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Managing for safe water

FIELD GUIDE 2007

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This field guide is based on AusAID's *Safe water guide for the Australian aid program 2005*. For further information, contact:

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COVER PHOTO: *S Wasanthi, 11, pulls up some water from her family's well at Madhukarai, Sri Lanka (Madhukarai Integrated Resettlement Project and Community Integration and Resettlement Project).* PHOTO: *Will Salter*

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Abbreviations and acronyms

AusAID	Australian Agency for International Development
EC	electrical conductivity
mg/L	milligrams per litre
TDS	total dissolved solids
UV	ultraviolet
WHO	World Health Organization
WQMP	water quality management plan (sometimes called a safe water plan)

Glossary

The following terms are used generally in managing for safe water.

Aquifer	Subsurface layer or layers of earth, gravel or rock of sufficient porosity and permeability to allow storage of groundwater.
Bacteria	Simple single-celled 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.
Blue baby syndrome	A blood disorder caused when nitrite interacts with the haemoglobin in red blood cells. This reduces the oxygen available in the bloodstream, causing an infant to go blue. Blue baby syndrome is rare among adults.
Catchment	An area of land in which rainwater drains to a particular stream, river, lake, etc. Sometimes it is called the river or lake basin or watershed.
Contaminant	A substance that is accidentally or inadvertently introduced to food, water, soil or air that may be harmful or potentially poisonous.
Diarrhoea	Frequent and watery bowel movements. Diarrhoea can be a symptom of infection, food poisoning, colitis or a gastrointestinal tumour.
Environmental sanitation	The promotion of hygiene and the prevention of disease and other consequences of ill health relating to environmental factors.
Filtration	The process of passing water through a porous substance to remove solids in suspension.
Groundwater bore	A narrow lined hole drilled to monitor or withdraw groundwater from an aquifer.
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 tropical countries.
Parasite	A plant or animal that lives, grows and feeds on or within another living organism.

Pathogen	A bacterium, virus or parasite that causes or is capable of causing disease. It may contaminate water and cause waterborne disease.
pH	Measure of the relative acidity or alkalinity of water. Pure water has a pH of 7; acidic solutions have lower pH levels and alkaline solutions higher pH levels.
Recharge	Replenishment of the groundwater aquifer from water at the surface. Usually expressed as millimetres of water per year.
Ringworm	A fungal skin infection characterised by ring-shaped, red, scaly or blistery patches.
Sanitary inspection	An assessment of potential sources of human faecal pollution, as well as other sources of pollution in the water supply.
Toxic	Relating to the harmful effect of a poisonous substance on a person caused by physical contact, ingestion or inhalation.
Viruses	The smallest life forms known that are not cellular in nature. They live inside the cells of animals, plants and bacteria and may cause disease.
Water quality parameter	Chemical or biological characteristics in water. If particular characteristics in water exceed certain guideline levels the water may be harmful to people 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 way 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 storage, distribution and treatment.

Purpose of the field guide

Managing for safe water: field guide 2007 is based on AusAID's *Safe water guide for the Australian aid program 2005*. The field guide is designed to provide practical advice to planners within local governments, and to non-government organisations (NGOs) and other parties involved in water-related activities at local and community levels. It will assist this target group in planning and resourcing the design and management of water supply systems.

The field guide is based on AusAID's *Safe water guide* produced in 2005.

It is assumed that users of the field guide have a basic understanding of water supply and sanitation systems as well as an appreciation of the role of safe water in developing healthy and sustainable communities. Only experienced people should be involved in the design and management of these systems.

The guide provides an overview of risks associated with different water sources and distribution systems. It also explains briefly the design and implementation of plans to manage water quality, which should focus on managing the threats to water quality and maximising the opportunities to maintain a safe water supply. Such plans assist local officials and other people working with or within communities to understand what is required to manage the water supplies to ensure they are safe.

Although the field guide will assist in identifying key issues in managing water quality, it is not a comprehensive reference for all water quality issues. More technical information should be sought from *Safe water guide for the Australian aid program 2005*, other references suggested and water quality experts as required. An electronic version of *Safe water guide for the Australian aid program 2005* is available from AusAID's website <www.ausaid.gov.au/publications/pdf/safe_water_guide.pdf>.

This guide is tailored for use in the field. It is not a comprehensive reference.

If there is uncertainty about a particular situation it is best to seek professional advice.

The distribution point of a rural water supply in East Timor (AusAID-funded Community Water Supply and Sanitation Project). PHOTO: *Marcus Howard*

The need for improved water supplies

Managing water resources and supplying safe water are two of the greatest challenges for many local communities throughout the world.

Access to safe water is critical for sustainable development in a country, as it contributes to improvements in health, gender equality, community development, the environment, and economic and social wellbeing. Designing and implementing a water supply program that takes into account these links is more likely to have a positive impact on local communities.

In 2006, 1.2 billion people did not have access to safe water and 2.6 billion lacked adequate sanitation.

In recognition of the importance of water to development, international agencies such as the United Nations, the Asian Development Bank, the World Bank, and AusAID, along with many others, are working with poorer communities to help address these challenges.

Table 1 highlights the importance of keeping water safe, of being aware of sanitary measures and of adopting good practices to prevent diseases related to poor water quality and sanitation. The focus of this guide is improving access to safe water.

Most cases of diarrhoea are attributed to unsafe water and inadequate sanitation and hygiene.

Table 1 begins to demonstrate the links between safe water and aspects of the water cycle and day-to-day activities. More information is available from the International Water and Sanitation Centre <www.irc.nl>. Each year there are an estimated 4 billion cases of diarrhoea, of which 88 per cent are attributed to unsafe water and inadequate sanitation and hygiene. From these 4 billion cases 1.8 million people die every year from diarrhoeal diseases, the vast majority being children under 5 years of age.[1]

1 WHO, *Combating waterborne disease at the household level*, International Network to Promote Household Water Treatment and Safe Storage, World Health Organization, Geneva, 2007.

TABLE 1 MAJOR MEASURES TO PREVENT THE SPREAD OF WATER AND SANITATION-RELATED DISEASES

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

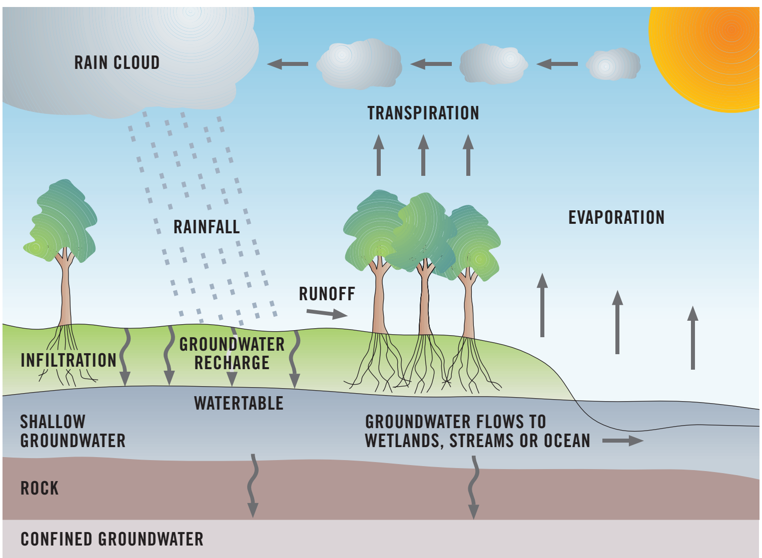
Safe water – part of the big picture

People responsible for developing safe water supply systems need to be aware of the water cycle and how activities can influence this cycle and the quality of water in their area.

Water continually circulates between the atmosphere, the land (including soil and vegetation), and the rivers, wetlands, lakes and oceans (Figure 1). Water emits in three forms: water vapour (gas), fresh water or rain (liquid) or snow, ice or hail (solid). Water moves through these forms in what is referred to as the water cycle. Human and environmental impacts that affect one part of the water cycle can consequently affect the entire cycle or the water supply system for one community. Some parts of the water cycle are important sources of drinking water – for example, stored rainwater, shallow and deep groundwater, runoff, wetlands and streams. All of these are prone to contamination and need to be protected.

What affects the water cycle can ultimately affect the water supply system for one community.

FIGURE 1 THE WATER CYCLE



Assessing and managing risk to water quality

To provide safe water, managers and users of water supply systems need to be aware of all potential risks to water quality. Once risks are known, appropriate strategies can be implemented to minimise the impact of those risks. The process of identifying risks to water quality and of implementing a program to minimise the risks is referred to as 'water quality management'.

Managers and users of water supply systems need to be aware of all potential risks to water quality.

Problems with water quality can result from:

> the nature and associated characteristics of the water source

> how the distribution and storage systems (and surrounding areas) are managed, and

> the sanitary measures and hygiene practices of individuals and communities.

In a water supply system there are various points at which activities and practices can pose risks to water quality (Figure 2). There are numerous options for managing water quality at these points and throughout the water supply system, and some of these are discussed in the section 'Task 3: Prepare water quality management plan'.

FIGURE 2 KEY POINTS OF RISK IN A WATER SUPPLY SYSTEM

Water quality management is most effective when started early and continued throughout the selection, design, construction and operation of a water supply system. The local government, NGO or other interested group that is supporting the village or community when building and managing the water supply needs to ensure that the village or community is fully involved in the process from its inception. One way of doing this is to set up a village or community water management committee, with the assistance of the village or community leader. The committee should represent the different views in the community. It is especially important to involve women in the committee as, in many countries, women are responsible for collecting and using water.

Such a committee will play an important role in guiding the decisions on what type of supply will be most appropriate for the community and how it will be managed. In a rural community, the committee will usually become responsible for operating and maintaining the water supply, whereas in an urban setting it may act more as a consultative group.

The local government or NGO should work closely with the committee to develop a plan for providing a safe water supply and managing water quality. The major tasks to be undertaken by the local government/NGO and the water management committee are:

1 Gather all available information on water quality in the area
2 Identify water quality problems and assess risks to the specific water supply system
3 Prepare a water quality management plan (WQMP), sometimes called a safe water plan, and
4 Implement, review and regularly update the WQMP.

It is essential to identify the problems and potential risks that are specific to an individual water supply system.

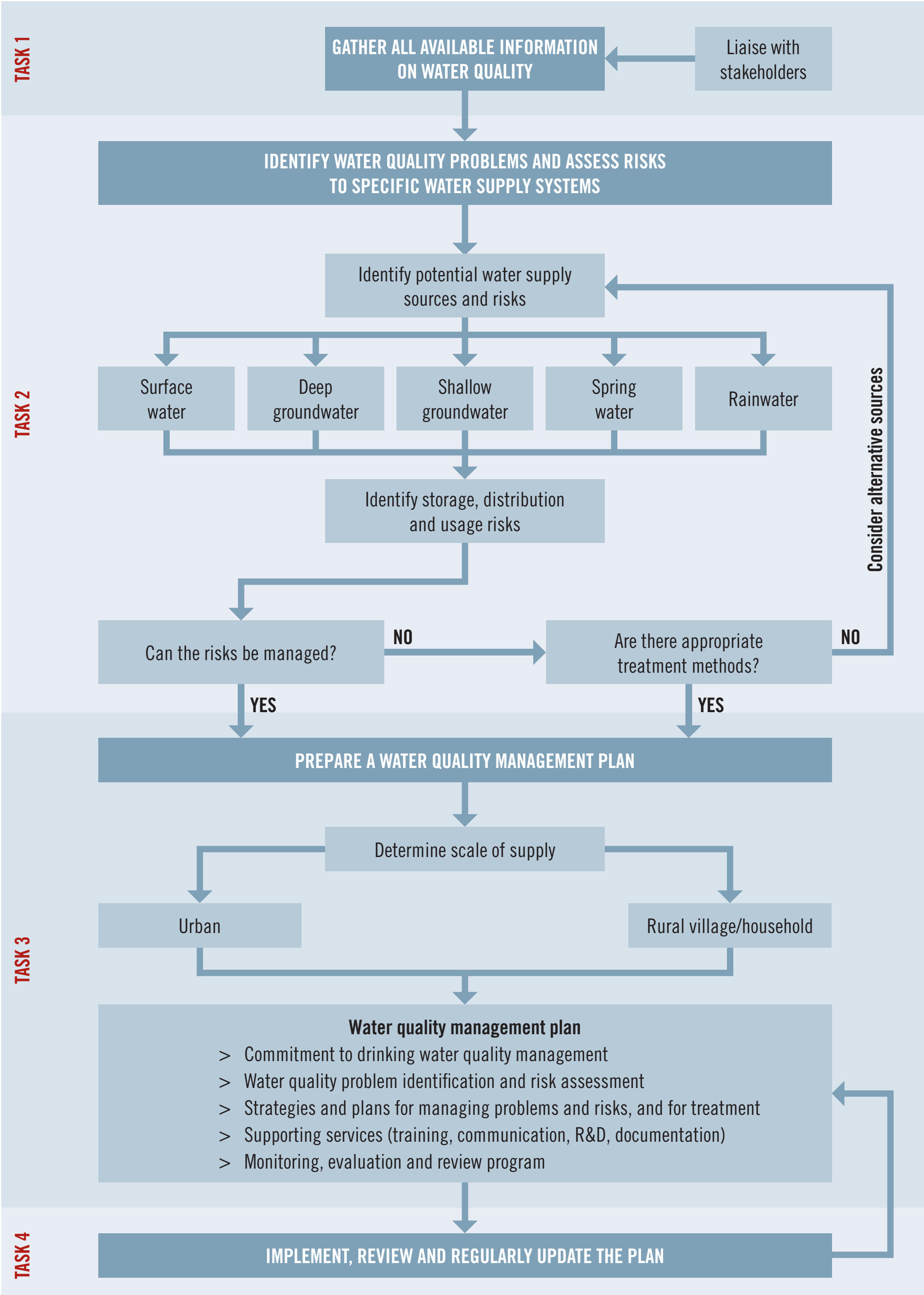
Water supply systems vary significantly even within similar geographical locations. Therefore it is essential to identify the potential risks that are specific to an individual water supply system and then work out how they can be managed.

It is also important that the effort put into collecting information is appropriate to the level of risk associated with providing water of a required quality. It is not practical to spend many hours collecting information on issues that are not important. Being able to judge the level of work required is a skill that is gained through experience. Experienced people in the local government, NGO or other supporting group should be able to assist the water management committee in this risk assessment process.

For more detailed information on the tasks involved in managing water quality refer to *Safe water guide for the Australian aid program 2005* (pp. 13–33).

Figure 3 illustrates diagrammatically the key tasks and decision points required to manage water quality.

FIGURE 3 OVERVIEW OF MANAGING WATER QUALITY



The approach described above is referred to as a 'risk-based framework' for managing the quality of drinking water. The principles of this approach are recommended by the World Health Organization (WHO) and are being applied in many places around the world. Table 2 presents an example of such a framework that could be used by a local government or village.

TABLE 2 EXAMPLE OF A FRAMEWORK FOR MANAGING THE QUALITY OF DRINKING WATER IN A VILLAGE

FRAMEWORK ELEMENTS AND INDICATIVE ACTIVITIES
1 Make a commitment to manage drinking water quality Ensure that there is a commitment to provide an adequate supply of safe water to the village or community in the long term. This commitment should involve both the community and the local government or other supporting organisation, and may require establishing a water management committee to be involved in the identification, design and construction of the water supply and to be responsible for its operation as appropriate.
2 Identify and assess water quality problems and risks Ensure that the entire drinking water supply system is assessed – from water source to user. Ensure that measures are in place to prevent or reduce the risk of water quality problems.
3 Develop and implement strategies and plans for managing risks Ensure operational processes and tasks required to effectively and efficiently prevent water quality problems are implemented and established. Ensure that the water quality meets guideline values (if there are any doubts, avoid sources assumed to be contaminated) and treat it where needed. Ensure that communities are able to identify and respond to situations that can cause the supply system to fail.
4 Provide support (training, awareness raising, R&D, documentation) Ensure that local government officials, NGO staff, the water management committee and other support people understand drinking water quality and the requirements for managing the village water supply through awareness raising and training. Ensure that all relevant parties above are kept up to date on the requirements for adequate management of local water supply systems. Ensure that records of the water supply system and its operation are kept to guarantee accountability, transparency and a record of issues and problems.
5 Monitor, evaluate and review effectiveness of management Ensure that the results of monitoring the water supply system and water quality are regularly reviewed. Ensure that the local government and water management committee periodically review the status of the drinking water supply system and how it is being managed. Ensure problems are addressed and the system is revised to prevent them happening again.

Elements of this framework are discussed in this field guide and are explained in more detail in *Safe water guide for the Australian aid program 2005* (pp. 39–93). The systems that are set up as part of this framework are not static and require regular attention and review to ensure communities are protected from unsafe drinking water.

Water has many uses and risks to its quality. K Kanageshwarren, 28, washes his cow in preparation for a festival at the Peniya Gomarasankulam Resettlement Village in Vavuniya, Sri Lanka. PHOTO: *Will Salter*

Task 1

GATHER ALL AVAILABLE INFORMATION ON WATER QUALITY

When gathering information, consult all relevant stakeholders as many water quality issues are likely to be known locally.

The initial gathering of information should be led by or at least should be undertaken in conjunction with the relevant local government agency wherever possible. Local officials need to understand the framework for managing water quality so they can provide the appropriate resources. This provides an important opportunity to build the capacities of the health, water and sanitation agencies.

The local government/NGO or other supporting group would work closely with the water management committee to gather as much information as possible about water quality in the area and risks to it. This information can then be used to assess the range of water quality problems and risks that may need to be managed for a specific water supply. As part of the assessment, relevant policies and local development strategies and plans should be reviewed to understand any local views on water quality management.

In general, the information gathered should:

> help decision-makers understand key water issues that need to be considered

> facilitate design plans, work programs and effective ongoing management arrangements for water supply systems, and

> help to identify and assess water quality problems and/or risks that may need to be managed to achieve or maintain safe water.

When gathering information it is important to consult all relevant stakeholders, as many water quality issues are likely to be known locally. Stakeholders may include community groups, governing councils and agencies, schools, health professionals, non-government organisations, older people who have lived in the area for a long time, business groups and any other community-based organisations.

Although water quality issues vary significantly across countries and regions, an overview of the common water quality problems in the Asia-Pacific region is provided in Table 3. A more detailed table is included in *Safe water guide for the Australian aid program 2005* (pp. 20–22).

TABLE 3 COMMON WATER QUALITY PROBLEMS IN THE ASIA-PACIFIC REGION[a]

PROBLEM	CONTAMINATION POTENTIAL	EXAMPLE EFFECT OF EXPOSURE TO HUMANS	COMMON TREATMENT METHOD
Pathogens (bacteria and viruses) **Extreme risk**	Widespread and most significant risk to water quality. Contamination – either directly or indirectly – is via excreta and the micro-organisms (pathogens) in human or animal faeces.	Gastroenteritis, diarrhoea, dysentery, hepatitis, cholera and typhoid fever.	Most but not all pathogens are removed by common treatment methods (disinfection/boiling).
Parasites **High risk**	Spread by mosquitoes often found in stagnant water in streams, drains and uncovered storage or drinking vessels and some worms found in contaminated land and water.	Mosquito-borne aliments including malaria and dengue fever. Intestinal ailments.	Treatment for parasites includes water source management.
Algal toxins **High risk**	Algae are widespread in warm, stagnant or slow-moving surface water. Some species (blue-green algae) generate toxins harmful to humans. Some species also generate offensive taste and odour in the water.	Affects the central nervous system and damages the liver.	Filtration treatment will remove algae. Toxins are not removed by common treatment methods and require advanced treatment technologies.
Metals (e.g. lead, arsenic) **Medium risk**	Confined to certain geographic areas, catchment types and groundwater. Can enter water sources through natural mineral leaching. Can also come from corrosion of pipes and fittings or contamination from industrial wastes.	Affects the central nervous system and can be carcinogenic.	Generally metals are partially removed by common treatment processes, although effectiveness depends on the chemical form.
Nitrates/nitrites (sometimes used interchangeably) **Medium risk**	Widespread in groundwater discharge, particularly associated with wastewater (sewage treatment plants and septic tanks), livestock facilities and fertilised croplands.	Blue baby syndrome.	Not removed by common treatment methods.
Fluoride **Medium risk**	Confined to certain areas and groundwater.	Bone disease at high concentrations.	Common treatment may achieve some reduction.
Organic chemicals **Medium–low risk**	Found only in individual supplies or localised areas. Usually discharged from large manufacturing industries or chemical storages into surface and groundwater reservoirs.	Can be carcinogenic.	Not removed by common treatment methods.
Pesticides/ fertilisers **Medium–low risk**	Found only in individual supplies or localised areas of pesticide use as residuals from agricultural and forestry practices.	Affects the central nervous system and can be carcinogenic.	Common treatment may achieve some reduction.

a Based on common experience in Bangladesh, Vietnam, 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 3. As such, the summary must not be relied on for the characterisation of water supplies. It serves only as a basis for initial assessment.

CHECKLIST FOR TASK 1

- [ ] a) Identify information sources on water quality in the area and undertake an initial assessment of water activities that have been or are being undertaken and identify any water quality issues.
- [ ] b) Engage with relevant stakeholders – all communities affected or likely to be affected, local government officials, the water, environment and health agencies, the 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.
- [ ] c) Gather available water quality data. This information may be anecdotal and collected from the relevant stakeholders listed above.
- [ ] d) Collect a geological map of the catchment area, aerial photographs, planning scheme, land use map and documentation.
- [ ] e) Identify any policy documentation that may provide guiding principles in the management of water supply systems (eg users pay, community management, preference for gravity systems)
- [ ] f) Find out about future development plans for schools, hospitals and other urban, industrial and agricultural facilities for the area if appropriate.
- [ ] g) Identify how the water is used in the area and obtain a breakdown of usage.
- [ ] h) Investigate known health problems in the community and whether they could be related to water quality. Local health clinics can often provide data on health issues related to water quality.
- [ ] i) Investigate 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 catchment area, what activities can affect water quality and what controls are in place to protect the water supply.
- [ ] j) Collate all of the above information and generate a list of potential risks to water quality.

Task 2

IDENTIFY AND ASSESS RISKS TO SPECIFIC WATER SUPPLY SYSTEM

Having gathered and collated as much information as possible on water quality, the people leading the planning process should meet with the community and stakeholders (eg the water management committee) for initial discussions and planning. With their initial ideas, these two groups need to identify in more detail the types of problems and risks that need to be managed for the particular water supply system.

The water supply system and the processes for its management must be safe, acceptable and sustainable.

Designing or rehabilitating a water supply system should be the responsibility of a team that includes members with appropriate engineering and design skills, specialists who understand how to manage water quality, and people skilled in consulting stakeholders. Stakeholders include the affected community, relevant local government agencies (in particular, village officials) and religious leaders. Local non-government organisations and people involved in donor-funded activities can often be a useful source of relevant information. It is vital that all communities potentially affected by any proposed activity in the community actively participate in the consultation process.

It is essential that the water supply system and the processes for its management that evolve from this process are safe, acceptable and sustainable; consultation should continue until this is achieved.

When assessing risks to a particular water supply it is necessary to consider the entire supply system – from source, to storage and distribution systems, to usage points – and the water cycle (see Figure 4).

When assessing risks to a particular water supply, consider the entire supply system and water cycle.

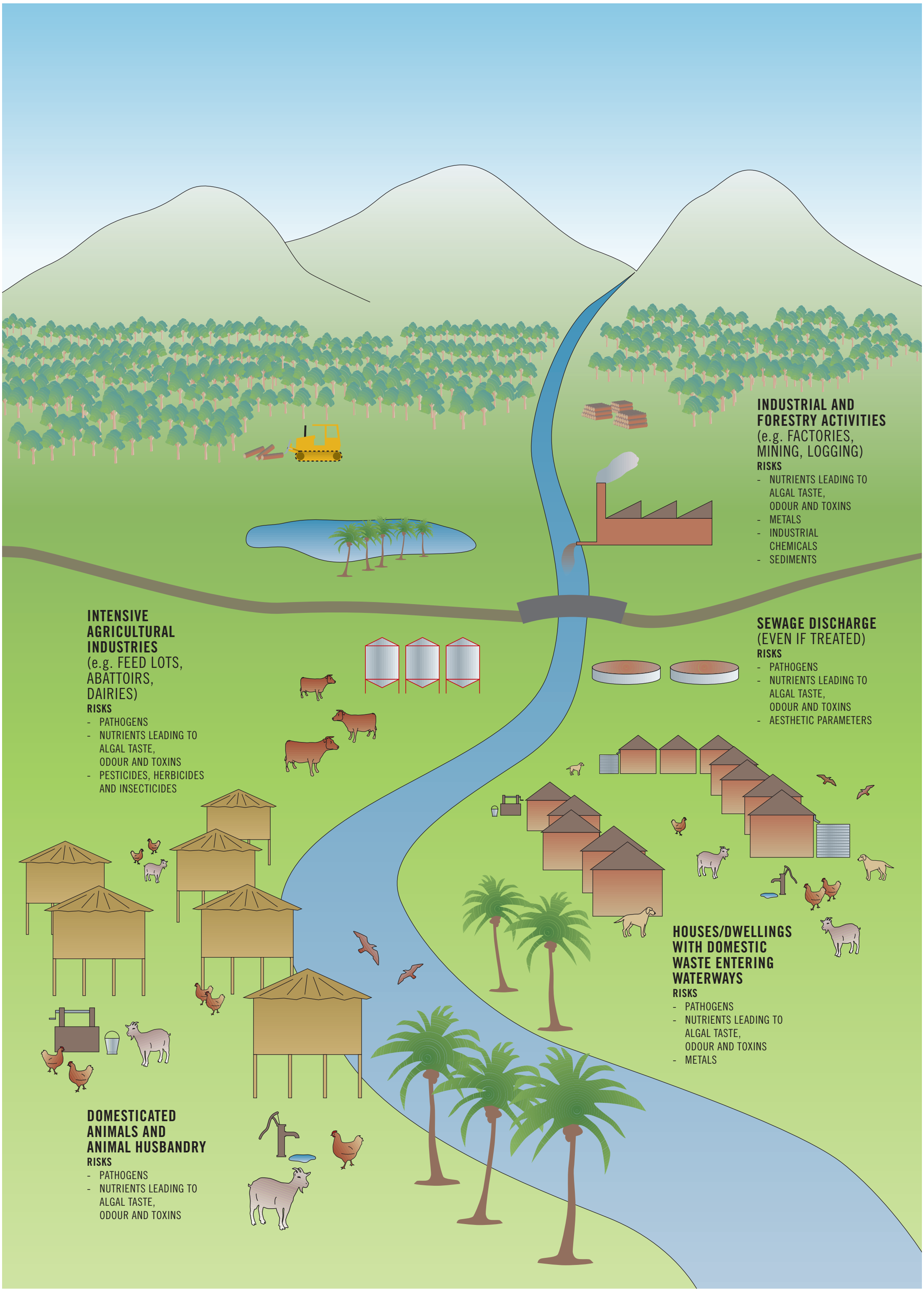
A supply system may serve an individual dwelling, a small settlement, a village of a few hundred people, a town or a city. So it can vary greatly in size and include a well, rainwater tank, filter, rainwater pot, small chemical treatment system for a household, small reticulated village system, large urban system, or formal or informal tanker deliveries. There are risks associated with each supply system.

There are tools to test water quality and these may be used by a community and provide a potential source of information. However, many simple test kits are not accurate. So, if they indicate the presence of a contaminant the best strategy is to assume that it is a risk to water users (see pp. 28–31).

Identify water quality problems through testing.

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

FIGURE 4 RISKS TO WATER SUPPLIES



Many activities in and around a community can pose a risk to water quality. To ensure a water supply remains safe, it is important that planners and managers of the supply undertake campaigns to increase awareness of the need for adequate sanitation and good hygiene practices, and provide programs to educate the community on their role not only in caring for their water system but also the surrounding environment.

Ensure that the community understands their water supply system and their role in ensuring the supply remains safe.

Risks associated with each point of a water supply system are discussed briefly in the following sections. More detailed information on specific risks is included in *Safe water guide for the Australian aid program 2005* (pp. 43–74).

If there is uncertainty about the risks associated with different types of supply system, further advice should be sought from experts.

ASSESSING RISKS TO WATER SOURCES

When selecting a particular source of water for a water supply system, the risks that are specific to that source need to be assessed. The common sources of water are surface water, deep groundwater, shallow groundwater, spring water and rainwater (Table 4). Activities that create potential risks in different types of water sources are outlined in Table 5.

Assess risks that are specific to the particular source of water.

TABLE 4 COMMON TYPES OF WATER SOURCES

TYPE	CHARACTERISTICS
Surface water	Surface water sources include rivers, lakes or ponds.
Deep groundwater	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 may be located a significant distance from the bore site.
Shallow groundwater	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.
Spring water	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.
Rainwater	Rainwater is generally collected from a roof (catchment surface) via a gutter and pipe that leads to a collection tank.

TABLE 5 EXAMPLES OF ACTIVITIES, PRACTICES AND EVENTS THAT POSE RISKS TO SPECIFIC WATER SOURCES

HIGH-RISK ACTIVITY, PRACTICE OR EVENT	WATER SOURCE IMPACTED	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Swimming and washing (people and clothing)	Surface water	✓	✓				✓
Sewage discharge (even if treated)	Surface water, Groundwater, Spring water	✓	✓				✓
Houses/dwellings with domestic waste entering the waterways	Surface water, Groundwater, Spring water	✓	✓	✓			
Storms in the catchment that wash faecal matter and other contaminants into waterways	Surface water	✓	✓		✓	✓	✓
Intensive agricultural industries (e.g. feedlots, abattoirs and dairies)	Surface water, Groundwater, Spring water	✓	✓		✓		
Recontamination prior to use (e.g. during storage and distribution)	Surface water, Groundwater, Spring water, Rainwater	✓					
Domesticated animals and animal husbandry	Surface water, Groundwater, Spring water	✓	✓				
Stagnant water	Surface water, Rainwater		✓				✓
Chemical processing industry and fuel storage	Surface water, Groundwater, Spring water			✓		✓	
Stormwater from villages	Surface water, Groundwater, Spring water	✓				✓	✓
Open defecation systems	Surface water, Groundwater, Spring water	✓					
Weed spraying along water courses	Surface water				✓		✓
Poor groundwater bore construction or maintenance, allowing seepage of contaminated water from shallow aquifer into the deep aquifer below	Groundwater	✓		✓	✓	✓	✓
Incorrect or inadequate construction of the groundwater bore, allowing surface water to enter down the outside of the well casing	Groundwater, Spring water	✓		✓	✓	✓	✓

SURFACE WATER GROUNDWATER SPRING WATER RAINWATER

TABLE 5 EXAMPLES OF ACTIVITIES, PRACTICES AND EVENTS THAT POSE RISKS TO SPECIFIC WATER SOURCES continued

HIGH-RISK ACTIVITY, PRACTICE OR EVENT	WATER SOURCE IMPACTED	PATHOGENS	NUTRIENTS LEADING TO ALGAL TASTE, ODOUR AND TOXINS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Leaching of metals (e.g. arsenic, mercury) from natural rock formation in the groundwater recharge area	Groundwater, Spring water			✓			
Leaks from underground fuel storage tanks in the recharge area	Groundwater, Spring water					✓	
Surface water entering either at the spring site or through porous soil/rock in the recharge area	Spring water	✓	✓	✓	✓	✓	✓
Faecal matter from people, birds and animals on the roof or in the gutters	Rainwater	✓	✓				
Organic matter (e.g. leaves, twigs) on the roof surface, and dust or aerosol residues from industry, mining or cropping	Rainwater		✓	✓	✓	✓	✓
Corroded metal pipe fittings due to low alkalinity	Rainwater			✓			✓
Animals die in the gutters or the rainwater tanks	Rainwater	✓	✓				✓
Animals and insects (e.g. snails, mosquito larvae, water fleas) in the rainwater tank	Rainwater	✓	✓				✓
Open (uncovered) rainwater tank, which allows recontamination via faecal matter, algal growth, etc.	Rainwater	✓	✓				✓
Incorrect operation of point-of-use treatment technologies (e.g. failure to replace filter cartridges, which can result in growths on cartridges)	Surface water, Rainwater	✓	✓				✓

SURFACE WATER GROUNDWATER SPRING WATER RAINWATER

ASSESSING RISKS TO STORAGE, DISTRIBUTION AND USAGE POINTS

Assess risks that are specific to the particular water storage and distribution systems and usage points.

Most water supply systems have a collection and **storage system**. 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 people's access to water.

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

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

Tables 6 and 7 highlight the activities and practices occurring during storage, distribution and usage that can pose risks to water quality and have an impact on users. Refer to *Safe water guide for the Australian aid program 2005* (pp. 82–7) for further information.

Ho Thi Tu, 59, of Hiep Xuong Commune, Vietnam, pours water that has come directly from the canal in to a clay container. The water is boiled and then used for drinking. PHOTO: *Will Salter*

TABLE 6 EXAMPLES OF ACTIVITIES, PRACTICES OR EVENTS THAT POSE RISKS TO THE QUALITY OF WATER WHEN STORED, DISTRIBUTED AND USED

HIGH-RISK ACTIVITY, PRACTICE OR EVENT	PATHOGENS	ALGAL TASTE, ODOUR AND TOXINS CAUSED BY EXCESS NUTRIENTS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
STORAGE SYSTEM						
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	✓	✓	✓			
Underground storage in proximity to agricultural/farming areas		✓		✓		
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	✓					
Stagnant water (a major cause of malaria and dengue fever)		✓				✓
Poor maintenance practices	✓				✓	✓
Types of construction material			✓			✓
DISTRIBUTION SYSTEM						
Sewage discharge (even if treated) entering the system 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 the distribution system	✓					✓
Types of construction material			✓		✓	✓
USAGE POINTS						
Dirty containers used for collecting water (may be affected by unhygienic collection or previous contents of containers)	✓					✓
Rusty containers used for collecting water	✓		✓			✓
Stagnant water (a major cause of malaria and dengue fever) around collection point	✓	✓				✓
Incorrect operation of point-of-use treatment technologies (e.g. failure to replace filter cartridges, which can result in growths on cartridges)	✓	✓				✓
Poor hygiene and sanitation practices	✓					✓

TABLE 7 TYPICAL WATER QUALITY PROBLEMS, THEIR CAUSES AND THEIR POTENTIAL IMPACT ON USERS

QUALITY PROBLEM	CAUSES OF WATER QUALITY PROBLEMS	IMPACT ON USERS
Pathogens	**Storage system** Ineffective treatment prior to storage. Faecal matter (e.g. from humans or animals) entering the storage, especially if reservoirs or tanks are open. Recontamination of water during maintenance. **Distribution system** An inadequate supply of water so that a positive pressure is not maintained at all times in the 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.

The water flows after the AusAID-funded water supply has been officially turned on at Kungguo village, Tibet.
PHOTO: *Peter Davis*

TABLE 7 TYPICAL WATER QUALITY PROBLEMS, THEIR CAUSES AND THEIR POTENTIAL IMPACT ON USERS continued

QUALITY PROBLEM	CAUSES OF WATER QUALITY PROBLEMS	IMPACT ON USERS
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 or chronic 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 (e.g. reinforcement in concrete and galvanised tanks). **Distribution system** Corroded pipelines (copper, lead), and water treatment chemicals (aluminium). **Usage points** Collection method (e.g. rusted vessels).	
Pesticides, herbicides and insecticides	**Storage system** Ineffective treatment prior to storage. Open storages where spraying occurs.	
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 an entrance 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 (e.g. lime leached from a concrete tank or hot water from a plastic tank). **Distribution system** Construction materials (e.g. lime leached from concrete pipes). **Usage points** Collection method.	These problems generally affect the taste, odour and appearance of water. While high salt content or 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.

PRIORITISING WATER QUALITY RISKS

After identifying and assessing the risks to water quality (based on activity, practice or event), these risks need to be prioritised in order of importance. This requires a good understanding of the impacts of various contaminants. The people leading the design and planning of the water supply would undertake this task (local government, NGO or other supporting organisation) together with the water management committee.

Drinking contaminated water has three diverse effects that can be used to help prioritise the risks to be managed (Table 8).

TABLE 8 EFFECTS OF DRINKING CONTAMINATED WATER

TYPE	IMPACT	EXAMPLE
Aesthetic		
Non-critical	Tastes or looks bad. Tends to pass through the body with little if any impact.	Salt, colour
Health		
Acute	Causes immediate adverse effects.	Diarrhoea due to microbes in water. Excess zinc, which causes vomiting (removes the metal from the body).
Cumulative/ chronic	Accumulates in the body causing ongoing problems once certain levels are reached Gives rise to problems after long-term continued exposure.	Mercury accumulation in body due to high levels in fish Build up of arsenic from water and food sources (problem doesn’t show symptoms for many years)

Prioritising those risks to water quality that can cause most harm results in effective use of money and human resources.

In practical applications, WHO gives priority to addressing water quality problems in the following ways:[2]

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

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

When prioritising water quality risks it may be useful to prepare a table ranking the risks in terms of their significance. This ranking can then be used to determine the funding and resources required to manage the risks. By first addressing those risks that can cause the most harm, the available funding and people can be allocated in the most effective way. These are the difficult evaluations and decisions that often face local planners and managers.

A semi-quantitative risk assessment can be used to prioritise the risks identified. This is a simple 4-step process:

1. Determine how severe the water quality problem would be if it were to happen. A graded scale from 1 to 5 can be used to quantify the severity. A rating of 1 would be considered of minor severity and usually relates to aesthetic impacts. A rating of 5 would be considered very severe. Severe impacts relate to health issues. Ratings of 2, 3 and 4 would be the transition from minor to high severity.
2. Determine the likelihood of an incident occurring. The same scale can be used, with 1 being unlikely and 5 being highly likely.
3. Calculate the overall risk by multiplying the value in the severity column by the number in the likelihood column.
4. Prioritise the risks to water quality using these combined values.

Table 9 illustrates how this process could be applied using a couple of examples.

TABLE 9 TWO TYPICAL RISKS TO WATER QUALITY AND A PRACTICAL ASSESSMENT OF THEIR PRIORITIES

RISK	IMPACT	SEVERITY (S)	LIKELIHOOD (L)	OVERALL RISK ASSESSMENT (S x L)	PRIORITY
Toilets close to groundwater supply	Diarrhoea	4	3	12	1
Minor salt water intrusion into a groundwater supply	Taste	1	3	3	2

Note:
Severity: 5 = severe, 4= major, 3 = moderate, 2= minor, 1= negligible
Likelihood: 5 = almost certain, 4 = likely, 3 = possible, 2= unlikely, 1= rare
Overall risk assessment: 20–25 = extreme, 15–19 = high, 10–14 = medium, 0–9 = low

CHECKLIST FOR TASK 2

After all available information has been collected, a detailed analysis should be carried out of the water supply system being considered. While doing this – tasks a) to h) below – the following should be done:

> Photograph (if this is not possible, do a thorough sketch drawing) the entire water supply system – the potential sources of the water quality problems in the catchment area, collection of source water, any existing infrastructure, treatment, storage and distribution to users, and usage. (Be aware of local cultural issues with photography.)

Undertake the following to identify specific risks to the water supply using the Task 1 checklist as a reference:

☐ a) Inspect the water currently being used and ask local people about its taste, odour and appearance. Ask for historical 'stories' or anecdotes about water quality and appearance, illnesses in the community and activities that may affect water quality.

☐ b) Inspect the water sources and immediate surrounding areas, looking for possible sources of contamination.

☐ c) Review the catchment 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 a landslide or industrial spill. Identify seasonal issues that affect water quality (e.g. pesticide use during the crop-growing season or variable discharge from industry).

☐ d) For rehabilitation works, inspect the storage and distribution systems and usage points (tanks, pipelines, taps, water tankers), looking for water quality problems.

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

☐ f) List all of the specific activities that will have an impact on water quality.

☐ g) Collate all the risks in a table, identifying existing and potential water quality problems, any existing controls and their effectiveness in managing risk for users.

☐ h) Assess the risks (one way of doing this is the severity–likelihood approach described) and prioritise them so that risk management strategies can be identified.

Task 3

PREPARE WATER QUALITY MANAGEMENT PLAN

After the water quality problems have been identified and the risks to the specific supply system have been assessed, the team responsible for designing or rehabilitating the water supply system should then document its findings and prepare a water quality management plan (WQMP). This plan may need to be changed during the actual construction, operation, implementation or rehabilitation of the water supply system as more information becomes available.

The WQMP is the key tool for managing water quality – avoiding risks and maximising benefits.

The WQMP is the key tool for managing water quality during the construction of a water supply system and for ongoing operation, maintenance and use of the system. The purpose of the plan is to avoid or minimise any risks to water quality, both during initial operation and operation in the long term.

For a small water supply system the WQMP should be simple and easy to follow. For a larger water supply system the plan may need to be more complex. However, the principles are the same for all plans.

A WQMP should take into account the impact of sanitation facilities and hygiene practices.

As mentioned previously, water that is safe at its source is in constant danger of being contaminated during storage, distribution or use. Often water is contaminated by faeces because storage and distribution systems are poorly maintained or hygiene practices are poor. Therefore a WQMP should take into account the impact of sanitation facilities and hygiene practices on safe water.

Most of the health benefits of water supply activities stem from changes in hygiene practices. By linking activities to improve hygiene practices and sanitary measures to safe water supplies it is possible to break the contamination–transmission cycle. Such links can involve providing effective community-based education on hygiene and introducing and promoting safe water storage and distribution and sound maintenance practices. These activities can be included in the WQMP.

An example of a simple WQMP is presented in Table 10. At the very minimum, a WQMP should list:

> what action is required to manage a potential risk to water quality

> who is responsible for that action, and

> the deadline or schedule for completing the action.

TABLE 10 EXAMPLE OF A SIMPLE WATER QUALITY MANAGEMENT PLAN

RISK	IMPACT	SEVERITY (S)	LIKELIHOOD (L)	OVERALL RISK ASSESSMENT (S x L)	PRIORITY	ACTION REQUIRED TO MANAGE	PERSON RESPONSIBLE	DEADLINE TO BE DONE
Toilets close to groundwater supply	Diarrhoea	4	3	12	1	Establish a monitoring program Move toilet/latrine if possible	Local water manager/ owner of toilet/latrine	As soon as possible
Minor salt water intrusion into a groundwater supply	Taste	1	3	3	2	Reduce pumping rates from water supply	Local water manager	Immediately

Note:
Severity: 5 = severe, 4= major, 3 = moderate, 2= minor, 1= negligible
Likelihood: 5 = almost certain, 4 = likely, 3 = possible, 2= unlikely, 1= rare
Overall risk assessment: 20–25 = extreme, 15–19 = high, 10–14 = medium, 0–9 = low

TREATING THE WATER SUPPLY

A key strategy for improving water quality is treating the water supply.

A key strategy for improving water quality that may be included in the WQMP is treating the water supply. Water treatment is used to improve quality by removing physical, chemical or microbiological compounds. Water testing may be necessary to identify contaminants and confirm that the treatment is effective.

Water treatment typically occurs at storage points in the water supply system. However, primary treatment may occur at the source, depending on the specific water quality issues. Treatment at usage points may also be required, depending on the quality prior to use.

The basic treatment measures in Table 11 are relevant to a range of water supplies – from an individual dwelling to a major urban area. Water supply managers should 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)[3] for further information.

In Table 11 a tick 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 will be required.

TABLE 11 A GUIDE TO THE EFFECTIVENESS OF VARIOUS WATER TREATMENTS AND RISK-REDUCTION MEASURES

TREATMENT OR RISK-REDUCTION MEASURE	PATHOGENS	ALGAL TASTE, ODOUR AND TOXINS CAUSED BY EXCESS NUTRIENTS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Boil water	✓					✓[a]
Coagulate and filter water	✓	✓	✓	✓	✓	✓
Disinfect (chlorine or ultra violet (UV))[b]	✓	✓				
Avoid use of water if contamination is likely (e.g. after storm)	✓	✓				✓
Store water for more than 4 weeks in sunlight (UV irradiation)	✓					
Shift water source offtake upstream of contamination source	✓	✓	✓	✓	✓	✓
Selectively divert first flush rainwater during a storm	✓					✓
Flush groundwater bore before use						✓
Use activated carbon filter		✓		✓	✓	✓
Microfiltration/membranes		✓	✓	✓	✓	✓
Seek an alternative water source	✓	✓	✓	✓	✓	✓

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. 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.

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

SAMPLING AND ANALYSING WATER QUALITY

Sampling and analysing water remain essential tools for confirming that water is safe.

Managing the risks to safe water emphasises the importance of adopting good management procedures. However, sampling and analysing water remain essential tools for **confirming** that water is safe. When carried out correctly, sampling and analysis can provide vital information on water quality that can be used to protect communities from unsafe water. A sampling and analysis program needs to be included in the WQMP.

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.

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 required to confirm that the water is safe. Risks associated with water contamination may also arise from continuous exposure at low concentrations, giving rise to effects in the long term (chronic), or from exposure to high concentrations with immediate effects (acute).

Water analyses should be undertaken by trained people who are aware of local conditions and potential contaminants.

Samples can be analysed in a laboratory or in the field, depending on the accuracy required. In many areas access to a suitable laboratory is limited and analysis is restricted to field-based work. Whether field or laboratory analyses are conducted, water analysis should be undertaken by trained people who are aware of local conditions and potential contaminants.

The WHO *Guidelines for drinking-water quality* (3rd edn) provides guidelines on how frequently water supplies should be sampled and on the procedures for analysing the samples. It is essential that water from a newly constructed drinking water supply system that involves pipes and distribution structures be sampled and analysed prior to it being used.

Although regular water quality testing is necessary to ensure communities are protected from potentially unsafe water, the aim of risk-based management is to minimise water quality problems. This consequently reduces the frequency of water quality testing required and improves the sustainability of systems.

Testing may not be possible for all small-scale systems such as wells and hand pumps. In such cases all risks to water quality must be assessed and, where there is the potential for problems, action taken to avoid them.

The maximum acceptable concentrations for various contaminants in drinking water may be set by the national or local government. Alternatively, the WHO guidelines may be used. 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 (for example, if microbiological contaminants are present, boil the water). Sampling and testing will not fix a problem, but it is important in identifying water quality issues as well as the success of water treatment practices used.

Table 12 lists some basic characteristics that can indicate the presence of potential water quality problems. If water users are aware of these characteristics, the water should be tested or some other management response initiated.

TABLE 12 CHARACTERISTICS THAT INDICATE THE PRESENCE OF POTENTIAL WATER QUALITY PROBLEMS

CHARACTERISTIC	PATHOGENS	ALGAL TASTE, ODOUR AND TOXINS CAUSED BY EXCESS NUTRIENTS	METALS	PESTICIDES, HERBICIDES AND INSECTICIDES	INDUSTRIAL CHEMICALS, FUELS AND ORGANIC COMPOUNDS	AESTHETIC PARAMETERS
Turbid, cloudy or dirty, particularly after storms	✓					✓
Colouration 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)						✓
Colour						✓

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

The test kit and procedure must be suitable for the particular conditions of the water supply system.

There are numerous kits and procedures for testing water quality in the field and it is important that the chosen kit and procedure are suitable for the particular conditions of the water supply system. Table 13 gives examples of the types of kit available. Most kits involve ongoing costs for replacing batteries and active testing chemicals (reagents). For further information refer to *Safe water guide for the Australian aid program 2005* (pp. 109–13).

TABLE 13 KITS AVAILABLE TO TEST WATER QUALITY

PARAMETER	TEST
Aesthetic	
Colour	Colour disc, spectrophotometer (with test reagents)
Dissolved oxygen (DO)	Electronic meter/sensor with a probe
pH	pH strips, liquid colorimetric indicators, electronic meter/sensor with a probe
Salinity	Electronic meter/sensor with a probe
Temperature	Thermometer, electronic meter/sensor with probe
Turbidity	Secchi disc, turbidity meter, turbidity tube
Health	
Arsenic	Specific arsenic test kits
E. coli/coliforms	Coliform test kits, portable incubators
Metals	Spectrophotometer (with test reagents and specific light sources), metal test strips
Nitrates, nitrites	Spectrophotometer (with test reagents and specific light sources)
Pesticides, algae	Test kits/ strips

CHECKLIST FOR TASK 3

a) Summarise available water quality data and graph water quality parameters against time so that a historical record is available. ☐

b) Develop strategies to manage the risks and improve water quality, including the action required, person responsible for the action and the timeframe to complete the action. Management strategies can include:

i) Protect the water source from contamination and remove the causes of water quality problems at their source if possible (e.g. keep animals away from water source. ☐

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

iii) Provide treatment as required. ☐

iv) Minimise the potential for contamination in collection, treatment, storage and distribution (e.g. maintain infrastructure in good condition). ☐

v) Develop an appropriate operation and maintenance program and train the water management committee or selected representatives on its use. ☐

vi) Ensure all stakeholders understand the requirements for good hygiene and safe water. This is likely to involve developing and implementing awareness and education training programs. ☐

vii) Develop a monitoring and evaluation program that includes appropriate water sampling and analysis. It should also include a series of checklists that are used to confirm effective management practices are occurring in the community. ☐

Task 4

IMPLEMENT, REVIEW AND REGULARLY UPDATE THE WQMP

Ensure that those responsible for operating and maintaining the water supply are undertaking their tasks.

The final task in managing the water supply in a safe way involves implementing the WQMP. This can require:

> implementing cleaning and maintenance activities
> operating and maintaining treatment systems
> sampling and analysing water quality when appropriate, and
> establishing a mechanism to monitor activities associated with managing the water supply.

Reviewing and updating the WQMP is also an important task in the overall process for maintaining a safe water supply as conditions can change over time. It is important to ensure that those who are responsible for operating and maintaining the water supply are undertaking their tasks in accordance with the WQMP. This responsibility may lie with the head of the water management committee or an external person such as a village leader or representative from a local government agency.

A community meeting on water in Munshiganj District, Bangladesh (AusAID-funded Bangladesh–Australia Centre for Arsenic Mitigation Project).
PHOTO: *Alison Baker*

Managing arsenic in water supplies

Although arsenic is only one of several water contaminants, its occurrence is worthy of special commentary. To date the full public health implications of exposure to levels of arsenic above safe limits in drinking water are not fully understood. Yet large populations around the world are affected by, or are at risk of, arsenic contamination.

Users of this guide should note that this section provides only a very basic background to water quality issues related to arsenic. It should be noted that testing and treatment methods for arsenic in drinking water are complex and should be undertaken only by appropriately trained personnel.

Research on arsenic mitigation in water supplies is being continuously updated, requiring all relevant stakeholders to be aware of the latest information relating to this issue.

Testing and treatment for arsenic in drinking water should be undertaken only by appropriately trained and qualified personnel.

MINIMISING THE RISK OF ARSENIC CONTAMINATION

Arsenic is a naturally occurring toxic metal that is widespread in groundwater and found in many countries – India (especially Bengal), Bangladesh, Nepal, Thailand, China, Mongolia and Tibet, Vietnam, Laos, Cambodia, Myanmar, various South American countries and areas in North America and Australia. Arsenic is released into the water system through chemical processes occurring in rocks, soil and sediments. Arsenic poses the greatest threat to public health through contaminated drinking water.

Arsenic also occurs as a contaminant as a result of mining and manufacturing industries. Arsenic contamination is commonly associated with fluctuating water tables and flooding cycles and the level of arsenic contamination in water supplies can vary through a year, which adds to the difficulties of identifying and monitoring it.

When considering a water supply, stakeholders need to ascertain whether arsenic is present locally.

When considering a water supply system in a country where groundwater is known to be affected by arsenic, stakeholders need to ascertain whether arsenic is present locally. In locations where groundwater may be affected by arsenic, a new water source should be sought to eliminate the risk of arsenic contamination to public health.

Any agency knowingly supplying drinking water contaminated with arsenic (or other contaminants) at levels that are known to result in serious health effects is likely to be in breach of their duty of care.

EFFECTS OF ARSENIC IN DRINKING WATER

Water contaminated with arsenic has no easily recognised or distinguishing properties.

As with pure water, water contaminated with arsenic is odourless, tasteless and colourless, making identification extremely difficult in the absence of expensive and complex testing equipment and procedures.

The first physical changes to people exposed to arsenic in drinking water for 5 to 15 or more years are usually observed in the skin. Typically their skin develops small black or white marks (melanosis), then the skin on their palms and feet thickens (keratosis), which is followed by skin lesions and eventually skin cancer. Internal cancers are a late phenomenon, and usually take more than 10 years to develop. In advanced stages of arsenic contamination, parts of the body develop gangrene.

It should be noted that absorption of arsenic through the skin is minimal, so arsenic-contaminated water should not pose a risk to human health if used for purposes other than drinking – for example, hand-washing, bathing and laundry.

TESTING, TREATMENT AND PREVENTION

Specific scientific testing equipment needs to be used to accurately test for the presence of arsenic in water supplies. Some field testing kits will detect the presence of arsenic in high concentrations. However, field test kits for low concentrations of arsenic in water supplies are generally inaccurate.

If simple testing indicates arsenic in the water, the source is too risky to use.

To identify arsenic in water at low concentrations or to measure such levels accurately requires complex and expensive laboratory analysis. But, if simple water testing indicates the presence of arsenic the source should be considered too risky to use.

Arsenic can be removed from water supplies in a number of ways using a variety of different technologies. The most common methods include adsorption, a combination of oxidation and adsorption, and filtration.

The efficiency and appropriateness of the various technologies available need to be assessed on a case by case basis. Most technologies are efficient at removing arsenic. However, appropriate technology must be economically viable and socially acceptable. If treatment is the only viable solution, then appropriate waste disposal procedures must also be available to safely dispose of the arsenic removed.

The most important response to arsenic-contaminated water is to provide safe drinking water.

As already noted, **testing and treatment methods for arsenic in drinking water are complex and should be undertaken by appropriately trained personnel.**

The most important remedial action for arsenic contamination is prevention of further exposure by providing safe drinking water. Alternative low-arsenic sources such as rainwater may be a viable preventive measure.

Appendix

EXAMPLE OF WATER QUALITY MANAGEMENT PLAN FOR CHAPAI NAWABGONJ POURASHAWA, BANGLADESH

ELEMENT	AQUIFER	WELL	CHORINE DOSING	STORAGE	PIPE DISTRIBUTION	USER
Risks	Land uses and activities pollute aquifer.	Surface water entering well via ingress or backflow. Arsenic, nitrate or manganese above national drinking water standards.	Failure to disinfect water due to chlorinator problem.	Faecal contamination via gaps in water tank.	Contamination enters distribution system via leaking reticulation system, valves and service lines.	Contamination of user water due to storage tank leak, poor hygiene or backflow.
Management strategy	Polluting land use and activity must be excluded within 10 metres of wellhead.	Arsenic, nitrate and manganese must be within national drinking water standards. Wellhead, sealing, drainage and backflow prevention must be intact.	System must be dosing at >3 mg/L to reach >0.2 mg/L at end of system, and bleaching powder stocks must be within use-by date.	Roof, hatches and vermin proofing must be intact.	Leaks must be minimised through sound construction, maintenance and repair practices. System must be pressurised as much as possible.	Hygiene education and awareness must be carried out to promote safe water handling, leakage reporting, storage and backflow prevention.
Monitoring	Sanitary inspection monthly by inspector.[a]	Sanitary inspection monthly by inspector. Arsenic, nitrate and manganese testing 6 monthly by inspector with field kits.	Bleaching powder stock date and chlorine dosing rate daily by operator. Chlorine concentration at end of system monthly by inspector.	Sanitary inspection monthly by inspector.	Monthly inspection.	Community survey of hygiene awareness triennially by inspector.
Corrective actions		Inspector to decommission well within 6 months. Engineer to repair fault within 1 month.	Operator to replace stocks, increase dose or repair fault within one day.	Inspector to fix all holes, hatches or vermin proofing within 1 month.	Engineer to repair fault within 1 week.	Increase education efforts.
Verification and surveillance	Internal audit and field assessments by water management committee/inspectors to confirm that operational monitoring and corrective actions are being undertaken. External audit and field assessments to confirm operational monitoring and corrective actions are being undertaken. 20% of field kit chemical tests done by inspector being check-tested in lab using standard methods.					
Support programs	Staff training, community education, maintenance and calibration, implementation of improvement actions.					

a Sanitary inspection involves assessing potential sources of human faecal pollution, as well as other sources of pollution getting into the water supply.

Source: SG Mahmud, Sk Abu Jafar Shamsuddin, M Feroze Ahmed, A Davison, D Deere and G Howard, 'Development and implementation of water safety plans for small water supplies in Bangladesh: benefits and lessons learned', *Journal of Water and Health*, IWA Publishing, vol. 5, no. 4, 2007, pp. 585–97.

Bibliography

Ainsworth, R (ed.), *Safe piped water: managing microbial water quality in distribution systems*, Published on behalf of the World Health Organization by IWA Publishing, 2004 <www.who.int/water_sanitation_health/dwq/924156251X/en/>.

Appleton, B and Sijbesma, C, *Hygiene promotion*, Thematic Overview Paper 1, revised edn, IRC International Water and Sanitation Centre, Delft, Netherlands, December 2005 <www.irc.nl/page/27611>.

AusAID 2005, *Safe water guide for the Australian aid program 2005: a framework and guidance for managing water quality*, Australian Agency for International Development, Canberra.

Bartram, J and Balance, R (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 <www.who.int/water_sanitation_health/resourcesquality/wqmonitor/en/>.

Howard, G, *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 <www.who.int/water_sanitation_health/dwg/wsh0306/en>.

Nadebaum, PR, Chapman, M, Morden, R and Rizak, S, *A guide to hazard identification & risk assessment for drinking water supplies*, Research Report 11, CRC for Water Quality and Treatment, April 2004 <www.waterquality.crc.org.au/publication_occppr_resrpts.htm>.

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 <www.nhmrc.gov.au/publications/synopses/_files/adwg_11_06.pdf>.

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

WMO, *Manual on water quality monitoring – planning and implementation of sampling and field testing*, Operational Hydrology Report No. 27, Secretariat of the World Meteorological Organization, Geneva, 1988.

World Health Organization and United Nations Children's Fund, *Global water supply and sanitation assessment 2000 report* <www.who.int/docstore/water_sanitation_health/Globassessment/GlobalTOC.htm>.