WATERWISE

WATER RESOURCE MANAGEMENT AND CONSERVATION

WATERWISE

FOR SENIOR STUDENTS

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WaterWise

Water resource management and conservation

by

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WATERWISE

Endorsed by the WaterWise campaign as an educational resource

Contents

Introduction

Why we need to manage water as a precious natural resource

We all depend upon land, water and biological resources. The way we manage these resources is of vital importance to the economy and to our quality of life.

It is becoming increasingly clear that we need a better way of managing our natural resources to maintain essential ecological processes and to meet the needs of current and future generations.

Our lifestyles place many demands on water and other natural resources. Community attitudes are changing from the 'develop at all costs' concept to one of using water and land in a combination of ways. This multi-use process will protect biological diversity and maintain essential ecological processes and life support systems.

Community expectations of natural resource management are changing. If these resources are going to be available in the future, they need to be well managed. Progressive land and water users are aware of the need for careful and responsible use of these resources.

Development is no longer seen as beneficial for its own sake and water resource planners now take into consideration the views of various community based interest groups and water users.

Water resource management considers urban, industrial, agricultural and recreation usage, together with the requirements of the environment. Management of the environment considers the requirements of the aquatic environment and the maintenance of down stream ecosystems in order to preserve the visual character and conservation of our natural and cultural heritage.

The community is also becoming more aware of environmental issues such as erosion, salinity, the effects of agricultural chemicals, pollution and insensitive development. The complexity of these issues has led to the evolution of integrated land and water management.

Water has many uses for groups of people in the broad community. Each of these groups has different ways of using water to suit its lifestyle. People may use water for urban, industrial, rural and recreational purposes.

In urban environments, few people experience the hardship of limited water supply, apart from some restrictions on garden usage during the hot summer months when demand stretches the capacity of the water supply scheme.

Many Australians have water supplied as part of a community service and consequently have no real incentive to conserve or value this precious resource. Where water charges are made, these are often relatively low and do not reflect its real cost.

Of all the water piped to the Australian home, we typically drink less than 1%. The other 99% is used to maintain our lifestyle.

Research has shown that a reduction in water use in general is possible without necessarily reducing our quality of life. This reduction would save millions of dollars per year in operating and maintenance costs on existing water supply infrastructure, and through the deferral of new water supply infrastructure development. It would also contribute significantly towards a better environment, lower water charges and lower hot water charges to the household.

Urban water conservation programs need to involve as many Australians as possible to reduce water consumption nationwide. The need for this has been identified by many Australian studies. As well as recommending the development of new water supply dams, trunk mains and pump stations to satisfy future water needs over the next 100 years, studies have also recommended demand management be implemented Australia wide.

With the need to conserve water clearly identified, state and local water authorities are engaged in public education campaigns (such as WaterWise Queensland) with a long-term objective of reducing urban water consumption.

In some communities, significant progress in water conservation has already been made by local authorities with their own public education programs, sprinkler restrictions, mandatory installation of low flow dual flush toilets, and 'user pays' pricing policies.

The WaterWise campaign takes a practical approach, reviewing and consolidating successful ideas from the existing demand management strategies of other States' water authorities.

There are four clear goals for local authorities applying the WaterWise campaign in their own areas. These are:

- to more effectively utilise existing resources
- to defer capital expenditure for new resources
- to promote voluntary water conserving practices
- to minimise any impact on the environment.

This book is based on research which identified that urban Australians in general know very little about what happens before the tap or after the plug hole.

Chapters 1, 2 and 3 explain how modern society impacts on the natural water cycle, how it obtains water for its use and how it reclaims its wastewater. Chapter 4 details practical water conservation methods and projects.

Focus

Water is a multipurpose resource upon which we all depend for a range of purposes including recreation, sewage disposal, industrial use and irrigation. There are conflicting demands for the use of this water.

Chapter 1

Water in the environment

The water cycle

Water moves in an endless cycle from the sea and land to the atmosphere and back again as shown in Figure 1.

The sun's energy converts sea water, as well as water from lakes, rivers and the surface layers of soil, into water vapour. This process is called **evaporation.** Plants also add water vapour to the air through **transpiration.** Humans, animals and machines add small amounts of water vapour through **respiration** and **combustion.**

The water vapour rises into the atmosphere and condenses into clouds. It then precipitates and falls back to the land or sea as rain, sleet, hail or snow.

Most of the precipitation that falls on land either soaks into the soil in a process called **infiltration**, or runs off the land surface into rivers, lakes and eventually out to sea.

Some of the infiltrated water returns to the atmosphere through evaporation or transpiration, while the rest soaks down to the water table. This **groundwater** is a valuable resource that can be pumped to the surface (subartesian water) or flows naturally to the surface (artesian water) when tapped by a bore.

The water that runs off the land surface makes its way through a **catchment** before being carried away by streams and rivers out to sea.

Groundwater and surface water are what most life on our planet depends for survival and well-being.

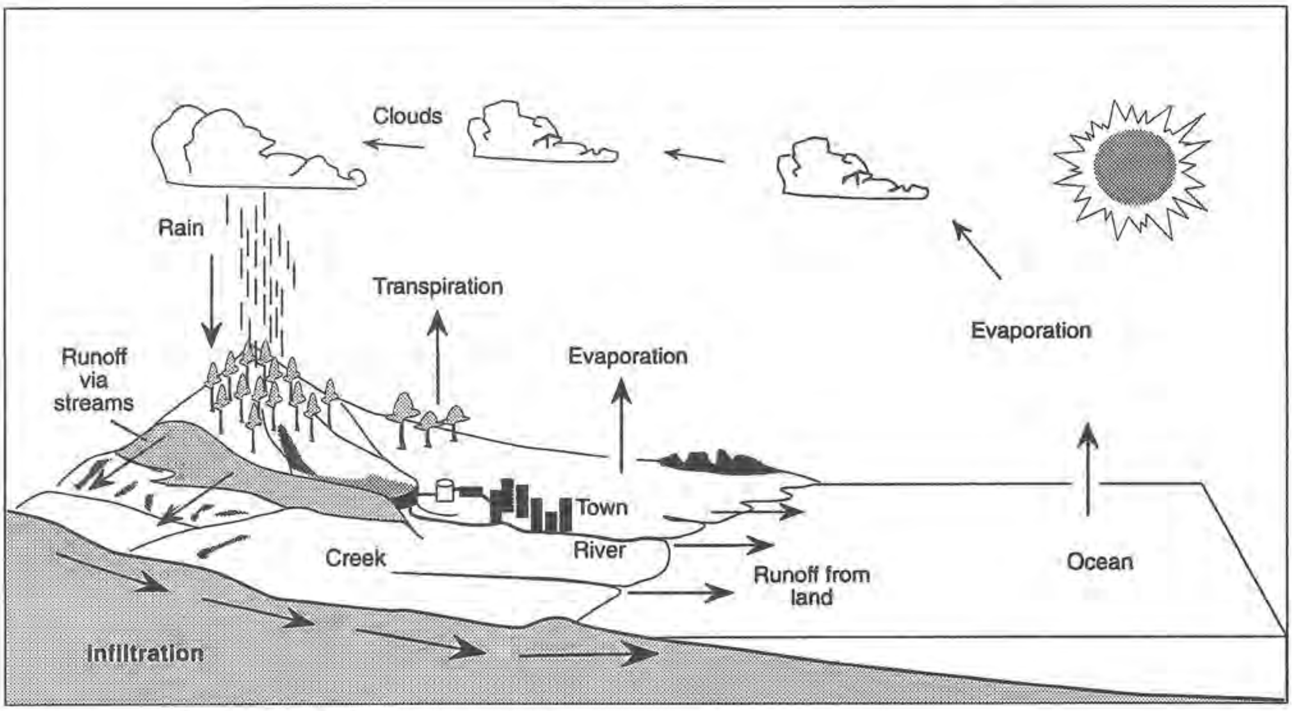


Fig 1 A summary of the main features of the water cycle

Water for towns and cities

As rainfall in Australia is seasonal and erratic, it is often necessary to dam rivers to ensure a reliable, year-round water supply.

Over the last 200 years, with the growth of cities and towns in Australia, many of our catchments have been significantly altered. Each one of us uses, on average, 600 litres of water a day. Much of this ends up in the sewerage pipes, and is taken to wastewater treatment plants.

In recent times, the use of this wastewater has been the source of much controversy, with pollution an all too familiar occurrence (see Chapter 3).

Figure 2 shows a schematic illustration of a coastal urban area showing its use of surface water. Alternatively if groundwater was the source of the city's raw water then item 3 in Figure 2 would be replaced by a bore or series of bores.

1. Water evaporates from the ocean and forms clouds which condense over mountains into rainfall.
2. Surface water runoff from the catchment accumulates in creeks and streams.
3. A dam has been built above the city to store raw water (untreated water including everything that rainwater accumulates through the catchment area).
4. Water treatment plants treat the water to make it fit for human consumption.
5. Pipes carry the treated water from reservoirs to individual households.
6. Wastewater is transported from the houses to wastewater treatment plants where solids, dissolved nutrients and other materials harmful to the environment are removed.
7. Effluent from the wastewater treatment plant, called reclaimed water, is stored in a pond where fish, ducks and birds can live.
8. Reclaimed water can be used on golf courses, nurseries, sporting fields or parks during dry periods.
9. Reclaimed water that is not used can be safely discharged into the sea.
10. Reclaimed water in the future could be totally recycled.

Storm water runoff from downpipes, roads and fields has not been shown on Figure 2.

Groundwater

This forms an important part of our water resources, particularly in western areas where water supplies are drawn from the Great Artesian Basin.

The availability of groundwater is not uniform, as some types of rock strata are more permeable than others.

The material in which groundwater is stored and through which it slowly permeates is called an **aquifer.**

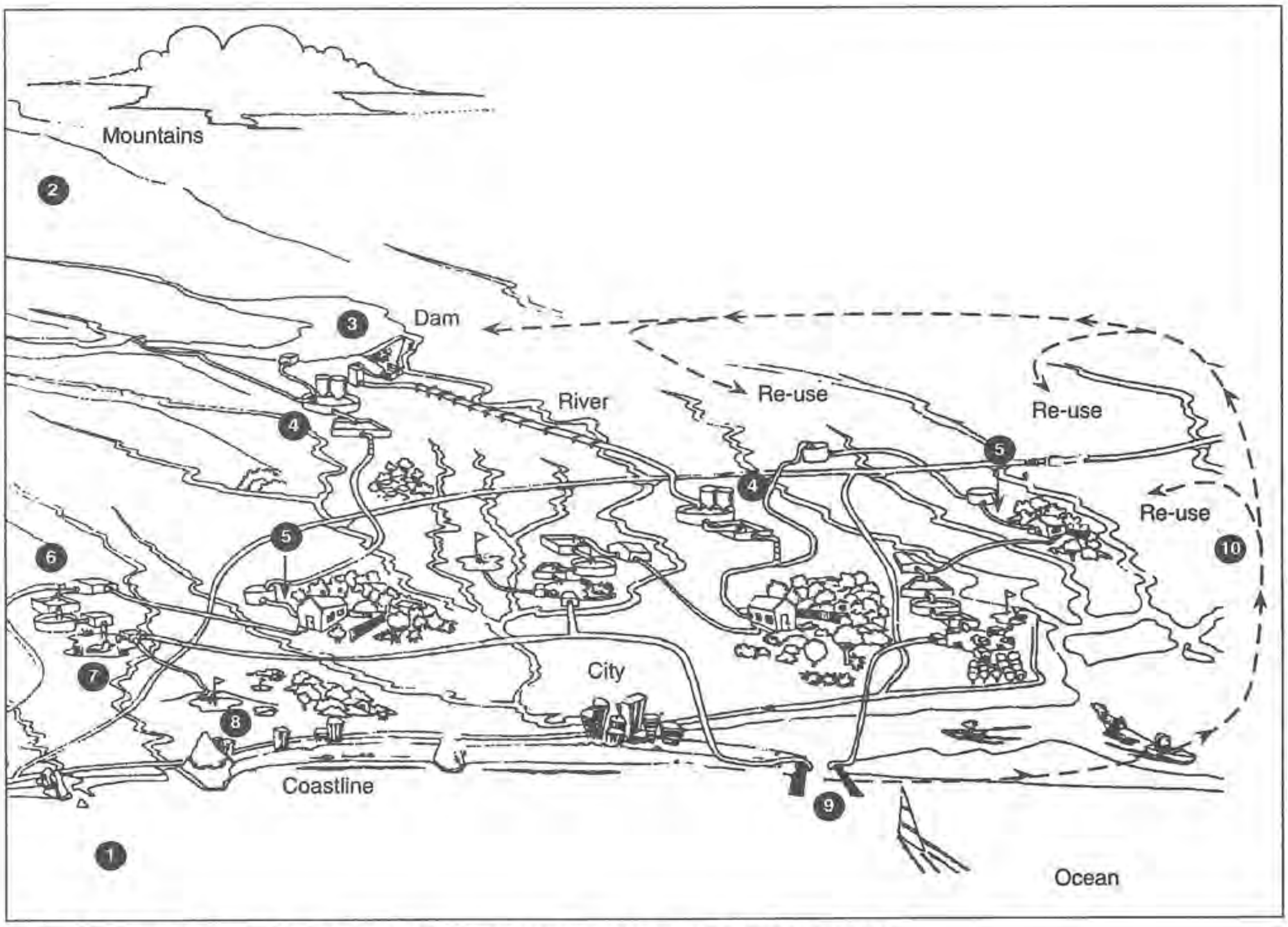


Fig 2 A schematic illustration of a coastal urban area showing its use of surface water.

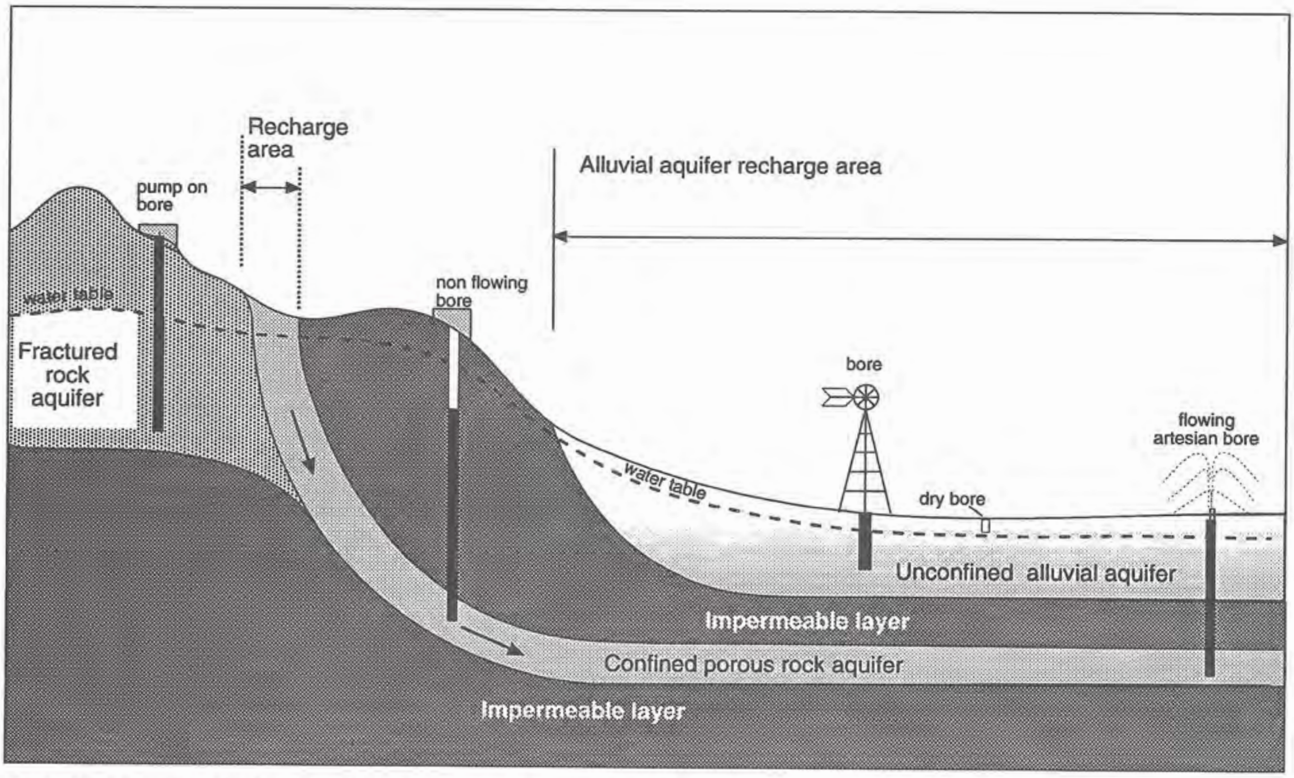


Fig 3 Groundwater can be tapped from three main types of aquifers — alluvial, porous rock and fractured rock.

Considerable distances may separate the water's point of entry into the aquifer from it's point of use.

Aquifers can be either unconfined or confined. Confined aquifers are encased between impermeable layers of material whereas unconfined aquifers are not.

Figure 3 shows three main ways in which groundwater is stored.

- **Alluvial aquifers** store water in layers of sand or gravel which have impermeable rock below them.

  Here the water is held in an unconfined aquifer and can be pumped to the surface through a bore using a motorised pump or windmill, as shown in Figure 4. This is also referred to as subartesian water.
- **Porous rock aquifers** are sometimes confined by impermeable layers above and below. Water seeps into the aquifer where the permeable rock material is exposed at the surface (**recharge area**). As water accumulates in the aquifer, it builds up pressure, and when tapped by a bore can flow to the surface under pressure. This is also referred to as artesian water.
- **Fractured rock aquifers** store water in fractures occurring in solid rock material. This may include basalts and other volcanic rocks and sandstone.

Many of our towns and cities rely heavily on groundwater supplies especially from alluvial aquifers which supply more than 50% of the groundwater used. In some areas groundwater picks up soluble impurities such as salt as it travels underground, but in general it is less prone to pollution and contains less solid materials than surface water.

Surface water

Water that is available on the land surface is more easily utilised than groundwater. However, during its overland trip through a catchment, its quality can be seriously affected by poor management.

What is a catchment?

A **catchment** is an area of land bounded by natural features such as hills or mountains, from which runoff water flows to a low point. It is like water in a bathtub flowing to the plug hole, or water that falls on a roof flowing to a downpipe. In the case of a natural catchment, the low point could be a dam, a location on a river, or the mouth of a river where it enters the sea.

Catchments vary in size and make-up. Many large catchments are bordered by mountain ranges and include major networks of creeks and rivers. These large catchments are often made up of many smaller catchments. Figure 5 shows a large catchment that consists of a number of smaller catchments. These all contribute water to the large catchment. Poor quality water flowing into a creek in one small catchment will affect the water quality in the river of the large catchment.

A trip through the catchment

As rainwater falls through the air, it collects dust particles from atmospheric pollutants (e.g. sulphur dioxide), bush fires, etc . Insects and other organic matter are also collected as rain penetrates through the forest canopy and falls to the ground. Some of this rain will percolate into the ground and some will form what is called surface runoff.

As the surface runoff flows over the land, it collects the remains of dead animals, excrement containing substances such as nitrates, phosphates and pathogenic organisms, naturally occurring bacteria, and other organic matter such as rotting leaves, twigs and logs. If bare areas of ground are exposed, soil can be picked up and carried in the flow.

Human activities can also have a significant effect on the quality of surface water. Farming, mining industry and towns can contribute waste materials and cause excessive soil erosion.

The influence of nutrients, herbicides, pesticides and other chemicals from agriculture or industry must also be allowed for in managing the catchment. Even in so called 'pristine' rainforest catchments, native birds and animals contribute to the contamination of surface water runoff.

Finally, all of this surface runoff water, enters creeks and flows into rivers and to the sea. Groundwater too is influenced by activities undertaken in recharge areas of the catchment, and water quality can be put at risk.

Catchment management

Governments have major responsibilities for ensuring the sustainable and balanced use of our natural resources now and in the future. By working together and caring for our river catchments we can secure a sustainable future whilst

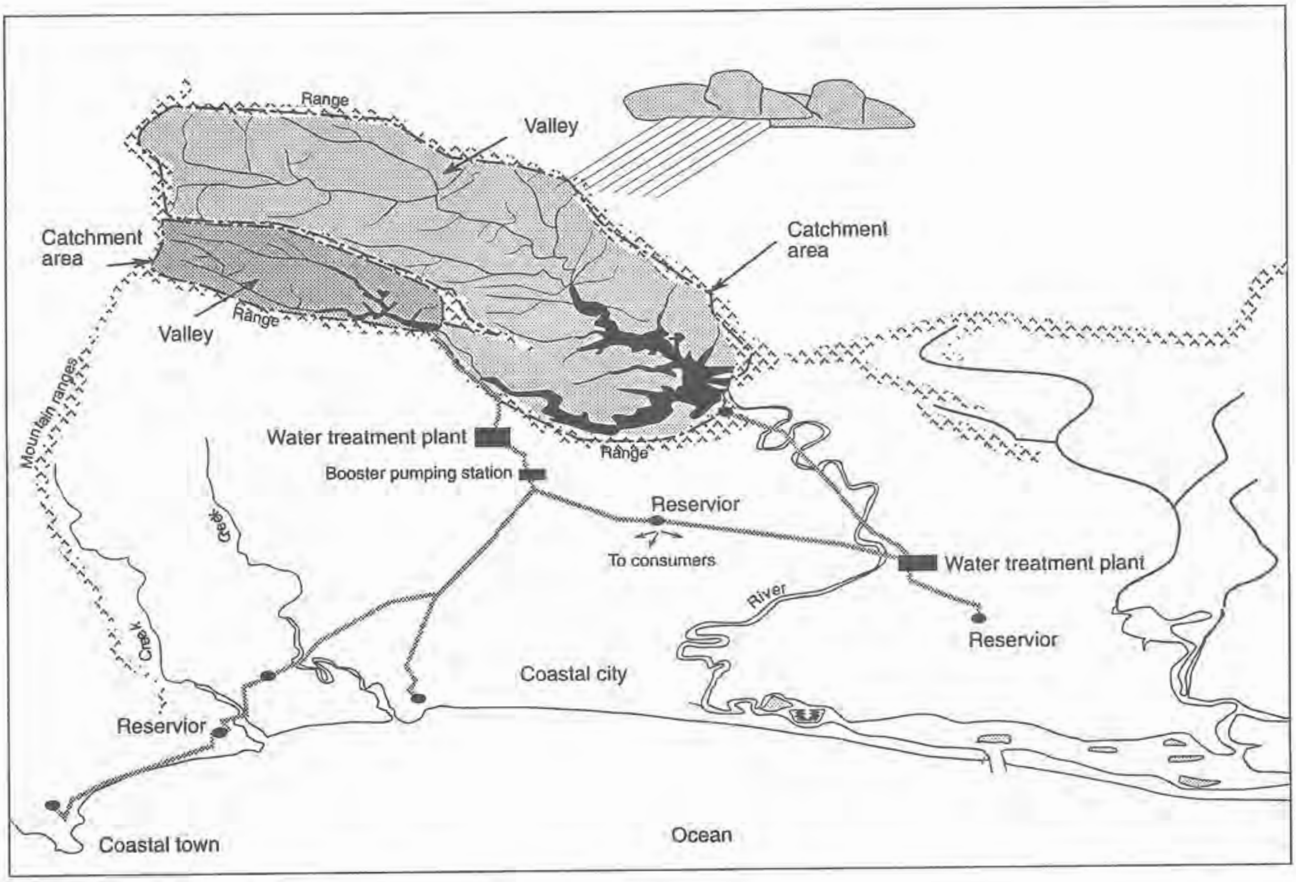


Fig 5 A catchment area

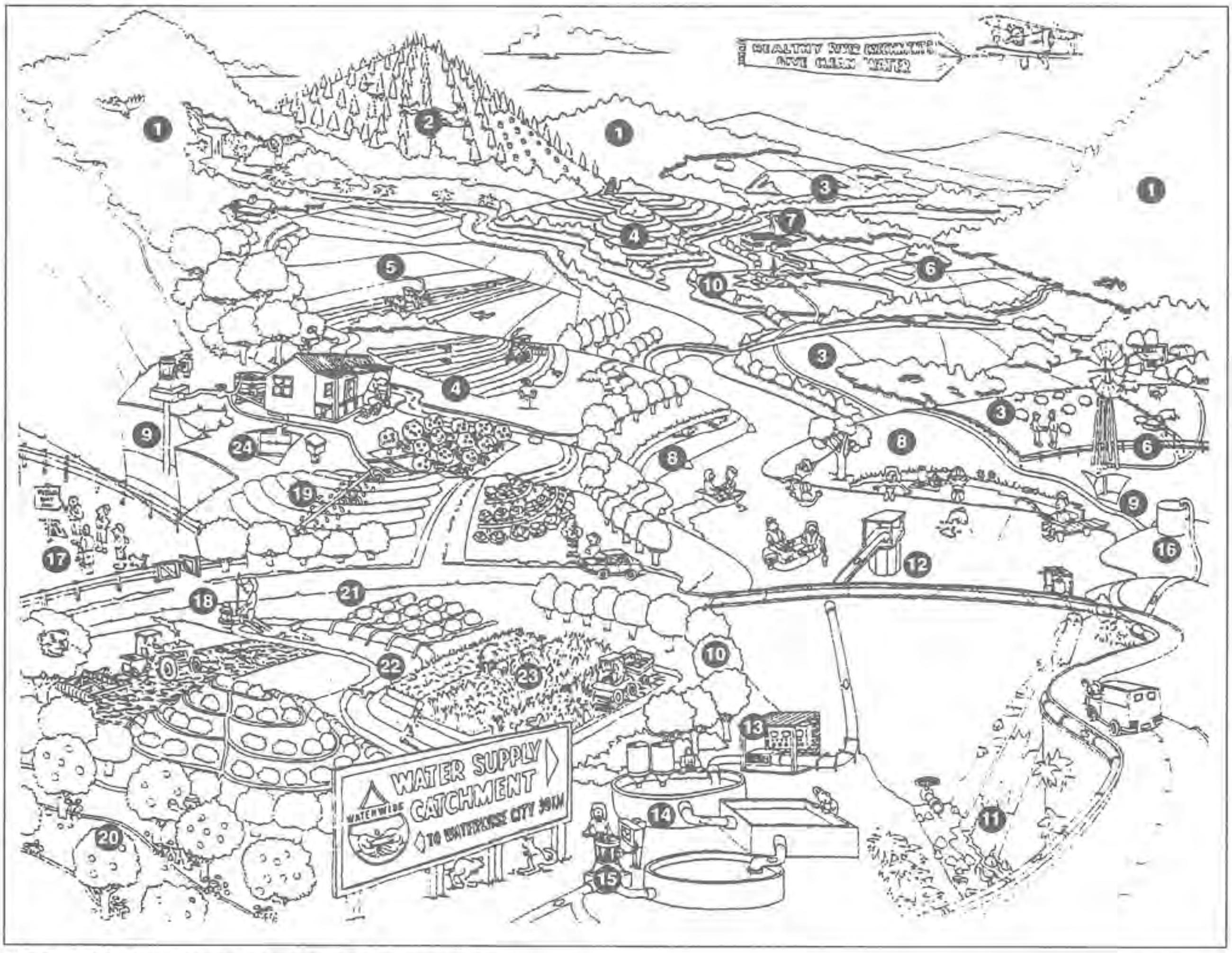


Fig 6 A healthy river means a clean water supply.

maintaining ecological processes, habitats for fauna and flora and our natural landscape features.

Community groups can become involved in catchment management and land conservation projects through the National Land Care Program.

State governments are promoting integrated or total catchment management strategies aimed at achieving the sustainable and balanced use of land, water and related biological resources. These strategies also help to ensure that we make our contribution to the global environment. Individuals, community groups and government agencies can use the framework provided by these strategies.

Good catchment management

Clean water in our streams and rivers means our water supplies are safer and more economical, and the environment will be preserved for future generations. The main features of good catchment management as shown in Figure 6 are summarised below.

1. Very steep areas should be left undisturbed to minimise soil erosion. Forests maintained on steep slopes protect the soil and maintain water quality. National parks provide wildlife habitats and cater for recreational areas and tourism.
2. Steep hillsides can be used for forestry. Permanent ground cover should be maintained between trees to minimise soil erosion (also shown in Figure 7)
3. Moderate slopes can be used to graze stock. Adequate ground cover should always be maintained to prevent soil erosion.
4. Low-sloping land is suitable for crops. Contour banking and stubble mulching are necessary to minimise soil erosion.

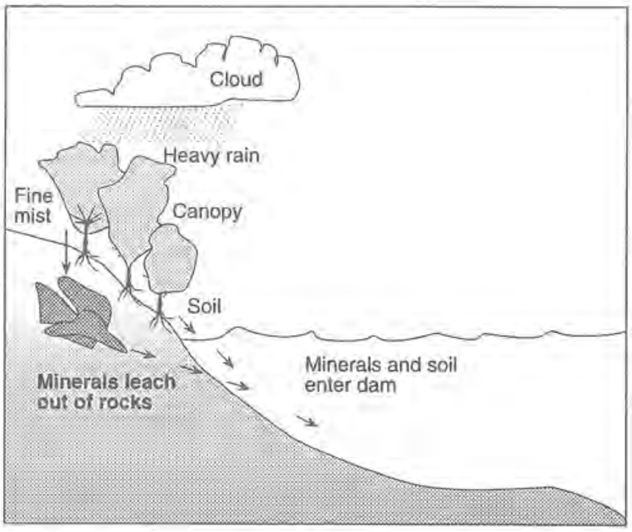


Fig 7 The canopy in the catchment area acts as a fine filter creating a mist. This fine mist percolates through the soil.

5. Floodplains that are cropped require strip cropping to reduce erosion problems. Well managed farm land which maintains a good ground cover of trees, grasses or crops helps to
   - minimise erosion
   - increase yields and farm income
   - maintain high quality farm water supplies
   - prevent silting of streams.

   The maintenance of trees in the upper catchment and efficient irrigation practices on well drained land ensures sustained use of land.
6. Stock should be kept away from the river and watered from farm dams or troughs to reduce stream bank erosion.
7. Treatment of industrial and domestic wastes ensures that discharges do not harm the environment.
8. The high quality of the water in the storage is maintained because the water has been "filtered" by the forested area. The water is clear and suitable for farm, domestic and industrial use.
9. Cut-away shows water being pumped from a groundwater aquifer. The water is used to supply the household and farm.
10. Trees maintained along stream banks help prevent stream bank erosion. Strips of trees provide wind breaks to prevent soil erosion, shade and shelter for livestock and wildlife and improve the appearance of the farm.
11. Sufficient water is kept flowing downstream to maintain a healthy river system below the dam.
12. Inlet tower allows the water to be drawn from different levels of the dam to ensure appropriate quality water is delivered to the treatment plant and downstream.
13. Bulk water meter.
14. Water treatment plants prepare water for piping to WaterWise City.
15. The treated water pump delivers water to WaterWise City.
16. Reservoir stores treated water.
17. Education in farm management.
18. The amount of water used for irrigation should be carefully monitored to ensure minimum losses in runoff and evaporation. The water that is left over after irrigation should be recycled and not allowed to flow directly into the river.
19. Spray irrigation.
20. Mini-sprinkler irrigation.
21. Furrow irrigation
22. Irrigation channel.
23. Travelling irrigator.
24. On-site treatment of domestic wastewater is undertaken using a septic tank installation.

Water storage

Rivers, creeks and bores are all sources of raw water. **Dams** and **weirs** are used to store raw water.

Dams (see Figure 8) also can collect water during heavy rain to prevent local flash flooding. The flood gates of some dams are designed to back up water to prevent flash flooding by controlling the volume of water flowing downstream. Every dam has a spillway to allow excess water to flow safely downstream.

Water from dams is drawn through an intake tower. As the water level in the dam falls, intake points in the tower allow water to be progressively drawn off (see Figure 15 on page 10).

Types of dam

Dam walls are usually made of concrete or earth fill.

Fig 8 Dam A - a earth fill dam and its catchment

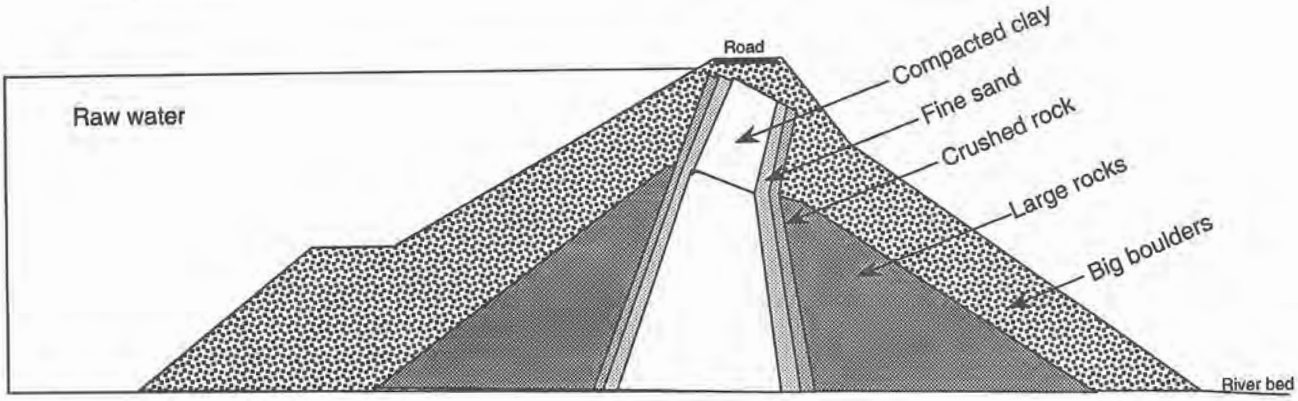


Fig 9 A cross section of an earth fill dam wall

Fig 10 Dam B - a mass concrete dam

The first type of dam wall in Dam A, shown in Figures 8 and 9, is earth fill. The dam wall has an impervious clay core with layers of sand, finely crushed rock, larger rocks and huge boulders as shown in Figure 9.

Dam wall B, shown in Figure 10, is a mass concrete dam. Water fills behind the dam wall and flows by gravity to a water treatment plant.

From this water treatment plant, the water flows to towns or cities via gravity mains to storage reservoirs.

The water storage environment

Dams create a special environment in which living and non-living factors interact.

Living (**biotic**) factors include types of algae, bacteria, water plants and fish and their population densities. Non-living (**abiotic**) factors include such things as temperature, water density, dissolved oxygen and nutrients (nitrates and phosphates) dissolved in the water.

Elements such as iron and manganese can also affect water quality. Water flowing into a dam carries with it particles of soil; a wide variety of organic materials such as leaves, wood and animal faeces; dissolved minerals such as iron and manganese which originate from the weathering of the catchment rocks; and nutrients such as nitrogen and phosphorus.

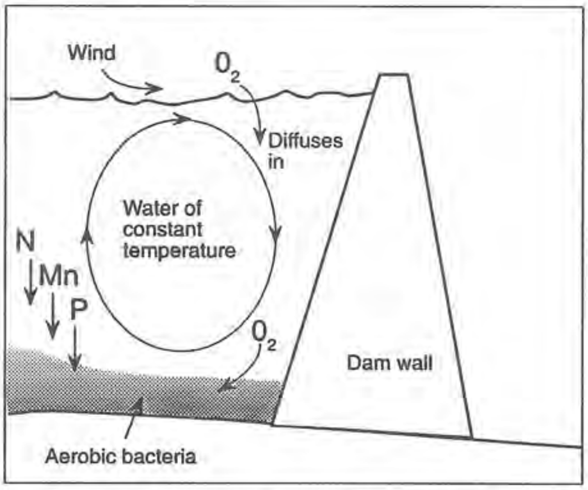


Fig 11 In winter, oxygen can get to the bottom of a dam.

Most of this material eventually ends up in the sediment at the bottom of the dam, however on its way to the sediment, it may be processed a number of times. Bits of it may serve as foodstuff for fish and animals that live in the water or in the sediment; other bits of it may provide nutrients for microscopic animals (zooplankton), microscopic algae (phytoplankton) and large plants (macrophytes), all of which, in turn, provide food for fish and animals that live in the water. Water quality technicians monitor water storages with special probes which collect data from various depths. Figure 14 over shows a probe and on-board computer collecting water quality data.

To illustrate some of these interactions, factors such as temperature and density, water chemistry in dams, and the operation of dams will now be discussed.

Water quality in water storages

Water density increases as temperature decreases and vice versa.

In winter, overnight air temperatures are often lower than the temperature of the water in a dam and the surface layer of water is chilled. The density of this water is increased slightly and it sinks to the bottom of the dam, setting up convection currents as it displaces the warmer, less dense bottom water. These convection currents are assisted by currents set up by wind action and as a result, the water in the dam mixes freely and temperature and density variations are minimal. This free movement of water carries oxygen-rich surface water down into the bottom of the storage as shown in Figure 11 and results in destratification of the dam.

In summer, the sun heats the water near the surface in a dam. Because the temperature of this water is raised, its density is lowered and the warm water will remain in a layer near the surface, floating on the cooler, more dense water below. As summer progresses, the difference in temperatures between the surface and bottom layers

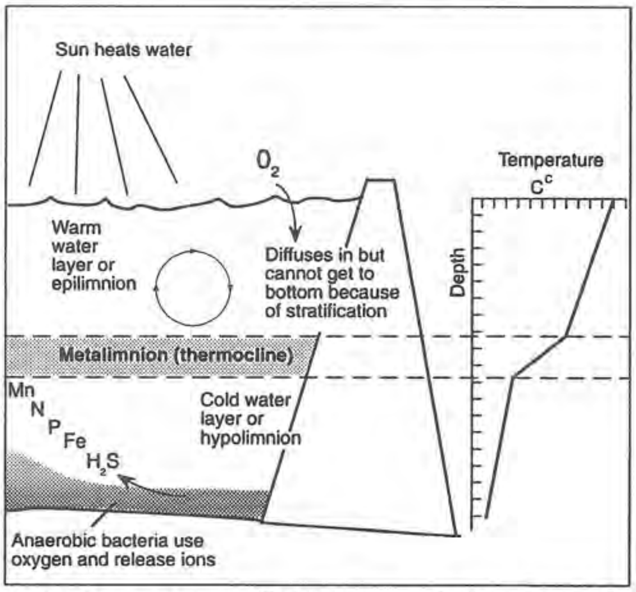


Fig 12 In summer, stratification occurs, blocking the supply of oxygen to the bottom water and changing the behaviour of the bacteria that live in the sediment.

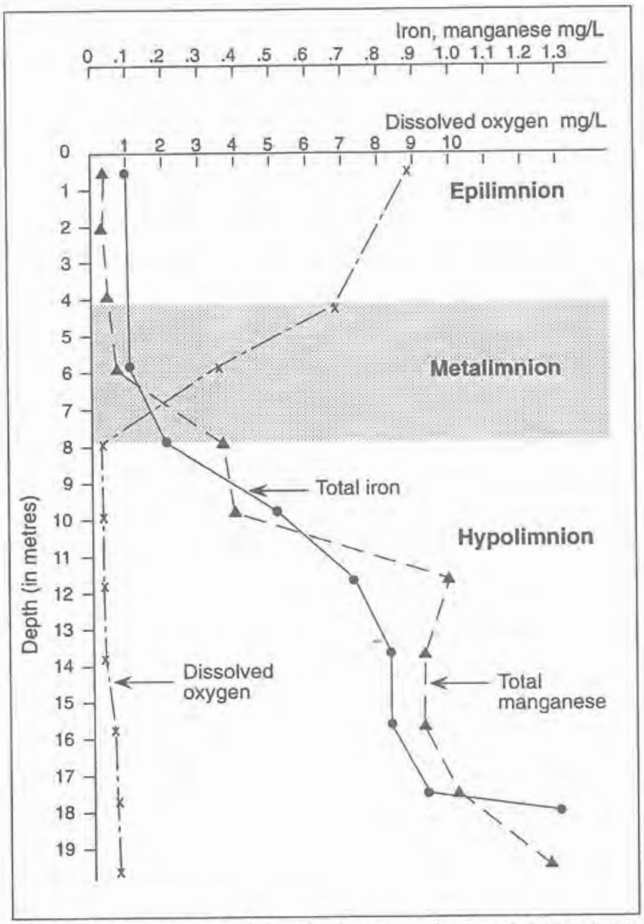


Fig 13 Typical profiles of dissolved oxygen, iron and manganese in a stratified dam.

become more pronounced and the water body is said to be stratified. A third, relatively thin intermediate layer is often found in stratified water between the upper and lower layers.

Temperature and density change rapidly in this intermediate layer. A change in water chemistry may also occur.

The three layers are shown in Figure 15 and are referred to as the **epilimnion**, the **metalimnion** and the **hypolimnion.** The metalimnion is sometimes referred to as the thermocline, because of the marked change in the gradient of water temperature with depth.

Fig 14 Water quality officers taking measurements of dissolved oxygen and temperature in a dam

Because the water in the epilimnion is less dense than that in the underlying layers, currents and water movements set up by the wind are confined to this surface layer of water. Oxygen diffuses into this layer but it cannot penetrate to the metalimnion or the hypolimnion because the differences in density create a barrier to mixing.

The water body goes through an annual cycle of natural stratification and destratification. A sudden large influx of water in wet weather may also cause destratification.

The **pH** of the water and the amount of **dissolved oxygen** present are fundamental factors which affect the organic and inorganic chemistry of the water in a dam and the growth of organisms. **Seasonal stratification** has a big effect on water chemistry because it affects water movement and the dispersion of oxygen.

During winter there is a plentiful supply of oxygen at all levels in the dam, and fresh oxygen is added continuously by diffusion and mixing. Such conditions favour plants and bacteria which require oxygen in the water and allow them to live at all levels including the water/sediment interface. These organisms break down the incoming organic materials in such a way that most nutrients pass into the sediment. Inorganic compounds

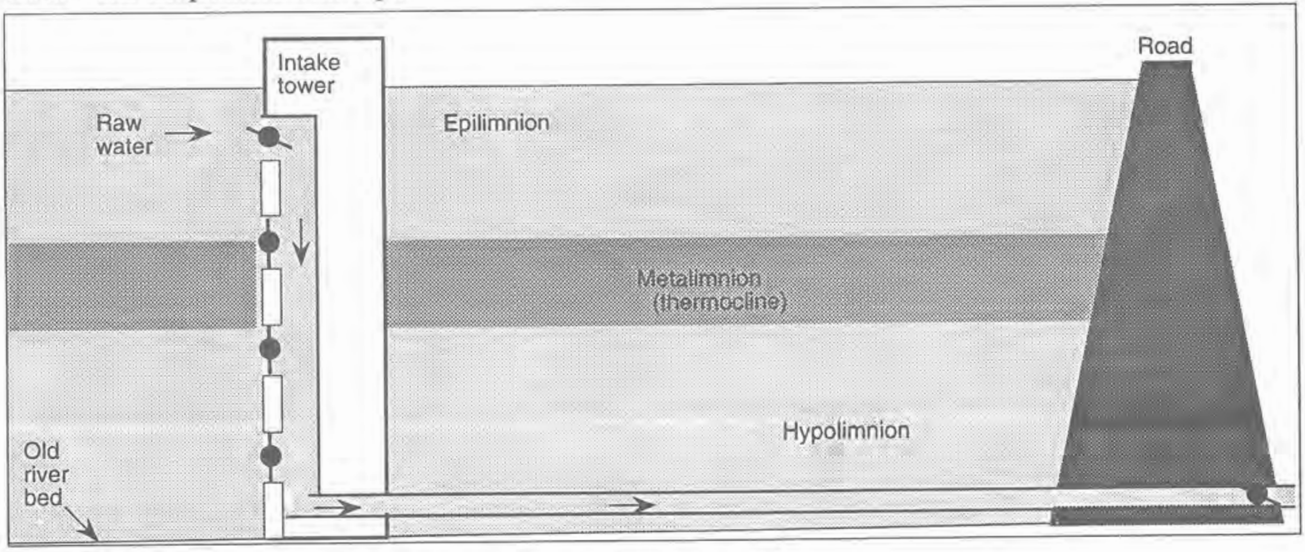


Fig 15 Water intakes at different levels allow the best water to be drawn off .

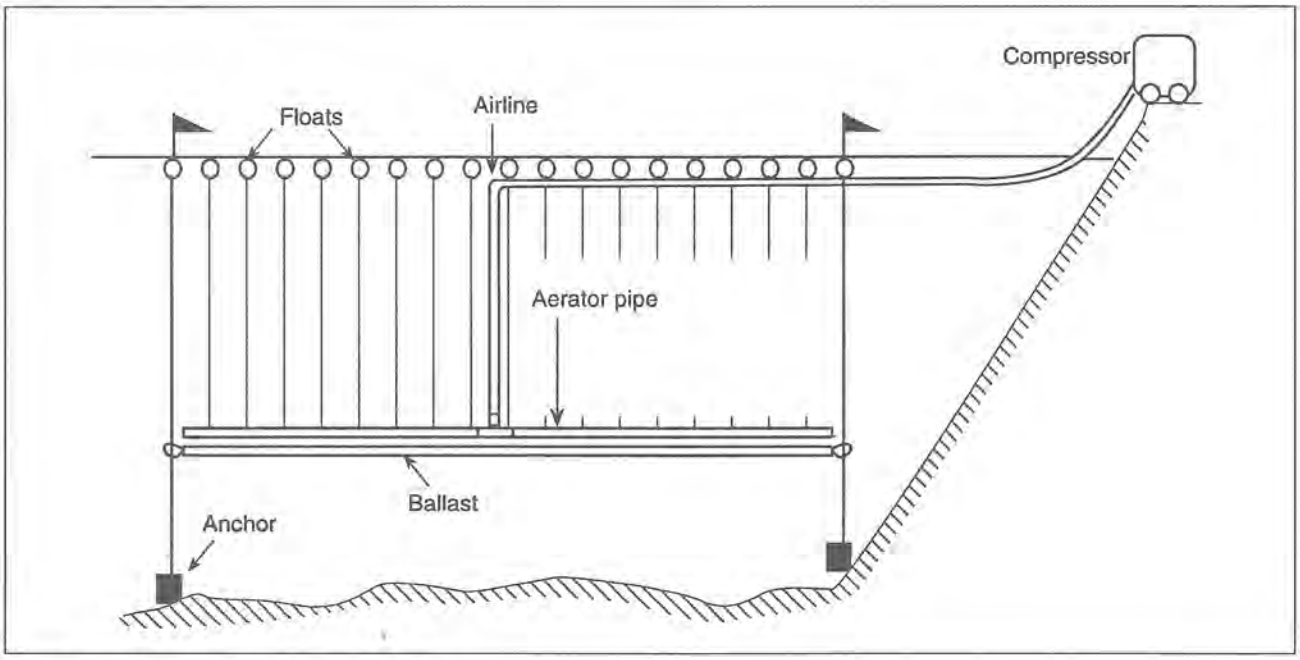


Fig 16 An Aeration/destratification system

washed in from the catchment (for example iron and manganese compounds) form insoluble substances which also settle into the sediment at the bottom of the dam (Figures 7 and 11).

During summer, stratification prevents mixing, so the transport of oxygen from the surface into the metalimnion and hypolimnion is stopped. Organisms, plants and bacteria which require oxygen in the water can only survive in the epilimnion where there is a plentiful supply. In the hypolimnion, the aerobic bacteria present when stratification begins rapidly use up the remaining dissolved oxygen.

The environment in the hypolimnion changes to favour anaerobic bacteria, that is, those species which do not require oxygen to survive. The decomposition of organic material by such bacteria releases ammonia, methane and **hydrogen sulfide**. Hydrogen sulfide (rotten egg gas) can sometimes be smelt when bottom water is released from dams during summer.

At the water/sediment interface, the lack of oxygen gives rise to an environment where compounds of iron, manganese and phosphorus in the sediments become soluble and pass into solution in the hypolimnion (Figure 15).

When destratification allows the compounds of nitrogen and phosphorus to move freely throughout the water body, they act as fertilisers and increase plant growth, particularly in the surface zone. Algae thrive on nitrogen and phosphorus and heavy crops (algal blooms) may develop.

In summer, if the water from the hypolimnion is drawn into town water supply systems through one of the lower level intake levels, as shown in Figure 15, iron and manganese compounds may cause severe dirty water problems. This can happen in water pipelines where chlorine is used for disinfection or in washing machines which use laundry detergents.

Algae, which occur mainly in the epilimnion, can also give rise to water quality problems. Many species are capable of imparting tastes and odours to water while certain species may contain toxins. Others may cause problems in water treatment by clogging filters or interfering with water treatment processes.

In order to avoid water quality problems, water supply engineers need to know what type of water they have to treat. The necessary information is obtained by monitoring water quality in the dam. Water samples for chemical analysis are collected from various depths in the dam and routine measurements are made of dissolved oxygen and temperature (see Figure 14). These are plotted to show patterns of stratification.

Typical profiles for temperature, dissolved oxygen, iron and manganese are shown in Figure 13. The rate of growth of crops of algae is also observed.

Water in the epilimnion of a stratified dam is usually of much higher quality than that in the hypolimnion. Dam managers try to draw water from this zone during periods of stratification, using the valves and inlets provided in the intake tower.

This strategy may not always be successful. If large crops of algae are present in the surface zone, it may be necessary to take water from lower levels or treat the algae with algicides.

If the layers of water containing iron and manganese cannot be avoided, the compounds must be converted to insoluble products at the treatment plant and then removed from the water before it is supplied to consumers.

Large **aeration systems** installed in dams can also be used to alleviate water quality problems by preventing stratification and the subsequent chemical and biological changes. (see Figure 16).

Algae and water

Algae are a group of simple plants, varying in size, shape and colour, found in healthy water bodies. Algae are found in all water systems and are a natural and necessary part of the aquatic ecosystem. Algal blooms are also a natural part of the cycles in nature occurring over a long period of time.

Algae are photosynthetic, that is, they are able to fix and utilise light energy from the sun for their metabolism. Microscopic algae (phytoplankton) are classified into two groups, true algae and blue-green algae (cyanobacteria), the latter being more closely related to bacteria than plants. The true algae of most significance in freshwater are the green algae, diatoms, dinoflagellates, chrysophytes and euglenoids. Some of these are shown in Figure 17.

When an algal population becomes dense it is said to **bloom.**

Which algal group is dominant at any time is determined by the nutrient status of the water and other factors such as water temperature, light intensity and pH.

Algae and water supply

Algae can cause a number of problems in water treatment processes (refer to chapter 2 for descriptions of these).

- Clogging of filters is most commonly caused by diatoms, which have hard silica shells.
- Interference with coagulation.
- Algal blooms increase the pH of water.
- Taste and odour problems. This one is the most noticeable to consumers. Blue-green algae, in particular the genera *Anabaena* and *Microcystis* (see Figures 18,19 and 21) produce two chemicals, which produce taste and odours characterised as earthy and musty at extremely low concentrations. Diatoms produce grassy and fishy tastes and odours.
- The increased organic content of the water resulting from algal activity demands more disinfection.

In untreated water supply systems, algal cells enter the distribution system and may result in increased complaints about dirty water, taste and odour problems and poor disinfection.

Production of toxins by some species of blue-green algae creates many problems. Toxins are released when algal cells die or are disrupted. Not all blooms are toxic and toxicity of blooms can change over time or with the age of the bloom.

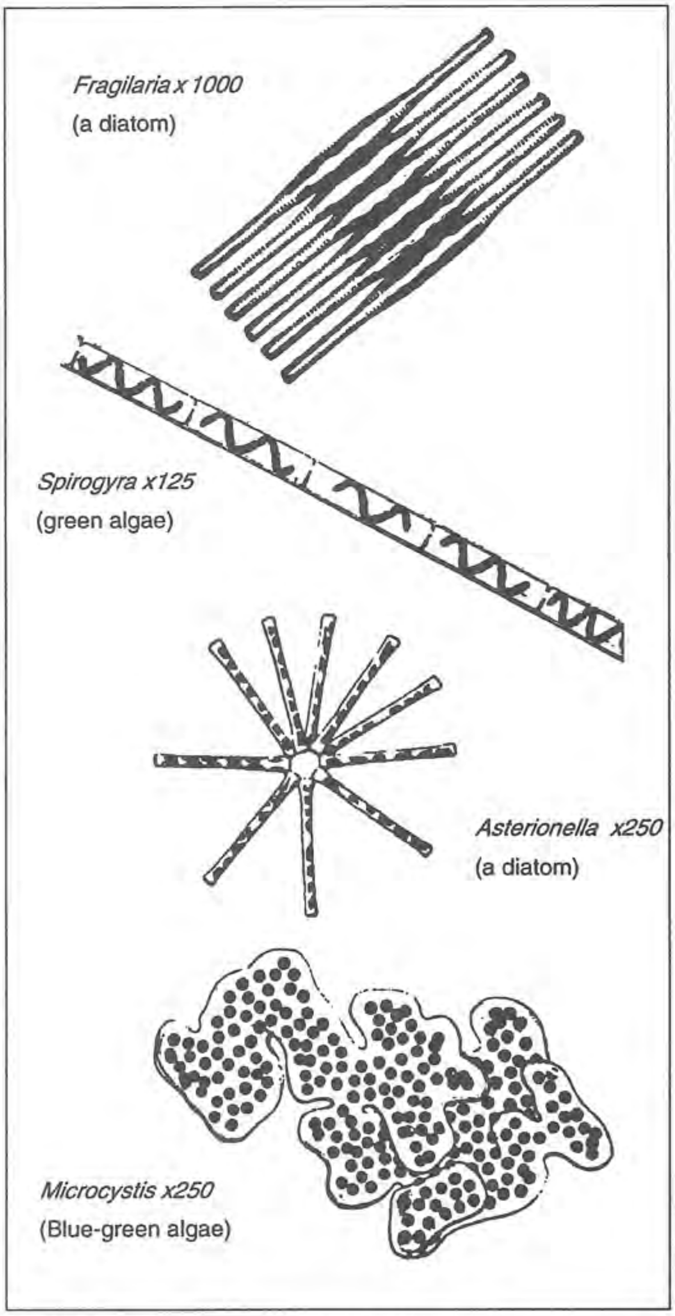


Fig 17 Algae affecting our drinking water

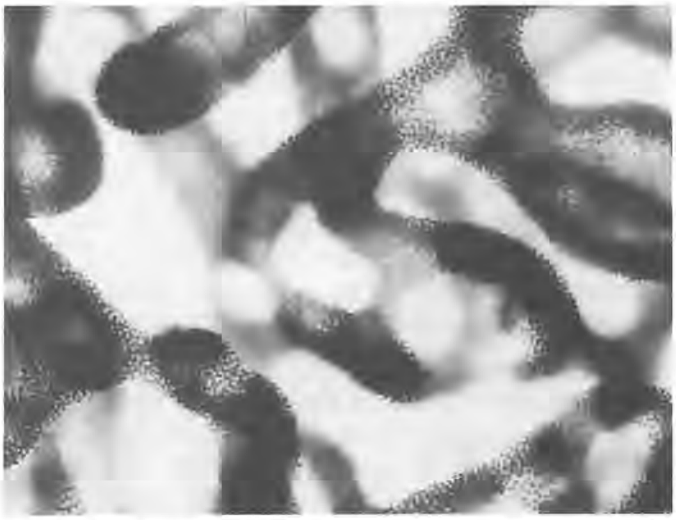


Fig 18 *Microcystis* x 200 (Blue-green algae) Photograph courtesy NSW Water Resources, Reproduced with permission.

Blue-green algae

Blue-green algae are closely related to bacteria because they lack a well-defined nucleus. However they share with all plants the common characteristic of chloroplasts (seen as small dots in the photograph (see Figure 20). These trap the sun's energy and together with nutrients and carbon dioxide, produce food for the plant. Unlike the plants in your garden, the plants in the algae group have no leaves, stem or roots.

Anabaena is just one of the numerous types of blue-green algae which link their cells together in chains. These algae can reproduce very quickly, the long chains becoming twisted as shown in Figure 19. Blue-green algae are found in streams and rivers and pose no threat to humans most of the time. They form part of the natural ecology and are eaten by larger organisms.

Algal blooms

Blue-green algal blooms occur in streams and rivers in some Australian states. Some waterways have had to be closed to swimming and recreation to protect users from possible internal infection.

Detergents, natural runoff of nutrients and sewage effluent may be responsible and there seems to be some relationship between the concentration of nitrogen to phosphorus in water and the expected possibility of an algal bloom.

Current research seems to indicate that a total nitrogen to total phosphorus ratio of less than 29:1 favours growth of blue-green algae.

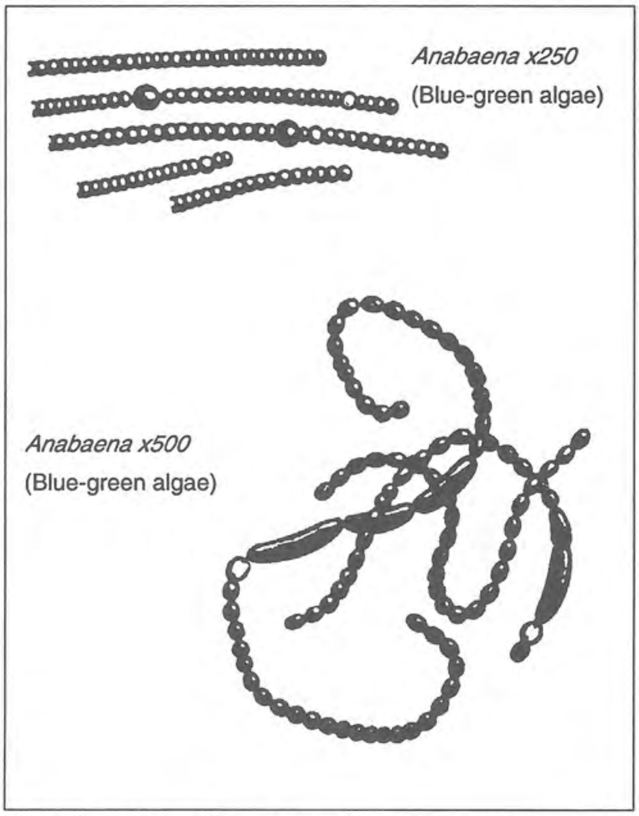


Fig 19 *Anabaena* (Blue-green algae)

Water treatment plant operators have to know what type of water they are going to have to treat. Aeration techniques (Figure 16) and variable depth off takes (Figure 15) are techniques for ensuring the best quality water is available from a dam.

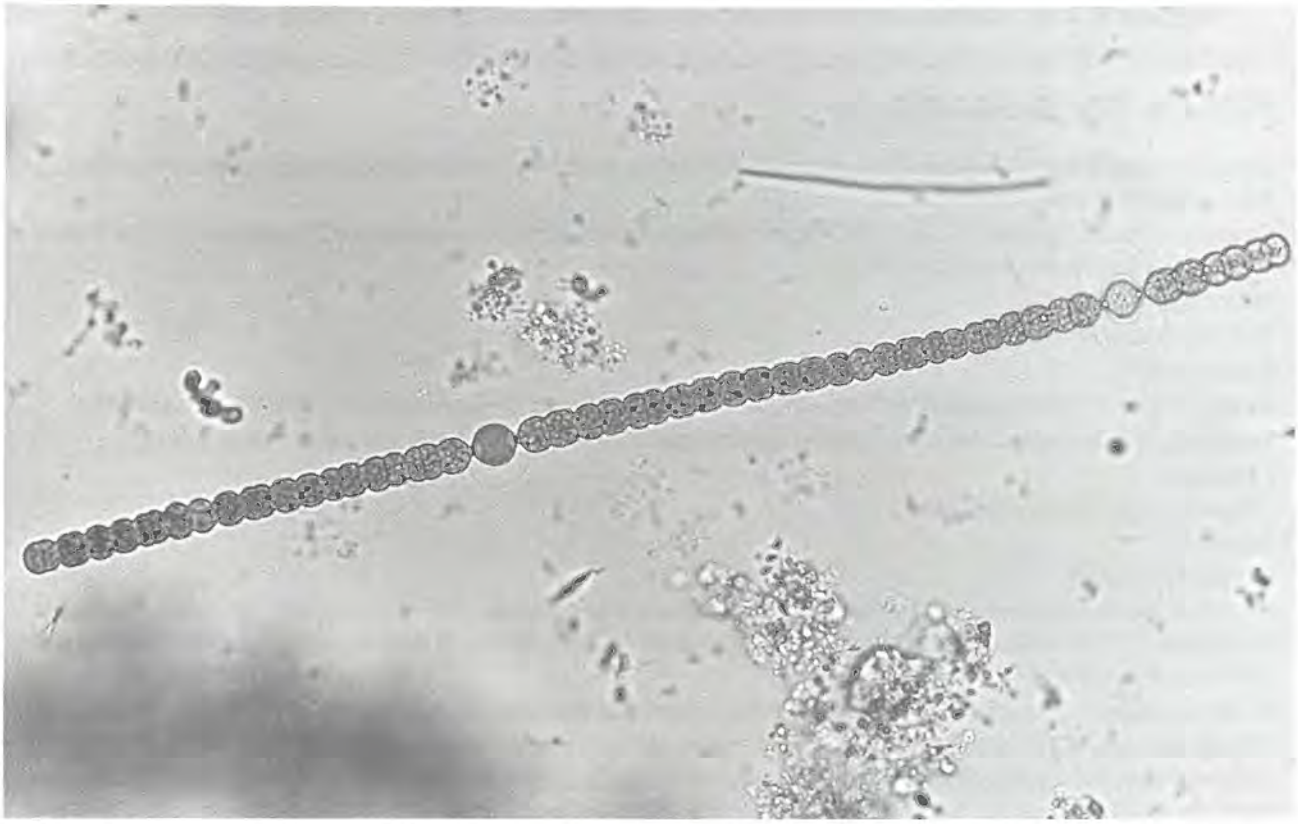


Fig 20 *Anabaena* x 400 (Blue-green algae) Photograph courtesy NSW Water Resources, Reproduced with permission.

Research

1. The water cycle, when interrupted by a dam, creates special problems in a catchment. What are some of these?
2. Catchment management above the dam is important to maintain good quality raw water treatment. Discuss the roles of trees, grasses and human activities.
3. Discuss the pros and cons of rainwater tanks as a supply for domestic water use.

Excursions

Teachers note: Three excursions are suggested within the scope of this book. A visit to a water storage area, such as a dam, and a water treatment plant could be done together. Visits to a wastewater treatment plant (see Chapter 3) and a house under construction could form part of a second excursion which fits more appropriately with Chapter 2)

The following questions or discussion points may be helpful in writing a short report on your visit to a water storage area involving a dam wall and treatment plant. If visiting a ground water situation, these questions will need to be modified.

1. What is the name of the river or creek that has been used for the source of raw water?
2. What materials are used in the dam wall to hold back the water?
3. How is the catchment area above the dam managed to minimise the amount of treatment necessary to bring the water to a safe drinking level?
4. How is water drawn off from the dam to the local water treatment plant? Is the plant at a higher or lower elevation?
5. Has a dam been constructed to store water, and if so, is the dam above or below the town or city it is feeding? What is the difference in elevation?
6. Has the dam area ever run dry or become dangerously close to running dry? How did people in the town or city react during this time and how did they attempt to conserve water?
7. Make a sketch of the storage area indicating the draw off point for the water.
8. Approximately how much did the dam cost to develop and what expenses are involved in maintaining it as a viable water source?
9. Are algae found in the dam? If so, what types and what problems might they create?
10. Are there any elements such as iron or manganese in the water that create problems for local water engineers? If so, what are some of the solutions they have put in place to improve water quality?

Notes for educators

Schools in New South Wales can become involved in the special environmental program run by the Water Board. For further information contact:

Streamwatch programme, PO Box A53, Sydney South, 2000. A video is also available and can be purchased through Corporate Communications Unit
Water Board
115-123 Bathurst St
Sydney 2000.

Rivers of Blue Project operates in Western Australia and schools can contact their local Regional Offices.

Landcare in Queensland operates a water quality education program and to keep up to date write to:
Landcare
Department of Primary Industries,
Meiers Rd
Indooroopilly 4068

Catchment care and landcare are two important issues that integrate with this chapter. In many catchment management programs, students trace a stream or river from its source to its entry to the sea and monitor the quality of water along its length.

In almost every case, parameters such as the volume of dissolved oxygen in the water, pH, temperature differences, aquatic life and nutrient levels are measured and related to catchment care practices. An original program from the United States influenced much thought in Australia. The reference for this is; Stapp and Mitchell, *Field Manual for Water Quality Monitoring,* 2050 Delaware Ave., Ann Arbor, Michigan, USA, 48103.

Activity 1. Water quality in the catchment

Note: It is important to identify a local issue in this activity and make links with other schools in the catchment. Trace the path of your local river from its source to its entry to the sea. Find out which schools are in the catchment and conduct some of the water quality tests in experiments 1 - 4 at different points in the river.

Teachers note: School trials have identified the following as a possible three- week program for a group of Year 11 Environmental Studies students.

1. An identification and mapping of a watershed and places on the coastal plain that are study sites that lead into the estuary of ocean basin. This could be done using aerial photographs and topographical maps. (Two lessons.)
2. Beginning the project where community members are involved in planning committees and workshops are conducted. Letters and telephone calls. (2 lessons.)
3. A bus trip where the entire study site is traversed and photographed while collecting initial samples. Discussion of water use in the catchment area. It is advisable to contact local authorities during the trip. (Half day.)
4. Discussion and practice in using test equipment. Discussion of the factors that affect the parameters to be tested. Allocation of groups to each test. Students work in the laboratory using either collected samples or tap water, in order to understand each test procedure. Seawater samples are analysed to determine dissolved salts. (2 lessons)
5. Allocation of groups. Collection of water samples from sites to be tested and analysis of water. Determination of water quality index as each group reports their findings. Completion of data tables.
6. Communication with other schools. Letter, visit or fascimile of results to other schools. Computer input to computer network.
7. Building skills to identify and define problems and their sources.
8. Action planning community involved to increase awareness of water quality in local area. Working with local water quality control officers and councillors. Planning action through school P and C if necessary.
9. Communicating with other students overseas and interstate.

Activity 2. WaterWise catchment

Aims

1. To discover some catchment management strategies and how these practices influence water quality.
2. To debate the effectiveness of these strategies.

Each group needs

- Two copies of the WateWise Catchment poster.
- Note pad and pen

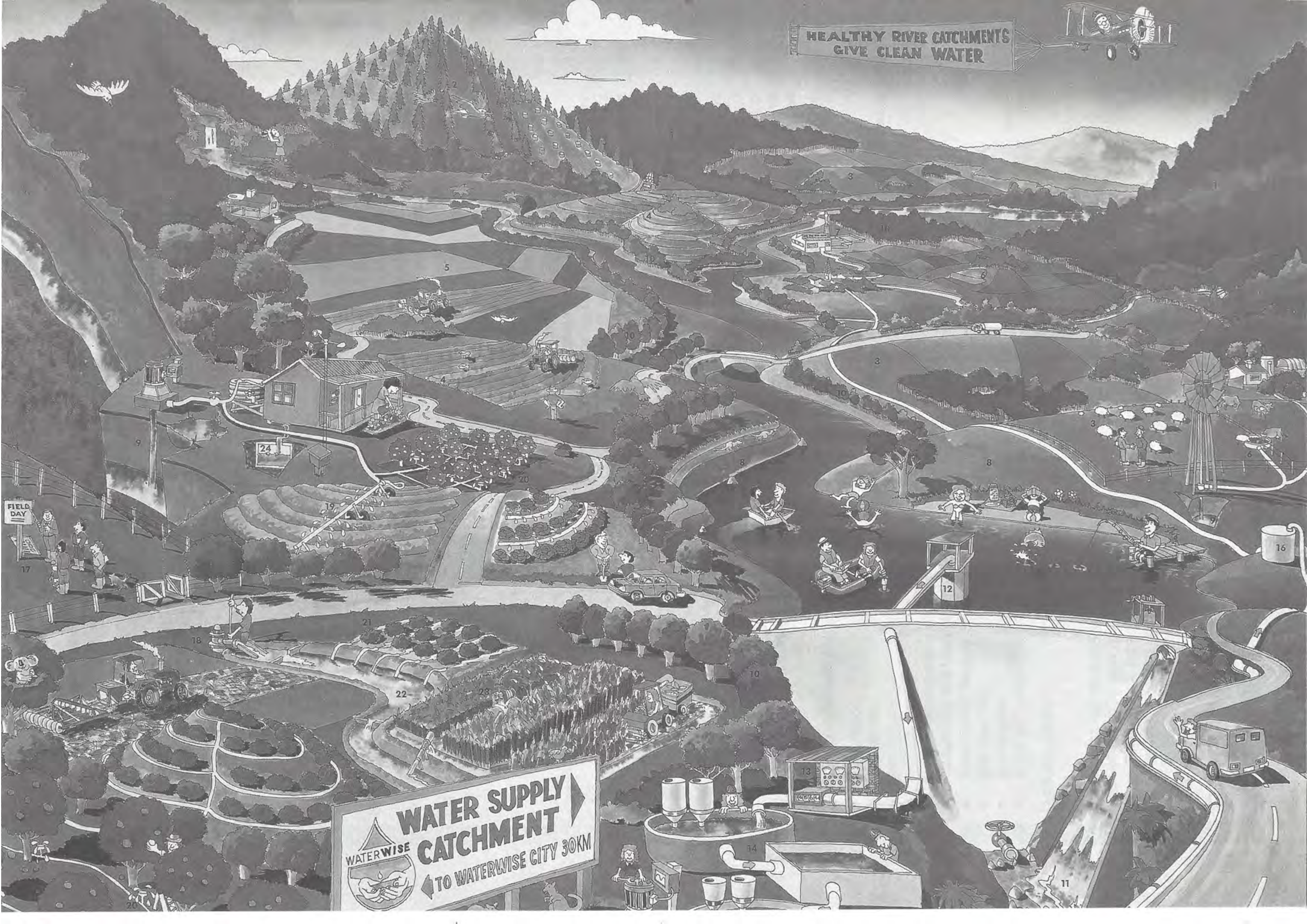
What to do

You will need a copy of the WaterWise catchment poster

1. Form groups of three to five people.
2. Groups work on the numbers in the poster as follows:
   - Numbers: 1-3 (Group 1)
   - Numbers: 4-6 (Group 2)
   - Numbers: 7-9 (Group 3)
   - Numbers: 10-12 (Group 4)
   - Numbers: 13-15 (Group 5)
   - Numbers: 16-18 (Group 6)
   - Numbers: 19-21 (Group 7)
   - Numbers: 22-24 (Group 8)
3. In your group, allocate each member a number from the poster and prepare a very short talk to include:
   - Where your number is located on the poster
   - What it is you are describing
   - How it works
   - One positive and one negative aspect of this aspect you are describing
4. When all the class has finished, each person gets to speak about the number allocated to them. When you speak make sure you cover the points mentioned in 3 above.
5. Use the additional questions over to assist you.

Additional questions for WaterWise catchment activity

1. Very steep areas should be left undisturbed to minimise soil erosion. In the poster these are shown as the dark green hills. What would happen if the trees were logged like those shown in 2 on the poster?
2. Steep hillsides can be used for forestry. This is shown in the second hill from the left. Notice how grass has been planted between the cut trees. Why?
3. Moderate slopes can be used to graze stock. Adequate ground cover should be maintained to prevent soil erosion. This is shown in three places. Can you find them all? If too many stock are grazed, what will be the effect on the nitrate/phosphate ratios in the waterways near these pastures?
4. Low sloping land is suitable for crops. Contour banking and stubble mulching are necessary to minimise soil erosion. Why have the trees been left around the bank? What do contour banks do?
5. Flood plains that are cropped require strip cropping to reduce erosion problems. Why is it important to grow summer and winter crops in alternate strips? What is a flood plain and what type of soil do you think this area will contain?
6. Stock should be kept away from the river and watered from farm dams or troughs to reduce stream bank erosion. What effect does this have on the catchment? Why is this good management practice?
7. Factories must ensure that harmful pollutants don't enter the river. What type of factory do you think would be built here? Refer to licence requirements page 46 and write down a list of possible substances that could affect the water quality in the dam.
8. How does vegetation around the dam filters out pollutants? What types of pollutants could there be? Kangaroos are seen in this area. What effect on animals would there be if the trees (shown on the land above them) were cut down? Predict also the effect on the soil in the field marked 4 above this area.
9. Cut-away shows water being pumped from a ground water aquifer for the household and farm. Describe how this aquifer works (refer back to page 5). Is any ground water used in your local area? If so, where?
10. Wildlife corridors. In how many places are these shown? Why are they necessary? Predict the effects on biodiversity if these areas were removed. Are there any corridors in your local area?
11. Sufficient water should be kept flowing downstream to maintain a healthy river system below the dam. What is the name of this structure and what is it made of? At the bottom of the dam wall is shown a purge valve. When the dam is full, this valve is opened to release water from the bottom of the dam. Why is this done?
12. Inlet towers allow the water to be drawn from different levels from the dam to ensure appropriate quality water is delivered to treatment plants and downstream. Describe how this could be done and list two problems the procedure may create. How can an aeration system be used in conjunction with an intake tower to improve the quality of water piped to the water treatment plant?
13. Bulk water meter. What environmental problems could this create? Why is it necessary? How does it work?
14. Water treatment plants prepare water for piping to town. Describe the five main processes as listed in the summary on page 26.
15. Treated water pump. Why is this pump necessary? Where does it pump water to? What environmental problems do you think it could create? What maintenance is necessary?
16. Reservoir stores treated water. Describe how water can enter this reservoir and why reservoirs are necessary.
17. Education in farm management. List five topics that would be discussed on the day.
18. This shows a gate valve. Where do you think the water is coming from? Why should the amount of water used for irrigation should be carefully monitored? What is 'tail water' and why should it be recycled and not allowed to flow directly into the river?
19. This shows spray irrigation. Where does water come from in this method? Describe two problems this method may create. What types of crops are grown using spray irrigation?
20. Fruit trees require a regular supply of water and a drip irrigation system is shown here. What is a drip system and how are the pipes connected? Will water flow out at the same rate as shown in 19? If the flow rate is different, how is this achieved by the farmer? Why is this system used instead of a spray system and what advantages does it have?
21. Furrow irrigation. How is water delivered to the plants? Name one advantage and one disadvantage of this method.
22. Irrigation channels. Name one advantage and one disadvantage of this method. Where does the tail water accumulate?
23. Shows a travelling irrigator. How does this work and what types of crops would require water to be delivered using this method?
24. Septic tank. Why is this necessary? How is it different from the removal of waste in a city?


HEALTHY RIVER CATCHMENTS
GIVE CLEAN WATER
WATER SUPPLY
CATCHMENT
TO WATERWISE CITY 30KM
WATERWISE
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Experiment 1 The water cycle

As the water evaporates from the ocean, it separates itself from pollutants, salts and other debris collected from its passage over the land. This experiment investigates this evaporation and separation process.

You will need

- a 250 mL beaker
- 6 test tubes
- test tube rack
- silver nitrate solution
- crushed ice and hand towel
- bunsen burner, tripod stand and gauze mat
- distilled water
- salt
- stirring rod
- table spoon

Part A Comparing salt and fresh water

What to do

Step 1. Make up a saltwater solution by adding 6 g of salt to 200 mL of distilled water in a 250mL beaker and dissolving with a stirring rod.

Step 2. Fill three test tubes with small amounts of distilled water, tap water and the made-up saltwater as shown in Figure 21 and place these in the test tube rack as shown.

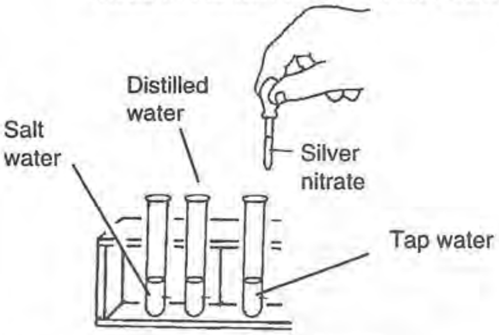


Fig 21 Establishing a test for salinity

Step 3. Now add three drops of silver nitrate solution to each.

Step 4. Look carefully at the bottom of each tube and describe what you see in each.

Step 5. Write up the results you've observed and describe a test for salt in water.

Part B The water cycle

What to do

Step 1. Pour a small amount of saltwater (about the size of your finger nail) into the bottom of a test tube and place it in the test tube rack.

Step 2. Now set up a bunsen burner, gauze mat and tripod stand and saltwater solution you made in the 250 mL beaker in Step 1 in Part A (see Figure 22).

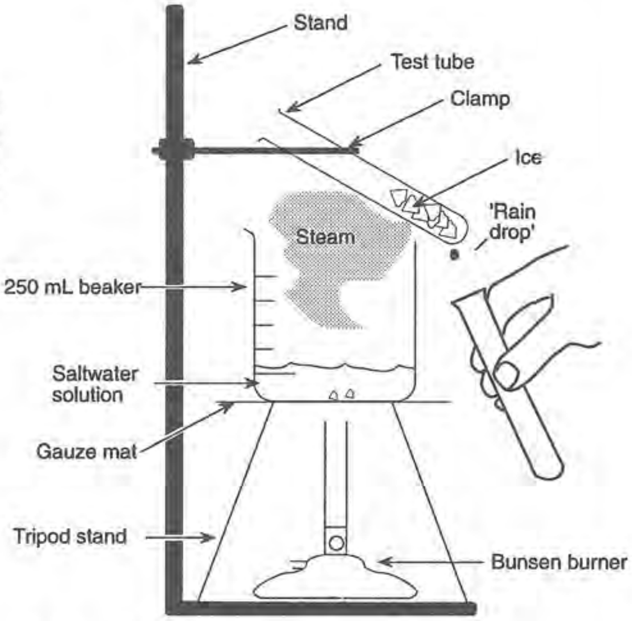


Fig 22 Experimental setup

Step 3. Light the bunsen burner. While you are waiting, for the solution to boil crush some ice and fill a test tube. Keep the tube cold and wrapped in the towel.

Step 4. When the solution is boiling, take the test tube containing the ice and hold it over the steam.

Step 5. Record what you see happening. Look carefully at the bottom of the test tube.

Step 6. Now position the test tube in the steam over the boiling saltwater again and have your partner tell you when a drop is about to fall. Your partner should have a test tube ready. Let us call these drops "rain".

Step 7. Carefully move the test tube containing ice over another test tube and collect the drop of "rain".

Step 8. Repeat collecting the drop of "rain" until you have collected the same amount of rain water as you tested in Part A. Be careful not to collect any boiling saltwater. You may need some practice at collecting your 'rainwater'.

Step 9. Now place the test tube containing your rainwater beside the test tube containing the original saltwater. Test the rainwater for salt and draw up a data table summarising your results.

Discussion

1. Did any of the salt evaporate with the water?
2. What would happen if all the pollution we poured out into our oceans ended up in the clouds?
3. Comment on the statement, 'Water is used over and over again, so that when we shower, we are really washing in old sewage'.

Experiment 2 Investigating micro-organisms

The aim of this experiment is to investigate micro-organisms in a water sample.

You will need

- a stocking
- wire coat hanger
- small bottle
- broomstick
- test tube
- needle and thread
- hand lens or microscope

What to do

Step 1. Using the above materials make the swish net shown in Figure 24. Bend the coat hanger into a circle and sew on the stocking around the wire. Insert the small bottle into the end of the stocking and add the broom handle last.

Step 2. Collect a sample of water and examine the micro-organisms in the sample under a microscope or hand lens (see Figure 23).

Step 3. Report on what you see under the microscope.

Fig 23 A hand lens and test tube can be used to examine small animals and plants caught with the swish net from Figure 25.

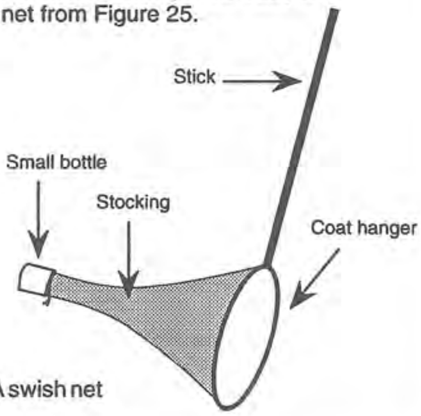


Fig 24 A swish net

Experiment 3 Dissolved O_2

Note: You may also use a meter to obtain similar results

The major gas dissolved in natural surface water is oxygen. In groundwater this is often replaced by carbon dioxide. Groundwater may also contain hydrogen sulphide. How well these gases dissolve in sea water depends on three factors:

- pressure as caused by depth. Oxygen concentration varies with depth and in surface waters it is related to water temperature. As water temperature increases, solubility of oxygen decreases (see Figure 26). Other ways oxygen can vary in water are given below.
- The accumulation of organic waste. The term **organic** means anything that contains the element carbon. Our living planet is based on this element. Plants, animals, bacteria and the wastes they produce all contain carbon. So any materials that contain carbon are called organic. Sewage is one form of organic waste.
- Discharges from food processing plants, meat packing works and dairies will contain organic materials.
- Leaves, twigs and dead plants can also contribute organic material. If the natural removal of these is inhibited by changes to natural river patterns like weirs or canals, they can accumulate and reduce water quality.
- Places where the current is slow and wave action is reduced are places for low DO levels. Surf beaches with high currents would be places for high DO levels. Clear surface waters will have a high DO whereas deeper muddy waters will have a low DO. You may like to predict other places for high and low DO.

Fig 25 Dissolved oxygen kit

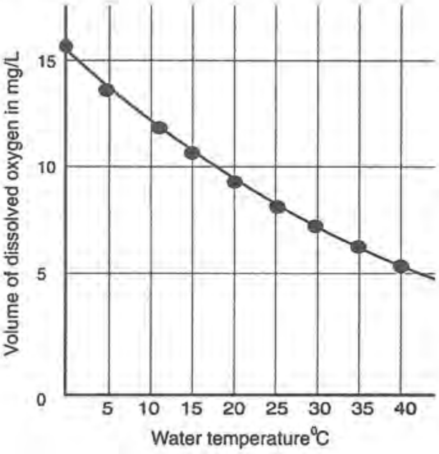


Fig 26 As temperature increases, dissolved oxygen decreases

As mentioned earlier, the temperature of the water determines the solubility of the dissolved oxygen and % saturation levels. A graph (see Figure 27) must be used to change the figures of mg/L of dissolved oxygen into a % saturation level.

After you calculate your concentration (mg/L) of dissolved oxygen, you measure the temperature of the water sample and then draw a straight line connecting the two. You can now read the % saturation from the point where the line crosses as shown in Figure 28.

The kit described below is the HACH Dissolved Oxygen Kit. Alternatively a meter can be used. (Note: HACH is a brand name, see Figure 25).

This is the DO test described in the HACH kit. If you are using another kit or titration, use the instructions in it.

Safety warning

In addition to these instructions, you are to wear goggles for the rest of the exercise.

Step 1. Fill the Dissolved Oxygen bottle (round bottle with glass stopper) with the water to be tested by allowing the water to overflow the bottle for two or three minutes. (If you have sampled from depth, bring your water sample to shore and siphon off the water sample so that no air bubbles can enter the bottle. Allow the water to run out of the bottle for 30 seconds). To avoid trapping air bubbles in the bottle, incline the bottle slightly and insert the stopper with a quick thrust. This will force air bubbles out. If bubbles become trapped in the bottle in steps 2 or 4, the sample should be discarded before repeating the test.

Step 2. Use the clippers to open one *Dissolved Oxygen 1 Reagent Powder Pillow* and one *Dissolved Oxygen 2 Reagent Powder Pillow.* Add the contents of each of the pillows to the bottle. Stopper the bottle carefully to exclude air bubbles.

Grip the bottle and stopper firmly; shake vigorously to mix. A flocculant (floc) precipitate will be formed. If oxygen is present in the sample, the precipitate will be brownish orange in colour. A small amount of powdered reagent may remain stuck to the bottom of the bottle. This will not affect the test results.

Step 3. Allow the sample to stand until the floc has settled halfway in the bottle, leaving the upper half of the sample clear. Shake the bottle again. Again let it stand until the upper half of the sample is clear. **Note the floc will not settle in samples with high concentrations of chloride, such as sea water.** No interference with the test results will occur as long as the sample is allowed to stand for 4 or 5 minutes.

Step 4. Use the clippers to open one *Dissolved Oxygen 3 Reagent Powder Pillow.* Remove the stopper from the bottle and add the contents of the pillow. Carefully re-stopper the bottle and shake to mix. The floc will dissolve and a yellow colour will develop if oxygen is present.

Step 5. Fill the plastic measuring tube level full of the sample prepared in steps 1 through to 4. Pour the sample into the square mixing bottle.

Step 6. Add Sodium Thiosulphate Standard Solution drop by drop to the mixing bottle, swirling to

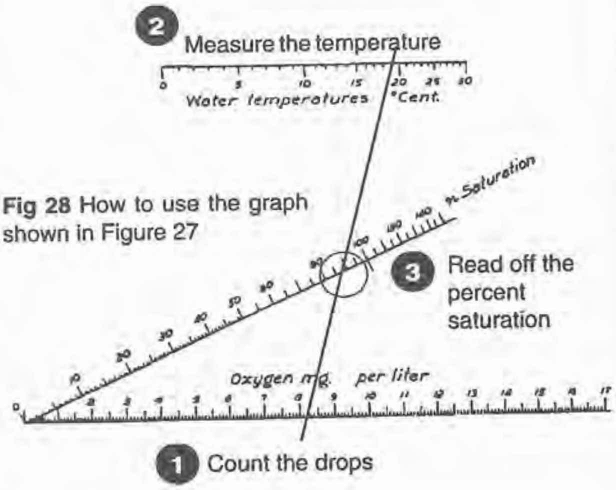


Fig 28 How to use the graph shown in Figure 27

> Mitchell and Stapp 1988 says that 'Rivers with a constant 90 per cent dissolved oxygen saturation value or above are considered healthy. Rivers below 90 per cent saturation may have large amounts of oxygen-demanding materials (organic wastes)'.

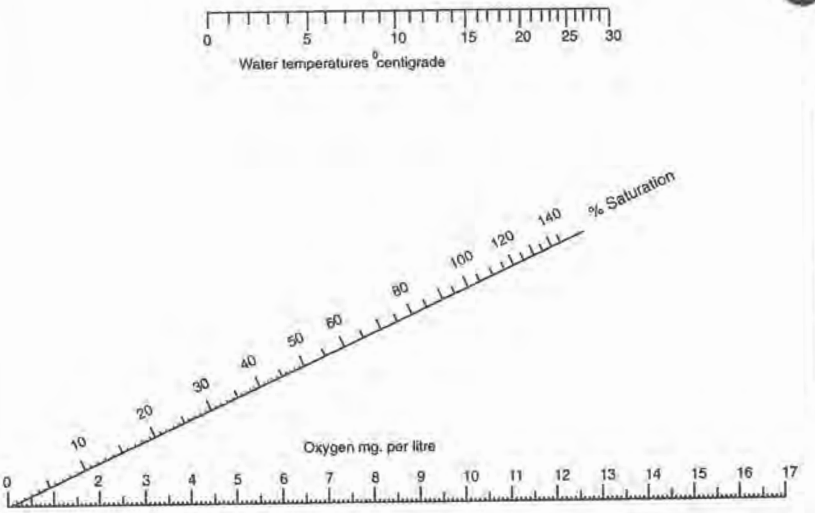


Fig 27 How to calculate % saturation. Water temperature = 20° C. Dissolved oxygen 6 mg/L% saturation = 65%. (From Mitchell and Stapp 1988. Reproduced with permission.)

mix after each drop. Hold the dropper vertically above the bottle and count each drop as it is added. Continue to add drops until the sample changes from yellow to colourless.

Step 7. Each drop used to bring about the colour change in step 6 is equal to 1 mg/L of dissolved oxygen (DO).

The following steps are now to be followed regardless of which kit or titration you used

Per cent saturation

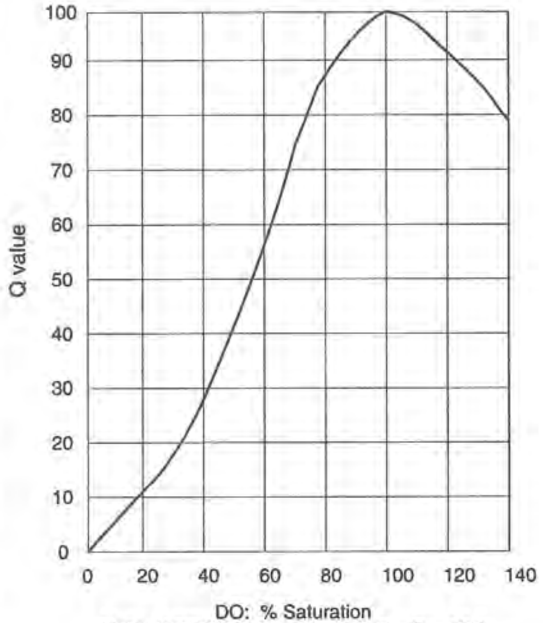
To determine the quality of this result you must determine % saturation. The saturation level is determined by the temperature.

Step 8. When you have established the DO concentration in m/L, measure the water temperature and use the 'level of saturation' chart in Figure 27 determine the per cent saturation of dissolved oxygen. (See Figure 28 for how to use the graph and the temperature scale. If you look back to Figure 26, you can see how the amount of dissolved oxygen varies with temperature)

Step 9. Now use the chart in Figure 28 to determine the Q value. Note: The Q value is used by Mitchell and Stapp to indicate natural water quality is on a 1:100 scale.

Dissolved oxygen (DO) test results

After Mitchell and Stapp (1988) Page 66. Reproduced with permission.



Note: If DO % Saturation > 140.0, Q = 50.0

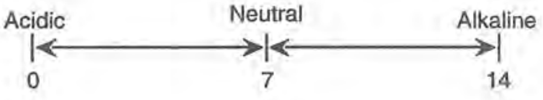
Fig 28 Use this graph for step 9 to determine the Q value

Experiment 4 pH of a water sample

The water molecule (H_2O) can divide to form two charged particles called ions. One is called a hydrogen ion (H^+), the other a hydroxyl ion (OH^-). This can be summarised:

$H_2O \longrightarrow H^+ + OH^-$

pH is a measure of the concentration of hydrogen ions (H^+) in water measured on a 0 to 14 scale. As the pH value decreases, the hydrogen ion concentration increases.



Natural waters will have a pH of about 7 but can vary due to local conditions. At extremes of pH ranges, organism diversity decreases. Ranges of 5 and below have been recorded in many places overseas which affects the larval stages of fish and other small invertebrates. pH can be measured with pH paper or a meter and can be used to determine water quality.

This experiment looks at how to determine the pH of a water sample.

You will need

- pH paper or a pH meter
- water sample
- colour comparator (if using paper)

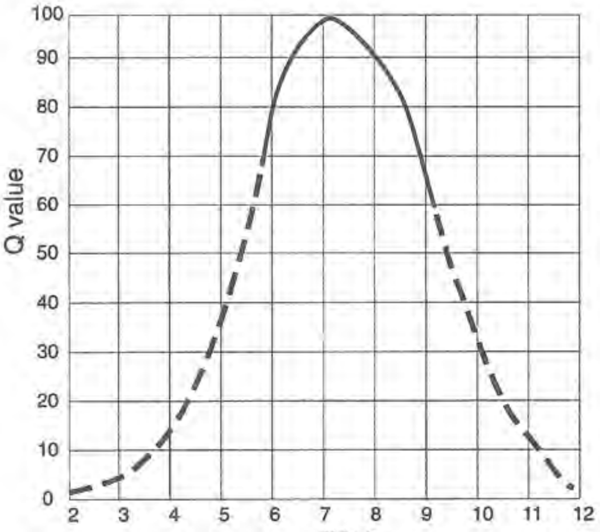
What to do

Step 1. Dip the probe or paper into the water sample.

Step 2. If using paper, allow 30 seconds for colour to develop and compare the colour on the paper with the colour on the sample card to determine the pH of the water sample. If a probe is used, a buffer solution and some calibration may be necessary to determine the pH (follow the manufacturer's directions).

pH test results

Adapted from Mitchell and Stapp (1988) Page 66. Reproduced with permission.



Note: If pH<2.0, Q = 0.0; if pH >12.0, Q = 0.0

Fig 29 Q value determination of pH (the dotted line indicates you should check natural pH with your local authority)

Meters

A variety of electronic meters are available on the market today. These meters can measure a wide range of environmental variables including:

- dissolved oxygen
- pH
- temperature
- salinity
- turbidity
- heavy metals

Some meters, such as those shown in Figure 30, can log data from a stream over time. After the logging period the meter and probes can then be returned to the lab where the data they have collected can be fed into a computer.

Fig 30 A field-lab analyser for conductivity, salinity, pH, temperature, dissolved oxygen. Illustration courtesy TPS Pty. Ltd. (Reproduced with permission)

This data can then be graphed or analysed to see changes over time. Some supply companies are renting these probes to schools to ensure maximum performance and the teachers guide can be consulted to obtain up-to-date information on hire fees and supply company addresses.

Fig 31 A dissolved oxygen meter. Illustration courtesy TPS Pty. Ltd. (Reproduced with permission)

Revision questions

1. How important is the management of a catchment in the collection of high quality domestic drinking water?
2. What is a catchment?
3. Why are trees in the dam catchment important in preventing soil erosion?
4. Discuss your local water cycle and how dams have been used in your local area to interrupt this cycle.
5. How do trees in the catchment area filter rain and contribute materials to dams? What problems does this present for catchment managers?
6. Draw the structure of your local dam.
7. Discuss three water quality problems associated with damming water.
8. Why is water chlorinated and what alternatives exist for disinfection?
9. How are nitrogen and phosphorous levels monitored and how does the N/P ratio affect algae populations? What ratio of total nitrogen to total phosphorous is necessary for a blue-green algal bloom? How does this occur?
10. How is water trapped in an aquifer?
11. With the aid of a diagram, explain how water can be obtained from an aquifer.
12. What is raw water?
13. List any six features of catchment management.
14. Why are wildlife corridors necessary?
15. What is a gate valve and how should it be used to manage catchment water?
16. How does vegetation filter out pollutants around a dam?
17. Name two types of dam wall
18. What is stratification and how does it occur?
19. The thermocline is poorly named. What should its correct term be?
20. With the aid of diagrams, illustrate the difference between a summer and winter dam.
21. Why doesn't an earth fill dam leak?
22. How does oxygen get down to the bottom of the dam in winter?
23. Draw a diagram of a aeration/destratification system and describe how it works.
24. Draw any two types of algae and any two diatoms.
25. Describe a simple test for determining the mg/L of oxygen dissolved in water. How is this converted to % saturation and why is temperature an important factor?

Chapter 2

Water treatment and use

Why do we treat water?

The provision of a safe, reliable and affordable water supply is an essential element in community health and well-being.

Raw water from a dam as shown in Figure 1 requires some form of treatment because it contains such things as:

- dissolved organic material
- algae, bacteria and viruses
- vegetation, tree roots and branches
- chemicals such as manganese and iron leached out from rocks and soil.

Treated water is provided to consumers for a number of reasons, but principally to:

- provide a good quality linking water
- reduce the risk of outbreaks of dangerous diseases
- prevent exposure to organisms and chemicals harmful to health
- provide a water supply that is free from objectionable tastes and odours
- ensure that the water supply does not contribute to corrosion of reticulation or household pipework and fittings
- prevent problems with staining of laundry and fixtures such as baths and basins
- establish levels of service that avoid consumers' complaints about water quality, at a price they can comfortably afford

Water treatment is central to this provision of a safe, reliable and affordable water supply. But that's not all there is to the story. Integrated catchment management, storage management and reticulation management each has a part to play, as does consumer education , in issues such as water conservation and the prevention of recontamination of the water supply through backflow and cross-connections.

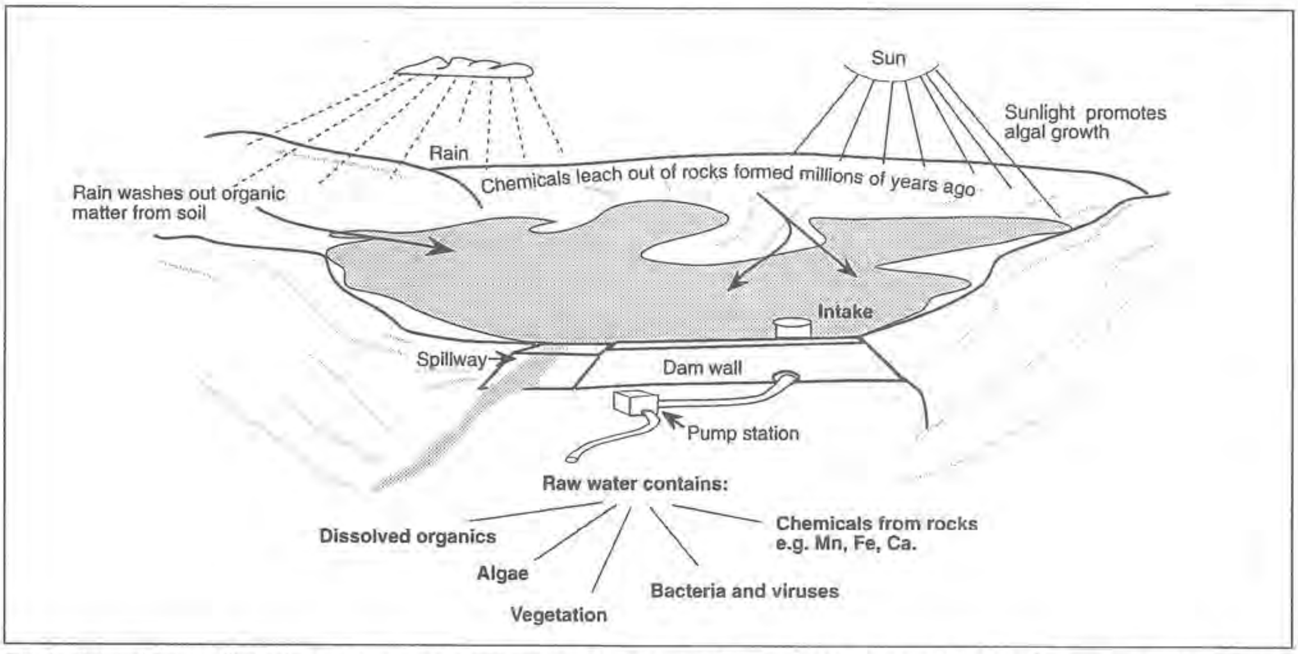


Fig 1 Natural forces like rain and sun create raw water with many problems when dams are built in natural catchment areas

Knowing the catchment and storage characteristics of an area can lead to strategies for managing the storage to improve raw water quality.

Water may leave a treatment plant in an excellent condition but it must then be managed in such a way as to ensure that both chemical and bacteriological quality is maintained through hundreds of kilometres of pipes.

Water treatment plants

Good drinking water is safe to drink, looks crystal clear, smells and tastes just great. Good washing water means that the detergents we use lather well so that our washing machines can remove the dirt that accumulates in the fibres of our clothes.

So that we can have safe drinking water, the raw water from dams is pumped or fed by gravity to a water treatment plant. From here water is fed to reservoirs located at different heights above sea level, and then to homes. Figure 2 shows a schematic diagram of a water supply scheme.

Raw water

If you take a jar, fill it with dirt and water, give it a good shake and let it stand, over time the bigger particles fall to the bottom and clear water forms on the surface. However, it takes some days for the finer particles to settle out. Suppose however, you could make these finer particles stick to the bigger particles. This would mean that as the bigger particles fell to the bottom of the jar, they would take the smaller ones with them. This process can also be hastened by the addition of materials that attract solid particles.

Raw water collected from a catchment or storage area can look a lot like the jar filled with water and dirt:

Colour and turbidity are two of the features that have to be considered when treating water.

- Colour is caused by colloids and organic materials (such as humic acid and tannins), as well as compounds of iron and manganese. The "tea" coloured waters of a swampy coastal areas is due to the presence of colour in the water.
- Turbidity is caused by clays, suspended solids and particulate matter (such as micro-organisms, decaying organic material, ova, cysts, algal cells and silt and sand).

In some treatment plants, if the raw water is of high enough quality, all treatment except disinfection can be bypassed and the water flows straight to homes.

Inlet structure

To remove organic matter and leached chemicals, oxygen, alum and polyelectrolyte are added to reduce colour and turbidity levels.

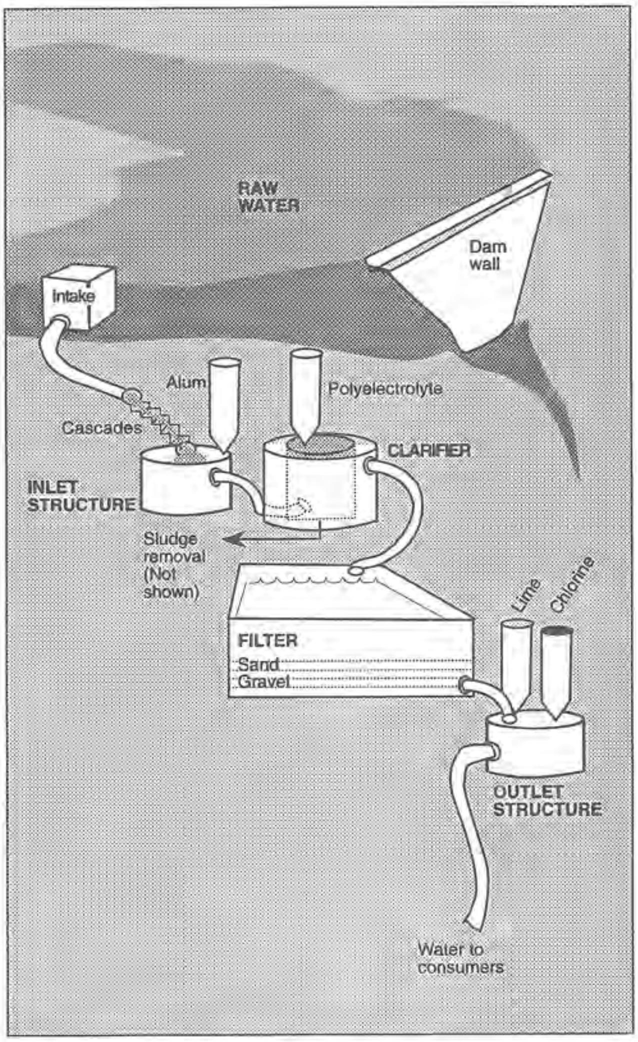


Fig 2 Schematic diagram of a water supply scheme

Oxygen

The addition of oxygen is achieved by allowing water to run through concrete channels or fall over waterfalls creating a cascade effect, known as aeration and as shown in Figure 2. Oxygen simply enters from the atmosphere and helps improve the taste of the water, removes carbon dioxide and hydrogen sulphide, and assists in the removal of iron and manganese. Activated carbon can also be used to remove compounds which give water an unpleasant taste.

Colour and turbidity

To remove both colour and turbidity, two processes called **coagulation** and **flocculation** are used in most treatment plants.

- **Coagulation** involves the addition of a coagulant, usually alum or iron salts which have a positive charge. This charge destabilises the negative charge on the colloids so that they can clump together to form small flocs. The process requires rapid mixing to achieve close contact between the coagulant and the colloids.
- **Flocculation** involves the slow stirring and mixing of the coagulated water to enable the coagulated particles

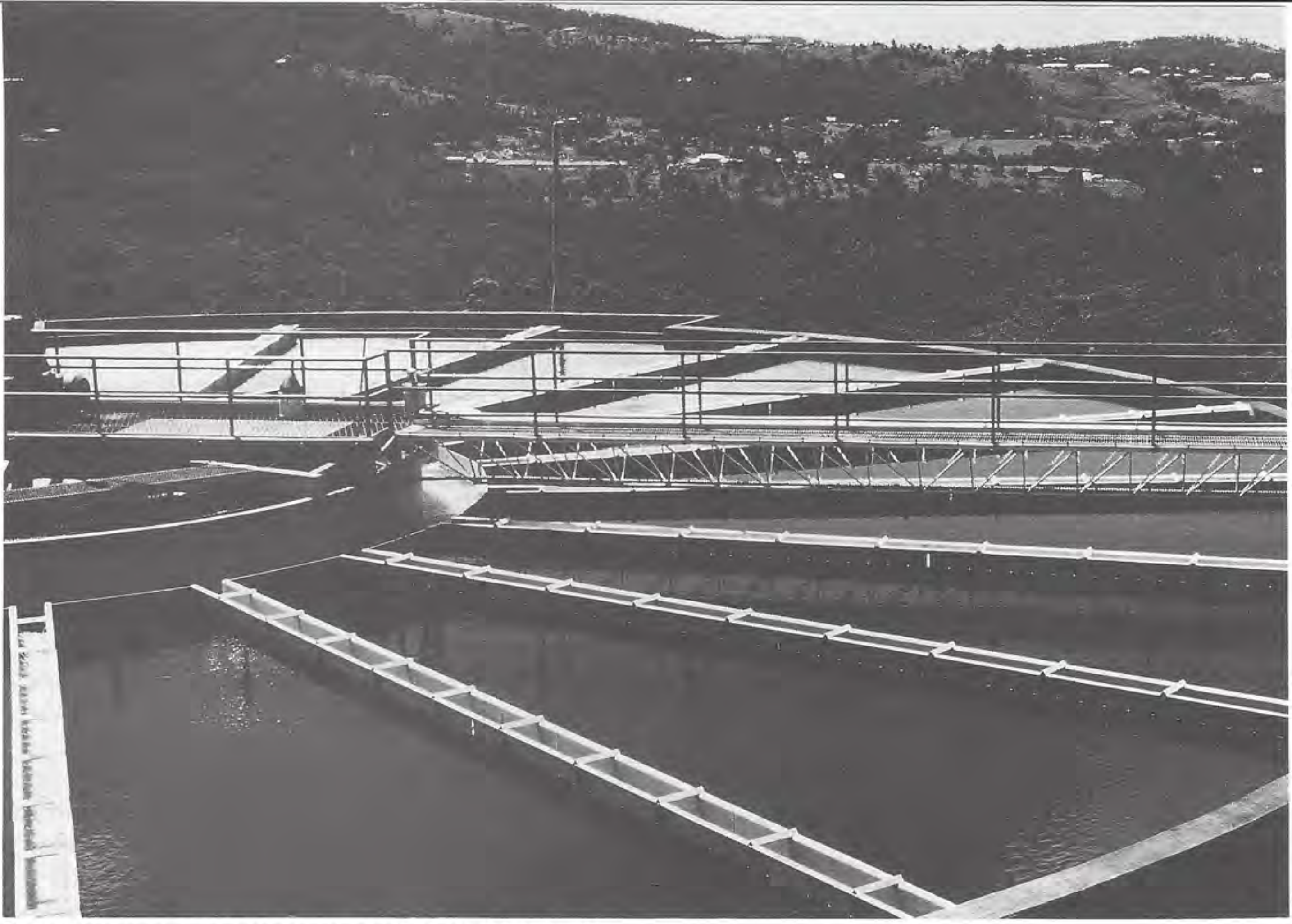


Fig 3 Water treatment plant showing clarifier in the foreground

to stick together and grow in size to form larger flocs which then settle out in the clarifier. In some plants, polyelectrolytes are added which act as 'bridging agents' to help the particles grow in size. The process by which polyelectrolyte and particulate matter combine to form sinking particles is called flocculation and is not a chemical reaction. This is shown at step 2, in Figure 4.

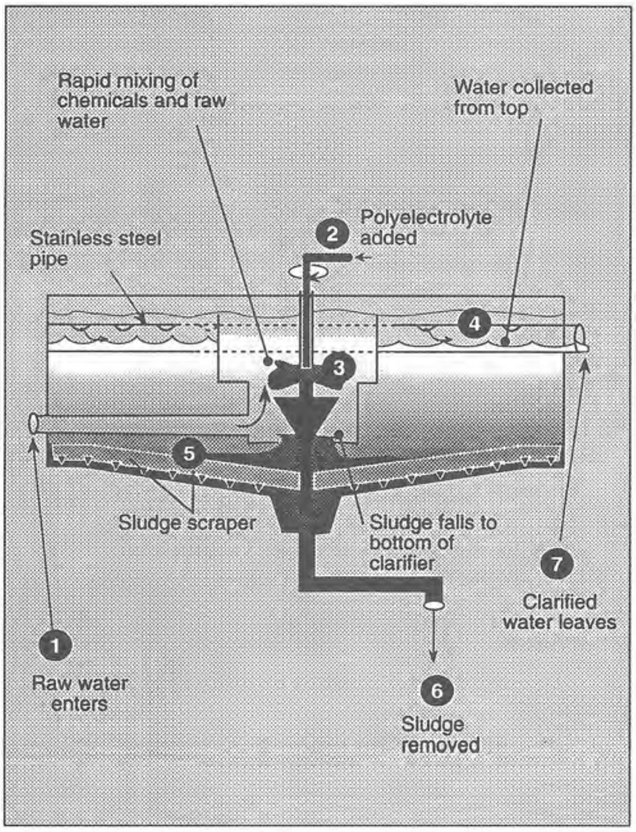


Fig 4 A clarifier is used to remove solid materials by the addition of polyelectrolyte.

Clarifier

- **The clarification** process settles out flocculated particles in a tank.

Figure 4 shows a clarifier as well as other parts of a treatment plant. Figure 5 shows an empty clarifier. Scrapers can be seen at the bottom of the empty tank. They remove the settled material from the tank.

To understand the settling process, follow steps 1-6 in Figure 4.

1. Water, containing lime and alum enters the centre of the clarifier from the inlet structure.
2. **Polyelectrolye** (a synthetic organic polymer, with many electrically charged points) is added and rapidly mixes with the raw water coming up from below.
3. Organic material in the water is attracted to the polyelectrolyte, becomes more dense than the surrounding water and settles.
4. Clear water that flows to the surface is collected in channels and leaves the clarifier through a pipe at 7. This clarified water still contains dissolved chemicals of which manganese is one.
5. The settled material is known as **sludge** and is removed by scrapers which rotate around the bottom of the tank.

6. The sludge is removed and pumped to sludge thickeners, where water is removed (not shown in this diagram).
7. Clarified water leaves the clarifier.

Filter

Clarified water from 7 in Figure 4 is delivered to a filtration tank for further removal of fine suspended matter and algae not removed in the clarification process.

The filter beds must be backwashed at regular intervals to remove the material taken from the clarified water.

Sludge

Sludge from step 6 in Figure 4 as well as backwash water is concentrated in a thickening tank where further chemicals are added to de-water the sludge. The chemicals cause the sludge to separate from the water particles.

The sludge is then fed to a rotating drum, filter press or lagoon for further removal of water before being dumped as landfill.

Summary - water treatment process

1. The first stage is coagulation. Alum is one type of coagulant. The addition of polyelectrolyte assists flocculation by forming bridges between smaller particles to form larger particles.
2. The second stage is flocculation. This occurs at step 3 in Figure 4 where slow stirring/mixing helps the smaller coagulated particles grow in size (floc together) to form larger flocs which settle more readily in the clarifier.
3. The third stage is clarification where solid material is allowed to settle to the bottom of a tank called a clarifier.
4. The fourth stage is filtration where chemicals like manganese and organisms such algae can be removed along with other fine solid particles not removed in the clarifier.
5. The fifth stage involves the addition of lime to correct the pH and chlorine to kill any harmful bacteria remaining in the system (disinfection) before the water is delivered to reservoirs and to the home.

Why water needs to be disinfected

Drinking water is disinfected to prevent the spread of water-borne pathogens that cause diseases such as cholera, typhoid and gastroenteritis and to control biofouling (growth of bacterial slimes) in reticulation systems.

When evaluating a disinfectant, the following aspects are considered:

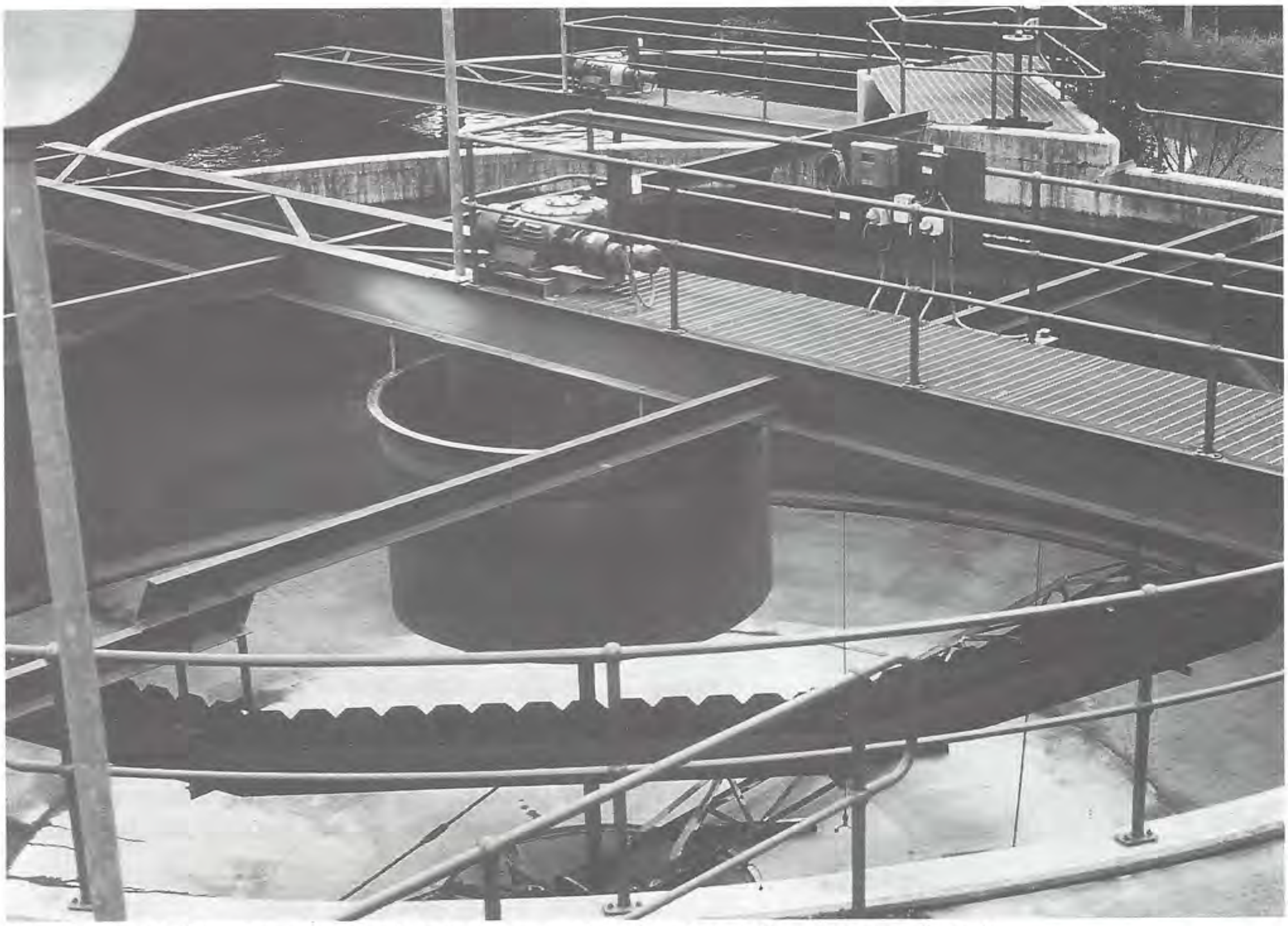


Fig 5 Empty clarifier - the rows of teeth in the foreground is where the clarified water is collected

- its ability to kill pathogens under the prevailing conditions of pH, temperature, and turbidity
- the provision of residual disinfectant for the distribution system
- the toxicity of end-products, by-products and residuals
- the effect of the disinfectant and by-products on palatability and acceptability of water to consumers, e.g. taste and odour
- the availability of simple and inexpensive testing techniques for dose, residuals, end-products and by-products
- capital and operational costs
- safety aspects and ease of transport and storage.

Common disinfectants

The disinfectants that are most commonly used in domestic supplies are:

- chlorine ($C1_2$)
- chlorine dioxide ($C10_2$)
- chloramine
- ozone.
- ultraviolet light (UV)

Their properties are summarised and compared in Table 1.

None of the options discussed fulfill all of the requirements for a desirable disinfectant. The advantages and disadvantages have to be assessed for individual system requirements and water quality goals.

Chlorine is the most commonly used and cost effective disinfectant for potable water supplies. In practice, just enough is used to produce a free chlorine residual of 0.2 mg/L at the consumer's tap. This level of disinfection prevents the growth of harmful bacteria in the distribution system.

The alternative disinfectants such as ozone, chlorine dioxide, chloramines and UV light all have important disadvantages such as lack of residual, higher cost and, in some cases, poorer biocidal activity.

Most disinfectants produce by-products which can damage your health. While every effort should be made to minimise the presence of toxic disinfection by-products, there should be no compromise on the microbiological safety of water.

	Chlorine	Chlorine dioxide	Chloramine	Ozone	UV
Ability to kill pathogens					
• bacteria	good	good	good	good	good
Time to kill bacteria	moderate	moderate	moderate/long	short	short
• viruses	moderate	good	poor	good	good
• protozoans	poor	poor	very poor	good	poor
pH dependent	yes	slight	yes	slight	no
Concentration required to kill bacteria down the pipeline	moderate	moderate	long	no	no
Relative complexity of technology	simple/ moderate	moderate	simple/ moderate	complex	simple/ moderate
Ease and safety of					
• transport	yes	yes	yes	no	no
• storage	substantial	substantial	yes	moderate	minimal
By-products of possible health concern	THMs, other chlorinated organics	chlorite	THMs but at lower levels; nitrite & nitrate	oxidised materials - significance unresolved	no
Existing testing techniques					
• dose/residual	yes	yes	yes	yes	n/a
• by-products	yes (not routine)	yes	yes	research	n/a
Process control	well developed	developing	well developed	developing	developing
Cost*	+	++	+	+++	++

Table 1: Relative comparison of alternative disinfectants. Note: Costs: comparison is difficult because of the lack of Australian data for methods other than chlorination and chloramination. Rating given is relative based on USA data. Plant size is a further complicating factor. Chlorine is the cheapest disinfectant but only for small plants (< 5mL/day) UV and chlorine dioxide may be comparable. Protozoans include parasites such as giardia and crytosporidium.

The risks from water-borne diseases still outweigh the risks associated with drinking water containing disinfection by-products such as trihalomethanes (THMs).

Chlorine, chlorine dioxide and ozone are strong oxidants and have other treatment uses in domestic water supplies such as oxidation of iron and manganese and the oxidation of organic substances that cause tastes and odours.

For systems where water remains in pipes for a long time, chloramination may be a more effective means of maintaining residual disinfectant levels.

Chlorine dioxide can be used as an oxidising and a disinfecting agent in both pre and post water treatment. However, water quality limits on the concentration of oxidising residuals means that it is more often used as a chemical oxidant rather than for post treatment disinfection. It is important to distinguish between the use of these chemicals in raw water treatment or treated water systems.

For small supplies of good quality water (low colour and turbidity) where residual disinfection is not required, UV irradiation is useful.

While ozone treatment is expensive it is probably the best available technology for oxidation. This method filters the water first through activated carbon. Chlorine and chloramine are then added to the water. Ozone has not yet been used for water supply disinfection in Australia, but may be used in the future.

Water reservoirs

Treated water is fed by gravity or pumped to storage points in a town. These are called water reservoirs, as shown in Figures 6 and 7.

When you turn on the tap at home, the water rushes out under pressure. This water pressure allows you to use a hose or to have a shower. How does the water pressure get there?

Fig 6 A water reservoir

This pressure is caused by the relative height of the reservoir above the town. This height is called the **static head** and is measured in metres as shown in Figure 7. So if a place in the town is to have 24 metres pressure, the reservoir must be greater than 24 m above that place in the town. Pressure is lost due to friction when the water flows through pipes and fittings.

Pressure is important as many household appliances rely on it to work efficiently. A dripper system in the garden will not work efficiently if the pressure is too low. Many hot water systems also fail to function in low pressure situations and people who fight fires would have great difficulty using hoses if the pressure was not maintained.

Reservoirs therefore must maintain a certain height of water in them for these uses.

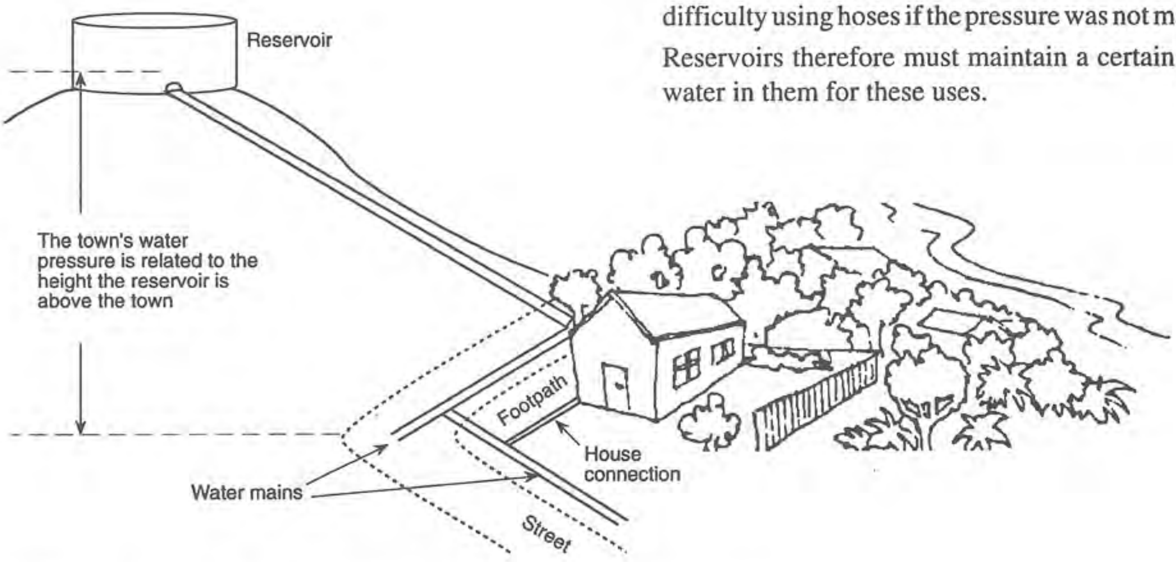


Fig 7 Water pressure is caused by the height of the reservoir above the town

Reticulation pipes called **water mains** carry this water under streets and footpaths. In some cities, these pipes can be many kilometres long.

Measuring household water use

In most cities and towns water meters are installed to measure the volume of flow to a house, so they pay for water as they use it. This means the people who use more will pay more and people with positive water conservation attitudes and values will be rewarded.

The water meter

Figure 9 shows a typical water meter and how it is read. If no water enters the house, the reading will be zero. If the stop valve is turned off and you turn off all the water appliances inside and outside, and the house, and the meter ticks over, then you need to contact your plumber or check for leaks in the household system.

If any leaks are observed at or before the water meter your local councils should be notified.

Because water is used in large quantities, the unit of measure used is a kilolitre (1 kilolitre = 1 000 litres).

The reading in Figure 9 shows that 7834.72 kL have been used by the household since the meter was installed.

Normally the meters are read each year and the amount of water used for the year is obtained by subtracting the previous year's reading from the current figure.

Each local authority is responsible for setting the local water charges and determining the methods by which the meters are read.

Household water use

When a house is built, all the pipes go in the wall or under the ground. Figure 8 shows the wall of a partly completed house with both the water and wastewater pipes installed.

Fig 8 Part of the wall of a house under construction.

A qualified plumber is required to do the plumbing. In most States plumbers are required to hold a license. This allows people who build their own houses to easily identify suitably qualified people. The pipes in most modern houses are copper and poly plastic. If you look carefully in the photograph you can see the smaller copper pipes running along the wall. These will be covered by a tar paper and finally bricks will be laid on the outside.

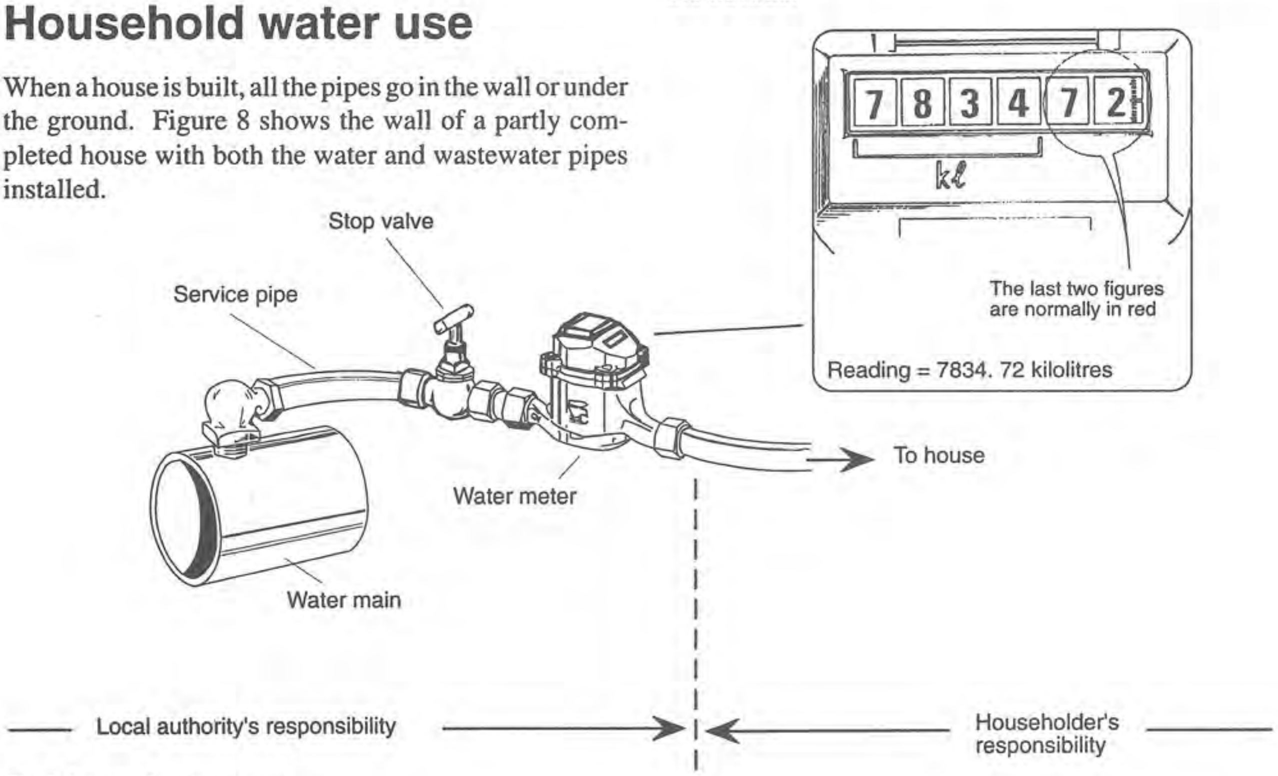


Fig 9 A typical water meter

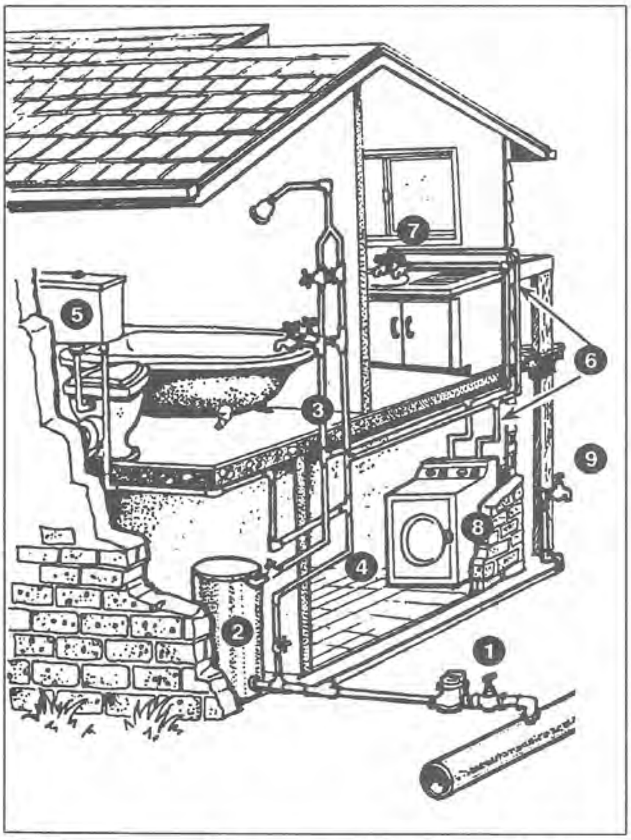


Fig 10 A summary of the main plumbing processes in a house

The inside of the wall is usually sealed with plaster board or fibro and paint, tiles, wallpaper or some other suitable covering.

Plumbers try to keep these internal pipes low down and in the centre of studs so that when the householder hangs pictures, the nail holes do not enter the pipes and cause leaks. The internal water pipes are under pressure and, if damaged, will spurt water out under pressure.

The two large pipes in the foreground of the photograph are wastewater pipes. They are larger and are arranged so that what enters them will fall with gravity.

A plan, showing where all the pipes go in the property (called a **drainage plan**), is always issued for a new house and is approved and inspected before the house is occupied. Local authorities have strict regulations on disposal of wastewater for obvious health reasons.

When the house is finished, only the storm water pipes from the roof will be visible and some people looking at a house may forget how the water enters and leaves.

Figure 10 shows where the pipes go in a house. Follow the numbers to learn more about household plumbing.

1. Reticulation pipes or water mains deliver water to your street. An individual household is supplied from a tapping into these water mains. A water meter can be used to measure the volume of water used in a house over a year so that water charges can be made.
2. Water on entering the house is then used as either hot or cold water. There are two separate sets of pipes for hot and cold water. If a solar hot water system is used, then the pipes will connect to the system on the roof, where the sun heats the water.

Fig 11 Section of a house showing pipes in the wall

3. Hot water pipes are connected to showers, baths, sinks, vanity basins, laundry tubs and many appliances such as dishwashers and washing machines.
4. Cold water pipes are connected to the same points as the hot water pipes as well as the toilets and garden taps.
5. Cold water fills a reservoir called a cistern in the toilet. A button at the top of the cistern delivers water to the bowl below.
6. Hot and cold water pipes are connected to the washing machine and kitchen sink.
7. At the kitchen sink, cold and hot water can run through a mixer or separate taps.
8. The washing machine can be connected to the hot and cold water taps. The flow rates are controlled by the machine. Front loading machines usually use less water than top loading machines.
9. Cold water pipes deliver water to taps in the yard where sprinklers and hoses can be connected. If the water flow in the pipes is changed quickly (tap turned off quickly, washing machine cutting on and off) loud noises can occur in the pipework. This is called water hammer.

Domestic water appliances

Taps

Ask anyone where water comes from and they will probably tell you — from a tap. It is important to make sure taps are in good working order.

If they leak then water can be lost at an alarming rate.

Taps are prevented from leaking by washers located at the base of the thread located below the tap handle. So that the tap fitting can look attractive, a cover encloses this mechanism.

When closed, the tap washer fits onto a tap seat, as shown in Figure 12. This seals off water, which is under pressure from the water main outside the house. If the washer is worn or broken, the tap will leak as the water pressure forces water under the broken part of the washer.

The tap is opened by the handle which releases the washer from the seat. The further the washer is from the seat, the more water will flow out of the tap.

Taps are commonly made of brass or materials that resist corrosion. The water that passes through them should have a pH of between 7 and 8 so that fittings last as long as possible, saving the consumer money.

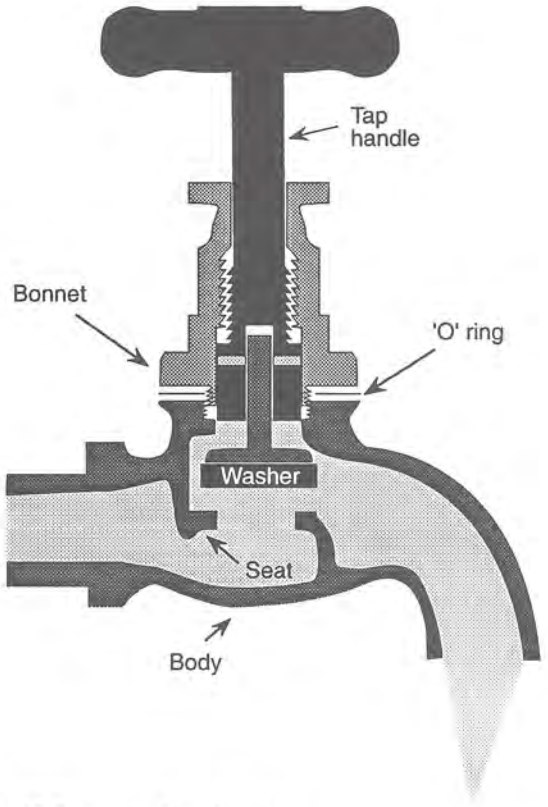


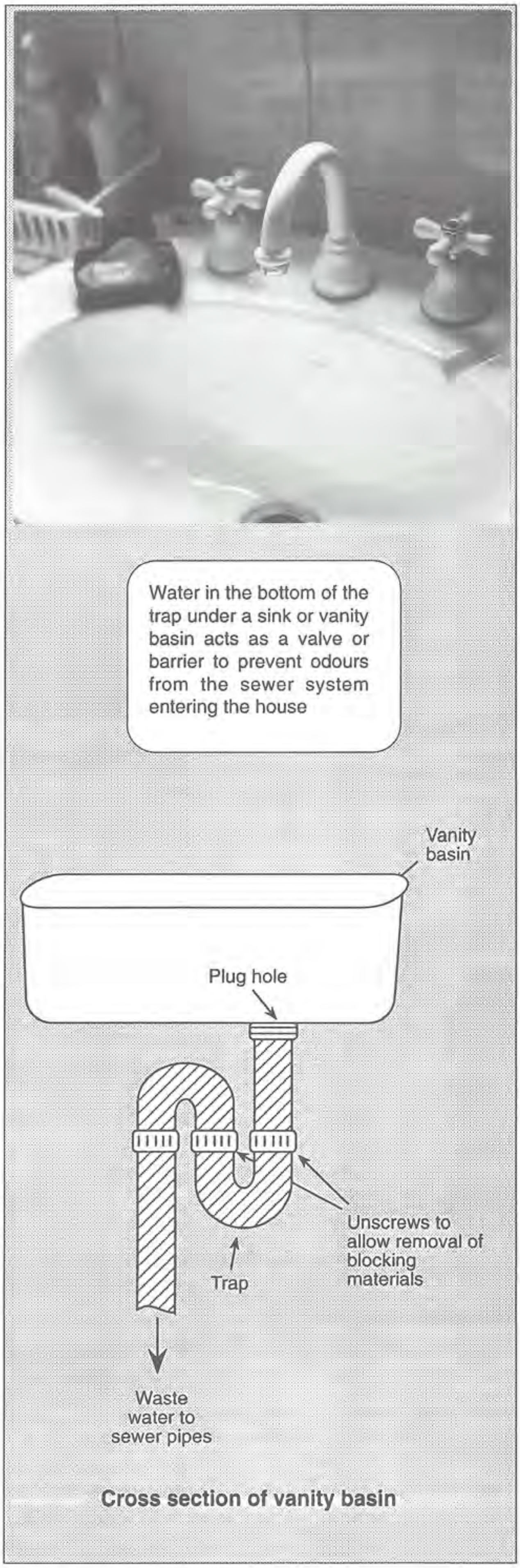
Fig 12 Cross section of a tap

Vanity basins

In most bathrooms, a vanity basin as shown in Figure 13 is installed for people to wash their hands or brush their teeth. In most cases there are hot and cold water taps.

Water runs down through the plug hole and into the sewer system.

It passes through a **trap,** which is full of water so that smells from the sewer system do not come back through the plug hole. If this becomes blocked with hair or dirt, it can be cleaned by opening the trap as shown in Figure 13.


Water in the bottom of the trap under a sink or vanity basin acts as a valve or barrier to prevent odours from the sewer system entering the house

Cross section of vanity basin

Fig 13 Vanity basin

Hot water systems

Many years ago, water was heated over a fire and the whole family washed in a bathtub. Today most water is heated in the house by a hot water system which users either gas, electric or solar energy.

In a gas hot water system, water pipes are heated by gas jets in an enclosed space. A small light, called a pilot light, continually burns in the hot water system.

In some hot water systems, an **'off peak'** supply of electricity is available. Here, the water is only heated at 'off peak times' which is usually at night. This way the householder can save money. However, if everyone uses all the hot water during the day, there will be no hot water until the heater is switched on during the off peak period.

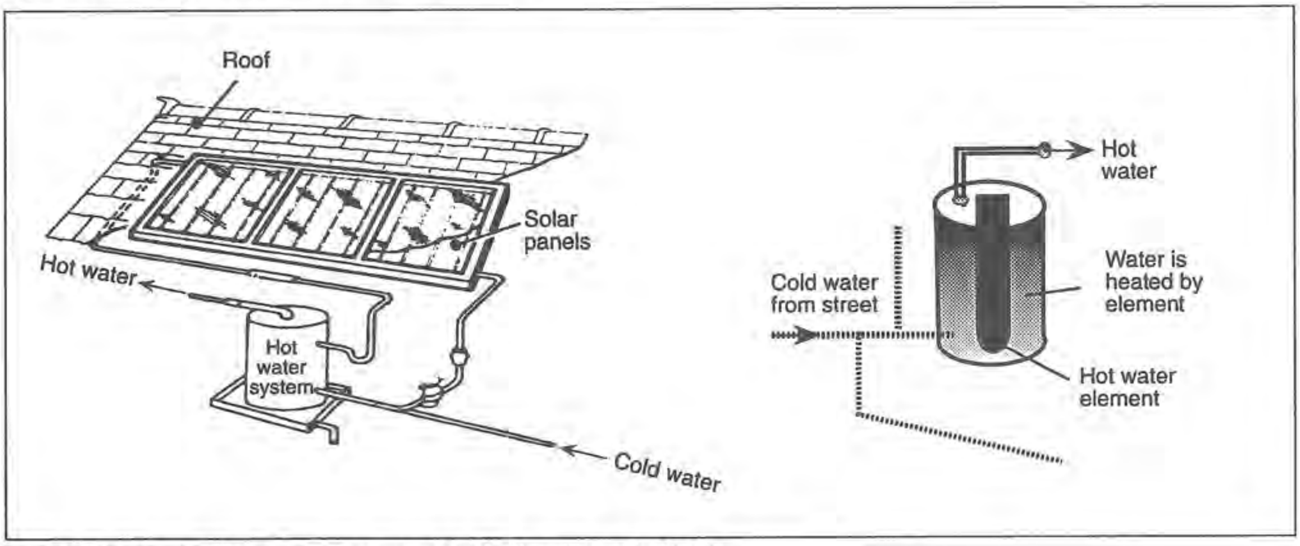


Fig 14 Two types of hot water system: solar (left) and electric (right)

When the hot water tap is turned on, a series of jets ignites from this pilot light in the hot water system. These jets heat water as it passes over them and hot water can be generated in the system.

Figure 14 shows solar and electric hot water systems. In an electric hot water system, water is heated by an element inside a large container called a boiler. Water is kept hot by this element, which is controlled by a thermostat. If the temperature falls below a certain setting, the element will heat the water in the system. In some systems, an **'off peak'** supply of electricity is available. Here, the water is only heated at 'off peak times' which is usually at night. This way the householder can save money. However, if everyone uses all the hot water during the day, there will be no hot water until the heater is switched on during the 'off peak period'.

In solar hot water systems, the sun heats the water. The system is usually on top of the house and many systems have been developed. Some track the sun as it moves across the sky, some are in a fixed position facing north and some are in hoses spread throughout the house roof. All rely on sunlight to heat the water during the day.

Showers

Figure 15 shows how hot and cold water are mixed from the cold and hot water tap in a shower. The hot and cold water pipes from the taps join so that the water is mixed to the desired temperature.

The flow of water in a shower can be controlled by .

- How far you turn on the hot and cold taps.
- A flow reducing valve inserted in the tap or the shower arm.
- Different types of water conservation shower roses on.

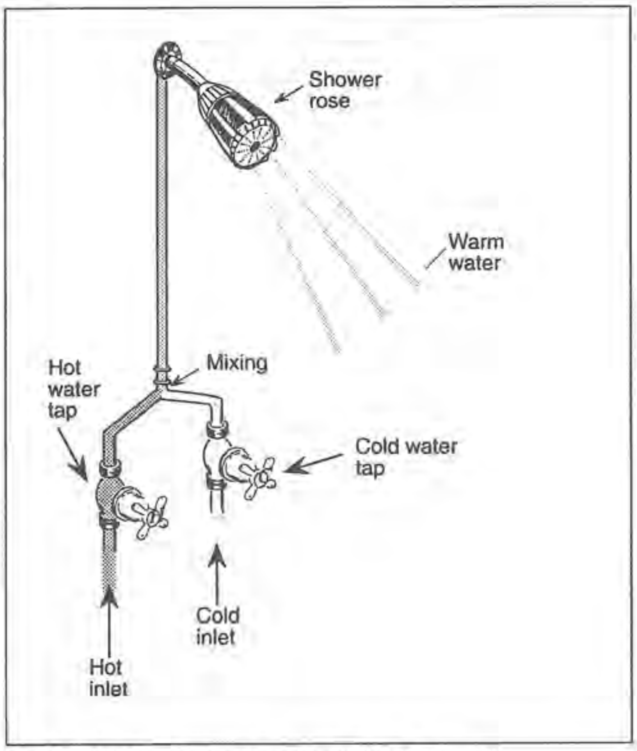


Fig 15 Water is mixed in pipes behind the wall.

Fig 16 Hot and cold water is mixed in a shower.

Toilets

The toilet works by flushing a bowl from a reservoir called a **cistern**. The cistern refills with water after the toilet has been flushed. Figure 17 shows a cross section of a toilet and cistern.

Water enters at the top of the cistern under pressure from a water pipe in the house. It passes through a refill assembly containing a valve controlled by a float on the end of a rod. The refill assembly delivers water only when the water level in the cistern is not high enough to turn the valve off.

When the toilet is flushed, a plunger at the bottom of the cistern opens and releases the water into the bowl. This forces the water in the bottom of the bowl down and up past the toilet leg allowing it to fall by gravity to the sewer pipes below.

The shape of the toilet leg ensures a quantity of clean water remains to form an air trap in the bottom of the bowl. This prevents odours from the sewer system entering the house.

As the water flows out of the cistern, the float drops, opening a valve on the in coming water pipe that is connected to the cistern. Water then refills the cistern. After flushing the toilet, the plug at the bottom of the toilet cistern closes stopping any further water from leaving the cistern. The refill assembly will then refill the cistern as disclosed before.

In a dual flush system you have the choice of either a full or half flush. Older toilets flushed with 24 L of water. Modern dual flush toilets use a system of 12 L full and 6 litres half flush. Toilets are currently be made to flush with 6 L full and 3 L half flush.

The volume of water to empty the bowl can be greatly reduced by the shape of the bowl. Modern dual flush toilets can flush with a 6:3 litre ratio, however the bowl and cistern must be bought together.

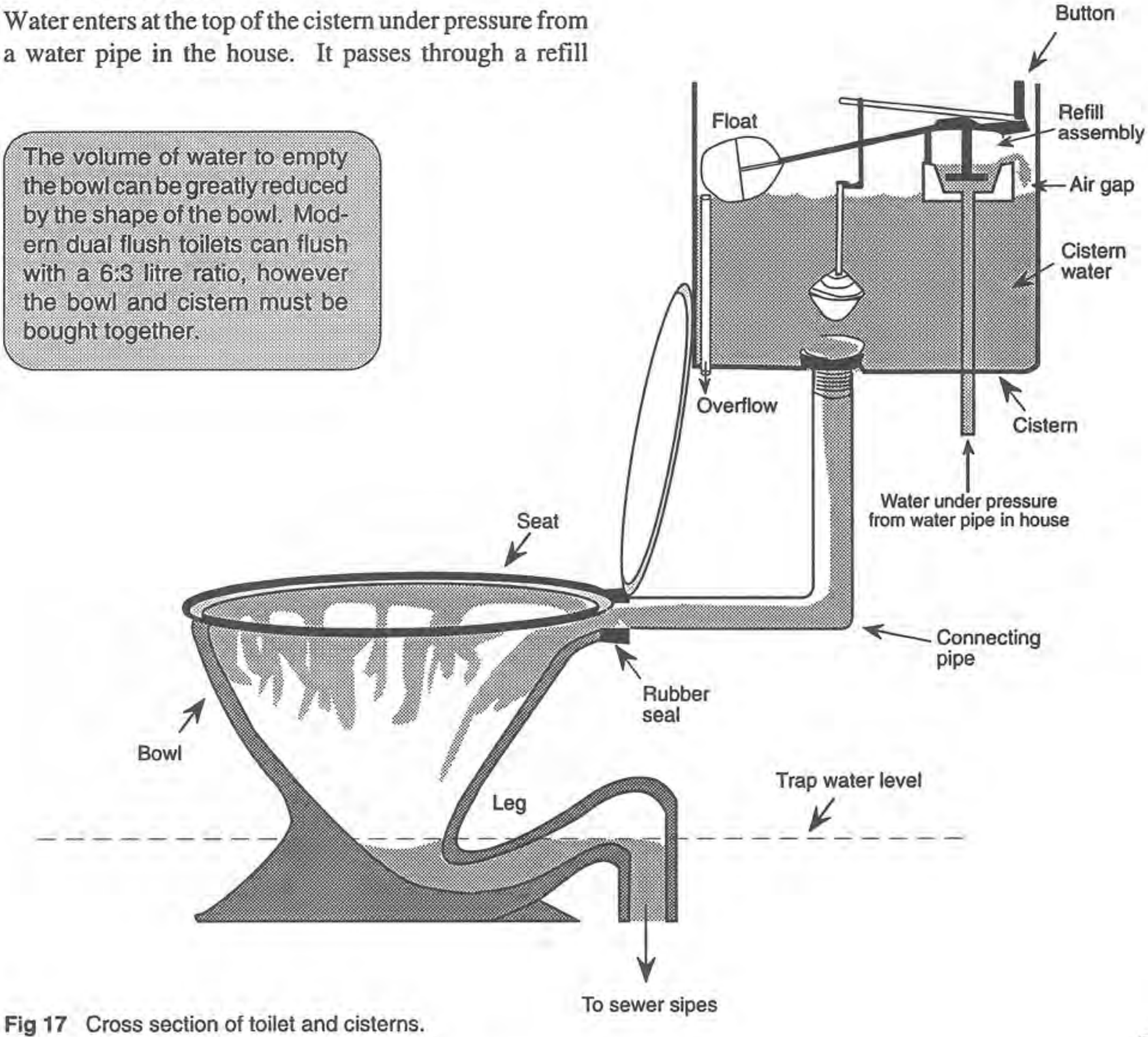


Fig 17 Cross section of toilet and cisterns.

Fig 18 Washing machine. Illustration courtesy Hoover Australia Pty Ltd (Reproduced with permission).

If installing a dual flush toilet cistern, you need to check to see if the bowl has to be replaced as well. If the bowl and cistern are incompatible the dual flush system will not work correctly.

Washing machines

There are many machines available including:

- semi automatic
- twin tub and
- fully automatic.

Semi automatic and twin tub washing machines require the operator to adjust the water level manually for each wash. Fully automatic machines this is done automatically once set.

Many modern washing machines (see Figure 18) have a suds saving option allowing water to be reused. They also have the ability to mix hot and cold water.

To ensure the most efficient use is made of the washing machine it should only be used when it has a full load of clothes to wash.

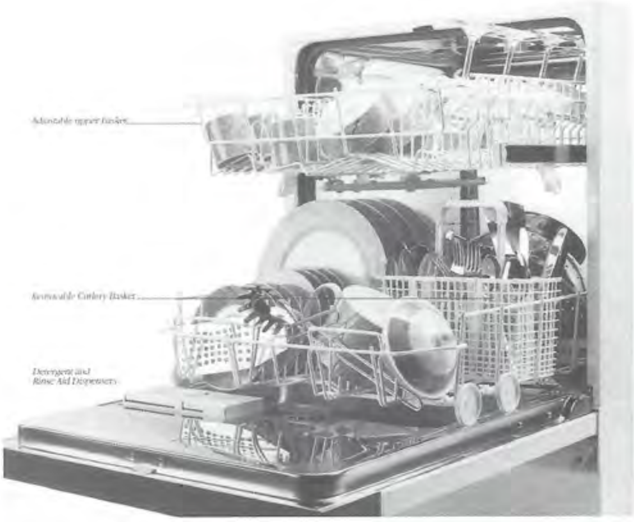


Fig 19 Dishwasher. Illustration courtesy Simpson Ltd (Reproduced with permission)

Dishwashers

Dishwashers use water under pressure with detergent to remove dirt from glasses and dishes inside a machine. Water is usually used in cycles and the householder can select the desired cycle depending on the type of wash required. Modern dishwashers (see Figure 19) have economy cycles that enable less water to be used. To ensure the most efficient use is made of the dishwasher it should only be used when it has a full load of dishes etc. to clean.

Domestic irrigation systems

A domestic irrigation system consisting of sprinklers, sprays, drippers and pipes can be used to in the garden to water plants and vegetables. A system such as this will ensure only those areas that need to be watered are. Often the use of times with an irrigation system will help householders to minimise water waste. Figure 20 shows a pop up sprinkler.

Fig 20 Pop up sprinkler. Photo courtesy Nylex Gardena, (Reproduced with permission)

Excursion

A visit to a local water treatment plant and / or raw water source

Depending on where your school is located and the availability of staff, arrange a visit to your local water treatment plant and / or raw water source. The following questions or discussion points may be helpful in writing a short report on your visit.

1. What is the name of the raw source, where is it located?
2. How does the raw water get to the water treatment plant?
3. How far does water have to travel to the treatment plant from the raw water source?
4. What is the name of the treatment plant, where is it located and how many staff are employed there?
5. How much water is treated by the water treatment plant on a typical day and what is the treatment capacity of the water treatment plant?
6. What is the first thing that happens to the water in the treatment plant?
7. Is coagulation and flocculation used in the plant and what purpose do these serve?
8. What chemicals are used in the coagulation and flocculation process?
9. Does the plant have a clarifier? If so, at what stage in the treatment process is it used? What happens inside the clarifier?

   Draw a cross section of the clarifier.
10. Is the water filtered at any stage? If so, what is trapped in the filter beds?
11. Ask the operator or engineer to tell you what backwashing is and make notes about this. How often are the filters backwashed?
12. Is chlorine added in the treatment process? When and why?
13. What is the best thing that happens to the water in the water treatment plant?
14. Draw a flow diagram of the treatment plant indicating where the treatment process occurs.
15. What is the water quality of the raw water and the treated water? Parameters such as colour, turbidity, hardness, total dissolved solids, pH, temperature and taste and odour should be checked.

    Ask if you can have a copy of a typical water treatment plants daily records.

Videos

The Local Government Training Council has produced a Water Treatment video for local authorities which is useful for this chapter. The video is called *Water Treatment* and is available from Local Government House, 60 Edmondstone Rd, Mayne, PO Box 2179 Fortitude Valley, 4006.

Video questions and activities

1. Why is catchment management important and how can impurities be introduced into a catchment area?
2. What is an aeration system and how does it improve dam water?
3. Why is potassium permanganate added to water prior to treatment at a water treatment plant?
4. What safety precautions are taken at a plant to prevent accidents?
5. What happens in the following processes?
    - flash mixing
    - coagulation
    - flocculation process
    - clarification
    - filtration
    - pH correction and disinfection
6. Why is workplace safety important?
7. What happens to wastewater at this water treatment plant?
8. A reserve is needed in water reservoirs. Why?
9. Why is training needed for water treatment operators?
10. What is the training levy guarantee and what obligations do employers have under this piece of legislation?

Australian geographical enquiries

The part of the water cycle that resides in urban drinking water and wastewater systems raises many issues that can be used as a model for a geographical enquiry. Here are some suggestions.

1. Selecting a topic

You may wish to use this book as a source of ideas and information to select a topic. Information is also available from local authorities about the water supply and wastewater schemes, their history and development, how they changed with settlement patterns and what political decisions were made to increase their size. Data is normally available from water and wastewater treatment plants as are the licence requirements imposed on them. Finally, the attitudes of consumers present an opportunity for a well thought out survey. Try to be specific in selecting a topic so as not to become overloaded. Some suggestions for topics include:

- attitudes of a local community to water conservation and water use
- problems associated with raw water sources and sewage treatment
- environmental effects associated with water supply and sewage.

2. Identifying questions, issues or problems

Questions associated with water use arise from where the raw water source is located, how water is treated, distributed and used in the home, and what type of waste material are mixed with this treated water. Questions can stem from a dam's location and its environmental impact; the types of water saving appliances available on the market and how readily available they are to the community; the type of trade waste policy a local authority has and the perception of its importance by the community. In many Australian cities, sewage disposal and the use of chlorine is an issues (these are discussed in the next chapter). Problems arise from perceived community priorities and what engineers and designers can realistically achieve given budget and time constraints. Engineers are trained to solve problems. The methods they use, as well as the ways they proceed with a problem, can make an interesting study.

3. Selecting the enquiry procedures

This section involves organising data collected. It is important to keep the big view in your sights (as discussed in Chapter 1). Research has suggested that many people have a poor understanding of 'where the pipes actually go'. It is recommended that this be the initial enquiry. Other aspects, such as preparing maps of catchment areas, sample urban or house drainage and reticulation plans, or surveys of volumes of water used in a street, all fit into this big view.

4. Concluding the enquiry

This could involve communicating results about the use or abuse of water. The enquiry could lead to new questions and new problems such as:

- Should a community chlorinate its water supply or not? What are the health risks? Does the community have the right to make these decisions? Who should have the final say?
- Do people value water enough to recycle it back to the dam and reuse it?

Notes

The following questions or statements may also assist with your enquiry.

1. Water is distributed in a house by a series of pipes. Draw a plan sketch of your house showing where you think all the pipes go.
2. How is water is heated in your house? On the diagram you drew for question 1, show where the hot water pipes go.
3. After connection to a tap, water can be used in an uncontrolled manner in household appliances such as washing machines and dishwashers. Investigate the way household appliances use water. Collect data on how much water is used. Compare a full cycle with a half cycle, or different brands with your neighbours'. Do front loading washing machines use less water than top loading machines?
4. Statements to consider:
   (a) 'Humans are rewarded for the use of water by seemingly pleasurable experiences reinforced by attitudes from a non-conservationist era. The lush green lawn and long hot showers are examples of this ethic.'
   (b) 'The price urban dwellers will pay for overuse of water will be measured in terms of environmental degradation.'
   (c) 'Water conservation is just one part of a total change in attitude people need to adopt to maintain our present lifestyle in future generations.'
   (d) 'Water can be conserved inside and outside the home by water saving appliances and a change in attitudes.'

6. In one day, how much water is used in your house? How does this compare with three other households in your street?

Activity 1 Simulated water flow in a suburb

Based on original ideas by Kerry Kitzelman

In a house, a number of domestic water wasting appliances and inefficient practices combine to place a drain on water supply infrastructure.

Some water domestic appliances include

- a big shower rose
- a top loading washing machine
- leaky taps.
- an uncontrolled sprinkler.

Some inefficient practices include

- long showers
- leaving the tap running while brushing your teeth
- sprinkling the lawn in the middle of the day
- washing the car with the hose
- hosing the path to remove leaves
- washing only a half load of laundry.

Aim

To compare traditional domestic water appliances with the equivalent water saving devices by using a number of model houses connected to the water supply in a suburb.

Equipment

- Hardie Pope sprinkler kit set out on a sprinkler board (see Teacher's Resource Kit).
- Litre bucket with connection (see Teacher's Resource Kit)
- poly pipe and model house
- tidy box

Setting up houses in the suburb

A model house is made from a piece of pine timber, approx 435 mm x 30 mm x 20 mm. To this timber is attached a piece of poly pipe and in-line tap as shown in Figure 22. The poly pipe then has a series of holes punched in it. Into these holes are screwed different types of sprinkler which can be made to represent either a water wasting or water saving situation.

Sprinklers that have a high flow rate are used to represent water wasting situations. For example, there is a connection called a riser tube with a veriflow attachment. Water will pass through this at a certain rate. If we screw a full circle sprinkler attachment to the end of the riser tube, we can slow the water flow rate considerably as shown in Figure 22.

Make sure the layout is ready at the beginning of the lesson if you only have a 40-minute period. Otherwise you can spend about ten minutes setting the suburb up with other members of your class. Ensure that:

- the poly pipe has six holes already punched in
- the in-line tap is off, the T-piece has been connected to the polypipe that connects the other suburbs together and the last house has an extra short piece of tube with an end stop so that the system is closed.

Part A Water wasting

The first part of the activity will look at situations where there is a free flow of water. This could be the result of poor attitudes to household water use or a lack of knowledge of flow rates of household water appliances. You will need to connect the following sprinklers from the sprinkler board and attach them to your model house. Make sure you work outside and collect the water in a tidy tray.

- 4 riser tubes with veriflow sprinkler attachments
- 1 microspray with the top removed
- 1 drip irrigator with the green tap top off

After all the houses are connected, use the extra polypipe supplied, along with the T-piece on your house, to connect up four houses to a bucket on a bench (see Figure 22). This bucket acts as a reservoir and has a connector attachment and an in-line tap to allow the other houses to be connected.

When all is in place, turn the in-line taps on, and record the time taken for the reservoir to empty.

In school trials using a 9 Litre bucket, four water wasting houses emptied the reservoir in just over a minute.

Fig 21 Model suburb layout

Part B WaterWise

The second part of this experiment is designed to see if water flow rate can be reduced by using different types of attachments.

To study this effect, disconnect all but the drip irrigator and return these sprinklers back to the board. Now collect the following from the board:

- the green cap to the drip irrigator — this could represent a change in attitude e.g. turning the tap off when you brush your teeth.
- 2 x half circles representing a half flush toilet, shorter showers, drip system in the garden.
- 2 x full circles representing fully loaded dishwasher or washing machine
- 1 x microspray - water saving shower, platypus valve in system.

The reservoir is re-filled, and the experiment repeated with the new time recorded. Now calculate how much extra time/volume of water you could get from a reservoir as a result of a change in attitude or using water saving device.

Part C Writing up the experiment

Complete aim, apparatus, method and results for homework in your note pad and complete the following questions.

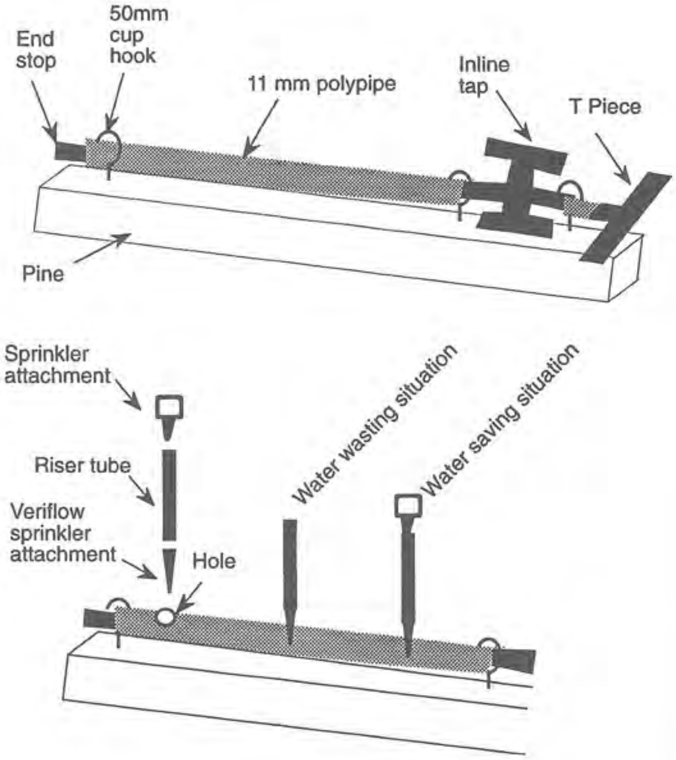


Fig 22 The construction of a model house and addition of sprinklers

Questions

1. Make a list of water saving devices or attitudes you could employ in each of the following places: Shower, toilet, vanity basin, kitchen sink, laundry, backyard, front yard.
2. How do you wash a car using a water wasting method?
3. How do you make a plant's roots grow deep into the ground?
4. How does a water saving shower work?
5. Why do we need to conserve water?
6. Why does a drip system save water?
7. What is a microspray and how does it work?
8. How many litres of water do we each use daily?
9. By what percentage do we need to reduce our water use to defer building any more dams forever?

Activity 2 How much do people know about volumes of water used?

People seem to know very little about the volume of water they use. This activity will see if this is true.

Survey of people's knowledge of volumes of water used

Do you know how much water you use when you have a shower? Or wash the dishes? Or when you brush your teeth? Does anyone else know?

To understand volumes, try to answer the following questions yourself and then design a survey form to see if anyone else knows. For each answer circle the one you think is closest to your estimate.

1. How much water does your washing machine use on the wash cycle?

   a 10 L **b** 20 L **c** 40 L **d** 100 L

2. How much water do you use to wash the dishes?

   a 5 L **b** 10 L **c** 40 L **d** 100 L

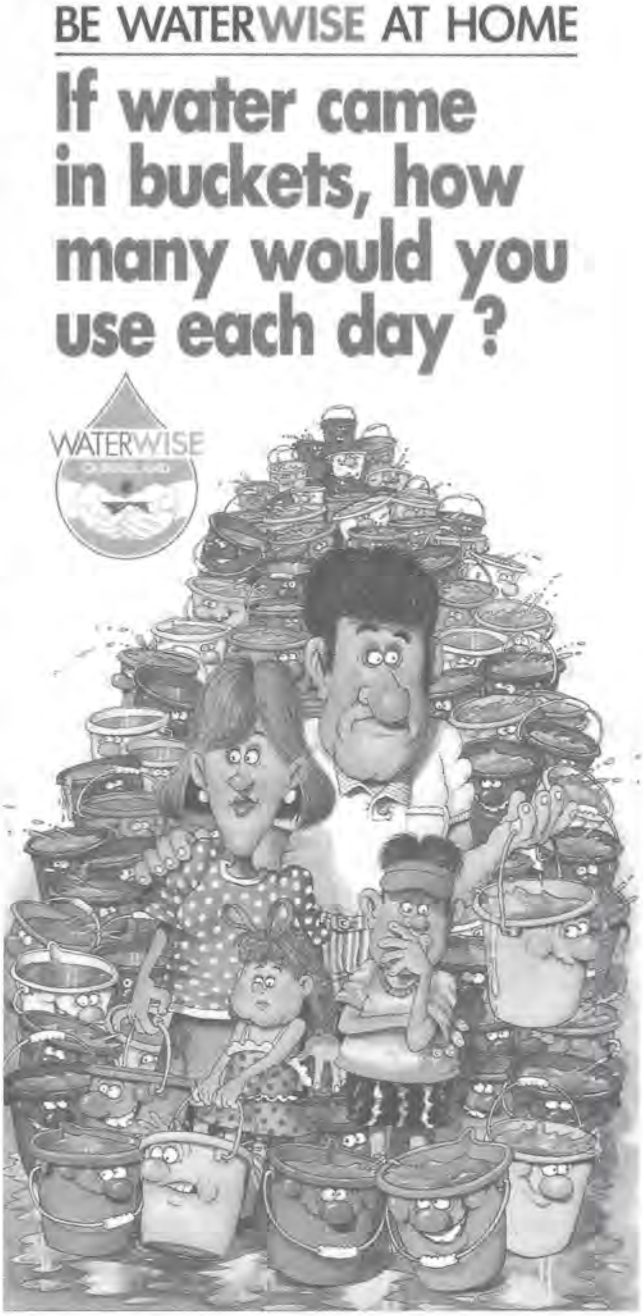
3. Suppose you had a dripping tap in the bathroom. How much water would be wasted in a day (12 hours)?

   a 50 mL **b** 500 mL **c** 5 L **d** 50 L

4. Instead of leaving the water running when you clean your teeth, you turn it on only when you need to. How much water would you save by doing this?

   a 50 mL **b** 500 mL **c** 5 L **d** 50 L

In this section you will be able to check how many of the estimates of water flow and water volume you got correct.



BE WATERWISE AT HOME

If water came in buckets, how many would you use each day?

Fig 23 This brochure is available from your local water authority or Water Resources, Department of Primary Industries, PO Box 2464, Brisbane, 4001.

Activity 3 Build a sprinkler and drip system

Write to James Hardie Industries to obtain a copy of their 'When Should I Water Brochures'? James Hardie Irrigation, 53 Howards Rd Beverley SA 5009. Telephone: (08) 268 7200 Fax (08) 268 3677

Use the information in these brochures to construct a drip system for either a school vegetable patch, pergola with plants, native garden, or other projects.

The activity is designed to increase knowledge of drip irrigators, water use of plants, plant species and water, timers, backflow prevention, some handy hints on systems, design systems, following instructions, hanging baskets, a typical pergola system, garden beds and borders, a typical spray system, trees, pots and vegetables, typical drip systems for vegetable garden.

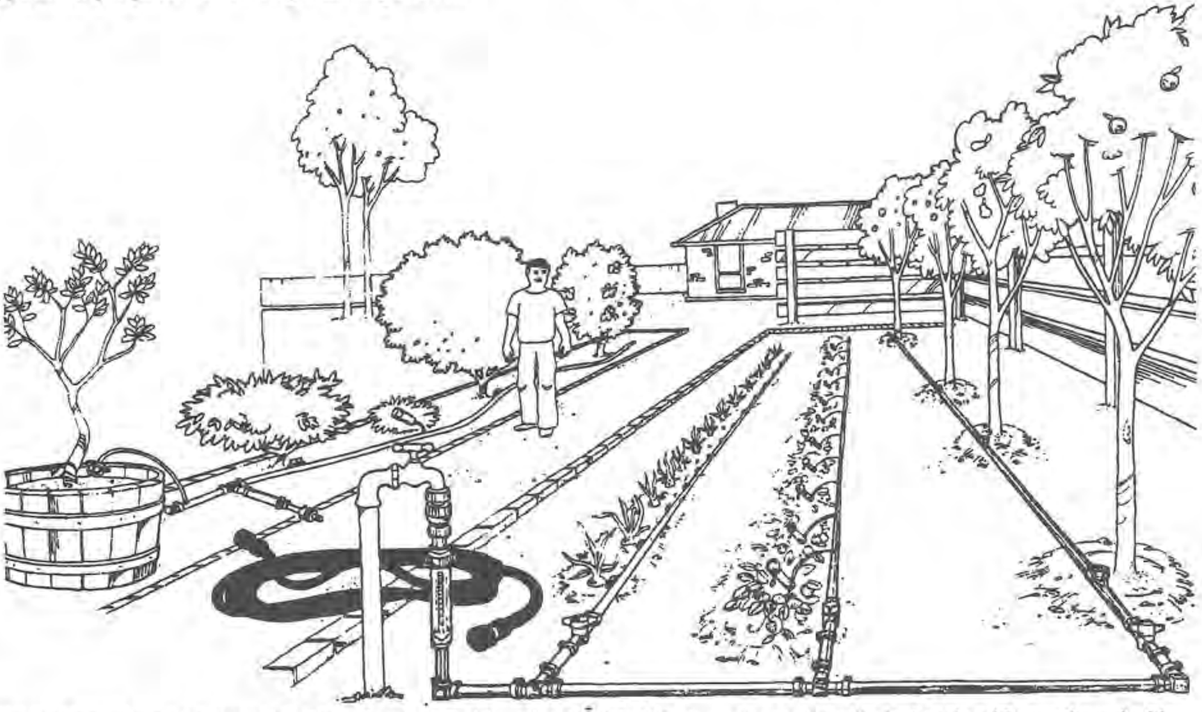


Fig 24 Part of a page from the Easy Garden Guide. Illustration Courtesy James Hardie Industries (Reproduced with permission).

Experiment 1 Coagulation and flocculation

In this experiment we investigate the effect of alum on the turbidity of water. Some experimentation may be necessary with the amount of dirt and alum added.

You will need

- two bottles with lids
- a teaspoon of alum (from the science lab or treatment plant)
- a spoon or spatula

What to do

Step 1 Add equal quantities of dirt and water to each of the two bottles. Add just enough dirt to discolour the water.

Step 2 Add a teaspoon of alum to one and screw the lids of both on tight.

Step 3 Now shake both for 20 seconds.

Step 4 Place on the bench and remove the lids.

Step 5 Slowly stir each with the spoon or spatula for 5 minutes.

Step 6 Allow the bottle to settle.

Step 7 Make careful observations over the next 10 minutes and then the following day, noting any difference between the two bottles.

Discussion

The shaking represents rapid mixing in the coagulation process where colloidal particles are given a negative charge. The alum has a positive charge which destabilises the negative charge on the colloids.

The positive and negative attract causing the turbid particles to collect to form a floc. Slow stirring simulates the flocculation process, where the colloidal particles grow in size to form larger flocs. These are allowed to settle out in the clarifier.

Experiment 2
Understanding pressure

Based on an original idea by Peter Stannard

Discussion

Look at Figure 25. Suppose you dived to the bottom of swimming pool A. You then got out and dived to the bottom of swimming pool B.

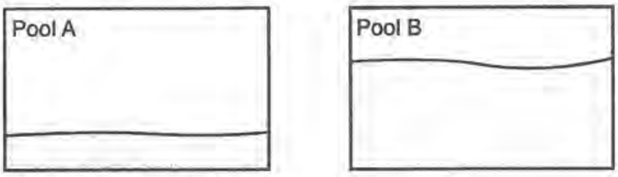


Fig 25 Two depths in a pool

- At the bottom of which pool would the pressure be greater? Give reasons for your answer.
- Suppose you had your eyes closed in each pool, how can you tell whether the pressure is greater in one pool than the other?

Take a large syringe full of water. How could you show that increasing the force on the water increases the water pressure? From your discussion of these questions you probably realise that pressure and force are related.

When you push on the syringe's plunger, you can feel the force of the water at the nozzle end. If you push harder, the force of the water is greater.

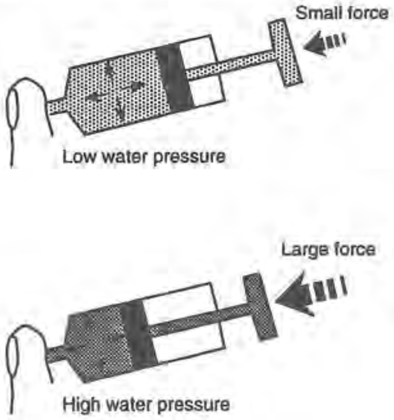


Fig 26 Demonstrating the difference in pressure

The pushing force creates a **pressure** in the water inside the syringe. The pressure of the water is the outwards force pushing on a particular area of the syringe. Pressure is measured in newtons/m^2. (That is, force/area.)

Aim

To find out what factors change the pressure of water.

You will need

- 2 x 9 L buckets, one with an outlet
- plastic tubing

Fig 27 A simple demonstration of pressure - you can use it to understand the head of pressure concept.

- a ruler
- a plastic tap

Part A Water pressure and volume

Step 1 Place the bucket (with the outlet) on a step or ledge and place your finger over the outlet.

Step 2 Have your partner fill the other bucket full of water and then pour the water into the bucket with the outlet.

Step 3 Let your finger go and quickly measure how far the water shoots out from the end of the outlet. Record this in your note pad.

Step 4 When the bucket is approximately half full, measure how far the water shoots out.

Questions

1. What do your measurements tell you about the pressure of water in the bucket?
2. Where in the bucket full of water is the pressure the greatest? Why?
3. Suppose that your bucket was only one-quarter full of water. How could you increase the pressure of the water without moving the bucket? (You can use other equipment and be as ingenious as you can!)

Part B Water pressure and height

Step 1 Attach the plastic tubing to the outlet of the bucket. Then attach the tap to the other end of the tubing.

Step 2 Turn the tap to the off position and fill the bucket with water.

Step 3 While holding the tap at ground level, investigate what happens to the water pressure when the bucket is raised and lowered.

For discussion

1. Describe what happened.
2. Write a generalisation about the effect of the height of water on pressure.

Revision questions

1. How does water enter a suburban street?
2. Where is water turned off in the street? Find out how this can cause backflow.
3. Where does water enter the house and how is the flow rate measured?
4. Name five water using appliances in your house.
5. How does water in a shower get hot? Name two methods.
6. How can the pressure in the shower be controlled?
7. How many litres a minutes does a shower use?
8. If you had a five minute shower, how much water would you use?
9. Where does wastewater go?
10. Discuss the overall process and purpose of water reticulation and domestic water use with particular reference to:
    (a) domestic water use
    (b) tap components and function
    (c) water flow and flow rates
11. How are leaks detected inside and outside a house?
12. How do the following household water appliances work? Draw diagrams to illustrate your answer.
    (a) shower
    (b) toilet
    (c) washing machine
    (d) dishwasher
13. What is the difference between the internal mechanism of full and half flush toilets?
14. What is a composting toilet and how does it work?
15. What is the difference between wastewater and storm water?
16. Describe how a water meter works and how it is read.
17. List some water quality problems associated with damming water and describe how these are overcome.
18. Draw a schematic view of a water treatment plant.
19. How does a clarifier work in treating water?
20. When water enters a treatment plant, what happens if the raw water is of high quality? Of low quality?
21. What is collected at the bottom of the clarifier and what happens to it?
22. What is the name of the water that is collected off the upper layers of the clarifier?
23. Summarise the five steps to treating water.
24. What is added to clarified water before it is filtered?
25. How are manganese and iron removed from water in some treatment plants?
26. What is backwashing and why does it occur?
27. Why do we disinfect water and what do we use?
28. Some water supplies are not disinfected. What risks do consumers run in drinking this type of water?

Chapter 3

Reclaiming water

Why do we reclaim water?

Just as the provision of a safe, reliable and affordable water supply is an essential element in community health and well-being, so to is the provision of wastewater disposal or sewerage systems.

Wastewater or sewage is the liquid waste that is discharged from households and industry. Wastewater disposal systems or sewerage systems are the pipes, manholes, pump stations, and treatment plants used to collect and treat sewage. **Effluent** is the treated sewage discharged to either the land, streams or rivers, or the ocean. Wastewater or sewage contains organic matter, nutrients, oils and greases, bacteria and may contain viruses and toxic chemicals as well as water thus requiring treatment before discharge to the environment. The community must aim to discharge wastewater effluent into the environment in a safe, reliable and affordable manner.

Nature's sewerage system

In a rocky pool or mountain stream, oxygen is in abundance and dissolves in water from the air. In Chapter 1 you learnt how to test this oxygen and determine the volume dissolved in water. Values vary according to temperature and are expressed in milligrams per litre or mg/L. Seawater, for example, can have values varying from 8mg/L at 15^{0}C, to 7.3 at 20^{0}C and 6.7 at 25^{0}C. All animal life depends on oxygen to survive and cannot tolerate low levels of this gas.

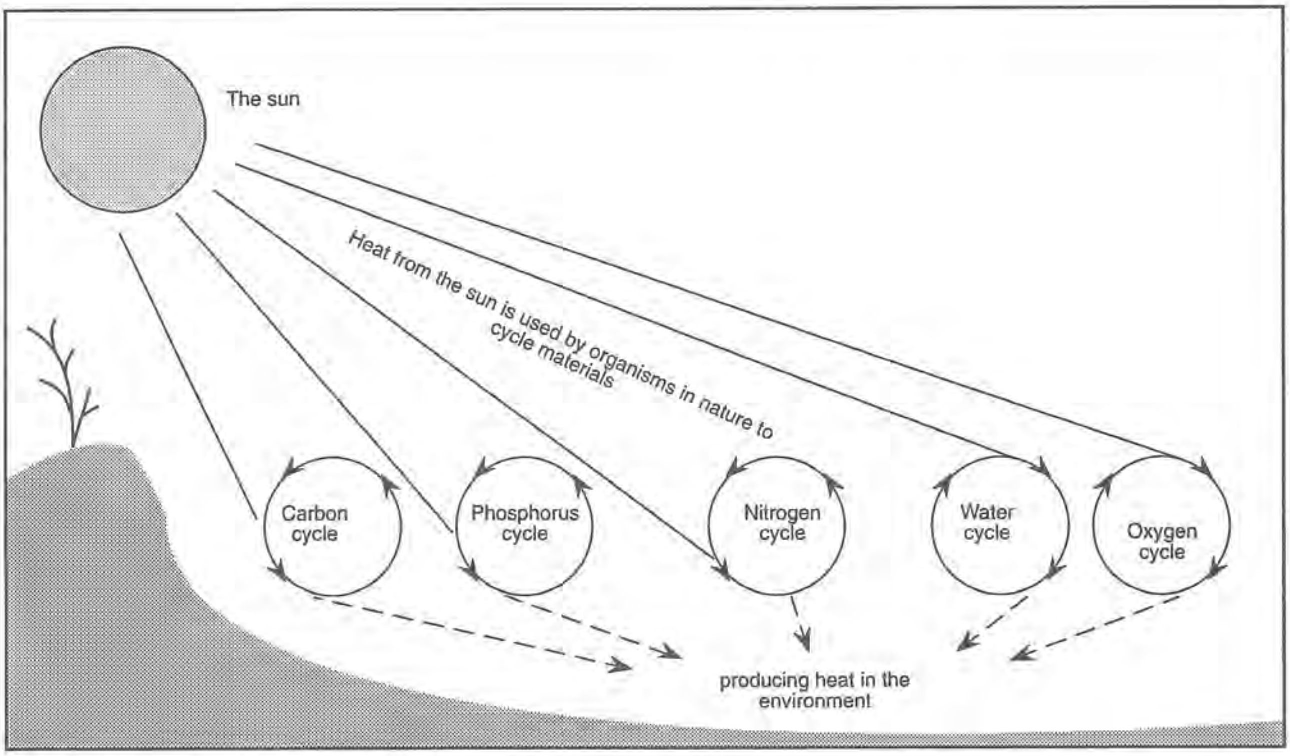


Fig 1 Cycles in nature (Adapted from *Environmental management- An environmental Education Program for Local Government.* Local Government Training Council, PO Box 130 Newstead, 4006)

Oxygen presence is just one of the many factors affecting survival in nature and is part of a cycle we call the oxygen cycle. The water cycle was discussed in Chapter 1. Carbon, phosphorus, and nitrogen are three other cycles shown in Figure 1.

Animals and plants living in nature produce wastes which require recycling. All the cycles mentioned in Figure 1 interact to achieve this. However, many of us have difficulty understanding this process because industrialised nations have been polluting our planet now for many centuries and it is difficult to obtain reliable background data on what our planet was like before pollution began.

Pond life

Consider water in a pond that has had no human interference. Microscopic plants called phytoplankton live in pond water, taking the sun's heat and converting carbon dioxide produced by animals to sugars inside their body. Pond weeds and other plant life known as **producers** do this as well. Ducks, birds, tortoises, fish and other aquatic life rely on these producers for food and live in and around the pond. These organisms are called **consumers** and produce wastes which wash or dissolve into pond water.

Living in, around and at the bottom of the pond are microscopic bacteria and small single-celled animals called **protozoa**. Collectively they make up what the wastewater industry calls the **decomposer bugs** which rely on wastes for food, as shown in Figure 3.

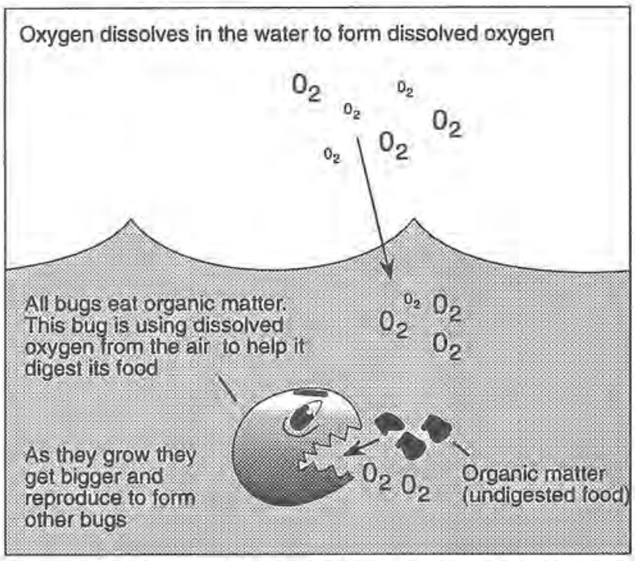


Fig 2 Bacteria and microscopic plants and animals eat organic matter.

These bugs play a vital role in the phosphorus and nitrogen cycles and in the general recycling of nutrients in the pond. Part of their role is to keep nitrates and phosphates down to a level that will maintain a good quality water for animal and plant life. How they do this is only just being understood.

Oxygen is important

In the pond, bugs use oxygen dissolved in the water as shown in Figure 2. It is believed that a relationship develops between the amount of available oxygen re-

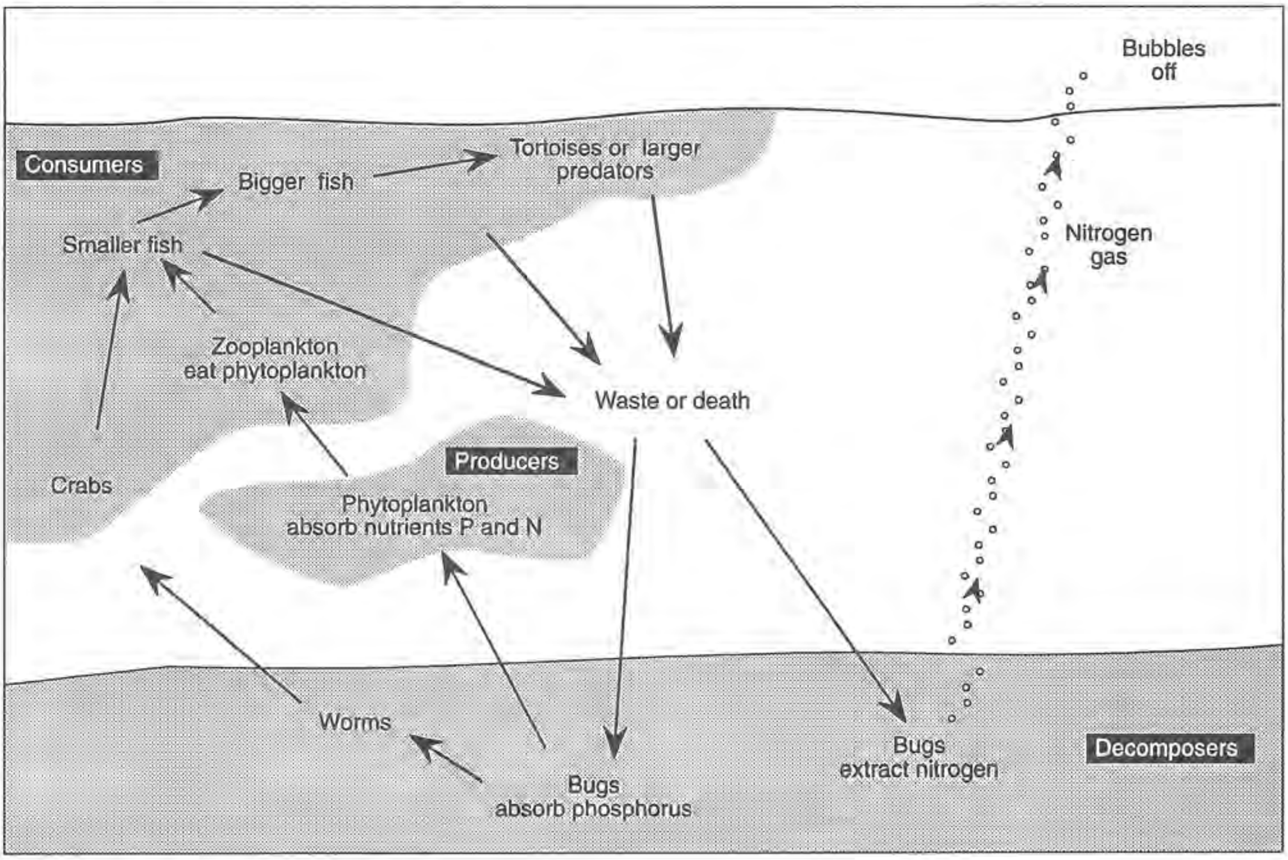


Fig 3 Possible cycles of nutrients in a natural pond system

Fig 4 Dissolved oxygen bottle and sample

quired by the bugs and the amount of food (in the form of waste) that has to be processed. The more food the bugs eat the more oxygen they require.

Biochemical oxygen demand (BOD)

If you did the dissolved oxygen experiments in Chapter 1, you will have found that oxygen is dissolved in water in milligrams per litre or mg/L.

Fish in an unpolluted stream require 5 mg/L of oxygen in the water to survive. If anything is put into the stream that reduces this oxygen content fish will find it difficult to survive.

The **biochemical oxygen demand** or BOD is the amount of oxygen used over a specific period of time by the bugs that biodegrade organic matter. The higher the BOD, the more oxygen will be demanded from the water to breakdown the organic matter.

If the new oxygen demand of the treated wastewater exceeds the oxygen resources of the body of water, (lake or stream) into which the wastewater is placed, then the oxygen will completely depleted. The lake or stream will be unable to support aquatic life near the wastewater entry point.

Measuring BOD

The following procedure is used to measure the BOD of treated sewage effluent.

- dilute a 200 mL sample of treated sewage effluent with 800 mL of distilled water (see Figure 5)
- make two samples in DO bottles (see Figure 4 and 5)
- test the DO of one sample immediately and record the result eg. 8 mg/L (see Figure 5)
- store the other sample for five days in a dark place at 20 degrees Celsius. (see Figure 5)
- test the DO of the stored sample after five days eg. 5 mg/L (see Figure 5)
- Subtract the DO results eg. 8 - 5 = 3mg/L
- Multiply the above calculation by 5 (diluted 5 times) eg. 3x5=15mg/L
- Therefore BOD is 15mg/L (see Figure 5).

Figure 5 summarises the above procedure. The same test can be done directly on stream or estuarine water but the sample is not diluted.

Licence requirements

If a stream has little organic matter present its BOD will be low. BOD values of 0-3 mg/L indicate very little organic matter is present and a stream that is unpolluted.

The discharge of wastewater on land, into streams or to the ocean requires a licence.

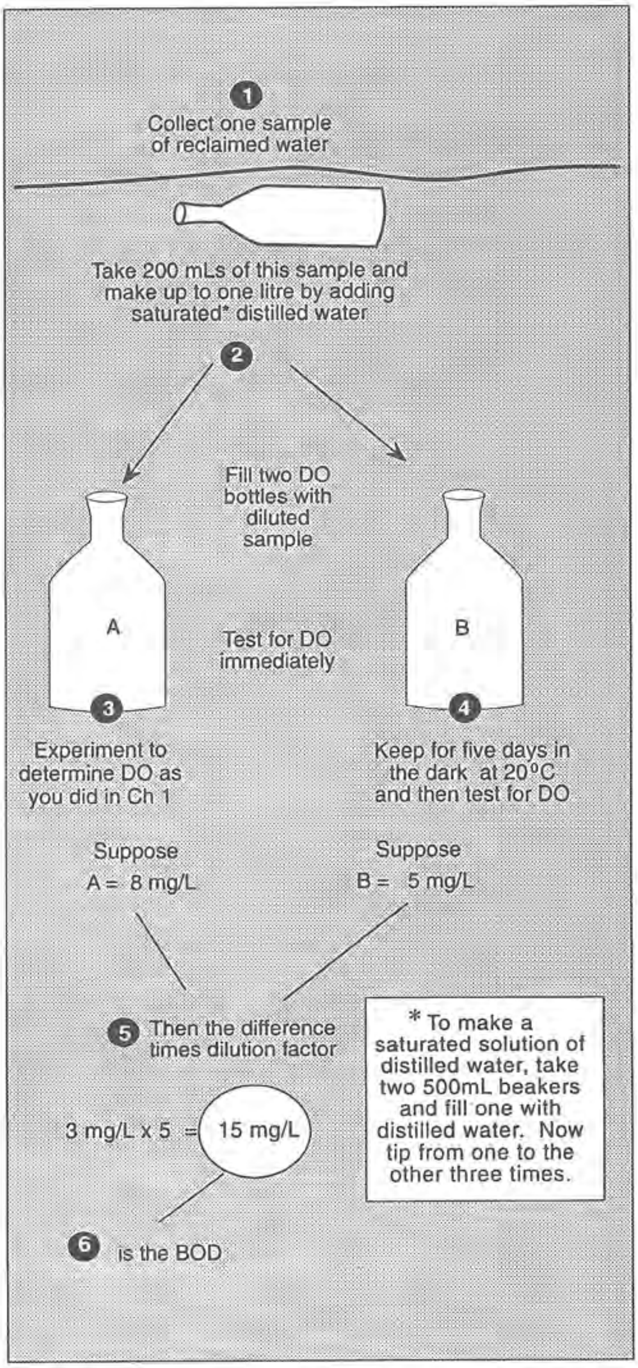


Fig 5 Summary of a general method for determining BOD

Wastewater discharge licences commonly require that the BOD should not exceed 20 mg/L. Some typical BOD levels are given below.

- Clean river water ....<2 mg/L
- Untreated sewage .... 350 mg/L
- Waste from breweries .... 550 mg/L
- Waste from oil refineries .... 850 mg/L
- Waste from abattoirs ....2650 mg/L
- Pulpmill wastes .... 25 000 mg/L
- Milk ....100 000 mg/L.

It is obvious therefore that if any of the above industries are to discharge wastewater into a pond, stream or on land, treatment is necessary.

BOD and aquatic life

If industry releases materials such as those mentioned above into streams or rivers, much of the available dissolved oxygen is used by the bugs in streams or ponds, robbing other aquatic organisms of the dissolved oxygen that they need in order to live. Organisms that are more tolerant of lower levels of DO may become more numerous. These organisms are usually few in number and the presence of certain species may indicate that BOD is high. Rivers and streams with a high BOD often show a low diversity of species.

An ideal natural system should have low BODs with decomposer bugs only having to process minimal amounts of organic matter.

The role of nitrogen and phosphorus in the food chain

Living organisms carry out a wide variety of chemical reactions to keep them alive. As a result, waste products such as carbon dioxide are produced. All consumers use protein as part of their diet which results in wastes containing nitrogen. Ammonia (NH_3) is a common waste product which is poisonous if allowed to accumulate in the body of the consumer.

To counteract this possibility, the consumer either converts ammonia to a less poisonous substance or excretes it into the environment. In the environment, ammonia is converted to nitrite (NO_2^-) and then nitrate (NO_3^-) by the bugs (see Figure 6).

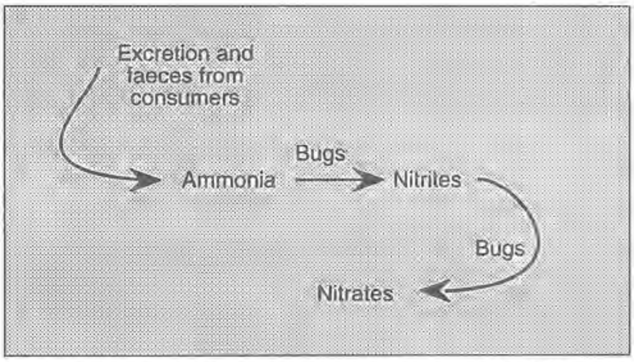


Fig 6 In the environment, ammonia is converted to nitrites and then to nitrates.

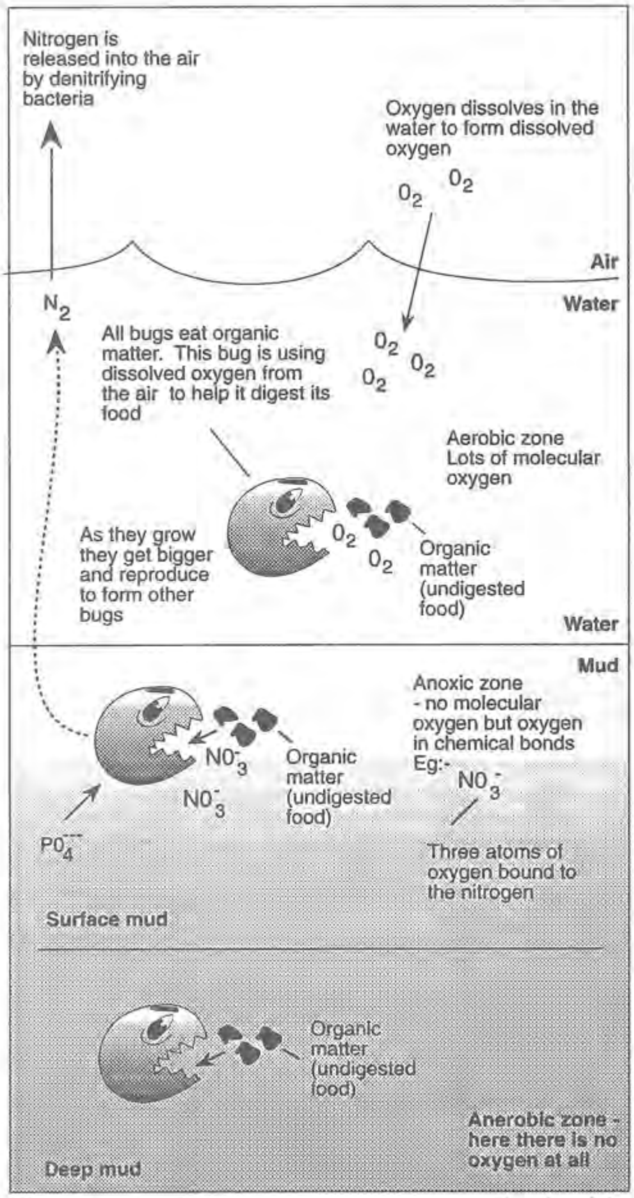


Fig 7 A pond contains its own sewage treatment plant involving bugs removing wastes and keeping 'pollution levels' down.

At the bottom of a stream, in the absence of oxygen, the bugs extract the oxygen from nitrate and release nitrogen into the air. In certain circumstances, other bacteria can absorb phosphorous into their bodies.

Single and multi-celled animals, like worms, eat these bacteria and so take the nitrogen and phosphorus into their bodies.

These worms are eaten by crabs and other mud life which move around in this muddy environment. These in turn are eaten by fish feeding off the bottom which in turn are eaten by bigger fish further up in water column.

When these fish die, urinate or defecate, the cycle starts again. This can be seen in Figure 2.

So the bottom of a pond filled with micro-organisms, or a sea-bed covered by sea grasses and similar micro-organisms, contains nature's nitrogen and phosphorus sewage treatment plant (see Figure 7).

Wastewater

On land, we collect our waste in a sewerage system which consists of pipes, manholes, and pump stations. This is then treated at a sewage treatment plant. The treated sewage which is called effluent is then discharged either on land, to a stream or to the ocean.

Sewage treatment uses some of the natural biological processes described above to reduce the organic and nutrient concentrations in the waste water.

Wastewater or sewage is the used water from a community. In 1979, the Centre for Environmental Research Information in the USA identified that wastewater is actually 99.94% water by weight.

They identified the 0.06%, as material dissolved or suspended in the water. The suspended matter is often referred to as 'suspended solids' to distinguish it from pollutants in solution.

While 'sewage' usually brings to mind human wastes, the term also includes everything else that makes its way from the home to the sewers from drains, showers, bathtubs, sinks and washing machines as shown in Figure 8.

A generally accepted estimate is that each individual contributes approximately 220 to 275 L of wastewater each day to a city sewerage system.

Wastewater also comes from commerce, industry, storms or from the ground.

- Commercial wastewaters from offices and small businesses include both human wastes and water from cleaning or other smaller light industrial operations like photocopier liquids accidentally poured down the sink.
- Industrial wastewaters may consist of larger volumes of water used in the industrial process, e.g. breweries, dairy factories and tanneries.
- Substances such as paint thinners and petrol and oil illegally discharged into a sewer
- Storms wash waste from car parks, backyards, industrial sites into storm water pipes. Storm water overflow may enter sewers through manholes.
- The ground also can contain toxic wastes dumped years before that leaches out and infiltrate groundwater systems. Seepage also contributes to wastewater where ground water infiltrates old sewer pipes and adds to the volume of sewage that has to be treated.
- Storm water systems carry water from the roofs of houses and buildings, carparks, backyards, city streets, parks and gardens, sporting fields, golf courses and industrial sites but excluding domestic and industrial wastewater. The storm water system should not be connected to the sewerage system.

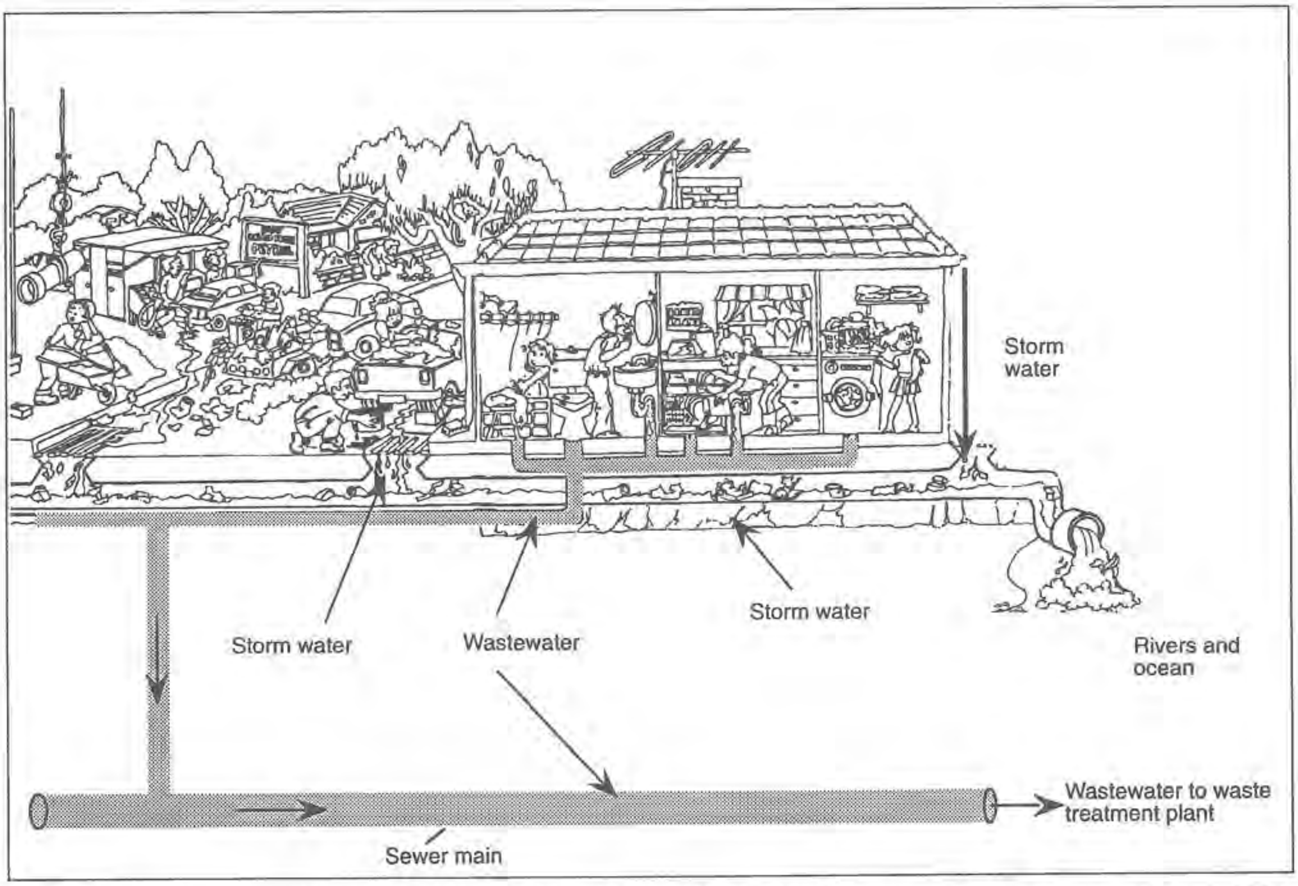


Fig 8 Storm water and wastewater. A generally accepted estimate is that each individual contributes approximately 220 to 275 L of water each day to a city sewerage system (Redrawn from an original concept by the Sydney Water Board).

Wastewater treatment

There are three (3) major wastewater treatment processes that are discussed in this chapter. These all refer to the secondary treatment stage of treating sewage.

They processes are:

- bio-filtration (trickling filter)
- activated sludge and a variation, extended aeration
- oxidation ponds.

The wastewater components of major concern are those which:

- deplete the oxygen resources of the environment into which they are discharged (organic matter)
- stimulate undesirable growths of plants or organisms such as algae (nutrients such as N and P)
- have undesirable aesthetic effects (oil and grease)
- have undesirable health effects on human or animal life (bacteria, viruses, toxic chemicals)

Figure 9 summarises the main processes that occur in the treatment of raw sewage.

Primary treatment

The major goal of primary treatment is to remove from wastewater those pollutants which will either settle (such as the heavier suspended solids) or float (such as grease).

Plastic bags, needles, rags and wood are removed by bars or rotating screens and burnt or buried. Grease and oils float to the surface of the large tank called a sedimentation tank.

Primary treatment will typically remove about 60% of the raw sewage suspended solids and 30% of the BOD in the sedimentation tank. The larger suspended solids settle to the bottom of the sludge.

Soluble pollutants are not removed. At one time, this was the degree of treatment used by many cities. Now secondary treatment is becoming commonplace.

Settled sludge from the sedimentation tank is digested by anerobic bacteria in airtight gas collecting digestors.

Anaerobic bacteria live without oxygen and convert the organic matter into methane and carbon dioxide. This gas can be used as an energy source.

Secondary treatment

The major goal of secondary treatment is to remove the soluble BOD that escapes the primary process and to provide added removal of suspended solids.

Secondary treatment breaks down the suspended solids and dissolved organic matter (measured as BOD).

Secondary treatment is a biological process where naturally occurring microbes or 'bugs', in controlled situations stabilize the organic material by using it as a food source (see Figure 10).

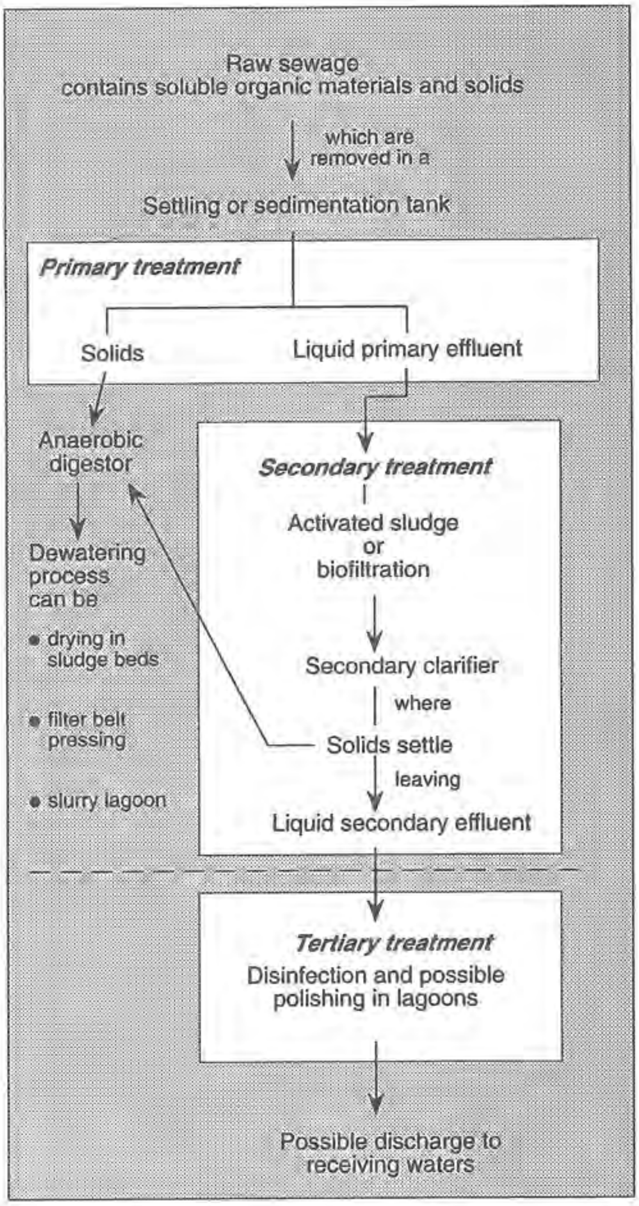


Fig 9 Treatment of sewage

This biological breakdown of organic material requires oxygen .

The basic materials needed for secondary treatment are

- the availability of many micro-organisms
- good contact between these and the organic material
- the availability of oxygen
- the maintenance of other favourable conditions such as temperature.

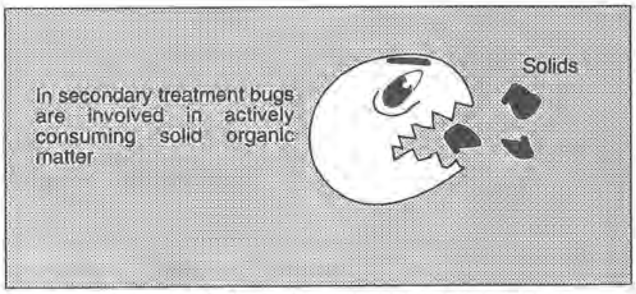


Fig 10 Bugs and their effects in secondary treatment

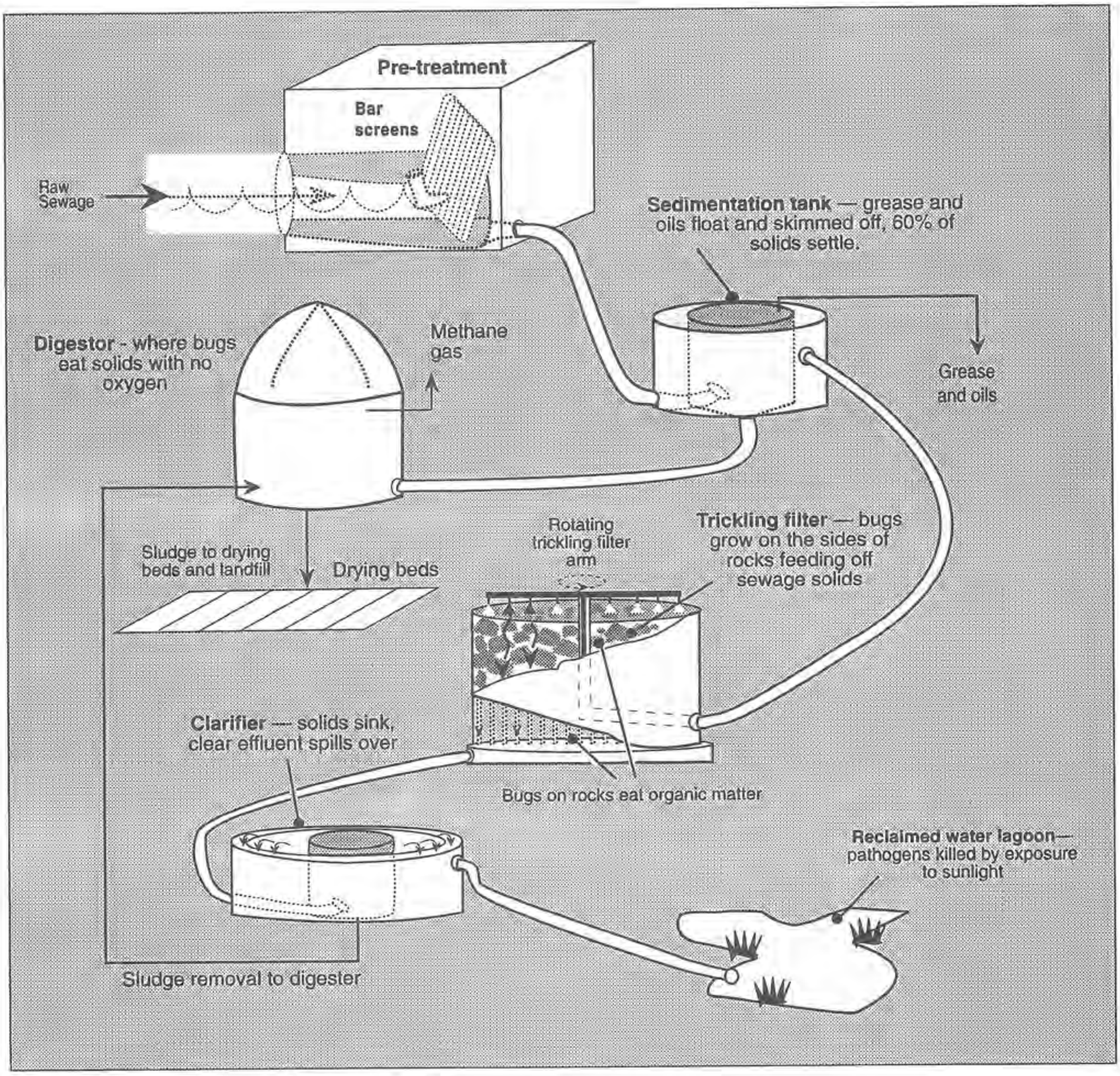


Fig 11 Bio-filtration treatment plant (generalised)

Fig 12 Bio-filtration. Sewage is allowed to trickle over layers of rocks covered with algae and bugs which remove organic matter from the sewage.

Secondary treatment can be achieved by either bio-filtration, activated sludge or oxidation ponds.

Bio-filtration (trickling filters)

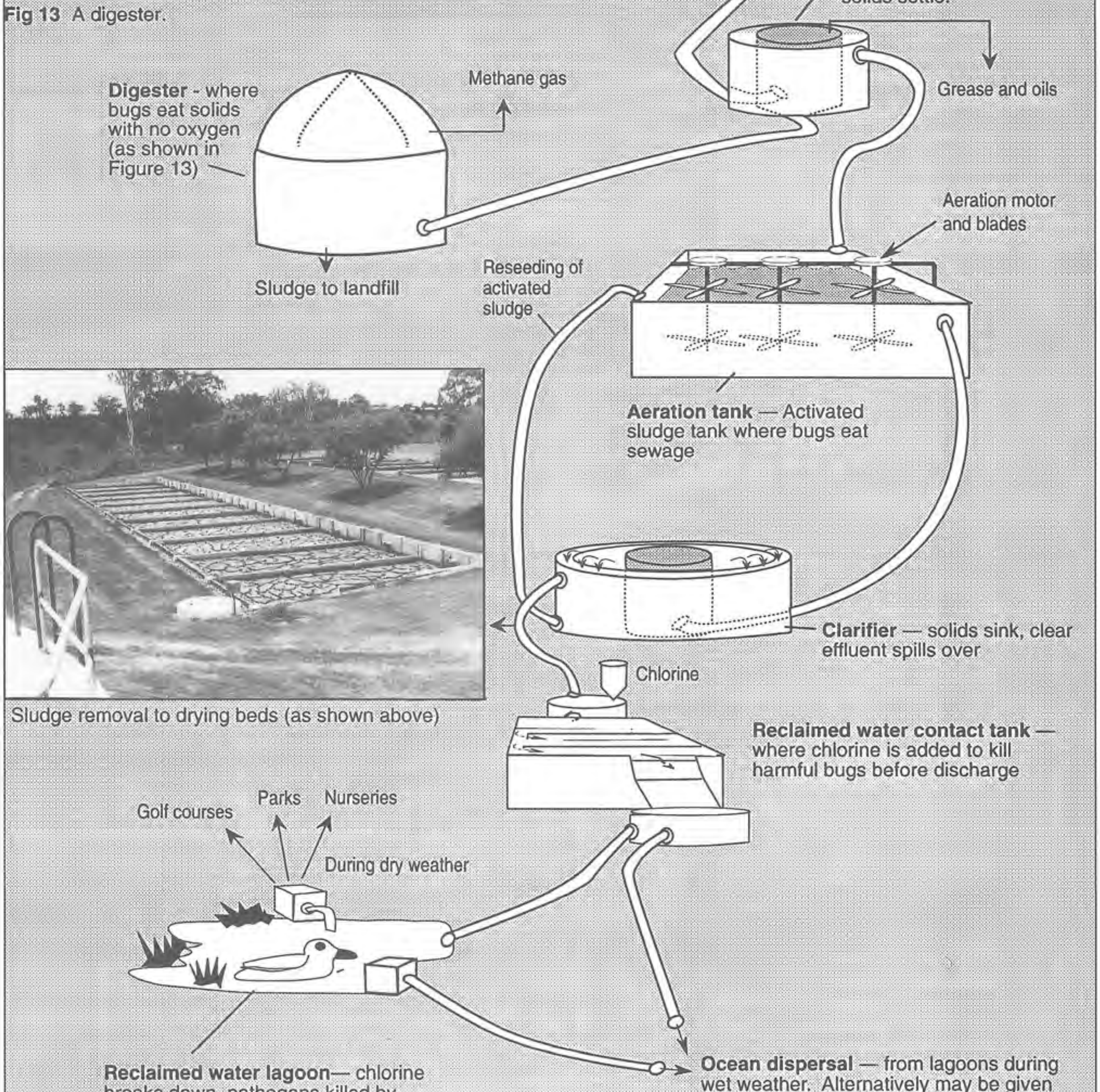
The bio-filtration process is shown in Figures 11 and 12. In this process primary treated sewage is allowed to trickle over layers of rocks covered with algae and bugs which remove organic matter from the sewage.

Excess solids are removed in a clarifier and returned to the anaerobic digester. The effluent is disinfected prior to reuse or discharge.

Activated sludge process

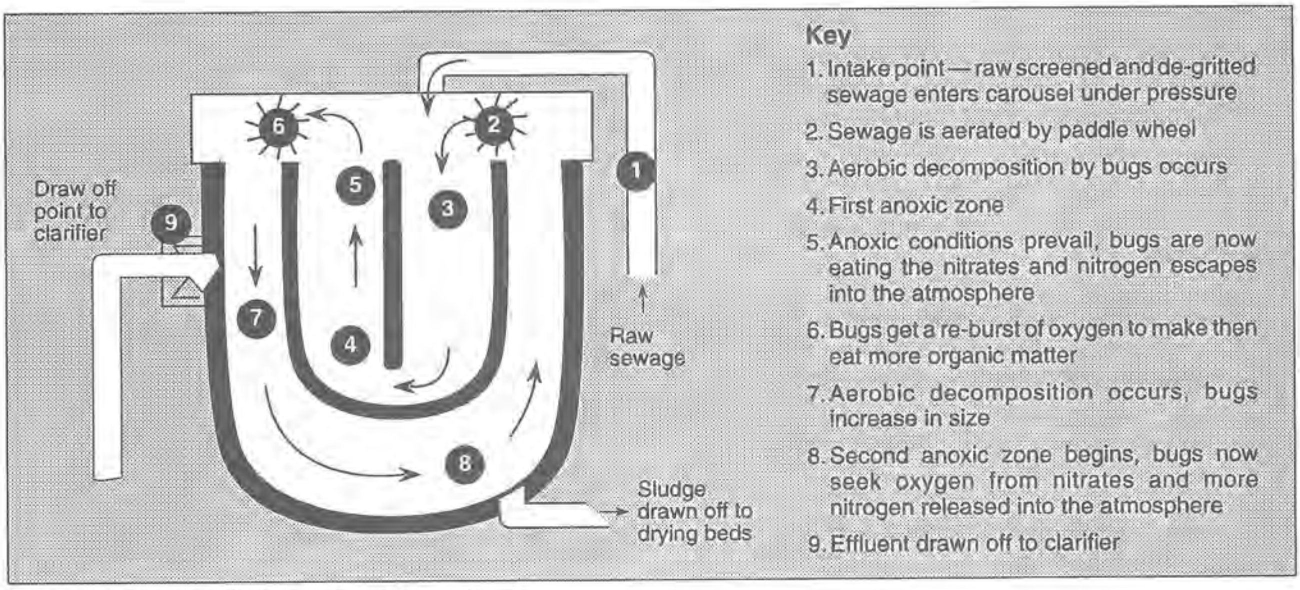
The activated sludge process uses a mixture of sewage and biological sludge (micro-organisms) with the addition of oxygen from aerators which agitate the tank contents as shown in Figure 14. Biological solids are subsequently separated from the treated sewage and returned to the aeration process as needed.

Fig 13 A digester.



Sludge removal to drying beds (as shown above)

Fig 14 Activated sludge wastewater treatment plant



Key

1. Intake point—raw screened and de-gritted sewage enters carousel under pressure
2. Sewage is aerated by paddle wheel
3. Aerobic decomposition by bugs occurs
4. First anoxic zone
5. Anoxic conditions prevail, bugs are now eating the nitrates and nitrogen escapes into the atmosphere
6. Bugs get a re-burst of oxygen to make then eat more organic matter
7. Aerobic decomposition occurs, bugs increase in size
8. Second anoxic zone begins, bugs now seek oxygen from nitrates and more nitrogen released into the atmosphere
9. Effluent drawn off to clarifier

Fig 15 An oxidation ditch (as viewed from above)

Under these conditions, micro-organism are mixed throroughly with the organics thereby stimulating their growth through the use of the organics as food.

The primary treated sewage is mixed with the activated sludge providing a continuous food source for the bugs.

The bugs break down all of the complex proteins, carbohydrates and some fats into simple soluble organic compounds, nitrates and phosphates. From here the bugs are allowed to settle with the sludge in a clarifier. Reclaimed water is drawn off, chlorinated and released into a reclaimed water lagoon as shown in Figure 14. Some of the sludge is returned to the aeration tank to 'seed' the primary treated sewage. The rest is transferred to the anaerobic digester.

Some treatment plants use a variation of the activated sludge process often referred to as an **oxidation ditch**, to treat raw sewage. It combines primary and secondary treatment in a single tank (see Figure 15). Careful control of aeration creates anoxic zones to enhance nitrate removal.

In anoxic sections, bacteria seek oxygen from nitrate, forming nitrogen as a by-product. This nitrogen is in the form of a gas and bubbles off into the atmosphere (as shown in Figure 20).

Oxidation ponds

In this method, bugs are encouraged to grow in a series of ponds which flow into one another by gravity. By the time sewage enters the last pond, the bugs have consumed all the solids and the numbers of pathogenic bacteria and viruses has been reduced. The process is similar to that described in Figure 7.

Phosphorus removal

Phosphorus may be removed biologically by incorporating an anaerobic zone into an activated sludge process at the point where the food is added. Some bacteria are able to accumulate phosphorus as long chain polyphosphates in their bodies under these conditions. Alternatively, phosphorus may be removed from waste water by chemical precipitation using iron or alum salts or lime.

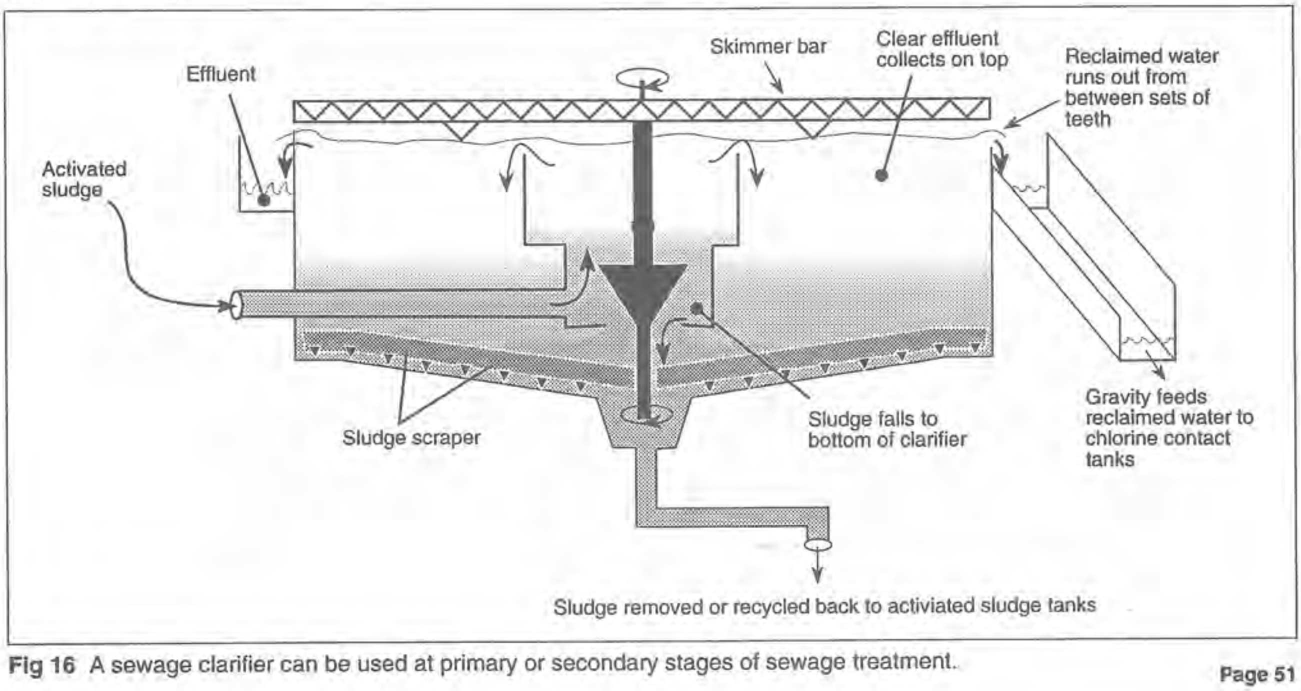


Fig 16 A sewage clarifier can be used at primary or secondary stages of sewage treatment.

Clarification

Figure 16 shown how a clarifier works. A clarifier provides an environment where bugs and other solids can settle. The reclaimed water on top flows out through a series of 'teeth' into a collection trough (see Figures 16 and 17).

Disinfection

Before it is discharged into natural waters, effluent from wastewater treatment plants must be disinfected to kill bacteria and so reduce the risk of disease.

Chlorine is commonly used for disinfection. Alternative methods include UV light, ozone and lagooning (see Figure 20).

Use of the sludge

Sewage sludge contains organic matter and nutrients which make it a useful soil conditioner. Contaminants such as pathogenic micro-organisms, heavy metals and pesticides may restrict its use for some purposes. Controlled composting of sludge with a dry material such as sawdust is one way of disinfecting the sludge and converting it to a useful fertiliser.

Reclaimed water lagoon

Disinfected reclaimed water may be allowed to settle in a lagoon, where chlorine added from the disinfection process breaks down in sunlight. Sunlight also helps to kill viruses (UV treatment) and bacteria.

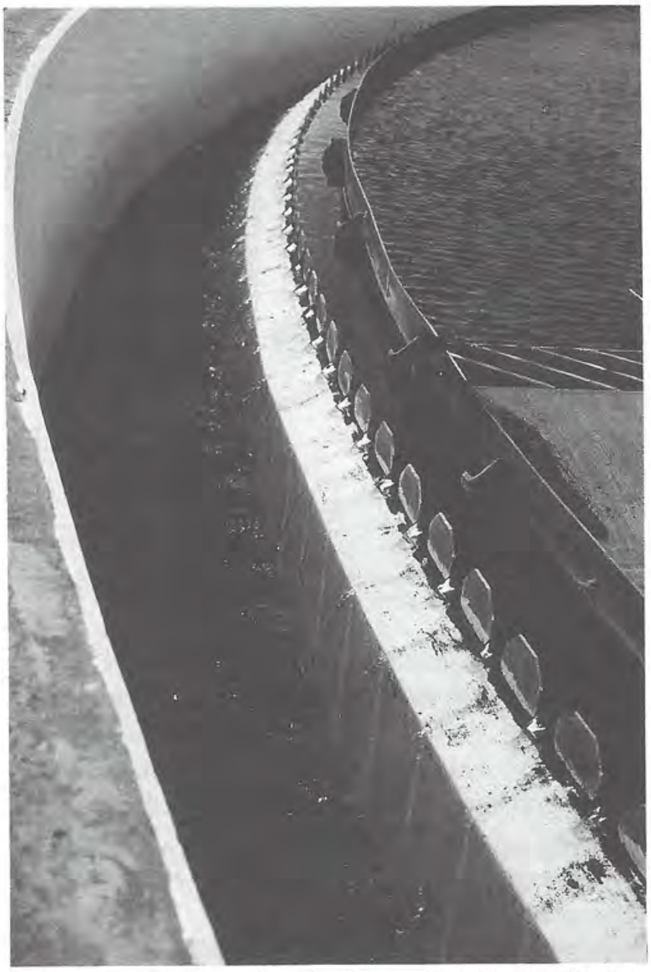


Fig 17 A sewage clarifier showing reclaimed water flowing between the teeth of the collection weir.

Fig 18 Wastewater treatment plant. Clarifier in the foreground is empty for cleaning; oxidation ditch is in the background

Fig 19 Reclaimed water after it has been disinfected

Disposal and use of reclaimed water

Reclaimed water or effluent as it is sometimes called, can be disposed of by discharge to and dilution with, river , stream or ocean water or can be used in the following ways:

- Irrigation for golf courses, parks, gardens and sporting fields. Careful management is required to prevent over watering and overfertilising with any remaining nutients, otherwise runoff and percolation may contaminate surface and ground water.
- Recharging the water source but only if all organic material and nutrients are removed and the reclaimed water has been disinfected.

Note that phosphorus levels in reclaimed water ponds after secondary treatment can range from less than 2 mg/L to 10 mg/L with nitrogen levels ranging from less than 10 mg/L to 30 mg/L. Activated sludge treatment as shown in Figure 14 will yield nitrates at approximately 30 mg/L compared to 3 mg/L in Figure 20 where an oxidation ditch is used.

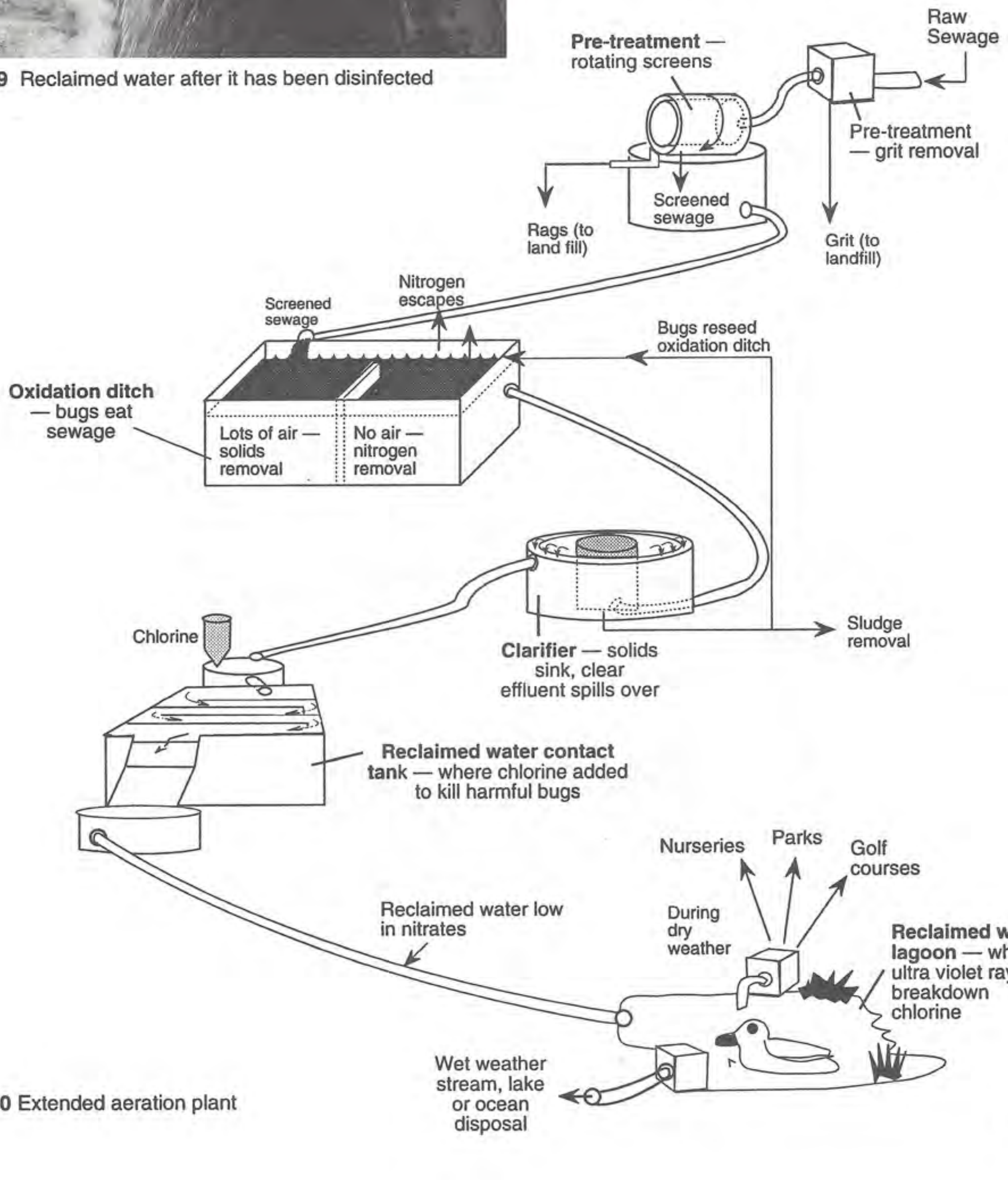


Fig 20 Extended aeration plant

An example

On the Gold Coast, results from two studies over the past 6 years have shown that 1 L of effluent mixes with approximately 200 L of seawater as shown in Figure 21.

- Based on this dilution figure, phosphates of values 6 mg/L in the effluent pipe would dilute to 0.03 mg/L and nitrates of values of 4 mg/L in the effluent pipe would dilute to 0.02 mg/L. Compare these values with the graphs shown in Figures 36 and 38 to see the environmental effect.
- In this case, reclaimed water that is not used on land is pumped out to the seaway from a pipeline. From here reclaimed water dilutes with seawater which in turn evaporates to form clouds and the cycle is repeated.

In the future it is hoped to tertiary treat this reclaimed water and pump it back to the water storage area for reuse by the Gold Coast community.

Tertiary treatment

Polishing

Tertiary treatment polishes the reclaimed water to remove the remaining nutrients, phosphates, and nitrate organics and solids. This improves effluent quality to the point that it can be used safely for a variety of purposes.

A number of processes are used to remove the remaining pollutants, for example:

- phosphorus is removed by chemical coagulation and sedimentation
- further removal of suspended solids and heavy metals by filtration
- removal of organic contaminants by carbon absorption
- nitrogen control by biological nitrification - denitrification.

These modes of treatment are technically complex and very expensive. Some local authorities have added one or more stages of tertiary treatment to their operations. Total tertiary treatment is, however, rarely found in Australia.

Environmental impacts

(The following text is reproduced from pages 33 to 38 of the Environmental Management Handbook, *Published by the Local Government Training Council)*

'Concern about the environmental impact of sewage centres over three major problems:

- The large volume of water used in collecting and transporting sewage.
- The difficulty of removing pollutants by conventional methods of treatment.
- The capacity of waters receiving treated effluent to cope with the load. These problems have resulted in

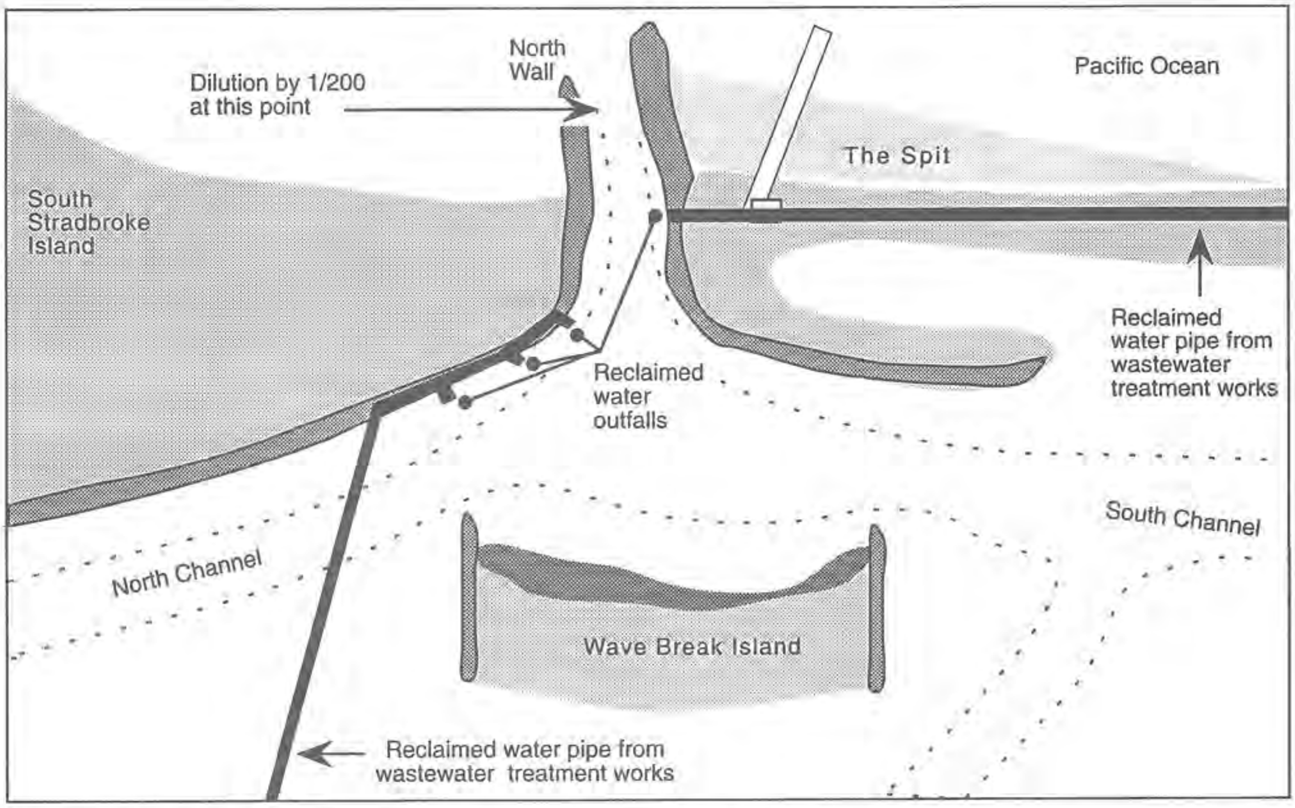


Fig 21 The Gold Coast reclaimed water outfalls. Studies indicate that dilution by 1/200 occurs in oceanic waters within 200 metres of the end of the outfall pipe. Possible alternative methods include altering pipework to tertiary treatment and recharging the city's water supply.

two basic approaches to the treatment of sewage. The first is to mix liquid and other wastes together and transport them to a treatment works, using large volumes of high quality water. The second approach is to use a complex assortment of technologies to treat some of the wastes in sewage, while the remainder are treated by dilution in the natural environment.

The problem of wastewater

As mentioned in this chapter, water-borne wastes are by-products from households, offices, industries and institutions, normally referred to as sewage. There is also runoff from roads, farms, industries and other surfaces. This is often referred to as **storm water**.

The composition of wastewater on average is surprising—it is 99.44% water, and just 0.06% suspended solids and dissolved substances. The amount of water contained in wastewater places heavy demands on sewage treatment works and water supplies. It also affects the chemical and biological composition of the receiving waters— streams, rivers, lakes, estuaries, ground water and ultimately, oceans.

The small percentage (0.06%) of wastewater made up of suspended and dissolved substances consists of:

- organics — compounds of oxygen, carbon, hydrogen, sulphur, phosphorus and iron
- inorganics—sulphates, phosphates, chlorides, salts and heavy metals
- micro-organisms—such as bacteria, fungi, and algae.

These substances, despite conventional treatment and their release in small quantities, have dramatic effects on the environment. These effects are felt both locally and at the ultimate repository of the wastes; in the short term and in the long term.

Treatment processes designed to remove a few milligrams of pollutant per litre of wastewater are comparable to sifting a haystack to remove a needle. But fish die and algae proliferate as a result of minute changes in oxygen and phosphorous levels.

The changes to aquatic life, the loss of potentially productive nutrients and the costly water used as a transport medium, together with the transfer of contaminants to natural systems, combine to make water-borne disposal of liquid wastes increasingly unacceptable in the long term. Alternative means of disposal should be carefully assessed and, wherever feasible, adopted now.

Environmental impacts of sewage content

The full environmental impact of sewage can only be understood by examining the effects of its various components (other than the water). These consist of:

- Biodegradable components— the process of breaking down these compounds reduces the oxygen content of receiving waters. This Biochemical Oxygen Demand (BOD) is the most widely used measure of organic pollution. High levels of BOD kill fish.

This illustration shows the difference between reclaimed water and raw sewage.

Fig 22 Reclaimed water compared to raw sewage. Both contain 99% water (Illustration courtesy Gold Coast City Council)

- Non Biodegradable components (e.g. pesticides) — these substances react with receiving waters to affect their colour, taste and odour. Chemical Oxygen Demand (COD) measures the quantity of these substances present in effluent.
- Phosphorous and nitrogen components—these chemicals stimulate undesirable growth of algae in lakes and streams (algal bloom) affecting water supplies, and oxygen content when algae die.
- Heavy metals (mercury, silver, lead, chromium, zinc, selenium, cadmium)—these substances have been of increasing concern since high levels of mercury in fish eaten by Japanese fishing communities were named as the cause of Minimata disease. They kill fish in great numbers. The effects of small quantities are still incompletely known.
- Dissolved salts (calcium, magnesium, sodium, potassium, chlorides, sulphates and phosphates)—these substances are pollutants which are difficult to remove. They adversely affect industrial, stock and irrigation uses, wildlife water sources and human health.
- Pathogens—bacteria, viruses and parasites are difficult to remove or destroy. They are often transferred to receiving waters which become the source of drinking water for downstream settlements.

Wastewater—the extent of the problem

Two recent studies have highlighted the extent of environmental problems associated with sewage disposal in Australia.

Study 1

Findings of the national 'Water 2000' Report were that in Queensland for instance:

- some areas have no treatment or primary treatment only
- septic systems are frequently over-taxed
- sewage treatment plants have broken down and the effects have been critical in some places. (Oxley Creek Works, 1982)
- heavy reliance on chlorination pollutes streams
- pollution accumulates in rivers and affects downstream water supplies.
- treatment sites are sometimes badly sited— for example, above or below water supply dams, in estuaries with inadequate flushing and in wetlands.

This report also revealed that outside of major cities, the general standard of operation and maintenance of sewage treatment plants was inadequate. Factors adversely affecting standards of operation included:

- lack of control of wastewater inputs
- lack of monitoring of effluent quality at outlets
- inefficient and high cost treatment techniques
- generally low standards of design and operation of works
- adverse environmental impacts of some treatment techniques
- leakage of wastewater at some stages of treatment.
- loss of water in wastewater management and the need to include provision for its re-use as part of plant design
- loss of the nutrient value of wastewater

Study 2

This study by the Australian Environmental Council focused on the problem of nutrient levels in Australian waters. It underlined the difficulty of determining the effects on water bodies of high nutrient levels derived from sewage and of setting effluent standards for all treatment works.

The study concluded that conventional treatment does not remove nutrients to any appreciable extent and that treatment works are generally operating at or beyond their design capacity. The report concluded that there is a continuing need to protect inland and estuary waters.

Alternative methods for effluent dispersal

Options available to Councils depend upon the constraints within which each must work. A large coastal city and a small inland town have widely divergent options. Whatever the circumstances, each Council should consider carefully the environmental implications of its choices.

Alternatives open to Councils go beyond merely adding a technological refinement to the form of treatment they currently operate. Among the available alternatives are the following:

Fig 23 Biological toilet in Noosa Shire

Method 1 Land treatment or treated effluent reuse

In Australia, the driest continent on earth, of the total annual sewage flow, only 5% of treated effluent is reused, rising to 7% during unusually dry periods.

This is despite the fact that a high quality effluent can be produced by land treatment. This method entails application of effluent to land (usually after secondary treatment) by means of either irrigation, surface flow, or infiltration and percolation.

Not all areas are suitable for land dispersal of primary or secondary treated effluent, however. Careful investigation of ground water movement and the subsequent uses of ground water are necessary before this method can be safely adopted.

The advantages and disadvantages of the method can be summarised below:

Advantages

- Natural processes are used to disperse the water and its contents.
- Nutrients can be used for crops, forests, parks and gardens.
- Water can be used in industry, or to re-charge ground water supplies.
- End-use can be planned according to the level of treatment it has received.

Disadvantages

- Possible dispersal of heavy metals.
- Nutrients may cause excessive plant growth in water bodies receiving effluent run-off.

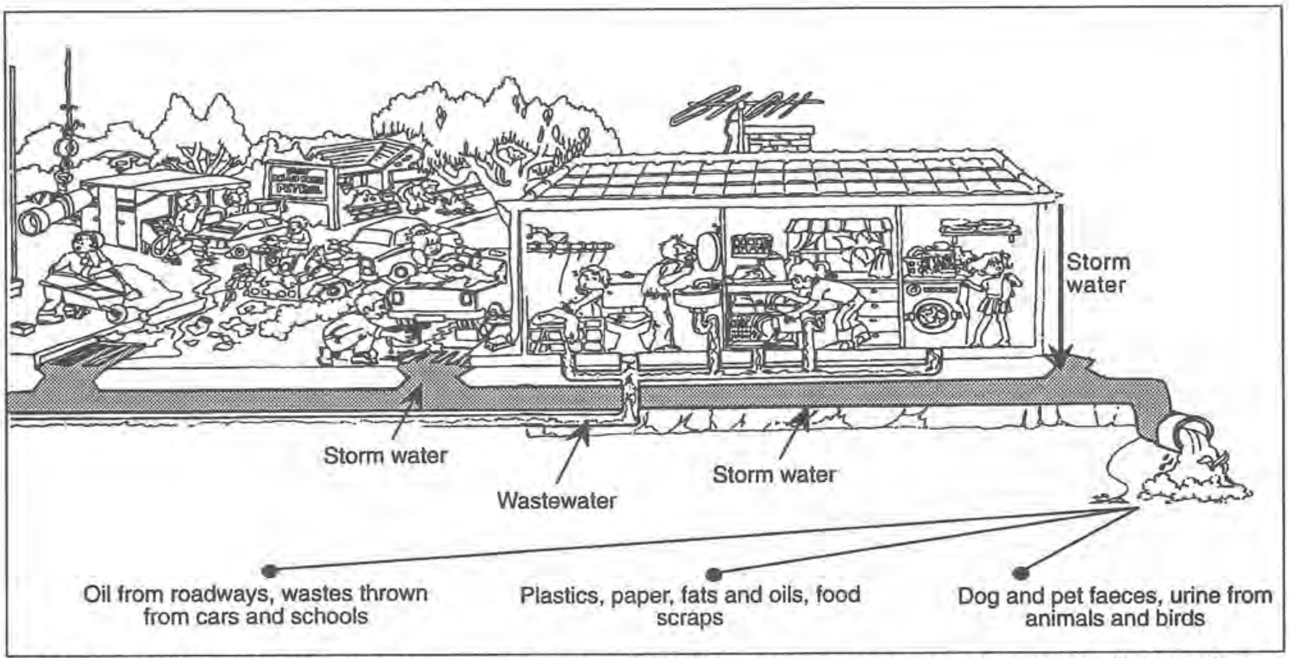


Fig 24 Storm water can be potentially dangerous when combined with the attitudes of poor catchment users (Adapted from an original concept by the Sydney Water Board)

- Nitrogen levels in ground water must be carefully monitored.
- Primary treated wastewater has more limited use than more fully treated effluents.

Method 2: The biological toilet

This is a self-contained, composting technology with no drain, no sludge pumping and no chemicals It is an efficient method which is environmentally sound.

It can be used in remote or environmentally sensitive areas due to its sealed operation. Water-less or biological toilets have been installed in recreation areas in Noosa and Redland Shires in Queensland. (Figure 23)

Method 3: Sludge treatment and use

The higher the degree of wastewater treatment, the greater the residue of sludge that must be disposed of by burning, treating for use, or some other way.

In the United States some cities treat sludge by thickening, chemically stabilising and dewatering it. It is then packaged for sale as fertiliser. Sludge contains nutrients and some beneficial trace elements which make it useful as a soil conditioner.

Problems with its use are still under investigation. They centre around the micro-organisms and heavy metals which it contains.

Method 4: Estuary outfall

Estuary outfall differs from ocean outfall to the extent that the former has lower levels of flushing and greater variations in flow. Estuaries are ecosystems with high biological productivity as compared with oceans. Heavy metals deposited in estuaries, or increased nutrient levels, have far-reaching effects in such dynamic ecosystems.

Ocean, estuary and river outfall are common practices in Australia. Yet they are not sound environmental practices, nor are these methods cost-effective when water wastage and the costs of environmental impacts are fully assessed.

It can be argued that these practices simply defer the inevitable need for more self-contained methods, as environmental standards become more stringent

Method 5: Ocean outfall

One of Australia's capital cities, Sydney relies on primary treatment (or no treatment) followed by ocean discharge. Studies of nutrients present in Australian waters indicate that, at this time, nutrient load in ocean waters poses no serious problems. However, the worsening condition of Sydney's Bondi Beach does give reason for concern in the future. While ocean outfall provides high levels of dilution by natural processes, there have been instances in Hawaii, Japan, the United Kingdom and especially the United States where 'black ooze' and other forms of pollution associated with ocean outfall have caused serious concern. In the United States these problems have caused serious economic loss, disruption of tourist trade, massive fish kills and major public health threats. The salient point to be made at this time is that the dynamics of effluent movement in aquatic environments are poorly understood. The advantages and disadvantages of Ocean Outfall can be summarised as follows:

Advantages

- Cheaper than most forms of secondary treatment.
- Large volumes can be dealt with.

Disadvantages

- Reliance on ocean currents and ecosystems for dilution and dispersal.

Fig 25 Storm water drains

As Australian Educators learn more about their environment, overseas methods will be replaced by more local standards and procedures,

- No reuse of water.
- Nutrients are lost and no contaminants removed.
- Micro-organisms persist in ocean waters.

The decision to dispose of large amounts of Sydney's wastewater, from the Malabar Treatment Plant, in the form of primary treated effluent and digested sludge by deep water ocean outfalls was a landmark which set the precedent for other coastal cities. It also raises questions with long term implications.

What will happen to marine ecosystems and environments if other coastal cities in the region follow suit? The capacity for any environment to absorb pollution is limited — when will these limits be reached and what will be the consequences? Can they be halted or reversed? Are these costs of cleaning up being passed on to future generations?

Recent experience in North America and Europe has underlined the enormous cost of remedial measures. Estimates of $45 billion have been mentioned in newspaper reports.

Summary

There are many alternatives for wastewater treatment, but none offers a 'quick fix' solution to all the varied conditions faced by Local Government. In setting up or assessing more environmentally acceptable wastewater systems Councils should consider these initiatives.

- Make a detailed assessment of the current system, effluent quality and its effects on receiving waters, the incidence and cost of breakdowns, costs in terms of water usage and electricity.
- Conduct a land suitability study to see where septic tanks and biological toilets are feasible.
- Review building standards to evaluate alternative domestic plumbing practices.
- Include careful assessment of existing or proposed sewerage systems in Environmental Impact Studies for proposed developments.

It will require a conscious effort for Local Government to free its thinking from the constraints imposed by conventional methods of sewage collection and treatment.

As evidence accumulates of the long-term limitations of traditional methods, however, closer examination of alternatives will become more widespread.

Liquid trade (industrial) waste wastewater from industrial and commercial activities requires special attention by Local Government because:

- large volumes of water are used.
- large quantities of wastewater are released into sewerage systems.
- higher concentrations of pollutants are present than in domestic wastewater.
- large savings of water can be achieved by water reuse techniques.

Manufacturers of processed foods, beverages, textiles, paper, chemicals and metal use water for cooling, boiling, washing or adding to their products. Waste treatment may be carried out in the industry itself, or by Local Government. Some Councils and Waste Management Authorities have special liquid waste treatment plants to handle a variety of trade wastes. In Sydney and Melbourne, State Government agencies operate liquid waste disposal facilities at Castlereagh and Tullamarine, as well as Industrial Waste Advisory Services.

In Brisbane, the city council operates a hazardous waste treatment and disposal facility at Willawong which accepts wastes from industry; the council also provides a householder service at no cost to the householder.

Programs designed by Councils to reduce the cost of trade waste treatment and disposal should:

- regulate on-site waste management treatment
- provide incentives or industry to practise water conservation.
- increase re-use and recycling.
- levy charges in accordance with the load placed on sewage operations.
- monitor uncontrolled discharges and reject or regulate toxic materials and pollutants.
- advise upon and regulate improved practices.'

(Reproduced with permission of the Local Government Training Council).

Storm water

Ideally, storm water should pass through small wetland areas before entering rivers or the sea, so that most of the pollutants could decompose prior to discharge into natural waters. However at present there is no treatment of storm water apart from gross screening traps at major pipe intakes in the catchment area. In parts of USA and Europe, pollution of urban catchments has forced some local authorities to treat storm water.

Whatever we drop on the ground and whatever fluids we allow to be deposited on streets or footpaths washes down the storm water pipes and out into rivers, streams or the sea.

Some storm water pipes enter beach areas, others enter streams or rivers. After heavy storms, any rubbish from carparks or the street will end up in the river, stream or beach. Faeces from domestic pets will also be washed into the local swimming holes or into the surf, affecting the water quality for beach and river users.

In some urban catchments, beaches and local parks are cleaned regularly by machines or by manual labour. Street sweepers are sometimes used to clean the surfaces of pavements to remove oil and grit.

It is up to us all to help by making sure rubbish does not enter drains that lead to the sea and by supervising pet behaviour (some local authorities insist that dog owners carry a 'pooper scooper'). Our tourist industry depends on clean parks, rivers, streams and beaches.

Water quality

To appreciate water quality, we must refer to some type of environmental standards. Two American researchers, Stapp and Mitchell, have presented their results as given below.

In the Mitchell and Stapp method, a water quality index called a Q value is established to measure water pollution (see Figure 26).

(Copies are available from WB Stapp, 2050 Delaware Ave, Ann Arbour, Michigan, USA, 48103). In this scheme, Q values are used as follows to indicate water quality levels:

- 80 -100 indicates excellent water
- 60 - 80 good
- 40-60 poor
- 0-40 very poor

As Australian educators learn more about their environment, these methods will be replaced by local standards and procedures.

Individual values can also be taken as a pollution index, however an overall value should be used when assessing water quality.

Examples:

- Values of 4 mg/L of phosphate rates about 15 on the table and 5 mg/L of nitrate about 70 on the graphs in Figures 36 and 38. These values in natural waters would indicate some degree of pollution. To minimise eutrophication problems, total phosphorus of less than 0.05 mg/L and total nitrogen of less than 0.5 mg/L are desirable. (Eutrophication is discussed on Page 56)
- Values of pH can vary and the tables should be applied generally. Values of 6 may be normal for some healthy stream waters and yet rate low on the table. The pH of a stream or river is usually specific for that particular stream or river and a local water quality officer should be consulted when attempting to determine what is normal for a local river or stream.

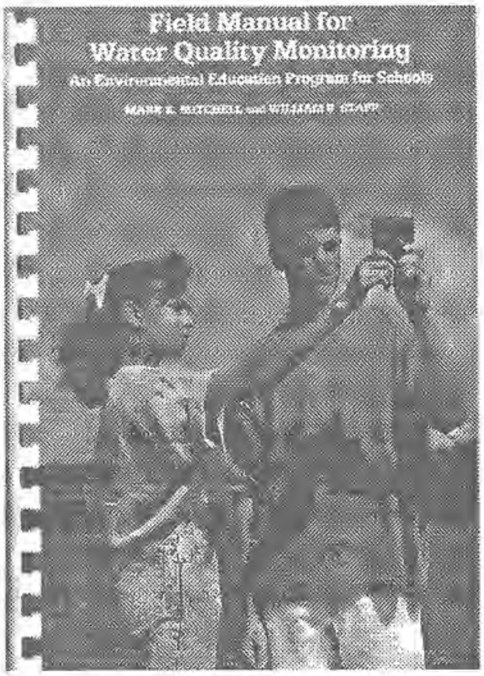


Fig 26 The reference used in this section is the *Field Manual for Water Quality Monitoring*, by Mitchell and Stapp, used in many Australian schools as part of pollution studies.

Faecal coliforms and water

Faecal coliforms are bacteria derived from the faeces of humans and other warm blooded animals. These bacteria can enter rivers through direct discharge from mammals or birds, from agricultural or storm runoff carrying bird or mammal wastes or sewage discharge into the water.

Faecal coliforms which include the bacteria called *E. coli* (Figure 30) are used as indicators of faecal contamination and indicate that there may be other harmful bacteria present such as those causing gastroenteritis, dysentery, typhoid fever, hepatitis or outer ear infections. The standards for these bacteria in water are summarised in Figure 31.

Faecal coliform counts are also used as indicators of water quality.

A test for faecal coliforms

The aim of this test is to count the number of faecal coliform colonies present in a 100 mL sample of water. A number of methods are commercially available.

The kit and procedure described here is the Sartorius membrane filter method which involves trapping bacteria in a filter and then culturing colonies on a nutrient pad set at a specific temperature for a specific time in an incubator. The test has very specific instructions. For example, the very fine membrane filter is placed between two halves of a filter set as shown in Figure 27. A hand pump is used to create a vacuum in the lower half of the chamber and water flows into the lower half, trapping bacteria in the minute pores in the filter.

The filter is then transferred to the specially prepared Sartorius 14068047N nutrient pad (see Figure 29), and then incubated according to the manufacturer's specifications. The special nutrient pad has been embedded with M-FC medium that only *E. coli* can grow on (see Figure 30). The end result using this medium is a blue

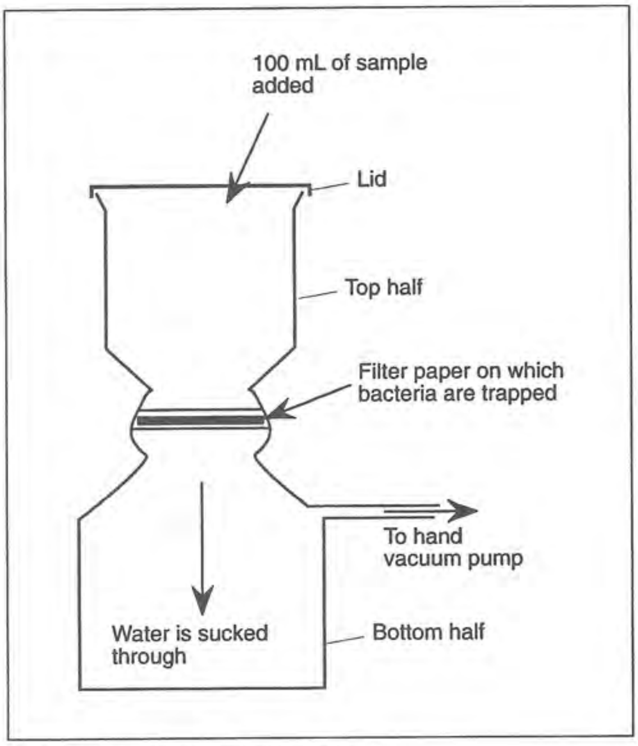


Fig 27 Sartorius membrane filter set

Fig 28 Using a membrane filter pad set, showing the two sections and the hand pump

Special note:
Other nutrient pad sets require different incubation temperatures. People wishing to perform their own faecal coliform test are advised to carefully consult the manufacturer's directions.

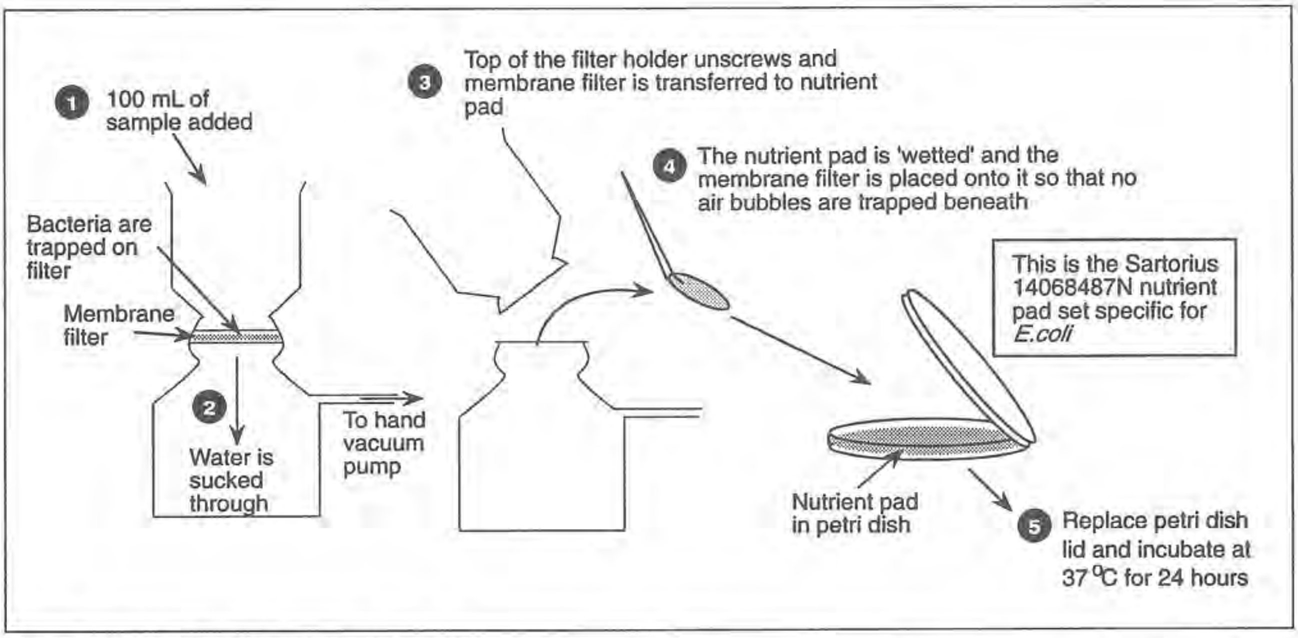


Fig 29 Steps in using the membrane filter set

coloured colony of 1-2 mm in diameter. Colonies of different colours are not evaluated and if counted will give an incorrect result.

There are a variety of methods available for the isolation of faecal coliforms based on different combinations of selected nutrient media and incubation temperatures. It is most important that a given method be carried out as per instructions.

What values are of concern?

Figures 31 and 32 indicate the acceptable values for water. Storm water runoff can sometimes act as a source of high levels of faecal coliforms arising from native and domestic animals.

Local authorities have the power to prosecute offenders if a sewage pipe has been illegally connected to a storm water pipe.

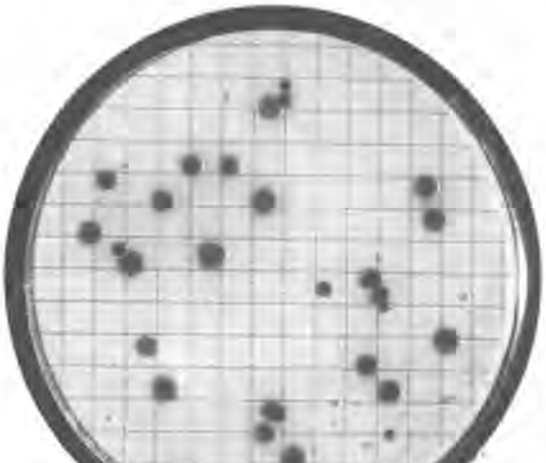
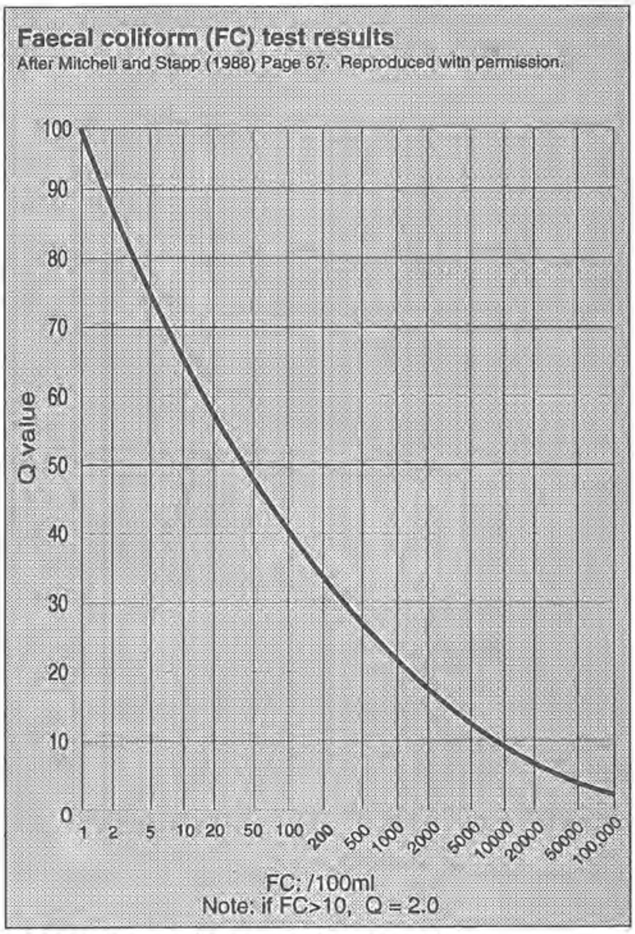


Fig 30 Faecal coliform colonies growing on a special nutrient pad that has been embedded with M-FC medium that only *E. coli* can grow on produce a blue coloured colony of 1-2 mm in diameter.

Faecal coliforms	Safe colony numbers
Drinking water	0/100 mL
Swimming / surfing	200/100 mL
Boating / fishing	1000 / 100mL
Disinfected treated sewage effluent	No more than 200 / 100 mL

Data supplied Dept of Environment

Fig 31 Values set by health standards on faecal coliform counts



After Mitchell and Stapp (1988) Page 67. Reproduced with permission.

Fig 32 Water quality graph for faecal coliforms

In many Australian cities, it is mandatory to carry a 'pooper scooper' when you walk your dog. Collecting your pet's faeces is a really simple task and it helps prevent faecal coliform numbers increasing. In some surf beaches, there are areas clearly marked where dogs are prohibited for this reason also.

Remember that, in general, the *E.coli* colonies are not harmful. They indicate that other more harmful pathogens can be present and alert the water control officer to begin serious testing for their presence.

Eutrophication

If an animal dies and gets washed into the sea, the phosphorus in its body re-enters the food chain. So it is classed as organic phosphorus. Detergents and inorganic phosphorus ions attached to soil particles make up the inorganic components. Phosphorus is an essential component of life and is required for plant growth. It is usually found in very small concentrations in the sea or estuaries and is rapidly taken up by plants. So if the level of phosphorus increases rapidly, plants will grow very quickly. Algae are the most common form of plant life and they colour the water a pea soup colour, indicating a condition called **eutrophication.**

Definition

Eutrophication is an enrichment of water by the nutrients nitrogen and phosphorous. It may result from human activities which result in pollution or from natural fallout from volcanic eruptions, forest fires or natural springs.

Pollution comes from human and animal wastes. Inadequately treated sewage can cause increases in phosphorous levels.

Consider a pond environment. With increased phosphorus levels, algal growth may be rapid. Considerable amounts of oxygen will be produced during the day because of **photosynthesis**.

Why algae use oxygen

At night the algae will remove oxygen by respiration and may deplete the oxygen available for fish and other aquatic life. As a result of increased algal growth and water weeds the amount of organic matter will increase. When organic matter dies, it sinks to the bottom and accumulates, resulting in anaerobic conditions. These conditions favour the production of hydrogen sulphide or rotten egg gas.

The odour from this can be quite normal in areas with a high organic matter content (such as mangrove swamps). The amount of phosphorus in our environment can be lowered by reducing the amount of fertilisers we use in the garden, decreasing the amount of phosphorus used in farm fertilisation, preserving natural vegetation wherever possible near shorelines, and requiring industry to pre-treat wastes.

Many household detergents contain phosphorous. By shopping for phosphate-free products and using natural cleaning agents at home, we will reduce the amount of phosphorous in our environment.

Fig 33 Testing for hydrogen sulphide with a stick in a mangrove swamp

Mangrove activity

(Based on an original idea by John Burnett)

- Take a stick as shown in Figure 33, to a mangrove swamp.
- Push the stick well into the mud and smell it. If the mud has a strong smell, this indicates hydrogen sulphide is present.
- The characteristic hydrogen sulfide gas can be found in many places where organic matter is high.
- Eutrophication is a natural part of ecosystems.
- In other places where there is not as much organic matter, the stick will not smell at all.

Excursion to a wastewater treatment plant

Aims

- To develop good communication skills with a local authority or council
- To unmask some of the unrealistic perceptions humans have about their own waste and how this waste is linked to the water cycle
- To test samples of reclaimed water for pH, nitrates, phosphates, dissolved oxygen and faecal coliforms

Developing communication skills

Make contact with the local wastewater treatment plant manager and arrange an excursion. Also make contact with the local water authority chemist and arrange a visit to see what tests are conducted on site (in some cases the chemist may be a plant operator).

If your school has purchased any of the water testing equipment described in this chapter, take it with you and have the chemist check your technique. Then ask if you can test the reclaimed water yourself and what sort of results you should obtain.

Remember that good public relations are needed to establish a friendly working relationship between the ordinary staff who are responsible for water quality and the school which is going to test the water the plant puts out.

All to often, environmentalists take a confrontational approach, whereas simple communication will overcome any anxiety in the testing of reclaimed water.

Unmasking some of the misconceptions

If good communication results between school and local authority, a tour can be arranged as well as the possibility of visiting the laboratory on site. Make a plan drawing of the plant like the one shown in Figure 34. Carefully mark where you go with numbers and relate these to the processes described in this chapter. If possible, ask if you can have a sample of the reclaimed water explaining what you are going to do with it and the equipment you are going to use.

Testing reclaimed water

You have to realise that daily values will vary with a plant according to flow rates and infiltration by water. Each plant will have its own specific requirements based on where it discharges and the volumes and types of sewage processed: for example, the plant shown in Figure 34 below outputs water with the following parameters:

- nitrates 0-6 mg/L
- pH 7.2 - 7.6
- phosphates 2-7 mg/L

Note 1. Coliform tests should be done in strict accordance with sterile procedures to obtain an accurate result and be duplicated up to five times to verify results. Coliform results from the point of discharge from the disinfection tank will be different from that in the reclaimed water lagoon. This is due to the effect that the bird wastes have on the water

Note 2. Dissolved oxygen tests should be done on site.

Note 3. You must check your own personal technique to see if your lab skills are up to scratch. Never take one value only and if results are different, re-read the instructions very carefully before you contact the lab.

Arrange for samples of reclaimed water to be taken and conduct tests to establish, pH, % saturation of oxygen (Refer Chapter 1), concentrations in mg/L of nitrates and phosphates and faecal coliforms.

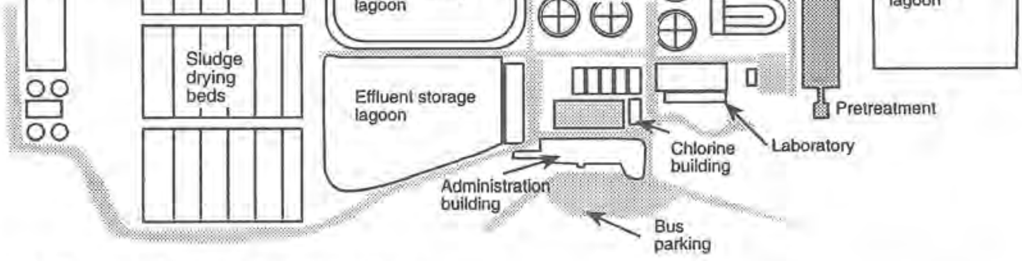


Fig 34 Site plan of a waste treatment plant

Phosphate in reclaimed water


Fig 35 Phosphorus testing kit

Note

Other test kits or probes can be substituted for this test.

The Hach kit and method described here consists of a small hexamine burner, square mixing bottle, 50 mL conical flask, potassium sulphate power pillow, 5N sodium hydroxide solution, phosVer 111 Phosphate Reagent powder pillow, one black box and colour comparator. Tip all solutions into the slop bottle for return to school and disposal according to departmental safety instructions.

You will need a sample of effluent from a chlorine contact tank.

Safety warning

Safety goggles to be worn during this experiment. This kit contains dangerous chemicals. Hands should be washed after the experiment and all solutions disposed of according to Departmental Safety Instructions. The chemicals contained in the pillows are listed in the kit.

What to do

Step 1. Fill the square mixing bottle to the 20-mL mark with the water to be tested. Pour the sample into a clean 50-mL erlenmeyer flask.

Step 2. Use the clippers to open one Potassium Persulfate Powder Pillow. Add the contents of the pillow to the flask. Swirl to mix.

Step 3. Add 2.0 mL of 5.25N Sulphuric Acid Solution by twice filling the dropper to the 1.0-mL mark and discharging the contents into the flask. Swirl to mix.

Step 4. Set up the boiling apparatus. The use of a boiling aid is recommended to prevent violent boiling of the sample.

Step 5. Boil the sample for 30 minutes. Add a little demineralised water occasionally to keep the volume near 20 mL. Do not bring the volume above the 20-mL mark near the conclusion of the 30-minute period. Do not boil to dryness.

Step 6. Allow the sample to cool.

Step 7. Add 2.0 mL of 50N Sodium Hydroxide Solution by twice filling the dropper to the 1.0-mL mark and discharging the contents into the flask.

Step 8. Return the sample to the square mixing bottle. If the volume is less than 20 mL, add demineralised water to return the volume to 20 mL.

Step 9. Rinse the square mixing bottle with demineralised water.

Step 10. Add 2.0 mL of the water to be tested by twice filling the dropper to the 1 -mL mark with the sample and discharging the contents into the mixing bottle.

Step 11. Add demineralized water to the mixing bottle to the 20-mL mark. Swirl to mix.

Step 12. Use the clippers to open one PhosVer 3 Phosphate Reagent Powder Pillow. Add the contents of the pillow to the bottle and swirl to mix. Allow at least two minutes but no more than 10 minutes for colour development. If phosphate is present a blue-violet colour will develop.

Step 13. Fill one of the colour viewing tubes to the mark with the prepared sample. Insert it into the right top opening of the colour comparator.

Step 14. Fill the other tube to the mark with the untreated sample. Insert this tube into the left top opening of the colour comparator.

Step 15. Hold the comparator up to a light source such as the sky, a window or lamp and view through the openings in front. Rotate the disc to obtain a colour match. Read the mg/L phosphate ($P0_4$) from the scale window.

Step 16. To obtain the value as mg/L phosphorus (P), divide by 3 the value obtained in Step 15.

Evaluating the results

Figure 36 shows a graph which can be used to evaluate the quality of effluent.

Before taking the raw figure and applying it to the graph, you should work out how much the effluent is diluted as it mixes with the waters in the environment.

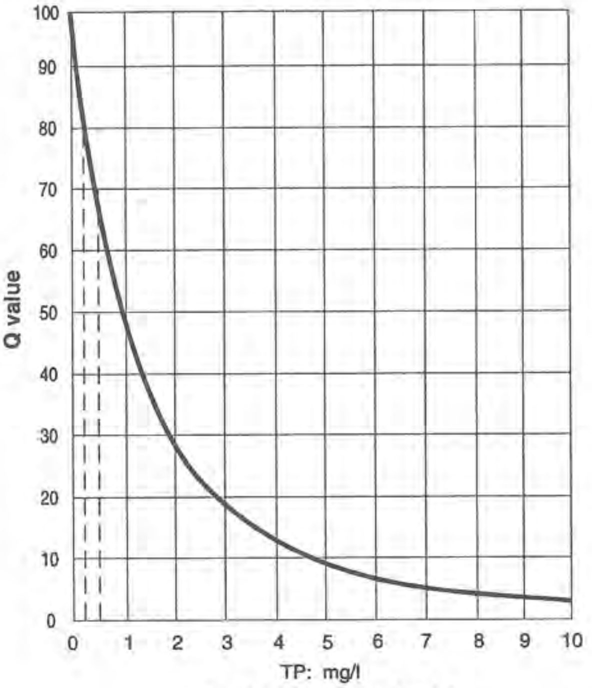
If the effluent was pumped out into a dry creek bed, the dilution would be zero.

However if pumped into the ocean, the dilution could be as much as 1 in 200 within 100 m.

This is important before making judgement based on Figure 36.

Total phosphorous (TP) test results

After Mitchel and Stapp (1988) Page 71. Reproduced with permission.



Note: if T-PO_4 > 10.0, Q = 2.0

Fig 36 Phosphorus water quality curve

Fig 37 Hold the comparator up to the light and rotate the disc until you get a colour match.

Other test kits are available and it is worthwhile looking at the following:

- TPS meters
- Palintest Kit
- Lovi bond

A spectrophotometer, which can be programmed to make accurate measurements, however these are very expensive.

Nitrates in reclaimed water

The kit again is the HACH kit using a colour comparator. Because nitrates vary so much in water samples there are two tests - a low and high range. Note: Only one test is discussed here 0 - 50 mg/L range.

Cadmium warning

The NitraVer reagent contains cadmium metal which should be disposed of in accordance with your local safety officer's recommendation.

Nitrate - nitrogen 0 - 50 mg/L

Step 1. Rinse a colour viewing tube several times with the water to be tested, then fill to the 5 mL mark.

Step 2. Use the clippers to open one NitraVer 5 Nitrate reagent Powder Pillow. Add the contents of the pillow to the tube. Stopper the tube and shake vigorously for exactly one minute.

Step 3. An amber colour will develop if nitrate is present.

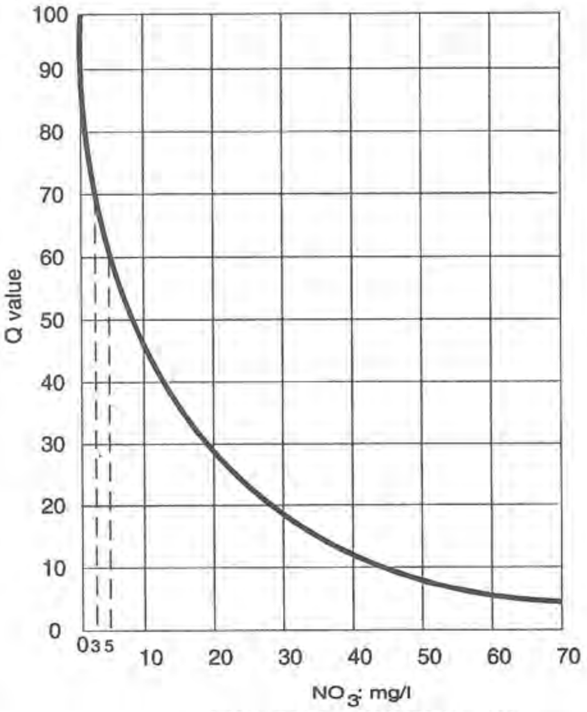
Step 4. Allow the prepared sample to set undisturbed for one minute, then place the tube of prepared sample in the right opening of the comparator.

Step 5. Fill the other viewing tube to the 5 mL mark with some of the original water sample and place it in the left opening of the comparator.

Step 6. Hold the comparator up to the light and view through the openings in front. Rotate the disc until a colour match is obtained. Read the mg/L nitrate nitrogen (N) through the scale window. (See Figure 37)

Nitrate as (NO_3)

After Mitchell and Stapp (1988) Page 72. Reproduced with permission.



Note: If NO_3 > 100.00, Q = 1.0

Fig 38 Nitrate water quality curve

Research

Prepare a report as directed by your teacher on the following topics:

1. Wastewater and its composition
2. Local sewerage systems
3. The problems phosphorous causes in our environment
4. Wastewater pollutants and their measurement
5. Primary and secondary treatment processes and the role of bugs in this process
7. Tertiary treatment of sewage
8. The clarifier and its role in sewage treatment
9. The roles disinfection and ponding play
10. Storm water problems associated with your local area
11. Microfiltration systems e.g. MEMTEC
12. Discuss the statement, 'The less water we use, the less that has to be treated'
13. Discuss the three stages of sewage treatment in terms of the chemical, physical and biological processes occurring in each using diagrams to illustrate your answer. Compare your local treatment plant to these stages.
14. Removal of organic matter from wastewater can be by biological processes or membrane filtration techniques. Discuss these methods using diagrams to illustrate your answer.
15. How can reclaimed water from secondary treatment be used on the land for irrigation?
16. The problems associated with reclaimed tertiary treated water being returned to the domestic water supply.

Revision questions

1. What is sewage and what is sewerage?
2. Why have sewerage systems been constructed in urban communities?
3. Name four locations from which sewerage pipes leave a house.
4. About what percentage of wastewater is actually water?
5. What is the remaining amount composed of?
6. Approximately how many litres of wastewater does each individual contribute to a city sewerage system each day ?
7. What happens in the pre-treatment process in a wastewater treatment plant?
8. What is the difference between a storm water system and a sewerage system in terms of treatment?
9. What is eutrophication and how is it caused? Does it occur in nature? If so, where?
10. Wastewater is made up of organic and inorganic materials. Name three organic materials and three inorganic materials that require treatment.
11. What is the principle in removing solids in a clarifier?
12. Why is chlorine added to wastewater?
13. What should the ultimate goal be of all sewerage plants?
14. What is BOD and how is effluent BOD measured?
15. What should be the BOD of clean river water?
16. What is the meaning of the term 'anoxic'?
17. Draw a diagram showing the difference between primary and secondary treatment of sewage.
18. What is the basic principle of secondary treatment of sewage?
19. Why do we reclaim water from our treatment processes?
20. Name five alternatives to ocean disposal of sewage.
21. Would you drink water with a faecal coliform count of 21 colonies/100 mL? Explain your answer.

Chapter 4

Water conservation

Imagine you are a convict building Australia's first dam in the eighteenth century. It was possibly made of earth, using hollow logs to pipe the water to the colony. By today's standards, the quality of the water would not have been very good; perhaps even dangerous.

Today, urban Australians enjoy high quality drinking water available at the turn of a tap. However, more sophisticated technology than convict labour and hollow logs are required to achieve this.

The value of water

Water's availability has dictated the location and survival of civilisations down through the ages. Maintaining public health and providing food is impossible without a reliable water supply.

Water is also essential to a community's quality of life. Relaxing in a quiet garden or park enjoying lush green gardens and lawns would not be possible without a reliable water supply. People flock to dams, lakes and rivers for recreation. Water has an intangible social value that cannot easily be measured in money terms.

On the other hand, the tangible economic value of water is demonstrated by industry's needs for its use. The average cost of water production in one Australian state is $.46 / kL. Economic stability for all sectors of industry depends on access to reliable, good quality water. Water shortages, whether caused by natural drought or human mismanagement, seriously affect a nation's economy.

Our water resources must therefore be managed appropriately to make the most of the social and economic potential of the land, both for the public interest and the economic future of Australia. Whatever its role, water plays an important part in our lives.

How much money has been invested in water supplies?

Australia's water supply infrastructure of modern dams, pumps, treatment plants, and reticulation pipes is valued at over $50 billion. This represents more than $15,000 invested for every Australian household. Add to this annual operating and maintenance costs of over $3 billion, and we can start to appreciate the true cost of the water that flows from our taps.

Figure 1 shows a comparison of water supply investments for various urban centres and States throughout Australia (AWRC survey 1988-89).

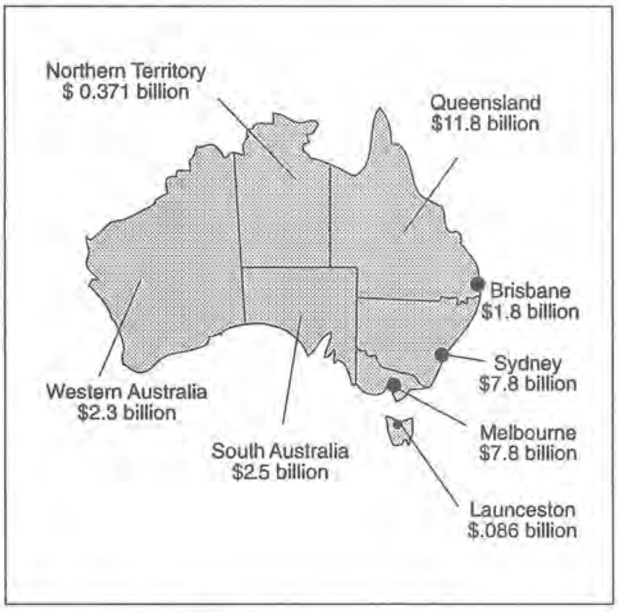


Fig 1 Australian Water Supply Investment

Other costs, not so easily measured, have an even greater significance than dollars.

If demand for water is greater than the available supply, new dams, treatment plants, reservoirs, pumping stations, and reticulation pipes are required, bringing with them the possibility of adverse environmental effects.

Dams, weirs or water storages flood large areas of land, often with drastic effects on people as well as the native flora and fauna. Higher water usage also means increased energy consumption (e.g. pumping, heating), treatment costs, storm water discharges, and sewage flows. These unnecessary loads are detrimental to the environment.

Who looks after our water supply?

Because water is valuable to the community, water supplies must be protected from exploitation. Acts of Parliament involving water resources empower water authorities to investigate, develop, manage, and regulate water resources. These water authorities develop expert staff and technical services to support and ensure that communities and industries have reliable, sufficient, acceptable quality water. The water authority must also manage today's water usage so that there is enough for future generations.

State governments, and regional and local water authorities have the responsibility for managing our water resources. The level of government at which any particular water resource is managed varies throughout Australia.

Research and water conservation

Research on water conservation has been undertaken by water authorities in Australia since the 1970s. In more recent times this research has been used to formulate strategies aimed at achieving real savings in water use.

Recent research on water conservation conducted throughout Australia found that people were motivated to conserve water by:

- an awareness of the quantity of water actually used
- a wish to conserve the environment
- the price of water
- installation of water meters
- use of water restrictions
- excess water charges, and
- incentives to update to new water efficient appliances

The research also indicated that education of the general public is needed in the following areas:

- the quantity of water used
- source of tap water and the processes it goes through before it gets to the tap
- awareness of measures for conserving water-especially outside the house, and
- the roles of the various levels of government and other water authorities involved with managing water resources.

Some key questions asked by the research of over 500 Australians are summarised in Figure 2. Similar research has been carried out elsewhere in Australia, although at a more localised level.

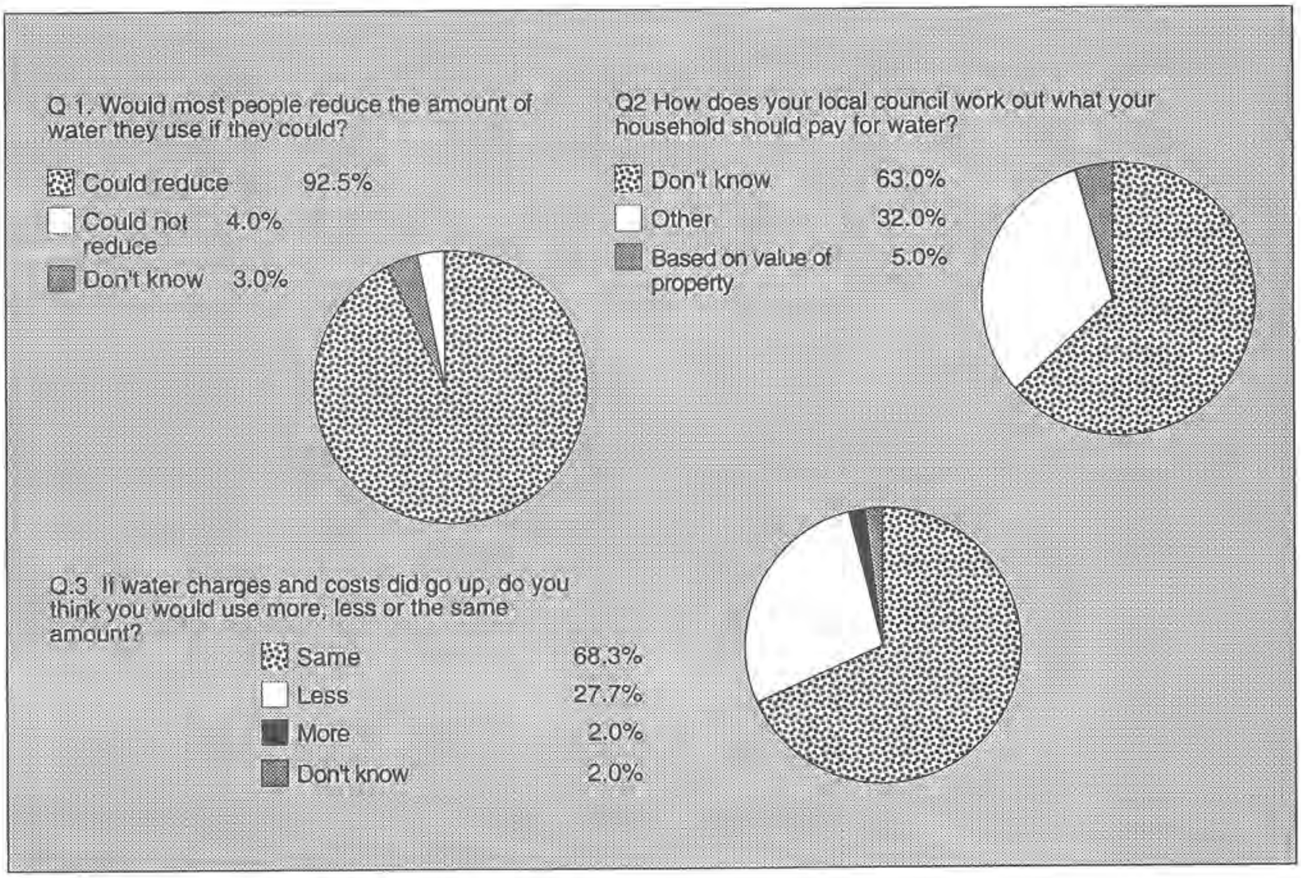


Fig 2 WaterWise survey results from recent research

What governments do to help conserve water

Federal Government

- organising national councils to set guidelines and advise the states on water conservation issues, research findings, and research proposed or being undertaken
- promoting WaterWise 2000 community information
- publishing proceedings of workshops and conferences.

Standards Australia

- producing specifications for plumbing and drainage products and materials
- establishing and promoting the water conservation rating and labelling scheme
- establishing the national plumbing and drainage code which specifies installation of drinking water supply, hot water, and irrigation systems in domestic premises.

State Governments

- passing Acts of Parliament which set standards and by-laws for sewerage and water supply systems
- organising committee meetings to authorise use of plumbing and draining fittings
- providing funds to organise a water conservation campaigns (Figure 3).

Local authorities and water authorities

- enforcing the standard by-laws
- providing reliable, adequate and acceptable quality water supply
- administering local requirements and by-laws
- establishing education programs to encourage people to save water, and
- charging for water use by a metered (user pays) system

Fig 3 Governments help by organising water conservation campaigns.

Standards Australia and water conservation

Labelling

A water conservation rating label from standards Australia is awarded to water-efficient domestic appliances which conform to a specific standard of water efficiency.

The scheme is voluntary. Any manufacturer or importer of water-saving appliances may apply to the quality assurance services division of standards Australia for a certificate and licence to use the water conservation rating label.

As illustrated in Figure 4, appliances are rated against the three categories of water usage specified in the water efficiency standard. The three ratings are:

- A acceptable efficiency
- AA high water efficiency
- AAA excellent water efficiency

Both the supplier and the customer will benefit from the water conservation rating labelling scheme.

For the supplier it:

- tells the customer their product is water efficient
- proves the product has been independently tested and certified, and
- offers a powerful point-of-sale feature.

For the customer it:

- makes buying decisions easier
- gives the comfort of knowing they have made an environmentally friendly decision
- offers the potential to save money on their water and hot water charges.

Fig 4 The quality assurance service AAA water conservation rating scheme

Water Use

Factors affecting water use

Water use in a city is affected by many factors including:

- climate
- availability of water
- water quality
- ownership of the water
- policies
- pricing mechanisms (e.g. pay for use water rates)
- regulation of usage (e.g. restrictions)
- community affluence and lifestyle
- community expectations.

Current water use

As Australia's population rapidly expands, the demand for water is also increasing, thus putting the existing water supply infrastructure under pressure. In some areas, new dams, treatment plants, reservoirs, pumping stations, and water reticulation pipes are already required, and most areas of Australia have to accept some level of water use restriction.

Australians are among the top three consumers of water in the world, yet we have the driest continent. Because Australia is so dry, and hot, we often use water inefficiently and sometimes inappropriately. Our lush green lawns, swimming pools, automatic washing machines, dishwashers, garbage disposal etc. have become the norm in modern urban life, but all of these consume water. Typically, less than 1% of treated water is actually consumed (that is drunk) by people. The other 99% of treated water is used to maintain our lifestyle.

Table 1 compares domestic water use (in-house and garden use) major cities in Australia all of California in the United States of America.

Table 1 Domestic water use comparisons

Urban centre	Domestic water use (kL/person/year)
Adelaide	142
Brisbane	132
Perth	183
Melbourne	107
Sydney	128
California, USA	227

Research has shown that a reduction in general water use is possible without necessarily reducing our quality of life. This reduction would save millions of dollars per year in operating and maintenance costs on existing water supply infrastructure, and through the deferral of new water supply infrastructure development. It would also contribute significantly towards a better environment, lower water charges and lower hot water charges to the household.

All we have to do is be conscious of the way we use water, and set a good example for others to follow. This involves not only using appliances which are water-efficient, but also using the most effective water-saving device.

Water consumption levels

Water is used in many ways for the community's benefit, including fire fighting parks and gardens, etc. When this use is included in water consumption levels, they can vary from as little as 180 kL/person/year (approximately 500 litres/person/day) to as much as 1800 kL/person/year (approximately 5000 litres/person/day) throughout Australia.

Queensland's WaterWise campaign has estimated the State's average consumption to be 220 kL/person/year (approximately 635 litres/person/day). Table 2 is a reasonable estimate of average water use in one Australian state.

Table 2 Queensland's daily water use

Place used	Volume (litres per person)
Daily inside average	205 litres
Daily outside average	205 litres
Industrial, commercial	125 litres
Fire fighting, leakage & community use	100 litres
Overall daily total	635 litres
Average usage household activity/appliance	**Volume (litres per person)**
Toilet (full flush)	12 litres
Bath	100 litres
Shower	150 litres
Dishwasher (per load)	50 litres
Washing machine	150 litres
Tap running while brushing teeth	5 litres
Hand basin	5 litres
Drinking, cooking, cleaning	8 litres
Garden sprinkler per hour	1000 litres
Car washing with hose	200 litres
Hosing driveway	75 litres
Dripping tap all day (one drip per sec)	30 litres

Water efficient appliances

A water-efficient appliance (as shown in Figures 5 and 6), has water conservation as one of its design criteria. One of the important aspects of water-efficient appliances as a means of achieving water conservation is that, once they are installed, they are generally independent of the attitudes or behaviour of the user.

Background

More information is available from Fact Sheet Number 2.

Australian studies show that a significant proportion (25%-60%) of domestic water consumption is used inside the home. The use of this water can be typically divided thus:

- 19% in the bathroom
- 12% in the toilet
- 10% in the laundry
- 9% in the kitchen
- A further 50% is used outside for gardens, lawns, washing cars, etc.

These figures highlight the importance of water-efficient appliances in reducing consumption, and the potential savings that could be achieved. Many water-efficient appliances are now on the market, including dual-flush toilets, shower roses and dishwashers. Considerable progress has also been made on producing clothes washing machines which use less water.

Other water-efficient appliances include smaller baths, aerators on taps, spring-loaded self-closing taps, flow control valves and waterless toilets. For example, if all shower roses were changed to those which ran at 9 L per minute (and shower lengths stayed the same), then we would cut water consumption in the shower by up to 50%.

Similar savings can be achieved by using water-efficient washing machines and dual-flush toilets as will be discussed later in this chapter.

However, we should ask ourselves whether it is economical to encourage a more rapid change over from these resource-rich appliances than is likely to occur naturally. Is it enough to simply take into account the forecast savings?

Real savings from introducing water-efficient appliances takes time because items are introduced slowly, generally as existing appliances are replaced. However, changes to appliances could produce a saving of up to 15%.

Detecting leaks

As discussed in Chapter 2, water enters the house from the street through the water main. When the stop valve, located on the footpath, is turned on, water usually flows through a water meter to the house. The water meter and stop valve are situated on local authority land. Any water used past the meter is paid for by the householder. This is why it is important for householders to make sure that there is no inefficient use (eg. leaks) in the their part of the system.

You can use the water meter to detect leaks in your household water pipes and/or water appliances. To do this, read the meter and then make sure no water is used over a reasonable period of time (say three hours). After this time, take another meter reading and if there has been a leak, the meter readings will be different.

Fig 5 A water saving shower head

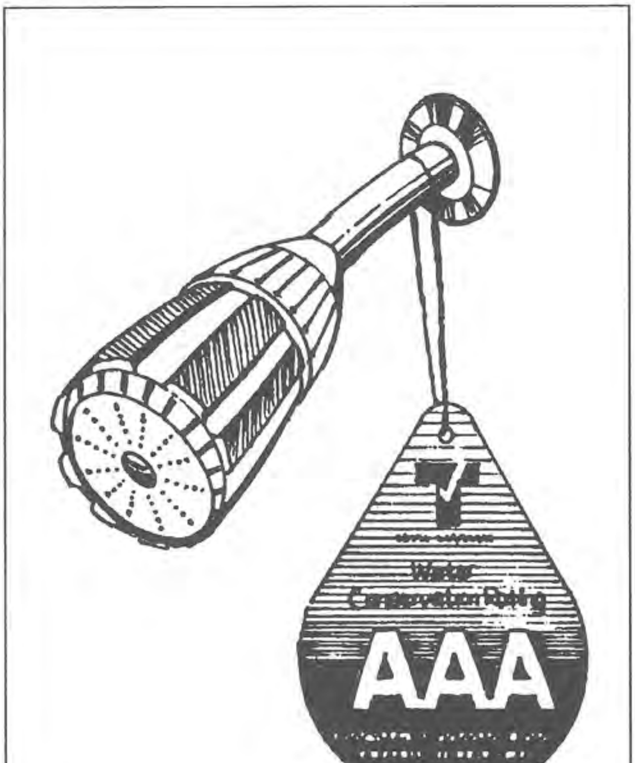


Fig 6 The AAA rating for a water-saving device

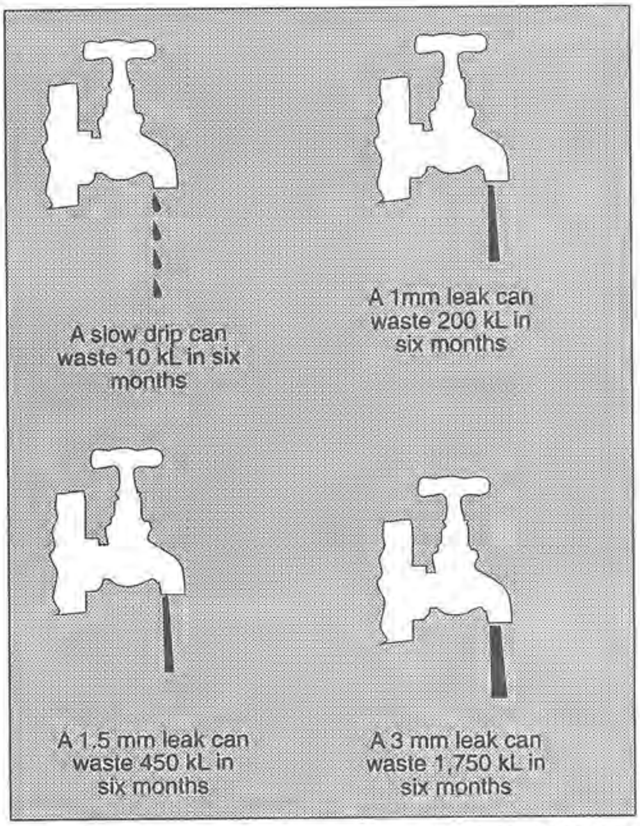


Fig 7 Huge amounts of water can be waste from leaking taps (based on an original idea from the Brisbane City Council)

Figure 7 gives an indication of just how much water can be wasted from leaky taps.

Wetness around taps and hot water systems is an indication of leaks in your household plumbing system. If the leak is underground and in sandy soils, it may be impossible to find as the leaking water will soak into the water table. If you suspect there is a leak underground, you need to seek expert advice from your local plumber or council water supply officers .

The WaterWise town

As you can see from Figure 9, there are many aspects of urban water conservation. A colour poster is available from your water authority and there is an activity at the end of this chapter to highlight the main features which are:

1. Water for the town is stored in the dam.
2. Water treatment plants prepare water for piping to town.
3. Reservoirs store water. Pipes from reservoirs gravity feed to houses.
4. Depth testing is carried out at night to determine leaks.
5. Pump used to supply water to elevated suburbs.
6. Pipe being installed to bring water to the school.
7. Pipe leak detection.
8. Turning tap off to check and repair pipeline.
9. Water enters the house via the water meter.
10. Turning off dripping tap.
11. Washing house windows with water from a bucket.
12. Washing the car with water from a bucket.
13. Making a mound of soil around a tree to hold the water until it soaks down to the root system.
14. A water-saving shower rose
15. Turning the tap off when brushing teeth.
16. Washing vegetables with the plug in the sink.
17. A dual-flush toilet.
18. A drip system with a timer on the tap for the garden.
19. Sweeping the path rather than hosing.
20. Planter boxes with dripper system.
21. Planning a WaterWise supply system for a high rise building.
22. Public meeting discussing how to reduce water consumption by 20%.
23. Designing a WaterWise supply system.
24. Water-efficient public toilets.
25. We all pay for the water we use.
26. Checking sewers for leaks.
27. Leaks in sewers being repaired.
28. Waste water from the house drains into the sewer pipes.
29. Pump in the sewer system pumps waste water to treatment plants.
30. Waste water treatment plants recycle water for use on the land.
31. Golf courses are excellent places for reclaimed water to be used.
32. Pipeline construction
33. Treated water stored in pond after treatment.
34. Saving water means saving energy.
35. Washing machine water level is adjusted to suit load.

How to conserve water inside your house

How can we conserve water without affecting our lifestyle? It's easy-read on and just follow the simple tips.

In the bathroom

- There is no need to run water down the plug hole while brushing your teeth (see Figure 8). Just wet your brush and fill a glass for rinsing. If everyone turned off the tap while cleaning their teeth in a city of about 1 million people, on average, 10 Olympic swimming pools of water would be saved each day.
- Don't rinse your razor under a running tap. Fill the sink with a little warm water for rinsing. This is just as effective as running water and far less wasteful.

Fig 8 Turn the tap off when you brush your teeth and have a glass of water to rinse out with.

If everyone turned off the tap while cleaning their teeth in a city of about one million people, on average, nine to ten Olympic swimming pools of water would be saved each day.

A colour poster of Figure 9 below is available from Water Resources, Department of Primary Industries, GPO Box 2464, 4001.

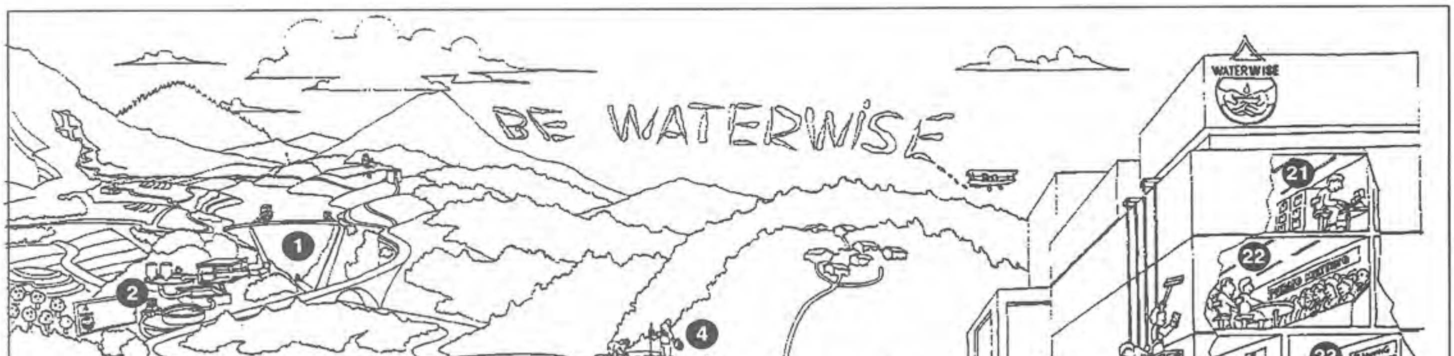


Fig 9 Summary of main features of urban water conservation

- Install a dual flush toilet (see Figures 10 and 11). Modern toilets give the option to flush either half or all the cistern's water. Traditional toilets can usually be converted to dual flush. The installation of these types of toilets is now mandatory in new homes in many local authority areas.

Fig 10 Large amounts of water can be saved by installing a dual toilet

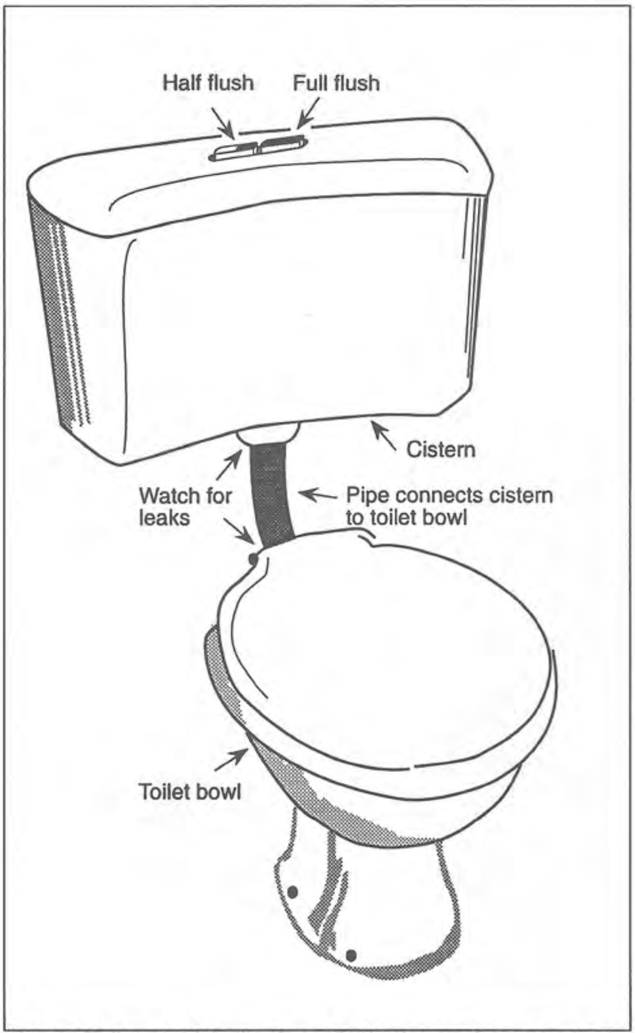


Fig 11 Toilets work by having a flush of water from the cistern to the bowl.

- **A word of caution.** Toilets are currently manufactured to flush with 6 L full and 3 L half. If installing a dual toilet cistern, you need to check to see if the bowl has to be replaced as well.
- Remember the toilet is not a rubbish bin to flush away tissues, wrappers or small scraps. This wastes water and places an extra burden on the sewerage system.
- The toilet was often called a WC or water closet. However not all toilets have to use water and much research is being directed to the development of waterless toilets. These toilets break down human waste on site using bacterial action (composting toilets) and are already being used in some National Parks. Before we see the use of composting toilets in everyday urban situations, however, much research and development is required.
- A continuously running toilet can waste more than 16 000 litres of water per year. To check if the toilet leaks, put a little food colouring in the tank. If, without flushing, the colouring begins to appear in the bowl, the cistern should be repaired immediately. A common site for internal leaks is shown in Figure 11.
- Take shorter showers (see Figure 12). Limit showers to the time it takes to soap up, wash down, and rinse off. Four minutes is ample and you will have saved water without losing the enjoyment of the shower. Remember that shorter showers also save on hot water costs. If time is what you like, try a bath.

Fig 12 Shorter showers save water.

- Install a water-saving shower rose. Many showers put out 20 L of water per minute, however, 10 L is enough for a refreshing, cleansing shower. Water wasting showers usually have a big shower head with large holes in the shower rose. A water saving shower head has a flow control unit as shown in Figures 5 and 6. Alternatively, a water saving valve can be installed in the shower recess.

In the laundry

There are basically two types of clothes washing machines: top loaders and front loaders. In terms of water and energy efficiency, the front loaders lead the way. Front-loading machines are approximately 25% more water efficient than top loading machines.

The Urban Water Research Association of Australia (UWRAA) calculated in 1989 that for a household with 4.5 kilograms of washing and 5 to 7 loads a week, annual water savings between 9000 L and 13000 L can be made by choosing a front loading machine rather than a top loading machine.

One of the authors of the UWRAA report noted in January 1992 that although top loaders have improved in recent years, they still do not rival front loaders for water efficiency.

Here are some suggestions for conserving water in the laundry:

- Make sure the washing machine's load adjustment is right for the load. If there's no load adjustment, wait until you have enough clothes for a full load. Washing machines use 100-200 L of water per load (see Figure 14); and money is wasted on electricity and water by running the machine more than is necessary. Always check for leaks from your washing machine.
- Front loading machines are generally more efficient than top loaders and save water and power. Also, use the sud-saver option (if available) when several loads have to be washed.

In the kitchen

Dishwashers

Dishwashers have become more water efficient over the last 10 years. Households with dishwashers have traditionally used a third more water for washing up than households without a dishwasher. However, as newer, more water-efficient models penetrate the market this discrepancy is disappearing; but dishwashers are still not as energy efficient as manually washing up.


Fig 13 Don't let the water run down the drain when you prepare vegetables

The UWRAA notes that 'manufacturers (of dishwashers) are continually improving the designs and washing actions in an endeavour to reduce running costs and water consumption'.

The UWRAA reported in 1989 that the various models of dishwashers use between 20 and 60 L per normal cycle, with the average being 35 L. This final figure represents about 12 L per meal and compares favourably with manual washing of dishes, where the average amount of water consumed is estimated to be between 12 and 15 L per meal.

Here are some handy hints:

- When washing dishes by hand, don't rinse them under a running tap. If you have two sinks, fill the second one with rinsing water. If you have only one sink, stack washed dishes in a dish rack and rinse them with a pan of hot water.
- Wash up by hand rather than always using the dishwasher.
- Don't run the automatic dishwasher until you have a full load. This saves water and electricity.
- Don't let the tap run when cleaning vegetables (see Figure 13). Just rinse them in a plugged sink or a pan of clean water.
- Keep a bottle of drinking water in the refrigerator. Running the tap until the water is cool enough to drink is wasteful.
- Aerating taps are inexpensive and can reduce water flow by 50%.
- When cooking, use only a little water in the saucepan and keep the lid on.


Fig 14 Use a full load when washing.

- Garbage-disposal units use about 30 L of water per day and send a lot of extra rubbish into the sewers. This places an additional load on sewage treatment plants. Perhaps some of your food scraps could be used in the garden.
- When buying a new appliance that uses water, be sure it has a high water conservation rating.

Hot water pipes and systems

- Insulate hot water pipes. This avoids wasting water while waiting for hot water to flow through and saves power.
- Make sure your hot water system thermostat is not set too high. Adding cold water to cool too-hot water is wasteful.
- If you have a spa, ensure it is well insulated to keep water warm for longer. Reheating the water during the re-circulation/spa process reduces water wastage.

How to conserve water outside your house

The garden

- Soak, don't spray. While giving the garden a quick drink every night may be good therapy for you, it does nothing for the plants. It makes them shallow rooted and dependent on the meagre amount of water you provide. Most of this water is wasted through evaporation.
- Water your plants every fourth day in summer, but for longer periods. This makes the plants hardier and encourages the roots to go deeper into the soil to seek out moisture. Train your plant and lawns to be tough.

  Too many plants are pampered to the point where they are so dependent on you for water they do not go out of their way to find water. Use an indicator species like bamboo and water when the leaves start to droop.
- Water the roots, not the leaves. Contrary to popular belief, watering the leaves of trees and shrubs is not beneficial. It just increases water loss through evaporation. In fact, in some circumstances water on leaves on hot sunny days can damage them.
- Use a good mulch. Mulches can prevent up to 73% evaporation loss and they are one of the cheapest and easiest ways to make the most of water in the garden. The best mulch is a well rotted compost which will also improve the soil structure. Place the mulch away from the trunk to prevent 'collar rot' occurring around the base of the plant.
- Group plantings make sense. By grouping the plants in the garden into high and low water users, you can design a watering pattern that is better for your plants. Also find out which species are native to your local area as these will tend to use the least water.
- Catch it if you can (Figure 16). A small trench dug around a tree will give the water a chance to soak into the ground. Install a rainwater tank for garden use.
- Install a drip system (see Figure 16). This is probably the most beneficial and efficient method of watering your plants. It places the water where needed, is cheap and easy to install.
- Sprinkler days are there to help us keep us all honest. Your local water authority publishes tables like the ones shown below.

WaterWise Watcher

House No	Sprinkler Days						
	M	T	W	T	F	S	S
Odd		✓		✓		✓	
Even/ unnumbered			✓		✓		✓

- A forgotten sprinkler can waste over 1000 L an hour. Use a timer (see Figure 15).

  Manual timers are ideal because they won't even turn themselves on unnecessarily.
- Avoid watering when it's hot or windy and you'll reduce waste through evaporation (see Figure 14)

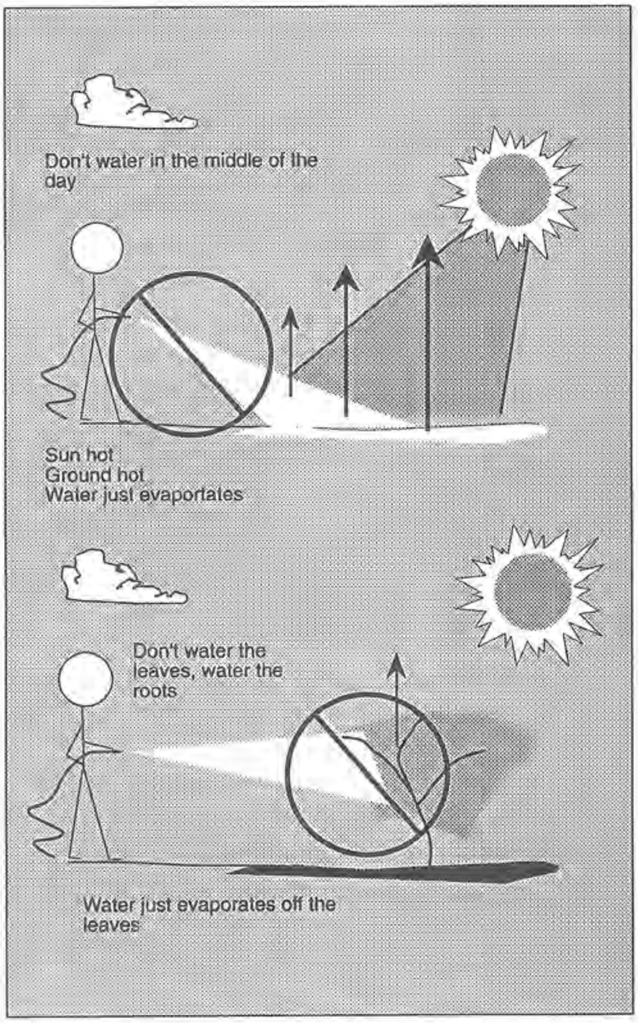


Fig 14 Watering in the heat of the day is a waste of time.

Fig 15 A timer for the tap is an inexpensive way to manage watering.

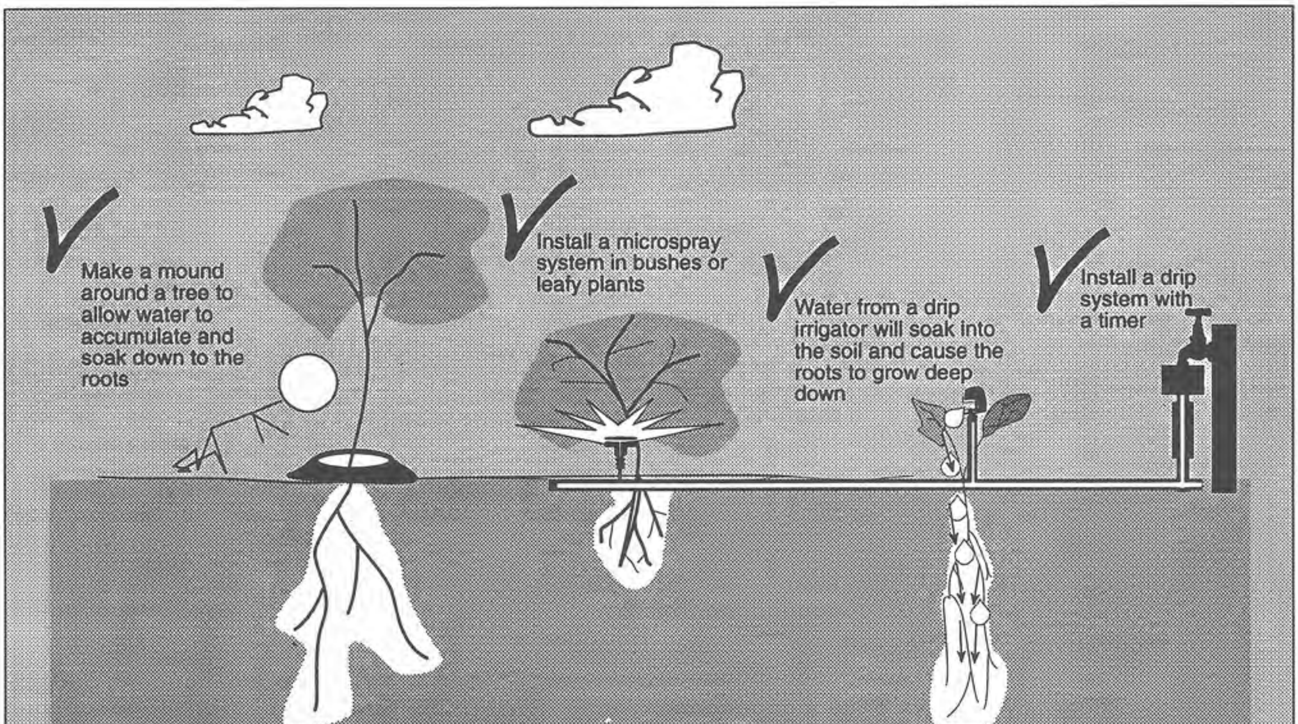


Fig 16 Some ideas on how to conserve water in the garden.

Fig 17 Watering the road and footpath is a rather fruitless activity. Position sprinklers so that water can be directed to where it is required.

- Remove weeds. Weeds compete for water and nutrients in the garden. Once removed, a good mulch will help stop other weeds taking root.
- If you have a lot of annuals or ferns and feel that a drip system is not appropriate, use a microspray. The water is placed on the garden at a rate the soil can absorb, reducing the water lost as runoff.
- Hoses are not playthings! If children want to run around the garden squirting water, use water pistols.

The lawn

Perhaps the greatest amount of water can be wasted here. Gardens, lawns, trees all need water. Here are some hints for conserving water.

- Let the lawn go brown. A lawn uses more water per square metre than any other area in your garden. While your lawn may go brown if not watered during summer, as soon as summer rain comes, the transformation to green is dramatic.
- If you want a budget green lawn:
  - toughen the lawn with only two waterings per week.
  - give it a feed (but do not over fertilise)
- Aerate the soil
- Be careful to water the lawn, not the driveway or street (see Figure 17). Move your sprinklers to water

Fig 18 Watering during the middle of the day in the wind is also unproductive

the garden and not the concrete. If you want clean paths, use a broom.

Swimming pools

- Use a swimming pool cover. Not only will it keep the leaves and children out of the pool, it will reduce evaporation and keep heat in.

Washing cars, bikes, and pets

It's easy to save water while washing. Here are some hints which also may help you discuss the topic:

- Wash the car or your bike on the lawn
- Use a bucket to wash the car and a hose to rinse it.
- Use a trigger hose. This means that you are in control and water is not wasted when moving the hose around. But remember to turn off the tap when you are finished in case the hose springs a leak.

Water conservation in the community

It's so easy to pass by and not care about water conservation. If you truly value water, your care should extend to the community. The signs shown in Figure 19 have been erected by one local authority to remind people of the water conservation campaign.

Here are some suggestions:

- turn off drinking fountains and taps in public places.
- report leaking taps, fountains and toilets immediately.

Remember

By using water wisely, you:

- save one of the resources humans must have to live
- save money
- save energy
- save flooding of land for water storage.

Fig 19 Signs in the community remind us of the need to save water.

Activity 1

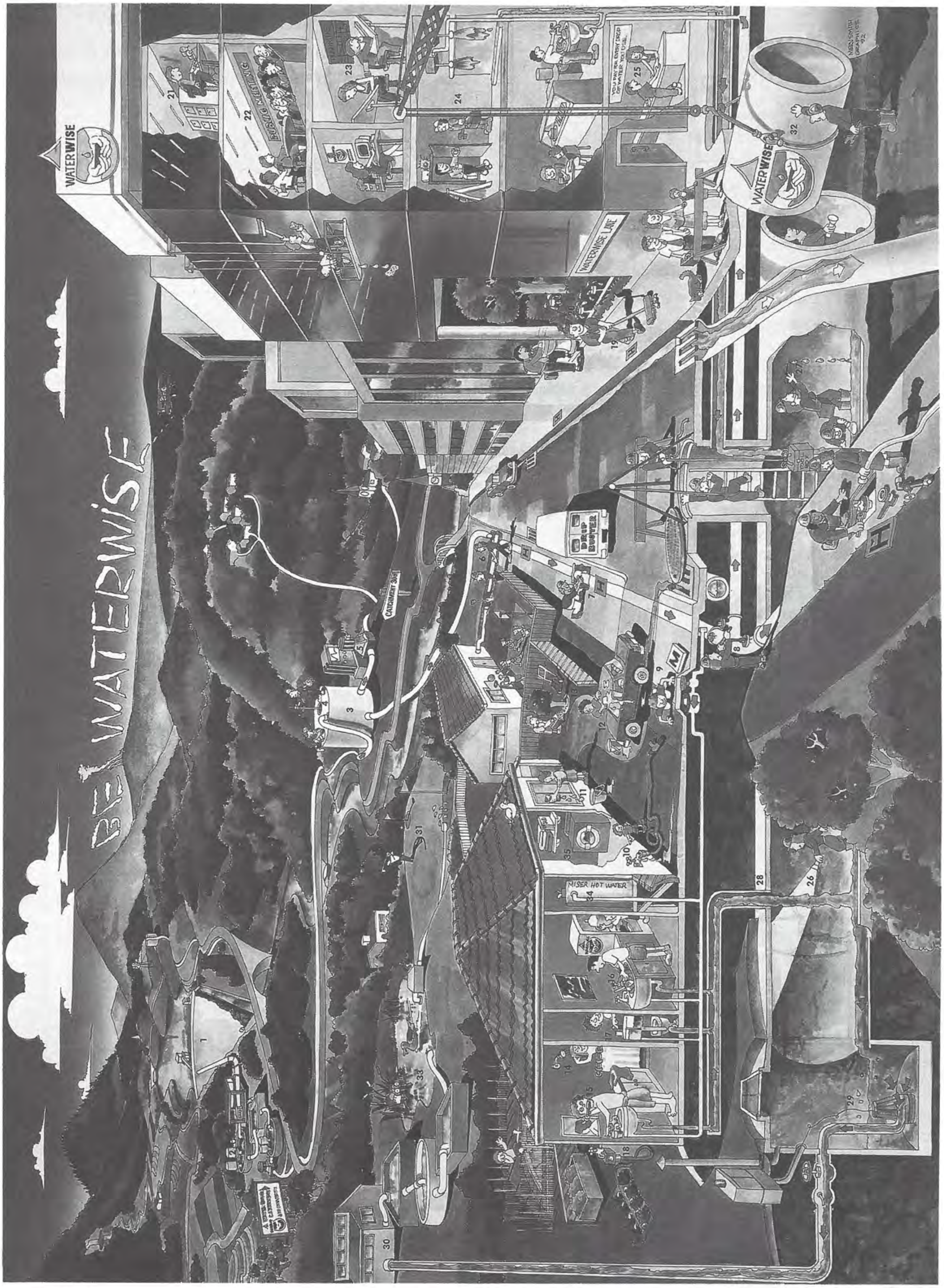
based on an original idea by Jan Oliver

My attitudes to water conservation

Draw up a survey table relating to your personal commitment to conserving water and avoiding water pollution. The activity should be done twice: Once at the beginning of the unit, and again at the end of the unit. You can then see if you have a commitment to water conservation and if your attitudes change over the duration of the unit.

The survey table should include choices as follows:

The likely actions	I am doing it now	I might do it in the future	I will never do it
● turn tap off when cleaning my teeth			
● wash my hands with plug in basin			
● buy phosphate free detergent			
● use unbleached toilet paper			
● throwing tissues down loo			
● pouring fats down kitchen sink			
● wash car with bucket on lawn			
● use compost bin for food scraps			
● use half flush toilet			
● sweep leaves on the driveway			
● sprinkle the drive or footpath			
● restrict use of garden pesticides/fertilisers			
● use phosphate free washing powder			
● pick up plastic litter from beaches			


BE WATERWISE
WATERWISE
MUSIC MEETING
YOU PAY FOR EVERY DROP OF WATER YOU USE.
WATERWISE LANE
DRIP BUSTER
CATCHMENT 3km
MISER HOT WATER
NEIL SMITH GRAPHICS 92
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Activity 2

WaterWise town poster and pamphlet

Aims

- To discover some water conservation strategies for a city and its suburbs
- To discover how much water a house would use in a day.
- To debate the effectiveness of some suggested water conservation strategies and establish the top five

You will need per group

- Two copies of the WaterWise town poster, available from the Water Resources DPI or your local authority
- A copy of the pamphlet 'If water came in buckets, how many would you use each day?', available from the Water Resources DPI or your local authority (see page 39).
- A copy of the WaterWise town illustration
- Copies of WaterWise fact sheets 2, 3 and 4 (available from the Teachers Resource Kit)
- Note pad and pen

What to do

1. Form groups of four to five and elect a scribe and presenter for each group
2. Groups work on the numbers in the poster as follows:
   Numbers 1-6 (Group 1) Numbers 7-10 (Group 2)
   Numbers 11-14 (Group 3) Numbers 15-18 (Group 4)
   Numbers 19-22 (Group 5) Numbers 23-26 (Group 6)
   Numbers 27-30 (Group 7) Numbers 31-35 (Group 8).
3. In your group, allocate each member a number and answer the questions from the list below on each number.
4. Now prepare a very short talk to include;
   - Where your number is located on the poster.
   - What it is you are describing.
   - How it works.
   - The answers to the question/s.
5. When all the class has finished, each person gets to speak about the number that was allocated. When you speak make sure you cover the points mentioned in 4 above.

Questions

1. Water for the town is stored in a dam. Why is a dam necessary and what environmental impacts does it have?
2. Water treatment plants prepare water for piping to the town. List five processes that are involved in water treatment (refer back to page 26). Why is chlorine added to the pipes that carry water to the town?
3. Reservoirs store water and are filled from pumps like those shown in 5. Pipes from reservoirs deliver water to houses. What is a head of pressure and why is it important to a town? A certain amount of water is always kept in a reservoir for emergency purposes. What types of emergencies would occur that would draw on this emergency supply?
4. Depth testing is carried out at night. Here the rate at which water drops is measured between 1 am and 4 am when there should be very little water use. If a large drop was found, what could be some of the causes?
5. This is a special type of pump used to supply water to houses above the reservoir. The pump is designed to pump at a rate equal to the householders demand. The alternative is to have reservoirs which are filled every day. Why is the variable speed pump more efficient?
6. Pipe being installed to bring water to the new school. Name five strategies a school should take to conserve water. Notice how close the school is to the golf course which uses reclaimed water. Could a school use reclaimed water from the sewage treatment plant? What problems could this create?
7. Pipe leak detection. The truck parked opposite has high tech. ultrasound gear installed on board with very sensitive water meters to pinpoint leaks. All the water from an area can be redirected through this sensitive water meter. The meter assumes that at some point in time, no one will be using water and by a sophisticated computer program will calculate when this should occur. The meter then records any leaks in the water pipes in the street. Explain this to the class when its your turn and comment on the effectiveness of this method. Are there any other ways leaks in the street could be detected. Refer to number four in the poster.
8. Pipes in the street accumulate scale and deposits over time. A useful way to minimise this is to flush the pipes out under pressure. This can be done at fire hydrants. Look at the people working on the hydrant further down this pipe.

At the bottom of the hydrant are two lugs which connect the hydrant the main. These have been designed for quick access to water. Why? Water can also be turned off in a street. This creates a pressure drop in the household pipes and if a hose is left in a pool, the water from the pool will be sucked back into the hose and into the household plumbing system. This is called backflow.

When the water in the street is turned on again, the pool water will be forced out of the household taps. What would happen if you drank this pool water? What would happen if you had been spraying with insecticide from your hose? What precautions should you take to prevent this? Are their any backflow meters available on the market to prevent this from happening? Where could you buy them?

9. Water enters the house via the water meter. How could you use a water meter to see if you had any household leaks? Who is responsible for the water distribution system on either side of the water meter? Refer back to page 29. How could you use the water meter to see how much water you used in a five minute shower?

10. The person shown here is pointing to a dripping tap. If a tap dripped once every second, what volume does this represent and how many buckets of water could be saved each day? Refer to the pamphlet. The water is also seeping into the ground beside the house. What long term effects will this have on the house if the leak is not repaired? At the end of the hose a water saving device is shown. What is it and how does it save water?

11 Have you ever seen people washing windows with a bucket? Why is this important? Guess how much water can be saved using this method.

12. How much water can be saved if we washed a car with a bucket? How does your family wash their car? Is it possible to change their attitudes if they don't use a bucket? The water from the car flows into the street. Where does this water go? What is storm water and is it treated at a sewage treatment plant? If not where does it go and is it treated at all? (Refer back to page 52)

13. When planting new plants, a mound of soil is made around the plant. How does this save water and what happens to the water in the mound? Why don't we hose plants during the middle of the day? Refer back to page 67. The figure is showing mulching around a plant. What goes into making a mulch and how does this help water conservation? It is recommended that the grass be cut not less than a height of 2 cm (see WaterWise fact sheet number 4 - your teacher will have this)

14. This shows a water-saving shower rose. How much water can be saved by converting from a 24 L/minute to 9 litres/minute for a five minute shower. Express your answer in buckets. (Refer to pamphlet) Make up a table of average water use from the following activities — brushing teeth, washing hands, flushing toilet, shower, bath, washing machine, drinking, cooking and cleaning, dishwasher by hand, dishwasher, garbage disposal unit (refer to fact sheet 3).

15. Turning the tap off when brushing teeth. How many Olympic sized swimming pools of water could be saved if we all did this? (Refer to page 68 and pamphlet)

16. This shows washing vegetables in the sink. What types of vegetables need water to be prepared? How can you save water in the sink? You can also wash dishes by hand. How much water does this save? (Refer to fact sheet 3)

17. A dual-flush toilet. How much water is used in a full flush? A half flush? (see page 74). If a family of five used the toilet twice a day and did not have a duel flush system, how much water would they use? (Refer to pamphlet)

18. What is the name of the device connected to the tap and how does it work? How much water could it save? (Refer to pamphlet)

19. What does this show and how much water could be saved by this activity? (Refer to pamphlet) How many people do you seen doing this? What strategies would you use to change their attitudes?

20. This shows planter boxes with a dripper system. What types of drippers could you use? (Refer to pages 40 and 77). What's a microspray and would it be effective in this case? Give reasons for your answer.

21. This person is planning a waterwise supply system for a high rise building. What is the total water supply infrastructure asset in the state mentioned in fact sheet 2?

Based on operation and maintenance costs plus replacement costs depreciation, how many cents per litre does water cost in this state? Are you surprised by this cost? How much did you think water cost per litre?

If you used 500 litres per day, seven days a week, 52 weeks a year, what would be your water bill based on this figure? Would you pay it? If you were charged one tenth of this would you pay it? How much would you be prepared to pay?

22. This public meeting is discussing how to reduce water consumption by 20% and the issues involved with demand management. List three items that would be on their agenda and what types of arguments would occur at the meeting. Use technical Information Sheet 2 to help you .

23. These people are designing a WaterWise supply system for a local authority. Detail three things they would consider and say which one would be of greatest importance. Refer to numbers 5, 6 and 9 to help you.

24. Urinals can be made to flush on demand or automatically. Which is better and why?

25. In many local authorities, householders are given a certain amount of free water before they are charged. Read the banner over the desk. Do you agree with this idea? Give reasons for your answer.

26. How did this person get into the sewer? What safety precautions were instigated and what type of disruption to traffic does this cause?

27. Infiltration is the process by which water seeps into sewer pipes and is a problem because it increases the volume of water that has to be treated at the waste treatment plant. The person in the sewer pipe is checking for leaks. What problems might this create and how would infiltration be fixed?

28. Waste water from the house drains into the sewer pipes. What appliances in the house create wastewater? What percentage is actually water? What are the other components of wastewater. (see page 42)
29. Wastewater falls by gravity to a low point. Where is the wastewater going and how does it get there?
30. Waste water treatment plants recycle water for use on the land. The plant is a secondary treatment plant. List the steps involved in a secondary treatment process.
31. Golf courses provide excellent places for reclaimed water to be used. What is the approximate mg/L range of nitrates and phosphates in this reclaimed water? (see pages 53 and 54)
32. What machinery is used to lay this pipe? How much distruption is caused to a town by pipe laying? Why did the planner mentioned in 21, design such a large pipe? Do you think this is a waste of money designing such large pipes?
33. Treated water stored in pond after treatment. Is chlorine needed? What will be the effect of the ducks in the pond on the faecal coliform counts? What would be acceptable levels for pumping onto the golf courses? (see page 59)
34. Conserving water means saving energy. How does a hot water system work? Describe the alternatives (see page 32)
35. Washing machine water level is adjusted to suit load. How does this help to conserve water? (Refer to pamphlet and fact sheet 3).

Activity 3

Based on an original idea by the Melbourne Water Board

A home water audit

This activity is done at home over two nights and is divided into two parts, A and B. Part A is done on the first night and part B the second. Each part involves you reading your home's water meter, making sure that no other water appliance is using water. Just make sure that the meter is not running before and after your Investigations.

Part A Personal water wasting activities

Start by reading the water meter and filling a bucket. Make sure you read the water meter before and after you fill the bucket. Now calculate the volume used and check it with the volume of the bucket to see if you are reading the meter correctly. Most household buckets are 9L, so the meter should show that amount used.

You are now going to investigate some water wasting habits. Many of us have long showers or big baths or leave the tap running while we brush our teeth or shave. Part A gets you to measure some ways in which water is wasted.

1. Making sure no-one else uses any water, go and brush your teeth while leaving the water on. Make sure you give your teeth a good brush. Now read the meter to calculate how much water was wasted. Now brush your teeth again leaving the tap off and go and re-read the water meter. Record how much water you have saved.
2. Flush the toilet three times, making sure the toilet cistern fills each time. Record the reading after the third time and calculate the volume used.
3. Run a big bath or take a long shower and think about how wonderful it is to live in such a great country and how lucky you are to have water laid on at the end of a tap. Now record the meter reading and calculate the volume used.

Now calculate the total volume used by you during these activities.

Part B Family water wasting activities

Draw up a table of how you could determine the total volume of water used by the family in a day.

These activities are designed for a multiplicity of purposes. Each class will be different and each activity can be used in a different way. By increasing knowledge and awareness over time, the attitudes of students will change in the home so that as urban water users of the future they will display the following characteristics:

- when purchasing a first home they will install water reduction flow plumbing.
- when landscaping their first home they will choose a drip system and plant a garden that uses low volumes of water.

It is hoped also that present attitudes will change to water use and we hope students will:

- take shorter showers and turn off the tap when they clean their teeth
- use buckets to wash cars
- encourage their parents or grandparents to adopt water conservation behaviours such watering the lawn in the morning or in the evening on low wind speed days.

Activity 4 How much water do people use?

Based on an original idea by Peter Stannard

If you found from Activity 2 in Chapter 2, that people know very little about water use, then this activity will help. Outlined below are a number of activities. You can do them in any order that you wish, and you can do them on your own or in a group. You can compare your values with the average figures presented in the WaterWise brochure.

Some of the activities can be done in the lab or at home. You decide where you want to do them. In this way you will be able to check your estimates to the four questions in Activity 2.

For each of the activities you will need a measuring jug (from the kitchen), a small bucket with volume markings on it or a large beaker. You will also need a container such as a lunch box or ice cream container.

Part A Teeth and water

Place the plastic container under a tap.

Now imagine you are cleaning your teeth and leave the water running while you do so.

Collect the water in the container.

Use the measuring jug to find out how much water you used.

Now repeat the process, but this time turn the tap on only when you want the water.

- Record the two volumes of water.
- How much water did you save by turning off the water when brushing your teeth?

Part B The dripping tap

Turn on a tap so that it drips.

Place the plastic container under the tap and record the time.

Collect the water for a measured length of time, say 1 or 2 hours.

- Record the volume of water collected.
- How much water would the dripping tap waste in one day (12 hours)?

Part C Washing up

Fill a 9 L bucket with water, then pour the water into your kitchen sink until it is at the level of a normal wash-up.

- Measure the volume of water remaining and calculate how much water you used .
- How much water do you use to wash the dishes?

If you use a dishwasher, use the instruction manual to find how much water these machines use.

Part D Water for washing

Look for the brand and model number of your washing machine. Ask your parents for the instruction manual and try to find the amount of water the machine uses. (If the manual gives the total water used for a complete cycle, work out a way to find the water used in the wash cycle.)

If you do not have a manual, contact an electrical retailer and ask for their help.

Another way to find the volume of water used is to use a bucket to fill the machine to the high wash level. Count the number of bucketfuls you poured in and multiply this by the volume of the bucket (usually 9 L). How much water does your washing machine use in its wash cycle?

Part E Short showers

How much water do you use in the shower? To do this activity you will need a bucket and a watch (a waterproof one would be best!).

- The next time you are about to have a shower, turn on the taps and find out how long it takes to fill the bucket from the shower rose.
- Then take your normal shower and measure the time you take.
- Calculate how much water you use when you shower.
- Suppose you were allocated 40 L for your shower. How long would your shower last before the water ran out?
- Can you think of a way of having a longer shower on 40 L? Try it and write down how you feel about this.

Water conservation projects

Based on original ideas by Bob Moffatt and Jan Oliver

Students often produce quite remarkable projects and learn the most when confronted with an open-ended project. The following are a series of such student projects which can be for either assessment, competition or part of an environment club activity.

1. Make your own water conservation TV commercial

View the six commercials on the video above and design your own TV commercial. Use the library video camera to make about a 30 second commercial. Then edit to make a short 15 second version.

2. Don't take the rap for a leaky tap

Write your own rap song using water wasters as a theme. Dress up and perform it in class. Listen to the rap song in the video to brainstorm ideas.

3. How to read your water meter.

Locate your water meter at home and experiment to see how it works. Find out how the water authority reads it and how accurate it is.

By turning off all taps in the house determine if you have a leak or not. If so how can you go about fixing it and what is involved?

4. WaterWise soil?

Using a set profile of soil, measure the absorption rates of water in soil by drips, sprays and bucketfuls.

You can also use a metre stick, a funnel and a clear hose to see how fast the water soaks into the soil. Take accurate times and use a variety of soil types - clay, sand, sandy loam.

You may have to go to a nursery to obtain samples or make up samples yourself with sieves. Present your results graphically using a computer and take photographs to show your experimental design. Investigate if plants of similar water use grouped together use less water.

5. How much water do you use? Do you value water?

Using the water meter fitted to your house, measure in litres how much water is used in the following situations

- 5 - minute, 10 - minute and 15 - minute showers
- half flush compared with a full flush toilets
- how much water is used to clean your teeth if you leave the tap on
- how much water is used in a bath
- in an automatic dishwasher
- when washing up by hand
- how much is drunk by a child and by an adult
- washing the car or hosing the lawn

How does this compare with water used elsewhere amongst friends or neighbours? Present your results graphically using a computer plotter.

6. How does a tap work?

Obtain an old tap from a plumber and pull it apart. Ask the plumber to describe how it works and the problems that taps can cause.

Find out how water pressure can influence tap performance. Can you think of any ways that the flow of water can be reduced in the tap or in the pipes that lead up to it. Can you come up with an invention and if you do, how do you patent it? Use a camera to photograph tap parts and present these with your findings in a report.

7. When to water?

Investigate evaporation of a controlled volume of water under a variety of conditions such as low humidity, high humidity, low temperature, high temperature, low wind velocity and high wind velocity to determine under what conditions water will enter the ground and be available for a plant. Repeat your experiments and make a summary comment. Use line drawings or photographs to present your report and prepare a 'When I should water guide' for the area you have experimented.

8. How much variation is there between the flow rates of different shower heads?

Make a model test tank, and test the flow rates of different shower roses. Make accurate measurements in litres per minute and check the manufacturers claims are true. Locate a consumer magazine in the library (like *Choice*) and prepare an article for that magazine comparing shower heads.

9. Do houses leak?

Use the water meter to determine if your house's water supply leaks or not. Examine a number of places where leaks can occur and make notes. Form a drip busters team and survey other houses in the street (make sure you check with the householders first). Make up a survey report and summary of where most leaks occurred.

10. Setting up a new home

You are building your first home and have been allocated $75,000 to do it.

- Find a builder and ask, 'What proportion of this will go into the plumbing?'
- What will this buy and what additional costs are involved in setting up a WaterWise house?
- How do these costs compare with inexpensive tap fittings and washers?
- What are the water conservation regulations required for local areas and the setting up of new home?

Present your findings in a report showing what you can buy and how much it costs. Use manufacturer's brochures to illustrate your report.

11. How can we reduce evaporation of water from the ground?

Create a control and experimental situation with soil of different types and covers. Use a water moisture meter to determine which condition holds water for the greatest amount of time. Does mulching have any effect on water evaporation from soils and are their any different types of mulch? Do wood chips effect the rate of evaporation?

12. How does your house plumbing system work?

Prepare a house plan of where the water pipes enter and leave the house. Use the direct observation method to locate the positions of the sink, toilet, shower, laundry, dishwasher and garden taps. Find out if you have any water saving devices installed. Evaluate the effectiveness of these. Also distinguish between waste and storm water and mark this clearly on your diagram.

13. How effective are drip systems?

Experiment with a drip system such as the Hardie Pope system to see how much water is used in 20 minutes by a variety of sprinklers.

Read brochures and make a summary of what they are saying. Design a lawn or garden bed and draw a plan of how you would set up a drip system.

- How much would this cost? Which is the cheaper system? If a drip system was not used, how much difference would this make to the amount of water saved per day? What is the effect of using a tap timer?

14. What creates problems for sewage systems?

Make an appointment to see a plant operator at a sewerage treatment plant. Ask what the greatest problems are for treatment and which consume the greater amount of time and effort. Make up a poster showing what you should and should not place down the toilet.

15. Why is there water in the bottom of the toilet bowl?

This activity looks at some basics of how a toilet works and the importance of half and full flush mechanisms.

16. How waterwise are plants?

Experiment with a variety of plants to see which use the most water. Use a moisture meter to see how little water a plant can survive on.

Discuss the ethics of the possibility of killing a plant as part of this experiment. What are native plants and are there any better species of plant for different soils? Do you have to have different watering rates for different soils? Use the Hardie Pope, 'When should I water publication", as a guide.

Are some plants more resistant than others to receiving less water. Investigate if plants grouped together use less water. See if you can determine the critical dosage of water needed to grow the biggest plant with the least amount of water.

Questions

1. What percent of treated water is actually consumed by people in Australia?
2. What is the value of water supply infrastructure within Australia and how much does each Australian household contribute?
3. Name four factors which contribute to water conservation in Australia.
4. Discuss the responsibility for water resource management. Use the following headings as a guide.
    (a) investigation of resource
    (b) development
    (c) management
    (d) regulation.
5. List any two other responsibilities of a water resource management authority.
6. List four conclusions from research into peoples attitudes on water conservation.
7. How do Standards Australia help with water conservation? How effective do you think these methods are?
8. Make up a table of any four water efficient appliances and say how each controls its flow rate of water.
9. Make up a table three columns listing four places water could leak in a home, the appliances that contribute to these leaks and the ways you could detect the leak.
10. Make up a table of two columns listing five main places water can be conserved in the home and ways water can be conserved.
11. Draw a pie graph showing the percentage of water use outside the home.
12. Draw a line graph use during a 24 hour period for three areas inside the house.
13. Debate the use of front loading washing machines v's top loading machines. List three arguments in each case.
14. Do you think dishwashers waste water? How do they compare with washing up by hand?
15. Its a hot windy day and you see your neighbour watering the leaves of a bush in the front garden. Why is this person wasting time watering?
16. You see a leaky tap in the park. Who should you report this to and how would you go about reporting the problem?
17. Why are spar and hot water pipes insulated?
18. You have just moved into a new house and are planning a lawn. List two points that will make for a WaterWise lawn.
19. How many times should you water your lawn a week.
20. Complete the slogans
    (a) "Water twice a week nice and .... "
    (b) "Don't take the wrap for a .... "
    (c) "Be WaterWise, its .... "
    (d) " Sun hot, ground hot, water just .... "

Video

A number of video segments are available for class discussion. These are:

- Three WaterWise TV commercials
- WaterWise Media Launch (News item)
- Three general TV commercials
- A WaterWise rap song: "Don't take the rap, Be WaterWise"

The video segments are available from your local authority or the Water Resources DPI .

Glossary

Some terms used and their explanation

This glossary is from the *Environmental Management Handbook* and is published by the Local Government Training Council.

Activated sludge process:

an artificially accelerated self-treatment process used in the secondary treatment of sewage. The sewage is brought into contact with biologically active micro-organisms in the presence of mechanically introduced air.

Aerosol:

a particle of solid or liquid matter of such small size that it can remain suspended in the atmosphere for a long period of time. Aerosols are classified as smoke, fumes, dust and mists.

Aerobic:

living or active in the presence of free oxygen. An aerobic process is one taking place in the presence of free oxygen.

Anaerobic:

living or active in the absence of free oxygen. An anaerobic process is one taking place in the absence of oxygen.

Atmosphere:

the gaseous envelope of air surrounding the planet Earth. The principal constituents are nitrogen and oxygen in proportions by volume of about 79.1% and 20.2% respectively. Carbon dioxide is also present to the extent of about 0.03%. Also present are water vapour, traces of ammonia, organic matter, ozone, salts and suspended solid particles.

Biodegradable:

readily decomposed by bacterial activity .

Biomass:

the total weight of all living matter in a particular habitat or area.

Biome:

a community of plants or animals inhabiting a region; a major regional ecological system such as tropical rainforest.

Biosphere:

the sphere of living organisms, (plants, animals, micro-organisms). The biosphere includes the human habitat or environment.

Catchment:

the land area drained by a stream system. Through the water cycle acting in a drainage basin, landforms, soils, plants and other systems are united. They form a distinct unit which should be considered when activities such as forestry, water supply, industry or settlement are being planned for an area.

Biota:

the animal and plant life found within an environment or geographical region.

Composting:

a biological process whereby organic material (or waste) is converted to a usable residue by the action of micro-organisms.

Dual-flush toilets:

toilets fitted with mechanism for half or full flushing, as a water conservation device.

Ecology:

the study of ecosystems. The relationships between living organisms and their environment.

Ecosystem:

a natural system of plant and animal communities, together with the physical conditions under which they exist.

Effluent:

liquid, solid or gaseous by-products of processes, usually industrial processes. (Often applied to liquid wastes.)

Effluent sewage:

sewage flowing away from treatment, whether or not it has been completely treated .

Endemic:

belonging or indigenous to a particular geographical region; not introduced or naturalised.

Environmental impact:

Ecosystems are always adapting to changes from within and from outside. If the impacts are positive then the ecosystem develops greater diversity and complexity. If the impacts are negative, from either natural or human activities (for example, insufficient availability of energy or nutrients, the presence of toxins or too many predators) then change may cause the ecosystem to become simpler and less diverse. Species may die, others may come to dominate. The features of that ecosystem will be altered, possibly irreversibly.

Environmental impact statement (EIS):

a report based upon detailed studies, disclosing the probable environmental consequences of a project or development. Its purpose is to alert the decision maker, the developer, government agencies and the public to the environmental risks of a proposed development.

Fauna:

the animal species of a region (or a geological period). The term is sometimes used to cover both domesticated and wild species. Dr H.J. Frith has estimated that the present day fauna of Australia includes over 60 000 species of insects, some 80 amphibians, about 400 reptiles, 230 mammals and more than 700 species of birds.

Feral:

term usually applied to animals which were previously domesticated but have now reverted to a wild state, e.g. dogs, camels, cats, donkeys, horses (brumbies).

Flood plain:

that portion of a river, valley, or drainage system subject to recurrent flooding.

Flora:

the plant species and communities of a region or geological period.

Fuel efficiency:

the proportion of a fuel's potential energy which is converted into useful forms of energy.

Groundwater:

water occupying pores, cracks and crevices in rock or soil. Groundwater is especially vulnerable to pollution and contamination due to its limited self-cleansing capacity.

Habitat:

the physical environment of plant and animal species. Habitats are characterised by a degree of uniformity of physical conditions and generally close interactions of their flora and fauna.

Herbicides:

agents, usually chemical, used to kill plants.

Indigenous: (plants and animals)

native to an area or region as distinct from introduced species.

Landfill:

disposal of refuse by burial on land sites. Sometimes referred to as 'controlled tipping' or 'sanitary landfill'.

Leaching:

the process by which substances such as organic matter and mineral salts are washed out of soil, rocks, or dumped materials.

Littoral:

relating to, or occurring on or near, the shore. The littoral zone is the region lying along the shoreline of the sea or lakes.

Methane:

a flammable gas which is a major component of natural gas. It occurs naturally as a product of decomposing organic residues. It is one of the 'Greenhouse gases'.

Primary treatment:

treatment of sewage to remove most of the floating and suspended solids, with limited effect on colloidal or dissolved material. It is a mechanical process.

Recycling:

a term commonly used to mean the return (by any means) of discarded or waste materials to productive use.

Resources:

When parts of the environment are seen as being useful they are called resources. 'Uses' may include economic activities or scientific, religious, or recreational uses. Conflict of uses may occur. Resources can be classified as non-renewable and renewable. Renewable resources are those where the natural production rate for them is equal to or exceeds the demand for them. Non-renewable resources are those which are being consumed at a rate which exceeds production of them by natural systems. Fossil fuels are considered non-renewable. However, by this definition, forests, clean air, fertile soils and clean water may be fast becoming non-renewable resources.

Salinisation:

the raising of levels of minerals, especially soluble salts, in soils. In Australia it is usually associated with agricultural practices, especially irrigation. It has become a major source of land degradation and reduced production. It is often related to a rise in the water table.

Secondary treatment:

treatment of sewage by biochemical, chemical and mechanical processes designed to remove, oxidise, or stabilise colloidal and dissolved organic material.

Sewage:

the contents of pipes or conduits transporting waterborne wastes. It does not normally include storm water.

Siltation:

the deposition and build up of inorganic granular material transported by water. It is often a consequence of accelerated erosion. It may damage agricultural land, block drains, cover roads, destroy crops and reduce the capacity of culverts and dams.

Storm water:

naturally occurring surface water in the form of run-off from land, paved areas, roofs, etc.

Sullage (or sullage water):

liquid domestic waste other than sewage, (e.g. from kitchens, bathrooms and laundries).

Suspended solids:

solids present in liquids which can be removed by filtration or sedimentation.

Tertiary treatment:

any sewage treatment process capable of removing over 98% of pollutants after secondary treatment.

Trade wastes:

organic or inorganic wastes discharged by commercial and industrial enterprises.

Turbidity:

visible suspended materials and pollutants carried in water.

Types of environments:

Differences in both biophysical and human features produce different environments. For example rainforests, deserts, rural, coastal, urban, suburban, and industrial environments differ greatly because of their particular biophysical and human features.

Waste management:

a term used to describe a comprehensive, integrated and systematic approach to the transport, treatment and disposal of waste products.

Watershed:

the physical boundary separating the headwaters of separate river systems, or catchments.

Water table:

the ground-water level, or upper surface of the zone saturated by water present beneath the ground.

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AUSTRALIAN MADE