Consumers Guide to Drinking Water

WHY TREAT WATER?

Drinking water is treated to protect public health by removing microorganisms and natural or man-made chemicals that may cause illness in consumers. Water treatment may also be used to improve the water's colour, taste and odour as required.

Protection of water sources from pollution by human or animal waste can reduce the amount of microorganisms entering the water supply, but even water from the most protected wilderness environment may sometimes contain microorganisms capable of causing human disease. Illness can be easily and rapidly transmitted to large numbers of people by contaminated water supplies, therefore it is necessary to treat and/or disinfect water supplies to safeguard against disease. This provides insurance or a barrier against actual or potential contamination.

While some earlier civilisations apparently appreciated the importance of a clean and reliable water supply, the development of scientific understanding of why this was important did not occur until the second half of the 19th century. This was when the nature of infectious disease was first understood and the ability of water supplies to transmit diseases such as cholera and typhoid was first demonstrated.

The observations of Dr John Snow (1813 - 1858) were important in showing this link between water supply and disease. He began his work during a major cholera outbreak in Britain in 1848 - 49 in which at least 53,000 people died. His systematic investigation of the 1854 outbreak in London showed that cholera death rates were much higher in people consuming water from sewage-polluted regions of the Thames River than in people drinking water from a cleaner part of the river.

At that time the germ theory of infectious disease was unknown, and cholera was thought to result from "bad air" or "filthy conditions". John Snow proposed that cholera was transmitted by a "specific poison" (now known to be the bacterium *Vibrio cholerae*) that could be transmitted from person-to-person or indirectly through contaminated water, food or objects.

Dr Snow is best remembered for an incident related to a cholera outbreak in the Golden Square section of London where more than 500 people died within 10 days. He determined that most of the sick people drank water from the Broad Street pump, while residents with a different water supply were not affected. After his findings were reported to the Board of Guardians of the parish, the handle of the pump was removed as a public health measure to prevent people using the water. A memorial to Dr Snow now marks the place where the pump once stood.

Dr Snow's findings were published in 1855 in the classic work *On the Mode of Communication of Cholera*, however it was another 30 years before the germ theory of infectious disease was fully accepted.

Link to UCLA site on Dr John Snow

http://www.ph.ucla.edu/epi/snow.html

The approach to the provision of water services that emerged from this 19th century experience was to separate as much as possible the sources of water supply from human habitation and waste disposal. Since complete protection of water sources was often not possible, methods of treating water to kill or remove microorganisms were also developed.

The technologies used to treat water are similar worldwide. There have been a great variety of treatment processes developed and the more important of these are discussed elsewhere in this Guide. The choice of treatment technology depends on the characteristics of the source water, the types of water quality problems likely to be present, and the costs of different treatment systems.

Innovative water treatment technologies are being developed in Australia and overseas with the aim of improving water quality further and reducing the cost of doing so. Much of this Australian research is conducted within the Cooperative Research Centre for Water Quality and Treatment.

Water treatment, together with improved sanitation, has produced great benefits to public health in developed countries by reducing the incidence of many diseases. However, in the developing world, waterborne diseases are still a major cause of illness and death, especially in children. In 2002 the World Health Organisation estimated that over 1.1 billion people (17% of the world's population) lacked access to improved water supplies, and 2.6 billion (42%) lacked basic sanitation facilities. The United Nations General Assembly has proclaimed 2005-2015 as the *Water for Life* decade, with increased focus on achieving the twin goals of providing safe water and basic sanitation to people in developing countries.

More information can be found on the Water, Sanitation and Health (http:/www.who.int/water_sanitation_health/en/) page of the World Health Organisation website.

Treatment aims to ensure that water is:

- Safe for human consumption.
- Pleasant to consumers.
- Provided at a reasonable cost.

HOW IS WATER TREATED?

Introduction

The water treatment processes developed in the 19th century and refined during the 20th century are simple in nature. However, engineers have since developed ways of making these processes happen faster, in a smaller area and in a more controlled way at lower cost.

These earlier technologies are referred to as traditional or conventional technologies to distinguish them from technologies developed more recently.

There are a great variety of water treatment processes, although only a few are applied in most situations. A summary of each of the main treatment processes is given below.

Coagulation, flocculation and sedimentation

In traditional water treatment, certain chemicals are added to raw water to remove impurities. While some particles will spontaneously settle out from water on standing (a process called sedimentation), others will not. To cause particles that are slow to settle or are non-settling to settle out more readily, a soluble chemical or mixture of chemicals is added to the water. Such a chemical is called a coagulant and the process is called coagulation.

The coagulant reacts with the particles in the water, forming larger particles called flocs, which settle rapidly.

Flocs can also be effectively removed by passing the water through a filter. The process is controlled so that the coagulant chemicals are removed along with the contaminants.

Coagulation/flocculation processes generally use aluminium sulphate (alum) or ferric chloride as the coagulant.

A combination of coagulation/flocculation/sedimentation and filtration is the most widely applied water treatment technology around the world, used routinely for water treatment since the early part of the 20th century.

Coagulation/flocculation processes are very effective at removing fine suspended particles that attract and hold bacteria and viruses to their surface. Research has shown that these processes alone are capable of removing up to 99.9 per cent of the bacteria and 99 per cent of the viruses from water supplies.

These processes also remove some of the organic matter washed from soil and vegetation as water travels across the landscape, from raindrop to river. It is usually this natural organic matter that is responsible for any brown discolouration in water. However, not all of this natural organic matter (what water scientists call NOM) is removed by coagulation: certain taste and odour problems may remain.

Filtration

One of the oldest and simplest processes used to treat water is to pass it through a bed of fine particles, usually sand. This process is called sand filtration. In its simplest form, the water is simply passed through the filter with no other pre-treatment, such as the addition of a coagulant. Usually this type of filter will remove fine suspended solids and also some other particles such as larger microorganisms.

Sand filtration is even more efficient when the water being treated passes through the sand filter very slowly. Over time the sand particles become covered with a thin surface layer of microorganisms. Some might refer to this layer as a slime but water scientists call it a biofilm. Even very small particles stick to this biofilm and are held, while water of greatly improved quality passes out through the filter.

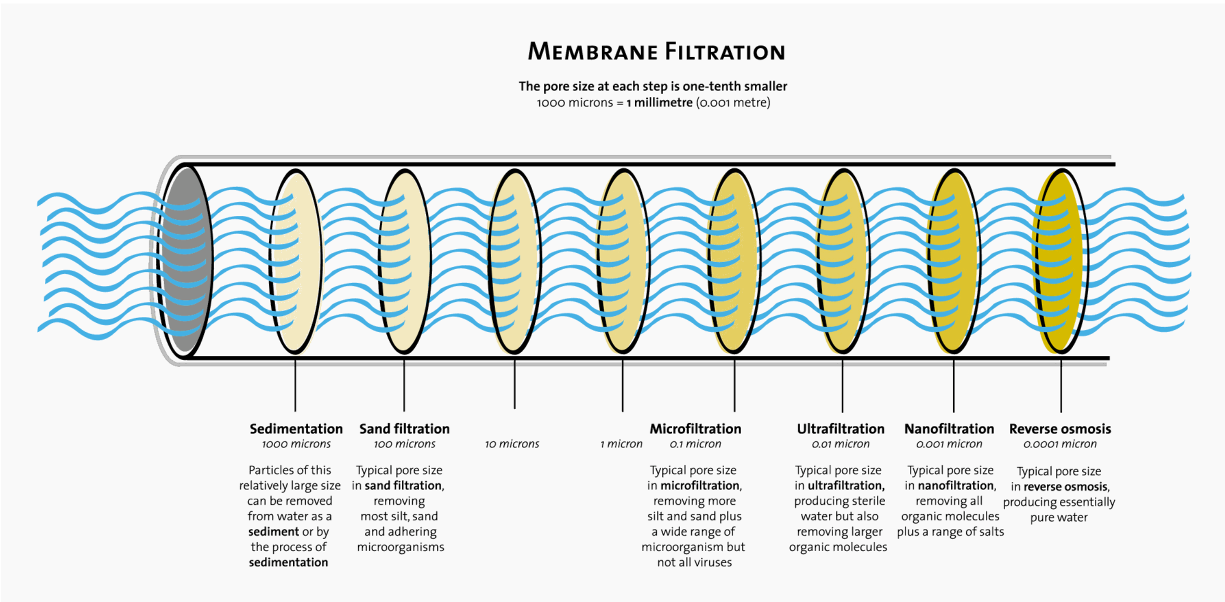
First operating in London in the 19^{th} century, slow sand filters are still widely used throughout the world today. Although very effective, they require a large area of land to achieve the sort of flows required by a large modern city. Additional processes may also be needed to achieve adequate water quality.

In the early 20^{th} century, engineers developed rapid sand filters, which use high rates of water flow and sophisticated backwashing of the filter bed to remove trapped contaminants.

Because the sand filtration processes become less effective at removing fine suspended particles at higher water flow rates, the water must be pretreated – coagulated and flocculated – before passing through the filter bed. Such high rate direct filtration processes are widely applied to raw water with low levels of suspended matter. A good example is the water treatment plant at Prospect in Sydney.

The water treatment plant at Prospect in Sydney is one of the largest direct filtration plants of its type in the world. The plant produces more than 2000 megalitres a day of treated water. It is operated by Australian Water Services on behalf of Sydney Water Corporation. The raw water being treated at Prospect comes from Warragamba Dam, operated by Sydney Catchment Authority.

Membrane filtration



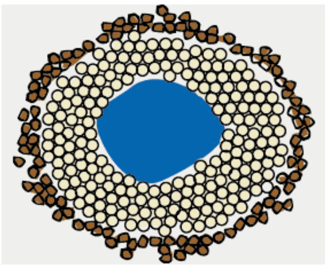
The development of plastics has led to a new range of filter materials and methods. Processes based on these new filter materials are now increasingly used to treat water for urban and industrial purposes.

In membrane filtration, water is filtered through tiny holes (usually referred to as pores) in a membrane wall rather than a bed of sand. The smaller the pore size, the greater the proportion of material the membrane retains as the water passes through.

Processes of membrane filtration are categorised by the pore size in the membrane. Pore size can vary from 0.1 microns (1000 microns is equivalent to 1 millimetre) for microfiltration down to 0.001 microns for nanofiltration.

The most common form of microfiltration membrane is a one-metre long bundle of thin, thread-like hollow fibres. A microfiltration water treatment plant would contain many such bundles.

A cross-section of a single hollow fibre is shown below (in yellow). Particles (in brown) are retained on the outer surface of the membrane while the purified water (in blue) passes into the central channel from where it flows lengthwise along the hollow fibre.



Previously too expensive to use in many circumstances, recent advances have reduced the cost of membrane filtration to a level approaching that of conventional water treatment processes.

While membrane water treatment plants are simple and reliable in operation, especially in small to medium-sized applications, there are some disadvantages. High energy costs are involved in pumping the water through the membrane. If a lot of natural organic matter is in the water, the membrane tends to block easily. This is referred to as membrane fouling. If cleaning cannot reverse the membrane fouling, the life of the membrane will be significantly shortened. This increases the cost of water treatment, since replacing membranes regularly is expensive.

Microfiltration

Microfiltration will remove most of the fine suspended solids in the water and almost all protozoa and bacteria but is not able to remove the dissolved part of the natural organic matter in the water. It is this dissolved part of the natural organic matter that is frequently the cause of colour, taste and odour problems.

The microfiltration process is becoming increasingly popular for small-scale water treatment plants supplying smaller communities in rural and regional Australia. It has become the most widely used membrane water treatment process in Australia.

Microfiltration plants installed by water authorities in recent years include: Batlow (Tumut Shire Council, NSW) Babinda, Bramston Beach and Mirriwinni (Cairns City Council, Queensland), Crystal Creek (Townsville Thuringowa Water Supply Board, Queensland), Coen (Cook Shire Council, Queensland) Birregura and Meredith (Barwon Water, Victoria) Creswell, Frogley and Yarra Glen (Melbourne Water, Victoria) Gunbower, Tooborac and Trentham (Coliban Water, Victoria).

Ultrafiltration

Ultrafiltration membranes have smaller pores than those used in microfiltration and can therefore remove finer particles from the water. This process is capable of removing almost all the viruses (the microorganisms most difficult to remove) and improving colour.

Because of the relatively high levels of natural organic matter found in raw waters in Australia, ultrafiltration technology has not found wide application here at this stage of its development.

Nanofiltration

Nanofiltration uses membranes with even smaller holes than for ultrafiltration, so requires a high operating pressure to force the water through the membrane. This results in high energy and operating costs.

However, nanofiltration is more effective than other filtration methods at improving water quality. For example, it is capable of removing all virus particles and most of the NOM. However, it also removes some natural minerals from the water, which can cause pipes to corrode. To reduce corrosion in these circumstances, stabilising chemicals, such as lime, must be added to the treated water.

The cost involved in using this technology, and the fact that backwashing of the membrane can consume a significant proportion of the water produced, limits its use to specific circumstances.

There are no working examples of a nanofiltration plant in Australia at present, but the process is in operation elsewhere, including Europe, where it is used to treat surface waters contaminated by herbicides and insecticides.

Additional Treatments for Unusual Circumstances

While coagulation processes and/or filtration remove most of the troublesome contaminants from water, they usually do not remove all of the dissolved (or soluble) material. This includes low concentrations of dissolved organic matter that microorganisms in the water can use as a food supply and perhaps algal toxins and associated taste and odour compounds.

If water contains undesirable contaminants, additional treatment processes are required, like adsorption and oxidation.

Adsorption refers to the process by which chemicals are attracted to and held by a solid surface and is quite different from the similarly sounding process of absorption.

In water treatment, specialised adsorbent materials are used. Examples are activated carbon and ion exchange resins. These adsorbants can be used to remove purely soluble contaminants from water.

Activated carbon is the most widely used adsorbent material in water treatment, because it is highly effective in removing taste and odour compounds and algal toxins. It can be used as a powder or in granular form.

In Australia, there has only been limited use of granulated activated carbon. In this treatment process, the activated carbon is usually placed in a column or filter and the water percolated through the bed of carbon granules. After some time the activated carbon will become saturated with the adsorbing material and will need to be replaced or regenerated. Current technology to regenerate the carbon granules involves heating in a high temperature furnace. Because of the cost of this regeneration process, it has not been used in Australia.

If water contamination occurs only occasionally, a better approach is to add powdered activated carbon to a conventional coagulation/flocculation process when the problem arises. The carbon is collected in the filters and then discarded with the normal water treatment plant sludge. Such intermittent dosing of activated carbon powder is used in Australia at numerous locations that have problems with blue-green algal blooms.

The use of activated carbon is a very costly and can be justified only when there are particular problems with toxins or taste and odour compounds.

Ion exchange resins can also remove soluble materials from water by exchanging ions (charged atoms or molecules) in the water and on the resin. This form of treatment is more often used for industrial purposes in industries that require very pure water for specialised processing, for example in computer chip manufacture. It has also found general application in the treatment of boiler feed water to reduce the problem of scaling.

With new developments in the technology, ion exchange resins are also being used to treat urban water supplies. For instance, the Water Corporation of Western Australia has established the biggest ion exchange water treatment system of its type in the world at the Wanneroo Groundwater Treatment Plant to remove intermittent odour problems occasionally experienced in some of Perth’s groundwater supply schemes. This plant uses an Australian invention, MIEX (magnetic ion exchange) resin manufactured by Orica Watercare.

Another treatment technology commonly used in Europe but only now appearing in Australia is oxidation with chemicals such as ozone or chlorine dioxide. These are strongly reactive chemicals able to oxidize a range of substances in water.

Ozone in particular is a strong oxidizing agent and is used as a disinfection agent (see below) and as a means of destroying soluble contaminants such as algal toxins, taste and odour compounds and (particularly in Europe) trace levels of insecticides. It is quite often used in combination with a column of granular activated carbon, as any soluble organics remaining after the chemical oxidation stage are biologically degraded by the film of microorganisms that develops in the activated carbon bed.

Experience with the process in Europe has been very good, with consumers reacting positively to the improved taste of the water produced. However, the technology is more expensive than standard coagulation and is suited to applications only where taste and odour problems are becoming severe. For example, Grampians Water, supplying water services in the Wimmera region of Victoria, has installed such a plant at Edenhope to overcome problems caused by algal contamination of the local water source.

Water Stabilisation

Some raw water supplies are not stable, becoming acidic or alkaline depending on which material they are in contact with. This condition often leads to corrosion in piping systems and hot water services and can result in dissolved metals appearing in the water. For example, where copper corrosion occurs, a telltale bluish stain can appear where a tap drips on to a surface.

To prevent such corrosion problems, many waters are chemically stabilised before distribution by the addition of lime and sometimes carbon dioxide. The addition of lime (calcium carbonate) will make the water slightly harder by increasing the level of calcium in the water. Here, hardness refers to the characteristic of the water that prevents soap from lathering. In contrast, soft water will allow soap to form a lather easily.

Disinfection

Disinfection is carried out to kill harmful microorganisms that may be present in the water supply and to prevent microorganisms regrowing in the distribution systems.

Good public health owes a lot to the disinfection of water supplies. Without disinfection, waterborne disease becomes a problem, causing high infant mortality rates and low life expectancy. This remains the situation in some parts of the world.

There can be no higher priority in any water supply system than effective and safe disinfection of the water. The only possible exception to this rule occurs with secure groundwater supplies, where harmful microorganisms are prevented from entering the underground water source or contaminating the water when it is brought to the surface. Such water supplies need to be inspected and tested regularly to make sure that they remain safe.

The two most common methods to kill the microorganisms found in the water supply are oxidation with oxidising chemicals or irradiation with ultra-violet (UV) radiation.

The most widely used chemical disinfection systems are chlorination, chloramination, chlorine dioxide treatment and ozonation.

Key factors considered by a water authority in selecting a disinfection system are:

- Effectiveness in killing a range of microorganisms.
- Potential to form possibly harmful disinfection byproducts.
- Ability of the disinfecting agent to remain effective in the water throughout the distribution system.
- Safety and ease of handling chemicals and equipment.
- Cost effectiveness.

A summary of each of the main disinfection processes is given below.

Chlorination

Chlorination is the most widely used disinfectant for drinking water in Australia. Its introduction a century ago removed the threat of cholera and typhoid from Australian cities.

It is cheap, easy to use, effective at low dose levels against a wide range of infectious microorganisms, and has a long history of safe use around the world.

Chlorine is a strongly oxidising chemical and may be added to water as chlorine gas or as a hypochlorite solution.

Chlorine's main disadvantage is a tendency to react with naturally occurring dissolved organic matter to form chlorinated organic compounds.

The substances formed by the disinfectant reacting with the natural organic matter in the water are referred to as disinfection byproducts.

In the 1970s, as scientific instruments capable of measuring lower and lower concentrations of substances were developed, trace quantities of chloroform and other similar chemicals were identified as disinfection byproducts in chlorinated water supplies.

While the concentration of these disinfection byproducts is usually very low (a typical figure might be 0.1 part per million), some have been identified as potential carcinogens. As a precaution, many countries limit the allowable level of chlorinated disinfection byproducts in the water. The ***Australian Drinking Water Guidelines*** also suggest maximum values for a range of byproducts (for example, 0.25 part per million for chloroform-type compounds).

Studies have compared the health risk from microbiological contamination of drinking water with the potential chemical risk from chlorination byproducts. The conclusions so far are:

- The risk of death from pathogens is at least 100 to 1000 times greater than the risk of cancer from disinfection byproducts.

- The risk of illness from pathogens is at least 10,000 to one million times greater than the risk of cancer from disinfection byproducts.

The ***Australian Drinking Water Guidelines*** encourage action by water authorities to reduce organic disinfection byproducts in water supplies but not in a way that would compromise the proper disinfection of the water.

The likelihood of such byproducts forming can be greatly reduced by treating the water to lower levels of dissolved organic matter before chlorine is added for disinfection purposes.

Some Australian examples of chlorinated water supplies are those of Melbourne, Adelaide, Perth, Canberra, Hobart and Townsville.

Chloramination

Chloramines are produced when ammonia and chlorine are added to water together. They are less effective than chlorine in killing microorganisms because they are not as chemically active. However, chloramines maintain their disinfecting capability longer than chlorine and are ideal for very long distribution systems or for water supplies with long holding times in service reservoirs. For example, the disinfected water supplied to some Australian communities may travel through the distribution system for more than a week before use as drinking water from someone's tap.

Chloramines also react less with dissolved organic matter in the water and so produce fewer disinfection byproducts.

Chloramination is a common disinfection system in Australia and many examples of its use can be found in regional Australia.

Chlorine dioxide

Chlorine dioxide is about 10 times more expensive than chlorine and its use in Australia is very limited. Its most significant use is by the Gold Coast City Council in Queensland.

The choice of chlorine dioxide in this application was primarily to prevent an aesthetic water quality problem caused by naturally occurring manganese compounds in the raw water. The problem is sometimes described as "black water" and can result in black stains on customers' washing. When "black water" occurs, the material being washed effectively acts as a filter for the tiny black particles during the rinse cycle of the washing machine.

Chlorine dioxide is a strong oxidant that can be used in low doses. It is a highly reactive, unstable gas that must be generated at the water treatment plant from sodium chlorite. Its use does not lead to the formation of chlorinated disinfection byproducts, but other possible byproducts of oxidation, such as chlorate and chlorite ions, can be a public health concern.

Ozone

Ozone (O_3) is the most powerful disinfectant used in water treatment. It is even effective against the difficult to treat protozoan parasites, *Cryptosporidium* and *Giardia*.

Ozone, which only recently began to be used in Australia, destroys soluble contaminants such as algal toxins, taste and odour compounds and trace levels of insecticides.

Ozone is an unstable gas that must be generated at the water treatment plant. This is done by passing an electric discharge through clean, dry air or oxygen.

Because it is so reactive, ozone decays quickly in water. For this reason, it is usually used together with a small dose of chlorine or chloramine to ensure that some residual disinfection capacity is maintained in the water supply distribution system to prevent regrowth of microorganisms.

The use of ozone does not lead to chlorinated disinfection byproducts. However other possible oxidation products, such as bromate formed from the naturally occurring bromide found in some water sources, are a potential health concern.

Ultraviolet irradiation

Ultraviolet radiation (UV) is a component of sunlight. Sunlight achieves disinfection by ultraviolet irradiation naturally. In water treatment, an appropriate level of UV irradiation, produced by mercury lamps, can kill bacteria and viruses. However, there is some uncertainty surrounding the effectiveness of UV irradiation against *Cryptosporidium* and *Giardia*.

UV irradiation adds no chemicals to water and uses equipment that is relatively simple to operate and maintain. However, impurities in the water that cause colour and turbidity can severely reduce the effectiveness of the process because UV radiation cannot penetrate the water effectively.

UV irradiation has no lasting effect and a further disinfectant such as chlorine or chloramine is usually added to ensure that some residual disinfection capacity is maintained in the water supply distribution system to prevent regrowth of microorganisms.

The cost of UV treatment of water supplies is becoming increasingly affordable, especially for small water supply systems where the raw water is clean and cold.

UV irradiation may also be chosen where the water source is close to the customers, allowing only a short time between when the water is disinfected and when it is consumed.

IS A WATER FILTER NECESSARY?

Generally, people living in major Australian cities and also in many parts of regional Australia, do not require a filter to meet health requirements because of the quality of water supplied.

Filters can change the aesthetic quality and taste of drinking water. Installing a filter for these reasons is a matter of choice.

Those people who choose to install a filter should make sure that it meets their specific needs and is properly maintained.

Maintenance of a water filter is very importance from a health perspective. If the filter is not changed frequently, a build up of microorganisms or chemicals may be released back into the water resulting in worse, not better quality, water.

The Australian Consumers' Association magazine “Choice” published an article on water filters in February 2003. According to the “Choice” article most Australians usually do not have to worry about the quality of their drinking water. The article can be viewed at www.choice.com.au (enter “water filters” in the ‘Search' field)

Where there is a concern about any aspect of the quality of the local water supply, it is advisable to contact the water supplier in the first instance.

DELIVERING WATER TO THE COMMUNITY

The distribution system

After water has been treated to protect public health, improve aesthetics by removing colour and taste and odour as required, it is ready to be delivered to consumers. The system of mains and pipes used to deliver the water is known as the distribution, or reticulation, system.

Treated water may be held at a treatment plant or immediately discharged into the system of mains and pipes that will transport it to consumers' taps. On the way it may be held in short-term storages, usually known as service reservoirs, which are located as close as possible to where the water will be used.

Sufficient water is required in a local area to supply periods of high demand, as on a hot summer day. From a design perspective, the needs of fire services usually determines the capacity of the system.

An important characteristic of a drinking water distribution system is that it is closed, to prevent contamination by birds, animals or people. In contrast, irrigation water is usually delivered in open channels or aqueducts.

A significant part of the water supply system lies buried underground. Out of the public eye, such infrastructure can be overlooked. It is easy to forget how valuable and essential water distribution systems are to the community. In terms of money spent on supplying water in Australia, most of it has been invested in the mains and pipes buried under the streets of towns and suburbs across the country.

Most distribution systems have developed and expanded as urban areas have grown. A map of a water distribution system would show a complex mixture of tree-like and looped pipe networks, together with valves and pumps.

Distribution systems require regular cleaning (flushing and scouring), maintenance and a program to replace pipes and other equipment as they near the end of their useful lives. Water mains can be expected to have a useful life of 40 to 100 years. Many of the pipes under the older parts of our cities may be towards the upper end of this range.

Dual pipe systems

In future, it is possible that many Australian communities will be supplied with water of two qualities: one of drinking water quality and the other of a quality that is not safe for drinking but which is suitable for other purposes such as toilet flushing and outdoor use.

Such dual systems have been used in other parts of the world and in recent years have been trialed in Australia. For example, in Sydney, New South Wales, a new housing development at Rouse Hill has been built with a dual pipe system. More recently, housing developments at Newhaven and Mawson Lakes in Adelaide, South Australia have also featured duel pipe systems.

This system has the advantage of using less high quality water where lower quality water will do, but it is difficult and expensive to dig up existing suburbs and install dual pipe systems. In addition, there are public health risks if cross-connections occur between the two systems.

Cross-connections

If a connection is accidentally made between a pipe carrying high quality drinking water and water of low quality, the drinking water can be contaminated.

Most cross-connections occur when a backflow of contaminated water mixes with the water in a supply pipe. This usually happens when the drinking water supply is at a lower pressure than the contaminated source. A range of devices has been developed to limit the potential for backflow and cross-connections. Standards Australia has several Australian/NZ standards to manage backflow/cross-connections.

Another possible source of contamination is a fall in distribution system pressure, which allows contaminated groundwater to enter the system through the gap in a joint or other similar route.

What about rural and remote communities?

Most Australians live in cities where large investments have been made to ensure an adequate supply of water, even in time of drought. Approximately seventy per cent of Australians live in cities containing more than 100,000 people. These cities represent less than one per cent of the area of Australia. The other ninety-nine per cent of this large land contains the other thirty per cent of Australians. Many of those people live in smaller cities and towns and also have an adequate mains water supply. However, some do not.

For communities not connected to mains water supply, some provision for the supply of water is essential. This could be, for example, groundwater, stored rainwater or a combination of both.

The safe use of a private water supply is discussed under Urban Water Systems

However for many small communities in remote parts of Australia, the provision of an adequate supply of water is a major challenge. Many of these communities are Aboriginal and Torres Strait Islander communities.

Aboriginal and Torres Strait Islander community water supplies

A significant proportion of the small settlements in Australia with less than a thousand inhabitants are Aboriginal and Torres Strait Islander communities.

Some understanding of the needs of these communities can be obtained from an Australian Bureau of Statistics survey published in 2001 which details community housing and infrastructure needs (CHINS 2001). At the time of the survey:

- There were a total of 1291 discrete Indigenous communities throughout Australia.
- Ninety per cent of Indigenous communities were considered very remote in terms of accessibility and distance from a main centre
- Seventy-three per cent of the discrete Indigenous communities had a usual population of less than 50.

Many of these communities still have inadequate water supplies and some do not have a reticulated water supply at all. The provision of water services to small remote communities is particularly difficult. The remoteness makes it slow and expensive to get materials delivered. It also makes it difficult to get maintenance teams and support services on site.

For the communities themselves, on-going maintenance and repairs to water supply systems is difficult because community members generally lack access to the required technical training and to the specialised services that might be needed.

Water provision in Aboriginal and Torres Strait Islander communities was the subject of a Human Rights and Equal Opportunity Commission Report in 1994. The Report recognised the practical difficulties associated with the provision of adequate water services to remote communities and acknowledged that government departments and agencies had made efforts to improve water supplies in remote Indigenous communities.

However, it concluded that no significant improvement in Aboriginal living conditions would occur without a number of other developments. These included:

- recognition of the need for community control in decision-making
- recognition of difference between cultures
- development of the means for communities to receive and respond to independent scientific and technical advice
- consideration of how to achieve sustainable development solutions
- identification and implementation of the necessary changes in Government policies and programs

In the Report, the Federal Race Discrimination Commissioner stated:

"If equality is assessed on outcomes (not inputs or the stages leading to the outcome), useful options are created for the consideration of the water supply. It is now possible to ask whether the desirable outcome is going to be a reticulated water supply which delivers water that meets NHMRC Guidelines or whether it is that people have free and unimpeded access to water supply which they can afford and over which they can exercise control to the extent of adjusting the system to suit their changing circumstances"

The Report argued that it was important to ensure that water was safe to drink but that it was also important that Aboriginal and Torres Strait Islander people were able to make their own decisions about how it was provided and maintained.

Progress made in the light of the recommendations contained in the Commission's 1994 report was reviewed on behalf of the Federal Government in 2001. That review is available at

www.hreoc.gov.au/racial_discrimination/report/water_report/index.html

The CRC for Water Quality and Treatment has an active involvement with a number of remote Indigenous communities, providing scientific and technical advice in support of their efforts to achieve improvements with their water supply. In these activities the CRC works closely with many other organisations and in particular with the Centre for Appropriate Technology in Alice Springs

Further information on the Centre for Appropriate Technology is available at

www.icat.org.au

WATER AND HUMAN HEALTH

Introduction

The importance of good drinking water in maintaining human health was recognised early in human history, with water storage and treatment mentioned in historical records dating back to at least several hundred years BC.

In more recent times, the studies of Dr John Snow on the transmission of cholera by London's drinking water in the mid-1800s contributed to the recognition that specific microorganisms cause specific human diseases.

By the early 1900s, better protection of water supplies from sewage pollution and simple but effective methods of water treatment (chlorination, sand filtration) greatly reduced rates of waterborne disease in developed nations. However, waterborne diseases continue to be a major cause of illness and death in the developing world, especially in children.

Since most people drink water every day, contamination of a public drinking water supply has the potential to expose nearly all members of a community to harmful chemicals or microorganisms in a very short period of time. For this reason, it is important that the protection of public health is the first consideration in managing any water supply.

Waterborne diseases

Microorganisms that are capable of causing disease are called pathogens. The pathogens of concern in water supplies are mainly those that are found in the excrement (faeces) of humans or animals. If these microorganisms are present in water, and are not removed by water treatment or disinfection, then consumers may suffer infections.

Many types of pathogenic bacteria, viruses, protozoa and helminths may be transmitted by contaminated water supplies. These pathogens can also be transmitted directly from human to human, from animal to human, from swimming in contaminated water, by contaminated food, or indirectly through contact with contaminated objects. The fact that contaminated water causes an outbreak of a particular disease does not mean that the disease is only or mainly transmitted by water under normal circumstances.

Generally, faecal contamination from human sources is regarded as the greatest risk to water supplies, as some diseases such as cholera, typhoid, and gastroenteritis viruses are found only in humans. However, some pathogens from animals including mammals and birds can also cause illness in humans.

More on pathogens

Zoonotic diseases

Zoonotic diseases or zoonoses are those diseases that are naturally transmitted between vertebrate animals and humans. Mammals in catchments and birds in service reservoirs are the most common cause of waterborne zoonotic disease. For example, Salmonella bacteria entering the water supply from such sources can result in waterborne zoonotic disease.

Zoonoses can be spread from pets, such as dogs and cats, and agricultural animals (cattle, sheep and pigs), or from native or feral animals.

The lack of a safe water supply and waste disposal system causes waterborne disease to spread easily in poorer countries. For example, several serious diseases are spread by freshwater snails associated with irrigation canals in certain areas, as well as by bathing, swimming, wading and washing clothes in such waters.

Water also plays a role in the transmission of other types of diseases. For instance, insects that breed in water, such as mosquitoes, may also spread disease to humans by sucking blood. Such diseases include typhus, dengue fever, malaria and yellow fever.

The amount of illness in a community is affected by the quantity of water that is available, as well as its microbiological quality. If there is not enough water for people to bathe themselves, or to wash cooking utensils or clothing, high rates of gastroenteritis are common. In this situation, increasing the amount of water for people to use will generally produce a health benefit even if the quality of the water is not changed.

More on water-related diseases

What do the Guidelines say?

The 2004 edition of the ***Australian Drinking Water Guidelines*** incorporates a Framework for Management of Drinking Water Quality that provides guidance on assessing and managing risks to drinking water supplies throughout the water supply system. This Framework emphasises a preventive approach so that potential problems can be identified and managed to avoid impacts on the quality of water supplied to consumers. Ensuring the microbiological safety of a water supply entails a wide-ranging program of protection, treatment and monitoring, with barriers to the entry and transmission of pathogens throughout the system.

The barriers should include most of the following:

- The water sources selected should be protected from contamination by human or animal faeces and an active catchment management program maintained.
- Water should be pre-treated, for example by detention and settling in reservoirs for long enough to allow bacteria to die off (at least several weeks but preferably longer).
- Water storages should be protected from public access, malicious or accidental contamination and vandalism.
- Some form of treatment (such as coagulation, settling and filtration) should be carried out.
- The water should be disinfected before it enters the distribution system.
- An adequate concentration of disinfectant should be maintained throughout the distribution system. This is referred to as the disinfectant residual.
- The distribution system should be secure against possible re-contamination.

In addition, the Guidelines discuss monitoring for microbiological quality as a check that the barriers to contamination are working.

In summary, ***Australian Drinking Water Guidelines*** highlights the concept of multiple barriers to prevent pathogens or other contaminants reaching consumers. Such barriers may include:

- Protected catchments
- Storage reservoirs
- Treatment plants
- Disinfection systems
- Closed distribution systems

How do you know if there are bugs in the water?

Protection of public health depends on having multiple barriers in place to keep bugs (pathogenic organisms) out of the water supply. This includes trying to keep them out of the catchment or water source in the first place. Other barriers to these organisms are water treatment technologies, disinfection and a closed distribution system.

Measurement of pathogens in the water may appear to be the best method to determine whether the water supply is safe. However, this is an immensely difficult task, requiring expensive and sophisticated technology and taking considerable time.

It is also a very complex task due to the diversity of pathogens that exist and the different test methods required. A further problem is the inability of existing technology to continually monitor for pathogens. Because of these factors, indirect methods are used to measure microbiological water quality.

One such method is to measure the concentration of disinfectant at various points throughout the distribution system. If chlorine is used as the disinfectant, what is referred to as the chlorine residual is measured. According to the ***Australian Drinking Water Guidelines***, a chlorine residual of 0.2 milligrams per litre (mg/L) to 0.5mg/L is generally adequate. Chlorine at this level kills the target organisms.

The second method of measuring microbiological water quality is to monitor for organisms that might indicate that the water is contaminated with faecal material or that disinfection is inadequate. These organisms are referred to as indicator organisms. They are not harmful to health but their presence indicates that other faecal organisms (including harmful pathogens) may also be present in water.

Members of the coliform group of bacteria are used as indicators of water quality. This group contains many species of bacteria that grow in the environment, but a sub-group of coliform bacteria, called thermotolerant coliforms (coliforms preferring warmer temperatures), are found predominantly in the intestine and faeces of humans and other warm-blooded animals.

One member of the thermotolerant coliform group, *Escherichia coli* (often referred to as *E. coli*) is recognised as the most specific indicator of recent faecal contamination in water supplies. This organism is now the preferred indicator for assessing the microbiological quality and safety of drinking water.

In some instances, a more general test for thermotolerant coliforms may be used instead of a specific test for *E. coli* , however thermotolerant coliforms are a less specific indicator of faecal contamination. Some non-faecal environmental coliform bacteria (*Klebsiella, Citrobacter* and *Enterobacter*) are also thermotolerant, and in certain circumstances these may produce a positive result on the test even if faecal contamination is absent.

Other groups of bacteria may be used by water suppliers as operational indicators to assess whether water supply systems are operating normally as expected. These organisms (total coliforms and heterotrophic plate count bacteria) have no significance for assessing health risks but unusual variations in their numbers may signal a change from normal operating conditions that requires investigation.

Indicator organisms can be used to:

- Measure the effectiveness of treatment processes including disinfection.
- Indicate the risk of faecal pathogenic organisms being present in the water supply.
- Provide evidence of recent faecal contamination from warm-blooded animals.

The indicators most commonly used to measure the microbiological quality of water are *E. coli* , and thermotolerant (or faecal) coliforms.

More on indicator organisms

Do chemicals in water affect human health?

A wide variety of chemicals may enter a body of water used for water supply purposes via stormwater runoff. Such chemicals can be natural or manufactured substances.

Inorganic chemicals, such as mineral salts, can be leached from the natural environment. Manufactured chemicals such as pesticides, herbicides, insecticides, pharmaceuticals and industrial waste products can also be picked up from the land in the catchment or discharged into a waterway from a specific source.

Every chemical has an effect on living organisms exposed to it. The study of the negative or harmful effects of chemicals on living organisms is known as toxicology.

Living organisms respond in different ways when exposed to chemicals. Some effects in organisms are immediate; that is, they show up within 24 to 48 hours. Other effects may be delayed and not show up for 10 or 20 years or more; for example, cancer in humans.

The response of a living organism exposed to a chemical depends upon the chemical dose or the exposure level. Generally, the higher the dose the more significant the effect. Simply knowing that the compound is carcinogenic is not sufficient to assess the risk to human health – it is necessary to know the harmful dose as well.

Ingestion of low levels of some chemical contaminants in drinking water over long periods of time has been associated with negative health effects, but these associations are not fully understood.

The ***Australian Drinking Water Guidelines*** provide guidance to water authorities on safe levels of chemicals in drinking water based on the best scientific information available.

Inorganic chemicals in water

Inorganic chemicals may be present naturally in raw water, be derived from contamination of source water or obtained from contact with piping and plumbing materials used to transport water.

Generally a naturally occurring phenomenon, hardness is a measure of the calcium and magnesium salts dissolved in the water. Hardness levels of less than 200 milligrams per litre (expressed as a concentration of calcium carbonate) are described as good quality water in ***Australian Drinking Water Guidelines***.

On the basis of taste, a concentration of total dissolved solids of less than 500mg/L is also described as good quality water in ***Australian Drinking Water Guidelines***.

Sometimes, domestic plumbing can be a source of elevated levels of copper or iron measured at the tap. Copper in drinking water can have health effects. Plumbing can also be a source of lead in drinking water.

Several elements are essential to human nutrition at low doses, yet can have negative effects at high doses. These include arsenic, selenium, chromium, copper, molybdenum, nickel, zinc and sodium. The elements lead, arsenic and cadmium are suspected carcinogens.

A summary of the scientific evidence that the guideline values for these and other chemicals are based upon can be found in ***Australian Drinking Water Guidelines***.

Organic chemicals in water

Organic chemicals in water derive from:

- The breakdown of naturally occurring organic materials.

- Contamination of source water.
- Reactions that take place during water treatment and distribution.

The breakdown of naturally occurring organic materials is the predominant source of organic chemicals in water. These chemicals are derived from vegetation, soil humus, and microbiological activity. Water scientists refer to this material as natural organic matter (or NOM). These organics are typically benign, although they can be responsible for such aesthetic problems as colour, taste and odour.

Excessive algal growth in source waters can lead to the tainting of drinking water supplies with complex and unpleasantly scented organic components such as geosmin and methylisoborneol.

The toxins produced by some blue-green algae – or cyanobacteria – are an exception to the usually benign character of NOM. These toxins are harmful to human health.

Cyanobacteria

A wide range of organic substances can enter the water source from human activities in the catchment. These sources include agriculture, runoff from urban settlements, wastewater discharge and leachate from contaminated soils. Most organics in water supplies that have harmful health effects are part of this group. They include pesticides and solvents.

Organic contaminants formed during water treatment include disinfection byproducts formed, for example, when chlorine reacts with natural organic matter.

Disinfection byproducts

Disinfection of water, using treatment methods such as chlorination, has removed the threat of waterborne epidemics and reduced infant mortality rates to very low levels in Australia. Without disinfection, Australians would still be at risk from diseases such as cholera.

However, there is a downside to disinfection; the use of oxidants for disinfection, taste, odour and colour removal can produce undesirable organic byproducts.

During chlorination of water supplies, the chlorine reacts not only with the microorganisms but also with most of the other organic material present in the water, either dissolved or in suspension. This produces a range of organic compounds known as disinfection byproducts. The presence of these compounds has been detected only as more and more sensitive scientific equipment has been developed.

These disinfection byproducts contain halogens, a group of elements with similar chemical properties. These halogens are fluorine, chlorine, bromine and iodine. While a lot remains to be known about many of these disinfection byproducts, they include a group of chemicals called trihalomethanes (THMs), mainly chloroform (trichloromethane), plus a broad range of other compounds including haloacetic acids, halonitriles, haloaldehydes and chlorophenols.

In order to keep the level of disinfection byproducts low in the water supply, treatment of raw waters is carried out to remove as much NOM as possible before disinfection. Less NOM means there is less material to form disinfection byproducts and also less chlorine is required to achieve adequate disinfection of the water supply.

Several epidemiological studies have indicated a possible association between chlorinated drinking water and increased risks from a variety of cancers, mainly to do with the bladder, colon and rectum. However, other studies have not found such associations. Therefore, because of the limitations of the data, no definite conclusions can be based on these studies.

Alternative disinfectants - chloramines, chlorine dioxide and ozone – can also react with organic matter in source water to produce disinfection byproducts. The byproducts from these reactions are also not widely understood.

The ***Australian Drinking Water Guidelines*** suggest guideline values for a range of disinfection byproducts.

WATER REGULATIONS, GUIDELINES AND STANDARDS

While Australia has national drinking water guidelines prepared by a joint committee of the National Health and Medical Research Council (NHMRC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), regulation of drinking water is a matter for each state and territory.

Under Australia's constitutional arrangements, public health and natural resource management, including water, are largely state or territory responsibilities. Therefore, the government of the particular state or territory decides whether and how the latest Australian Drinking Water Guidelines, World Health Organization (WHO) Guidelines for Drinking Water Quality or some other guidelines are to be implemented.

Protection of public health is the most important factor for state and territory governments to consider but other factors, such as the views of consumers, are also very important. Indeed, community consultation is discussed in detail in the **Australian Drinking Water Guidelines**.

Generally speaking, drinking water quality has not been subject to specific legislation in Australia. However, other means have been used to require the water supply to meet particular standards. These include operating licences, charters, memoranda of understanding and customer contracts.

The Australian water industry is expected to provide supplies that are safe for the community at large, including infants and the aged who are more at risk from waterborne infection than most.

Some people have special needs that may make them particularly vulnerable to infection, including waterborne infection, for example immunocompromised persons. In these circumstances medical advice should be sought as to any possible risk associated with consuming tap water.

Some medical and industrial processes have water quality requirements that are more stringent than those for drinking water. For example, some require water to be sterile, that is free of all microorganisms, or require the complete absence of dissolved salts. Mains water usually contains microorganisms from the biofilm that develop on the inside surface of the water main. It always contains some level of naturally occurring dissolved matter.

ASSURING QUALITY

Since their first publication in 1987, the ***Australian Drinking Water Guidelines*** have provided advice to drinking water suppliers on management of their systems and encouraged the adoption of quality systems.

In recent years, the division of responsibilities between various agencies, and in particular the transfer of catchment and water resource management to agencies other than drinking water suppliers, has made it more important for water suppliers to have formal processes for assuring the quality of drinking water.

The range of agencies involved in individual water supply systems can be large. Water resource departments, natural resource and environment departments, agriculture departments, local governments, planning authorities, catchment water management boards, and community-based interest groups and organisations can all have a role in ensuring water quality.

In some cases, restructuring of responsibilities has also extended to dividing the traditional functions associated with drinking water supply, with separate agencies being responsible for bulk water supply, water treatment and water reticulation.

Clear agreements between agencies are necessary to provide safe and pleasant drinking water. Responsibility for water extends beyond the drinking water supplier and requires collaboration and consultation with other agencies. Ultimately, however, it is the drinking water suppliers that are responsible for the delivery of safe drinking water to consumers.

There has been an increasing trend for Australian water authorities to adopt quality systems including ISO 9001 (Quality Management), ISO 14001 (Environmental Management), AS/NZS 4360 (Risk Management) or Hazard Analysis and Critical Control Point (HACCP).

These available systems provide generic requirements for organisations undertaking a diverse range of activities, but it was recognised that they may have some limitations in their applicability to the management of drinking water quality.

Therefore, during the most recent revision of the ***Australian Drinking Water Guidelines*** , a comprehensive *Framework for the Management of Drinking Water Quality* was developed to address the specific challenges of drinking water supply. The Framework provides guidance on the design of a structured and systematic approach for the management of drinking water quality from catchment to consumer, to assure its safety and reliability.

The Framework incorporates a preventive risk management approach; it includes elements of HACCP, ISO 9001 and AS/NZS 4360, but applies them in a drinking water supply context to support consistent and comprehensive implementation by suppliers.

The Framework addresses four general areas:

• **Commitment to drinking water quality management** . This involves developing a commitment to drinking water quality management within the organisation. Adoption of the philosophy of the Framework is not sufficient in itself to ensure its effectiveness and continual improvement. Successful implementation requires the active participation of senior executive and a supportive organisational philosophy.

• **System analysis and management** . This involves understanding the entire water supply system, the hazards and events that can compromise drinking water quality, and the preventive measures and operational control necessary for assuring safe and reliable drinking water.

• **Supporting requirements** . These requirements include basic elements of good practice such as employee training, community involvement, research and development, validation of process efficacy, and systems for documentation and reporting.

• **Review** . This includes evaluation and audit processes and their review by senior executive to ensure that management system is functioning satisfactorily. These components provide a basis for review and continual improvement.

For more information on the Framework, consult the ***Australian Drinking Water Guidelines (http:/www.nhmrc.gov.au/publications/synopses/eh19syn.htm*** **)** .

WATER AND PUBLIC POLICY

Overview

It was intended by those drafting the Constitution of the Commonwealth of Australia at the close of the 19th century that natural resource policy, including that relating to water, would remain a responsibility of the States.

In fact, one section of the Constitution specifically restricts the role of the Commonwealth in relation to water.

Towards the close of the 20th century that remained largely the case, although the legal position has become less clear as a result of decisions by the High Court.

100. The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation.

However, the Commonwealth Government has the capacity to indirectly influence any area of public policy in Australia.

In relation to water, the Commonwealth has acquired an important role in policy development in recent years.

Given the increasing commercialisation and private sector involvement in the water industry, the option remains for the Commonwealth to explore the extent of its direct powers under the Constitution. However, the path being followed in the development of national policy and a regulatory framework in this area, as in others, is one of cooperation with the State and Territory governments.

In 1994 the Council of Australian Governments (COAG) agreed on a Water Reform Agenda to work towards reform in the water industry at the national level. More recently, in 2004, this was succeeded by the formation of the National Water Commission and adoption of the National Water Initiative (NWI). The NWI represents the Australian Government's and state and territory governments' shared commitment to water reform in recognition of:

- the continuing national imperative to increase the productivity and efficiency of Australia 's water use;
- the need to service rural and urban communities; and
- ensuring the health of river and groundwater systems, including by establishing clear pathways to return all systems to environmentally sustainable levels of extraction.

National Water Commission website (http://www.nwc.gov.au/index.cfm)

The National Water Quality Management Strategy is also a national initiative aimed at developing guidelines to assist regulation of public health and the environment. ***Australian Drinking Water Guidelines*** fits within the umbrella of the National Water Quality Management Strategy.

At the level of the individual States and Territories, commercial pressures from within Australia and from overseas have also produced changes in the way water services are delivered.

Commercialisation and corporatisation of many Australian urban water businesses has led to management responsibilities being vested in commercial boards, in contrast to earlier arrangements where services were provided directly by an arm of government. Now the role of board members is to provide significant commercial skill and focus, as well as to buffer the organisation from extraneous political involvement.

Competition for inputs to the water industry in Australia is well developed with outsourcing and Build Own Operate (BOO) and Transfer (BOOT) contracts for major treatment plants completed and currently in operation.

Another recent development in the water industry in Australia has been the growing involvement of large international water companies.

Who is supplying the water now?

In Queensland, New South Wales and Tasmania, local government has long had a key role in the provision of water services. This remains the case. In the other states and territories, various other arrangements have evolved.

In Sydney, a catchment authority (Sydney Catchment Authority) has been established to work with the government-owned corporation that formerly had total responsibility for the city's water supply (Sydney Water Corporation) but remains responsible for water distribution and wastewater services. Sydney Water Corporation services a population of four million.

In Melbourne, three government-owned companies (City West Water Ltd., South East Water Ltd., and Yarra Valley Water Ltd.) are the retailers and the wholesaler is a government-owned corporation (Melbourne Water Corporation). The wholesaler also controls the catchment for most of its supply.

In Adelaide, a privately owned water company (United Water International Pty. Ltd.) provides water services under an agreement with the government authority (South Australian Water Corporation).

The Water Corporation is a government-owned corporation that provides urban water services in Perth, and in most of Western Australia.

In Canberra, and the ACT generally, a public-private multi-utility partnership now provides services (ActewAGL).

A government-owned multi-utility (Power and Water Authority) provides services to the larger and less remote communities in the Northern Territory, including Alice Springs and Darwin.

Brisbane is an example of local government in a major Australian city providing water services (Brisbane City Council). Bulk water is supplied to Brisbane and neighbouring councils by South East Queensland Water Corporation.

Most organisations providing urban water services in Australia have experienced some degree of structural reform in recent years, which has clarified accountabilities by separating policy, regulatory and commercial (operational) functions. The accepted wisdom is that this separation provides urban water businesses with clear commercial goals of customer service, while safeguarding public health and achieving environmental compliance in a sound business operation, free of other conflicting objectives.

Community Consultation

The COAG Water Reform Agenda, agreed in 1994, adopted the principle of public consultation by government agencies and service providers when change and/or new initiatives were being contemplated involving water resources.

Subsequently the ***Australian Drinking Water Guidelines*** emphasised the right of communities to participate in the development of policies relating to their water supply.

> *" The ADWG are intended to provide consumers with safe and aesthetically pleasing water and ultimately it is*

consumers who will be the final judges of water quality. It is vitally important that consumers are viewed as active partners in making decisions about drinking water quality and the levels of service to be adopted. Community expectations and willingness to pay must be considered."

Australian Drinking Water Guidelines

The ***Guidelines*** also provide advice on how customers should be involved in considering options for effective and acceptable monitoring and reporting on performance of their water supply, and on the frequency of such reporting.

The COAG Water Reform Agenda also mentions the need for the public to be informed of the cause and effect relationship between infrastructure performance, standards of service and related costs, with a view to promoting levels of service that represent the best value for money to the community.

The direction that community consultation on drinking water supplies will take is difficult to predict. State and territory governments determine policy within their jurisdiction, usually with a measure of community and industry consultation and certainly with accountability for policy to Parliament and to the electorate.

Community consultation is a process of mutual education. The community learns what is involved with the development of a drinking water quality program and water businesses learn about the "grassroots" issues.

Ideally, public involvement brings people together with different needs and values to develop a plan for the "common good" through respectful dialogue.

Public interest groups bring key issues to the process.

The ***Australian Drinking Water Guidelines*** provide advice on public consultation strategies and programs.

A fair price for water

In Australia, most water businesses have changed from a charging system based largely on property value to one based on actual water consumed (a user-pays policy). This reflects the major change in the philosophy contained in the COAG Water Reform Agenda.

Hunter Water in the Newcastle area of New South Wales pioneered this policy in Australia in the 1980s and reported a fall in household water consumption of 30 per cent over previous trends. Even before the COAG decision, this experience encouraged other water authorities to adopt the policy with a view to managing demand for water.

The user-pays system gives the right economic signals to consumers about the real value of this dwindling resource and encourages people to make more efficient use of water.

However, low-income households in Australia spend in proportional terms much more on utility services than high-income households. The implication is that increases in the price of utility services, if not accompanied by other compensation, will have a regressive and disproportionately negative impact on low-income households. This is an issue for governments to consider.

Currently in Australia, the COAG-initiated industry reforms have led to water-pricing structures based on a tariff comprising:

- A fixed charge reflecting the cost of the service provision.
- A variable charge based on the volume of water purchased.

Demand management and water conservation

The term "demand management" can be defined as any regulatory, policy, technical, service or commercial interaction with customers or consumers that enables volumes to be managed to minimise economic costs and environmental impacts to society.

Demand management measures to ensure consumers use less water have included advertising, education, pricing and appliance redesign.

Some current approaches to demand management include:

- Improved information for customers on water-saving devices.
- Promotion of the National Water Conservation Labelling (AAA) Scheme.
- Information for homeowners and gardeners on more efficient watering practices and irrigation systems.
- Provision of information on low water-use gardens, plants and shrubs.
- More efficient watering of public open space.
- Integrated and coordinated planning involving all agencies with an interest in water-related issues.
- Water and energy efficiency in the planning, design and construction of homes and buildings.

Further information can be obtained at www.savewater.com.au

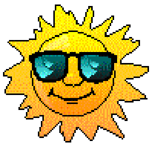
Encouraging the use of alternatives to conventional surface and groundwater harvesting can also be regarded as a form of demand management. These alternatives include stormwater, effluent reuse, rainwater tanks and greywater use. As always, pricing plays an important part in weighing up these options. How do the costs of these alternative sources of water compare with the construction of new reservoirs? Producing a non-potable water supply (for example, garden and fire use only) from some of the above sources involves significant treatment and cost.

Water restrictions

Some water businesses in Australia have opted for restrictions on water use to conserve water supplies and minimise capital expenditure.

Restrictions can enable construction of expensive major storage reservoirs to be deferred for many years. By developing a series of restriction levels, depending on remaining storage capacity, the maximum daily consumption can be curbed during drought periods.

Following a community consultation process, community endorsement should be obtained for such a policy.



Several water authorities in very hot and dry regions of Australia have adopted a cooperative policy with consumers to restrict peak water usage on very hot days or to restrict garden watering to periods in which it is more effective.

In the Victorian rural city of Mildura and several other large towns serviced by Lower Murray Water, only hand-held hoses may be used (that is, there is a ban on fixed sprinklers) between 10am and 10pm when the forecast temperature is 39 degrees C or above. On average, this applies about 14 days a year.

Perth, Western Australia has a permanent ban on sprinkler use between 9 am and 6 pm. The Water Corporation introduced the ban several years ago due to low storage in its dams. It has been retained since then as a water conservation measure.

Melbourne , Victoria has also introduced permanent water saving rules including restrictions on garden watering systems, a ban on hosing paved areas, and permit requirements for filling new swimming pools.

WATER IN THE FUTURE

Addressing tomorrow's problems

Just as issues around water have moulded much of Australia's past, they will also influence the future. Several issues threaten to impact strongly on water resources and urban supplies in Australia in the future. These include climate change due to global warming, salinity and environmental degradation generally.

Increasingly, communities are asking questions about basic quality of life issues, such as their water supply. They have a right to ask these questions, and to expect answers, just as they have a right to expect the drinking water available to their children to be safe and pleasant.

The needs of the population in the next 30 to 50 years are uncertain. Demand management programs will help to halt the previous trend of increasing per-capita consumption.

The optimum population of Australia has been the subject of speculation and debate by governments, academics and the community for decades. In recent times, the term ecologically sustainable development has been used when estimating limiting conditions on population growth. Issues such as the impact of increasing urban development on the environment and on quality of life need to be included in those discussions.

Water supply, use and disposal did not undergo major technological changes in the last century: there were no paradigm shifts in relation to technology of water management. In the 21st century, technology is likely to provide much more change for the water supply industry.

Increased use of water-efficient appliances by urban consumers will play a part in achieving ecologically sustainable development. A water-efficient appliance is one that has water conservation as one of its design criteria. It uses or enables the use of water more efficiently.

Water-efficient appliances generally do not rely on attitudes or behaviour of the user; rather, they impose responsible water use on the user. Savings from water-efficient appliances take time, because they are introduced slowly, replacing existing appliances. However, the water-efficient appliances being promoted at this time are expected to lead to a significant fall in per capita water use over the next couple of decades.

Climate change

According to CSIRO's latest climate change estimates, Australia will become hotter and drier in coming decades. Warmer conditions will produce more extremely hot days and fewer cold days. CSIRO scientists estimate that over most of the continent, average temperatures will be 0.4 to two degrees C greater in 2030 than 1990. By 2070, average temperatures are likely to increase one to six degrees C. These temperature ranges reflect the scientific uncertainty associated with the projections.

CSIRO climate projections indicate that the warming won't be the same everywhere, with slightly less warming in some coastal areas and Tasmania, and slightly more warming in the north-west.

South-western Australia can expect decreases in rainfall, as can parts of south-eastern Australia and Queensland. Wetter conditions are possible in northern and eastern Australia in summer and inland Australia in autumn.

In areas that experience little change or an increase in average rainfall, more frequent or heavier downpours are likely. Conversely, more dry spells are likely in regions where average rainfall decreases.

Evaporation is expected to increase over most of the country. When combined with expected changes in rainfall, there will be a clear decrease in available moisture across the country.

Governments and water authorities have to consider climate change now in planning water supplies for the future.

Environmental degradation

Significant deforestation has occurred in Australia since British colonisation in 1788. One result of this change in vegetative cover, affecting transpiration rates from forests, has been a reduction in rainfall in some catchments. Another has been salinity. A wide understanding of the need to reverse previous land management practices now exists, but in some areas it may be too late.

Across the country we need to find a meaningful balance between the competing demands for water of agriculture, urban consumption, and ecosystems.

One action to help achieve this balance was the establishment by the Federal Government of the National Land and Water Resources Audit. The Audit recently produced ***Australian Water Resources Assessment 2000 - surface and groundwater availability and quality***, the first comprehensive national audit of Australia's surface water and groundwater resources covering both water quantity and water quality.

The Audit reveals that, on average, Australia's water use has increased 65 per cent since the early 1980s.

Using the best available information provided by state and territory agencies, the Audit shows that 26 per cent of Australia's surface water management areas are approaching or beyond sustainable extraction limits and that 34 per cent of Australia's groundwater management units are approaching or beyond sustainable extraction limits.

Further information on the Audit is available on the Internet (www.nlwra.gov.au)

Salinity

Changes to the Australian landscape, and in particular tree clearing, have resulted in the widespread and rapidly growing problem of salinity. While naturally occurring salinity is part of the Australian landscape, human impacts have upset the previously existing balance.

The problem has developed slowly. With the removal of the natural vegetation, the amount of water entering the water table (called the recharge) has increased and the rising groundwater level has dissolved the accumulated salt within the soil. Eventually, and perhaps more than 100 years later, the groundwater level reaches the surface, bringing the salt with it. This results in the death of all but the most salt-tolerant plants with consequential changes to other parts of the ecosystem.

While farmers were among the first to be affected, through salt-affected agricultural land, the impact on sources of freshwater has also been of growing significance.

Biodiversity, as well as regional and urban infrastructure, such as water supply, roads and buildings are now also at risk.

Just as it has taken a long time to appreciate the scale of the environmental degradation, the timeframe for these changes to be slowed or reversed will also be considerable.

The cost of the problem to the wider Australian community will be huge.

A comprehensive national assessment of the problem, ***Australian Dryland Salinity Assessment 2000***, has recently been undertaken and a plan for tackling it has been developed. The National Land and Water Resources Audit has undertaken this work. Full details are available on the Internet (www.nlwra.gov.au).

According to a statement issued by the Prime Minister in October 2000 at the launch of the National Action Plan for Salinity and Water Quality in Australia, salinity and water quality problems were critical and demanded urgent attention. Among the problems detailed by the Prime Minister were:

- One-third of Australian rivers are in an extremely poor condition.
- Adelaide's drinking water is likely to fail World Health Organization salinity standards in two days out of five within 20 years.
- Land and water degradation, excluding weeds and pests, is costing up to $3.5 billion a year.

For more details see the National Action Plan for Salinity and Water Quality website (http://www.napswq.gov.au/) .

APPENDIX 1

Why is Australia's rainfall so variable?

Since the use of weather satellites began in the 1960s, great advances have been made in understanding the world's weather patterns. This has enabled scientists to explain and even predict the cycles of droughts and floods that are so much a feature of the weather pattern over much of Australia.

El Nino, La Nina and Southern Oscillation Index are terms used to describe a major influence on this weather pattern.

El Nino refers to the extensive warming of the central and eastern Pacific Ocean that leads to a major shift in weather patterns across the Pacific. In Australia, and particularly in the eastern part of Australia, El Nino events are associated with an increased probability of dry conditions. The most recent strong El Nino event was 1997/98. Another weak to moderate event occurred in 2002/03, causing major rainfall deficiencies across the country.

La Nina describes the reverse of the El Nino effect and is related to changes in atmospheric conditions and ocean circulation. In Australia, and particularly in the eastern part of Australia, La Nina events are associated with an increased probability of wetter conditions. The most recent strong La Nina was 1988/89, a much wetter than average season across much of Australia. A fairly weak La Nina event occurred in late 1995 and early 1996, leading to conditions slightly wetter than average in many areas. A moderate event occurred in 1998/99, which weakened back to neutral conditions before forming again for a shorter period in 1999 and ending in 2000.

The Southern Oscillation Index describes a key indicator of this weather pattern based on measurements of atmospheric pressure. It is used to predict the likelihood of extended very wet or very dry periods.

The El Nino phenomenon affects runoff in catchments serving all major Australian water supply systems.

Detailed information about Australia 's climate and weather can be obtained from the Bureau of Meteorology (http://www.bom.gov.au)

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Irrigation

Where sufficient low-cost water is available, irrigated agriculture is practised in Australia. This activity is attracting increased attention from government policy-makers as concern grows at the proportion of water flows taken from the environment and at how efficiently water is used in irrigated agriculture.

In recent years, the irrigation industry has undergone major changes in the way it is structured, in the way water is priced and with the use of market mechanisms to reallocate resources to more productive uses. Efforts have also been made to promote efficient and sustainable irrigation practices.

In the past, state governments have met the cost of establishing the irrigation industry. The price structure for irrigation water is now moving to better reflect the value of the resource.

It is difficult to provide a typical figure for the cost of water used in irrigated agriculture because it is influenced by many factors. However, a large proportion of irrigation water would be available for less than $50 a megalitre.

In contrast, one megalitre of good quality drinking water would cost an urban household in Australia between $500 and $1,000 piped to their home.

According to Australian Bureau of Statistics (ABS) figures for 2000-01 published in May 2004, the total gross value of irrigated agricultural production was $9,618 million.

Irrigated crops accounted for 28 per cent of the value of total agricultural production in 2000-01.

Vegetables and fruit are the most valuable irrigated crops per megalitre of water used while rice produces the lowest value. Rice is also the thirstiest crop per hectare of irrigated area.

Further information about irrigation in Australia can be obtained from several sources, including CSIRO Land and Water (http://www.clw.csiro.au), the National Program for Irrigation Research and Development (http://lwa.gov.au/taxonomy/term/748) and the Irrigation Association of Australia (http://www.irrigation.org.au).

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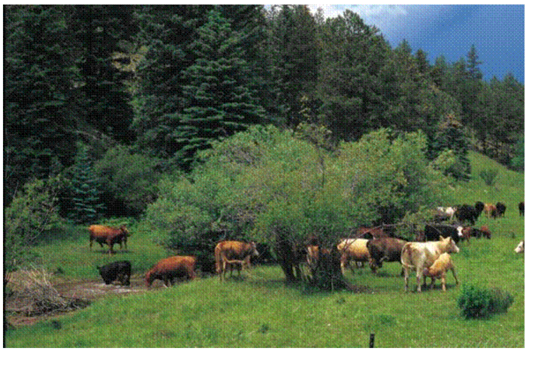
More About Catchments

In some limited areas, catchments exist in their natural state and minimal water treatment is needed. For example, most of the water supply for Melbourne and Canberra comes from natural wilderness catchments set aside solely for water harvesting.

In contrast, most of Adelaide's water is derived from the Murray River, the catchment for which is a vast area of Australia, home to almost two million people, containing more than 50,000 farms and referred to as the Murray Darling Basin. The other significant source of Adelaide's water supply is harvested in the catchments of the Mount Lofty Ranges.

Murray Darling Basin

Adelaide's Mount Lofty Ranges



Within larger catchments, water harvesting can be one of a variety of often competing activities. Other activities such as logging, farming, mineral extraction, recreation and tourism, as well as residential and industrial development, may occur.

As Australia has been developed, increased urbanisation, industrialisation and intensive farming have affected the quality of water entering streams and rivers. The water collected by such waterways requires varying degrees of treatment before it is suitable for drinking.

Careful land management practices can protect water quality. For example, maintaining intact vegetation along the sides of watercourses (referred to as the riparian zone) can protect water quality. Riparian vegetation can provide a good natural buffer against erosion and a build-up of sediment in watercourses.

However, if such vegetation is degraded or removed, protection against the impacts of land use on water quality is reduced.

In 2002 the National Land and Water Resources Audit published the **Australian Catchment, River and Estuary Assessment** . This report is the first comprehensive assessment of catchments, rivers and estuaries in Australia

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Murray Darling Basin

The Murray Darling Basin, located in south-eastern Australia, is of particular significance as a catchment. It contains Australia's three longest rivers, the Darling (2740km), the Murray (2530km) and the Murrumbidgee (1690km). It also drains 18.2 per cent of the land area of Australia containing 42.3 per cent of the nation's farms. Irrigation in the Murray Darling Basin accounts for about 70 per cent of the water used in agriculture in Australia.

Detailed information on the Murray Darling Basin can be obtained from the Murray Darling Basin Commission (www.mdbc.gov.au)

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Adelaide's Mount Lofty Ranges

The major source of Adelaide's water is the Murray River. This water is supplemented by water from catchments in the Mount Lofty Ranges. This locally harvested water is stored in various water supply reservoirs around Adelaide.

The proximity of these catchments to Adelaide has meant that grazing, broad scale cropping, intensive horticulture and urban development have occurred there. For example, more than 70 per cent of the Onkaparinga catchment, which supplies the Mount Bold and Happy Valley Reservoirs, is affected by urban developments, intensive horticulture or mixed agriculture.

Land use and water quality are closely linked. Water running from undisturbed native vegetation is of the highest quality, while water coming from developed areas, particularly where there is urban development and intensive horticulture, is of lesser quality.

Because of the poor quality of the source waters, the water supply for Adelaide requires extensive treatment before it is distributed for use.

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AUSTRALIA'S LARGEST RESERVOIRS

Dam	*River*	*State*	*Capacity (megalitres)*	*Completed*
Gordon (Lake Pedder)	Gordon	TAS	12,450,000	1974
Ord River (Lake Argyle)	Ord	WA	5,797,000	1972
Eucumbene	Eucumbene	NSW	4,798,000	1958
Dartmouth	Mitta Mitta	VIC	4,000,000	1979
Eildon	Goulburn	VIC	3,390,000	1927/1955
Miena Rockfill (Great Lake)	Shannon	TAS	3,356,000	1967
Hume	Murray	NSW	3,038,000	1936/1961
Serpentine (Lake Pedder)	Serpentine	TAS	2,960,000	1971
Warragamba (Lake Burragorang)	Warragamba	NSW	2,057,000	1960/1989
Burdekin Falls (Lake Dalrymple)	Burdekin	QLD	1,860,000	1987

Source: ANCOLD Register of Large Dams in Australia

BACK

Water recycling

A growing amount of treated effluent is used for industrial and agricultural purposes in Australia . For example, the South Australian Water Corporation, which provides water services in Australia 's driest state, aims to recycle 30 per cent of the total wastewater flow from Adelaide 's wastewater treatment plants, to reuse schemes by 2006.

Generally speaking, few additional sources of surface and/or groundwater remain unexploited to meet the future needs of major urban communities in Australia. These communities are demanding that the environment be managed in a sustainable manner. This will require more water resources being allocated to the environment rather than less. The water supply industry can no longer rely on building new dams to quench the thirst of growing cities. It needs to consider other strategies to match supply with demand.

In these circumstances, governments and industry have started to regard treated urban wastewater (sewage) flows as a potential resource rather than an effluent to be quickly discharged back into the environment at the nearest convenient point. Urban stormwater flows are also being examined for their potential as a water source.

While it is technically feasible to treat these sources to drinking water quality, as currently happens with most raw water supplies, there are greater public health risks, requiring multiple precautions and incurring greater costs.

Furthermore, the human psychological resistance to consuming our "own" has been a major public disincentive for further considering these schemes, despite the fact that all water is eventually recycled.

Indirect use of wastewater for drinking has been occurring for a long time, particularly in denser populated areas, such as Europe and the United States, where flows from upstream cities and towns are fully treated before being discharged to cities and towns downstream. Recycling of river water in this way occurs less frequently in Australia, due to our smaller and less dense population.

The most frequently quoted example of direct potable reuse is by Windhoek City Council in Namibia (Southern Africa). This water reclamation plant has been in successful operation at Windhoek for the last 25 years for the production of potable water for direct re-use. More recently, Singapore has initiated the NEWater scheme, where highly purified recycled water is used to supplement the drinking water supply

In a recent development in South Australia, below ground storage of treated effluent is being investigated where aquifers are being recharged. The water is intended for irrigation. For further information see: http://www.groundwater.com.au

In recognition of the need for national guidance on water reuse for a range of different purposes, in 2004 the Environment Protection and Heritage Council and the Natural Resource Management Ministerial Council initiated the development of **National Guidelines for Water Recycling**

(http://www.ephc.gov.au/taxonomy/term/39) The guidelines will comprise a risk management framework and specific guidance on managing the health risks and the environmental risks associated with the use of recycled water. The first stage of guideline development will be completed in 2006.

BACK

Australian Drinking Water Guidelines

Development of drinking water guidelines in Australia

Australian drinking water guidelines, first issued in 1972, tended to follow World Health Organization recommendations, but modified for Australian conditions. In 1987, the publication ***Guidelines for Drinking Water Quality in Australia*** was released. Then in 1996, ***Australian Drinking Water Guidelines*** was published jointly by the National Health and Medical Research Council (NHMRC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). The Guidelines were reviewed and updated again in 2004 and published by the National Health and Medical Research Council in collaboration with the Natural Resource Management Ministerial Council (formerly ARMCANZ).

These guidelines are subject to review by these organisations and are updated as new medical and scientific information becomes available. The review is a transparent process and submissions are routinely invited from the public, interested organisations, state and federal governments, and scientific and professional bodies. Scientists associated with the Cooperative Research Centre for Water Quality and Treatment are contributing to this review process.

The document provides guidance to the Australian water industry on the treatment levels and procedures needed to manage water supply systems that are required to produce safe and pleasant drinking water.

An Internet version of the Australian Drinking Water Guidelines can be found at http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm

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More on pathogens

Bacteria

Bacteria are tiny, single-celled microorganisms that are often observed forming colonies. They can occur in various shapes, for example, round, rod-like, or spirals. Typically, they can be as small as half to one micron wide, and as large as several microns long.

Bacteria capable of causing human illness through contaminated water supplies include *Campylobacter, Salmonella, Shigella, Vibrio* and *Yersinia*.

Other bacteria of environmental origin may be found in water supplies including *Aeromonas, Legionella, Mycobacterium* and *Pseudomonas aeruginosa*. If found in drinking water, these bacteria are generally less of a health risk than those of faecal origin.

Viruses

Viruses are a large group of infectious agents, much smaller than bacteria, and are able to be viewed only through an electron microscope. They are not cells but biologically active particles that vary in size from 0.01 to 0.1 microns.

Viruses may survive in the environment for some time in soil or water, but they cannot multiply unless they infect a suitable host. The viruses that are of concern for water supplies can only infect humans, therefore they can arise only from human waste.

Viruses cannot be simply cultured in the laboratory in the way bacteria are identified, and for this reason it is difficult to detect viruses.

Problem viruses identified in the ***Australian Drinking Water Guidelines*** include adenovirus, enterovirus, hepatitis viruses, norwalk viruses and rotaviruses.

Protozoa

The term protozoa refers to a collection of generally colourless, single-celled organisms with a well-defined nucleus. They are much bigger than bacteria, ranging in length from 5 to 100 microns.

Protozoa are among the simplest of all living organisms. As a group, protozoa are extremely diverse. Pathogenic protozoa found in water supplies include *Cryptosporidium, Giardia, Cyclospora, Naegleria, Acanthamoeba* and *Entamoeba.*

Helminths

Other causes of waterborne disease in humans include helminths. These worms or worm-like parasites infect the intestine and include roundworms, tapeworms and flatworms. The worms in humans that originate from helminth eggs are relatively easy to cure and present a problem only in developing countries where proper nourishment is a problem.

BACK

More on water-related diseases

Four types of water-related diseases are recognised in public health:

Waterborne diseases are those where a person contracts the disease by drinking water contaminated with the disease-causing organism. Most diseases of this type are spread by the faecal-oral route (for instance, by swallowing small amounts of faecal material in water, in food, or from hands).

Water-washed diseases are those which can be reduced by improving domestic and personal hygiene. Such improvements in hygiene usually depend on the increased availability of water for washing people, cooking utensils and clothing, rather than the quality of the water.

These diseases include pathogens that are transmitted by the faecal-oral route, as well as skin and eye diseases such as scabies, bacterial and fungal skin infections, and trachoma. Other health problems, such as lice and ticks, are also reduced by better hygiene.

Water-based diseases are those where the pathogen spends part of its life cycle in a water snail or other aquatic animal. These diseases are caused by parasitic worms, and include schistosomiasis and dracunculiasis (Guinea-worm).

Water-related insect-borne diseases are carried by blood-sucking insects that breed in water or by insects that bite near water. Examples of these are diseases such as malaria, yellow fever and dengue fever that may be carried by mosquitos, and trypanosomiasis (sleeping sickness) carried by tsetse flies.

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More on indicator organisms

When drinking water treatment was first developed, it was recognised that faecal contamination from humans and animals posed the greatest threat to water supplies. A need was recognised to test untreated water to determine whether such contamination had occurred, and treated water to check that contamination had been successfully removed.

However, testing water for harmful microorganisms was not practical because knowledge of the organisms responsible for disease was very limited and the methods for detecting them were complex and time consuming.

Instead, public health microbiologists decided to search for microorganisms that were always associated with faecal pollution, but did not cause illness. The desirable properties of such microorganisms were:

- Always present in faeces of humans and animals.
- Present in high numbers.
- Easy to detect by simple and inexpensive methods.
- Unable to multiply after they had left the body and entered the water supply.

Thus the presence of indicator microorganisms could serve as a warning that faecal contamination had occurred, and that faecal pathogens might also be present in the water supply. A series of indicator organisms was identified, and these became the basis of microbiological quality monitoring around the world.

Escherichia coli

E. coli is found in the intestines of animals, and does not originate from environmental sources. For this reason, *E. coli* is a highly specific indicator of faecal contamination in drinking water.

Thermotolerant coliforms

This group of bacteria includes *E. coli* and other intestinal bacteria that are able to grow at 44° C. It also includes some bacteria that live in decaying vegetation and agricultural or industrial waste. In some laboratories, a slightly different testing method is used, and the bacteria detected are called faecal coliforms. Faecal coliforms and thermotolerant coliforms are essentially the same.

Thermotolerant coliforms are less specific indicators of faecal contamination than *E. coli*, because they may sometimes arise from non-faecal as well as faecal sources.

Total coliforms

This is a larger group of bacteria which includes *E.coli* and faecal coliforms. It also includes many non-faecal organisms that can grow in the environment. Total coliforms occur in much greater numbers in water sources than faecal coliforms *or E. coli*, and for this reason changes in their numbers (reduction by disinfection) are easier to detect.

Total coliforms are not good indicators of faecal contamination, because they may originate from many sources other than faeces. Increases in their numbers in water distribution systems may be due to regrowth or external contamination.

Microbiologists can often tell the difference between contamination and naturally occurring microorganisms in the pipeline. Contamination is likely to produce a growth of fairly uniform and limited number of species; natural growth is likely to contain a much wider variety of organisms.

Heterotrophic plate count (HPC)

The HPC measures a broad group of bacteria that are defined by their ability to grow under certain laboratory conditions. These bacteria have no direct relationship to faecal contamination or health risks but are used as a general indicator of the microbiological content of water, and the levels of nutrients that can support bacterial growth.

An elevated HPC can be useful as an early indicator of excessive bacterial growth (possibly regrowth during warmer periods) in the distribution system, particularly on pipe walls and sediments.

The HPC can also be a useful measurement to water authorities in managing disinfection in distribution systems.

Changes in the use of indicator bacteria

It has long been recognised that among indicator organisms, *E. coli* provides the most specific warning of faecal contamination, however in the early 1900s there was no simple test available to distinguish *E. coli* from other coliform bacteria.

The observation that *E. coli* formed the majority of coliform bacteria in human faeces, and that total coliforms were readily isolated from contaminated waters, led to the belief that the presence of total coliforms reflected the presence of *E. coli*. Therefore total coliforms were adopted as the standard indicator organism. At the time, sanitation standards were low and faecal contamination of water supplies was common. As such, total coliforms were a reasonable surrogate for *E. coli*.

As sanitation standards improved in developed nations, faecal contamination of water supplies became less common. The percentage of total coliforms in water that were of faecal origin declined, and total coliforms were no longer a good indicator of faecal contamination.

In 1948, the more specific test for faecal/thermotolerant coliforms was developed, and this was soon adopted for general use in water quality monitoring. Total coliform testing was retained because it had already gained wide acceptance.

Over the years, the test methods used to identify coliform organisms have been changed to make them simpler and more rapid, however this has also meant that more non-faecal bacteria are now detected by the tests. Therefore the relationship between these indicator bacteria (total coliforms and faecal coliforms) and faecal pollution is not as definite as it used to be.

More recently, rapid and inexpensive methods for identification of *E. coli* have been developed, and this organism is being adopted as the primary indicator organism in a number of countries.

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Cyanobacteria

Cyanobacteria, also known as blue-green algae, are a group of microorganisms with bacteria-like properties. Although not pathogenic themselves, that is they cannot bring about an infectious disease, they produce toxins which are of considerable concern to water supply and public health authorities.

Cyanobacteria are naturally occurring components of all aquatic environments. Individual cells are microscopic but are capable of dividing and doubling every two to three days and forming thick smelly green scum, the consistency of paint, on water surfaces. These concentrations of cyanobacteria are often referred to as "blooms".

The species that most commonly affect water supplies in Australia are:

- *Anabaena* (reservoirs and slow-moving rivers).
- *Microcystis* and *Cylindospermopsis* (reservoirs and dams).
- *Nodularia* (brackish waters).

Some cyanobacteria produce toxins that can kill animals and are highly toxic to humans. For example, microcystin LR (produced by *Microcystis*) has a relative toxicity 1000 times greater than cyanide.

Some cyanobacterial toxins can damage the tissues of vital organs such as the liver and kidneys, and even the skin. Other cyanobacterial toxins damage nerve cells. There is also concern regarding long-term exposure to some toxins which have been demonstrated to be carcinogens.

There is some debate as to the cause of blooms and in fact whether there is an increase in their occurrence. There is no doubt that the presence of nutrients (such as phosphate and nitrate), strong sunlight and slow flowing warm water are conditions which favour bloom formation.

In Australia, water authorities monitor their water sources for cyanobacteria during warmer, sunny periods - conditions that favour growth of cyanobacteria.

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