Environment Australia

# Drinking Water Quality


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# Preface

*Australia: State of the Environment 1996* (the first ever independent and comprehensive assessment of the state of Australia's environment) was presented to the Commonwealth Environment Minister in 1996. This landmark report, which draws upon the expertise of a broad section of the Australian scientific and technical community, was prepared by seven expert reference groups working under the broad direction of an independent State of the Environment Advisory Council. While preparing the report, the Department of the Environment, Sport and Territories, on behalf of the reference groups, commissioned a number of specialist technical papers. These have been refereed and are now being published as the State of the Environment Technical Paper Series. Reflecting the theme chapters of the report, the papers relate to human settlements, biodiversity, the atmosphere, land resources, inland waters, estuaries and the sea, and natural and cultural heritage. The topics covered range from air and water quality to sea grasses and historic shipwrecks.

# Abstract

This paper reports possible water quality indicators for Australian water supplies which can be measured and used in national State of the Environment reporting. Indicators need to describe the quality of natural waters harvested and the quality of water supplied to the consumer at the tap.

The process of identifying appropriate indicators to measure the current status of, and future trends in, Australian drinking water first involves recognising potential water quality problems. The approach adopted for selecting indicators included the indentification of potential problems. The indicators selected are representative of health, aesthetic and amenity values which are commonly measured.

It is also recommended that attention be given to settlement type, including metropolitan areas, large cities, rural areas and remote communities when reporting the status of drinking water. This will allow the identification of regional water quality problems.

To facilitate future State of the Environment reporting for different geographical and demographic areas, a classification scheme ranking the microbial, chemical and aesthetic quality of supplies as poor, satisfactory or excellent is proposed.


# 1 Introduction

Water quality is about what is in water and how quality affects its usefulness. A major contributing factor to the high standard of living across most of urban Australia is the quality of town water supplies. Where supplies fail to measure up in terms of water availability and quality, as occurs in some rural and many remote supplies, the human environment is compromised.

State of the Environment reporting for water supplies should provide a quantifiable measure of the state of Australian water supplies. The reporting must reflect both on how good the quality of water is and what problems exist or should be anticipated.

The first task for reporting is to **identify** potential water quality problems and indicators of Australian drinking water quality. Indicators must quantify the current status of and future trends in drinking water quality.

Since many supplies receive no treatment, it is important that indicators reflect the effectiveness of management of the whole water supply system including the water catchment, storage and distribution system. Such problems have been reviewed in a seminar to reconcile the wide implications of catchment management and wastewater discharges on water quality (Bell 1992; Lawrence 1992) as well as elsewhere (Lawrence et al. 1994; Maher et al. 1995; Wade & Cooper 1992).

The issue of measuring water quality and changes in water quality at the tap is complicated by the fact that source water quality and its management and treatment may all change. Issues such as culturally induced environmental degradation of existing water supply catchments have to be aligned with the reality that even where water is naturally of poor quality, supply sources are nevertheless selected on the basis of being the best available. Trend reporting in water supply quality will reflect a mixture of changes in source water quality, state of repair of the reticulation system, and level of water treatment practised.

# 2 Potential water quality issues

Water for drinking should be free of disease-causing microorganisms, harmful chemicals, objectionable taste and odour problems, and excessive levels of colour and suspended material. Ideally the quality of the water should not impair its myriad other general amenity uses (user convenience values).

While over 2000 by-products of disinfection have been identified, and there are some 60 000 chemicals in wide use in western societies, in practice few chemical constituents are present in water. Nearly all Australian supplies are free of direct catchment chemical contamination since few are impacted by urban runoff or industrial discharges. It would appear that, unlike many parts of Asia, North America and Europe, few, if any, Australian supplies are obtained from waters impacted by chemical industries, although there may be minor impacts from the use of agricultural chemicals in rural catchments.

Of all the potential organic chemical contaminants in water supplies in Australia, only a few by-products of disinfection, including the better known trihalomethanes and haloacetic acids, appear to be present at any level of concern. The risks to health presented by these by-products are extremely low. The majority of organic chemicals resulting from human activity are either known to be absent from supplies or are present at very low levels (NHMRC–ARMCANZ 1996).

Several inorganic chemical indicators of water quality have been targeted in regional State of the Environment reporting, either because they are of occasional concern (e.g. nitrate) or because there is widespread community concern (sometimes with no scientific evidence for any health effect) about their presence in water, for example aluminium (Wade & Wilcox 1995; Florence, Kovacevic & Tran 1992; Reiber, Kukull & Standish–Lee 1995). Occasionally, toxic substances such as cadmium and radionuclides are present in waters that might potentially be used for water supply; however, in practice, surveys identify such contamination so that supply problems do not arise. Elevated natural fluoride levels are occasionally encountered in source waters, but are of such isolated occurrence that they are of little value in assessing the overall status of the nation's water supplies. Fluoride, zinc, copper and lead problems are dealt with under the chemical section and are of isolated occurrence. Other toxic substances, for example arsenic, cyanide, and mercury, are a potential problem for only a handful of supplies.

Typically, source waters contain high levels of soil and plant material, including clay, suspended debris, coloured plant material—fulvic and humic acids—(Christman & Gjessing 1983), and salts.

**Table 1: Major tap water quality concerns**

| Health and aesthetic concern | Cause | Treatment |
|---|---|---|
| Carcinogenic compounds | Organic compounds arising from disinfection | Activated carbon filtration, chloramination, pretreatment to remove organic carbon |
| Colour, taste and odour | Organics, iron | Oxygenation, activated carbon filtration |
| Corrosion and leached products | Low pH/aggressive water, poor choice of reticulation and plumbing materials | Water buffering, replacement of pipes and fittings |
| Hardness | High calcium and magnesium | Water softening |
| Salinity | High mineral content | Water de-ionisation |
| Toxic algae | High nutrients, generally poor catchment control | Activated carbon, bloom control |
| Toxic inorganic substances | Source contamination (e.g. cyanide, nitrate of anthropogenic origin) | Source surveillance and control |
| Turbidity | Suspended solids | Storage, coagulation/filtration |
| Water transmission of disease | Bacteria, viruses, protozoa | Storage, coagulation/filtration, disinfection |

Collectively these affect the appearance, taste, smell, and general amenity value of water. For example, water hardness (calcium and magnesium salts) causes scaling of hot water systems, while salts promote corrosion. Both hardness and salinity affect taste. Above 0.1% salt composition (1000 milligrams per litre) salts have a marked effect on taste and a wide range of water uses (NHMRC–ARMCANZ 1996). Simple colour and turbidity measurements reflect respectively a measure of dissolved plant extracts (also iron and manganese), and colloidal and suspended material.

Acidity problems (low pH levels) may be encountered in unbuffered coloured waters and are well known in bore waters containing high levels of dissolved carbon dioxide. Such waters can be extremely aggressive towards metal plumbing and storage tanks. Naturally alkaline waters and aggressive waters that dissolve cement products, may have pH levels sufficiently elevated to inhibit residual chlorine disinfection.

Major water quality problems that may arise in tap water are provided in Table 1.

## 2.1 Microbiological

The major health issues attributable to water quality relate to faecal contamination of water. The World Health Organization (1993) states that the potential consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised. The coliform bacteria group are widely used as indicators of such faecal pollution.

Most coliforms are not pathogenic, that is they are not disease-causing. The fact that coliforms are present in very large numbers in the gut means that source waters containing few thermotolerant coliforms (or *E. coli*) and free of large numbers of total coliforms are unlikely to contain significant faecal pathogen loads. The number of coliforms present provides essential information for day-to-day operation of water supply systems and provides an indication of the level of water treatment needed. More importantly, the measurement of coliforms provides an essential measure of the effectiveness of disinfection at treatment plants and the safety of water at the tap.

Despite the fact that the absence of coliforms may not indicate the absence of environmental pathogens and disinfectant-resistant faecal pathogens (e.g. some protozoans and viruses), effective public health engineering practices—management of the supply, treatment system, and water supply catchment—can nevertheless ensure that water is safe to consume. A comprehensive survey of microorganisms of concern in Australia is provided by McNeill (1985). Routine measurement for individual disease-causing organisms, often technically difficult, has never been recommended except where a disease outbreak has occurred, or where a persistent problem is known to exist (NHMRC–ARMCANZ 1996).

Source waters may contain some thousands of different microorganisms (NHMRC–ARMCANZ 1996), fortunately only a handful of these organisms present potential enteric or **epidemic** health risks in Australia. Where modern water treatment is practised, none are known to present a significant problem. However some water-borne **opportunistic** bacteria, viruses (e.g. Norwalk virus and entero–viruses) and protozoa (e.g. *Giardia* and *Crypto–sporidium*) may cause gastroenteritis and other ailments. For Australia, their risk to public health is largely unknown and several epidemiological studies are being designed through the Cooperative Research Centre for Water Quality and Treatment to ascertain their significance (CRCWQT 1996). In practice simple monitoring, using the coliform group of bacteria and maintenance of disinfectant residuals, has proved to be very effective in providing a measure of the safety of water supplies. Thermotolerant coliforms (including faecal coliforms and *Escherichia coli*) are indicative of faecal pollution.

While multi-barrier systems have been engineered into water supplies and increasingly stringent standards are being applied to sewage discharge, these systems can and do fail. Pathogenic microorganisms disseminated by water still present one of the greatest risks to public health—risks far greater than those resulting from exposure to chemicals. The infectious risks from other uses of water, for example water contact recreational activities in spa and swimming pools and on polluted beaches, while not large, are also significant.

Recent examples include the apparent viral outbreak (presumed sewage-contaminated supply) affecting some thousands of individuals at Sunbury in Victoria, the now famous Milwaukee *Cryptosporidium* outbreak in the United States affecting 400 000 people, and sporadic outbreaks of cholera *(Vibrio cholerae)* in less-developed countries. Unspecified outbreaks of gastroenteritis in unprotected untreated Australian country town supplies also appear to be common; their intermittent nature makes tracking the specific cause of disease difficult to define.

Specific pathogens and pathogen groups of concern in Australia include enteric viruses, environmental protozoans (e.g. *Naegleria fowleri*), faecal proto–zoans (e.g. *Cryptosporidium* and *Giardia*) of human and probably animal origin, environmental bacteria (normally opportunistic pathogens) including *Legionella* spp., *Aeromonas* and *Pseudomonas,* and faecal bacteria (*Salmonella* spp. excluding *S. typhae*; *Compylobacter*, *Shigella*, *Vibrio cholerae* (now low risk), and enteropathogenic *E. coli)*.

There is difficulty in quantifying risks due to specific pathogens as none are routinely monitored. Routine monitoring is confined to faecal bacterial indicators (total coliforms and *E. coli* or thermotolerant coliforms). While these indicator bacteria are reasonable surrogates for assessing faecal pollution episodes, they generally fail to establish the absence of non-faecal pathogens. They are also of limited value in assessing the presence of disinfectant-resistant enteroviruses and faecal protozoans.

Rapid urbanisation and increasing intensity of animal production are leading to concerns about decreasing security of water supplies, especially those supplies which are untreated or which are only disinfected. Increasing wastewater discharges and limited control, and virtually no treatment of stormwater discharges to lakes and streams, will increasingly be viewed as threats to public water supplies.

There is some evidence of trends in the quality of surface waters in Australia. Many rural water supplies are of generally unsatisfactory quality—poor surveillance and high frequency of detection of faecal coliforms (see for example Department of Conservation and Natural Resources (1991), Queensland Department of Water Resources (1991)).

Trends in the quality of water supplied at the tap vary from supply to supply and an overall trend is not apparent. Where full treatment is applied, systems are well maintained and some forms of catchment management are practised, water supplied at the tap appears to be of excellent microbiological quality. However, raw water quality may be declining, that is existing sources or augmented sources may be of lower quality than existed previously. There is some evidence of improved drinking water quality in rural New South Wales and Victoria, due to a steady increase in the numbers of supplies fully treated. For major capital city supplies, improvements in treatment, close surveillance and more open reporting are encouraging maintenance of quality and in some cases are resulting in improved water quality.

Since the built environment offers the opportunity to prevent water supply pollution problems through water treatment, State of the Environment (SoE) trend reporting needs to cover both raw and delivered water quality:

- to determine environmental contributions and heightened risk of epidemic outbreaks of serious water-borne disease resulting from failure of barriers or limited treatment capability; and
- to assess reliability of treatment and security of supplies.

For example, there is now ample evidence to suggest that roofing of reticulation service reservoirs and routine mains flushing has dramatically reduced detection of faecal coliforms in water supplied to customers. Monitoring of these supplies has shown that post-treatment recontamination by animals and birds has been effectively eliminated. However, the value of such measures in health terms has not been supported by adequate epidemiological studies.

One emerging water supply issue of concern is the growing awareness that previously undetectable organisms, including enteric viruses and *Cryptosporidium parvum,* may be present even in fully treated supplies. Whether hundreds of millions of dollars should be expended on upgrading Australian water supplies, including those currently regarded as safe, to ensure the absence of these organisms requires urgent epidemiological study. Plans to rectify this position, given the relatively low cost of research relative to infrastructure and ongoing operational costs, have been proposed recently (Australian Health and Water Research Consortium 1995).

There have been general pressures to increase treatment not only because of perceived risk to public health, but also because of the perceived threat of poor water supplies on food export industries and to tourism (Australian Health and Water Research Consortium 1995).

Catchment protection, especially where supplies are derived from largely unoccupied catchments, needs to remain a priority. There is little potential for reversion of land use to protected catchment (e.g. Adelaide Hills contribution to Adelaide supply). There are major pressures for development of protected catchments (e.g. around Melbourne and Darwin) and for urban–isation of groundwater catchments (e.g. Perth). Water authorities are moving rapidly to quantify costs of increased water treatment which would occasion development of closed and protected catchments, to assess the risks (including microbiological hazards) associated with clearing catchments for agriculture and urban development.

Toxic blue-green algae (cyanobacteria) have emerged as an issue of concern for supplies affected by nutrient-impacted catchments. To date, extensive research has been directed towards characterising toxicity of blooms and the chemistry of toxins produced by different algal species. The new drinking water guidelines provide trigger total algal number alert levels, but until very recently these have not been reported. Future SoE reports should cover reporting on episodes of water supplies adversely affected by blue-green algae. However, while open reporting of blooms in source waters is encouraged, only the supplies adversely affected will warrant monitoring.

## 2.2 Chemical

There are no broad indicators of the chemical quality of water. Contamination of drinking water by toxic chemicals (disinfection by-products are a possible exception) is extremely uncommon in Australia due to the low level of industrial activity in water catchments.

### 2.2.1 Trihalomethanes

Disinfection of water with chlorine results in the formation of disinfection by-products. Trihalomethanes, along with some other oxidation by-products such as haloacetic acids and haloacetonitriles, are of concern as they may induce tumours in rats and mice at high doses. Trihalomethanes are a reasonable indicator of formation of other disinfection byproducts.

### 2.2.2 Nitrate

High nitrate levels may cause a condition (methaemoglobinaemia) in which the capacity of the blood to carry oxygen is reduced (NHMRC–ARMCANZ 1996). This is especially a problem for newly born infants with other complicating conditions. There have been no documented cases of the disease in Australia. Many arid zone water supplies have naturally elevated nitrate levels; their amenity and hygiene value warrants special consideration especially since bottled waters and rainwater are so readily available to meet drinking water needs.

### 2.2.3 Aluminium

There is little or no evidence to suggest that aluminium is associated with the degenerative brain disease known as Alzheimer’s Disease, although there has been wide interest in its supposed effects (Wade and Cooper 1996, Florence 1996, Wade & Wilcox 1995; Douglas & Pilotto 1995). Aluminium sulphate or polyaluminium salts are added to drinking water to coagulate and flocculate colloidal and fine particulate material. Treated material settles rapidly and the quality is further improved by filtration.

Current guidelines are set to prevent post-flocculation of aluminium salts in the reticulation system and effects on the appearance of water. These are in line with the World Health Organisation—International Programme on Chemical Safety (1995) findings that guideline levels of aluminium in drinking water should reflect aesthetic concerns only.

### 2.2.4 Other indicators

Problems associated with other chemical constituents in drinking water in Australia are rare, although there is increasing concern, reflected mainly from ecological studies, for the potential for pesticide pollution of surface and ground waters. Extensive monitoring of city water supplies has indicated that such pollution is essentially unknown in those supplies.

Heavy metal contamination of drinking water in Australia is sufficiently rare not to warrant being included in national SoE reporting. Copper, zinc and, rarely, lead contamination at individual consumer taps is known but is almost always traced to domestic metal plumbing systems serviced by soft aggressive supplies. Plastic (PVC) piping stabilised by lead stearate does not appear to leach significant lead after installation and initial flushing.

Fluoride is widely added to supplies to arrest dental caries and appears to be universally carefully controlled. Of the major supplies, only the Brisbane supply is unfluoridated. The health risk related to fluoride appears to be confined to the potential for inhalation exposure of water supply operators and is covered by occupational health and safety measures. While a few ground water supplies contain elevated natural fluoride levels, the problems are overcome by mixing the water with low fluoride water prior to reticulation.

## 2.3 Aesthetic quality

Poor water clarity, high colour, odour and taste affect the palatability and general acceptability of drinking water and often result in customer complaints. Supplies containing high suspended solids (high turbidity) greatly reduce the efficiency of disinfection (NHMRC–ARMCANZ 1996). The presence of dissolved salts (particularly hardness; see below) adversely affects taste. Acidic waters (those with a low pH) and unbuffered aggressive waters may indirectly affect aesthetic quality by promoting corrosion of metal and cement reticulation system pipes and tanks.

## 2.4 Supply amenity (user convenience)

Waters containing high levels of calcium and magnesium (hardness) increase the use of soap and detergents, cause deposits in pipes and plumbing fittings, and reduce the life of domestic hot water services, spa heaters, water-based cooling systems and household appliances. Hardness also adversely affects the taste of water.

Elevated levels of iron and manganese can cause staining of basins, showers and laundry fittings as well as staining of washing.

## 2.5 Open versus closed catchments

The supply of safe drinking water involves the use of multiple protection barriers. These barriers comprise catchment protection and land management practices, extended reservoir impoundment (to promote settling of suspended material and to allow die-off of pathogens), coverage of water supply storage tanks, water treatment, and effective maintenance of a sound water supply distribution system. Collectively these measures either prevent entry and transmission of pathogens, or exclude and remove nuisance material such as plant debris and soil and clay particles.

In the later part of the nineteenth century and the early part of this century, a number of water supply authorities adopted a closed catchment policy as the basis of water quality protection.

The closed catchment policy excludes other land use activities and human habitation and use, in the interest of protection of the primary water-harvesting use of the catchment. This approach was seen as a way of safeguarding the quality of supplies at minimal cost.

With growth in populations, demands for resources (timber) and recreational opportunities, the closed catchment policy has come under increasing pressure, resulting in some relaxation of restrictions over activities in the catchments. As a result of growing concerns regarding the bacteriological safety of the supplies, water authorities have introduced disinfection of supplies from these catchments, as a further safeguard.

For supplies which are already tested, some reappraisal of the adequacy of the level of treatment related to the source of supply may also be required. Table 2 provides an indication of the types of problems that can be encountered, particularly when land use practices impact on runoff or when time of storage is short.

**Table 2: Pollutant type and treatment requirements related to source of supply**

| Source of supply | Potential problems | Typical treatment |
|---|---|---|
| **Groundwater** | | |
| Bores and artesian wells excluding microbiologically contaminated soaks | Bacteria, hardness, total dissolved solids, nitrates, iron and manganese, carbon dioxide, hydrogen sulphide | Disinfection, softening, reverse osmosis, aeration, denitrification, activated carbon, filtration |
| **Surface waters** | | |
| Large reservoir, uninhabited catchments | Bacteria, turbidity, protozoa | Disinfection, filtration |
| Large reservoir, inhabited catchments | Bacteria, turbidity, algae, pesticides, heavy metals, protozoa | Disinfection, coagulation–sedimentation, filtration, activated carbon filtration |
| Small reservoir or short retention time | Bacteria, turbidity, algae, pesticides, heavy metals, viruses, protozoa | Disinfection, coagulation–sedimentation, filtration, activated carbon filtration |
| Run of river abstraction | Bacteria, turbidity, pesticides, heavy metals, algae, cyanobacteria, viruses, protozoa | Disinfection, coagulation–sedimentation, filtration, activated carbon filtration |

Where a source water is of variable quality or fails to meet water quality guidelines, intervention is required in terms of storage, improved catchment management (where this is feasible), and treatment of the source to yield a reliable and safe quality of water supply. The level and type of treatment are determined by constituents of health or aesthetic concern, particularly the pathogen load, and the turbidity or the level of suspended solids (see Table 2).

Treatment may comprise simple disinfection, or a train of flocculation, sedimentation, filtration and disinfection processes (Figure 1). Poor water clarity and high colour affect the general acceptability of drinking water and often result in customer complaints. Turbid waters present particular problems in achieving effective disinfection. Suspended material and dissolved organic carbon can greatly increase chemical demand on oxidising biocides such as chlorine, shield microorganisms from disinfectant and even provide a source of food for microorganism regrowth. This necessitates a higher dosage of disinfectant and longer contact times with no guarantee that the treated water will be free of pathogenic microorganisms. For this reason, drinking water guidelines have consistently advocated reducing the turbidity to low levels, ideally to 1 NTU at the point of disinfection (WHO 1993; NHMRC–ARMCANZ 1996).

As a result of intensification of development in many catchment areas and inadequate controls of land-use activities, an increased incidence of algal blooms has been observed within a number of water supply reservoirs. Well-designed off-take structures, with their multiple level off-takes, can limit both the amount of algal material and iron/manganese-rich water abstracted from reservoirs into supply systems.

Treatment plants incorporating full flocculation, sedimentation, filtration, addition of powdered activated carbon, and disinfection are capable of substantially eliminating the nuisance by-products of algal breakdown. Chloramination, as an alternative to chlorination, is now widely employed to improve the persistence of disinfectant in large complex supply systems (e.g. Adelaide, Sydney and Brisbane) and has the added advantage of minimising trihalomethane formation, especially when high levels of natural organic matter are present in water.

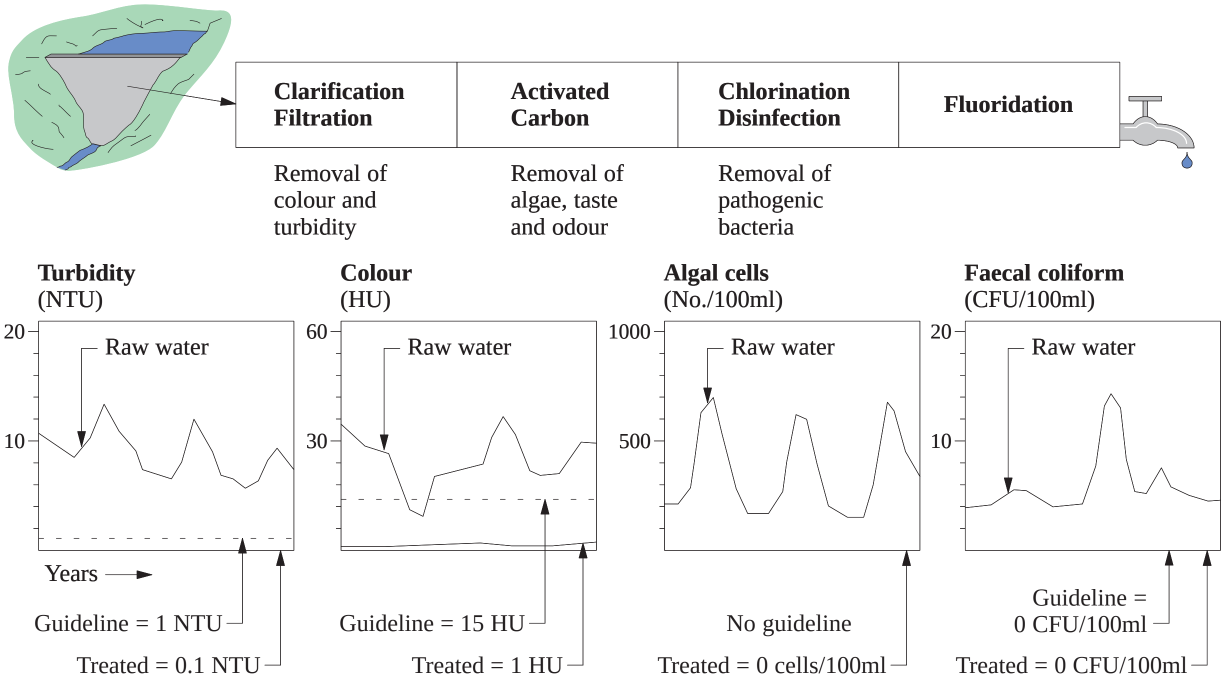


**Figure 1: Water treatment process**

Where multiple-level off-takes or full water treatment facilities are not available, algal blooms can result in serious odour and taste problems throughout the water distribution system, and can promote regrowth of bacteria within the supply system. Algae and their breakdown products increase disinfectant demand, can increase the formation of by-products, and cause taste and odour problems.

These problems highlight the importance of tight planning controls over land uses in water supply catchments. In the absence of a closed catchment policy, total catchment management plans are needed to identify and limit nutrient pathogen and sediment export to water courses across the catchment to levels consistent with the maintenance of drinking water quality objectives.

## 3 Selection of national water quality indicators

Selection of suitable drinking water quality indicators for SoE reporting is a seemingly daunting task. Natural waters, largely unimpacted by human endeavour, typically contain several hundred trace chemical constituents such as breakdown products from algae, plants and mineral constituents, although nearly all are present at vanishingly low levels.

There are many measurable characteristics of water that can serve as indicators of drinking water quality. It is important to focus on measuring those properties of water that tell us about the safety, acceptability and amenity of any supply system. Characteristics which measure both existing water quality and long-term water quality changes in source waters and at the tap provide an index of resource sustainability, and hence are especially important.

In view of the practical limits to the extent of detail that can be reported in a national overview, and the need to communicate information in a simple way, it is necessary to identify a few key indicators that provide a representative indication of water quality. In practice, simple measurements of turbidity, colour, total dissolved solids, water hardness, coliform bacteria, and a handful of chemical variables have proved to be remarkably robust in their ability to track complex underlying water quality problems.

To be useful, these indicators must be capable of measuring both:

- the quality of natural waters harvested for water supplies; and

- the quality of water supplied to the consumer at the tap.

The approach adopted for selection of indicators was based on identification of areas of concern (health, aesthetic and amenity values, see Section 2) and selection of indicators which:

- are representative of these values; and
- are already commonly measured.

The *Australian drinking water guidelines* (NHMRC–ARMCANZ 1996) list some two hundred and sixty measurable indicators of water quality.

The costs and logistics of sampling and analysis, the almost total absence of the vast majority of toxicants and the technical difficulties associated with many analyses mitigate against any full compliance or performance assessment process. Not only must the indicator provide a valid measurement of health, aesthetic and user convenience requirements, but tests must also be cost-effective and reliable. There is no point in specifying a test which costs thousands of dollars to conduct if a problem is unlikely to exist or if the ratepayers cannot afford the expense.

**Table 3: Summary of water supply quality problems and indicators**

| Indicator | Guideline level | Indicative problem |
|---|---|---|
| **Microbiological** | | |
| Total coliforms | 0 CFU/100 mL* | Possible faecal contamination; action required whenever detected |
| Thermotolerant coliforms | 0 CFU/100 mL* | Very likely faecal contamination; action required whenever detected |
| **Chemical** | | |
| Trihalomethanes | 0.25 mg/L | Disinfectant by–product formation |
| Nitrate | 50 mg/L (as $NO_3$); 100 mg/L (non–neonates) | Groundwater pollution, minor health risk |
| Other parameters (pesticides, heavy metals etc.) | See *Australian drinking water guidelines* for details | Source (catchment or groundwater) pollution, aggressive waters attacking reticulation and plumbing materials |
| **Aesthetic quality** | | |
| Acidity (pH) | 6.5–8.5 | Promotes corrosion (low pH); interferes with residual chlorine disinfection (high pH) |
| Aluminium | 0.2 mg/L (ideally < 0.1) | Poor control of chemically assisted water clarification |
| Colour | 15 HU | Measure of light absorption |
| Turbidity | 1 NTU (for disinfection); 5 NTU (at tap) | Measure of water cloudiness or light scattering |
| Total dissolved salts | 500 mg/L (good); 1000 mg/L (poor) | Measure of water brackishness |
| **Supply amenity** | | |
| Hardness | 200 mg/L (as $CaCO_3$) | Water scaling potential |
| Iron | 0.3 mg/L | Rusty staining of laundry and plumbing fitting |
| Manganese | 0.1 mg/L | Black water and staining problems |

*Longer term, typically annual, performance in terms of percentage of samples achieving this ideal, are dealt with at length in the *Australian drinking water guidelines* (NHMRC–ARMCANZ 1996).

Other issues, such as frequency of measurement (e.g. American Public Health Association 1989), sample stability and practical availability of analytical methods, also need to be considered.

As already stated, selected indicators must be capable of identifying present and potential water quality problems. Indicators need to be particularly sensitive to catchment activities, water treatment practice, and distribution system integrity. Table 3 presents a summary of possible water quality problems of national concern and accepted indicators.

Core measures of water quality can be used to indicate the status of source waters; they can indicate a need for water treatment, they can provide a measure of catchment land use impacts, and (in terms of raw water quality) they are a direct measure of water quality delivered at the tap where treatment is not employed. Such an emphasis on the importance of source water quality has been pursued by the Australian and New Zealand Environment and Conservation Council (1992). They emphasise the importance of source waters not being unacceptably degraded.

Whether or not water is treated, the quality of source waters is important from an environmental standpoint. Poor or degrading supply sources present a range of problems to water supply agencies and to the community, not the least to ensure that undue reliance is not placed on treatment and to ensure that, as much as possible, water treatment remains affordable.

# 4 Reporting on data

## 4.1 Guidelines

Drinking water quality guidelines are widely used to benchmark water quality. Put simply, the guidelines define limits to how much of any substance can be present in water before the likelihood of a problem may arise. Such guidelines focus on microbiological and chemical safety and on the appearance, taste and odour of drinking water. The *Australian drinking water guidelines* (NMHRC–ARMCANZ 1996) provide independent guideline values against which to assess supply quality.

Although not explicitly stated, the guidelines benchmark health, aesthetic, and user convenience (or amenity) requirements (Maher et al., 1993):

- health criteria which emphasise that water used for drinking, beverage preparation and cooking purposes should be free of harmful levels of toxic substances and pathogens;
- aesthetic criteria which indicate that water to be consumed should be free of objectionable taste and odour, and excessive levels of colour and suspended material; and
- user convenience (amenity) criteria which deal with water used for washing, bathing and other domestic purposes and which highlight the importance of water being free of gross microbial contaminants and excessive levels of corrosive (acidic) or scale-forming agents.

Actual risks to health presented by water supplies have never been quantified in Australia. The risks presented by pathogenic (disease-causing) microorganisms, while probably of greatest importance, are essentially unknown. While level of performance against guideline values can be ascertained[1], it is generally recognised that the guidelines have been established very conservatively, that is, high margins of safety have been built in. Consequences of lifetime exposures to known toxicants are very effectively covered in the draft *Australian drinking water guidelines* (NMHRC–ARMCANZ 1996); however, assessment of the effects of actual exposure to contaminants in drinking water is beyond the bounds of current understanding, so assessment of risks to health presented by toxicants, which are probably extremely low, may be some time off. The Australian Health and Water Research Consortium (1995), coordinated by the National Centre for Epidemiology and Population Health at the Australian National University, and the newly-formed Cooperative Research Centre for Water Quality and Treatment are currently attempting to coordinate research efforts to establish the nexus between health effects and water quality.

## 4.2 Adequacy of reporting

Confidence in data is dependent not only on the integrity of sampling, storage and analysis procedures, but also on the frequency of sampling relative to the natural water quality variation.

**Table 4: Variability of water quality with source of supply**

| Source of supply | Variability |
|---|---|
| Groundwater | Extremely low |
| Surface waters: | |
| Large reservoirs in uninhabited catchments | Low |
| Large reservoirs in inhabited catchments | Moderate to high |
| Small reservoirs with short retention time | High |
| Run of the river abstraction | Extremely high |

The latter is primarily a reflection of the source of supply (Table 4).

In the case of inorganic and physical characteristics, the *Australian drinking water guidelines* (NHMRC–ARMCANZ 1996) adopt large storage reservoirs or groundwater supplies, or small storages or rivers with water treatment provision, as the basis for identifying monitoring requirements (Table 4). More specific monitoring frequency recommendations are made in the *Australian drinking water guidelines* (NHMRC–ARMCANZ 1996); in the case of bacteriological characteristics, a frequency based on the size of population serviced is recommended. While it may be some years before the ideals of these monitoring regimes are widely adopted, a progression towards comprehensive monitoring complemented by sound water supply management procedures including source control, are needed to ensure the safety and amenity of all supplies.

While these requirements might be adopted as the basis for SoE reporting, monitoring frequency in practice commonly falls short of guideline recommendations. If a percentile basis of reporting were to be adopted, then the confidence levels would automatically adjust estimates on the basis of the number of available results. While less than ideal, a simple process of reporting average performance against guideline values is recommended for national reporting. The reality is that current data bases, at best difficult to access, do not allow easy comparison of supplies given the wide variation in sampling frequency, sampling locations, sampling methods, analytical techniques used and parameters reported on.

While great emphasis is placed on actual reporting of results of water quality testing, there are many advocates of the approach which records the effectiveness of management of supplies, so-called quality assurance and quality control (QA/QC) programs. In essence this system amounts to documenting good public health engineering practice and in principle provides an equal or complementary indication of the safety and amenity value of water supplies. The *Australian drinking water guidelines* (NHMRC–ARMCANZ 1996) note that the monitoring simply provides a check that water supply barriers are working.

# 5 Determination of quality of Australian water supplies: Suggested approach

## 5.1 Tap water quality

**Suggestion 1**

Data should be collected for indicators listed in Table 3 which address the major water quality problems expected to arise in tap water. Data for individual indicators should be presented as performance (exceedance) against guideline values.

**Suggestion 2**

Special attention to settlement type (metropolitan areas, large cities, rural areas, remote zones) should be recognised to allow regional water problems to be identified. Classification by settlement type is especially important since smaller communities normally have insufficient resources to provide and operate water treatment plants. Where these supplies are of surface origin, removal of pathogens, turbidity and suspended solids may be impracticable and source protection—catchment management, limiting access to storages, covering storage tanks, and groundwater protection—provides the most obvious measure for securing supplies.

**Table 5: Assessment of the quality of tap water (incorporated into Figure 2)**

| Ranking | Assessment basis |
|---|---|
| Poor | > 5% of bacteriological, >5% of chemical and > 10% of aesthetic values for last twelve months exceed medium-term objectives*. |
| Satisfactory | <5% of bacteriological, < 5% of chemical and < 10% of aesthetic values for last 12 months exceed the medium-term objectives but >2% of bacteriological, >5% of chemical and >10% of aesthetic values exceed the long-term objectives. |
| Excellent | <5% of bacteriological, <5% of chemical, and <10% of aesthetic values exceed the long-term objectives. |

* Objective may be a guideline value or some other value determined by socio-economic considerations.

**Suggestion 3**

To facilitate future SoE reporting for different geographical and demographic areas, a classification scheme ranking supplies as poor, satisfactory or excellent is proposed (Table 5) to enable comparisons to be made about water supplied at the tap. This may be presented graphically (Figure 2).

## 5.2 Raw water quality

**Suggestion 1**

Trends in raw water quality (e.g. turbidity, colour, iron, manganese, coliforms and algae) should be reported to illustrate changes of raw water quality deterioration.

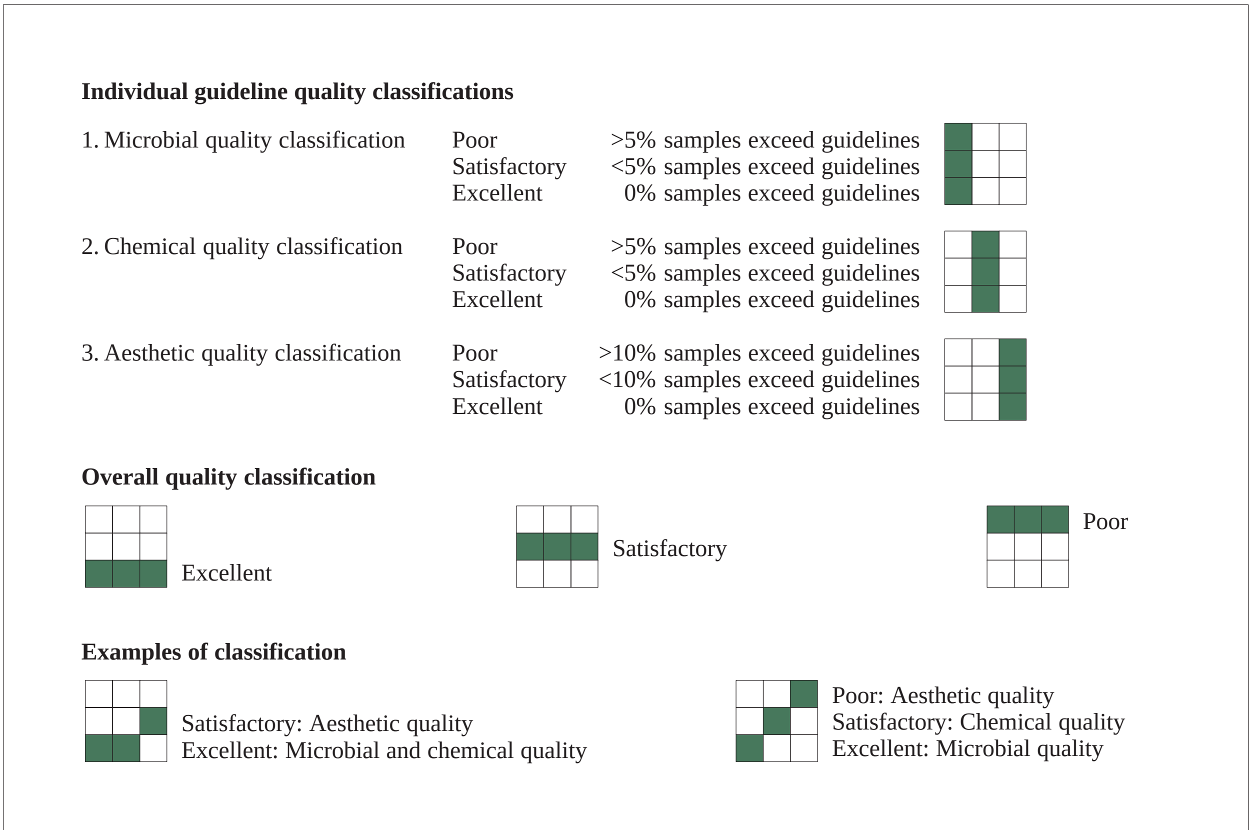


**Figure 2: Classification of water supplies**

## Endnote

1. *Australian drinking water guidelines* provide a useful outline of the range of methods available for measuring performance, namely:

- performance against a maximum value—percentage of samples tested that are within a guideline value—concludes that this approach has a number of serious deficiencies;
- performance using a mean—comparison of the mean value for the twelve month period with the guideline value—concludes that this approach provides a better indication of overall trends in quality especially for aesthetic characteristics, but that it may mask a few high values exceeding guideline values; and
- performance using a percentile—the percentage of results that are within the guideline value—concludes that this approach provides a robust assessment of health-related characteristics, and is statistically more rigorous, while its disadvantage is that estimates of percentiles are more uncertain than estimates of means (particularly where the number of available results are limited).

Adoption of the *Australian drinking water guidelines* percentiles approach appears to be desirable. In a future scenario, a range of percentile levels complying with guideline values could be used as the basis for ranking performance.

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