15 Water sample analysis

15.1 Overview

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15.1.1 Introduction

Like many countries around the world, Australia's annual rainfall fluctuates highly, having an impact on surface water flows and sources for drinking water. Huge improvements have been made in the provision of drinking water around the world. For example, since 1990, 2.6 billion people have gained access to an improved drinking water source. An improved source is one that is designed to protect against contamination at the point of distribution or collection. The main concern in drinking water contamination is the presence of bacteria (such as *E. coli*) from faecal contamination, which has been detected even in protected water sources. Low-cost techniques for testing local water supplies are intrinsic to protecting the health of billions of people around the world. In Australia, the challenges of fluctuating rainfall are being met with the creation of additional water sources, such as desalinated water, to ensure that sufficient drinking water sources are available.

In this topic, you will explore the sampling protocols employed when testing for drinking water and some of the contaminants found in water supplies.

FIGURE 15.1 Since 1990, 2.6 billion people have gained access to an improved drinking water source.

KEY KNOWLEDGE

In completing this topic, you will investigate:

- the existence of water in all three states at Earth's surface, including the distribution and proportion of available drinking water
- sampling protocols, including equipment and sterile techniques for the analysis of water quality at various depths and locations
- the definition of a chemical contaminant and an example relevant to a selected water supply.

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15.2 The states of water and sampling protocols

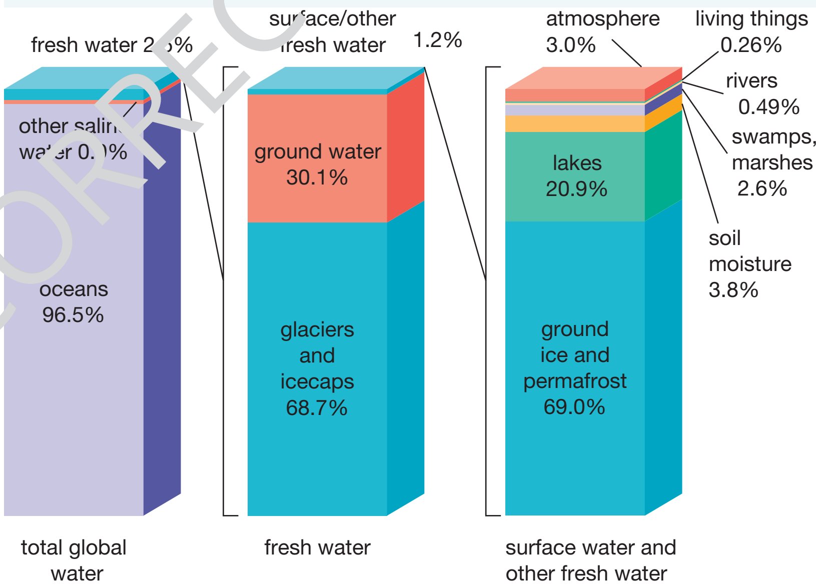
KEY CONCEPTS

- Existence of water in all three states at Earth's surface, including the distribution and proportion of available drinking water
- Sampling protocols, including equipment and sterile techniques for the analysis of water quality at various depths and locations

15.2.1 Using water

Nearly all the water that is used around the world every day, including that used for drinking, is not pure. This is because, as we have seen in previous topics, water is an excellent solvent. In the environment, water comes into contact with many substances that dissolve in it. As water falls through the atmosphere in the form of rain, gases from the atmosphere, both natural and pollutants, dissolve in it to some extent. When it travels over the Earth's surface, or soaks into the ground, naturally occurring salts also dissolve. As demonstrated in figure 15.2 and table 15.1, only ~2.6 per cent of all water on Earth is fresh water, and of this 2.6 per cent only 1.2 per cent is surface or other fresh water. This means only ~0.03 per cent of all water on Earth must sustain all land-based life, including more than 7 billion people.

FIGURE 15.2 Global distribution of water



As all water eventually flows into the oceans as part of the water cycle, this is precisely why the ocean is so salty and contains a wide range of dissolved substances. The major ions in sea water are shown in table 15.2.

The United Nations has estimated that water usage has grown at more than twice the rate of population increase in the last century and by 2025 an estimated 1.8 billion people will live in water scarce regions. Increased water usage is exacerbated by population growth and climate change, and by 2025 two-thirds of the world's population will live in water-stressed regions. Therefore, we need to ask, from a realistic viewpoint, whether the water we use is suitable for the purpose we have in mind. To answer such a question, we need to know not only *what* is dissolved in the water, but also *how much*. And we also need to know *how to measure* what the water contains.

TABLE 15.1 Approximate global distribution of water by percentage and state

	Location of water	State of water	Percentage of total water on Earth
Salt water 97.4%	Oceans	Liquid	96.5%
	Other saline water	Liquid	0.9%
Fresh water 2.6%	Glaciers and icecaps	Solid	1.72%
	Ground water	Liquid	0.753%
	Ground ice and permafrost	Solid	0.0207%
	Lakes	Liquid	0.00627%
	Soil moisture	Liquid	0.00114%
	Atmospheric water vapour	Gas	0.0009%
	Swamps and marshes	Liquid	0.00078%
	Rivers	Liquid	0.000147%
	Living things	Liquid and gas	0.000078%

Each state in Australia uses one or more sources of water depending on geography, available sources and population. Australia does not have a large number of natural lakes to assist in water storage, and as the driest inhabited continent, with highly variable rainfall and runoff, water management is a significant undertaking. In general, the sources of water in Australia are from:

- water catchments — protected and open
- lakes
- rivers and creeks
- groundwater (borewater)
- desalinated water
- recycled water.

TABLE 15.2 Major ions in sea water

Ion	Typical concentration (mg L^{-1})
Chloride, Cl^-	18 980
Sodium, Na^+	10 556
sulfate, SO_4^{2-}	2 649
Magnesium, Mg^{2+}	1 262
Calcium, Ca^{2+}	400
Potassium, K^+	380
Bicarbonate, HCO_3^-	140
Strontium, Sr^{2+}	13
Bromide, Br^-	65
Borate, BO_3^{3-}	26

About 15 670 billion litres of water was used for consumptive purposes across Australia in 2016–17. The biggest use of this water was agriculture (70%), followed by urban use (20%) and other industries (10%). Water in urban areas of Australia is sourced from a mains water supply, called **reticulated water**. Reticulated water is controlled by local water authorities and is carried via a pipe from a reservoir. These reservoirs may source their water from a few sources. For example, Melbourne's source of water is mainly from surface water assisted by desalinated water; Perth uses both groundwater and desalinated water; Adelaide relies on water from rivers and desalinated water.

In Melbourne, Melbourne Water is the authority treats and provides high-quality water across the Port Phillip and Westernport region. Figure 15.3 shows the sources of drinking water for Melbourne, including ten catchment reservoirs that are linked through a network of pipes. These reservoirs depend on rainfall on a catchment area or diversion from a river. To diversify the water supply system for a growing population, a rainfall-independent desalination plant was built. The plant assists with maintaining water storage volumes and recovery after drought periods, and is part of planning for increased water resources. Figure 15.4 demonstrates the long-term planning for Melbourne's water supply, which is based on modelling of climate change impacts and potential demand variations.

FIGURE 15.3 Melbourne water supply system (Melbourne Water)

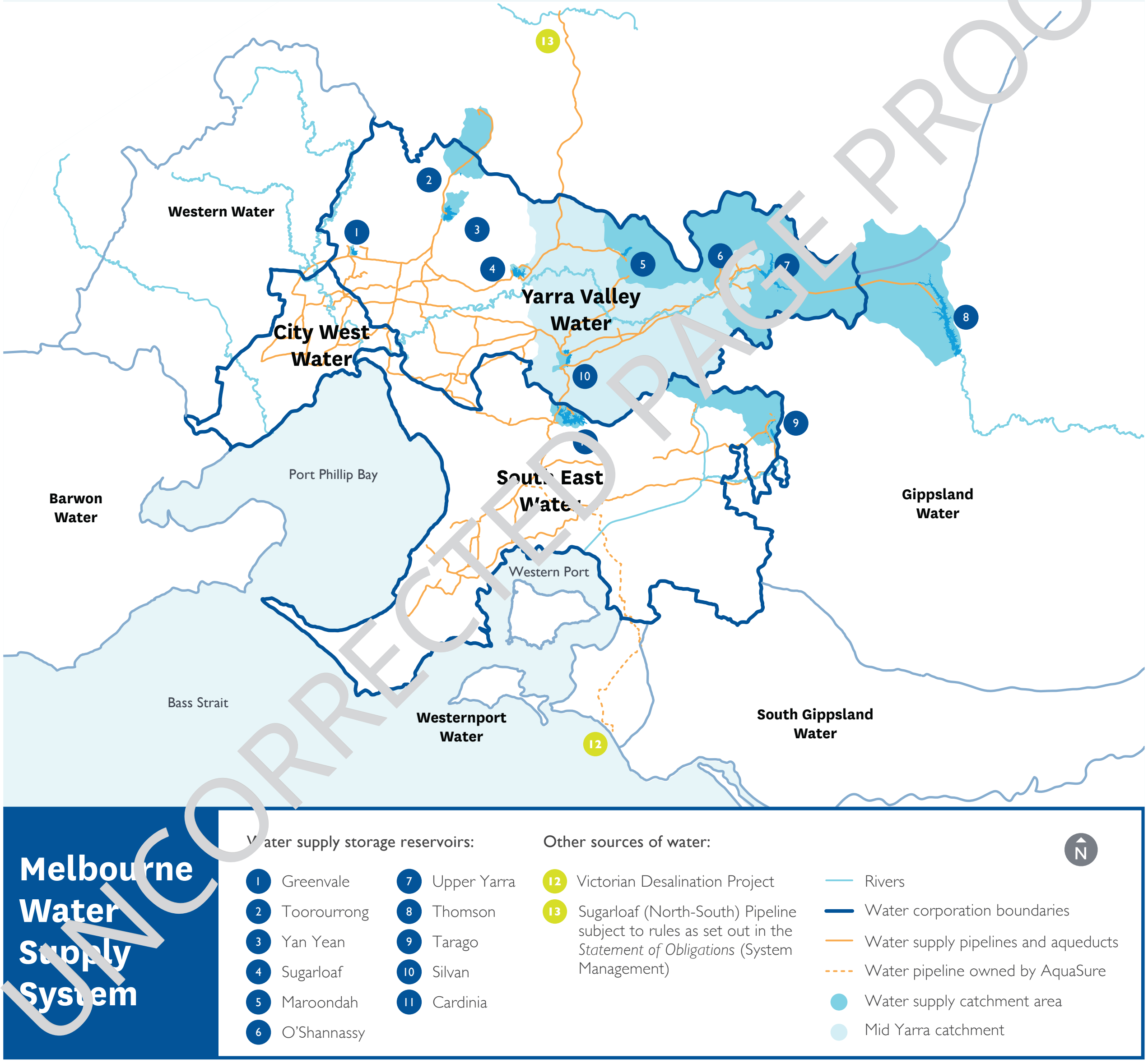


FIGURE 15.4 Long term water supply and demand for Melbourne.

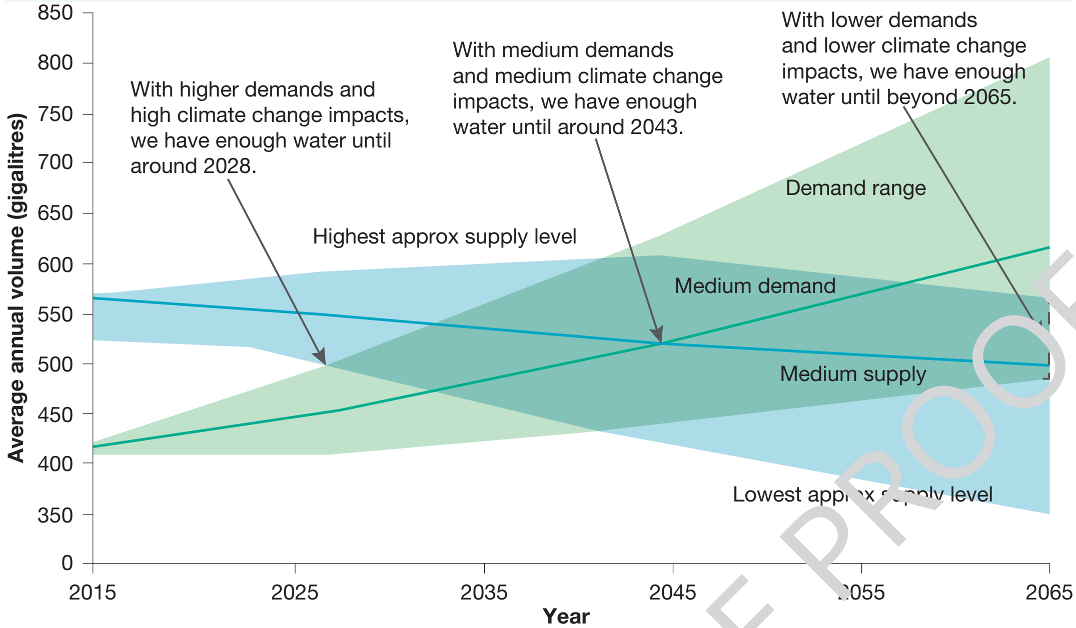


FIGURE 15.5 Thomson reservoir, the largest reservoir supplying water to Melbourne.

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Weblinks Melbourne's water supply

Water storage dashboard

15.2.2 Sampling protocols

Water sampling in the field can be a complex task because it depends on the water use and the type of analysis required. In Australia, to ensure consistency of sampling methods and result reporting, the Australian Government provides sampling standards and guidelines for sampling, and for transporting and preserving the sample (AS/NZS 5667.1:1998). These strict protocols exist for the collection of water samples in order to produce accurate analytical results. These apply before, during and after sampling takes place. Australia also has standards for water quality dependent upon its final intended use — drinking, recycling (for irrigation or animal use), swimming (contact), irrigation (agriculture), or treated wastewater (for discharge in the sea) — with a standard applied for each water purpose.

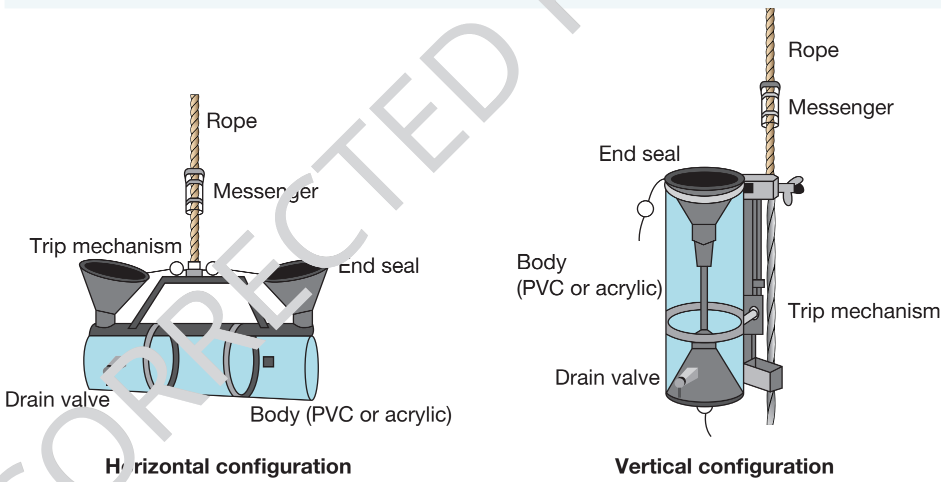
To obtain an accurate analysis of a water sample, it is important that a number of precautions are taken. These are discussed below.

Representative samples

The sample collected must be a **representative sample**. Considerations for a representative sample include sampling from a variety of locations and/or depths, or ensuring the water is well mixed. The sample should be representative of 'average conditions' for the particular location. It would not be appropriate, for example, to take samples during a flood, unless that was the specific reason for the analysis.

Surface water samples may be taken from 100 mm below the surface if the water is considered to be well mixed. Otherwise, several samples need to be taken at different depths that represent a specific 'layer' of water. In that case, a pump and a Van Dorn sampling instrument may be required (figure 15.6).

FIGURE 15.6 Van Dorn sampling instrument in vertical and horizontal configurations

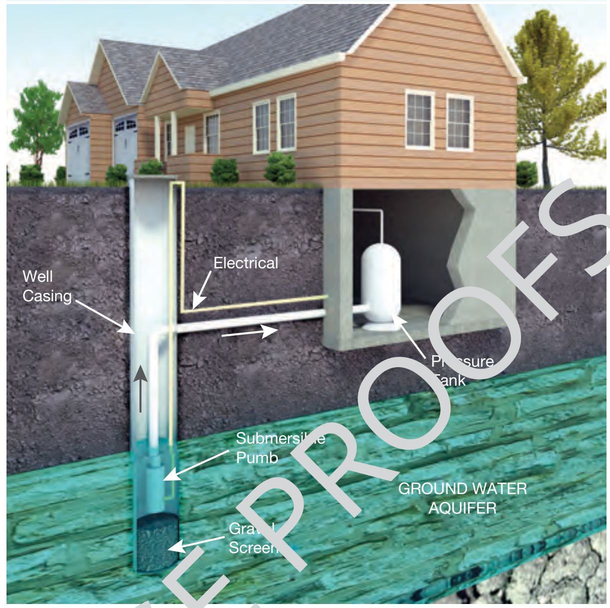


River water samples need to be taken at various locations that may be spread over a few kilometres. 'Grab' samples are usually taken to capture a representative sample for the location (figure 15.7).

Ground water is typically sampled via the existing bores, using specific instruments by trained personnel (figure 15.8). The bore needs to be purged several times before samples can be considered representative. The volumes of the bore to be purged need to be calculated based on the diameter of the bore and depth.

FIGURE 15.7 Taking grab samples from river water

FIGURE 15.8 Simplified schematic of groundwater use at house scale.



Sampling equipment and procedures

The choices of sample equipment and sampling techniques help prevent contamination. The material of the sampling container must be considered. For example, if the analytes to be tested are organics, a glass bottle is required, because they do not interact with the glass. Conversely, for inorganic samples, a glass bottle is not suitable because the active sites from the glass can interact with the inorganic analytes. In this case, a polypropylene bottle may be used. Container lids should also be considered. Pre- and post-contamination can be minimised by specifying if containers must be completely filled, and avoiding contaminants during transportation including exhaust fumes and dust. This is important because the expected level of contaminants in the sample may be in parts per million or even parts per billion.

Cross-contamination may be prevented by thorough cleaning of sampling equipment and bottles between sampling days to avoid contamination from a prior sampling date.

Duplicate samples or even triplicate samples are required to increase the precision of the analysis. When results are analysed the duplicates and triplicates need to agree within a range of 10 to 20% of each other.

Sample preservation

Sample preservation may involve cooling, freezing or adding chemicals. If chemicals are added, the preparation of 'blanks' is important; these contain the added chemical and distilled water only, rather than the sampled water. Once collected it is important that samples are analysed within certain prescribed times.

Finally, an appropriate analytical technique should be chosen. Prescriptions exist for analysis of particular contaminants, and are discussed in topics 17, 18 and 19. Additionally, such tests are often required to be carried out only by suitably qualified laboratories.

The level of sophistication required can be illustrated by the collection of samples for Fe^{2+} analysis. Many metals can be collected in glass, polyethene or polypropene containers, provided they are first washed with nitric acid to provide a pH between 1 and 2. However, for Fe^{2+}, hydrochloric acid must be used instead, because strong nitric acid is an oxidant and may convert some of the Fe^{2+} into Fe^{3+}. For the same reason, it is specified that the containers must be completely filled to exclude air, because oxygen gas is also an oxidant.

A number of tests are also done 'in the field'. These include measurements of temperature, pH, dissolved oxygen, some anions such as fluoride and sulfide, and turbidity (cloudiness). Portable instruments are used for these tests, and these must be regularly calibrated against laboratory standards to maintain their accuracy.

15.2 EXERCISE

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1. Australia has the highest per capita water storage capacity in the world. Why?
2. What ways can water be sourced if reticulated water is not available?
3. Explain why it is necessary to have strict protocols for the collection of water samples for analysis.
4. Why do we need to take duplicate samples when sampling water?
5. Use the **Sampling and analysis** weblink in the Resources tab to access a list of procedures to be followed for the collection of water samples. Use appendix A of the document to list some of the procedures that need to be followed to collect water samples for testing the following.
   (a) Sulfate ions
   (b) Magnesium ions
   (c) Cyanide
   (d) Fe^{2+}
   (e) Total mercury
   (f) Chlorophyll

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Weblink Sampling and analysis

15.3 Chemical contaminants

KEY CONCEPT

- The definition of a chemical contaminant and an example relevant to a selected water supply

In many ways, it is unfortunate that water is such a good solvent, because it means obtaining pure water is difficult and water is also easily polluted. For centuries, the oceans of the world have been a convenient and highly efficient water treatment plant, because almost anything we put in the sea is eventually dissolved or broken down into constituent atoms, molecules or ions. Natural processes include the addition of salts to rivers and oceans as rocks and soils are eroded.

The human impact on water sources is astounding. Globally, effluent has been poured into rivers, which eventually flow out to the sea. Much of this sewerage waste is not treated in any way. Oil is washed out of the holds of tankers (see topic 18 for a discussion of oil spills). Factories discharge waste directly into the sea.

The more sophisticated our technology becomes, the more complex are the pollutants that we discharge. This means that it takes longer for the sea to degrade the waste. Some waste is **biodegradable**. This means that it is broken down by natural processes. However, an increasingly larger proportion of waste is **non-biodegradable**.

15.3.1 Sources of contaminants in water

A **contaminant** can be defined as an unwanted substance that makes water unsuitable for an intended use. Both inorganic and organic contaminants enter water in many ways. Sources of contaminants include:

- *direct discharge* from factories and other sources in both surface water and sea water. This can also happen when poorly maintained sewerage systems overflow or when ships discharge ballast water inappropriately. Agricultural industries commonly contaminate surface and ground waters with nitrates from fertiliser run-off and farm animal wastes.
- *stormwater run-off*. As water flows over the surface, it may come into contact with surface contaminants and dissolve chemicals from them in the process. It may also flow through contaminated soil, dissolving soluble components and carrying soil particles along as a suspension.
- *contaminated air contact*. Components of contaminated air may either dissolve directly in water or react with it to produce a range of undesirable chemicals.
- *groundwater contamination*. This occurs when surface water comes into contact with contaminated soil and then soaks into the ground. It may also occur when leaching through old buried deposits such as landfill sites. Sometimes, the material being leached out is organic in nature and largely insoluble in water. In cases such as this, it may form 'pools' in underground reservoirs and become a source of long-term pollution as it dissolves very slowly over many years.

15.3.2 Contaminants: heavy metals

While **heavy metals** are natural components in the Earth's crust, they can contaminate the water through various means — both through natural contamination and as the result of human activity. They are contaminants of concern for human health because they do not degrade, they are cumulative in the human body and some of them are known to induce cancer and other health problems.

Humans are exposed to heavy metals mainly through drinking water and food consumption; therefore, close monitoring of the drinking water quality is paramount.

Limits for acceptable concentrations of heavy metals in water are included in almost all standards, but specifically in the drinking water standards in Australia. A selection of the guidelines for a few metals of concern is shown in table 15.3.

TABLE 15.3 Selection of heavy metals guideline values in drinking water

Heavy metal	Health guideline (mg/L)	Aesthetic guideline, (mg/L)	Source in drinking water
Arsenic	0.01		From natural sources and mining, industrial and agricultural wastes, including: manufacture of electrical components; wood preservatives and pesticides; gold mining; processing of ceramic materials
Cadmium	0.002		From industrial or agricultural contamination; contaminant in metals used to galvanise pipes and their subsequent erosion; metallurgical industries; improper waste disposal (e.g. nickel–cadmium batteries)
Chromium	0.05		From industrial or agricultural contamination of raw water or corrosion of materials in distribution system/plumbing; metallurgical processes such as alloying and electroplating; catalysts and oxidants; paint pigments

(Continued)

TABLE 15.3 Selection of heavy metals guideline values in drinking water *(Continued)*

Heavy metal	Health guideline (mg/L)	Aesthetic guideline, (mg/L)	Source in drinking water
Copper	2	1	From corrosion of copper pipes
Iron		0.3	Occurs naturally in water in small quantities; high concentrations stain laundry and fittings; iron bacteria cause blockages, taste/odour, corrosion
Lead	0.01		From dissolution from natural sources and domestic/industrial sources including household plumbing containing lead (e.g. pipes, solder); paint pigments; cable sheathing; ammunition; solder; batteries
Mercury	0.001		From mining and industrial wastes; fungicides; electrical equipment; batteries
Nickel	0.02		From prolonged contact of water with nickel-plated fittings
Zinc		3	From corrosion of galvanised pipes/fittings and brasses

Source: NHMRC, 2018, Australian Drinking Water Guidelines 6, Version 3.5.

15.3.3 Contaminants: persistent organic pollutants

Substances that persist in the environment because they cannot be broken down are non-biodegradable. On the other hand, those that can be broken down by natural means are biodegradable.

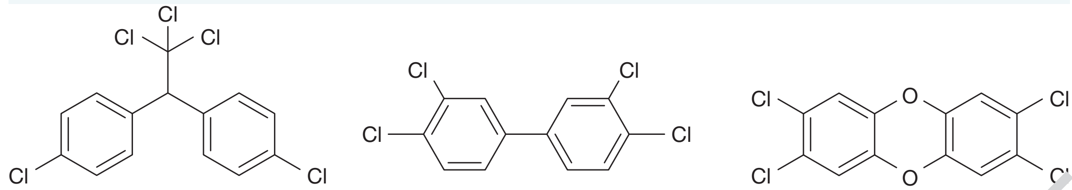
Persistent organic pollutants (POPs) are contaminants that are difficult to eradicate from the environment. Many have been used in large amounts in the past and are now considered a global concern. The Stockholm Convention of 2004 formally recognised an original twelve POPs, plus a further nine chemicals (or classes of chemicals) as posing a particularly unacceptable risk to the environment and to human health. This treaty aims to reduce and eliminate, where possible, the use of such chemicals. One of the most well-known chemicals on this list is DDT. DDT was an insecticide used in large amounts throughout the 1940s, 1950s and 1960s to control a number of insects, including the anopheles mosquito, the carrier of malaria. In this role, DDT was hugely successful and the amount used quickly escalated. The publication of Rachael Carlson's famous book *Silent Spring* in 1962, however, drew attention to a number of emerging concerns, including an apparent decline in the reproductive rates of a number of bird species. Birds, such as the American bald eagle, were producing eggs with very thin shells that broke as the parents sat on them. This in turn seemed to be associated with increased levels of DDT in the body fat of these birds. The use of DDT is now banned in many countries.

FIGURE 15.9 The American bald eagle was once on the endangered species list as its reproduction was compromised by the birds' ingestion of DDT.

Polychlorinated biphenyls (PCBs) and dioxins are two further groups of these POPs. PCBs have very specific uses in the electrical industry (in circuit boards) and are now being replaced with less dangerous alternatives. Dioxins, on the other hand, have no use at all but are often formed as unwanted by-products in other processes. Dioxins can even be produced by burning waste in domestic incinerators.

The structures of DDT, a typical PCB and a typical dioxin are shown in figure 15.10.

FIGURE 15.10 Structures of some persistent organic pollutants



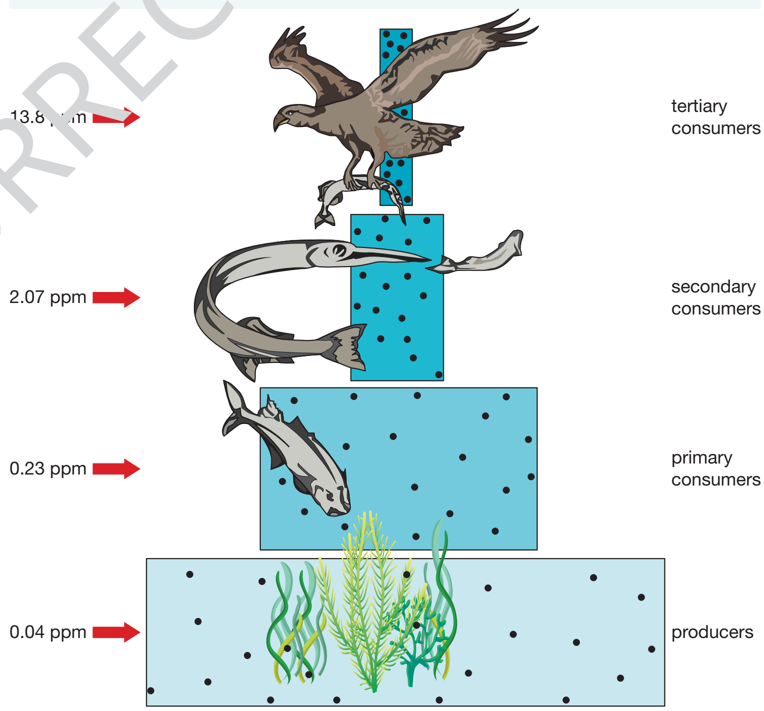
Biomagnification

Biomagnification is the process by which a substance becomes more concentrated in the tissues of organisms higher up the food chain. This results in the concentration of these substances in their bodies becoming higher than in the surrounding environment and the substances becoming impossible to eliminate. Biomagnification can occur when the substance involved is:

- persistent in the environment, even at low levels. This occurs when a substance withstands environmental processes that would normally break it down.
- fat soluble, rather than water soluble. Most substances that become biomagnified are non-polar in nature and, therefore, are soluble in the typically non-polar fatty tissues of animals. This non-polarity also means that they are water insoluble, a property that contributes to their persistence.
- difficult to eliminate. An animal may not be able to metabolise or excrete something once it has entered its body. If the substance is in the fatty tissues, this elimination is even harder.

Many cases of biomagnification have been well-documented, including mercury (especially in the form of methyl mercury), pesticides and DDT. Methyl mercury is discussed in further detail in topic 17.

FIGURE 15.11 Biomagnification of mercury resulting in levels at the top of the food chain considerably higher than the background environmental levels.



Resources

Weblink Persistent organic pollutants (POPs)

15.3.4 Contaminants: microorganisms

Fresh water contains many microscopic organisms such as phytoplankton, bacteria, algae and protozoa. These organisms may be harmful or beneficial to other forms of life. For example, the biological decay of plant and animal matter often produces nitrogen-rich urea and ammonia, both of which are very soluble. Bacteria may then react with these compounds, ultimately converting the nitrogen in them into free atmospheric nitrogen. This is a critical step in the nitrogen cycle, so it is important to life. On the other hand, disease-causing (pathogenic) bacteria may be present, especially if run-off has been in contact with animal waste, or poorly treated sewage has entered the water. By testing water for the presence of various bacteria, scientists can determine whether water is contaminated. The presence of *Escherichia coli* (*E. coli*) indicates that the water contains pathogenic bacteria.

FIGURE 15.12 *Escherichia coli* (*E. coli*) is a micro-organism commonly found in the bowel.

Eutrophication

When conditions are right, phytoplankton (and especially blue-green algae or cyanobacteria) may reproduce explosively to seriously affect water quality. These conditions usually include still water, sunlight and an excess of nutrients required for growth. Two important such nutrients are nitrates and phosphates, which may be present in excess as a result of human activity. Domestic waste water, agricultural practices and sewage are the main sources of these excess nutrients. This out-of-control growth is often noticed as an 'algal bloom' and, besides being unsightly, can have serious consequences. When these organisms die, their subsequent decomposition seriously depletes the level of dissolved oxygen in the water. As a result of this, animals, especially fish, and even plants may die due to a lack of oxygen required for respiration. Additionally, all this decay may produce biotoxins, which can be a serious health hazard to any organism that consumes this water. This condition is called **eutrophication**.

15.3.5 Drinking water standards

The production and treatment of water for drinking is subject to standards to ensure public health, and the maximum permitted levels of some contaminants are summarised in table 15.4. Federal and state standards cover allowed levels of biological, chemical and radiological contaminants, as well as other issues such as pH and turbidity. Various acts and guidelines describe what the standards are and how they are to be monitored. These include:

- *Safe Drinking Water Act 2003* and *Safe Drinking Water Regulations 2005*, which were set and administered by the Victorian Department of Health
- Australian Drinking Water Guidelines 2011, which were developed by the National Health and Medical Research Council.

To ensure water quality is met, water authorities in collaboration with EPA continuously plan, sample and monitor the sources of our drinking water to identify any contaminants of concern. EPA monitors industrial discharges to rivers and ensures they are properly treated prior to discharge. Water authorities protect the reservoir areas by restricting access, and then provide sampling and monitoring of water quality. The water is then treated prior to being distributed via the reticulated system. This way, only the highest quality of water is provided to users.

Water quality concerns for Melbourne include low water flow during periods of drought. Low precipitation levels lead to a low volume of water in reservoirs, which in turn leads to having to access water potentially contaminated with lake sediments. To mitigate this risk of a low volume of water available to use, a desalination plant was constructed to provide a secondary source of water.

Every other state in Australia faces different challenges, depending on weather fluctuations and the specific source of water. However, the typical treatment steps in the water treatment are coagulation, flocculation, sedimentation, filtration and disinfection. Fluoridation is also an additional step employed in some areas.

TABLE 15.4 Maximum permitted levels of some contaminants in drinking water

Contaminant	Maximum drinking water level (mg/L)
Mercury	0.001
Lindane (an insecticide)	0.01
Lead	0.01
2,4-D (a herbicide)	0.03
Sodium	180 (aesthetic level only)

Source: NHMRC, 2018, Australian Drinking Water Guidelines 6, Version 3.5.

15.3 EXERCISE

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1. List the ways that chemicals can enter water bodies.
2. (a) Define the term 'contaminant'.
   (b) Give an example of a situation in which water might be unsuitable for one particular use but suitable for another use.
3. Define POPs and give two examples.
4. What characteristics would a substance have to have to lead to biomagnification?
5. Through what mechanism can POPs be transported away from the source of contamination?
6. What are the sources in drinking water for the following.
   (a) Lead
   (b) Nickel
   (c) Iron

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15.4 Review

15.4.1 Summary

The states of water and sampling protocols

- Water is such a good solvent that it is rarely pure. Fresh water constitutes only 2.6 per cent of the Earth's total water but may still contain a number of dissolved substances.

- Strict protocols must be observed when collecting water samples for analysis so that the results obtained are accurate.

Chemical contaminants

- A contaminant is a substance that makes water unsuitable for an intended use.
- Contaminants enter waterways through a variety of methods, including direct discharge, stormwater run-off, contaminated air contact and contact with contaminated groundwater.
- A group of 21 substances or classes of substances have been identified as persistent organic pollutants (POPs). The use of these substances is now banned or severely restricted in many countries.
- DDT is an example of a chemical that was applied extensively as an insecticide but is now on the list of POPs.
- Compounds can be classified as biodegradable or non-biodegradable. Non-biodegradable substances may persist in the environment for an unacceptably long time.
- Biomagnification is the process by which levels of POPs build up in the fatty tissues of higher order organisms.
- Many pollutants dissolve in water because it is such a good solvent. Some waste is biodegradable and can be broken down by natural processes, but much is non-biodegradable. This poses environmental problems where species may be endangered due to water pollution.
- Eutrophication is caused by excessive levels of nutrients in water, which leads to explosive growth of microorganisms such as cyanobacteria. When these die, their subsequent decomposition leads to depleted levels of dissolved oxygen and the death of plants and fish.

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15.4.2 Key terms

biodegradable able to break down via natural processes over the medium term
biomagnification process by which a compound (such as a pollutant or pesticide) increases its concentration in the tissues of organisms as it travels up the food chain
contaminant the presence of unwanted chemicals, or chemicals present in a higher concentration than wanted that makes water unsuitable for its intended use
duplicate sample repeat of the original sample, taken under the same conditions, at the same time and the with same sampling equipment, in order to estimate the sample variability
eutrophication excessive levels of nutrients in water leading to explosive growth of microorganisms; subsequent death of these microorganisms can lead to depleted levels of dissolved oxygen and the death of plants and fish
heavy metal metal with high density or of high relative atomic weight and that is a risk to health or environment
non-biodegradable not able to break down in a natural environment
representative sample small sample with similar characteristics that accurately reflects the larger entity
reticulated water water provided through a network of pipes

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Digital document Key terms glossary — Topic 15 (doc-30904)

15.4 EXERCISES

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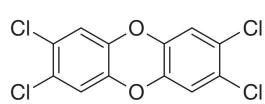
15.4 Exercise 1: Multiple choice questions

1. What is the use and phasing out of persistent organic pollutants governed by?
   A. The Geneva Convention
   B. The Stockholm Convention
   C. The Helsinki Convention
   D. The Dublin Convention
2. Which of the following statements about dioxins is true?
   A. Dioxins have been used in the past as insecticides.
   B. Dioxins are inorganic chemicals containing heavy metals.
   C. Dioxins are restricted to areas where there are large chemical industries.
   D. Dioxins are unwanted by-products that have no useful applications.
3. Biomagnification is the process whereby the concentration of a pollutant is increased
   A. as it is exposed to sunlight and microbial action.
   B. in organisms in each step up a food chain.
   C. as remains undergo decomposition.
   D. due to a population explosion of a particular species.
4. Despite their low solubility in water, many organic contaminants can persist in water bodies for a long time. Why is this?
   A. They adsorb strongly to the surface of soil particles in river beds.
   B. Other liquid impurities in the water dissolve them.
   C. They are broken down by natural microbial action in the soil.
   D. They accumulate in the bodies of aquatic organisms, which then die.
5. How is reticulated water delivered?
   A. Via an underground bore
   B. From a pump in a river
   C. Via a network of pipes
   D. From a desalination plant

15.5 Exercise 2: Short answer questions

1. What is the percentage of fresh water on the Earth?
2. Define the following:
   a. A biodegradable substance
   b. A non-biodegradable substance
3. Dioxins are a class of persistent organic pollutants. The figure shows the structure of a typical dioxin.



   a. Write the molecular formula for this dioxin.
   b. How are dioxins formed?
   c. Explain why the expected concentration of dioxins in water would be very low.
   d. Give two reasons dioxins accumulate in human fatty tissue

4. Undertake research to find an example of major contamination of ground water used for drinking water.
   a. What was the contaminant?
   b. What were the impacts?
   c. How was the contamination treated?
5. What are typical water treatments steps in a drinking water system?

15.5 Exercise 3: Exam practice question

1. A house in a remote area in Victoria needs to be connected to a water source as soon as possible. Reticulated water is not available. However, an option exists to source the water from a close-by river via an existing old pipe already connected to the house, or to use an old ground water bore close to the house. The owner employs a contractor to find out the water quality from both sources. The contractor drives on a rainy day for three hours from Melbourne to the house but forgets his sampling kit and bottles. The contractor takes a couple of clean plastic bottles from the owner and rushes to take a grab sample from the river. Then, the contractor comes back to the house, opens the bore tap and immediately takes a grab sample in a plastic bottle. He then drives straight back to Melbourne, to take the samples to the laboratory for analysis. However, the laboratory is closed, so he leaves the bottles with some instructions next to the sample drop-off area.

The laboratory results are shown in the following table. Some relevant guideline values are included for comparison. **11 marks**

Analyte	River water mg/L	Ground water, mg/L	Standard for drinking	Aesthetic guideline
Colour, HU	25	18	–	15
Total dissolved solids	100	3200	500	–
Arsenic	< 0.01	< 0.01	0.01	–
Cadmium	0.001	0.002	0.002	–
Copper	0.5	4	2	1
Chromium	0.01	0.08	0.05	–
Iron	0.2	4.5	–	0.3
Zinc	0.8	3.5	–	3

1. Identify five sampling protocols that have not properly been followed when collecting the samples. **5 marks**
2. Identify three laboratory analysis protocols that have not properly been followed when analysing the data. **3 marks**
3. Identify one contaminant and its water quality implications. Also consider contaminants not listed in the sample results. Discuss the likely contamination pathway for that contaminant. Propose a resolution. **3 marks**

15.5 Exercise 4: studyON Topic Test online only

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