed.
Metals – iron or manganese	Can cause brown or black water, staining and colouration of laundry and baths/sinks and an iron or bitter taste.

a High levels of any of these parameters can be problematic or can be an indicator of other related problems.

The treatment options in Table 1.10 are relevant to a range of water supplies – from an individual dwelling to a major urban area. Seek expert assistance as required to determine the appropriate level of treatment for each type of supply. Refer to the WHO *Guidelines for drinking-water quality* (3rd edn)[17] for further information.

A tick in Table 1.10 indicates that the treatment improves water quality and may be applied to correct the particular water quality problem. Further investigation (including testing) may still be required to determine whether the water is safe to drink. If the water is unsafe, additional treatment may be required.

Table 1.10: Deep groundwater: a guide to the effectiveness of various water treatments and risk reduction measures

TREATMENT OR RISK REDUCTION MEASURE	PATHOGENS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Boil water	✓				✓[a]
Coagulate and filter water	✓	✓	✓	✓	✓
Disinfect (chlorine or UV)[b]	✓				
Seek an alternative water source	✓	✓	✓	✓	✓
Store water for >4 weeks in sunlight (UV irradiation)	✓				
Flush groundwater bore before use					✓
Use activated carbon filter			✓	✓	✓

a Boiling and settling water over night can reduce turbidity.

b Most harmful pathogens in source water are inactivated through disinfection with an appropriate chlorine dose. However, there are some pathogens, particularly *Cryptosporidium* and *Giardia*, that are resistant to chlorine. Harmful *Cryptosporidium* and *Giardia* are generally found only in faeces from people and domesticated animals, particularly cattle and calves. Other forms of treatment are required to remove or inactivate *Cryptosporidium* and *Giardia*. These may include coagulation and filtration or UV irradiation. UV irradiation is not effective if water has high turbidity or iron.

17 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Shallow groundwater source

Shallow groundwater is accessed by bores that are typically less than 20–30 metres deep and draw water from the shallowest aquifer. The recharge area for a shallow groundwater bore is usually the area surrounding the bore site.

1. GATHER INFORMATION

- ☐ a) Undertake a desktop review of existing information on water quality in the area or region and of water activities that have been or are being undertaken and identify any regional issues for water quality that could occur in the water supply of interest.
- ☐ b) Speak to relevant stakeholders – all communities affected or likely to be affected, local government officials, local villagers, the water, environment and health agencies, local university/laboratory that may be a source of water quality or health data, and other aid agencies working on water supplies in the area, country and region.
- ☐ c) Gather available water quality data. This information may be anecdotal and collected from the relevant stakeholders listed above.
- ☐ d) Collect geological map of the recharge area, topographical maps, aerial photographs, planning scheme, land use map and policy documentation.
- ☐ e) Identify known water quality problems in the region that could occur in the water supply of interest.
- ☐ f) Find out future development plans (urban, industrial and agricultural) for the area.
- ☐ g) Identify how the water is used in the area and obtain a breakdown of usage.
- ☐ h) Investigate known health problems in the community or region and whether they could be related to water quality.

2. INSPECT THE WATER SUPPLY AND IDENTIFY WATER QUALITY PROBLEMS

While undertaking the tasks listed below (a to e):

> photograph the entire water supply and the potential sources of water quality problems in the recharge area, collection, treatment, storage and distribution to consumers (be aware of local cultural issues with photography)

> prepare a schematic (diagram) of the water supply (from recharge area to consumer), clearly indicating water quality problems, and

> use Table 1.11 as a guide to the causes of typical water quality problems and their potential impact on consumers, Table 1.12 as a guide to the types of activity or practice that can pose high risks to water quality, Table 1.13 as a guide to characteristics the water may exhibit, Table 1.14 as a guide to the implications for water quality of some parameters, and Table 1.15 as a guide to the effectiveness of various treatment options for particular water quality problems.

Undertake the following tasks to identify risks to groundwater supply systems:

a) Inspect the water currently being used and ask local people about its taste, odour and appearance. ☐

b) Inspect the transfer system, which encompasses the storage and distribution systems and end-use points (tanks, pipelines, taps, water tankers) (see the final section of this guideline, 'Storage, distribution and usage points', for specific risks). ☐

c) Assess the appropriateness or deficiencies of any existing treatment and infrastructure, given the water quality problems identified. ☐

d) Inspect the groundwater bore and the immediate surrounding area. ☐

e) Review the recharge area, preferably by including a field inspection but at least by reviewing maps and talking to local people. Find out whether the water quality varies after events such as a landslide or industrial spill. Identify seasonal issues that affect water quality (eg pesticide use during the crop-growing season or variable discharge from industry). ☐

3. ASSESS COMMUNITY AWARENESS OF WATER QUALITY ISSUES

- [ ] a) Assess the level of awareness of water quality issues in the community. For example, determine whether local people know the source of their drinking water, the location and extent of the recharge area, what activities can affect water quality and what controls are in place to protect the water supply.
- [ ] b) Ask for historical 'stories' or anecdotes about water quality and appearance, illnesses in the community and activities in the recharge area that may affect water quality.

4. PRODUCE MATERIAL FOR THE WATER QUALITY MANAGEMENT PLAN

- [ ] a) A summary of available water quality data and graphs of water quality parameters against time.
- [ ] b) A photographic journal of the water source and supply system (recharge area to consumer), identified water quality problems and any general features that may give rise to problems, and general water use in the community.
- [ ] c) A flow diagram or map of the water source and supply system (recharge area to consumers), identifying all infrastructure and indicating where water quality problems may arise.
- [ ] d) A risk assessment that covers key existing and potential water quality problems, existing controls and their effectiveness in managing risk for consumers.

5. RECOMMEND WAYS TO MANAGE OR IMPROVE WATER QUALITY

Based on the information gathered and the risk assessment, recommend an option or options for a safe water supply. For example:

- [ ] a) Protect the water source from contamination and remove the causes of water quality problems at their source if possible.
- [ ] b) Provide additional treatment as required.
- [ ] c) Minimise the potential for contamination in the collection, treatment, storage and distribution systems (see the final section of this guideline, 'Storage, distribution and usage points').
- [ ] d) Seek an alternative source if the risks are too high or management options are too expensive and/or not feasible.
- [ ] e) Ensure that users are aware of water quality problems and the requirements for good hygiene and safe water.

Table 1.11: Shallow groundwater: typical water quality problems, their causes and their potential impact on consumers

<table>
<tr><th>QUALITY PROBLEM</th><th>CAUSES OF WATER QUALITY PROBLEMS</th><th>IMPACT ON CONSUMERS</th></tr>
<tr><td>Pathogens[a]</td><td>Contaminated water containing faecal matter entering the aquifer or the groundwater bore.

Recontamination of water from tap to mouth due to poor sanitation and hygiene practices.</td><td>Impact can vary from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera or typhoid fever.</td></tr>
<tr><td>Nutrients, algae and algal toxins</td><td>Nutrients, particularly nitrogen and phosphorus, from urban activities and fertilisers, which increase the likelihood of algae in water.

Some algae, which generally grow in still water in the presence of sunlight and make the water look green, produce toxins that are harmful to people and animals.</td><td rowspan="4">Exposure to algal toxins, and organic and inorganic chemicals can have a range of effects – generally classified into:
> organ-specific diseases
> neurological or behavioural disorders
> reproductive or developmental diseases and disorders
> carcinogenic or mutagenic diseases.

Impact may be acute (short term or sudden) or chronic (exposure over a long period) and the nature, severity and incidence will generally increase as dose or exposure increases. (Refer to the WHO Guidelines for drinking-water quality for further details.)</td></tr>
<tr><td>Metals</td><td>Leaching of metals (eg arsenic, mercury) from natural rock formation. (Toxic chemicals, eg fluoride, may also be leached.)

Seepage from industrial waste dumps and processing industries.

Corroded pipelines (copper, lead) as a result of naturally corrosive groundwater.</td></tr>
<tr><td>Pesticides, herbicides and insecticides</td><td>Seepage into bore or recharge area of surface water affected primarily by intensive agricultural industries such as horticulture, cropping, forestry, feed lots and intensive grazing and by weed spraying.</td></tr>
<tr><td>Industrial chemicals, fuels and organic compounds</td><td>Wastewater discharges and spills from industries, and leakage from underground fuel storage tanks seeping into the aquifer.

Small-scale and informal industry with minimal controls over discharges.

Disinfection by-products resulting from the use of chlorine as a disinfectant (but these are secondary to achieving good disinfection).</td></tr>
<tr><td>Aesthetic parameters
> turbidity
> colour
> salt (TDS or EC)
> temperature/pH
> hardness/ alkalinity
> iron, manganese or aluminium</td><td>A wide range of sources, both natural and from human activities. Turbidity levels should be low (not visible in a glass) in a well-built and maintained bore. Colour may result from naturally present iron and manganese, and salt may result from salinisation. However, even apparently clear groundwater can contain iron, manganese or salt at concentrations of concern.</td><td>These hazards generally affect the taste, odour, appearance or ‘feel’ of the water. While high salt content or colour may make the water unpalatable, neither necessarily makes it unsafe to drink. Some aesthetic parameters can affect the ‘treatability’ of the water, reduce the effectiveness of disinfection or result in by-products formed during treatment. For example, colour may give rise to higher concentrations of disinfection by-products such as trihalomethanes.</td></tr>
</table>

a The primary pathogen risk is from surface water contamination entering a poorly constructed bore or contamination of the bore site. Generally properly constructed bores have limited potential for pathogen contamination from surface water or sewage ingress.

Table 1.12: Shallow groundwater: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS[a]	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Incorrect or inadequate construction of the groundwater bore, allowing surface water ingress either at the bore site or through porous soil/rock in the recharge area	✓	✓	✓	✓	✓	✓
Leaching of metals (eg arsenic, mercury) from natural rock formation in the recharge area			✓			
Leaks from underground fuel storage tanks in the recharge area					✓	
Sewage discharge (even if treated) in the bore recharge area	✓	✓				
Houses/dwellings with domestic waste seepage in the groundwater recharge area	✓	✓	✓			
Intensive agricultural industries (eg feedlots, abattoirs and dairies) in the groundwater recharge area	✓			✓		
Recontamination prior to use (eg during storage and distribution)	✓					
Domesticated animals and animal husbandry around the bore site	✓	✓				
Seepage from chemical processing industry waste dumps in the groundwater recharge area			✓		✓	
Stormwater from villages (particularly where wastewater capture, treatment and sanitation are poor) entering the bore	✓	✓				

a Generally unlikely to have algal toxins unless the water visually contains algae (water is green) and has some taste and odour.

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.13: Shallow groundwater: characteristics that indicate the presence of potential water quality problems

Guidance in the absence of water quality data

CHARACTERISTIC	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Turbid, cloudy or dirty, particularly after storms	✓					✓
Colour and/or organic odour		✓	✓			✓
Salty taste						✓
Bitter taste			✓		✓	✓
Difficulty forming lather with soap						✓
Blue stains (corroded copper pipes)			✓			
Rotten egg smell – sulphide[a]						✓
Scaling on pots or kettles (indicator of hardness)						✓

a Possible indicator of contamination by organic matter causing reducing conditions (ie absence of oxygen).

Table 1.14: Shallow groundwater: some basic quality parameters to consider

PARAMETER[a]	IMPLICATION FOR WATER QUALITY
E. coli (Escherichia coli)	Indicates faecal contamination of the water supply and that pathogens are likely to be present.
Coliforms	Generally should not be present after treatment (disinfection). Their presence after treatment can indicate that the disinfection was ineffective and that there is a risk of pathogens.
Turbidity	Can interfere with disinfection if above about 1 NTU (ie may be slightly cloudy in a glass).
Colour	Generally indicates organic material in the water, which can interfere with disinfection and produce harmful disinfection by-products. May also indicate the presence of iron or manganese.
Salt (TDS or EC)	Generally makes the water unpalatable or unpleasant to drink.
Hardness	Can affect treatability of the water and the ability of the water to lather.
pH	Should be in the neutral range (6.5–8.5). If above 8, effectiveness of chlorine disinfection decreases. At higher pH, scaling may occur if hardness is high. If below 6.5, water can be corrosive and attack metals.
Metals – arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc	Can be harmful to humans and animals if consumed.
Metals – iron or manganese	Can cause brown or black water, staining and colouration of laundry and baths/sinks and an iron or bitter taste.

a High levels of any of these parameters can be problematic or can be an indicator of other related problems.

The treatment options in Table 1.15 are relevant to a range of water supplies – from an individual dwelling to a major urban area. Seek expert assistance as required to determine the appropriate level of treatment for each type of supply. Refer to the WHO *Guidelines for drinking-water quality* (3rd edn)[18] for further information.

A tick in Table 1.15 indicates that the treatment **improves** water quality and may be applied to correct the particular water quality problem. Further investigation (including testing) may still be required to determine whether the water is safe to drink. If the water is unsafe, additional treatment may be required.

Table 1.15: Shallow groundwater: a guide to the effectiveness of various water treatments and risk reduction measures

TREATMENT OR RISK REDUCTION MEASURE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Boil water	✓					✓[a]
Coagulate and filter water	✓	✓	✓	✓	✓	✓
Disinfect (chlorine or UV)[b]	✓	✓				
Seek an alternative water source	✓	✓	✓	✓	✓	✓
Avoid use of water if contamination is likely (eg after storms)	✓	✓				✓
Store water for >4 weeks in sunlight (UV irradiation)	✓					
Flush groundwater bore before use						✓
Use activated carbon filter		✓		✓	✓	✓

a Boiling and settling water over night can reduce turbidity.

b Most harmful pathogens in source water are inactivated through disinfection with an appropriate chlorine dose. However, there are some pathogens, particularly *Cryptosporidium* and *Giardia*, that are resistant to chlorine. Harmful *Cryptosporidium* and *Giardia* are generally found only in faeces from people and domesticated animals, particularly cattle and calves. Other forms of treatment are required to remove or inactivate *Cryptosporidium* and *Giardia*. These may include coagulation and filtration or UV irradiation. UV irradiation is not effective if water has high turbidity or iron.

18 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Spring water source

Springs occur when the groundwater table reaches the surface. Spring water is collected by channelling or piping water into a collection area for direct use or storage. Spring water typically has similar quality issues to those of shallow groundwater and surface water. The recharge area is usually the area up gradient of the point where water reaches the surface.

1. GATHER INFORMATION

a) Undertake a desktop review of existing information on water quality in the area or region and of water activities that have been or are being undertaken and identify any regional issues for water quality that could occur in the water supply of interest. ☐

b) Speak to relevant stakeholders – all communities affected or likely to be affected, local government officials, local villagers, the water, environment and health agencies, local university/laboratory that may be a source of water quality or health data, and other aid agencies working on water supplies in the area, country and region. ☐

c) Gather available water quality data. This information may be anecdotal and collected from the relevant stakeholders listed above. ☐

d) Collect geological map of the recharge area, topographical maps, aerial photographs, planning scheme, land use map and policy documentation. ☐

e) Identify known water quality problems in the region that could occur in the water supply of interest. ☐

f) Find out future development plans (urban, industrial and agricultural) for the area. ☐

g) Identify how the water is used in the area and obtain a breakdown of usage. ☐

h) Investigate known health problems in the community or region and whether they could be related to water quality. ☐

2. INSPECT THE WATER SUPPLY AND IDENTIFY WATER QUALITY PROBLEMS

While undertaking the tasks listed below (a to e):

> photograph the entire water supply and the potential sources of the water quality problems in the recharge area, collection, treatment, storage and distribution to consumers (be aware of local cultural issues with photography)

> prepare a schematic (diagram) of the water supply (from recharge area to consumer), clearly indicating water quality problems, and

> use Table 1.16 as a guide to the causes of typical water quality problems and their potential impact on consumers, Table 1.17 as a guide to the types of activity or practice that can pose high risks to water quality, Table 1.18 as a guide to characteristics the water may exhibit, Table 1.19 as a guide to the implications for water quality of some parameters, and Table 1.20 as a guide to the effectiveness of various treatment options for particular water quality problems.

Undertake the following tasks to identify risks to groundwater supply systems:

☐ a) Inspect the water currently being used and ask local people about its taste, odour and appearance.

☐ b) Inspect the transfer system, which encompasses the storage and distribution systems and end-use points (tanks, pipelines, taps, water tankers) (see the final section of this guideline, 'Storage, distribution and usage points', for specific risks).

☐ c) Assess the appropriateness or deficiencies of any existing treatment and infrastructure, given the water quality problems identified.

☐ d) Inspect the spring and immediate surrounding area, look for possible surface water inflow and contamination where the water discharges at the surface and is collected.

☐ e) Review the recharge area, preferably by including a field inspection but at least by reviewing maps and talking to local people. Find out whether the water quality varies after storms or events such as landslide or industrial spill. Identify seasonal issues that affect water quality (eg pesticide use during the crop-growing season or variable discharge from industry).

3. ASSESS COMMUNITY AWARENESS OF WATER QUALITY ISSUES

a) Assess the level of awareness of water quality issues in the community. For example, determine whether local people know the source of their drinking water, the location and extent of the recharge area, what activities can affect water quality and what controls are in place to protect the water supply. ☐

b) Ask for historical 'stories' or anecdotes about water quality and appearance, illnesses in the community and activities in the recharge area that may affect water quality. ☐

4. PRODUCE MATERIAL FOR THE WATER QUALITY MANAGEMENT PLAN

a) A summary of available water quality data and graphs of water quality parameters against time. ☐

b) A photographic journal of the water source and supply system (recharge area to consumer), identified water quality problems and any general features that may give rise to problems, and general water use in the community. ☐

c) A flow diagram or map of the water source and supply system (recharge area to consumers), identifying all infrastructure and indicating where water quality problems may arise. ☐

d) A risk assessment that covers key existing and potential water quality problems, existing controls and their effectiveness in managing risk for consumers. ☐

5. RECOMMEND WAYS TO MANAGE OR IMPROVE WATER QUALITY

Based on the information gathered and the risk assessment, recommend an option or options for a safe water supply. For example:

a) Protect the water source from contamination and remove the causes of water quality problems at their source if possible. ☐

b) Provide additional treatment as required. ☐

c) Minimise the potential for contamination in the collection, treatment, storage and distribution systems (see the final section of this guideline, 'Storage, distribution and usage points'). ☐

d) Seek an alternative source if the risks are too high or management options are too expensive and/or not feasible. ☐

e) Ensure that users are aware of water quality problems and the requirements for good hygiene and safe water. ☐

Table 1.16: Spring water: typical water quality problems, their causes and their potential impact on consumers

QUALITY PROBLEM	CAUSES OF WATER QUALITY PROBLEMS	IMPACT ON CONSUMERS
Pathogens[a]	Contaminated water containing faecal matter entering the aquifer or the spring discharge point. Recontamination of water from tap to mouth due to poor sanitation and hygiene practices.	Impact can vary from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera or typhoid fever.
Nutrients, algae and algal toxins	Nutrients, particularly nitrogen and phosphorus, from urban activities and fertilisers, which increase the likelihood of algae in water. Some algae, which generally grow in still water in the presence of sunlight and make the water look green, produce toxins that are harmful to people and animals.	Exposure to algal toxins, and organic and inorganic chemicals can have a range of effects – generally classified into: > organ-specific diseases > neurological or behavioural disorders > reproductive or developmental diseases and disorders > carcinogenic or mutagenic diseases. Impact may be acute (short term or sudden) or chronic (exposure over a long period) and the nature, severity and incidence will generally increase as dose or exposure increases. (Refer to the WHO *Guidelines for drinking-water quality* for further details.)
Metals	Leaching of metals (eg arsenic, mercury) from natural rock formation. (Toxic chemicals, eg fluoride, may also be leached.) Seepage from industrial waste dumps and processing industries. Corroded pipelines (copper, lead) as a result of naturally corrosive groundwater.	
Pesticides, herbicides and insecticides	Seepage into the spring or recharge area of surface water affected primarily by intensive agricultural industries such as horticulture, cropping, forestry, feed lots and intensive grazing and by weed spraying.	
Industrial chemicals, fuels and organic compounds	Wastewater discharges and spills from industries, and leakage from fuel storage tanks seeping into the spring or recharge area. Small-scale and informal industry with minimal controls over discharges. Disinfection by-products resulting from the use of chlorine as a disinfectant (but these are secondary to achieving good disinfection).	
Aesthetic parameters > turbidity > colour > salt (TDS or EC) > temperature/pH > hardness/ alkalinity > iron, manganese or aluminium	A wide range of sources, both natural and from human activities. Turbidity levels of spring water should be low (not visible in a glass). Colour may result from naturally present iron and manganese, and salt may result from salinisation. However, even apparently clear groundwater can contain iron, manganese or salt at concentrations of concern.	These hazards generally affect the taste, odour, appearance or 'feel' of the water. While high salt content or colour may make the water unpalatable, neither *necessarily* makes it unsafe to drink. Some aesthetic parameters can affect the 'treatability' of the water, reduce the effectiveness of disinfection or result in by-products formed during treatment. For example, colour may give rise to higher concentrations of disinfection by-products such as trihalomethanes.

a The primary pathogen risk is from contamination occurring at the point at which the spring water discharges at the surface and is collected.

Table 1.17: Spring water: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Surface water ingress either at the spring site or through porous soil/rock in the recharge area	✓	✓	✓	✓	✓	✓
Leaching of metals (eg arsenic, mercury) from natural rock formation in the spring area			✓			
Leaks from underground fuel storage tanks in the recharge area					✓	
Sewage discharge (even if treated) in the recharge area	✓	✓				
Houses/dwellings with domestic waste seepage in the recharge area	✓	✓	✓			
Intensive agricultural industries (eg feedlots, abattoirs and dairies) in the recharge area	✓	✓		✓		
Recontamination prior to use (eg during storage and distribution)	✓					
Domesticated animals and animal husbandry around the recharge area	✓	✓				
Seepage from chemical processing industry waste dumps in the recharge area			✓		✓	
Stormwater from villages (particularly where wastewater capture, treatment and sanitation are poor) entering the spring or recharge area	✓	✓				

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.18: Spring water: characteristics that indicate the presence of potential water quality problems

Guidance in the absence of water quality data

CHARACTERISTIC	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Turbid, cloudy or dirty, particularly after storms	✓					✓
Colour and/or organic odour		✓	✓			✓
Salty taste						✓
Bitter taste			✓		✓	✓
Difficulty forming lather with soap						✓
Blue stains (corroded copper pipes)			✓			
Rotten egg smell – sulphide[a]						✓
Scaling on pots or kettles (indicator of hardness)						✓

a Possible indicator of contamination by organic matter causing reducing conditions (ie absence of oxygen).

Table 1.19: Spring water: some basic quality parameters to consider

PARAMETER[a]	IMPLICATION FOR WATER QUALITY
E. coli (*Escherichia coli*)	Indicates faecal contamination of the water supply and that pathogens are likely to be present.
Coliforms	Generally should not be present after treatment (disinfection). Their presence after treatment can indicate that the disinfection was ineffective and that there is a risk of pathogens.
Turbidity	Can interfere with disinfection if above about 1 NTU (ie may be slightly cloudy in a glass).
Colour	Generally indicates organic material in the water, which can interfere with disinfection and produce harmful disinfection by-products. May also indicate the presence of iron or manganese.
Salt (TDS or EC)	Generally makes the water unpalatable or unpleasant to drink.
Hardness	Can affect treatability of the water and the ability of the water to lather.
pH	Should be in the neutral range (6.5–8.5). If above 8, effectiveness of chlorine disinfection decreases. At higher pH, scaling may occur if hardness is high. If below 6.5, water can be corrosive and attack metals.
Metals – arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc	Can be harmful to humans and animals if consumed.
Metals – iron or manganese	Can cause brown or black water, staining and colouration of laundry and baths/sinks and an iron or bitter taste.

a High levels of any of these parameters can be problematic or can be an indicator of other related problems.

The treatment options in Table 1.20 are relevant to a range of water supplies – from an individual dwelling to a major urban area. Seek expert assistance as required to determine the appropriate level of treatment for each type of supply. Refer to the WHO *Guidelines for drinking-water quality* (3rd edn)[19] for further information.

A tick in Table 1.20 indicates that the treatment **improves** water quality and may be applied to correct the particular water quality problem. Further investigation (including testing) may still be required to determine whether the water is safe to drink. If the water is unsafe, additional treatment may be required.

Table 1.20: Spring water: a guide to the effectiveness of various water treatments and risk reduction measures

TREATMENT OR RISK REDUCTION MEASURE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Boil water	✓					✓[a]
Coagulate and filter water	✓	✓	✓	✓	✓	✓
Disinfect (chlorine or UV)[b]	✓	✓				
Seek an alternative water source	✓	✓	✓	✓	✓	✓
Avoid use of water if contamination is likely (eg after storms)	✓	✓				✓
Store water for >4 weeks in sunlight (UV irradiation)	✓					
Use activated carbon filter		✓		✓	✓	✓

a Boiling and settling water over night can reduce turbidity.

b Most harmful pathogens in source water are inactivated through disinfection with an appropriate chlorine dose. However, there are some pathogens, particularly *Cryptosporidium* and *Giardia*, that are resistant to chlorine. Harmful *Cryptosporidium* and *Giardia* are generally found only in faeces from people and domesticated animals, particularly cattle and calves. Other forms of treatment are required to remove or inactivate *Cryptosporidium* and *Giardia*. These may include coagulation and filtration or UV irradiation. UV irradiation is not effective if water has high turbidity or iron.

19 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Rainwater source

Rainwater is generally collected from a roof (catchment surface) via a gutter and pipe that leads to a collection tank.

1. GATHER INFORMATION

- [ ] a) Undertake a desktop review of existing information on rainwater quality and the use of rainwater in the area or region.
- [ ] b) Speak to relevant stakeholders – all communities affected or likely to be affected, local government officials, local villagers, the water, environment and health agencies, local university/laboratory that may be a source of water quality or health data, and other aid agencies working on water supplies in the area, country and region.
- [ ] c) Gather available rainwater quality data. This information may be anecdotal and collected from the relevant stakeholders listed above.
- [ ] d) Identify known rainwater quality problems in the region that could occur in the water supply of interest, including the presence of industry or mining that could give rise to dust that would settle on roofs and contaminate the water.
- [ ] e) Find out future development plans (urban, industrial and agricultural) for the area.
- [ ] f) Identify how the water is used in the area and obtain a breakdown of usage.
- [ ] g) Investigate known health problems in the community or region and whether they could be related to rainwater quality.

2. INSPECT THE WATER SUPPLY AND IDENTIFY WATER QUALITY PROBLEMS

While undertaking the tasks listed below (a to d):

- photograph the roof system and setting (eg overhanging trees) and potential sources of the water quality problems related to industry and emissions to air in the neighbourhood, the roof surface, collection, treatment, storage and distribution to consumers (be aware of local cultural issues with photography)
- prepare a schematic (diagram) of the water supply (from roof surface to consumer), clearly indicating water quality problems, and
- use Table 1.21 as a guide to the causes of typical water quality problems and their potential impact on consumers, Table 1.22 as a guide to the types of activity or practice that can pose high risks to water quality, Table 1.23 as a guide to characteristics the water may exhibit, Table 1.24 as a guide to the implications for water quality of some parameters, and Table 1.25 as a guide to the effectiveness of various treatment options for particular water quality problems.

Undertake the following tasks to identify risks to rainwater supply systems:

a) Inspect the water currently being used and ask local people about its taste, odour and appearance. ☐

b) Inspect the rainwater roof surface and any screen on the inlet to the system. Determine whether trees are overhanging and the types of tree (eg whether a poisonous variety), whether the roof gutters are clean and whether there are animals or birds (alive or dead) on the roof or in the gutters. Find out whether the water quality varies after storms or other events. Identify possible sources of contamination from dust or fallout from industry or mining, or seasonal issues that affect water quality (eg pesticide use during the crop-growing season). ☐

c) Inspect the collection, storage, treatment and distribution systems and end-use points (tanks, pipelines, taps, water tankers) (see the final section of this guideline, 'Storage, distribution and usage points', for specific risks). ☐

d) Assess the appropriateness or deficiencies of any existing treatment and infrastructure, given the water quality problems identified. ☐

3. ASSESS COMMUNITY AWARENESS OF WATER QUALITY ISSUES

☐ a) Assess the level of awareness of water quality issues in the community. For example, determine whether local people know where and how their drinking water is collected, what activities can affect water quality and what controls are in place to protect the water supply.

☐ b) Ask for historical 'stories' or anecdotes about water quality and appearance, illnesses in the community and activities that may affect water quality.

4. PRODUCE MATERIAL FOR THE WATER QUALITY MANAGEMENT PLAN

☐ a) A summary of available water quality data and graphs of water quality parameters against time.

☐ b) A photographic journal of the rainwater roof surface and trees, the overall supply system (roof surface to consumer), identified water quality problems and any general features that may give rise to problems, and general water use in the community.

☐ c) A flow diagram or map of the water source and supply system (roof surface to consumers), identifying all infrastructure and indicating where water quality problems may arise.

☐ d) A risk assessment that covers key existing and potential water quality problems, existing controls and their effectiveness in managing risk for consumers.

5. RECOMMEND WAYS TO MANAGE OR IMPROVE WATER QUALITY

Based on the information gathered and the risk assessment, recommend an option or options for a safe water supply. For example:

☐ a) Protect the roof surface from contamination and remove the causes of water quality problems at their source if possible. Ensure that there is regular cleaning of the roof and trimming or removal of trees overhead.

☐ b) Provide additional treatment as required.

☐ c) Minimise the potential for contamination in the collection, treatment, storage and distribution systems (see the final section of this guideline, 'Storage, distribution and usage points').

☐ d) Seek an alternative source if the risks are too high or management options are too expensive and/or not feasible.

☐ e) Ensure that users are aware of water quality problems and the requirements for good hygiene and safe water.

Table 1.21: Rainwater: typical water quality problems, their causes and their potential impact on consumers

QUALITY PROBLEM	CAUSES OF WATER QUALITY PROBLEMS	IMPACT ON CONSUMERS
Pathogens	Faecal matter on the roof or in the gutters. Recontamination of water from tap to mouth due to poor sanitation and hygiene practices.	Impact can vary from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera or typhoid fever.
Nutrients, algae and algal toxins	Open storages such as reservoirs or tanks that allow algae to grow. Some algae produce toxins that are harmful to people and animals. (Algae are unlikely to be a problem if tanks are closed.)	Exposure to algal toxins, and organic and inorganic chemicals can have a range of effects – generally classified into: > organ-specific diseases > neurological or behavioural disorders > reproductive or developmental diseases and disorders > carcinogenic or mutagenic diseases. Impact may be acute (short term or sudden) or chronic (exposure over a long period) and the nature, severity and incidence will generally increase as dose or exposure increases. (Refer to the WHO *Guidelines for drinking-water quality* for further details.)
Metals	Atmospheric dust containing, for example, heavy metals and organic compounds. Corroded pipelines (copper, lead). (Rainwater can be very soft [alkalinity <20 mg/L as $CaCO_3$] and highly corrosive.)	
Pesticides, herbicides and insecticides	Aerosol residue on the catchment surface as a result of spraying chemicals.	
Industrial chemicals, fuels and organic compounds	Aerosol residue from heavy industry (eg petroleum industry). Disinfection by-products resulting from the use of chlorine as a disinfectant (but these are secondary to achieving good disinfection).	
Aesthetic parameters > turbidity > colour > salt (TDS or EC) > temperature/pH > hardness/ alkalinity > iron, manganese or aluminium	A wide range of sources, both natural and from human activities. For example, high levels of turbidity and colour may result from smoke residue and leaves on the roof, and odour may come from stagnant water. Very low alkalinity can lead to corrosion of pipelines and tanks and result in an elevated pH in the water supplied.	These hazards generally affect the taste, odour, appearance or 'feel' of the water. While high colour may make the water unpalatable it does not *necessarily* make it unsafe to drink. Some aesthetic parameters can affect the 'treatability' of the water, reduce the effectiveness of disinfection or result in by-products formed during treatment. For example, turbidity may make disinfection less effective and, colour may give rise to higher concentrations of disinfection by-products such as trihalomethanes.

Table 1.22: Rainwater: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Faecal matter from people, birds and animals on the roof or in the gutters	✓	✓				
Organic matter (eg leaves, twigs) on the roof surface, and dust or aerosol residues from industry, mining or cropping		✓	✓	✓	✓	✓
Recontamination prior to use (eg during storage and distribution)	✓					
Stagnant water						✓
Corroded metal pipes and fittings due to low alkalinity			✓			
Animals die in the gutters or the rainwater tank	✓	✓				✓
Animals and insects (eg snails, mosquito larvae, water fleas) in the rainwater tank	✓	✓				✓
Open (uncovered) rainwater tank, which allows recontamination via faecal matter, algal growth, etc.	✓	✓				✓
Incorrect operation of point-of-use treatment technologies (eg failure to replace filter cartridges, which can result in growths on cartridges)	✓	✓				✓

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.23: Rainwater: characteristics that indicate the presence of potential water quality problems

Guidance in the absence of water quality data

CHARACTERISTIC	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Turbid, cloudy or dirty, particularly after storms	✓					✓
Colour and/or organic odour		✓	✓			✓
Odour from dead animals or tree leaves	✓					✓
Salty taste						✓
Bitter taste			✓		✓	✓
Blue stains (corrosion of copper pipes)			✓			
Rotten egg smell – sulphide[a]						✓

a Possible indicator of contamination by organic matter causing reducing conditions (ie absence of oxygen).

Table 1.24: Rainwater: some basic quality parameters to consider

PARAMETER[a]	IMPLICATION FOR WATER QUALITY
E. coli (*Escherichia coli*)	Indicates faecal contamination of the water supply and that pathogens are likely to be present.
Coliforms	Generally should not be present after treatment (disinfection). Their presence after treatment can indicate that the disinfection was ineffective and that there is a risk of pathogens.
Turbidity	Can interfere with disinfection if above about 1 NTU (ie may be slightly cloudy in a glass).
Colour	Generally indicates organic material in the water, which can interfere with disinfection and produce harmful disinfection by-products. May also indicate the presence of iron or manganese.
pH	Should be in the neutral range (6.5–8.5). If above 8, effectiveness of chlorine disinfection decreases. At higher pH, scaling may occur if hardness is high. If below 6.5, water can be corrosive and attack metals.
Metals used in storage and distribution systems	May be corroded by rainwater, giving rise to high concentrations of metals (eg copper) harmful to humans and animals.

a High levels of any of these parameters can be problematic or can be an indicator of other related problems.

The treatment options in Table 1.25 are relevant to a range of water supplies – from an individual dwelling to a major urban area. Seek expert assistance as required to determine the appropriate level of treatment for each type of supply. Refer to the WHO *Guidelines for drinking-water quality* (3rd edn)[20] for further information.

A tick in Table 1.25 indicates that the treatment **improves** water quality and may be applied to correct the particular water quality problem. Further investigation (including testing) may still be required to determine whether the water is safe to drink. If the water is unsafe, additional treatment may be required.

Table 1.25: Rainwater: a guide to the effectiveness of various water treatments and risk reduction measures

TREATMENT OR RISK REDUCTION MEASURE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Boil water	✓					✓[a]
Coagulate and filter water	✓	✓	✓	✓	✓	✓
Disinfect (chlorine or UV)[b]	✓	✓				
Seek an alternative water source	✓	✓	✓	✓	✓	✓
Selectively divert first flush rainwater during a storm	✓					✓
Store water for >4 weeks in sunlight (UV irradiation)	✓					
Use carbon filter, activated carbon filter or slow sand filter at usage point		✓	✓	✓	✓	✓

a Boiling and settling water over night can reduce turbidity.

b Most harmful pathogens in source water are inactivated through disinfection with an appropriate chlorine dose. However, there are some pathogens, particularly *Cryptosporidium* and *Giardia*, that are resistant to chlorine. Harmful *Cryptosporidium* and *Giardia* are generally found only in faeces from people and domesticated animals, particularly cattle and calves. Other forms of treatment are required to remove or inactivate *Cryptosporidium* and *Giardia*. These may include coagulation and filtration or UV irradiation. UV irradiation is not effective if water has high turbidity or iron.

20 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Storage, distribution and usage points

Most water supply systems use **storage systems**. After water is collected at the source it is usually stored in a tank. Such storage can provide a constant supply of water for distribution (providing the source continues to provide water) and increase users' access to water.

The **distribution system** transfers water from its storage to the consumer. It can range from major water supply lines under pressure to a manual collection–distribution system of pots and glasses.

Usage points are where consumers access the water. This may involve vessels to take the water to the house, or a tap within the house.

1. GATHER INFORMATION

STORAGE SYSTEM

a) If possible, undertake a desktop review of the existing storage system such as design drawings and/or design reports to gather information on: ☐

> the capacity of the system

> construction material

> controls – inlet and outlet lines and operating levels, and

> maintenance and management operations.

If this information is not available it will need to be obtained once in the field. The aim of the review is to understand how the storage system is operated so that risks can be identified.

b) Gather available data on storage water testing and quality. ☐

c) For a proposed storage system, gather such information as source outflow potential, expected supply volumes, population growth in the area and water movement (other potential storage locations) in order to calculate the appropriate size and identify all risks associated with managing and maintaining the system. ☐

It is critical that the source can maintain an adequate level of water in the storage tank to avoid loss of a positive supply pressure within the distribution system. A lack of pressure is sometimes given as a reason why water should not be distributed in an underground distribution system for a village supply.

DISTRIBUTION SYSTEM

☐ d) If possible, undertake a desktop review of the existing or proposed distribution system such as design drawings and/or design reports to gather information on:

- > distribution alignment – proximity to sewers or other potential contaminant sources
- > pipe material – its suitability for conditions (plastic lines can split under high pressure) and potential for leakage (screwed fittings, corrosion, flanges and illegal tappings)
- > location of air valves and taps where contamination may enter, and
- > infrastructure condition (locate sections of underground pipes that can be viewed, in particular valves).

If this information is not available it will need to be obtained once in the field. The aim of the review is to understand the function of the system and how it is or will be operated so that risks can be identified.

USAGE POINTS

☐ e) Gather all information in the field, principally by talking to consumers and watching their practices.

2. INSPECT THE STORAGE, DISTRIBUTION AND USAGE POINTS

While undertaking the tasks listed below (for the storage system, distribution system and usage points):

- > be aware of local cultural issues with photography
- > prepare a schematic (diagram) of the storage, distribution and usage points, clearly indicating potential water quality problems, and
- > use Table 1.26 as a guide to the causes of typical water quality problems and their potential impact on consumers, Table 1.27, Table 1.28 and Table 1.29 as guides to the types of activity or practice that can pose high risks to water quality, Table 1.30 as a guide to characteristics the water may exhibit, Table 1.31 as a guide to the implications for water quality of some parameters, and Table 1.32 as a guide to the effectiveness of treatment options for particular water problems.

STORAGE SYSTEM

a) Determine the supply capacity and whether the storage can run out of water and has ever run out of water. ☐

b) Inspect the storage system and speak to the team that maintains it. Review maintenance checklists – how often the storage is maintained, who does it, what the remediation actions are. Ask to see the corrective work undertaken. ☐

c) Photograph the storage system – location of inlet and outlet lines, valves and gauges, overflow lines, scour lines and covers on roofs. ☐

d) Photograph the surrounding area, ditches, paths, roads and vegetation. Look for how the surrounding area may affect the storage system. ☐

e) Assess the appropriateness or deficiencies of existing treatment and infrastructure. ☐

f) Identify other storage tanks in the area – whether they are the same as the ones you inspected and, if not, find out why they are different. ☐

g) Check whether the storage tank is covered or open to contamination. ☐

h) Check whether insects and animals can access the storage system via inlet/outlet lines, overflow line or cover. ☐

i) Note the location of the storage in terms of it security – whether it is in an open, visible area (less likely to be sabotaged). ☐

j) Note the location of the storage in relation to known flood levels – whether the storage tank could be inundated during heavy storms. ☐

k) Record any cracks, leaks or signs of deterioration with the storage system (photograph and measure). ☐

l) If the storage is underground, check the perimeter of the tank for any sign of earth movement (depressions or cracks in the earth) that may indicate ingress into the storage tank. ☐

DISTRIBUTION SYSTEM

It may be difficult to inspect a distribution line, particularly if it is underground. Nevertheless, efforts should be made to inspect all sections of the system that can be viewed. Wherever possible the following tasks should be undertaken:

- ☐ a) Determine whether the supply to the distribution system has or could run out, causing the pipework to operate under a negative pressure and resulting in contaminants entering the pipes.
- ☐ b) Check the location of sewage and drainage pipes and their proximity to the drinking water pipes.
- ☐ c) Inspect the outlet from the storage system.
- ☐ d) Walk along the distribution line (if possible). Note if the alignment is underneath a road, path, etc where heavy loads may be imposed on the trench, which can cause damage to the distribution line.
- ☐ e) Look for depressions along the trench line, which could indicate leaks and ingress into the distribution system. Look for taps that are left on, illegal tappings, flanges that are leaking and other evidence that there is water loss or illegal use and difficulty in maintaining an adequate supply of water to the distribution system at all times.
- ☐ f) Check that air valves are installed and working properly, as a faulty air valve can affect the quality of water and/or provide an entry point for contaminants.
- ☐ g) Where flow meters are installed, check that the valves are sealed properly, as leaks are a possible point for contamination ingress.
- ☐ h) Speak to the team that maintains the distribution system. Review maintenance checklists – how often the distribution system is maintained, who does it, what the remediation actions are. Ask to see the corrective work undertaken (if possible).
- ☐ i) Photograph the distribution system where possible.
- ☐ j) Assess the appropriateness or deficiencies of existing treatment and infrastructure.

USAGE POINTS

When identifying and assessing potential risks associated with the collection and use of water, undertake the following tasks:

a) Ask users how they collect the water and watch people collecting it. ☐

b) Note the types of vessel used (eg whether glasses, buckets, pots), how they are handled and stored when not in use, and whether there is potential for contamination. ☐

c) Ask whether the vessels are used for purposes other than water collection that may contaminate them. ☐

d) Photograph the collection points and people collecting water. ☐

e) Assess the appropriateness or deficiencies of existing treatment and infrastructure. Note whether ditches and an apron have been constructed around the collection points to divert excess water from the points to reduce the risk of introducing contaminated stagnant water to the collection point. ☐

f) Determine the range of uses of water at the collection point (eg for washing or for animals) that could give rise to contamination. ☐

g) Determine whether users know how to collect safe water and keep it safe. ☐

h) Determine whether users know who to contact if they have concerns about the quality of the water. ☐

i) Determine whether the water is treated or disinfected after collection, and the effectiveness and reliability of this. ☐

j) Assess the hygiene practices of users, especially young children. ☐

3. ASSESS COMMUNITY AWARENESS OF WATER QUALITY ISSUES

☐ a) Assess the level of awareness of water quality issues in the community. For example, determine whether local people know where the storage and distribution systems are located, what activities can affect water quality, that if they use too much water and empty the pipes this can give rise to contamination, and what controls are in place to protect the water supply.

☐ b) Assess how aware local people are of the need for sound hygiene and sanitation practices to achieve and maintain safe water.

☐ c) Ask for historical 'stories' or anecdotes about water quality and appearance, illnesses in the community and activities that may affect water quality.

4. PRODUCE MATERIAL FOR THE WATER QUALITY MANAGEMENT PLAN

☐ a) A summary of available water quality data and graphs of water quality parameters against time. (This may have been collected previously when assessing water sources).

☐ b) A summary of water usage and the capacity of the supply system and whether it is practical to maintain a positive pressure within the distribution system at all times.

☐ c) A plan for checking that the pipework does not leak or allow contamination in. (This may involve checking the level in a stand pipe with the supply turned off.)

☐ d) A photographic journal of the storage, distribution and usage points, identified water quality problems and water use in the community.

☐ e) A flow diagram of the storage, distribution and usage points, identifying all infrastructure and indicating where water quality problems may arise.

☐ f) A risk assessment that covers key existing and potential water quality problems, existing controls and their effectiveness in managing risk for consumers.

5. RECOMMEND WAYS TO MANAGE OR IMPROVE WATER QUALITY

Based on the information gathered and the risk assessment, recommend an option or options for a safe water supply. For example:

a) Protect the storage, distribution and usage points from contamination and remove causes of water quality problems at their source if possible. ☐

b) Ensure that water usage does not exceed the supply capacity if water is distributed via underground pipes. ☐

c) Provide additional treatment as required. ☐

d) Ensure that users are aware of water quality problems and the requirements for good hygiene and safe water. ☐

Table 1.26: Storage, distribution and usage: typical water quality problems, their causes and their potential impact on consumers

QUALITY PROBLEM	CAUSES OF WATER QUALITY PROBLEMS	IMPACT ON CONSUMERS
Pathogens	**Storage system** Ineffective treatment prior to storage. Faecal matter (eg from animals or birds) entering the storage, especially if reservoirs or tanks are open. Recontamination of water during maintenance. An inadequate supply of water so that a positive pressure is not maintained at all times in the distribution system. **Distribution system** Leaking valves, providing entry points for contaminants. Recontamination of water during maintenance. Cross-connections that allow wastewater to enter. **Usage points** Recontamination of water from tap to mouth due to poor sanitation and hygiene practices. Poor maintenance practices at usage points.	Impact can vary from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera or typhoid fever.
Nutrients, algae and algal toxins	**Storage system** Ineffective treatment prior to storage. Open storages such as reservoirs or tanks that allow algae to grow. Some algae produce toxins that are harmful to people and animals. (Algae are unlikely to be a problem if tanks are closed.)	Exposure to algal toxins, and organic and inorganic chemicals can have a range of effects – generally classified into: > organ-specific diseases > neurological or behavioural disorders > reproductive or developmental diseases and disorders > carcinogenic or mutagenic diseases. Impact may be acute (short term or sudden) or chronic (exposure over a long period) and the nature, severity and incidence will generally increase as dose or exposure increases. (Refer to the WHO *Guidelines for drinking-water quality* for further details.)
Metals	**Storage system** Ineffective treatment prior to storage. Corroded construction materials (eg reinforcement in concrete and galvanised tanks). **Distribution system** Corroded pipelines (copper, lead), and water treatment chemicals (aluminium). **Usage points** Collection method (eg rusted vessels).	

(Continued on next page)

Table 1.26: Storage, distribution and usage: typical water quality problems, their causes and their potential impact on consumers (continued)

QUALITY PROBLEM	CAUSES OF WATER QUALITY PROBLEMS	IMPACT ON CONSUMERS
Pesticides, herbicides and insecticides	**Storage system** Ineffective treatment prior to storage. Open storages where spraying occurs.	Exposure to organic and inorganic chemicals can have a range of effects – generally classified into: > organ-specific diseases > neurological or behavioural disorders > reproductive or developmental diseases and disorders > carcinogenic or mutagenic diseases. Impact may be acute (short term or sudden) or chronic (exposure over a long period) and the nature, severity and incidence will generally increase as dose or exposure increases. (Refer to the WHO *Guidelines for drinking-water quality* for further details.)
Industrial chemicals, fuels and organic compounds	**Storage system** Ineffective treatment prior to storage. Disinfection by-products in treated water. **Distribution system** Leaking valves or breaks in line, providing ingress path for wastewater discharges and spills from industries, and leakage from fuel storage tanks. Cross-connections from users in industry. Disinfection by-products in treated water. **Usage points** Cross-contamination if industrial waste is not disposed of properly around water collection point.	
Aesthetic parameters > turbidity > colour > salt (TDS or EC) > temperature/pH > hardness/ alkalinity > iron, manganese or aluminium	**Storage system** Ineffective treatment prior to storage. Disinfection by-products (taste). A wide range of sources, both natural and from human activities. Even a pristine catchment can produce water with high turbidity, colour, hardness, etc. Be aware that water quality may change seasonally and after storm or other significant events. Construction materials (eg lime leached from a concrete tank or hot water from a plastic tank). **Distribution system** Construction materials (eg lime leached from concrete pipes). **Usage points** Collection method.	These hazards generally affect the taste, odour, appearance or 'feel' of the water. While high salt content or colour may make the water unpalatable, neither *necessarily* makes it unsafe to drink. Some aesthetic parameters can affect the 'treatability' of the water, reduce the effectiveness of disinfection or result in by-products formed during treatment. For example, turbidity may make disinfection less effective and, colour may give rise to higher concentrations of disinfection by-products such as trihalomethanes.

Table 1.27: Storage system: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS[a]	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Swimming and washing (people and clothing)	✓	✓				
Sewage discharge (even if treated)	✓	✓				
Houses/dwellings with domestic waste entering the storage system (underground) or stagnant water around base	✓	✓	✓			
Open storage that allows animals, birds or people to enter	✓	✓		✓		
Open storage that allows storms to wash faecal matter and other contaminants into it	✓	✓		✓		✓
Loss of water supply and pressure in the distribution system	✓					
Storms in the catchment that wash faecal matter and other contaminants into storage system	✓	✓				✓
Stagnant water		✓				✓
Poor maintenance practices	✓				✓	✓
Unauthorised access (sabotage)	✓			✓	✓	✓
Insects/animals in storage system	✓					✓
Types of construction material			✓			✓

a Generally unlikely to have algal toxins unless storages are open to sunlight.

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.28: Distribution system: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS[a]	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Sewage discharge (even if treated) ingress via leaks	✓	✓				
Loss of pressure in the distribution system	✓					
Houses/dwellings with domestic waste entering the distribution system (leaks, valves)	✓	✓	✓			
Poor maintenance practices	✓				✓	✓
Unauthorised access (sabotage)	✓			✓	✓	✓
Insects/animals in distribution system	✓					✓
Types of construction material			✓		✓	✓

a Generally unlikely to have algal toxins unless the water visually contains algae (water is green or has visible cells) and has some taste and odour.

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.29: Usage points: examples of activities and practices that pose risks to water quality

HIGH-RISK ACTIVITY OR PRACTICE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS[a]	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Dirty vessel used for collection	✓					✓
Rusty vessel used for collection	✓		✓			✓
Stagnant water around collection point	✓	✓				✓
Incorrect operation of point-of-use treatment technologies (eg failure to replace filter cartridges, which can result in growths on cartridges)	✓					✓

a Generally unlikely to have algal toxins unless the water visually contains algae (water is green or has visible cells) and has some taste and odour.

Note: The table does not present a comprehensive list. The examples can be used by the assessor as a guide.

Table 1.30: Storage, distribution and usage: characteristics that indicate the presence of potential water quality problems Guidance in the absence of water quality data

CHARACTERISTIC	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS[a]	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Turbid, cloudy or dirty	✓					✓
Colour and/or organic odour		✓	✓			✓
Salty taste						✓
Bitter taste					✓	
Difficulty forming lather with soap						✓
Blue stains (corroded copper pipes)			✓			
Rotten egg smell – sulphide[a]						✓
Scaling on pots or kettles (indicator of hardness)						✓

a Possible indicator of contamination by organic matter causing reducing conditions (ie absence of oxygen).

Table 1.31: Storage, distribution and usage: some basic quality parameters to consider

PARAMETER[a]	IMPLICATION FOR WATER QUALITY
E. coli (*Escherichia coli*)	Indicates faecal contamination of the water supply and that pathogens are likely to be present.
Coliforms	Generally should not be present after treatment (disinfection). Their presence after treatment can indicate that the disinfection was ineffective and that there is a risk of pathogens.
Turbidity	Can be an indicator of contamination. Can interfere with disinfection if above about 1 NTU (ie may be slightly cloudy in a glass).
Colour	Generally indicates organic material in the water, which can interfere with disinfection and produce harmful disinfection by-products. May also indicate the presence of iron or manganese.
Salt (TDS or EC)	Generally makes the water unpalatable or unpleasant to drink.
Hardness	Can affect treatability of the water and the ability of the water to lather.
pH (can be affected by construction material of storage and distribution systems)	Should be in the neutral range (6.5–8.5). If above 8, effectiveness of chlorine disinfection decreases. At a higher pH and if water is hard, scaling may occur and block pipes. If below 6.5, water can be corrosive and attack metals.
Metals – arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc	Can be harmful to humans and animals if consumed.
Metals – iron or manganese	Can cause brown or black water, staining and colouration of laundry and baths/sinks and an iron or bitter taste.

a High levels of any of these parameters can be problematic or can be an indicator of other related problems.

If treatment is part of the water supply system the water should be treated at the treatment facility prior to storage. However, even if treatment has been completed, sometimes water quality can be improved further by using simple household treatments.

The treatment options in Table 1.32 are relevant to a range of water supplies – from an individual dwelling to a major urban area. Seek expert assistance as required to determine the appropriate level of treatment for each type of supply. Refer to the WHO *Guidelines for drinking-water quality* (3rd edn)[21] for further information.

A tick in Table 1.32 indicates that the treatment **improves** water quality and may be applied to correct the particular water quality problem. Further investigation (including testing) may still be required to determine whether the water is safe to drink. If the water is unsafe, additional treatment may be required.

Table 1.32: Storage, distribution and usage: a guide to the effectiveness of various water treatments and risk reduction measures

TREATMENT OR RISK REDUCTION MEASURE	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Boil water	✓					✓[a]
Coagulate and filter water	✓	✓	✓	✓	✓	✓
Disinfect (chlorine or UV)[b]	✓					
Seek an alternative water source	✓	✓	✓	✓	✓	✓
Avoid use of water if contamination is likely (eg after storms)	✓					✓
Store water for >4 weeks in sunlight (UV irradiation)	✓					
Use activated carbon filter		✓		✓	✓	✓

a Boiling and settling water over night can reduce turbidity.

b Most harmful pathogens in source water are inactivated through disinfection with an appropriate chlorine dose. However, there are some pathogens, particularly *Cryptosporidium* and *Giardia*, which are resistant to chlorine. Harmful *Cryptosporidium* and *Giardia* are generally found only in faeces from human and domesticated animals, particularly cattle. Other forms of treatment are required to remove or inactivate *Cryptosporidium* and *Giardia*. These may include coagulation and filtration or UV irradiation. UV irradiation is not effective if water has high turbidity or iron.

21 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Guideline 2

DEVELOPING A WATER QUALITY MANAGEMENT PLAN

A key output of applying the framework for managing water quality is the water quality management plan (WQMP). This plan is used to effectively manage the risks to water quality in a development activity. The size and nature of the water supply system involved determine the comprehensiveness and originality of the plan. For a simple, small-scale water supply system the plan may be very brief. However, the principles are the same for all plans.

The principles of risk management integrated into water quality management plans have been developed over a number of years in Australia and internationally. Efforts to reduce the risks associated with providing safe water supplies to communities in Australia resulted in the development of the *Australian drinking water guidelines 2004*, which incorporates the framework for drinking water quality management (see Table 2.1).[22] This framework, developed for a national context, is in alignment with the WHO *Guidelines for drinking-water quality* (3rd edn),[23] which necessarily have a more international perspective.

Although the contexts of each set of documents are slightly different, the principles in each are similar. As both organisations continue to work together to further the development of water quality management, there will be increasing harmony between approaches.

The Australian and WHO guidelines are the basis for the Australian aid program's *Safe water guide*.

22 National Health and Medical Research Council (NHMRC) in collaboration with Natural Resource Management Ministerial Council (NRMMC), *Australian drinking water guidelines 2004: national water quality management strategy*, Canberra, 2004, viewed 16 December 2004 <www7.health.gov.au/nhmrc/publications/synopses/eh19syn.htm>.

23 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

In practice, water supply systems in development activities can generally be categorised as either urban or rural, although even within these two categories there are a range of system types and degrees of management.

For example, a major urban supply system is likely to be complex and managed by an authority or utility with technical and managerial expertise. However, there may also be urban slum or squatter settlements with

Table 2.1: Structure of the Australian framework for drinking water quality management

FRAMEWORK ELEMENTS AND INDICATIVE ACTIVITIES	
Commitment to drinking water quality management	
Element 1	Commitment to drinking water quality management
	Drinking water quality policy Regulatory and formal requirements Engaging stakeholders
Water quality hazard identification and risk assessment	
Element 2	Assessment of the drinking water supply system
	Water supply system analysis Assessment of water quality data Hazard identification and risk assessment
Element 3	Preventive measures for drinking water quality management
	Preventive measures and multiple barriers Critical control points
Strategies and plans for managing risks	
Element 4	Operational procedures and process control
	Operational procedures Operational monitoring Corrective action Equipment capability and maintenance Materials and chemicals
Element 5	Verification of drinking water quality
	Drinking water quality monitoring Consumer satisfaction Short-term evaluation of results Corrective action
Element 6	Management of incidents and emergencies
	Communication Incident and emergency response protocols

(Continued on next page)

basic, unmanaged water supply systems. In a rural context, a village (or community) water supply system tends to be operated and managed by the village rather than a government or local authority. However, some village systems are managed by local authorities.

For the purposes of this guideline, two water supply systems are used to illustrate the management appropriate for different types of supply:

Table 2.1: Structure of the Australian framework for drinking water quality management (continued)

FRAMEWORK ELEMENTS AND INDICATIVE ACTIVITIES	
Supporting requirements (training, awareness raising, R&D, documentation)	
Element 7	Employee awareness and training
	Employee awareness and involvement Employee training
Element 8	Community involvement and awareness
	Community consultation Communication
Element 9	Research and development
	Investigative studies and research monitoring Validation of processes Design of equipment
Element 10	Documentation and reporting
	Management of documentation and records Reporting
Monitoring, evaluation and review	
Element 11	Evaluation and audit
	Long-term evaluation of results Audit of drinking water quality management Confirmation that system meeting requirements
Element 12	Review and continual improvement
	Review by senior executive Drinking Water Quality Management Improvement Plan

Source: Based on National Health and Medical Research Council (NHMRC) in collaboration with Natural Resource Management Ministerial Council (NRMMC), *Australian drinking water guidelines 2004: national water quality management strategy*, Canberra, 2004, viewed 16 December 2004 <www7.health.gov.au/nhmrc/publications/synopses/eh19syn.htm>.

- a major urban supply that is managed using skilled personnel, and
- a small rural village supply that is managed by representatives of the local community.

The principles used in each supply system's management are identical and reflect those outlined in the Australian and the WHO guidelines. The principles can be adapted to any situation, even a household system.

URBAN WATER SUPPLY SYSTEM

The water quality management plan for a major urban water supply system, which tends to be complex and requires technical resources, should be prepared from first principles using the WHO *Guidelines for drinking-water quality* (3rd edn), Chapter 4, 'Water safety plans', and the *Australian drinking water guidelines 2004* as references. The guidance provided in these documents can be adapted to the specific needs of the urban supply system. Of particular use to practitioners is the Australian framework for drinking water quality management (refer to Table 2.1), which highlights the key areas that should be addressed in a water quality management plan for a major urban supply system.

Use of these tools will require the managers and operators of the water supply system to review their management systems and ensure that the various requirements of WHO guidelines and the framework in the Australian drinking water guidelines are in place, and to add to or improve their systems as required. Many water authorities in Australia have undertaken this process and found it very valuable for improving their operations and managing their water quality. As part of an AusAID-funded activity these tasks would be undertaken with assistance from the activity team.

VILLAGE WATER SUPPLY SYSTEM

For a small water supply system in a rural village setting – often the case in AusAID-funded activities – local technical expertise and managerial resources are usually not available. However, the principles of developing a water quality management plan to achieve safe water still apply.

Table 2.2 presents important considerations and a set of tasks that could be undertaken to apply the WHO guidelines and the Australian framework for drinking water quality management (outlined in Table 2.1) in a village setting. While this approach should be suitable for the majority of village settings, the detail may need to be varied for certain situations. Nevertheless, the core principles would remain unchanged.

In the example presented, an AusAID contractor or NGO would assist the village to:

- understand the need for safe water
- take responsibility for establishing and maintaining the supply system
- develop the necessary knowledge to do this, and
- build in some checks to ensure that the water supply remains safe.

The table also indicates tasks that need to be undertaken to contribute to the sustainability of the water supply and building local capacity.

Table 2.2 is effectively a very simple set of guidelines, a manual and a training aid. It embodies the principles of good management and includes all the measures necessary to ensure a safe water supply system if implemented correctly. It includes the need to identify where water quality problems may arise and how these can be avoided. The benefit of this approach is that it adopts world best practice to the available resources of a rural village. It does not require a major allocation of money and resources, but maximises experience and ownership of the village community.

The table can also be a useful reference for establishing formal water quality management plans for individual household water supplies. All elements should be considered but simplified for a household system.

AusAID has a set of manuals that integrate all of the principles outlined in the table into an easy-to-use form.[24] The manuals, developed from AusAID-funded activities, outline construction, operation, maintenance and management tasks that can be undertaken in very small communities or even at the household level. These manuals can be referred to for examples of how this approach to developing a water quality management plan can be applied in practice.

The National Health and Medical Research Council is developing a simple software package to produce customised water safety plans for village supplies.[25] These should be very useful for practitioners.

24 These manuals will soon be available on AusAID's website <www.ausaid.gov.au>.

25 Contact NHMRC for more information.

Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 1	**Commitment to managing drinking water quality** Ensure a commitment to drinking water quality management that will assist the village to maintain an adequate supply of safe water in the long term.	
	Educate village leaders and the community about the benefits of having a group of people responsible for the water supply. Raise awareness in the community about the health benefits associated with having a clean, well-maintained water supply system. Establish a village Water Management Committee. This committee would be an elected group of village members who collectively coordinate the supply of safe drinking water to those households that have agreed, through consultation, to contribute money to a village-based water supply scheme in return for access to safe drinking water. The committee may vary in size and include a chairperson, a maintenance coordinator, a monitoring coordinator, an education coordinator, a membership coordinator, a payment contribution coordinator and other persons as appropriate. Commitment from an individual or individuals of high standing in the village is important. If possible, a village chief/head should be part of the committee. This reinforces the importance of managing drinking water quality. Women should be adequately represented on the committee, as they are usually the main users of water. (Also see the AusAID publication *Gender guidelines: water supply and sanitation – supplement to the guide to gender and development* <www.ausaid.gov.au/publications/pdf/gender_guidelines_water.pdf> attached in Part 3 of this guide.) Document the names, roles and responsibilities of committee members and the agreements on collecting payments and on operating and maintaining the system. In forming the committee, recognise, respect and draw on existing community structures. Villages are often organised on committee-type principles and villagers often collectively address certain issues, such as a wedding or sending one of the villagers to university. Establish a bank account or other accountable repository and monitor it to ensure that all contributions continue to be made and funds are expended as planned (for maintenance).	A Water Management Committee, each person with a specific responsibility. An agreement on how much money is required to establish and maintain the system, how this money will be collected, who will collect it, and who and how much each will contribute.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 2	**Assessment of the drinking water supply system** Ensure that the entire drinking water supply system is assessed – everything from the water source to the consumer.	
	Prepare a flow diagram to represent the water source and water supply system, including treatment, storage, distribution and point of use.	A diagram of the drinking water source and supply system.
	Review what is known in the village and in the region about the suitability of the source water for drinking, what treatment is needed, and what maintenance and checking of water quality is needed. This should include a review of any water monitoring data and of the performance of any similar systems in the area. Identify all possible water quality problems – ie any pollution or natural substances that have the potential to cause harm. Record the results of the assessment. Educate and increase the awareness of the Water Management Committee members about their water source and water supply system, the factors that influence the safety of the water, and potential water quality problems.	A description of possible water quality problems.
Element 3	**Preventive measures for drinking water quality management** Ensure that measures are in place to prevent or reduce the risk of water quality problems.	
	Identify existing preventive measures and determine whether they are effective. Identify and evaluate any improvements that are required to avoid problems. Preventive measures include: > for a groundwater supply – ensuring that the location is suitable, eg if possible more than 10 m from potential sources of contamination such as latrines, contaminated surface water bodies, animals and industrial activities involving chemicals > for a surface water supply – ensuring that the water source is protected as far as possible, eg it is upstream of any sources of contamination such as latrines, wastewater discharges, animals, swimming, washing, and agricultural chemicals. For more detailed information, refer to the WHO *Guidelines for drinking-water quality* <www.who.int/water_sanitation_health/dwq/guidelines/en/>. Document the measures taken to protect drinking water quality. Provide training for Water Management Committee members about simple preventive measures specific to the water supply.	A diagram of the water source and supply system that shows how water quality problems might occur, and indicates what needs to be done to avoid those problems and ensure that the supply will be safe. A list of important things that need to be done to ensure that the drinking water supply will be safe.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 4	**Operational procedures for the water supply system** Ensure that the procedures specify the operational processes and tasks required to effectively and efficiently prevent water quality problems.	
	Document the procedures for operating and maintaining the water supply system, and the actions that should be taken if guideline values are exceeded. Identify roles and responsibilities for operating the water supply system, and ensure that the villagers responsible for the water supply understand their individual responsibilities and the significance of them. These responsibilities could include: > regularly inspecting the source area to ensure that contaminating activities are not taking place > regularly replacing the sand in a slow sand filter, and > checking that pipelines (if there are any) are not leaking. Ensure that the Water Management Committee understands the need for an agreed and written summary of operational procedures.	Guidelines on how to do the things necessary for operating and maintaining the water supply system. A list of who is responsible for doing those things.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 5	**Verification of drinking water quality** Ensure that the water quality meets guideline values. Establish the water quality parameters to be analysed, the frequency of monitoring, the guideline values that must not be exceeded, and the actions that should be taken if the guideline values are exceeded. Key parameters can be expected to include microbiological indicator organisms and any health-related characteristics (such as arsenic) that may be expected to exceed the guideline value. Document the monitoring program – what tests need to be taken, how frequently, how the tests are to be done and by whom, and the guideline values. Ensure that the Water Management Committee understands that testing and checking have to be carried out, how these tasks should be done, and how testing and checking can be used to confirm that the water is safe. It is important to avoid excessive testing requirements, as this is costly and not always feasible. Testing should be done from time to time to confirm water quality. It should support other monitoring tasks that can be completed easily by the Water Management Committee or its representative on a regular basis (eg keeping animals away from the water supply, checking the condition of concrete tanks and ensuring that latrines are not contaminating the well). Provide training for the people who will arrange the monitoring and for those who will do the testing and determine whether the water is safe and whether remedial actions are required. Responsibility for testing the water could lie with the village family health workers, and one villager could be appointed as the maintainer of the supply and be paid to carry out this role. Establish a village feedback system through which residents can report and comment on water quality to a member of the Water Management Committee. Arrange for family health workers or the local health clinic to ask about and record any illness that may be related to water quality, and regularly advise the committee. Identify a member of the Water Management Committee who should regularly evaluate the results of monitoring and community comments. These results should be communicated to the community. Arrange to get the information to the villagers.	A list of tests and checking that should be carried out, who will do this work, the methods to be used, and who will evaluate the results. An arrangement for paying for the tests. An effective village health feedback system.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 6	**Management of incidents and emergencies** Ensure that villagers are able to identify and respond to situations that can cause the supply system to fail. Make arrangements to recognise and address problems with the water supply system. These should cover, for example: > what to do if the water becomes unsafe (eg boil the water) > what to do if the water supply fails (eg during a drought) > who is to do these things, and how they will be paid for > how the issues will be communicated to the villagers. The arrangements should be documented and made available to the community. Educate the Water Management Committee on what needs to be done if there are problems. Provide training on how to recognise that there is a problem, what to do, and how urgent it is. Following any water supply problem the Water Management Committee should investigate the causes of the problem, how it was recognised, how well it was fixed, how well it was communicated, and what improvement is required. Any improvements should be integrated into their risk management strategies (Element 3) and operational procedures (Element 4). Ensure that the Water Management Committee knows where to seek help if it is needed. Local government departments may be able to provide support and guidance.	Guideline on what to do if problems arise, who should do these things, and how they can be paid for.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Elements 7 & 8	**Community involvement, awareness and training**	
	Ensure that the Water Management Committee understands drinking water quality and management of the village water supply.	
	Provide training to the members of the Water Management Committee in charge of maintaining and monitoring the water supply system both qualitatively and quantitatively. They should be trained in maintaining the equipment, in sampling and analysing water quality and in interpreting the results. The training materials should be documented and regular (eg annual) training sessions set up to ensure that knowledge is retained. Establish an awareness program to educate the wider village community about the water source and water supply system, the requirements for and ongoing costs of maintaining a safe water supply, and the necessity of maintaining good hygiene practices to gain the full benefits of safe water. This may be achieved through training community health workers in water supply awareness and hygiene, so they can educate the wider community. For example, village members should be aware of: > the role of the Water Management Committee > how the water supply system operates (in general terms) > the roles and responsibilities of the Water Management Committee and community members > the way in which their actions can affect water quality and public health > the need for good hygiene (personal, domestic, food, water) to get the full benefits of safe water. Methods to increase community awareness include community education, advice by community health workers, a village notice board, and village meetings. Community education and communication should be ongoing and documented. Involve the community in decision making. Consultation is important and should be undertaken when decisions on the water supply or changes to it need to be made. Community consultation may take place at a village meeting or workshop, or through an education program. The outcomes of such consultation should be documented and placed on a public notice board. Ensure, as much as possible, that the community is involved in water management activities.	Documented training materials for the Water Management Committee. Documented village education materials on the water supply and hygiene, which should be placed on the village notice board if possible. A Water Management Committee trained in maintaining, sampling, analysing and interpreting the water supply. A village actively involved in water management issues and with access to training to build awareness.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 9	**Research and development** Ensure that the Water Management Committee is kept up to date on advances in treatment methods or can gain a better understanding of local water supply problems.	
	Provide training for the Water Management Committee on the concepts of appropriate research, development and continual improvement and on the benefits of sharing knowledge on water supply issues. Develop links with nearby villages to share understanding and experience in managing water supply systems. Develop links with local contractors, universities and other expert groups to keep up to date with current practice. At the village level, research and development would not normally be carried out. However, there should be communication with expert groups working in the area. Research and development is not a critical element of a village's water quality management plan. It is of greater interest to government agencies, donors and research institutions.	A Water Management Committee, familiar with the water supplies of surrounding villages, the concepts of continual improvement and any research bodies that are working on water in the area.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 10	**Documentation and reporting** Ensure that records of the water supply system and its operation are kept to guarantee accountability, transparency and a record of issues and problems. Establish a system for the Water Management Committee to document the water supply system and record its operation, and identify a secure location for keeping the documentation so that it remains intact and can be used by the committee members. The records should include: > the names and roles of committee members and records of meetings > a simple flow diagram of the drinking water supply system, including the results of the assessment of the system > measures taken to protect drinking water quality > the roles and responsibilities of the people operating the water supply system > the water supply monitoring and maintenance programs > the monitoring program, analytical results, and emergency response plan for when the guideline values are exceeded > training materials on water sampling and analysis, interpretation of the results and maintenance of equipment > community education and communication materials > agreements from any community consultation > financial records on contributions and expenditure. Provide training to the Water Management Committee on keeping and maintaining records.	A Water Management Committee able to accurately and correctly document and report on water management issues in the village.
Element 11	**Evaluation and audit** Ensure that the results of monitoring the water supply system and water quality are regularly reviewed. Establish a program for regularly reviewing monitoring results so that the Water Management Committee member in charge of monitoring can identify any trends or emerging problems. Train the Water Management Committee in reviewing monitoring results. The responsible committee member should confirm that the monitoring to ensure a safe water supply is being undertaken as required, including the regularity of checks (qualitative and quantitative). Any long-term monitoring data should be compared with known water quality standards. The monitoring, operation and maintenance records should also be reviewed. If there is an active local government authority in the area, it may be able to assist with reviewing and evaluating long-term results.	A Water Management Committee competent in reviewing monitoring results and identifying trends.

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Table 2.2: Example of how a water quality management plan may be developed for a village drinking water supply (continued)

ELEMENT	TYPICAL TASKS OR CONSIDERATIONS INVOLVED	TYPICAL REQUIREMENTS
Element 12	**Review and continual improvement** Ensure that the Water Management Committee periodically reviews the status of the drinking water supply system and how it is being managed.	
	Educate the Water Management Committee on the benefits of meeting regularly to discuss the status of the village's water supply. Provide training on how to conduct regular reviews of the supply's status and on how to assess it against baseline information. Establish a program for the Water Management Committee to regularly review the water quality management plan to determine whether it can be improved to achieve better outcomes. The committee may get assistance for this process from an external party such as a local government or other supporting group. Community leaders and/or an appropriate local official will play an integral role in leading this assessment and in making any decisions to change the approach if required. In some cases, the operation of the Water Management Committee itself may need to be reviewed. Alternative management strategies may need to be developed if the existing approach is not effective.	A Water Management Committee that meets regularly and is effectively managing the village's water supply.

Guideline 3

SAMPLING AND ANALYSING WATER QUALITY

Many important measurements of physical, chemical and microbiological parameters of water quality can be carried out in the field using analytical equipment made specifically for field use. Such measurements by well-trained users of the appropriate equipment can provide accurate measurements of constituents present at low concentrations. This makes field analyses of water quality attractive in comparison with more costly laboratory-based analyses.

Field analyses also have the significant advantage of being carried out on fresh samples whose characteristics have not been affected by transportation. Transport from remote regions may not be practicable, as it can be difficult to maintain refrigeration of samples and to carry out the analyses within the allowable holding times.

However, field analyses do have limitations. Methods used in the field cannot produce the level of precision that can be achieved in a laboratory and some parameters cannot be reliably measured in the field. Some field methods may not be able to measure down to the WHO guideline concentrations. Analytical equipment may deteriorate due to the harshness of field conditions. Ensuring that field testers comply with health and safety requirements and observe established procedures is important to ensuring the accuracy and precision of water quality investigations.

Guideline 3 provides summary information on typical field and laboratory programs for analysing water quality. It is based largely on the publication *Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes.*[26] It is not intended to be comprehensive, instead highlighting the importance of water sampling programs, quality assurance and quality control, and documentation.

26 J Bartram and R Balance (eds), *Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes*, Published on behalf of UNESCO, WHO and UNEP by E&FN Spon, London, 1996, viewed 24 November 2004 <www.who.int/water_sanitation_health/resourcesquality/wqmonitor/en/>.

WATER SAMPLING PROCEDURES

Whether field or laboratory analyses are conducted, water sampling should follow standard written procedures. Sampling should conform to a consistent and repeatable process, and field procedures must be developed to ensure that this is practicable. Field notes of sampling are important to ensure a repeatable sample process is maintained. An example of a sample form is included at the end of this guideline (p. 116).

It is important to ensure the sample is representative of the water of interest. If the study is of a water supply for a particular community, sampling should be undertaken close to the point where the community draws water. Samples destined for laboratory analysis should be stored in the appropriate containers for the parameters of interest. A number of containers of different materials and preservation methods may be necessary for every sample taken.

Samples of surface water should be removed with minimum disturbance of sediments or aeration of the sample. Before taking samples from taps, wells or pumps in villages, the taps, containers or pumps should be cleaned and sterilised, and some water should be run from the access point to remove any stagnant water.

Where heavy metals are to be analysed, filtration and acidification of the water may be required for storage or analytical purposes. This is especially the case where waters with higher acidities may occur (such as from groundwater supplies or from waters affected by acid mine drainage), or where sediment in water samples is unavoidable.

Some volatile organic compounds, nitrates and bacterial samples also have specific storage requirements to ensure sample stability and to prevent cross-contamination that may reduce analytical precision.

ANALYSIS

The methods of testing for specific contaminants considered in this guideline are not exhaustive but are indicative of the methods available. A review of the full range of field and laboratory methods and their advantages and disadvantages is outside the scope of this guideline and further information can be obtained from the WHO *Guidelines for drinking-water quality* (3rd edn)[27] or laboratories and manufacturers' sources. Tables 3.1 and 3.2 provide a brief summary of the typical methods used to analyse water

27 WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

samples. They assist users of the guidelines to understand the terminology involved in water quality monitoring and the nature of sampling and analysis methods that are available. Table 3.3 lists common chemicals of health significance in drinking water and their guideline values.

FIELD ANALYSIS

Table 3.1 provides examples of water quality parameters that can be detected reliably in the field. Reliable field analysis requires well-trained people using properly maintained and calibrated equipment following clear procedures.

LABORATORY ANALYSIS

Table 3.2 provides information on a range of laboratory methods for analysing water quality based on standard analytical methods for each particular parameter of concern. More traditional methods such as titration, distillation or precipitation using a variety of reagents and procedures are being superseded. The newer methods include atomic absorption spectroscopy (AAS), inductively coupled plasma mass spectrometry (ICPMS) and gas chromatography – mass spectrophotometry (GCMS). With a single instrument these newer methods can analyse for a wide range of contaminants depending on the sample preparation.

A well-equipped laboratory may include a variety of measurement equipment, including:

> pH meter, ion-selective electrodes, conductivity meter

> spectrophotometers
  - visual and ultraviolet
  - infra-red
  - fluorescence
  - atomic absorption with flame atomisation or electrothermic atomisation

> inductively coupled plasma with
  - atomic emission spectrophotometer
  - mass spectrometer

> polarograph

> total and dissolved organic carbon analyser (TOC/DOC)

> absorbable/extractable organic halogen analyser (AOX/EOX)

> gas chromatographs with different detectors

> ion chromatograph (for anions and/or cations)

> high pressure liquid chromatograph.

Sample preparation, transport and ensuring that holding times are not exceeded are important considerations when arranging for laboratory analysis. Because of this, local laboratories are likely to be preferred. Information should be sought from laboratories on, for example:

> certification by regulatory authorities
> compliance with national and international laboratory standards
> standard analytical methods
> detection limits for the range of contaminants
> sample container requirements
> lead time and turnaround times
> chain of custody methods
> quality control and supply of reagents and calibration standards
> quality assurance and quality control (QA/QC) procedures
> an appropriate contact person.

WATER SAMPLING PROGRAMS

The WHO *Guidelines for drinking-water quality* (3rd edn) provides guidelines for sample frequency and analytical procedures. It is essential that a newly constructed drinking water supply system be tested and analysed prior to the water being used.

A single water quality sample does not provide sufficient information to guarantee safe water for a community. Upstream conditions, seasonal variations and water usage patterns may change, so an ongoing sampling program is usually required to confirm that the water is safe. Risks associated with water contamination may arise through ongoing exposure at low concentrations giving rise to effects in the long term (chronic), or exposure to high concentrations with immediate effects (acute). For example, an upstream spill from a mining operation, a water treatment plant discharge, or a flood that increases erosion in agricultural areas can result in high concentrations of contaminants and immediate effects. These excursions may not be detected at a downstream sample site immediately. Monitoring over multiple rounds of sampling is more likely to indicate whether particular contaminants are present, and whether there are any trends for the contaminants of concern.

The risk management approach to assuring safe water emphasises the importance of adopting good management procedures, although sampling and analysis remain valuable tools for confirming that water is safe.

The key in an AusAID-funded water supply activity is to identify an appropriate level of sampling and monitoring to be undertaken to confirm that a water supply is safe, and to ensure that there is effective ongoing operation, maintenance and management and that records are maintained to confirm this.

For example, monitoring and recording that a disinfection system is operating continuously can provide a more direct indication that a supply is safe than occasional monitoring of the treated water. If the system is effectively managed it is more likely that the water is safe.

Water sampling programs should be designed with due consideration of the potential water quality problems, the treatment method, the climate, the regional conditions, and the analytical methods and laboratories available. They should also match available local resources. Sampling programs should be reviewed and modified following initial sampling rounds and as more information on the community, water quality and sources is gathered. Changes over time to upstream conditions (dams, industries and population) may also need to be considered.

Maximum acceptable concentrations for various contaminants in drinking water may be set by the local government or be as indicated by the WHO guidelines. If these concentrations are exceeded in a community water supply, people using the water may be harmed. Depending on the contaminant, urgent measures may need to be taken to improve the water quality (eg boil the water if microbiological contaminants are present). Sampling in itself will not fix a problem, but is important in identifying the problem and when the problem has been overcome and the supply is again safe.

Monitoring operational parameters or indicators of water quality can assist in ensuring that unacceptable concentrations of contaminants do not occur. An example of an operational parameter would be a disinfection system that is operating or a disinfection chemical used on a regular basis. An example of an indicator would be turbidity; if a treated supply has high turbidity the treatment system may not be working correctly.

QUALITY ASSURANCE AND QUALITY CONTROL

The best intentions, training and field procedures will not prevent errors and problems occurring in the analysis of water samples. To minimise risks associated with managing water quality and to provide a level of confidence in the results, all aspects of the analytical chain – from sampling to reporting – should be subject to scrutiny, and a quality assurance and quality control (QA/QC) program should be in place. In addition, users of the equipment should receive proper training, and a program of regular equipment maintenance and calibration should be in place.

QA/QC procedures should be designed to prevent or to detect and correct problems in the measurement process and to characterise errors statistically through quality control samples and various checking processes.

A well-documented QA/QC manual that is based on appropriate guidelines and conforms to international standards should be used. All field and laboratory testing should be conducted to the specified standards.

In the case of village supplies, a program of independent periodic checking of measurements and records by an appropriately trained person can confirm the results of the monitoring program.

Providing guidance on how to develop a detailed set of QA/QC procedures is beyond the scope of this guideline, but further information and references are available in chapter 4, 'Water safety plans', of the WHO *Guidelines for drinking-water quality*.[28] The International Organization for Standardization (ISO) has a set of standards on sampling and analytical control. Of particular relevance is the standard ISO 17025:2000, General requirements for the competence of testing and calibration laboratories.

DOCUMENTATION

As in any investigation, information and results must be recorded and reported with appropriate levels of diligence. Standardised forms (see an example at the end of this guideline), standard operating procedures and test checklists, and adequate training of personnel make monitoring water quality easier. A well-prepared person with a clear and comprehensive manual and suitable test equipment can undertake the required fieldwork and provide excellent analytical results.

28 WHO, 'Water safety plans', chapter 4 in *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Table 3.1: Parameters that can be measured in the field

PARAMETER AND FIELD TESTING METHOD	COMMENTS
Pathogens (bacteria, viruses, protozoa)	E. coli, faecal coliforms and faecal streptococci, often referred to as 'indicator bacteria' (They do not generally cause disease themselves, but may indicate the presence of other disease-causing bacteria, viruses and protozoa.)
H_2S strip	Coliforms in water are usually associated with H_2S producing bacteria. Test results must be used carefully. Pathogens can be present in the absence of measurable H_2S in the water, so a blank result does not necessary indicate that the supply is free from pathogens.
Transparency/turbidity	
A Secchi disc is generally used for measuring surface water turbidity in situ at the source. A turbidity tube can be used to determine the turbidity of a drinking water sample.	Measuring turbidity/transparency is extremely important as an indicator of the concentration of suspended sediments in the water. A boat should be used to reach the measurement site. The test should be done early in the morning or late in the afternoon. The average of two depth readings (ie the depth at which the disc disappears from view) is reported as the Secchi disc transparency. The turbidity test uses a similar principle, but in a laboratory apparatus for drinking water. When the 'cloudiness' of the water matches the cloudiness of the reference disc, the turbidity of the water can be quantified.
pH	
pH indicator paper	pH indicator paper is simple and inexpensive to use, but the method is not very accurate and requires a subjective assessment of colour by the user.
Liquid colorimetric indicators	Liquid colorimetric indicators change colour in accordance with the pH of the water with which they are mixed.
Ion-selective electrode meters	Electrometric pH measurement is accurate and free from interferences. Requires buffered standardised solutions for calibration and should be corrected for temperature. Electrodes are expensive and may have a short life (months). Maintenance of electrodes is important and may be difficult in the field. Calibration is sometimes difficult and readings may take minutes to stabilise. It is important to ensure fresh solutions at the correct concentrations are available.
Conductivity	
Conductivity meter	Measuring conductivity is a method of measuring salinity. Measurement should be made in situ, or in the field immediately after the water sample has been obtained, because conductivity changes with storage time. Conductivity is also temperature-dependent; thus, if the meter used for measuring conductivity is not equipped with automatic temperature correction, the temperature of the sample should be measured and recorded.

(Continued on next page)

Table 3.1: Parameters that can be measured in the field (continued)

PARAMETER AND FIELD TESTING METHOD	COMMENTS
Various contaminants	Arsenic, copper, iron (II) and iron (III), lead, mercury, chloride, sulphate, chlorine, nitrate/nitrite/nitrogen, pesticide, bacteria and other parameters according to manufacturer
Test kits/strip Depending on contaminant of interest, samples are processed in the field in dedicated individual and disposable sample jars using reagents supplied in set doses to prepare samples for analysis using test strips designed to provide qualitative data.	Relies on fieldworkers comparing test strips with standard colour strips to determine concentrations. Depending on operator experience, capability and test method, detection limits may be above guideline concentrations of some analytes. In general operators need relatively little training, provided that sufficient information is available and procedures are understood. Provides simple robust and cheap methods for fieldwork. Analyses take from seconds to 48 hours depending on analyte and method used. Samples may require a range of pre-treatment and processing using reagents provided in kit form. Test kits are relatively cheap and require basic training to obtain accurate and precise measurements. Accuracy of field analyses may be assessed by sending a percentage of samples tested to a laboratory for comparison. With some field test kits (ie arsenic) there is some concern over their accuracy. When this is the case laboratory results should be used to validate field results.
Heavy metals	
Ion-selective electrodes	Measurement is accurate and free from interferences. Electrodes are expensive and may have a short life (months) even when well maintained. Maintenance of electrodes is important and may be difficult in the field. Calibration is sometimes difficult and readings may take some time to stabilise.

Table 3.2: Parameters that can be measured in the laboratory

PARAMETER AND LABORATORY TESTING METHOD	COMMENTS
Pathogens (bacteria, viruses, protozoa)	E. coli, faecal coliforms and faecal streptococci
Microfiltration onto nitrocellulous filter (millipore method bacteriology)	Sterile filter allows water to pass through and collects the bacteria. This filter is then placed on an absorbent pad presoaked with an appropriate bacterial growth medium. Pad and filter are then put in a petri dish and put in an incubator for 24 hours. Colonies grow and can be counted. Filters are available for the following: E. coli, faecal streptococci, total viable colony count.
Multiple fermentation tube technique	Requires 48 hours for a positive result. Result is obtained indirectly by statistical approximation (low precision). Applicable to all types of water. Consumables are readily available in most countries.
COLILERT*Reagent	Enables the simultaneous detection, identification and confirmation of total coliforms and E. coli in 24 hours or less. It can be used in a laboratory or in the field. Colilert is US EPA-approved and is included in *Standard methods for examination of water and wastewater*.[29]
Major ions	Includes carbonate/bicarbonate, chloride, calcium, potassium, sodium and magnesium
Titration, precipitation, distillation, photometry	Requires well-trained staff with suitable instrumentation and equipment, and is labour intensive.
Ion-selective electrodes	Requires well-trained staff with suitable instrumentation and equipment, and is labour intensive.
ICPMS, GCMS, AAS	Depending on analytical requirements, sample is usually prepared in accordance with manufacturer's guidelines. High precision (ppm to ppt depending on analyte and equipment). Can analyse most elements. Is expensive, requiring high-quality laboratory and highly trained staff.
Cyanide	
Colorimetric method	Simple, rapid and can achieve a low detection limit, but is semi-quantitative and expensive, as well as cumbersome for a large volume of samples. More appropriate for field testing to obtain preliminary results.
Ion chromatography	A special form of liquid chromatography where charged species are separated by selective distributions in an electrolytic mobile phase and a stationary phase with weak ionic sites. Little or no sample preparation is required, and it uses only a small amount of sample. Detection in ion chromatography is usually performed by a conductivity detector – the greater the concentration of ions the higher the conductivity of the solution.

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29 LS Clescerl, AE Greenberg and AD Eaton (eds), *Standard methods for examination of water and wastewater*, 20th edn, American Water Works Association, January 1999.

Table 3.2: Parameters that can be measured in the laboratory (continued)

PARAMETER AND LABORATORY TESTING METHOD	COMMENTS
Algal toxins/cyanotoxins	
Light microscopy	Cyanobacteria are detected by light microscopy, identified using morphological characteristics and counted per standard volume of water. Algal toxins are produced by a range of blue–green algae species. It is common practice to test for the number of blue–green algae and specifically the species that are known to generate algal toxins. Once potentially toxin-producing algal numbers reach 'trigger' levels, it is assumed that toxins are present in the water unless toxin data are available to confirm otherwise.
ELISA assay	ELISA assay test kits can identify microcystins (an algal toxin produced by species of *Microcystis* and *Anabaena*). The kits can be expensive due to their short shelf life. Investigations are under way to develop ELISA assays for other blue–green algae toxins. However, the limitation with the ELISA assays is that they are specific to particular toxins. Therefore, the kits are generally useful only if the species of blue–green algae present (and hence likely toxins present) is known. Other procedures such as gene-based tests are being developed and may be available in test kits in the future.
Animal bioassays (mouse tests)	Have traditionally been used for detecting the presence of the entire range of cyanotoxins including microcystins. These tests provide a definitive indication of toxicity, although they cannot be used for precise quantification of compounds in water or for determining compliance with the guideline value.
Sulphur forms	Sulphur, sulphate, sulphite, sulphide, thiosulphate, oxidised sulphur
Colorimetric method	Simple, rapid and can achieve a low detection limit, but is semi-quantitative and expensive, as well as cumbersome for a large volume of samples. More appropriate for field testing to obtain preliminary results.
Titration	Requires well-trained staff with suitable instrumentation and equipment, and is labour intensive.
Fluoride	
Ion-selective electrodes	Requires well-trained staff with suitable instrumentation and equipment, and is labour intensive.
Heavy metals	
Titration, precipitation, distillation, photometry	Requires well-trained staff with suitable instrumentation and equipment, and is labour intensive.
ICPMS, GCMS, AAS	Requires well-trained staff with suitable instrumentation and equipment, and is labour intensive.

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Table 3.2: Parameters that can be measured in the laboratory (continued)

PARAMETER AND LABORATORY TESTING METHOD	COMMENTS
Nitrogen forms	Nitrate, nitrite, oxidised nitrogen, organic nitrogen
Method depends on analyte and may include a number of processes such as:	
Oxidation, distillation and titration	Requires well-trained staff, and is labour intensive.
Colorimetric method	Simple, rapid and can achieve a low detection limit, but is semi-quantitative and expensive, as well as cumbersome for a large volume of samples.
Ion chromatography	A special form of liquid chromatography where charged species are separated by selective distributions in an electrolytic mobile phase and a stationary phase with weak ionic sites. Little or no sample preparation is required, and it uses only a small amount of sample. Detection in ion chromatography is usually performed by a conductivity detector – the greater the concentration of ions the higher the conductivity of the solution.
Organic chemicals (from industrial and commercial operations)	Includes polynuclear aromatic hydrocarbons, monocyclic aromatic hydrocarbons, chlorinated hydrocarbons, halogenated hydrocarbons, organochlorine pesticides, organophosphorous pesticides, herbicides and polychlorinated biphenyls
ICPMS, GCMS, AAS	Requires well-trained staff with suitable instrumentation and equipment.

Note: There are a number of other parameters that can be measured. Further detail is included in WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

Table 3.3: Common chemicals of health significance in drinking water

INORGANIC CONSTITUENTS	GUIDELINE VALUE (mg/litre)	REMARKS
Arsenic	0.01 (P)	For excess skin cancer risk of $6x10^{-4}$. Some governments may set a higher guideline value.
Cadmium	0.003	
Chromium	0.05 (P)	For total chromium.
Copper	2 (P)	Concentrations at or below the health-based guideline value may affect the appearance, taste or odour of the water.
Cyanide	0.07	
Fluoride	1.5	Climatic conditions, volume of water consumed, and intake from other sources should be considered when setting national standards.
Lead	0.01	Not all water will meet the guideline value immediately; meanwhile, all recommended measures to reduce the total exposure to lead should be implemented.
Manganese	0.4	Concentrations of the substance at or below the health-based guideline value may affect the appearance, taste or odour of the water.
Mercury (total)	0.001	For total mercury (inorganic plus organic).
Nickel	0.02 (P)	
Nitrate (as NO^{-3})	50	Short-term exposure. The sum of the ratios of the concentration of each nitrogen compound (nitrate, nitrite) to its guideline value should not exceed 1.
Nitrite (as NO^{-2})	3	The sum of the ratios of the concentration of each nitrogen compound (nitrate, nitrite) to its guideline value should not exceed 1.
PESTICIDES AND HERBICIDES	**GUIDELINE VALUE (µg/litre)**	**REMARKS**
Aldrin/dieldrin	0.03	For excess risk of 10^{-5}.
Atrazine	2	
Chlordane	0.2	
DDT	1	
2,4-D	30	
Heptachlor	0.03	
Hexachlorobenzene	1	For excess risk of 10^{-5}.
Lindane	2	
MCPA	2	
Methoxychlor	20	
Pentachlorophenol	9 (P)	
Simazine	2	
Trifluralin	20	
2,4,5-T	9	

(Continued on next page)

Table 3.3: Common chemicals of health significance in drinking water (continued)

PESTICIDES (continued)	**GUIDELINE VALUE (µg/litre)**	**REMARKS**
Lindane	2	
MCPA	2	
Methoxychlor	20	
Pentachlorophenol	9 (P)	
Simazine	2	
Trifluralin	20	
2,4,5-T	9	
DISINFECTANTS	**GUIDELINE VALUE (mg/litre)**	**REMARKS**
Monochloramine	3	
Dichloramine chlorine		Inadequate data to permit recommendation of a health-based guideline value.
Trichloramine chlorine	5	Concentrations at or below the health-based guideline value may affect the appearance, taste or odour of the water. For effective disinfection there should be residual concentration of free chlorine of >0.5 mg/litre after at least 30 minutes contact time at pH <8.0.
DISINFECTANT BY-PRODUCTS	**GUIDELINE VALUE (µg/litre)**	**REMARKS**
Trihalomethanes (THMs) (The four compounds below form the trihalomethanes.)		Generated principally as by-products of the chlorination of drinking water, being formed from naturally occurring organic compounds. As outlined in the WHO guidelines, if an organisation wants to establish a total THM standard to account for additive toxicity a fractionation approach can be used whereby the sum of the ratios of each of the four THMs to their respective guideline values is less than 1.
Bromoform	100	
Dibromochloromethane	100	
Bromodichloromethane	60	For excess risk of 10^{-5}.
Chloroform	200	For excess risk of 10^{-5}.

Note: P = provisional guideline value. There is evidence of a health issue, but available information on health effects is limited.

Source: Extracted from WHO, *Guidelines for drinking-water quality*, 3rd edn, vol. 1, *Recommendations*, World Health Organization, Geneva, 2004, viewed 8 December 2004 <www.who.int/water_sanitation_health/dwq/guidelines/en/>.

EXAMPLE PAGE FROM A FIELD NOTEBOOK: STANDARDISED SAMPLE FORM

Site/sample location:			Description:		
Date:			Time:		
Weather conditions:					
Samples collected	Sample no.:				
	Sample no.:				
Sampling depth:					
Problems encountered/adaptations made during sampling:					
Sample preservation and storage:					
Sample transport:					
Analysis undertaken on site:					
Variable	Method used	Equipment no.	Sample/blank	Reading value	Units
Notes on on-site analysis:					
General remarks/observations about sample (eg colour, turbidity, odour):					
Sampled by:		Signature		Date:	
Samples received by:		Signature		Date:	
Data received by:		Signature		Date:	

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Part 3
Supporting guidance

Australian Government

AusAID

Managing arsenic in water supplies

INTERIM AUSAID GUIDELINES AND OPERATING PROCEDURES
FEBRUARY 2004

UPDATED APRIL 2005

www.ausaid.gov.au

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Contents

Purpose of these interim guidelines

These procedures provide guidance for AusAID officers, activity managers and NGOs on how to deal with water supplied from sources where arsenic contamination is likely and provide protocols to be undertaken prior to establishing new water supplies.

Although arsenic is only one of several water contaminants, its occurrence and chemistry make it worthy of special guidance. Other water quality issues will be addressed in more general guidelines to which the arsenic guidelines will be annexed. These guidelines are of particular relevance, but not limited to small-scale activities in remote locations, including:

> NGO projects

> small activity scheme projects

> community access fund projects

> small-scale water supply infrastructure.

The guidelines are intended as a practical field guide recognising AusAID's commitment to **duty of care** and, in this respect, require as part of overall project design that **all drinking water** provided under AusAID-funded projects **be safe drinking water**, that testing for arsenic or surrogates be conducted by **appropriately trained personnel** and, where existing supplies are contaminated, that **management strategies** to reduce health risks be developed with the relevant authorities.

The guidelines **focus on avoidance of water that is known to contain arsenic** precluding AusAID funding new water sources where WHO guidelines are exceeded unless specifically negotiated, and agreed with national authorities**.** They do not cover health advice or arsenic treatment advice (although further web references are provided).

Automatic selection of groundwater sources is discouraged with an emphasis on the **need to consider other options for drinking water** (rainwater collection, treated surface water). There are significant differences in volumes of water required for drinking and those required for washing and other purposes. In the longer term, the provision of roof water collection devices and tanks and/or treatment of surface water is likely to be less complex, less expensive and less time-consuming than treatment to remove arsenic and subsequent management of arsenic-contaminated wastes.

While the surrounding landscape and geology should be used to provide indicators of possible arsenic presence, in many instances water quality will not be known, and the only feasible method of testing water quality will be through the use of portable chemical test kits. **No personnel should be collecting samples, undertaking chemical tests, using test kits or analysing the results of such tests without having a basic understanding of the chemistry and test method being used**. Training and experience will be needed for any field personnel being sent to test for water quality.

Knowingly burdening the poor and vulnerable with contaminated water sources on the assumption that disease, inadequate nutrition and sanitation will impact on health before contaminated water is no longer a tenable argument.

The material in the guide is not referenced specifically. It is collated from a variety of standard chemistry texts and water quality management manuals, and is informed by the results of the ongoing AusAID Regional South Asia Arsenic Research Program. Periodic updating of the guidelines will be undertaken when new analysis and research findings emerge. The websites listed in the references are vetted for quality advice, and are updated regularly.

Appendix A to the procedures provides additional information on issues of water quality and the nature, occurrence and treatment of arsenic in water sources. This is provided as an introduction to more technical issues for NGOs or other small-scale activity managers who may need to consider them.

1 Background

1.1 ARSENIC OCCURRENCE

Arsenic (As) is a toxic metal that is widespread in groundwater in many countries in which AusAID operates. Arsenic occurs widely in aquifers in deltaic sediments near mountain uplift zones, and in deep sandy aquifer layers originating as riverine, lake or coastal deposits. This geology is common in the Ganges, Mekong and Red River deltas, and in other sandy alluvial deposits in South Asia, South-East Asia, South America, and in many parts of North America and Europe. Arsenic also occurs as a contaminant produced as a result of mining and manufacturing industries. Countries that have extensive naturally occurring arsenic in groundwater and hence, potentially in drinking water include: India (especially in Bengal), Bangladesh, Nepal, Thailand, China, Mongolia and Tibet, Viet Nam, Laos, Cambodia, Myanmar, various South American countries and areas in North America and Western Australia.

Arsenic contamination is commonly associated with fluctuating water tables and flooding cycles particularly in acid sulfide/sulfate soils or where iron and/or manganese-enriched layers, or saline-layered aquifers occur. Under these conditions the complex chemistry of arsenic will result in changes depending on exposure either to air or saturated soils. Levels of arsenic contamination in water supplies can vary through a year adding to the difficulties of identification and monitoring.

When considering a water supply activity in any areas/countries where groundwater is known to be affected by arsenic, activity designers/managers need to ascertain whether arsenic is present locally, and what other associated water quality issues might pertain to that groundwater or to alternative local surface waters. Guidelines for testing and managing the issue of arsenic are found in Sections 5, 6 and 7.

1.2 ARSENIC CHEMISTRY, AND THE DIFFICULTY OF MEASURING ARSENIC

Arsenic has the ability to switch between two valency forms, As^{3+} and As^{5+}. The three-valent form (As^{3+}) is more soluble and more likely to be absorbed than the five-valent form (As^{5+}). This switching property makes detection and measurement difficult and frequently unreliable. Measuring arsenic at low concentrations is not simple, and therefore needs to be undertaken with care by trained staff and with proper quality control measures in place. Any method designed to measure arsenic in only one form will commonly not detect its total presence or concentration [usually expressed as micrograms per litre (µg/L) or parts per billion (ppb)].

Additional caution is needed in sandy soils where recent research has shown that silica (sand) as grains or in solution[1] masks the signal of arsenic from many chemical test methods. This has a dual effect of creating false optimism – firstly, by making arsenic levels in sandy areas appear lower than they are and, secondly, by making it appear that sand filters have removed arsenic from water.

As a result, **the confident identification and quantification of arsenic in water requires sophisticated atomic absorption or mass spectrometer techniques**[2], preferably graphite furnace atomic absorption spectrophotometry (GFAAS), or inductively coupled plasma mass spectroscopy (ICP-MS).

These techniques, however, require relatively expensive procedures undertaken in well-equipped laboratories, and thus **are not generally recommended in small-scale and community-based NGO projects**.

1 Silica's solubility increases with water temperature.

2 We are aware that a more accurate field laboratory kit is being developed in Australia by CRC and may be available in the near future.

2 Need for procedures

Arsenic is toxic. Negative health impacts are related to: its concentration in food or water; cumulative exposure to arsenic; and genetic predisposition to its effects. Arsenic is bio-accumulative. Symptoms take 5 to 15 years to appear where continuous exposure occurs at concentrations in water of around 20 µg/L. Vulnerability to arsenic poisoning is also related to other health issues including nutrition. Symptoms include skin lesions, respiratory problems, multiple internal organ damage and subsequent cancers.

Although arsenocosis is unlikely to be a major cause of morbidity and mortality in comparison with severe diarrhoeal diseases, arguments to justify the supply of arsenic-contaminated water on that basis are invalid. Arsenic is carcinogenic and continuing exposure should be minimised. **Any agency knowingly supplying drinking water contaminated with arsenic (or other contaminants) would be in breach of their duty of care**.

These interim procedures have therefore been developed to provide guidance for dealing with the issue of arsenic in AusAID-funded activities and programs. To avoid arsenic-related health risks from water supply, AusAID's **focus is on providing safe water** for drinking and cooking, and to address problems of arsenic contamination in water for cereal crop irrigation, kitchen gardening or gardens for growing root crops.

AusAID is involved in the provision of water supplies through a number of activities. AusAID's water policy, published as *Making every drop count: water and Australian aid*,[3] highlights the improvement of water quality as a future direction for the aid program. The concepts discussed in this paper are applicable to all activities potentially affected by arsenic. However, these procedures, which are based on avoiding arsenic-related problems, are particularly relevant to small-scale projects.

[3] AusAID, *Making every drop count: water and Australian aid*, Australian Agency for International Development, Canberra, March 2003, <www.ausaid.gov.au/publications/>.

In larger-scale bilateral programs arsenic can be managed through water treatment technologies paid for by end-users that will generally be too complex, inappropriate because of scale, and unaffordable for smaller-scale activities.

Although the primary objective is the supply of safe water, it may not be possible to achieve that in a single step, especially for existing water supplies. **The application of these guidelines will call for some judgment, and typically will require a negotiated and documented decision-making process with partner governments, NGOs and other stakeholders**.

3 Current research activities & priority concerns

The AusAID South Asia Section has funded a program of applied research into various aspects of managing arsenic-contaminated groundwater. It involves three contractors/project managers and comprises three projects looking at the relative health impacts, identification, treatment and management of arsenic-contaminated treatment wastes, for both small and larger-scale applications. The ongoing findings of this research place AusAID in a position of being able to give sound and informed advice. There are lessons learned from South Asia that can be applied in the Mekong region and they have been taken into account in developing these procedures. Some issues are however particular to the nature of the Mekong region aquifers, and to cultural practices in South-East Asia. The AusAID Water Group has adopted water quality issues within their terms of reference and should be used as the AusAID coordinating point for ongoing information on this issue.

Research in South Asia has demonstrated that the primary danger comes from drinking or cooking with water with high levels of arsenic. However long-term ingestion of rice irrigated with arsenic-contaminated groundwater can also lead to symptoms of arsenocosis, and root crops (especially water-loving lily roots) such as taro, arum or lotus can also become contaminated if they are grown in gardens irrigated using arsenic-contaminated water. Such water is generally supplied from wells or bores, not river-flood irrigation.

Since arsenic is a cumulative poison, people living in areas of arsenic-contaminated groundwater should be encouraged to eat food irrigated with river water, and/or to dilute their arsenic intake by drinking and cooking with water from arsenic-free alternative sources whenever possible. Ongoing findings from the AusAID-funded South Asia Arsenic Mitigation Program in Bangladesh demonstrate that it is possible to shift community reliance on deep tubewells to more integrated, safe and cost effective alternative approaches.

4 Water quality standards & guidelines

WHO has published *Guidelines for drinking-water quality* (3rd edn) in which a contemporary **value for an acceptable maximum level of arsenic was set at 10 µg/L** for 'safe' water. This is a guideline only, and countries have adopted different national standards that set upper limits for arsenic. The United Nations has prepared a synthesis report on arsenic in drinking water, which identifies a number of countries' national standards for arsenic in drinking water. These standards range from 7 µg/L (Australia) to 50 µg/L (Viet Nam, Cambodia, Laos, Bangladesh) (see <www.who.int/water_sanitation_health/dwq/arsenic3/en/>).

As part of its duty of care AusAID requires that all drinking water provided under any project or activity that it funds, must be safe drinking water. To this end bilateral, multilateral and NGO activities and programs must ensure that any water supply programs funded by AusAID meet appropriate benchmarks for safe water. In the case of arsenic, they must endeavour to meet WHO guidelines for any drinking water being provided. This may be problematic in countries where national standards allow the use of water that does not meet WHO guidelines. In this case, after a due process of risk assessment and consultation and negotiation with partner government public health officials, a decision may be taken to continue to provide water that meets national government standards where these are not higher than 50 µg/L. In such situations project and program managers should continue to **advocate progressive application of WHO guidelines**, seeking first to avoid providing water from sources with the highest levels of arsenic contamination, and to provide appropriate public information on arsenic and its dangers. In countries where no national water quality standards exist, project managers should endeavour to negotiate adherence to WHO guidelines. As per Section 3, arsenic-free water should be encouraged for drinking, cooking and irrigation or root crop gardening.

Further technical details on standards, measurement and treatment are given in **Appendix A.**

5 Role of test kits in measuring arsenic

Test kits are relatively inexpensive, portable, and generally operate on measuring/observing an immediate chemical reaction. However, in practical terms, field test kits have inherent limitations to their use in isolated village situations. They require replenishment of chemical reagents so incur maintenance costs, and their results can be easily invalidated unless the chemical protocols that eliminate cross-contamination are adhered to strictly.

Test kits may be very good for demonstrating the presence of particular chemicals or pathogens, but currently they are not always sufficiently sensitive, or accurate for quantitative assessments. Test kit results should be regarded as initial indicators. Their main limitation is that in raw water samples many chemical reactions may be masked by others occurring in the same solution. The range of technical accuracy of test kits varies generally with their price, but none currently on the market is sufficiently sensitive to provide the data needed to ensure particular quality standards are reached.

Arsenic's propensity to switch valency states means that As^{3+} is more likely to be indicated by test results, while the presence of As^{5+} may not be identified because it reacts more slowly. Test kits therefore commonly under-evaluate total arsenic presence. The most effective use for portable test kits is to indicate the presence of arsenic. As a general principle, these guidelines recommend that, **if the test kit demonstrates the presence of arsenic, alternative safe drinking water sources need to be identified.**

6 Procedures for new water supply & irrigation projects

6.1 AWARENESS

All country, regional and NGO program areas dealing with water supply in any country potentially affected by arsenic should be aware of the latest information relating to this issue. Similarly project designers, activity managers, NGOs and Posts undertaking designs and/or monitoring small activities should check relevant literature and local anecdotal material to assess the likelihood of the presence of arsenic in the project area.

6.2 PROJECT FEASIBILITY AND APPROVAL

No project/activity that intends to provide drinking water from groundwater (either bilateral, multilateral or NGO) will be approved without evidence that:

> water quality or a surrogate indicator determined through a risk management analysis has been tested in advance

> the tested water meets WHO guidelines and/or meets national standards (with a clearly defined strategy to achieve safe water quality), and

> appropriately trained personnel will be responsible for field testing.

In special circumstances where laboratory testing is proposed or deemed necessary, initial and/or ongoing testing and appropriate quality assurance costs should be included in the proposals. Such laboratory testing would be appropriate only in uncommon situations where a risk analysis indicates the level of arsenic concentration is likely to be very low, and no alternative safe water source can be identified.

6.3 INDICATORS, TESTING, MEASUREMENT STANDARDS AND HANDLING

Given the complexity of arsenic-related issues and the broader water quality and development contexts, AusAID does not stipulate generic standards or methods for assessment of arsenic or other water contaminants. The *Safe water guide for the Australian aid program 2005*[4] is AusAID's broader water quality guide, which

[4] AusAID, *Safe water guide for the Australian aid program 2005: a framework and guidance for managing water quality*, Australian Agency for International Development, Canberra, April 2005, <www.ausaid.gov.au/publications/>.

advocates a risk management approach that NGOs and activity managers should follow.

As a first step program managers need to check relevant literature and local anecdotal material to assess the likelihood of the presence of arsenic in the project area. Geographic/geologic indicators should also be used to identify and avoid likely areas of contamination.

Where a test program is required, it will need to take into account that test kits in most cases can indicate only the presence of arsenic, but not its concentration with any degree of accuracy.

GUIDELINES FOR THE USE OF FIELD TEST KITS

If arsenic is recorded in a chemical field test kit, it is likely to be present in sufficient concentration to regard that water source as unsafe. The water source should therefore not be used for drinking, cooking or irrigating food crops. Similarly a positive value for arsenic from a portable X-ray diffraction/fluorescence device or similar should indicate that the source of water is unsuitable for drinking.

If a test kit result shows extremely high Fe or high Fe with Mn, the likelihood of arsenic being present is high, so the **water source should not be used for drinking, cooking or irrigating food crops.**

If, in an area that arsenic presence is considered likely, test kit results indicate no As, Mn or above-normal Fe, then such water sources appear on initial indication to be safe from arsenic contamination. **These sources can be used, but a random laboratory test program must be put in place**. If arsenic is later detected at high levels then program managers need to negotiate closure or a discrimination system, and where appropriate assist in the identification of alternate drinking water sources.

See **Procedure 6.3** for sample handling.

No single test kit procedure alone should be used as an indicator of absence of arsenic in areas where arsenic is known to be widespread. Follow-up tests need to take into account anticipated seasonal and water table variations. Moreover, seasonal/temporal variability in the presence and levels of arsenic in groundwater mean that scientific advice will normally be required, and if laboratory testing is warranted, this will require the use of accredited laboratories.

Where laboratory testing is deemed necessary and appropriate (eg in larger scale and urban water supply projects, or in special circumstances in smaller-scale activities), appropriate handling, laboratory and quality assurance protocols need to be followed with all samples tested. A NATA (National Association of Testing Laboratories, Australia), NOAA (National Oceanic and Atmospheric Administration), NAL (National Analytical Laboratory) or an equivalent certified laboratory should be used, and their handling protocols followed.

6.4 PRESENCE OR LIKELY PRESENCE OF ARSENIC

Where arsenic is confirmed as present in ground water, or surrogate indicators, iron (Fe) and manganese (Mn) [or in some areas iron and aluminium (Al)] are present at consistently high levels, the use of surface water sources and roof-collected rainwater should be encouraged. **Small-scale drinking water projects based on groundwater supply will not be supported where supplies are contaminated or where there is strong surrogate evidence of possible contamination.**

In retrospective situations project managers will need to negotiate with partner governments and communities to encourage closing of contaminated wells and/or a culturally appropriate system of marking wells to discriminate between 'safe' drinking water and water suitable only for other uses such as washing.

6.5 MONITORING, RECORDING AND COMMUNICATION

All project-implementing agents should document fully: protocols/procedures followed; results of tests for arsenic and surrogate indicators; and responses to arsenic occurrences. They should seek scientific and legal advice where necessary and report to AusAID, either through exception reporting and final project reports, on any issues of particular concern, and provide copies of any maps of arsenic occurrence that they produce.

In all cases where field or laboratory tests are carried out for arsenic, the location of the sample bore and the result should be noted – preferably using a GPS, but alternatively using map coordinates. A database should be maintained by any agency undertaking such testing, to be collated and mapped by a central coordinating agency as soon as possible (eg relevant government water/health agency). Where appropriate AusAID will attempt to facilitate such coordination, including through sharing info with WHO and UNICEF regional offices.

The results of all testing should be shared with the relevant local authorities and local communities. Any follow up action required by the test results (eg advocating closing wells or not proceeding with planned wells and instead seeking alternative water sources) should be negotiated with the agreement of the relevant local authorities and communities.

7 Procedures for an existing groundwater supply

7.1 PRESENCE OF ARSENIC

If water quality testing reveals the presence of arsenic in existing water supplies at unacceptable levels, or if it is shown to be highly likely, **all attempts should be made to inform the local authorities and community of the dangers of arsenic ingestion and to negotiate closing the source as a drinking water supply**. Negotiating to close a water source is normally very difficult unless there is an arsenic-free well or other safe water source located nearby, or the project-implementing agent can provide an alternative accessible water supply. However, AusAID cannot support continued use of an arsenic-contaminated source for drinking water and implementing agencies must ensure appropriate duty-of-care procedures are followed. This may mean that in clearly defined circumstances, AusAID will accept partner government standards for drinking water where these are higher than WHO guidelines, where the partner government assumes responsibility in writing for the quality of the drinking water. **However, this will be considered only in the context of a longer term plan to achieve WHO guidelines for safe drinking water.**

In situations where wells funded by AusAID are found to be contaminated with levels of arsenic above the WHO guideline for safe drinking water, and/or partner government standards, AusAID recommends that activity managers negotiate to close the source(s) or, if appropriate, to institutionalise a system of discriminating and/or colour-coding water sources on the basis of use-suitability. One colour or symbol could indicate that the source can be used for such purposes as washing and laundry, another that the source is safe for drinking, cooking and/or irrigating. To minimise health risks, wells should be closed progressively, starting with the highest levels of contamination, and working towards the provision of safe drinking water. (Refer to WHO on mitigation of arsenic in drinking water <www.who.int/water_sanitation_health/dwq/arsenic2/en/index3.html/html>.)

7.2 COMMUNITY/COUNTERPART RESISTANCE TO CLOSING AN EXISTING DRINKING WATER SOURCE

If local communities, or authorities, are adamant that contaminated wells meet their standards and cannot be closed down but that they will continue to be used for drinking water, the implementing agency is to follow appropriate duty of care procedures. This will involve undertaking a comprehensive awareness and information program to ensure that community members and local government authorities are fully informed of the dangers of continuing to use the water source/well for drinking. It should be noted that **AusAID cannot support the continued use of such wells for drinking** and implementing agencies should as far as possible, endeavour to obtain written agreement from the local government that it accepts responsibility for the ongoing quality of the well water. This is required so that AusAID can demonstrate that it has followed its Duty of Care responsibilities, and that the counterpart government accepts the risk and ongoing responsibility for continuing to use the water source. If appropriate, AusAID may consider funding alternative water supply sources such as treated ground water or water catchment techniques.

7.3 MONITORING, RECORDING AND COMMUNICATION

If arsenic is demonstrated to occur in an existing water supply, the procedures for monitoring, recording and communicating this information, as set out in section 6.5, should be followed (refer to the WHO guidelines).

A Water quality issues – arsenic in groundwater

A.1 INTRODUCTION

Water quality issues are a fundamental source of concern for agencies involved in the provision of water supplies throughout the world. Morbidity or mortality can result from the direct or indirect effects of faecal pathogens; other pollutants such as excessive organic wastes, nitrite, persistent organic pollutants (POPS); other hazardous chemicals, toxic effluents from a variety of waste disposal situations; or aquatic disease vectors.

Arsenic (As) as a water quality issue began to attract international attention in the early 1990s when widespread chronic arsenic poisoning became apparent in Bangladesh and West Bengal. **Chronic arsenic poisoning, or arsenocosis, occurs as a result of long-term arsenic exposure through drinking water and/or ingesting arsenic-contaminated food.** The symptoms and signs of arsenocosis appear to differ between individuals, population groups and geographic areas. Thus there is no universal definition of the disease caused by arsenic. The symptoms of chronic arsenic poisoning can take between five and fifteen years to appear and are apparently influenced by nutritional and general health status (refer to Section 3).

A.2 OCCURRENCE OF ARSENIC

Arsenic is a natural element, found throughout the earth's crust. Arsenic enters water through the dissolution of minerals. Industrial effluents also contribute arsenic to water in some areas. Arsenic does not affect the taste, colour or odour of water.

Inorganic arsenic can occur in the environment in several forms. In natural water sources, and thus in drinking water, it is mostly found as trivalent arsenite (As^{3+}) or pentavalent arsenate (As^{5+}).

Arsenite (As^{3+}) is more mobile and therefore more toxic than arsenate (As^{5+}), but transformations between the two occur naturally. Several arsenic treatment technologies rely partially on transforming arsenite into arsenate. This is because arsenate is less soluble, and therefore easier to remove from water.

There are several theories relating to how arsenic has been mobilised into the groundwater. According to the United Nations Foundation there are two leading theories (pyrite oxidation and oxyhydroxide reduction) but it is the oxyhydroxide reduction theory that is gaining credence. Both processes may also act in association.

Pyrite oxidation theory: Due to extraction of groundwater, air and water containing significant dissolved oxygen is drawn underground where it reacts with arsenopyrite minerals. This oxidation reaction releases arsenic into the groundwater. Thus the increased use of shallow tubewells is implicated as a cause of the current arsenic problem.

Oxyhydroxide reduction theory: Due to a high level of natural, arsenic-rich organic material buried in the sediments over time iron oxyhydroxides *are being reduced* and releasing the arsenic. This theory implies that the release of arsenic into groundwater has not been triggered by human action.

A.3 HEALTH EFFECTS

AusAID is acutely aware of further burdening the poor and vulnerable with contaminated water sources but in many situations there are no easy or rapid solutions to providing 'safe' drinking water. The health impacts of long-term exposure to arsenic contaminated water and foods are significant but in many poor communities disease, inadequate nutrition, sanitation and other factors are likely to have a more immediate impact on rural welfare. This however is no justification for donor compliancy and these guidelines are seen as an important step in ensuring the supply of safe drinking water.

Following long-term exposure of 5 to 15 or more years to arsenic, the first physical changes are usually observed on the skin. Typically this manifests in the appearance of small black or white marks (melanosis), then thickening of the skin on the palms and the feet (keratosis), followed by skin lesions and eventually skin cancer. Internal cancers are a late phenomenon, and usually take more than ten years to develop. In advanced stages of arsenocosis, parts of the body develop gangrene, making the victims appear similar to leprosy patients.

The early symptoms of arsenocosis (eg melanosis) appear to be reversible and/or can be arrested if exposure to arsenic- contaminated water is avoided (Egis et al. 2000).

Increased risks of lung and bladder cancer and of arsenic-associated skin lesions have been observed **in people drinking water with arsenic concentrations of less than 0.05 mg/L over long period of time** (WHO 2001).

It should be noted that absorption of arsenic through the skin is minimal, so the use of arsenic-contaminated water for non-potable uses (hand-washing, bathing, laundry, etc.) should not pose a risk to human health (WHO 2001).

Studies have shown that grain crops and water-loving root crops readily take up arsenic. Thus water that contains arsenic should not be used in their cultivation. There is some disagreement over the potential health impact of eating other food grown with arsenic-contaminated water. Recent work by the ANU indicates that, in general, there is a minimal health impact, but a UNDP study shows the converse. Further studies are being carried out, including the AusAID-funded Egis (now GHD) project, and work by ACIAR.

A.4 MEASUREMENT OF ARSENIC

Due to arsenic's tendency to shift valency states it is essential to test for both arsenite (As^{3+}) and arsenate (As^{5+}).

Field testing kits will detect the presence of arsenic where it occurs at high concentrations, and as such they can be useful as an indicator. However, kits are generally inaccurate for lower concentrations that are still of concern for human health (WHO 2001). Many of the test kits claim accuracy down to 0.05 mg/L, but independent tests have shown that **the kits are unlikely to meet this standard in practice** (Jadavapur University 1999).

To identify arsenic in water at low concentrations or to measure such levels accurately, requires laboratory analysis using one of three methods: (1) an atomic absorption spectrophotometer (AAS); (2) an inductively coupled plasma emission spectrophotometry (ICP-ES) analyses; or (3) a sensitive x-ray diffraction (XRD) analysis. Only three types of laboratory are likely to have this capability:

> hospital and other medical laboratories

> water quality laboratories attached to national and some provincial water supply authorities, and

> private and university consulting laboratories and/or research laboratories.

Note some research/teaching laboratories may be able to use alternative tedious but cheaper wet chemistry methods involving colorimetric (spectrophotometric) analyses. Also modern laboratories need to replace the special lamps for arsenic analysis when using AAS.

When choosing a laboratory attention needs to be paid to their quality certification (NAL or equivalent) or, failing that, to the laboratory's quality assurance system. Cross checks with a certified laboratory can be undertaken to ascertain the quality of non-certified laboratories.

Samples to be tested for total arsenic are robust, making it possible to send the sample over some distance to a laboratory. Whilst temperature does have an impact on the split of arsenite and arsenate in water, the total amount of arsenic is not likely to be affected at normal transport temperatures.

A.5 TREATMENT AND WASTE DISPOSAL

A.5.1 REMOVAL OF ARSENIC

Removal of arsenic from water supplies can be carried out in a number of ways and utilising a variety of different technologies. The efficiency and appropriateness of the various techniques available needs to be assessed on a case-by-case basis. Most arsenic removal technologies are most effective at removing the pentavalent form of arsenic (arsenate). Appropriate technology must be economically viable and socially acceptable.

Techniques for removal of arsenic from water are based primarily on a few basic processes:

> **Oxidation of As^{3+} to As^{5+} by addition of a suitable oxidising agent**
  The oxidation reactions do not remove arsenic from solution, but are often used to optimise other processes such as coagulation, adsorption or ion exchange.

> **Precipitative Processes including coagulation and filtration**
  Dissolved arsenic forms a low-solubility (solid) mineral (such as calcium arsenate). This solid can then be removed through sedimentation and filtration.

> **Adsorption processes**
  Various solid materials, including iron and aluminium hydroxide flocs, have a strong affinity for dissolved arsenic. Arsenic is strongly attracted to sorption

sites on the surfaces of these solids and is effectively removed from solution by adsorption.

> **Ion exchange**
Ion exchange is sometimes considered as a special form of adsorption. Ion exchange is a physical/chemical process by which an ion on the solid phase medium (the resin 'filter') is exchanged for an ion in the feed water. This solid phase is typically a synthetic resin, which has been preferentially chosen to adsorb the arsenic.

> **Membrane filtration Including reverse osmosis**
Membrane filtration concentrates ions (including arsenic ions) on one side of the membrane, leaving purer water on the other side.

In the developing country context, the removal of arsenic from water is generally accomplished by either adsorption or oxidation, together with precipitation. Sand filters are often used to remove the adsorbent/precipitate. **This contaminated sand material tends to provide the greatest challenge for disposal.**

A.5.2 TREATMENT OF ARSENIC

The following descriptions of treatment options have been drawn from Egis (2000) and Murdoch University (2000). They derive from the ongoing findings of the AusAID funded South Asia arsenic research and management program. **All methods require safe disposal of arsenic** (refer to section A.5.3).

Treatment by adsorption

> **Clay pot filtration**: using a tablet which oxidises arsenite to arsenate and binds it to iron oxyhydroxide formed through oxidation of iron in the water.

> **Use of natural or modified clay minerals** (particularly iron- or iron-aluminium oxides such as bauxite and laterites) to adsorb arsenic. Work on binding these clays into bricks/ceramics for disposal is ongoing.

> **Synthetic glass/ceramic materials**: use of synthetically prepared clay materials to adsorb arsenic. The raw materials required include saline water and aluminium rich materials (bauxitic minerals or oxidised aluminium cans).

Treatment by oxidation and adsorption

> **Iron salts:** The addition of iron salts forms a floc or gelatinous precipitate and contributes to oxidation of arsenite. The resultant arsenate adsorbs onto the floc, which is then removed by settling or filtering. This is particularly applicable to water with lower concentrations of arsenic.

> **Solar treatment:** This is a variant of the iron salt method in which the sun is used in the presence of iron salts to oxidise the more soluble arsenite to arsenate. Arsenic is then removed by precipitation and settling or filtration.

> **Hypochlorite tablets:** These tablets contain unstable hypochlorite which oxidises arsenic. Naturally occurring iron can be used to precipitate the arsenate compound or iron salts or alum can be added. Arsenic-free water can then be decanted off.

> **Potassium permanganate and alum:** This process is currently under trial. It uses potassium permanganate to oxidise arsenite, and alum to coagulate the resultant arsenates.

> **Oxidising bacteria:** This process is also currently under trial to convert arsenite to arsenate for removal as a precipitate.

Filters

> **Basic filters containing iron filings, sand and barium sulphate** can be used to precipitate arsenic. However arsenic remains in the filter medium, and must be safely disposed of.

Commercial or large-scale filtration

> **Ion exchange resin filters:** These are commercially available for arsenic removal but are expensive unless the cost can be spread over a large user population. The arsenic-loaded filter must be disposed of.

> **Reverse osmosis:** This is effective at removing arsenic. However it is an extremely expensive and sophisticated technology requiring electricity and is difficult to use on a very large scale. Arsenic wastes accumulate in the residual liquid and must be disposed of.

> **Adsorption into ferric oxide granules, followed by filtration:** This method can be used at village/township scale treatment plants. The arsenic-contaminated granules must be disposed of.

A.5.3 WASTE DISPOSAL

All of the arsenic removal methods at some point produce an arsenic-rich waste stream, which must be disposed of in a safe manner. Typically municipal water plants are accustomed to handling chemicals and disposing of wastes.

At community and household levels, operators need to be advised on the responsible handling of wastes. In addition, some of the techniques described above, require additional chemicals, either during routine operation or for media regeneration. The disposal of all these potentially hazardous waste materials must be considered when designing any arsenic removal system to avoid contaminating surface water.

The stability of waste products needs to be evaluated when considering disposal options. If arsenic is likely to leach out of solids, then the wastes may require a specialised disposal area. Achieving safe disposal of this arsenic-contaminated material has proved problematic in Bangladesh. In Bangladesh the groundwater tables are high across the country, so there is a high potential for contaminating surface water.

A.6 SUMMARY OF IMPLICATIONS FOR DEVELOPMENT ACTIVITIES

Activity managers and designers need to build into designs and/or project implementation the cost and activity of:

> prior testing and/or water source selection

> laboratory analysis and monitoring costs if suspect sources are used, and

> if deemed appropriate, treatment option(s) and safe waste disposal.

Activity designers and managers also need to remain aware of the outcomes of ongoing research. This can be done through contacting regional coordinating agencies, or vetted websites. The AusAID Water Group is also a source of information.

References & selected bibliography

This is a list of generic and basic factual material on arsenic in drinking water.

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Further reading for updates

Arsenic in drinking water is a topic of current research interest and material is being produced continuously.

Hanoi University of Science Publications: The Centre of Environmental Chemistry at this university was involved in the writing of the Berg paper and they continue to be involved in work in the field. Their website may be of use <www.hus.edu.vn/tienganh_ver/index.htm>

West Bengal and Bangladesh Arsenic Crisis Information Centre: Describes itself as an 'Online focal point for the environmental health disaster in Bangladesh and West Bengal, India', <http://bicn.com/acic/>.

United Nations Synthesis Report on Arsenic in Drinking Water: This report synthesises available information on chemical, toxicological, medical, epidemiological, nutritional and public health issues. It proposes a basic strategy for dealing with arsenic and provides advice on water treatment technologies and water quality monitoring and management. The draft report is available at <www.who.int/water_sanitation_health/dwq/arsenic3/en/>.

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Australian Government

AusAID

Gender guidelines: water supply and sanitation

SUPPLEMENT TO THE GUIDE TO GENDER AND DEVELOPMENT
MARCH 2000

UPDATED APRIL 2005

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This document is online at www.ausaid.gov.au/publications, where the broader guide *Guide to gender and development* is also available.

Contents

Guiding principles

Promoting equal opportunities for women and men as participants and beneficiaries of development is the goal of Australia's gender and development policy.

WSS projects are increasingly demand-driven. Projects have to be responsive to the articulated demands of users. If women play a minor role in community decision-making, they may well be marginalised under a demand-driven approach unless steps are taken to include them.

Addressing the different priorities of men and women in WSS activities improves the quality and sustainability of WSS projects. For example:

> **Women's needs for water** become more of a project focus. These needs are often related to small-scale activities (gardening, small-scale livestock production and domestic use) but they are vital for the household.

> **The design and siting of WSS facilities** will better reflect the needs of both women and men. For example, laundry facilities might be included and bathing facilities might be sited in areas that offer greater privacy for both men's and women's individual needs. The correct siting of sanitation facilities is particularly important because toilet practices are often the subject of cultural sensitivities that will usually differ between men and women.

> The **technology** adopted is likely to better reflect women's needs. For example, pour-flush toilets may not be preferred because they require considerably more work for women in transporting water. Another example is where hand-pump designs are selected on the basis that they are easier for women and children to use.

> **Technical and financial planning** for the ongoing operation and maintenance of WSS facilities is improved. As the main users of WSS facilities, women tend to be actively involved in maintenance. Women's financial skills make them ideal candidates in saving and managing funds for the ongoing operation and maintenance of WSS facilities.

> The **demand** for sanitation facilities is likely to be high because the strong desire of women and men to have private, convenient and secure facilities for themselves and their children is recognised.

> There are likely to be greater **health benefits** because all members of the community (men, women and children) are involved.

There are countless examples in the developing world of failed WSS projects – piped water systems that no longer carry water, broken hand-pumps and toilets that are never used. In many cases WSS facilities have failed because not all members of the community, and particularly women, were fully involved or fully committed to the project. Community participation does not necessarily mean that both men and women will be included in all project activities. Traditional community groups and community forums that 'participate' may exclude women or restrict their input. This exclusion can occur in spite of the fact that it is usually women who spend a considerable part of their day collecting and using water and who are the family leaders and educators in sanitation and hygiene practices. Including men and women in all project components will not happen unless the project has specific strategies to ensure equal access to project opportunities. Gender strategies vary across projects and environments but should always take into account:

> gender impact of all project components (eg the engineering, institutional strengthening, financial, community development and health components of a WSS project)

> resources (personnel, training, procurement) needed to implement the gender strategies, and

> assessment of the risks associated with implementing gender strategies.

Successfully including men and women in WSS project activities requires gender analysis of the project area. Such an analysis will include an understanding of:

> socioeconomic and cultural context of the project area

> the different priorities, demands and needs of men and women

> men’s and women’s knowledge, attitudes and practices relating to WSS, and
> the constraints to the participation of men and women in project activities.

Without strategies based on a thorough gender analysis, project activities that attempt to be gender inclusive will often become marginalised. For example:

> Women may be encouraged to take on management roles and additional work but receive no additional resources or influence.
> The introduction of ‘user-pays’ for water may be a considerable burden for women as they often have the prime responsibility for providing water.
> Men may stay away from areas identified as being ‘women’s areas’ such as hygiene education and as a result, those components may be seen as less important.
> Women may receive training but may be prevented from putting their new skills and knowledge into practice by cultural or social factors.

Encouraging and assisting men and women to undertake new gender roles requires ongoing project support. WSS projects, therefore, have to focus not only on technical solutions but also on long-term issues such as change management, building community decision-making and leadership skills and improving consultation processes within WSS agencies.

Design requirements

The following key questions are to be used as a guide only. It is not expected that every question will be relevant to all activities. The questions are designed to assist AusAID activity managers with their assessment and appraisal of water supply and sanitation (WSS) activities. The questions are also designed to assist contractors to incorporate gender perspectives into WSS activity preparation and design.

KEY QUESTION

Do the *terms of reference* for the project ensure that gender issues will be integrated into the project design?

WHY ASK THIS QUESTION

If gender issues are to be an integral part of all WSS project activities, the terms of reference must reflect this. Without a gender analysis and consequent gender strategies, the project is unlikely to provide equal access to project opportunities for men and women and is unlikely to be sustainable.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

To ensure gender issues are adequately addressed consult with AusAID's Gender Education Group and with other AusAID staff with experience in WSS projects.

The terms of reference should include the requirement for:

> a gender analysis (an analysis of how gender is relevant to all project components)

> formulation of gender strategies (strategies for ensuring that men and women have equal access to project opportunities), and

> gender expertise within the project team.

KEY QUESTION

Do the terms of reference identify the need for the project team to *raise awareness in counterpart institutions*, of the need for a gender analysis and the formulation of gender strategies?

WHY ASK THIS QUESTION

WSS projects are traditionally implemented by technical agencies such as construction, irrigation or water resource management agencies. Often these agencies do not have expertise in gender analysis or an understanding of how gender issues are relevant to the sustainability of WSS projects.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

The project team needs to provide counterparts with a practical understanding of how gender issues are relevant in the planning and implementation of all components of a WSS project. This can be done by:

- having expertise in gender and WSS on the project team
- explaining the AusAID gender and development policy to counterparts and providing practical examples of how the policy can be supported, and
- presenting gender as an issue that is vital to project sustainability.

KEY QUESTION

Is there *expertise* in gender analysis and gender strategy formulation in the project team?

WHY ASK THIS QUESTION

One or more team members should have gender expertise, particularly for larger, community-based WSS projects. However, in all projects it will be necessary for all team members to have some involvement in gender analysis and gender strategy formulation. This ensures the integration of gender issues into all aspects of the project and raises the profile of gender issues for the counterpart agency.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Because of the short time periods involved in project identification and design, team member/s taking the lead in the gender analysis and gender strategy formulation should:

> be familiar with the country (or a similar country) and with the WSS sector
> have experience in undertaking gender analysis and strategy formulation, and
> have experience in explaining gender issues and their importance to project sustainability to counterpart agencies and other relevant groups.

In project implementation, team member(s) taking the lead in gender analysis and gender strategy implementation should:

> have experience in the practical implementation of gender strategies
> have experience in assisting communities and counterpart institutions to promote the participation of both men and women (eg through community self-assessment, institutional self-evaluation), and
> have experience in monitoring and evaluating the impact of gender strategies.

KEY QUESTION

Does the project approach (such as the itinerary for the project identification mission or the project proposal for the design mission) allow *sufficient time* for consultation and data collection?

WHY ASK THIS QUESTION

Failure to provide sufficient time and resources for consultation and data collection will result in only superficial consideration being given to gender issues and the marginalisation of any gender related activities undertaken.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

In project preparation and design, the time and resources for consultation and data collection should allow:

> consultation with groups who are working in gender and development (religious groups, mothers groups, NGOs, mass organisations, bilateral and multilateral donors and project staff)

> consultation with a sample of target communities (time may limit community consultation during project preparation), and
> consultation with relevant counterpart agencies.

Use of local specialists (preferably women) will greatly improve the efficiency of the consultation and data collection process and give access to a wide range of views. Local specialists may be from a NGO, university or other research organisation or from the relevant WSS agency.

KEY QUESTION

Has AusAID adequately *briefed the project team* on the need to integrate gender issues into all aspects of the project?

WHY ASK THIS QUESTION

It is essential that the team understand AusAID's policies and expectations.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

All team members will be involved in gender analysis and gender strategy formulation. Therefore gender guidelines and other relevant data should be given to all members of project teams, regardless of whether there is a 'gender expert' on the team.

AusAID's Gender and Education Group can provide briefings.

KEY QUESTION

Does the project preparation or design report provide *a summary of the consultation process undertaken and the gender analysis*?

WHY ASK THIS QUESTION

Considerable information can be obtained during the consultation process and the gender analysis but it is of little value if it is 'lost' in an annex and never referred to.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Provide a summary of the consultation process and what steps were taken to include both men and women and what steps were taken to include organisations with an interest in gender issues.

The gender analysis must be presented succinctly to decision-makers in both AusAID and in counterpart agencies and the implications of the analysis for project design and implementation must be made clear.

KEY QUESTION

Has the *gender analysis* been *presented in a way that is relevant* to all decision-makers and to project design and implementation?

WHY ASK THIS QUESTION

Considerable information is obtained during a gender analysis and it should be incorporated into the project design.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

The implications of the gender analysis need to inform the project design and gender strategy formulation and should include:

- men's and women's preferences for water sources, sanitation facilities and design and siting of WSS facilities
- an assessment of the ability of men and women to express those preferences and be involved in project planning
- personal hygiene practices used by men and women
- the types of media most relevant for men and women
- men's and women's likely roles in ongoing operations, particularly whether women will be excluded or whether the project is likely to place a burden on women (eg payment of user fees)
- the skills and resources needed for men and women to fully participate in the project, particularly training and ongoing institutional strengthening and community support
- the skills and resources needed to improve opportunities for men and women in WSS agencies, and

- the skills and resources needed to improve opportunities for men and women in community-based organisations or NGOs in the water sector.

KEY QUESTION

Does the project preparation or design report provide *details of the gender strategies* proposed and have these been included in the *project logframe*, *risk matrix* and where appropriate, *project payment milestones*?

WHY ASK THIS QUESTION

If gender strategies are not specifically written into the project design it is unlikely that they will be adequately resourced or monitored. As with any project activity, there will be risks involved in the implementation of gender strategies and steps need to be taken to ameliorate these risks.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Gender strategies, the resources needed to implement the strategies and monitoring and evaluation requirements should be included in the project logframe.

A risk analysis on the gender strategies should be included as part of the project's risk analysis matrix.

Risks associated with gender strategies might include:

- difficulties in providing training opportunities to women due to the low number of suitably qualified women
- gender strategy is not integral to the project design
- difficulties in providing support to women in the community due to a lack of women field staff
- lack of suitably qualified and experienced locally engaged staff or NGOs
- strong resistance among either men or women to giving women greater access to project opportunities, and
- lack of support from counterpart agencies to giving women greater access to project opportunities.

Steps to ameliorate these risks might include:

> including training opportunities for locally engaged staff and NGO staff in order to build gender expertise
> linking with other agencies and organisations that have suitably qualified women and/or women field staff, and
> patience and persistence in dealing with resistance by some community members and/or counterparts.

Inclusion of gender outcomes as payment milestones will depend upon the degree of control the contractor has over achievement of those outcomes. For example, delivery of training by the contractor could be a payment milestone but increases in the number of senior women in a water supply agency would be beyond the contractors control, although this could still be a gender strategy.

KEY QUESTION

Have *gender strategies* been proposed in the project that will enhance the participation of both men and women in all project activities?

WHY ASK THIS QUESTION

It cannot be assumed that gender strategies will be implemented simply because they are written into the project design. Adequate project resources must be allocated to supporting gender strategies. Detailed gender strategies will vary depending on the nature of the project and the target communities.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Improving the inclusion of women in planning and management by developing their skills and leadership ability through:

> helping men to understand how women's involvement will improve project outcomes
> requiring women to be involved in planning (eg selection of technology, design, siting of facilities)
> providing training opportunities specifically targeted at women (eg women-only training sessions)

> encouraging a greater role for women in management through Water User Groups
> allowing women a say in determining revenue raising arrangements (eg encouraging them to take the financial positions on management committees), and
> building the capacity of local NGOs to provide ongoing support to women in communities.

Improving women's access to WSS facilities in a 'user-pays' environment through:

> flexible payment arrangements that take into account women's income-earning potential, which may be seasonal or uncertain (eg payment by instalment, ability to defer payments), and
> supporting income-earning activities and the provision of credit funds for women where relevant.

Strengthening the capacity of WSS agencies to include both men and women in their activities through:

> encouraging more women into field and extension roles (eg by allowing women field offices to travel together)
> including as a project counterpart agency, an agency that has more female field staff (eg education or health)
> promoting the use of participatory approaches that include both men and women WSS users in planning activities by WSS agencies
> improving the ability of water supply companies to listen to and act on consumer complaints (the majority of which are made by women), and
> providing training in community development and gender issues for upper and middle management in WSS agencies in order to strengthen management's understanding of the links between gender issues and sustainability.

Broadening community involvement in personal hygiene education and enhancing the status of improved hygiene through:

> involving men and men's organisations in personal hygiene education, and
> using various types of media (eg drama groups, television) that are accessible to men, women and children.

All gender strategies formulated during project design will need to reviewed and updated during project implementation.

KEY QUESTION

Have *project resources* (personnel, training, procurement) been allocated to allow implementation of gender strategies?

WHY ASK THIS QUESTION

It cannot be assumed that gender strategies will be implemented simply because they are written into the project design. Adequate project resources must be allocated to supporting the strategies.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Project resources might include:

> project staff with quality experience in gender analysis and implementation

> use of an expatriate gender specialist to coordinate gender activities (the inputs required will depend on the size and complexity of the project with large community managed projects needing the greatest inputs)

> use of an NGO with experience in gender analysis, gender strategy formulation and implementation

> use of long-term locally engaged gender specialists and developing the skills of locally engaged staff

> use of long-term or short-term locally engaged or expatriate specialists with skills in community participation, health promotion and training who also have skills to implement gender strategies, and

> gender awareness raising activities for counterpart staff over the life of the project.

The allocation of resources for the implementation of gender strategies will need to be reviewed during project implementation.

Implementation and monitoring

The following key questions are to be used as a guide only. It is not expected that every question will be relevant to all activities. The questions are designed to assist AusAID activity managers with their assessment and appraisal of water supply and sanitation (WSS) activities. The questions are also designed to assist contractors to incorporate gender perspectives into WSS activity preparation and design.

KEY QUESTION

Is there an appropriate level of expertise to *monitor, evaluate and review* the project's gender strategies?

WHY ASK THIS QUESTION

AusAID must assure itself that the project is meeting quality expectations.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

The technical advisory group (TAG) or equivalent must have specific gender, sector and country experience. AusAID project managers should check that gender issues are covered in project reporting.

KEY QUESTION

Have *gender-sensitive indicators* been established for monitoring the impact of the gender strategies?

WHY ASK THIS QUESTION

Quantifiable targets and indicators are useful for contract management. However, an overemphasis on them can result in a concentration on fulfilling numerical targets rather than looking at quality of project activities. Quantitative targets, therefore, need to be complemented by qualitative interpretation of the targets.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Examples of quantifiable gender indicators might include:

> women's and men's attendance at training sessions, planning meetings or construction activities

> recording the uptake of facilities by number and sex of users

> number of women and positions held within community management committees

> number of women in non-traditional positions in WSS agencies, and

> number of men and women involved in hygiene promotion activities.

In a project that uses a program approach, gender criteria can be drawn from gender indicators if:

> communities and relevant institutions are fully informed of the criteria, and

> criteria are applied realistically.

KEY QUESTION

Are the results of *gender strategy monitoring and evaluation* presented in the Annual Plan?

WHY ASK THIS QUESTION

Projects are undertaken in dynamic environments and gender strategies need to be regularly reviewed.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Progress towards quantitative indicators and qualitative interpretation should be in the Annual Plan. The results of monitoring and evaluation may indicate that a change in strategy is required. This in turn may require changes in project resourcing, which will need to be detailed in the Annual Plan.

KEY QUESTION

Are *gender strategies discussed* in regular contractor's reports (monthly, quarterly, six-monthly) and at project coordination committee (PCC) meetings?

WHY ASK THIS QUESTION

Progress on technical, financial and institutional matters is regularly reported on and discussed in PCC meetings but crosscutting issues like gender are less likely to be reported on and discussed.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

As gender strategies are relevant to all project components, they should be referred to in regular reports.

To raise the profile of gender issues in the project, a representative from the government agency responsible for women's affairs and/or a women's community body (eg a relevant NGO or national women's group) should be on the PCC.

KEY QUESTION

Has there been an ongoing *evaluation* of the impact of gender strategies and a final evaluation as part of project completion activities?

WHY ASK THIS QUESTION

Development projects are conducted in dynamic environments and gender strategies should be evaluated and revised during the project and at project completion.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Evaluations should be based on:

> quantitative data from gender indicators and a qualitative interpretation of that data, and

> a comparison of the situation at the commencement of the project (baseline) with the situation at the completion of the project (eg changes in men's and women's involvement in decision-making, in their WSS practices and in constraints faced by men and women). Large-scale household surveys are generally unnecessary for this comparison. Structured interviews of a sample of the target population are likely to be more effective.

Evaluations should examine the use and sustainability of the project's gender strategies. For example:

> Were opportunities for men and women to participate taken up? If not, why not?

> Are both men and women continuing to participate in and to benefit from the project after project involvement has been reduced or ceased? Again, if not, why not?

KEY QUESTION

Does the *project completion report* document the outcomes and impacts of the gender strategies and the lessons learned from the project?

WHY ASK THIS QUESTION

Gender issues should be specifically referred to in the project completion report, otherwise technical, financial and institutional outcomes will tend to dominate.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Evaluation of the impact of gender strategies and consequent lessons learned can be drawn from:

> changes in various indicators measured throughout the project, and

> a comparison of the situation at the beginning of the project with the situation at the end of the project.

Gender analysis in the field

The following key questions are to be used as a guide only. It is not expected that every question will be relevant to all activities. The questions are designed to assist AusAID activity managers with their assessment and appraisal of water supply and sanitation (WSS) activities. The questions are also designed to assist contractors to incorporate gender perspectives into WSS activity preparation and design.

KEY QUESTION

Have steps been taken to *consult with both men and women* in the target population *(eg communities, WSS agencies and other government institutions)* in order to understand their priorities, demands and needs?

WHY ASK THIS QUESTION

The consultation process must be wide-ranging and flexible as consultation through traditional community and government structures may exclude women. The consultation process should also provide information directly to women if traditional communication structures do not keep women informed.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

The consultation process might include:

> consultation with and providing information to women's groups (eg mothers groups, religious groups)

> scheduling community meetings to fit in with women's schedules (eg in the evenings after the evening meal)

> undertaking village walk-throughs or constructing village maps with women and men separately in order to identify current water sources and sanitation areas used by men and women

> using appropriate women interviewers

> consulting with women separately where women have difficulty speaking in public with men present
> consulting with women and men of different socioeconomic status and different ethnic or cultural backgrounds, and
> meeting with women working within relevant WSS agencies (eg water supply companies, public works departments).

During project implementation the consultation process will be ongoing. Building the capacity of either counterpart staff or a local NGO to undertake this consultation will therefore be necessary.

KEY QUESTION

Have *organisations with an interest in gender issues* been consulted?

WHY ASK THIS QUESTION

Such organisations are useful as part of the consultation process and for identifying resources which the project can potentially access.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Such organisations might include:

> international and local NGOs, volunteers (eg Australian Volunteers Abroad), and mass organisations
> government agencies involved in women's affairs and gender equity, and
> university and other research organisations.

During project implementation the involvement of such organisations will be ongoing and resources may need to be allocated to strengthen their capacity in implementing gender strategies.

KEY QUESTION

Has *sex-disaggregated data* been collected on current practices with regard to WSS and personal hygiene and how these practices differ between men and women?

WHY ASK THIS QUESTION

Practices and use of WSS facilities differ between men and women. Women, for example, do the majority of the water collection and are responsible for most domestic water use.

EXAMPLES OF PRACTICAL RESPONSES OR ACTIONS

Sex-disaggregated data collected might include:

> water source preferences (some sources might be preferred for drinking and some for washing)

> preferences for siting of facilities (some sites may be convenient for particular men's and women's WSS activities)

> design of facilities (women may prefer the inclusion of laundry and bathing facilities)

> attitudes and practices in personal hygiene (hand-washing, handling of faeces)

> cultural sensitivities relating to sanitation (men and women not being able to use the same toilet)

> types of media preferred by men and women for personal hygiene messages (radio, plays, TV), and

> roles of women and men in WSS agencies.

During project implementation this data should be reviewed and expanded as part of a baseline data collection exercise. Community self-surveying and institutional self-evaluation methods can also be used.

References and resources

MANUALS AND SOURCE BOOKS AND INTERNET SITES ON GENDER AND WATER SUPPLY AND SANITATION

Fong, MS, Wakeman, W and Bhushan, A, *Toolkit on gender in water and sanitation: Gender Toolkit Series No. 2*, Gender Analysis and Policy, Poverty and Social Policy Department, World Bank, Washington, 1996.

IRC International Water and Sanitation Centre <http://www.irc.nl> provides news and information, advice, research and training on low-cost water supply and sanitation in developing countries. IRC is an independent, non-profit organisation supported by and linked with the Netherlands Government, United Nations Development Programme (UNDP), United Nations Children's Fund (UNICEF), World Health Organization (WHO), World Bank and the Water Supply and Sanitation Collaborative Council.

UNDP – World Bank Water and Sanitation Program <http://wsp.org>. This site includes information on the Promotion of the Role of Women in Water and Environmental Sanitation (PROWWESS) project which advocates community participation and particularly the participation of women. The PROWWESS project developed the SARAR (Self-esteem, Associative strengths, Resourcefulness, Action-planning, and Responsibility) technique for participatory planning, conducted workshops and trained trainers in how to use the technique.

UNICEF, *Better sanitation programming: a UNICEF handbook*, UNICEF's Water, Environment and Sanitation Cluster (Programme Division) and USAID's Environmental Health Project, 1997.

United Kingdom Department for International Development (DFID), *Guidance manual on water supply and sanitation programs* <http://www.grc-exchange.org/info_data/record.cfm?id=327>. DFID commissioned this Guidance Manual to assist staff and partners develop effective and sustainable water supply and sanitation programs.

USAID's Environmental Health Project <http://www.ehproject.org/>. EHP is a USAID centrally funded project that helps organisations address both pre- and post-industrial transition environmental health preventive components in health and education programs. The principal objective of EHP is to reduce mortality and morbidity in children under five by improving environmental conditions or reducing exposure to disease agents.

Wakeman, W, *Gender issues sourcebook for water and sanitation projects*, UNDP – World Bank Water and Sanitation Program/PROWWESS, Washington, 1995.

Water, Engineering and Development Centre (WEDC), Loughborough University, United Kingdom <http://wedc.lboro.ac.uk/>. WEDC is a training and consulting organisation concerned with the planning, provision and management of physical infrastructure for development in low and middle income countries.

Water and Environmental Health at London and Loughborough (WELL) <http://www.lboro.ac.uk/well/>. WELL is a resource centre promoting environmental health and wellbeing in developing and transitional countries. WELL is managed by the London School of Hygiene and Tropical Medicine (LSHTM) and the Water, Engineering and Development Centre (WEDC), Loughborough University. It is also supported by a network of collaborating institutions. The centre is funded by the UK Department for International Development (DFID).

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Wijk, Christine van and Francis, Jennifer, Global trends in gender and demand responsive water supply, sanitation and hygiene, Paper presented to the UNESCO Regional Workshop on Women's Participation in Water Management, Pretoria, South Africa, 24–26 November 1997.

Wijk, C van, *Gender in water resources management, water supply and sanitation – roles and realities revisited*, IRC Technical Paper 33, 1998.

LESSONS LEARNED IN WATER SUPPLY AND SANITATION

Black, M, *Learning what works: a 20 year retrospective view on international water and sanitation cooperation, 1978–1998*, UNDP-World Bank Water and Sanitation Program, Washington, 1998.

Cairncross, S, *Sanitation and water supply: practical lessons from the decade*, UNDP-World Bank Water and Sanitation Program, Washington, 1992.

Feachem, RG, Bradley, DJ, Garelick, H and Mara, DD, *Appropriate technology for water supply and sanitation: health aspects of excreta and sullage management – a state of the art review*, World Bank, Washington, 1980.

Water and Sanitation for Health Project, *Lessons learned from the WASH Project: ten years of water and sanitation experience in developing countries*, www.WASH, Virginia, 1990.

GENDER ISSUES AND GENDER PLANNING – GENERAL

Briefings on gender and development (BRIDGE) <http://www.bridge.ids.ac.uk/>. An information-analysis service specialising in gender and development issues. Based at the Institute of Development Studies (IDS), Sussex.

ELDIS <http://www.eldis.org/>. Eldis is a gateway to online information on development. Coverage includes social, economic, political and environmental issues. Eldis makes a qualitative selection of materials and structures it for easy access. Eldis is funded by the Danish development agency Danida, and hosted by the Institute of Development Studies, Sussex.

Gendernet (World Bank) <http://www.worldbank.org/gender/>. This World Bank site promotes gender equality, summarises knowledge and experience, and contains a section to facilitate discussion on gender. It includes a number of checklists, namely:

- strategy options for incorporating gender in water and sanitation
- gender issues for project preparation and appraisal in the agricultural sector
- current interventions to incorporate gender into the project cycle, and
- gender issues in project identification and design.

Moser, CON, *Gender planning and development – theory, practice and training*, Routledge, London, 1993.

United Nations Development Fund for Women (UNIFEM) <http://www.undp.org/unifem>. UNIFEM promotes women's empowerment and gender equality. It works to ensure the participation of women in all levels of development planning and practice, and acts as a catalyst within the UN system, supporting efforts that link the needs and concerns of women to all critical issues on the national, regional and global agendas.

Womenwatch (United Nations) <http://www.un.org/womenwatch/>. A United Nations Internet gateway on the advancement and empowerment of women.

PARTICIPATORY METHODS IN WATER SUPPLY AND SANITATION

Narayan, D, *Participatory evaluation: tools for managing change in water and sanitation*, World Bank Technical Paper No. 207. World Bank, Washington, 1993.

Narayan, D, *The Contribution of People's Participation: Evidence from 121 rural water supply projects*, Environmentally Sustainable Development Occasional Paper Series No. 1. World Bank, Washington, 1995.

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