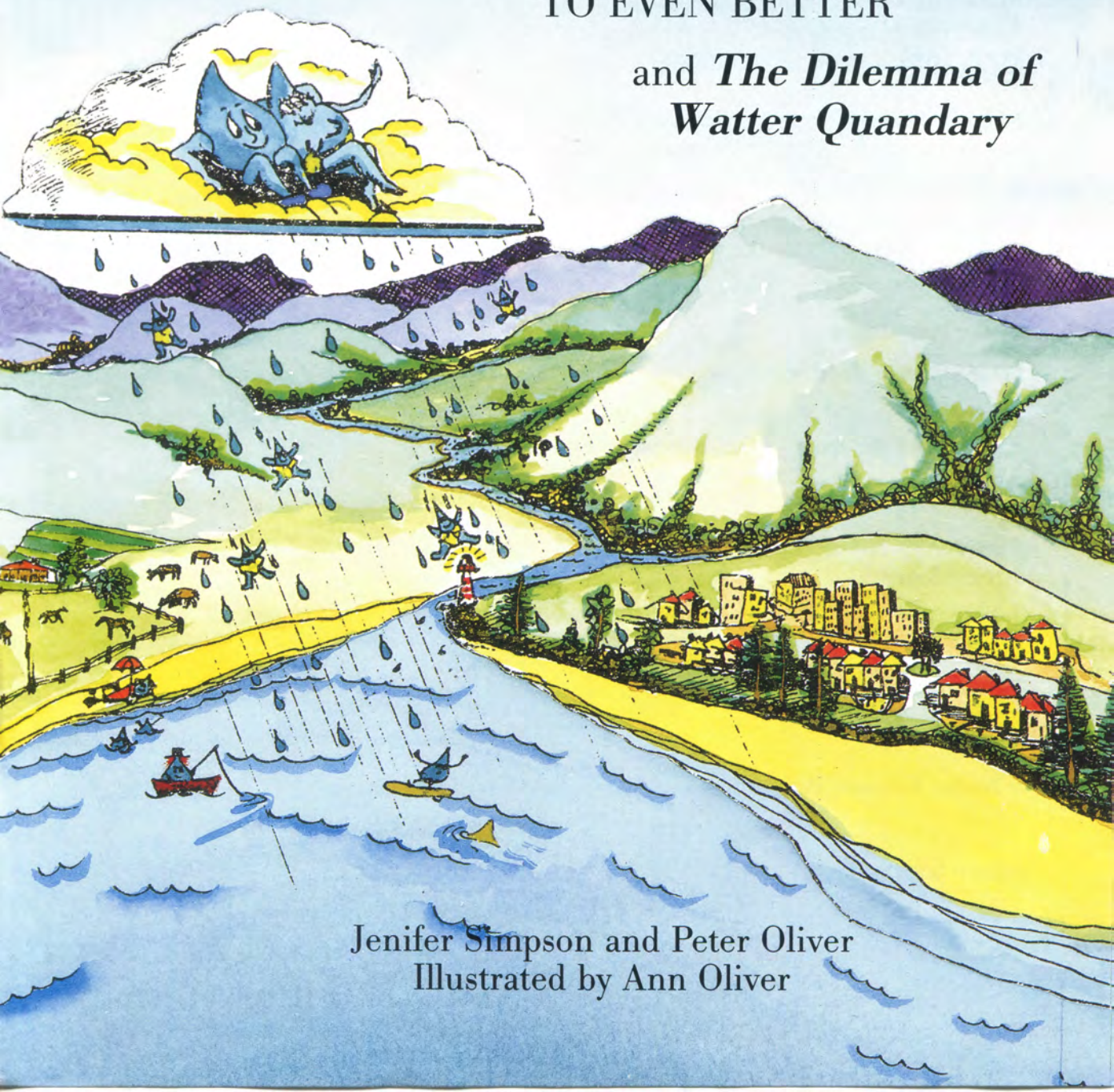
WATER QUALITY

FROM WASTEWATER TO DRINKING WATER TO EVEN BETTER

and *The Dilemma of Watter Quandary*



Jenifer Simpson and Peter Oliver
Illustrated by Ann Oliver

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Hey! Slow Down ! I Want to Look That Word Up!
Mary River Catchment Coordinating Committee

Jenifer Simpson

Dinosaur Technology Syndrome
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ABOUT THE AUTHORS

Jenifer Simpson

Jenifer Simpson (BSc, Birmingham, UK) had experience in teaching chemistry and physics at Headington School, Oxford and Abbotsleigh School, Sydney before becoming an industrial chemist in the food and household product industry.

She spent fifteen years roaming the world in a yacht, and then settled on a farm in the Sunshine Coast Hinterland with her late husband, Simon, where she bred donkeys.



Photo: Graeme Parkes

Jenifer became interested in water management issues in 1992 and was struck by the profound lack of understanding in the community of this very basic, essential and precious part of our lives. She has travelled widely to find out how water is managed in various parts of the world and visited more than fifty sewage and water treatment plants.

She is the Project Officer for Water Management Issues for the Sunshine Coast Environment Council and Environment Representative on the Mary River Catchment Coordinating Committee. She is also Chair of the Community Education and Wastewater Re-use Committee of the AWWA Queensland Branch.

Peter Oliver

An Honours Graduate in Environmental Science from Griffith University and qualified secondary school teacher, Peter completed his Master's Degree in Education in 1995.

Peter has a diverse background in school and community education and extension, having worked as a secondary teacher, outdoor and environmental educator, and curriculum master at Maleny High School on the Queensland Sunshine Coast. He is a champion of the Waterwatch movement for school and community groups initiated by Dr William Stapp and became the Waterwatch Coodinator of the Mary Valley Catchment Management Committee.

Peter's academic interests are diverse – from integrated catchment management and aquatic ecology through to action research. He sees the need to reconnect people with each other and their surroundings and help them to have informed input into the economic, ecological and social changes that are shaping our world.

He is currently the Coordinator of the Pumicestone Passage Integrated Catchment Management Committee.

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Several of our friends became involved in the exploits of Watter Quandary and provided some interesting ideas (and some that were too interesting as well). Our thanks to them and in particular to our invaluable editor, Jenny Osten.

FOREWORD

Water should not be judged by its history, but by its quality.
Dr Lucas van Vuuren

There are many challenges facing the urban water industry in Australia. Not least of these is for water professionals to clearly explain the issues involved in water management. It is equally important to give the community the opportunity to understand the technical aspects of water management, whether they are related to engineering, science or risk management.

I met Jenifer Simpson a few years ago when she firmly believed that water engineers and managers were dinosaurs (I'm not sure that this view has diminished).

Jenifer has applied enormous personal energy to understanding the technical issues of water management. She is also provoking water managers to change the paradigm of the urban water cycle and to transform their communication style.

This is not another water management text book. Rather, it aims to explain the science of water management and establish that sewage effluent is a valuable resource.

These objectives are achieved by the parallel stories. Readers will be amused by the *Dilemma of Watter Quandary* while learning about water administration and some of the industry's paradigms.

Jenifer proposes that water quality is defined by grades, rather than by the history of the level of treatment it has received. Before recycling of water is achieved, this latter concept will need to be embraced.

I congratulate Jenifer and Peter on having the energy and inspiration to write this book. I recommend it to members of the community and also to the country's water managers, who will surely be challenged not only by the concepts in this book but by the communities they will serve in the future.



Mark Pascoe
AWWA Federal President

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INTRODUCTION

Although water, H_2O, appears to be one of the simplest molecules, its behaviour is very complex. Water has an affinity for a great many other elements and compounds; its ability to combine with, dissolve and transport other substances accounts for the vital role it has to play in the existence – and sometimes the downfall – of all living matter.

It is almost impossible to completely free water of other molecules; even the rain that falls through the atmosphere collects oxygen and nitrogen compounds as it drops. Dust and particles floating in the air are gathered up too. The apparently pristine water that gushes from a spring or a mountain stream is not pure either, for it will contain small amounts of minerals from the rocks with which it comes in contact and often large numbers of naturally occurring micro-organisms.

We all know that water is essential for our lives but we don't always take time to think how its quality affects not only our own health, but that of our environment as well. Even small changes in water quality may cause a change in the lives of the creatures dependent on it; the change could be a calamity for one species, or it could make another so vigorous that it gets out of control. Just as we acknowledge the force of water lashed into an awesome monster by a flood or a storm, we should recognise its powerful impact on the balance of the environment.

Natural changes in water quality occur as a result of geological processes, such as erosion; they are greatly accelerated by human activity. We must be able to recognise the changes that the waste we create makes to our environment and assess how they impact on it and us. When the world population was smaller and people were 'hunter-gatherers' the natural environment was in a state of balance. Our fresh water supplies and oceans existed happily without stresses. This balance was upset as more and more people gathered into cities and became manufacturers and traders.

What options are there available for dealing with the problems we create? What will happen if we continue to pretend our waste is not important or that it will 'go away'?

We have the technology these days to manage the quality of our water; it is up to us to decide just what standard we desire and if

we are prepared to pay for it. Before we can make these decisions we need to be able to identify and understand the pollutants in water. What are they? How are they measured? How can they be controlled?

Our present method of defining the quality of water is letting us down badly. The term 'effluent' is used to describe any watery discharge we want to get rid of. The water which comes out of a sewage treatment plant is called effluent regardless of the degree of treatment it has received. The effluent is given many indefinite, enigmatic names; none of us is really sure what is meant by 'tertiary' effluent; 'advanced secondary' is even more obscure and open to interpretation. What is the quality of the water produced? What can we safely do with it?

What constitutes 'safe', 'good' or 'acceptable' drinking water? Are there risks to our health every time we drink a glass of water? If so, are we prepared to accept these risks or pay more to reduce them?

The quality of water and how it affects our health and that of our environment needs to be defined in a way that we can all understand. This book will do just that. It will take us from wastewater – to drinking water – to even better.

WHAT IS WASTEWATER?

Should we admit to there being such a thing as wastewater?

It is possible, these days to treat water to any desired standard so there is really no need to waste it at all, especially as it is a very precious resource. Being wastewater is a temporary condition but it is a useful term to define the starting point in our study of water quality.

Wastewater is water which has been used in, or produced by, a process: it has no further immediate value to that process.

Wastewater contains pollutants which make it unsuitable for some considered purpose. It reverts to being just 'water' when it is renewed by the natural processes of the water cycle. It can also be renewed by treating it. One of the problems about letting Mother Nature take care of it for us is that she is slow and, in large towns, she cannot possibly keep up with the demands made on her. In the meantime, the pollutants can have a devastating effect on the waterways and the plants and animals dependent on them – and that includes us! The epidemics of water-transmitted diseases of the last century show us what can happen when nature becomes overloaded. Those epidemics saw the birth of the sewerage system, to safeguard public health.

The sewerage system has not changed all that much over the years. Wastewater is taken to a treatment plant where the natural processes of Mother Nature are speeded up. Not only are the pollutants kept under control but the water can become available for use again – a big advantage in times of water shortage and drought.

The water discharged from the plant is called 'effluent' regardless of the amount of treatment it has received; this, as we will see, varies enormously. But if wastewater is treated – however inadequately – by Mother Nature it turns into 'water'. The relationship between wastewater, effluent and water is ill-defined and confused.

Sewage

Depending on who you are talking to, sewage may be the term used to describe the mixture of liquid waste of domestic and industrial origin that arrives at a treatment plant or it may just be the domestic component.

The composition of sewage of domestic origin is more predictable than industrial wastewater. It is produced in our kitchens and laundries and our bathrooms and toilets. Sewage is mostly water – a

THE DILEMMA OF WATTER QUANDARY

Once upon a time there was a drop of water. His name was Watter Quandary and he had an awful problem; he was polluted.

Like all drops of water, Watter was destined to go round and round in the water cycle, but he had a grandiose ambition to spend his time on the surface of the earth being drinking water. He considered the elite, pristine role of drinking water as the only one worthy of his breeding and upbringing.

'People will think so highly of me. I'll be measured, monitored, analysed, sampled and even tasted – the centre of attention.'

Watter could visualise his aesthetic appeal. He had always fancied himself in a sparkling crystal jug, suitably polished to match his over-inflated ego.

But he was polluted. He was banished to the

twenty litre drum of raw sewage contains less than a tablespoon of dirt. The pollutants in it include organic matter, nutrients and pathogens.

Organic Matter

The organic material is mainly faecal matter (the part of the food we have eaten which has not been absorbed in our digestive tracts) and vegetable and animal matter that has been washed down the kitchen sink. It also contains bacteria which feed on the organic matter and break down its molecules into carbon dioxide and water. They need oxygen to do this. The amount of oxygen required is therefore a measure of how 'strong' the sewage is. Biochemical oxygen demand – BOD – was developed as a measure of what happens in the water environment when 'effluent' is discharged into it. As the test is carried out over five days, it is called BOD_5.

Domestic sewage has a BOD_5 of about 250 milligrams per litre. (BOD_5 ~ 250mg/l)

Another way the strength of sewage can be measured is to determine, by a simple filtration technique, the amount of solid matter suspended in it. Domestic sewage has a suspended solid content (SS) of about 250 milligrams per litre. (SS ~ 250mg/l)

Nutrients (nitrogen and phosphorus)

Some nutrients are needed in water to make plants grow, but if they are in the wrong place, in the wrong amounts or out of balance, they can make the wrong plants grow. An excess of nutrients in water causes pollution (which is called eutrophication) and outbreaks of algae may occur. In fresh water many different algae can grow. One form, the blue-green variety, causes problems as, under some conditions, it can produce toxins which affect drinking water supplies. In salt water different algae occur, such as the one which causes 'red tides'.

The proportions of nitrogen and phosphorus in water are as important as the total amounts. The growth of blue-green algae is promoted by phosphorus (phosphorus limited) whereas red tides are caused by an excess of nitrogen (nitrogen limited). In some (few) waterways, nutrients do

not cause problems because there is insufficient light for the algae to grow. This could be because of natural colouration, shading by plants or turbidity. In estuaries, careful studies have to be done to determine if it is the nitrogen or phosphorus which is the limiting factor to algal growth.

There are nutrients, both nitrogen and phosphorus, in our human waste. Although most of the nitrogen compounds come from urine, only about half of the phosphorus found in sewage is of human origin; most of the rest comes from detergents used in the home.

Nitrogen is a relatively mobile element; most of its compounds are soluble in water. It is present in sewage as ammonia or urea. It is relatively easy to remove from sewage as it can be converted, by bacteria, into the gas form of nitrogen. The total nitrogen in domestic sewage is up to 55 milligrams per litre. (N~55mg/l)

The removal of phosphorus from sewage poses more of a problem. There are normally between 10 and 15 milligrams per litre of phosphorus in sewage. (P = 10 – 15 mg/l)

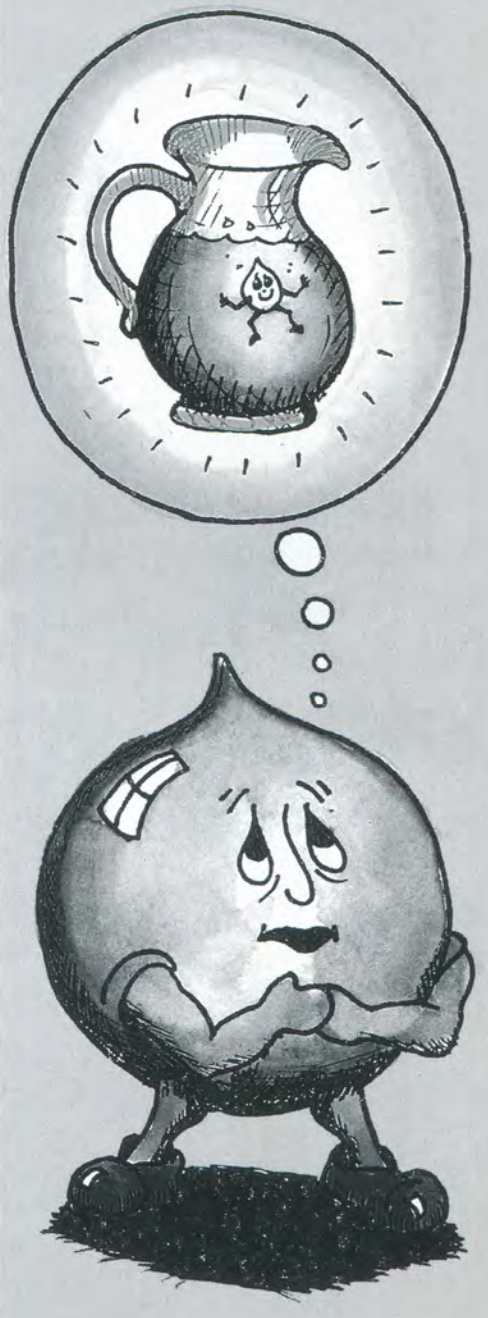
Pathogens

Pathogens are organisms capable of causing disease in a plant or animal, including man.

These disease-causing organisms are of four common types: bacteria, viruses, protozoa and helminths. The infections they cause range from minor inconveniences to major problems, such as cholera and typhoid. Ear, eye and throat infections and gastric upsets are often associated with waterborne pathogens.

There are many ways in which pathogens may gain entry to our bodies. Some need to be inhaled, often being carried in the air in very fine droplets or aerosols, others are sexually transmitted; some may infect us if our mucous membranes come into contact with them when we go swimming, or we could take them into our digestive tracts along with our food or water. We are constantly coming into contact with these organisms but we have strong defences against them – our immune systems.

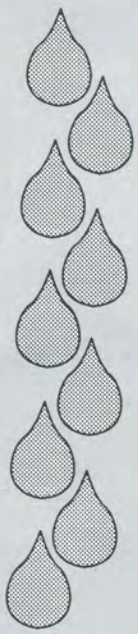
miserable status of wastewater, unwholesome and unworthy of consideration for any use at all.



Watter set off on a mission to try to become clean again. He wasn't a very religious drop, but he knew that cleanliness was next to godliness.

Perhaps, if he attained immaculate purity, he would be able to fulfil his ambition to become drinking water.

Perhaps.



These are usually very efficient but our bodies cannot build up resistance without some contact with the pathogens. Because the immune systems of the very young, very old or those with immune deficiencies are not as strong, these people are more likely to succumb to an invasion.

There are many factors involved in the transmission of pathogenic diseases; some of these are not all that well understood. Social factors such as living conditions, overcrowding, poverty and personal hygiene have a strong influence on the occurrence of disease, as do contaminated food and natural and acquired immunity. The supply of water, even of the purest quality, will not improve public health if these other factors are not also addressed.

Bacteria

Bacteria are simple single-celled organisms. There are many thousands of different bacteria; they have fundamental and essential roles to play in nature. Bacteria, along with fungi, are responsible for the decay of organic matter so that it is recycled to the food chain. Some bacteria are responsible for fermentation, yet others for fixing nitrogen from the atmosphere. Some are adapted to the presence of oxygen (aerobic bacteria) and others can only survive in the absence of oxygen (anaerobic bacteria).

Our lives are dependent on a very important group of bacteria, those which help us digest our food – there are many millions of them to be found in our digestive tracts and those of other animals.

A few bacteria are pathogenic and can be transmitted by water. Two of the most virulent are *Salmonella typhi* (typhoid fever) and *Vibrio cholerae* (cholera) which caused many deaths before sewerage systems were developed. Nowadays these diseases are largely under control and associated only with natural disasters, such as floods and earthquakes.

With most pathogenic bacteria large numbers, at least a million, are needed to cause an infection.

One bacterium (non-pathogenic) which is found in the digestive tract of all warm-blooded animals is called *Escherichia coli* (*E. coli* for short); it is a very useful bac-

terium as it can be identified, cultured and counted relatively easily. Its presence in water indicates faecal matter, although this may not be of human origin.

There are more than 10^{10} bacteria in 100 millilitres of sewage; very few of them cause disease. Some bacteria survive and multiply in sewage. We use these to our advantage to break down the organic matter in sewage at treatment plants. They can help to reduce the nutrient content too.

Viruses

Viruses are much smaller than bacteria and do not have a cell structure with a nucleus like other living matter. They consist of a simple organic compound, a nucleic acid, surrounded by a protein shell. Nucleic acids contain the genetic information for the formation of proteins in all their variety and complexity.

Viruses not only need a specific host in order to reproduce themselves, they also need specific cells within that host. They cannot reproduce themselves outside these cells so they are difficult to culture in the laboratory. Methods of detection are slowly being developed but, at the moment, they are time-consuming and expensive.

The host animal's immune system keeps viruses at bay – but the viruses have an ability to slightly change their outer protein structure in order to overcome the resistance of the host cells. The many different variations of the flu virus theme is typical of this characteristic. A constant microscopic battle of wits rages between the viruses and the host's cells. If the virus does manage to penetrate the host, it can sometimes have a devastating effect. Immunity is developed by exposure to the organisms or by vaccination; lack of exposure or vaccination can put an individual at risk. Unlike bacteria, infections from viruses can be caused by very few organisms.

The most common illness associated with swimming in water polluted with sewage is caused by a virus called Norwalk agent which causes a twenty-four hour gastric upset.

CLEAN FORGOTTEN

It all started because he had an affair.

He was an innocent young drop until the day he was caught out in a downpour. A great tide of storm water was running off from a nearby building site and, as it rushed on its way into the nearest creek, Watter was caught up in the flood. He was spun around and found himself being jostled, not just by other drops of muddy water, but by larger solid articles, plastic bags, empty cans. A dead bird floated past him and a soggy nappy liner.

The water became cloudy and began to smell. In the murk Watter noticed another drop, a pretty little female drop, who was desperately trying to avoid being swept into the mainstream. He made his way over to her.

'Let me help you,' he said, as he nudged her over to the edge of the flood into a calmer backwater.

'Oh, thank you, thank you,' said the pretty female drop.

Watter felt his heart beating faster, and it wasn't just because of his exertions. As he gazed at her, he realised his life would never be the same again.

'I'm Watter Quandary,' he said, introducing himself. 'What's your name?'

'Polly,' she gasped, 'Polly Plution.' She was trembling from her ordeal; she looked so forlorn and unprotected.

'What happened to you?' Watter asked with a friendly smile.

'I was trying to get to the STP,' said Polly, 'But there was too much water coming through the sewers. The pumps couldn't cope with it all so they had to bypass. I missed the plant and so did a lot of other things that usually go there. I'm ever so upset.'

She moved closer to Watter and looked up at him with hurt in her big brown eyes.

'You need a drop of the

Protozoa

Protoza are single-celled organisms. Some of them, the zooparasites, live in a parasitic relationship with a host. Several can cause human health problems; the two that give the most trouble are giardia and cryptosporidium. These can cause diarrhoea and vomiting if their numbers get out of control in our digestive tracts.

Many people have these infections without showing any symptoms. The problems they cause are usually low-level rather than a major threat to health, although less resistant people may be more severely affected and even die. The infection is often persistent.

The organisms form hard-coated cysts which contain their eggs; these pass out in the faeces. The cysts can be removed from water by filtration, but are resistant to chlorine disinfection. They can be killed by direct exposure to UV light and ozone, so long as the dose is strong enough.

Although the numbers of organisms found in water are variable, both giardia and cryptosporidium seem to be becoming more prevalent. It is said that there are few, if any, rivers in Europe where they cannot be found. The methods of detection, which are also expensive and slow, are improving but tests for these organisms are not carried out routinely on our drinking water supplies.

Other singled-celled organisms

In fresh water systems, blue-green algae (which should be called blue-green bacteria) can produce toxins which may be detrimental to human health. On-going research is determining the long-term risk if algal toxins are ingested with drinking water.

Some marine algae also have the potential to form toxins which are detrimental to health. An example of these are 'red tides', a marine algal growth which causes shellfish to become poisonous.

Helminths

Helminths are parasitic worms, such as round worms and tape worms. Their eggs are passed in faeces and, if they are ingested by a suitable host animal, will infect that animal. The eggs are resistant to chlorine disinfection, but are easy to filter – they do not pass through the sand

filters at water treatment plants.

Helminths do not pose a problem in treated drinking water, but care should be taken if unfiltered sewage effluent is used to irrigate areas where humans and other susceptible animals might come into contact with it.

Trade Waste

The pollutants in trade waste can be divided into two groups, inorganic and organic.

The former come mainly from industries which deal with metals or their salts e.g. copper from the electronics industry, chromium from electroplating works, lead and nickel from the battery shop, silver from the photographer and mercury from the dentist. If the concentrations of chemicals in the trade waste are too high, they may kill off the bacteria and lead to the failure of the sewage treatment plant.

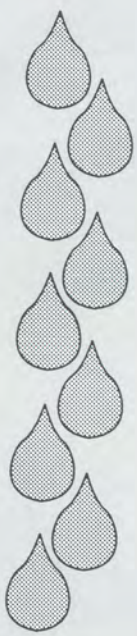
hard stuff,' said Watter. 'I know where my Dad has some hidden away for emergencies. Come with me.'

As Watter helped himself and Polly liberally to his father's gin he observed that although Polly was a very dishy drop, she was not as clear and sparkling as other drops he had met. In fact she was definitely turbid. But as they drank, Polly's cloudiness became less noticeable



and Watter was conscious only of the perfect curves of her full, rounded figure. She stopped trembling and edged closer to lean comfortably against his globular chest.

Then the inevitable happened; the alcohol reduced their surface tension and they coalesced.



Many of these industries have facilities to pretreat their effluent before it is discharged to the sewer so that the main problem usually arises from illegal dumping in domestic areas. The efficient implementation of trade waste policies and a supporting education program help to keep these undesirables out of the sewerage system.

Depending on the degree of treatment, the metals in wastewater usually find their way into the sludge. If their concentration is high, they limit the options available for managing the sludge. These 'heavy metals' are cumulative and, at high concentrations, can become toxic to humans and other species. Marine animals which feed on the bottom sediments of waterways are particularly susceptible.

The organic compounds include pesticides, weedicides, solvents and other specialised industrial chemicals. Mostly they are broken down by bacteria but some of them may be slow to degrade. If they are present in water which is intended for drinking, activated carbon (which is a porous granular form of carbon such as charcoal), may be used to adsorb them.

One of the biggest problems at sewage treatment plants is the presence of fats and oils. Fish and chip shops are notorious for causing these problems.

It is easier and more efficient to prevent these substances from entering the system than to manage them at the treatment plant. A trade waste policy should not only disallow the disposal of unsuitable waste into the sewers but also provide alternatives. Wastewater can be treated on-site to a standard where it can be discharged into the sewer without causing problems; if this is not possible, arrangements should be made for the waste to be collected and taken to a specific landfill site.

ARRIVAL AT THE STP: GRADE 1

The network of pipes through which our sewage travels to the STP, (sewage treatment plant) is called the **sewerage** system. The contents of the pipes, **sewage**, is propelled by gravity or may need help along the way with pumps. Usually about 80% of the cost of a sewerage system is in the pipes, only 20% is spent on the treatment plant.

If the sewage has to travel a long way it will start to ferment before it reaches the STP. This fermentation takes places in the absence of air and makes some very smelly gases. These gases can also cause corrosion of the pipes; this has the potential to lead to that ultimate embarrassment – sewer collapse!

The gases generated in the sewerage lines may generate odour problems at locations where the sewer is accessible to the air. These include pumping stations, vents and the inlet works at the treatment works. Odours can be reduced or eliminated by various means, including oxygen or air injection, covering structures and filtering the gases before they are released to the atmosphere. It is possible to have sewage treatment plants that don't smell offensively.

The volume of sewage always increases in wet weather. This is because some people, unknowingly or illegally, connect their stormwater pipes to the sewer. Also, especially if the sewerage system is ageing, stormwater can infiltrate into the system through cracked pipes (tree roots are notorious trouble-makers), leaking joints or badly fitting manhole covers. Peak wet weather flow (PWWF) of sewage is usually reckoned to be up to five times the average dry weather flow (ADWF) – but in old sewerage systems the increase is sometimes tenfold or more.

Wastewater Grade 1

	BOD_5	SS	N	P
Wastewater	~250	~250	~55	10 - 15
Grade 1	175	100	20 - 30	10 - 15

When it arrives at the plant, the sewage undergoes preliminary screening and the larger solids are removed – such as rags, plastics and paper and a range of other less-edifying unmentionables. These are buried or incinerated. Removing the larger solids helps to protect the pumps and other units further downstream in the treatment plant.

Air can be bubbled through the sewage to make the grease and oil

DR SOLOMON BUGZ, CONSULTANT

Next morning Watter was feeling very poorly indeed. His body had taken on a muddy look and his eyes were dull.

'I must be polluted,' he thought, 'Polluted! I must have picked up some dreadful disease from Polly. Nobody will want anything



easier to skim off and sometimes chemicals are added to assist in the sedimentation process.

In some plants, the sewage is then allowed to settle so that the bigger particles and the grit are removed. The settling tank (an Imhoff tank is one example) is designed so that the heavier particles sink to the bottom. The water passes over a 'launder' and only the clearer liquid from the top of the tank passes on to the next phase.

At the end of these primary treatment processes, there is some reduction in the amount of pollutants and pathogens in the sewage but many remain. The effluent is not suitable to 'dispose of' into waterways.

The disposal of minimally treated, Grade 1, effluent into the sea is a common occurrence in some parts of the world; it gives rise to the community's dislike and distrust of ocean outfalls (see page 45).

Sludge

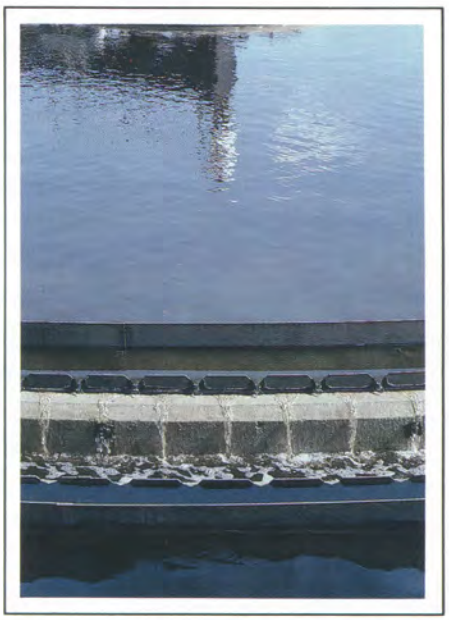
The solids which settle out of wastewater during treatment processes are called sludge – or more fashionably and euphemistically, biosolids. As we are now demanding more treatment of our sewage to obtain a cleaner effluent, we are also increasing the amount of sludge generated. How to manage this is becoming an urgent problem.

Ideally it should be recycled – put back on the land as a fertiliser, but if it is contaminated with trade waste, this application is limited and has to be carefully monitored. In Europe the amount of sludge produced is so great that much of it is incinerated. This has the advantage of generating energy but it also produces greenhouse gases.



Photo: Aquatec-Maxcon

When sewage first enters the sewage treatment plant it passes through a screen which sifts out the larger solids it contains. This helps to protect the downstream unit. The 'rag' that is collected is either incinerated or buried.



Settling tanks have a launder which separates the clear effluent from that which still contains solid particles. The clear effluent at the top of the tank passes over the launder and on to the next process.

EXPLOITING NATURE: GRADES 2, 3 & 4

When living matter dies it becomes the food of bacteria. Bacteria are always present; as soon as food is available and conditions permit, their cells divide and many millions of them are produced until all the food is used up. Some (the majority) of these bacteria of decay need the oxygen in air in order to survive (they are aerobic); during their feeding and multiplying process oxygen is used up. The organic matter in the sewage is converted into carbon dioxide and water. The process can be hastened if the bacteria are given access to extra air.

Other bacteria have a different metabolism and feed on organic matter in the absence of air (they are anaerobic). They produce methane and other gases such as hydrogen sulphide ('rotten egg' gas) which are responsible for the unpleasant smell of sewage.

Yet more bacteria utilise oxygen which is combined with other elements; importantly they can break down and use the oxygen in nitrates and more recently it has been discovered that they can be persuaded to take up the phosphates.

Effluent Grade 2 — Reduced Organic Matter

	BOD_5	SS	N	P
Wastewater	~250	~250	~55	10 - 15
Grade 1	175	100	20 - 30	10 - 15
Grade 2	20	30	20 - 30	>7

One of the first types of sewage treatment to be developed was the trickling filter. The sewage is trickled from a slowly rotating arm and makes its way through a big tank which is filled with rocks or plastic shapes. Aerobic bacteria attach themselves and grow in the slime on the surface of the rocks or shapes. They feed on the organic matter in the sewage as it trickles through. The large surface area allows access to plenty of air. The effluent produced therefore has reduced organic content. After the effluent has been through the trickling filter, it goes into a settling tank (humus tank) to remove residual particles.

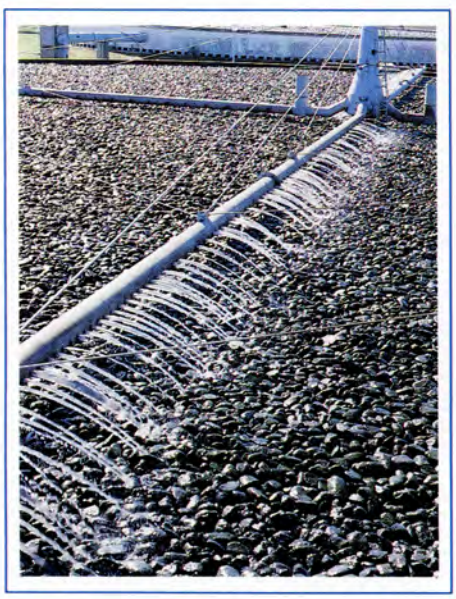
Trickling filter plants are easy and cheap to operate and maintain; they can be left to their own devices through the night and they produce a reliable, but not very high grade of effluent. They do not substantially reduce the amount of nutrients in the effluent; nitrogen, which is present as urea or ammonia may stay in this form or may be converted to nitrates depending on the 'load' on the plant. Ammonia

in sufficient concentration is toxic to marine life.

The first activated sludge treatment for sewage was introduced in 1914. Bacteria in the sludge are recycled continuously through the plant and air blowers or other aeration devices provide them with the extra oxygen they need to work at their maximum rate. Excess sludge is drawn from the settling or reactor tanks. One of the advantages of activated sludge treatment is that ammonia and urea in the sewage are oxidised to nitrites (NO_2) and then further to nitrates (NO_3).

The effluent still contains nutrients and, although the number of microbes in it will be considerably reduced, it still has considerable potential to cause infection. Some other pollutants may be present if the original wastewater contained trade waste.

The effluent can be disinfected (see page 33) before it is discharged – this is particularly needed if it might come into contact with people – or their food. Effluent of this quality should only be released into a waterway if it forms a very small proportion of the flow so that the nutrients and other pollutants are well diluted.



Trickling filters are cheap and easy to operate; they reliably produce a not-very-high quality (grade 2) effluent. Effluent trickles through a tank filled with rock to allow access to plenty of air.

to do with me because I'm not clean. I'm wastewater! What an awful predicament. Oh dear and oh dear. I must go and find a specialist – at once.'

Dr. Solomon Bugz frowned at Watter over his rimless spectacles and confirmed his worst fears.

'Yes, you're definitely polluted. I will take a sample of you and send it away for analysis.'

'As I thought,' said Dr. Bugz when the results came back, 'You have just about every pollutant known to water. You have a large number of suspended particles which carry with them heavy metals. These no doubt come from the industrial area – I noticed that the local council has been getting very slack about their trade waste policy lately.'

'There are also some ominous large organic molecules – they're toxic. Probably come from some agricultural run-off because they're meant for killing weeds and pests.'

'Your nutrient levels are very high – your P is over fifteen – but your dissolved oxygen is low. This is

because of all the organic matter you contain – no wonder you're feeling seedy.'

'You're carrying a full range of microbes, from bacteria and viruses to protozoa cysts. This would account for your sense of being undesirable and shunned.'

'Both your biochemical oxygen demand and suspended solids are over 400! It makes me wonder what you have been getting up to!'

Dr. Bugz stared accusingly at Watter as he delivered his awful diagnosis.

Watter blushed, his cloudy brown complexion taking on a pinker hue.

He hung his head as he confessed, 'I coalesced with Polly Plution. Only once. Oh dear and oh dear, what am I going to do?'

'There's only one place that can manage the likes of you, my boy, and that's the STP! And whatever you do, don't drive there; you're over the limit!'

Effluent Grade 3 – Nitrogen Reduced

	BOD_5	SS	N	P
Wastewater	~250	~250	~55	10 - 15
Grade 1	175	100	20 - 30	10 - 15
Grade 3	10	15	5 - 10	>7

Activated sludge treatment has been refined and developed over the years. By changing the conditions, different bacteria will become active and utilise other components of the sewage as their food. In conditions where there is no oxygen, some bacteria will use the oxygen in the nitrate ions instead of free oxygen as their source of energy. The nitrates yield their oxygen and form nitrogen gas which dissipates harmlessly into the atmosphere (which contains four parts of nitrogen to one of oxygen).

If periods of pumping air through the sewage are alternated with times when there is no air input (intermittent aeration) some reduction in the nitrogen content of the effluent will occur. The same effect can be achieved by passing the sewage alternately through aerated and unaerated zones in the plant (continuous operation).

This technique produces a higher quality product than Grade 2 effluent with a much lower amount of nitrogen. The amount of phosphorus remains high and therefore restricts (or should restrict) its discharge into waterways which are phosphorus sensitive. Pathogens are also

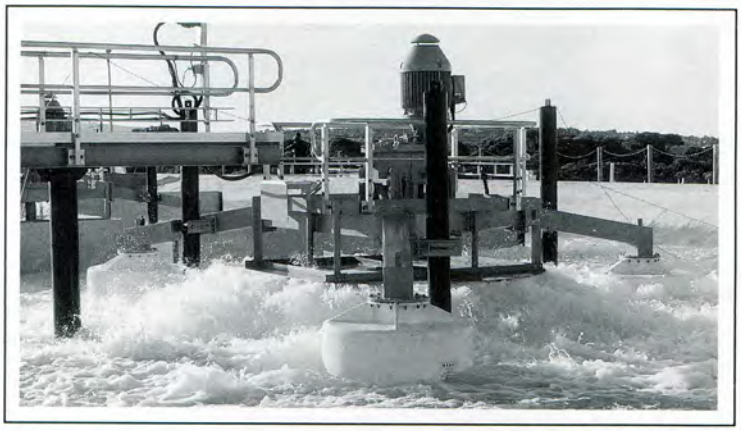


Photo: Aquatec-Maxcon

Activated sludge plant, aerators supply the bacteria with extra oxygen which helps them to break down the organic matter in the sewage. This unit is being tested in clean water.

reduced but disinfection (see page 33) will be needed if the effluent is likely to come into contact with humans or seafood.

Effluent Grade 4 — Phosphorus and Nitrogen Reduced

	BOD_5	SS	N	P
Wastewater	~250	~250	~55	10 - 15
Grade 1	175	100	20 - 30	10 - 15
Grade 4	10	15	5	0.5 - 2

The activated sludge process can be modified to further reduce the nutrients in the effluent. The process is called biological nutrient reduction (BNR). Under the right conditions, bacteria can be persuaded to use the oxygen in the phosphates in sewage so that the amount of phosphate in the effluent is considerably reduced. The phosphorus compounds are deposited in the sludge.

The technique to do this is quite complex; instead of two zones in the reactor tank as in the activated sludge process, BNR involves at least three zones: aerobic, anoxic and anaerobic.

In the aerobic zone lots of oxygen is present dissolved in the water. In the anoxic zone no oxygen is dissolved in the water, but it is present combined with other substances e.g. nitrates (NO_3) and phosphates (PO_4). In the anaerobic zone, no oxygen is present either dissolved in the water or combined chemically with other substances. By alternating these zones, the various bacteria can be persuaded not only to break down the nitrates, but, when all the nitrates have been used, to attack the phosphates as well.

Although the process is rapidly becoming more understood and reliable, the bacteria are sensitive to changes in their environment so it is preferable if both the quantity and quality of the incoming sewage are relatively constant.

As with the other biological sewage treatments, some other pollutants and pathogens remain in the effluent. The effluent can be disinfected more effectively than a lower quality effluent and its reduced nutrient load increases the opportunities for it to be discharged into a waterway without causing eutrophication. (See nutrients pages 10 and 63).

WHEN ONLY THE BEST WILL DO

Slowly Watter came to the dreadful realisation that he was going to have to overcome his inhibitions and mix in company that he had hitherto looked down on. He decided to visit all the STPs within reach so he at least could pick the one most suited to a drop of his quality – or lack of it, he thought ruefully. He could ask the drops already at the plants how they were being treated and what they would do after being discharged from the plant.

Watter spoke to a swarthy brown drop at the first plant he visited. A large, hairy individual, he looked more like a drop-out than a drop.

'Waste of money cleaning up sewage,' he said. 'After all, they don't clean up stormwater so why bother about sewage? Grade 1 and proud of it!'

The drop-out gave a knowing wink and leered.

'We get screened and then dumped in the sea through an ocean outfall. ***They*** *think it separates us infected drops from drinking water and safeguards public health, but we sneak back inshore and worry the bathers. We give them ear, eye and throat infections. On a good day we can close down the beach.'*

'But what's better still is that we're a wanton waste of water. At the same time as they tip us into the sea, they complain they're short of water. We're literally money down the drain – you should just hear the wails. Why don't you jump in and join us?'

It didn't sound like the life of Watter's ambition; he wouldn't get to be drinking water this way.

'There has to be something better than this,' he thought. 'Surely not every water manager has such an irresponsible and archaic attitude.'

'We have a trickling filter here. Grade Two when

Chemicals can also be used to reduce the phosphorus levels in effluent. They are the same chemicals, alum or ferric chloride, that are used in drinking water treatment plants and to keep the water in swimming pools clean (see page 29). They are used as a back-up to BNR, or if the plant is too small for BNR to work efficiently. They are also used if the effluent is to be discharged to a confined or sensitive waterway where eutrophication is a potential problem.

Chemical treatment is more expensive than BNR in large plants but cheaper in small ones. It has the additional advantage that it removes the heavy metals from the effluent – they find their way into the sludge.



Photo: Cardno & Davies

Aerial view of Loganholme Sewage Treatment Plant. This modern plant incorporates biological nutrient reduction and produces a high quality Grade 4 effluent.

EFFLUENT POLISHING: GRADE 4 PLUS

Grade 4 effluent can be further treated to produce water of a higher quality if it is needed in special circumstances. It could be destined for some specialised industrial use, for irrigation in an area where it is likely to come into human contact, for dual reticulation, for recharging ground or surface water supplies or to directly augment the drinking water supply.

The treatment given to the effluent depends on what is going to be its ultimate destiny. The techniques are the same as those used to produce extra high quality water from drinking water, or drinking water from a very polluted source (see page 32). They include disinfection, particularly with ozone, chemical coagulation, activated carbon, conventional and membrane filtration.

Disinfection techniques are described on pages 33 to 38 and activated carbon and membrane filtration on pages 39 to 43.

New technologies, including electrolysis and ion exchange, are constantly being explored. As they become available and more cost-effective, they will no doubt make an impact on water and sewage treatment in the future.

The quality of Grade 4 Plus water will depend on its purpose. It is likely that, for specialised purposes, the parameters used to measure sewage effluent (biochemical oxygen demand and suspended solids) will be irrelevant and other measures and analyses will be more appropriate. With drinking water, for example, total dissolved solids (TDS) and total organic carbon (TOC) are the standard parameters.

Natural processes can also be used to further polish effluent:

Maturation Ponds

Shallow lagoons are often provided at sewage treatment plants so advantage can be taken of natural UV rays in sunlight to disinfect the effluent (see page 34). The ponds are usually about a metre deep and the effluent takes between 10 and 50 days to go through them. After thirty days it is considered that the effluent is disinfected and suitable for discharge into waters which may have human contact. A disadvantage of maturation ponds is that the high nutrient content often causes dense growth of algae.

Artificial Wetlands

Wetlands should be specially created for their purpose of purifying effluent. If natural wetlands are used, their ecosystems will be altered

they've done with us.' The drop Watter spoke to at the next plant had a more positive attitude.

'Grade Two isn't very good but it isn't very expensive to produce either. We still have a lot of organic matter, a full compliment of phosphates and our nitrogen hasn't been oxidised – it's still ammonia so it's toxic to fish. They dispose of us on land when the weather is dry so we don't do any harm. But, oh boy, when it's raining – that's another story.'

'You should always ask the question, "what happens when it rains?" when you're thinking about a sewerage system,' advised the drop. 'Because it's then that we get tipped into the river and do all sorts of destructive things to the environment. We don't affect the place where we start, we go off down the river, out of sight and out of mind, and do our damage there.'

'Thank you for warning

and species lost. The wetlands are made so that the effluent passes through a series of ponds which are planted with macrophytes (water plants). The wetlands can be used to reduce the nutrients in the effluent. Most of the nitrogen is lost through the nitrification/denitrification process around the plant roots and rhizomes and most of the phosphorus is taken up in the surface of the soil base until it becomes saturated. Phosphorus may be released again if conditions change.

If wetlands are managed with care, they will absorb heavy metals so that the water discharging from them is of high quality. They will be released again when the plants die and decay; some plants therefore should be removed periodically otherwise the system's capacity to absorb continued inputs will diminish.

In order to be successful the wetland must be carefully managed. It is not enough to construct a wetland and leave it to renovate water without a high degree of knowledge and resources.

Wetlands have the advantage of providing pleasant areas for passive recreation – they attract birds so they are popular with bird watchers. Because wetlands attract a large number of birds, the *E. coli* count of the effluent issuing from the wetland is higher than at the beginning. These bacteria from bird faeces are not, however, human pathogens.

DRINKING WATER: GRADE 5

The quality of the reticulated supply of water we receive in our homes varies greatly. Ideally it should be clear and colourless, without taste or odour and, most importantly, safe to use. It must not contain harmful chemicals or pathogenic micro-organisms in quantities injurious to health.

The *Australian Drinking Water Guidelines* seek to define good quality drinking water and set out recommendations for the values of the various contaminants in water that should not be exceeded. It should be noted that they are 'guidelines' as opposed to 'standards' so there is no legal obligation on the part of water providers to adhere to them. It is intended that these guidelines should be used by water authorities in negotiating 'standards' with their customers.

The guidelines are applicable to any water intended for drinking irrespective of its source or where it is used. They are concerned with both the safety of water and its aesthetic quality. Water may be coloured or cloudy and even have a taste or odour yet still be safe to drink; conversely, the absence of unpleasant qualities does not mean that it is necessarily safe to drink. Water to be used in the drinking supply needs more safeguards than if it is used for other purposes. The main difference between Grade 4 Plus water and Grade 5 – drinking water – is that, with drinking water, a great deal of effort and expense have been outlaid to use extra barriers to ensure that it is reliably safe and fit to drink, not just most of the time, but all of it.

The amount of treatment that water needs to become Grade 5 depends on the quality of the source water.

Drinking Water Sources

Ground Water

Ground water is often good quality water. It may contain dissolved salts which make it 'hard' (difficult to lather soap) but should be free from micro-organisms. However, there are some recent instances where it has been found to be polluted. It is extremely difficult, if not impossible, to purify ground water in situ once it has become polluted, so it is very important that we protect it. Septic tanks have been implicated in causing these problems.

An aquifer is a geological seam or structure which stores ground water. Water can be drawn from aquifers and used as drinking water but, as their capacity is often difficult to measure, care must be taken

me,' said Watter politely, 'I think it's great that you can be disposed of on land, but it doesn't do anything to help with the water shortage problem. I want to be drinking water; I don't want to be wasted.'

'We get to Grade 3 here,' said a drop at the neighbouring plant. 'We were upgraded a few years ago, but it was before they learned how to persuade the bugs to remove our phosphates. It's called the activated sludge process.'

'We're quite good quality; our nitrogen has been considerably reduced but the phosphates are still high so we cause outbreaks of blue-green algae, especially if we find our way into a lake or a dam where there's limited flushing.'

'Phosphates don't cause a problem in drinking water so you could be treated here but we're disinfected with chlorine which isn't ideal for effluent.'

'If you can wait a couple of weeks, there's a new

that water is not drawn from the aquifer faster than it is being replaced.

In some parts of the world (San Diego and Paris are two examples) so much water is taken from the aquifer that it is in danger of becoming infiltrated with undesirable water, in the case of San Diego, salt water from the sea, or in Paris, very polluted water from the Seine. In San Diego sewage effluent is highly treated and injected into the aquifer. The drinking supply is taken from the same aquifer close by. In Paris the water from the Seine is treated and used for the same purpose. In this way effluent is recycled; it forms a major part of the drinking water supply.

Surface Water — Dams

In some parts of Australia, drinking water catchments are rigorously protected and no human activity of any kind is allowed anywhere near them. This practice is difficult to maintain as it becomes increasingly hard to keep the catchments pristine; even the jealously guarded Warragamba Dam (which provides most of Sydney's water) contains about 1% of sewage effluent of not-very-good quality. The water from the Warragamba now receives treatment. In Queensland few dams are in protected catchments.

Most of the convenient and easy dam sites have been exploited, so the cost of new dams and the transport of water from them to where it is needed is going to rise. Subsidies are no longer going to be provided for these costs unless they are transparent and supported by the community.

Surface Water — Rivers

A lot of drinking water comes from rivers which are, in some places, highly polluted, especially downstream of towns that discharge their minimally treated sewage into the river. This situation arises frequently in Europe. Although this water is often contaminated by industrial waste as well as domestic sewage, it is turned into drinking water which is safe and well-accepted by consumers.

The Miracle Mile

For some reason that defies explanation, sewage effluent, however minimally treated, which has been in a

river, for however short a time and regardless of the amount of diluting flow (if any) in the river, is considered to be suitable for turning into drinking water merely because it has travelled in the river for the 'Miracle Mile'.

Incongruously, highly treated effluent, which has had the benefit of advanced technology and sophisticated monitoring, is not considered suitable.

This anomaly seems to stem from the water having an apparent change of identity. However, pollution problems are not solved by moving them around the bend of a river.

Drinking Water Treatment

Good quality water, such as ground water or water from protected catchments, needs minimal treatment; sometimes it is not even filtered before it receives a dose of chlorine (or a chlorine compound) and is pumped on its way through the mains to our homes.

Water from unprotected catchments usually undergoes a flocculation process where chemicals are used to make the fine suspended matter aggregate into larger, heavier particles that settle into the sludge. Much of it also has to be treated for high iron and manganese levels, which although not harmful to health, cause the water to be 'dirty' and discolour white clothes, baths and swimming pools. The water is then filtered through sand and dosed with chlorine to disinfect it.

The chemicals used are alum (aluminium sulphate) or iron salts such ferric chloride. Other chemicals used may include lime, sulphuric acid or sodium bicarbonate to control the pH (acidity or alkalinity) of the water which has to be optimised to achieve efficient removal of the pollutants in the water. Polyelectrolytes are used in most modern treatment plants to reduce the use of alum or ferric chloride. This, in turn, reduces costs and sludge quantities and leads to more effective treatment. Polyelectrolytes may be synthetic (organic polymers) or natural (e.g. potato starch).

Ferric chloride and alum generally work equally well. The use of alum for the flocculation of drinking water has recently been questioned in the popular press as it has

plant coming on-line where they have the very latest nutrient reduction process and UV disinfection. You could have your microbes removed without getting any of the nasty by-products that chlorine produces.'

'That's where I'll go,' decided Watter. 'All I have to do now is work out how to get admitted. Perhaps I'll wait until it rains and slip through an illegal connection. They have so much infiltration in wet weather that they won't notice another drop.'

But he remembered the fate of the hapless Polly when she was bypassed; perhaps he would get better treatment if he arrived when there was less demand on the plant.

'I'll just have to find a way into the cistern. It really is undignified for a drop of my status but if anybody notices me I can tell them I was looking for the Cistine Chapel and made a little mistake. After all they're easily confused – they both have thrones.'

AROUND THE BEND

'Serious business going on! We'll soon be on our way.'

The shout from one of the scout drops in the bowl sent a buzz of expectant excitement through the drops waiting in the cistern. Watter was among them and became part of the gush of water that helped to transport the remains of last night's supper through the sewers.

After the first exhilarating roller-coaster ride around the bend, he was flushed with success.

But his sense of well-being was short-lived. He was swept along in bigger and bigger pipes with ever increasing amounts of sewage and the lumps and bumps it contained. It was dark and airless.

Several hours later he reached the STP and by that time the smell was unbelievable.

Watter was pleased when they passed through the screen – some of the

been linked with Alzheimer's disease, but the amount in optimally treated drinking water is minuscule compared with that which we take in from some of the foods we eat.

Chemical flocculation and sedimentation are followed by filtration. Specially graded sand is the usual filtration medium but sometimes extra beds of other materials, such as fine gravel, anthracite (finely-divided, high-carbon coal) or zeolite (a fine clay) are used. These are called dual or triple media filters. The suspended particles in the water are filtered out including most, but not all, of the pathogens.

When the filters are blocked up by the particles they have to be backwashed with a mixture of air and water. The water, which is likely to contain protozoa cysts, is sometimes recycled back to the beginning of the plant for retreatment. Care has to be taken that there is not a build up of the cysts in the system as they might eventually pass the filters, as has been the case in several outbreaks of cryptosporidium in drinking water overseas. Breakthrough can occur when a tunnel develops through the granular media, which is usually because the filters are poorly operated or maintained.

Drinking water is chlorinated to protect it from infection as it travels to our homes.

Drinking Water Monitoring

The plant where drinking water is being treated is monitored regularly to ensure it is working properly. In most plants, particularly the bigger ones, on-line sensors



Landers Shute Water Treatment Plant provides drinking water to part of Queensland's Sunshine Coast. It is a conventional plant which incorporates coagulation followed by sand filtration and chlorination.

detect any changes in the system. They may even be programmed to make automatic adjustments. The amount of chlorine in the water is particularly important.

At regular intervals, the water is analysed to make sure that it is meeting the *Drinking Water Quality Guidelines*; tests are carried out for organic and inorganic chemicals and micro-organisms. The regularity with which this is done depends on the resources of the water supplier; large suppliers carry out more sampling than the smaller ones which cannot afford frequent checks. Checks for taste and turbidity are carried out regularly. In drinking water, tests for TOC (total organic carbon) and TDS (total dissolved solids) are carried out. Typically TOC for raw water is 5 – 10 mg/l and for treated drinking water it is 3 – 6 mg/l. TDS in drinking water below 500 mg/l is regarded as good quality. It is acceptable up to 1000 mg/l. Nutrients at normal levels for unpolluted water sources are not a problem in drinking water.

Tests are also made to make certain that micro-organisms are not escaping through the net. As these are very small, and difficult and expensive to detect, indicator organisms such as *E. coli*, (see page 12) are used to check the microbiological quality of the water. Although the presence of *E. coli* is a sign that the water is contaminated with faecal matter of some sort – human, other mammals, or birds – its absence is not necessarily a sign that all other pathogens are absent too. This is because *E. coli* is less able to withstand changes in its surroundings than some other pathogens and it is more sensitive to chlorine.

Cryptosporidium and giardia cysts are resistant to chlorine and have the ability to persist in the environment for much longer than *E. coli*. Regular checks are not routinely carried out on our water supplies; we depend instead on the efficiency of the filtration system.

Drinking Water from Polluted Sources

It is possible to treat water to any required standard, regardless of the amount or type of pollutants it starts off with. However, sometimes it is not economic to do this, especially when the real cost of producing and supplying drinking water is not recognised. This situation is changing.

bigger articles which had been banging into him were caught up in the bars. He was particularly happy when the dead cats and sandshoes were left behind. He wondered how they had managed to get into the system.

He made a special effort to keep to the top of the primary settling tank – partly to keep away from the sludge but also to make sure he went on his way to the next part of the plant as soon as possible. He came up to the rim of the launder, and just made it over the top.



GETTING THE BUG

Watter started to chat and exchange experiences with some of the other drops. It was rather against his principles to mix with the menial, lower socioeconomic classes but he made a big effort to try not to let this show for it was reassuring to be able to discuss and compare his condition with the others.

Annie Oxic, a worldly-wise drop, said the plant they had come to provided a 'state of the art' biological nutrient reduction technology where the nutrients were reduced to a minimum. This would be followed by sand filtration and UV disinfection.

'It's a complicated process,' she said, 'but we 're going to end up Effluent Grade 4 with our P less than one and no pathogens. And then we will be discharged into the river and people will be able to swim in us.'

'But I want to become drinking water,' stated Watter firmly 'I've always

Blue-Green Algae

Outbreaks of blue-green algae are happening with increasing frequency in our drinking water reservoirs. Although the best way to deal with these is by controlling human and animal activity in the catchments and the nutrients they generate, this is a slow process. The situation currently seems to be deteriorating instead of improving. In the meantime, people have to drink.

Blue-green algae sometimes contain toxins which spill out of burst dead cells. (This is called 'lysis' from the Greek word meaning 'release'). It is therefore best if the cells can be removed while they are still alive, but this is just about impossible in a bad outbreak as there will already be dead cells among the live ones when the water comes into the plant. Microfiltration is useful as it can be used to remove the cells without killing any more.

Once released, the toxins have to be adsorbed by activated carbon. Ozone and chlorine dioxide are also useful to break down the toxins. Treatment for blue-green algae is expensive and places a painful burden on water authorities, especially the smaller ones.

Polluted Sources and Reclaimed Effluent

In many parts of the world the water which is used for drinking comes from a highly polluted source. In Europe, water is taken from some of the major rivers and used for drinking. The Seine, Rhine and Thames are examples; they all contain significant amounts of pollution from industrial waste and sewage effluent. In times of low flow it is not uncommon for some rivers, which are used as drinking water supplies, to contain as much as 90% effluent.

Similar situations frequently arise in Australia where a town discharges its effluent into a river for the consumption by the people in towns downstream of them – the Murray–Darling, Brisbane and Swan Rivers are examples.

Advanced technologies are available to treat water from polluted sources and they can also be used to reclaim effluent so that it is safe to drink. The processes are used in conjunction with each other so that there are several barriers against each of the pollutants reaching the drinking water supply. The technologies are discussed on page 39 to 43.

DISINFECTION

Although disinfection has some disadvantages, these are minimal compared to the hazards of drinking or coming into contact with water that has not been disinfected.

There are several disinfectants that can be used to kill pathogens in water. They include chlorine and its derivatives chlorine dioxide and chloramine, ultra violet (UV) light and ozone. Membrane filtration is also an effective method of disinfection as the filter forms a barrier to any pathogen larger than its pore size (see page 39).

Before drinking water is pumped through the reticulation system to our homes it is disinfected. Not only is the disinfection required to kill any pathogens in the water, it is also important to protect it from reinfection as it travels, sometimes quite long distances, to its destination. Chlorine and chlorine compounds provide residual disinfection for ongoing protection through the reticulation system but UV light, ozone and membrane filtration do not.

Sewage effluent is often disinfected before it is discharged: this is essential if people are likely to come into contact with it.

The effectiveness of a disinfection depends on the dosage of the disinfectant and the amount of time it is in contact with the pathogens. The clearer the water being disinfected, the more effective and efficient the disinfectants are.

Chlorine

Chlorine is generally used in Australia. It is cheap and easy to manage. It has good bactericidal properties, is moderately good at killing viruses but some viruses and cryptosporidium and giardia cysts are resistant to it unless the normal contact time is considerably increased. It is invariably used to disinfect drinking water as it provides residual disinfection. Its effectiveness as a disinfectant is considerably affected by the pH of the water (how acid or alkaline it is). If the water is alkaline (pH 8.5 or above) the disinfection properties of chlorine are greatly reduced.

Chlorine has the disadvantage that it can produce by-products called trihalomethanes (e.g. chloroform) which have the potential to damage our health. These are formed when there is a relatively high organic content in the water before the chlorine is added. Filtration before chlorination helps to overcome the problem. By-products such as chlorite and chlorate ions are also of concern.

wanted to become pure enough to drink.'

'But you can't ever become drinking water,' said Annie. 'You're effluent and no matter how clean, they never make drinking water out of effluent.'

Watter was about to argue with her when they were both swept up and plunged headlong into the reactor tanks.

It was a heady experience; they rushed from zone to zone in a swirl of heavy brown water which was thick with sludge. As they went through the aerators, they were tossed into the air.

A transparent orange bug approached; Watter could see his innards unashamedly working away digesting his food. He had a bristly proboscis at one end and a single eye which leered suggestively.

'Hi, I'm Eucoccia Rotiker and I'm looking for phosphates. I only work properly when I'm hungry – and I'm starving.' E. Rotiker giggled in a high pitched voice.

The residual chlorine is not toxic to humans (because we don't have gills) but it is highly toxic to fish and other marine life, so chlorine is not an ideal disinfectant for effluent which is going to be discharged into a waterway unless a further dechlorination step is included.

Chlorine Dioxide

Chlorine dioxide is a stronger disinfectant than chlorine and more effective against viruses although it still does not affect giardia or cryptosporidium cysts. It has the advantage that it does not form trihalomethanes but it is even more toxic to fish than chlorine. Chlorine dioxide is often used when there is a need to control taste and odour in drinking water. It has a residual disinfection effect similar to chlorine.

Chloramine

Chloramine (produced by dosing ammonia with chlorine) is a weaker disinfectant than chlorine but it produces fewer by-products which are potentially harmful to human health. It is mainly used where the transport system is very long as it has the ability to maintain residual disinfection right to the extremities of the system. There is some evidence that it is better at reducing biofilm (slime) build-up in the pipes. It is more toxic to fish than chlorine – it will quickly kill aquarium fish.

UV Light

UV light occurs naturally in sunlight and it can also be generated by mercury lamps. It is a potent disinfectant and it can kill bacteria, viruses and protozoa cysts if provided at a sufficiently high dosage. UV is even more dependent on the water being clear for effective disinfection than chlorine. Direct contact with the organisms is essential; any turbidity or colour will limit the UV penetration into the water and its efficiency at inactivating the pathogens. The lamps must be kept in good condition; regular maintenance and cleaning are essential. If the dose is not strong enough some bacteria can reactivate. Incomplete kills have been reported to promote the development of bacteria with resistance to the disinfectant. UV is safe and easy to use and it does not give rise to any by-

products. It is more expensive than chlorine and it does not have any residual disinfection effect.

Ozone

Ozone is a molecule consisting of three oxygen atoms (O_3) so it is a very powerful oxidising agent. It has the ability to break down organic molecules in the water as well as to kill all the microbes in it. It has been used for nearly a century in Europe where the drinking supply water is often highly polluted. It also is useful for controlling iron, manganese, taste, colour and odour in drinking water.

Ozone is a toxic gas but it is unstable – it breaks down to oxygen very quickly. The question of whether or not it forms by-products of possible health concern is still being debated. Its reactions and stability are pH dependent.

Ozone is generated on-site by passing an electric discharge through clean dry air or oxygen. Although it is a more expensive disinfectant than chlorine, its ability to break down large organic molecules can be used to increase the efficiency of the biological processes. It therefore has considerable value in the treatment of drinking water which comes from a polluted source. It does not have any residual disinfection effect.

Choice of Disinfectant

The disinfectants have

Watter cringed with embarrassment as the proboscis explored his body. Drops of his standing were not in the habit of providing pleasures for such creatures.

Watter lost count of the number of times he went around the tanks. His head was spinning with all the action – but when he eventually found himself in the calm of the secondary settling tank, he had time to notice that he was definitely feeling a lot cleaner. But Annie Oxic's words kept ringing in his ears. He had been through an STP so now he was effluent and no matter how clean, they never make drinking water out of effluent.

WATER QUALITY GRADES

WATER QUALITY	BOD5 (mg/l)	SS (mg/l)	N (mg/l)	P (mg/l)	PATHOGENS
Wastewater	~250	~250	~55	10-15	Microbial numbers very high
Grade 1 Effluent with reduced solids					
1a	~ 250	~ 250	~55	10-15	Microbial numbers very high
1b	175	100	50	9	Marginal reduction
Grade 2 Effluent with reduced organics	20	30	20-30	7	Reduction mainly due to adsorption of microbes to particles
Grade 3 Effluent with reduced nitrogen	10	15	5 -10	7	Many pathogenic bacteria are destroyed Some viruses and parasites may survive
Grade 4 Effluent with reduced nutrients (nitrogen & phosphorus)	10	15	5	0.5 - 2	Many pathogenic bacteria are destroyed Some viruses and parasites may survive
Grade 4 Plus Polished effluent	Quality depends on the intended use of the effluent. Can meet *Australian Drinking Water Guidelines* values or better				Pathogen free
Grade 5 Drinking water	Should meet *Australian Drinking Water Guidelines* health-related values for pollutants, microbiological quality and monitoring				Pathogen free
Grade 6 High quality water	Quality depends on the intended use of the water				Pathogen free

WATER QUALITY GRADES

OTHER POLLUTANTS	PROCESSES	COMMENTS
Yes, if trade waste is present		
Not affected	Preliminary screening	Protects downstream pumps
Marginal reduction	Primary settling	Provided at most plants
Some reduction	Biological processes. Naturally occurring organisms feed on the waste	The most commonly produced effluent — fairly clear but still containing nutrients & pathogens. Can be further treated and disinfected
Some further reduction	Activated sludge — modified form of biological treatment	A clearer effluent with significantly reduced levels of organic matter and dissolved nitrogen. Can be further treated and disinfected
Some further reduction	Biological nutrient reduction (BNR), chemical dosing	Produces a clear effluent with low organic matter and nutrients. Can be further treated and disinfected
Pollutants reduced to negligible levels	Disinfection, wetlands, chemical dosing, sand or multimedia filtration,ozonation, activated carbon, membrane filtration. Treatments used singly or in combination	Any quality can be produced. Treatment depends on quality of product required. Can be used for unrestricted irrigation, dual reticulation, to recharge ground or surface water storages or to augment drinking water supplies
Pollutants reduced to conform with *Australian Drinking Quality Guidelines*	Disinfection, chemical dosing, sand or multi-media filtration, ozonation, activated carbon, membrane filtration	Treatment depends on the quality of the source. Residual disinfection required for reticulated drinking water
Pollutants reduced to negligible levels	Ozonation, activated carbon, membrane filtration. Treatments used singly or in combination	Any quality of water can be produced.Treatment depends on quality of product required. Specific industrial or health applications

WATER FIT TO DRINK

Watter decided to pay another visit to Dr. Bugz for some advice about his predicament.

'Please, Dr. Bugz, I want to be so clean that I can become drinking water.'

Dr. Bugz stroked his neat goatee beard as he considered Watter's request.

'I'll take another sample and see what pollutants you still have after your treatment at the STP. There's no doubt they're much reduced – you're looking a good deal less turbid. Once we know what the problem is, we can prescribe some more treatment. The analysis will take longer

applications in different circumstances and not all are suitable for all situations. The table below summarises the characteristics of the most often used disinfectants.

Because they are poisonous to fish, chlorine and chlorine compounds are not the ideal for disinfectants for water which is going to be discharged to a waterway (unless a further dechlorination treatment is included). Nor are they ideal for the disinfection of water which has a high organic content because of the formation of chlorination by-products. However they provide residual disinfection so are ideal for drinking water.

Ozone or UV light are preferable for effluent disinfection. If they are used for drinking water, they should be followed by chlorine or chloramine to provide residual protection.

A combination of disinfectants is now being used to overcome some of the problems the disinfectants present.

If viruses or protozoa cysts are known to be present in a drinking water supply, efficient disinfection of highly clarified water using UV light or ozone, or membrane filtration will be required.

COMPARISON OF DISINFECTANTS

	Chlorine	Chloramine	Chlorine Dioxide	Ozone	UV light
Bacteria	Good	Good	Good	Good	Good
Viruses	Moderate	Poor	Good	Good	Good
Protozoa	Not effective	Not effective	Not effective	Good	Good
pH dependent	Yes	Yes	Slight	Slight	No
By-products of possible health concern	Yes	Fewer	Yes	Unresolved	No
Residual disinfection	Moderate	Long	Moderate	None	None
Contact time	Moderate	Moderate	Moderate	Short	Short
Cost	Low	Low/mod	Moderate	High*	Moderate

* produces cost savings at other stages in the process

AND EVEN BETTER: GRADE 6

Producing High Quality Water

There are several advanced treatments for water which can be used when a particularly high grade of water is required. The same processes are used if the water being treated has been highly polluted. They include ozonation, activated carbon and membrane filtration. They are quite often used in combination with each other and with the more usual processes.

Ozonation

As well as being a powerful disinfectant, ozone has the advantage that it will break down organic molecules in water. It is used extensively in Europe where, frequently, water supplies are polluted with industrial waste as well as domestic sewage. If it is used before activated carbon, it improves the efficiency of activated carbon treatment and lengthens the time before the carbon needs regeneration.

Activated Carbon

The surface of activated carbon has many pores; when water is passed through it, large organic molecules lodge in the pores and are removed from the water. This process where molecules and small particles attach themselves onto the surface of another substance is called adsorption. The bonds of attachment are often strong. Activated carbon removes the taste and smell from drinking water and is particularly useful if there is an outbreak of blue-green algae in a water source as it can adsorb the poisons they produce. The carbon can be regenerated by heating it in a furnace or by acid washing.

Membrane Filtration

The use of membranes for fine filtration is not new, but their application to the treatment of water has greatly accelerated in the past fifteen years. They are used where very high quality is needed. They are made of polymers or ceramics and have very fine pores which vary in size depending on the type of membrane. They are classified into four types:

Microfiltration	pore size 0.1 micron
Ultrafiltration	pore size 0.01 micron
Nanofiltration	pore size 0.001 micron
Reverse osmosis	pore size 0.0001 micron

These compare to a sand filter which allows all particles less than 10 microns to pass through. A micron is one millionth of a metre.

this time as we will be looking for more pollutants,' said Dr. Bugz.

'They can be divided into two categories, "organic" – the ones containing carbon – and the ones without carbon that are "inorganic". You have several heavy metals in the latter category; cadmium, copper, lead, nickel and mercury are all above the guideline recommendations. And you still have some nasty organics – some of these seem to be of industrial origin, others are from agricultural activities.'

'A good dose of salts will get rid of just about all the heavy metals; you can choose either alum or ferric chloride. As for the organics, they are adsorbed by activated carbon. That should make you drinking water quality – but if you want to be even cleaner, you could get yourself filtered through a membrane.'

'If you're not filtered, you will need to be disinfected, but it would be better if you

The great advantage of membranes is that they are barriers to particles which are larger than the pore size. If a pathogen is bigger than the pore size, the membrane will provide a definite barricade to that organism. Membranes can therefore be absolute disinfectants. This contrasts to other disinfectants, such as chlorine, which provide a percentage or statistical kill dependent on actual contact with the organism.

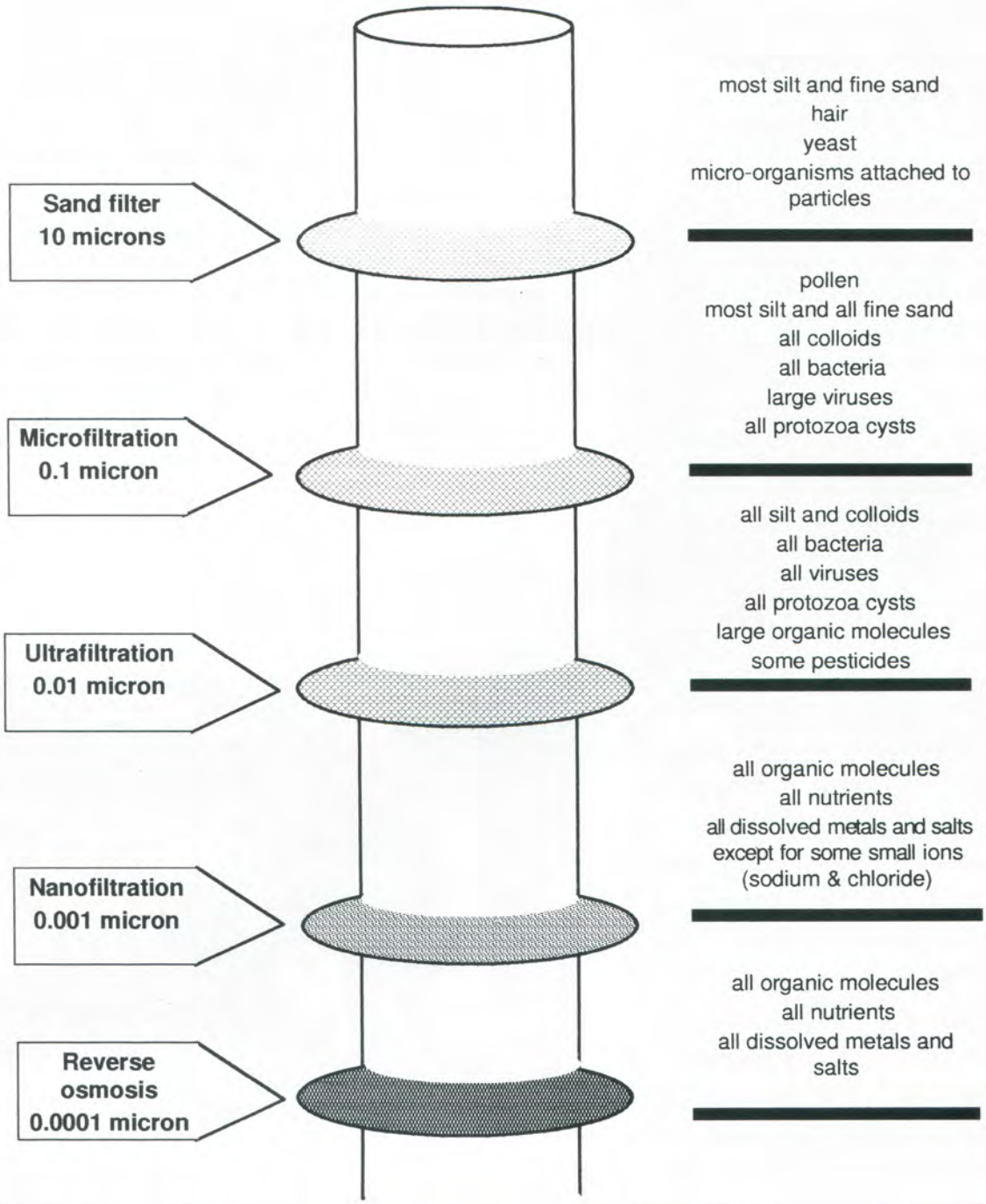
It takes energy to push water through the small pores of membranes – the smaller the pore, the more energy required. As could be expected, and as happens with sand filters, the particulate matter which is collected by the membrane has to be removed by some form of backwashing. Some elegant methods have been invented to do this.

Because of the fineness of the pores in the membranes they can block quite quickly so there are considerable advantages in staged filtration. In one such case, Water Factory 21 in San Diego, microfiltration is used ahead of reverse osmosis to optimise the performance of the latter. The high quality water produced from the sewage is used to recharge the aquifer which provides the city's drinking water.

The chart shows how smaller and smaller particles and molecules are removed as the pore size decreases until, with reverse osmosis, the water is essentially pure, similar to distilled water. The membrane used in reverse osmosis is similar to the membrane of a living cell which will only allow water molecules to pass. In reverse osmosis, instead of the water moving in to dilute the solution, pressure is applied so that it moves out. Reverse osmosis can be used to take the salt out of sea water to make it drinkable; it has replaced flash distillation as the preferred method of desalination of sea water. Small plants are often used on ships and in all modern submarines. Portable plants can be used in emergency situations, such as in earthquakes or floods, where public health is threatened by a contaminated water supply.

Nanofiltration can replace reverse osmosis (with the resultant saving in energy costs) if the water involved is not salty. It removes nearly all dissolved substances

MEMBRANE FILTRATION



were treated chemically first – the disinfectants work much better if you are sparkling clear because sometimes the bugs hide behind the particles.'

'Where do I find these chemicals?' asked Watter.

'They're used at the drinking water treatment plant – but they won't let you in there because you're effluent. You can sometimes find them in smaller sewage treatment plants which are too small for BNR yet have to have very low phosphorus because they discharge into a sensitive waterway. People use the same chemicals in their swimming pools too.'

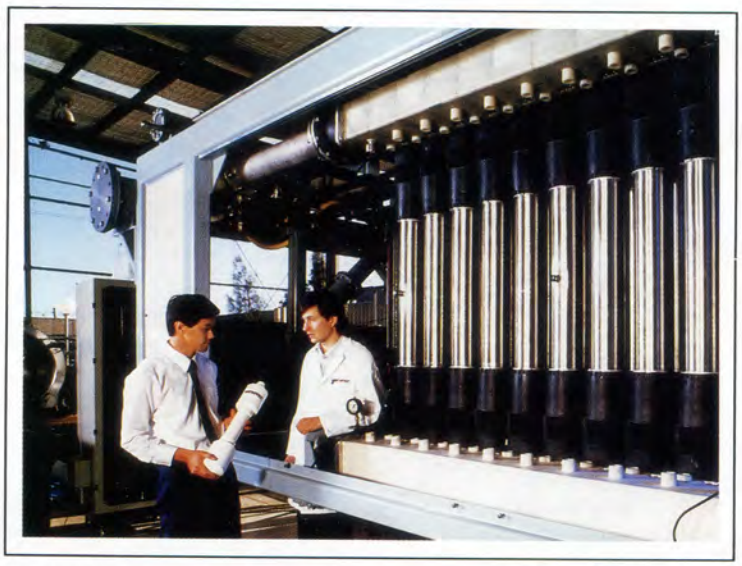
'Activated carbon is used where there are outbreaks of blue-green algae – it's ideal to adsorb big organic molecules such as the poison the algae produce. It's used in gas masks too.'

'I've heard that they have an Aqua Therapy Research Institute near the university. They have all the facilities there, including various

including bivalent ions (with two charges) such as calcium and magnesium, but only 20 – 30% of the monovalent ions (with a single charge) such as sodium and chloride, the main salts in sea water.

All treatment processes result in a residual product which contains the contaminants from the water. The purer the water, the greater amount of residuals produced. Membranes are no exception, so consideration must be given to the management of the residuals when designing the project.

Membranes have a role to play in reclamation of wastewater so that it can be returned to the drinking supply. The cost of new supplies of water will continue to rise and the cost of technology will continue to decrease, as the cost of computers has. It is for this reason, and because they produce a superior and more reliable product, that they will find increasing application in the treatment of water and in the reclamation of wastewater.

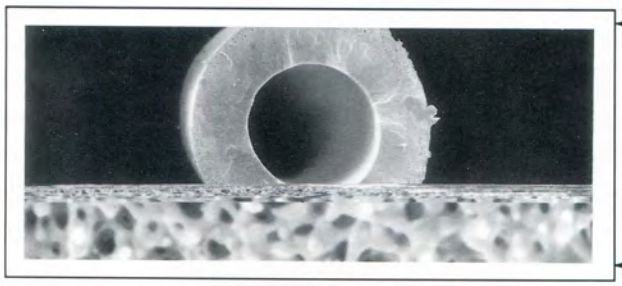


A microfiltration system in operation *Photo: Memtec Limited*

MICROFILTRATION

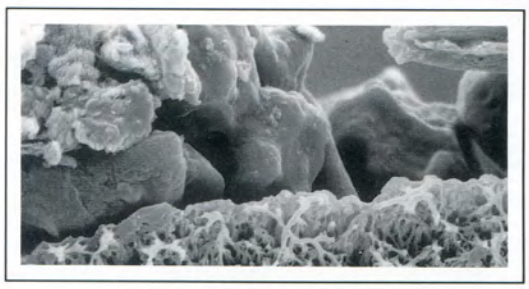


A bundle of polypropylene microfiltration fibres before being encased in the filtration module. Each fibre is about half a millimetre in diameter.



Fibre cross section magnified 70 times

Fibre cross section magnified 7,000 times



Sediment caught on the fibres

Photos: Memtec Limited

EFFLUENT MANAGEMENT

Ideally, we should look upon our use of water as a loan from the environment. Like anything we borrow, we should clean it up after use and return it whence it came in the same or better condition than it was before we borrowed it.

This rarely happens because we are not prepared to spend the amount of money required. We have acquired the habit of throwing our wastewater away, disposing of it, out of sight and out of mind; we assume there is plenty more water to meet our ever-increasing needs.

But we can't just throw our effluent away, for there's no such place as 'away', and we are coming to realise that new supplies of water are scarce and expensive.

Forming a Wastewater Management Strategy

Before we can reach a decision about what treatment will be needed for the wastewater, we have first to decide on a strategy for managing the effluent and the residuals.

Local conditions will have a strong bearing on the options that are available. The climate, the size of the plant, the nature of the surrounding areas, the soil types, the availability of new water supplies, the local waterways (and the value the community places on the quality of water in them), and the opportunities for recycling both the effluent and the sludge are among the factors that need to be taken into account.

It is important to identify all options, even those that seem farfetched. The options will have varying effects on human health, the environment, the water supply and the short term and long term costs. Some factors will be considered more important than others; they should be rated accordingly.

When deciding on a sewerage strategy, it is important to ask the questions; 'What happens when it rains?' and, 'What happens during a drought?'

In the hierarchy of waste management options, prevention and reuse are the preferred strategies. Disposal is acceptable only as a last resort.

Once the fate of the effluent has been decided, it is possible to decide how to treat it to achieve the appropriate quality.

Disposal Into Water

Ocean Outfall

Ocean outfalls are an example of the principle that dilution is the solution to pollution. In the (not very long-distant) past, inadequately treated effluent has been discharged through inadequate outfalls and the result has been polluted beaches and complaints of ill-health from the bathers; outfalls are therefore regarded by the community with distaste.

Organic matter in effluent provides a source of food for marine organisms but the nutrients have the potential to cause environmental damage such as algal growth and plagues of starfish and sea urchins. The nutrients also have an adverse effect on seagrasses and coral. Effluent discharged through an outfall should not contain any trade waste.

Any ocean outfall, even for higher grade effluent, has to be carefully designed and managed. The initial dilution, the distance of the outlet from shore, the efficiency of the diffusers and many other factors have to be taken into account. Ocean outfalls can work efficiently and may be satisfactory in places where the water supply is abundant. But, being a method of disposal, they are regarded by the community as, at best, a waste of a valuable resource.

Advantages:

- less expensive treatment required
- effectively separates effluent from drinking water supplies
- more tolerance of salinity than with land disposal

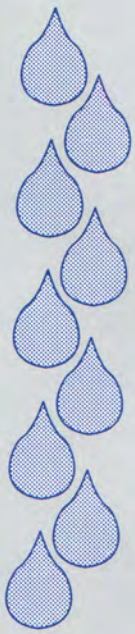
Disadvantages:

- no saving of the urban water supply
- some outfalls are inadequate and effluent from them pollutes beaches and infects swimmers
- they may cause environmental changes: excessive algal growth, plagues of echinoderms (sea urchins and starfish) and destruction of seagrass
- heavy metals and toxins may accumulate in marine organisms and enter the food chain.

types of membrane so I suggest you go and see if you can get in.'

Watter was impressed.

'Sounds like it might be just the place for me. I'll go at once.'



ENVIRONMENTAL ENCOUNTERS

Watter was shown into a consulting room. On the door was a sign:

N. Vera Mantle
Water Quality
Consultant

An elegant lady drop rose to meet him. She had an unusual green hue and a clear, fresh complexion.

'Please come in,' she said with a sparkling smile.

Watter was impressed; he had never before met such an attractive drop. He explained why he had come.

'At the moment I'm Grade Four but I want to become Grade Five, Drinking Water,' he said. 'I heard you have all sorts of advanced water treatments here, chemicals, filters and disinfectants which I could try.'

'I'm sure we'll be able to help.' Vera was sympathetic

'Yes, we have everything here. We can do even better than Drinking Water,

Disposal to a river or estuary

Although rivers have long been used as a drain to carry away our waste, this practice is increasingly coming into question. The quality of water in rivers is adversely affected if poor quality effluent is disposed of into them. Eutrophication, oxygen depletion and outbreaks of blue-green algae can occur. The effects of discharging inadequately treated effluent into our waterways are becoming more apparent and we are starting to look at ways of dealing with the problem.

Sometimes however, we seem to forget that it is the quality of water in a river that matters, not the water itself! Rivers need to have water in them to support their ecosystems.

Advantages

- may support ecosystems and the water supplies of downstream communities
- more tolerance of salinity than with land disposal

Disadvantages

- does not have a beneficial impact on urban water supply unless there is a community downstream
- risk to human health if inadequately treated effluent is discharged into a waterway used for recreation
- discharge of effluent with high organic and nutrient content may cause oxygen depletion and eutrophication
- may cause environmental changes such as excessive algal growth
- heavy metals and toxins may accumulate in aquatic organisms and enter the food chain
- alters the natural flow pattern in river systems, particularly in non-perennial rivers (ones that don't flow all the time).

Land Application

We are busy trying to feel virtuous 'doing the right thing' – disposing of our effluent on land. This is generally welcomed by the uniformed as a solution to our water management problems; it doesn't involve having to face up to cultural changes. Land application has its place but it isn't a universal panacea. There are limited opportunities

EFFECTS OF COMMON EFFLUENT CONSTITUENTS ON THE ENVIRONMENT WHERE THEY ARE DISPOSED

Material	Disposal Environment			
	Water		Land	
	Ocean	River	Arid	Wet & tropical
Water	Little effect	No effect on rivers, dilution effect in estuaries	Very beneficial	Sometimes beneficial: overwatering may contribute to salinity problems
Natural organic compounds	Undesirable: depletion of oxygen content of water	Very undesirable: depletion of oxygen content of water	Beneficial	Beneficial
Nitrogen	Undesirable but effect reduced by dilution	Very undesirable: contributes to eutrophication	Very beneficial	Beneficial but may leach into ground water if added in excess
Phosphorus	Undesirable but effect reduced by dilution	Very undesirable: promotes algal growth	Beneficial: leaching unlikely as it combines with the soil	Beneficial: erosion and soil wash-off must be avoided
Sodium	No effect	Little effect	Undesirable	Undesirable
Heavy metals	Very undesirable: bioconcentration in marine organisms	Very detrimental: bioconcentration in living organisms	Very detrimental: build up may occur	Very detrimental: build up may occur
Pathogens	Diluted but have the potential to spread disease if not properly managed	Likely to spread disease if not properly managed	Degrade harmlessly if properly managed	Degrade harmlessly if properly managed

you could become Grade Six, like me. Come, I'll show you around.'

'There are several stages of treatment, depending on just how pure you want to be. The treatment starts with some air blowing through you and any grease or scum are skimmed off. Then we adjust your pH. We give you a dose of alum to flocculate any heavy metals you have in solution and remove the last of your phosphates.'

'Ozone comes next, we make it by passing an electric charge through dry oxygen. It looks a bit scary but it's quite safe. It's a powerful oxidising agent so your big organic molecules are broken down and most of your pathogens are inactivated. This makes the next treatment, activated carbon, more efficient.'

'Heavens,' said Watter, 'How can anything so black possibly make me cleaner?'

'Don't worry,' said Vera, 'It doesn't come off! There

in large towns and in areas of high rainfall or poor soil. The problem of what to do with the effluent in wet weather always remains.

It is tempting to make the link between the need of urban dwellers to dispose of their effluent and the drought-stricken folk on the 'other side of the range'. This very expensive option is discounted by economists on the grounds that the recipients do not have the ability to pay – and it is unlikely that the townsfolk would be willing to pay either.

Parks, playing fields and golf courses are often irrigated with sewage effluent; it is an ideal way to dispose of the effluent and puts the nutrients in it to good use. Efficient disinfection is needed if it is likely to come into human contact. There should be no run-off into ground or surface waters. In large towns opportunities for this type of effluent disposal are limited.

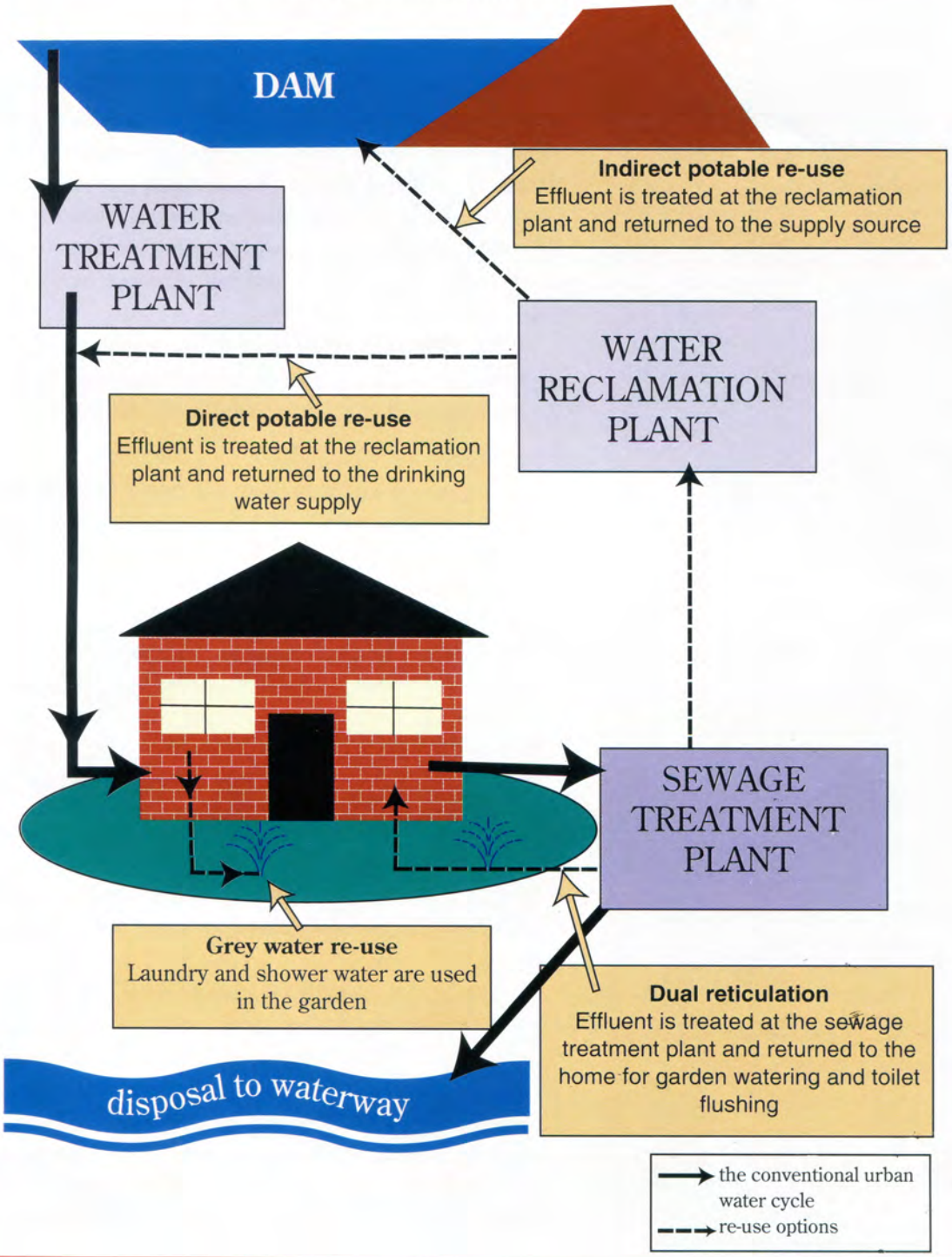
In situations where the waterways are environmentally sensitive, land application can be an alternative. A dedicated area is planted with crops which are chosen to maximise the uptake of water and nutrients. Careful management to ensure the system is sustainable and large storages are vital. Nutrient removal facilities will be necessary if excess effluent is discharged to the waterway in wet weather.

Effluent can be used to irrigate a crop in which case some of the costs of the scheme may be recovered by selling the effluent or selling the crop. It is particularly advantageous if effluent is used in a situation where water would otherwise be supplied from the reticulated supply.

Effluent irrigated tree plantations are being developed successfully in some inland areas. Dry climates are best – the annual evapotranspiration rate should substantially exceed the rainfall. Adequate land area and storage are needed, particularly in climates with a pronounced wet season. The most suitable soils are moderately permeable with good water and nutrient storage capacity and good depth.

The crop should be selected with care – some forest trees do not develop properly if over-watered; a mixture of species could be the answer in some areas. Ground and

DOMESTIC EFFLUENT RE-USE OPTIONS



are holes in the surface of the carbon; all our organic molecules lodge in them and stay behind. It's a process called adsorption. Activated carbon is particularly good at adsorbing things like weed killers, hormones and insecticides.'

'We also have a range of membranes. They're used if particularly pure water is needed for a special purpose, or as a safety barrier if badly polluted water is going to be used as a drinking water supply. They come in different pore sizes – the finer the pore, the more energy required to push you through.'

'There's a membrane with such fine pores that it will take out all your dissolved salts too. Nothing could make you purer than going through that. It's called reverse osmosis. It can even be used to make drinking water out of sea water.'

Watter spent a week at the Institute, trying out all the treatments that Vera pre-

surface water contamination are potential problems and, as with all irrigation, salts can build up quickly in the soil. The water table should be several metres below ground level.

Because of the mismatch between the relatively constant output of effluent from the STP and the highly variable needs of an irrigated crop, there is always a risk that efforts to make a project economically sustainable will result in it becoming environmentally unsustainable. Adequate monitoring is critical; the land re-use site is going to be constantly receiving effluent over the long term.

If the effluent is to be used to irrigate pasture for grazing cattle, precautions must be taken to ensure that it is free of pathogens and chemicals which may affect the cattle.

Advantages

- the quality of effluent does not need to be as high as for disposal to a waterway
- can be used for parks, gardens and golf courses but as these are often widely spaced, the distance the effluent has to be transported can make this expensive. The use of 'sewer mining' (sewage is intercepted on its way to the STP, treated and used locally) has the potential to be a way of over-coming this problem
- if the effluent is used to irrigate a commercial crop some costs of the scheme may be recovered by selling the effluent or by selling the crop.

Disadvantages

- no saving of the urban water supply unless it is replacing water that would otherwise have come from that supply
- environmental damage is possible – salinity or nutrient run-off to surface and ground water
- crops have a limited and very seasonal requirement for water, but in dry conditions demand can exceed supply. Sugar cane is a particularly good example of this. Very large storages are needed to overcome this problem
- the irrigation needs of a crop and the need to dispose of the effluent can result in a conflict of interests. Large

storages are again needed to manage this
- overwatering may cause a rise in the water table with resulting salinity problems
- the nutrient balance in effluent is not always correct for the crop under consideration so additional fertilisers are needed. Careful, expert management is required
- in urban situations the cost of sufficient land and storage is usually unacceptably high
- if excess effluent is released to a waterway in wet weather, facilities for producing a higher quality during these periods will be needed.

Industrial Re-Use

Recycled water can be used in industry; it is a good way of using it as the water can be treated specifically for its purpose. However, very little effluent can be reused in this way. An average large town may be able to reuse 7 – 8% of the available effluent if all opportunities were utilised. A town with more heavy industry could manage up to 12%.

Domestic Re-Use

If we are going to reuse a significant proportion of our urban wastewater, we have to turn to the domestic scene.

Of the water that comes into our houses, we consume only 1% of it and have contact with 30 – 40%. In dry weather we use more than half of our drinking-quality water to put on our gardens. Water of a lower grade would be adequate for this purpose.

The chart on page 49 shows the ways in which we can reuse water in our homes.

Greywater Re-use

Greywater is the wastewater produced in our bathrooms, kitchens and laundries. It does not include wastewater from toilets and, if it is going to be reused, the kitchen water should not be included as it is likely to contain grease and oil.

Greywater contains nutrients so its re-use for garden watering is beneficial. But, as it also contains pathogens, it poses a risk to health if care is not taken in its manage-

scribed. He came to appreciate that there was much more to water quality than he had realised. They had long, deep discussions about the future of water management and they discussed their own futures too.

'I'm going to get polished in a wetland', said Vera. 'I need a bit of a holiday and it's lovely there among the water plants. Lots of birds are attracted there and then people come to look at the birds. Wonderful things wetlands, provided they are managed properly, of course.' 'Why don't you come too?' she invited.

Watter hesitated. He realised that he was going to miss Vera's company. She was so knowledgeable and obviously appreciated the quality of drops. It was difficult to refuse but he wasn't quite ready to settle down yet. He had an ambition to fulfil: he knew he wouldn't be satisfied until he became drinking water.

'Thanks for asking me, it

sounds quite delightful and very tempting. But I've had every possible treatment except reverse osmosis and I want to become drinking water,' said Watter. 'I'm so clean they can't possibly refuse me now.'



ment. The irrigation system should therefore be subsurface – watering of lawns with greywater from sprinklers is not a recommended practice.

One of the main worries about the re-use of greywater is that it requires commitment from the individual householder to ensure that the system is functioning correctly and not causing pollution and a nuisance. Some householders have the reputation of being less than enthusiastic about accepting the responsibility for maintaining their waste management systems.

As reticulated water becomes more expensive and home greywater systems improve in efficiency and ease of maintenance, they may become more acceptable and popular.

Advantages

- has considerable potential to impact on water supply demand if all opportunities for implementation are taken up
- cheaper water available for consumers – but this is offset by high installation costs
- nutrients put to good use
- householders can water gardens when sprinkler bans are in force.

Disadvantages

- potential for public health risk if not adequately controlled
- potential for aesthetic problems – smells, unsightly slimes – which could cause conflict between neighbours
- depends on the efforts of individuals who may not remain committed
- increases the work load on local councils
- fluctuating quantity and quality of sewage arriving at the sewage treatment plant could cause problems
- the cost of a greywater re-use system (holding tanks, filters, pumps valves, sub-surface irrigation system) is a deterrent for widespread acceptance.

Dual Reticulation

Sewage is taken to the treatment plant and treated to a

standard where it is safe for use outside the house and for toilet flushing. It is returned to the houses in a separate pipe.

The main advantage is that householders do not have the responsibility of maintaining their wastewater re-use system. The main disadvantage is the cost of the second reticulation system. Dual reticulation is generally only cost-effective in new developments when both reticulation pipes can be laid at the same time.

Advantages

- could have some impact on augmenting the water supply. There is potential for about 30% of the total sewage flow to be used.
- nutrient loadings on waterways are reduced; instead they are put to good use on land.

Disadvantages

- unacceptably high capital cost if the second pipe is laid in areas that are already developed
- precautions must be taken to avoid cross-connection.
- if the cost of the ongoing higher treatment of the water is not covered by the sale of the reclaimed water, the general community will be subsidising the scheme
- nutrient management facilities will be required when effluent, which is in excess of requirements and storage capacity, has to be discharged to a waterway.

Potable (Drinkable) Re-use

Although effluent which is used for dual reticulation is of a high quality and would be unlikely to cause illness if consumed in small quantities, it is not subjected to such extensive treatment as is required if it is to be reclaimed for drinking. The quality of the water is not significantly different (although water of dual reticulation standard will not have been treated with activated carbon to remove organic molecules) but the degree of certainty that it will reach the standard is greater. A combination of treatments is used which provide several barriers to each type of pollutant or pathogen. These technologies are the same as can be used for producing water of a high quality for special purposes. (see page 39)

A DROP OF QUALITY

But they could!

Watter went for an interview at the water treatment plant. He felt proud of himself again and quite sure that he had regained his air of good breeding and distinction.

They were very impressed with his looks and his analysis but then they started to inquire into his history.

'Have you ever been through an STP?' they asked.

'Yes,' Watter answered truthfully. 'I got to Grade 4 and then had further treatment, chemical dosing, ozonation, activated carbon, even membrane filtration, so now I'm Grade 6. The best!' he said.

'But you're effluent!' they exclaimed in horror. 'You have no business to be in a water treatment plant. You must go before the rest of the water gets infected. Immediately.'



'But I'm clean!' said Watter, 'I'm clean! Please let me stay. I want to be drinking water.'

'Clean or unclean, you can't possibly become drinking water. You're effluent and we never make drinking water out of effluent. Now, away with you and stop having ideas above your station.'

Watter was frustrated and angry. He would go

If effluent is going to be reclaimed for potable re-use it is important to have in place a strictly enforced trade waste policy and to strongly deter the illegal dumping into the sewer of pollutants such as solvents, pesticides and heavy metals.

Modern technology and monitoring techniques make potable re-use safe and affordable.

Indirect potable re-use

This is returning the highly treated effluent to the drinking water supply source which could be a dam, a river or an aquifer.

With indirect potable re-use, it is particularly important that the phosphorus levels are reduced to the absolute minimum so as to avoid a build up in the storage.

Advantages

- has a significant effect on the water supply and the potential to defer the need to construct more dams
- reduces the amount of less-well treated effluent that is discharged to waterways
- due to high standard of treatment it is likely to be purer than some of our present reticulated potable water supplies
- makes a reliable water source – one that increases as the population increases.

Disadvantages

- has the potential to cause eutrophication of the supply source. Although the **concentration** of phosphorus is an important factor, more important still is the effect of **loading** of phosphorus on a confined water body. Care should be taken that the system is sustainable in the long term
- long pipes and pumps are likely to be needed; most sewage plants are a long way from, and lower than, the dam.

Direct Potable Re-use

Highly treated effluent is returned directly into the drinking supply.

The presence of nutrients in water intended for drink-

ing does not present a problem. According to the *Australian Drinking Water Quality Guidelines*, adults and children over three months can safely drink water with up to 50 mg/l nitrate; no health-based guideline value is considered necessary for phosphates.

Advantages

- has a significant effect on the water supply and the potential to defer the need to construct more dams
- no necessity to remove the nutrients to such a low level as would be required if the water was to be discharged into a confined waterway such as the case with indirect potable re-use
- few pipelines required
- reduces the amount of less-well treated effluent that is discharged to waterways
- due to high standard of treatment it is likely to be purer than some of our present reticulated potable water supplies
- makes a reliable water source – one that increases as the population increases
- can be used as an emergency supply if other sources are affected by outbreaks of blue-green algae.

Disadvantages

- a perception that breakdowns in the system could cause problems. Fail safe measures are avail able such as on-line monitoring and storages – the water is released only after it has been tested and found to be safe. The risks are insignificant compared to our present inadvertent re-use prac tices
- a perception that the authorities will be sued every time somebody has a stomach upset. There are so many ways in which infections can be transmitted that it would be almost impossible to blame the water supply. Legal advice is that the risk of this is extremely remote; this is confirmed by the lack of problems arising from inadvertent re-use.
- high operating costs if reverse osmosis is used. These



through the finest membrane of all and then go and see the Man from the Government. Surely ***he*** *would be able to see the injustice of the situation.*

He found the reverse osmosis was even more of an ordeal than his pre-

vious membrane experience. Afterwards he felt quite weak. Definitely wishy washy. He looked in the mirror and noticed his head was becoming rather pointed.

'Heavens! I'm turning into a drip,' he thought. 'Trouble is I'll lose my immunity if I have no exposure at all to pathogens and I need some traces of minerals in order to survive. I'm so insipid nobody will want to drink me.'

He made an appointment to see the Man from the Government. His name was Sir Genghiz Fendorf. Sir Genghiz was a large blustery man; he brushed his hair forward and sported a scrubby black moustache.

Watter explained to him his ambition to be drinking water.

'I've been through a state-of-the-art STP; I was Grade Four effluent. I've

can be reduced by the use of staged filtration and nanofiltration instead of reverse osmosis
- disposal of residue from reverse osmosis and nanofil–tration can present a problem.

Money Matters

The cost of reclaimed water is, at the moment, higher than the price we pay for reticulated water. However, in many areas this latter price does not fully cover the cost of storing, treating and transporting the water to our homes. The cost of providing water is going to increase; most of the closest and easiest dam sites have already been exploited; treatment costs are going to rise as water quality decreases due to the effects of increasing population pressure. Subsidies are no longer being provided to reduce the cost of water to the consumer.

At the same time as the cost of conventional water management is rising, the cost of technology – which is becoming more sophisticated and reliable – is decreasing.

It is vital, when considering how we should be managing our water, that we:
- take a long-term view
- take a holistic view of the whole urban water cycle
- take a holistic view of the funding of water supply and sewage management in order that the most cost-effec--tive solution can be identified (integrated least-cost planning)
- take care that the chosen solution is ecologically sus-tainable
- take care not to lock into a system with high capital cost that inhibits the use of new technologies as they become available.

WATER QUALITY AND THE ENVIRONMENT

What effect does the way we obtain our water and dispose of our wastes have on our stream systems, estuaries and coastal marine areas? Is it good or bad? Would it be better for our waterways if we changed our water collection and treatment and disposal/re-use system to another? Would it be better for us? What are the broader consequences of our interactions with the water cycle? What are the implications for the future?

In order to be able to answer these questions sensibly we need an understanding of the water cycle and the consequences of our interaction with it. We also need to be quite clear what it is we value in our surroundings – ecologically, economically and socially.

Values are tricky things. What one individual perceives to be significant, another may consider to be of little consequence. What our society thinks is important (or values) is often spelled out in the market place in dollars and cents. Decisions of our courts are based on points of law, which, in turn, are based on commonly held social values relating to right and wrong. Will this help us to decide what we value in relation to our interaction with the water cycle? Obviously water is important to us – so are our streams, estuaries and coastal marine areas. What 'wet bits' of our environment do we value? Why? Are the values derived in the market place and courts always adequate? Do they reflect our values?

The Situation has Changed

Not too long ago, the world seemed immense to us. The oceans and streams, the forests and fields, the skies above seemed infinite. Their capacity to provide us with our wants and to absorb the substances for which we had no further immediate use (wastes) appeared unlimited. Our environment seemed even able to perform feats of alchemy, decomposing and diluting wastes that were potentially hazardous to our health, often accepting them into the hydrological and ecological cycles and, in time, rendering them harmless, even useful.

While there weren't so many people on Earth this has seemed a fairly acceptable way to behave. With rapidly increasing human population numbers and concentrations in certain areas, the situation has changed. Most of us now realise that there really is no such place as 'away'. If we try to dispose of our wastes, be they gaseous, liquid or solid, without considering where we are putting them, we may run into trouble.

been treated chemically and had several ozonation therapies; I've even had reverse osmosis.' he said. 'I'm now a drop of perfect purity; pellucid and impeccable. Why can't I be drinking water?'

'But you're effluent!' said Sir Genghiz, outraged. 'We can't have the likes of you going round and round! Good heavens, boy, if you think you can do that, we won't have an excuse to build a new dam. And if the dam builders go out of business they won't be able to support the Government at the next election. You could bring the Government down with that sort of nonsense and I'd lose my job!'

'Just get this into your silly pointed head: the quality of water isn't important but its history is. And don't you believe anybody that tries to tell you any different.'

Unfortunately for us, unless we are dealing with a nuclear reactor or an atomic bomb, the law of Conservation of Matter always applies:
Matter cannot be created or destroyed. It can only be changed from one form to another.

We can try to solve our water pollution problems by using large quantities of water to dilute the nutrients, heavy metals, industrial waste, pesticides or whatever it is that concerns us, down to concentrations which research has shown are acceptable. This may be a good short term solution, but in the longer term problems may eventuate. Our solution to the problem focussed on getting those pollutant concentration levels down by increasing the quantity of water in which they were dissolved, rather than controlling actual pollutant quantities. Viewed in the long term, dilution is at best, a problematic and precarious solution to pollution. Trouble threatens again.

All Things Interact

Trouble takes unexpected forms. In terms of water quality issues, for example, no responsible government or community of people would ever consciously set out to cause blue-green algae (bacteria) in our waterways. This has nevertheless happened. We have acted as if there really is a place called 'away' where we could throw our wastes. Generally, we have acted as if all the 'bits' that make up our environment, the air, the land, the fresh and marine waters, the ground water, the animals and plants and the other people with whom we share our environment were all separate components.

We have interacted with one component such as the land by growing crops or grazing intensively on flood plains. We have drained urban stormwater into our coastal creeks. We have impounded our river systems, transporting huge volumes of water large distances to our cities and towns, used the water and in the process added various wastes to it and then disposed of it into our fresh and marine waters. We have behaved like this without realising, expecting or perhaps even caring, that these actions might cause problems with the productivity and diversity of the downstream components of our waterways.

Environmentally all things interact. The interactions we have with our environment are also influenced by the economic and social systems that form the fabric of our daily lives. Economic and social realities influence environmental decisions.

Putting Change in Perspective

Time and proximity may heavily influence our perceptions about changes in our surroundings. Sometimes they take place slowly or at a distance so we scarcely notice their happening. But if we take a closer look and compare what we see with what existed in the past, we become aware of the impact we are having on the environment.

Aquatic systems are constantly changing. Coastal rivers and creeks, for example, have always taken sediment and nutrients downstream to estuaries. We need to consider how we, in our human activity, affect these naturally occurring changes. Obviously we must interact with our surroundings in order to survive but the nature of that interaction may prove significant.

It is easy to evaluate the ecological changes that occur when Grade 1 effluent is discharged into a stream (a point source) by comparing upstream and downstream water quality and biological data. On the other hand, changes that occur over time when residential stormwater run-off (a non-point or diffuse source) enters an estuary, such as an increase in turbidity, changes in phytoplankton density, growth of epiphytic algae, changes in seagrass diversity and species occurrence, decline and death of seagrass meadows, the loss of economically significant marine productivity, may be more difficult to determine in the short term.

Time, proximity and the nature of our interaction with the aquatic ecosystems may influence our perceptions of how we are altering our streams, estuaries and coastal marine areas.

Environmental Values

How we interact with our environment will depend on what things are important to us – what things we value. Adam Smith, the 'father of modern economics' main-

THE MIRACLE MILE

Watter woke up next morning feeling tired. He had not slept at all well; the thoughts in his head had been going round and round. Round and round. He thought about the words of Sir Genghiz. 'We can't have the likes of you going round and round.'

He knew that water went round and round in the water cycle. Suddenly he realised the significance of it going round and round in a smaller cycle. It was a wonderful idea – not only would it save the cost of providing new supplies, it would mean that there would be less poor quality effluent being disposed of into the river. And it would be a wonderful way of drought-proofing the community because effluent is a reliable source of water. The amount produced increases with the population.

Everybody would benefit from this, except perhaps the Government, but there always seemed to be plenty

of those so losing one would-n't matter. And Sir Genghiz could get a new job at the reclamation plant. Watter's tiredness vanished; he felt the need of some fresh air.

'I'll go for a walk along the river and think about this idea. I could even discuss it with some of the river drops,' he said to himself.

There had been virtually no rain for the past three months so the river was low and flowing sluggishly. The water in it was brown and uninviting. The weather was hot but Watter didn't fancy jumping in to cool off; he didn't want to become polluted again. He was sitting on the bank deep in thought about his new idea when a passing drop in the river hailed him.

'Hi, Watter, remember me?'

Watter stared at the passing drops and saw one that was cleaner than the others. His heart leapt; it couldn't be – yes, it was – it was Vera; what was she doing in the river?

tained that objects only had a value in terms of their usefulness to us or how they could be traded for other useful objects.

The word 'value', it is to be observed, has two different meanings, and sometimes expresses the utility of an object, and sometimes the power of purchasing other goods which the possession of the object conveys. (Adam Smith, 1776)

Of course, he was only speaking 'economically'. We are all aware of objects, activities, locations and occasions that have other value or worth, ranging from works of art and mountain top views through to special time shared with friends and family.

Values are ethical in nature and therefore influence our behaviour, making us predisposed to act in certain ways.

There has been a tendency in recent times (with the rise of the notion of economic rationalism) for some individuals to view our environment purely in economic terms. Natural 'resources' they may be, quite useful, able to be bought and sold or exchanged for other goods; but our environment is many other things as well. Economic fundamentalist thinking will never fully explain the ways in which we value the environment. The value we may prescribe to objects and the wealth we may perceive cannot simply be measured in monetary or utilitarian terms. Nobel Prize winner and eminent scientist, Edward O. Wilson makes the point:

Every country can be said to have three forms of wealth: material, cultural and biological. The first two we understand very well, because they are the substance of our everyday lives. Biological wealth is taken much less seriously. This will be a strategic error, one that will be increasingly regretted as time passes.
(Edward O. Wilson, 1989)

How does this apply to our interactions with the water cycle?

Hopefully, in a democratic society, the Laws of the Land are based on commonly held societal values relating to certain principles or ideals held by the members of that society. They are **held** values.

On occasions certain individuals or groups may assign values to objects or resources. They are termed **assigned** values.

These two types of values are interdependent. A community will possess held and assigned values relating to their waterways. These may relate to the uses to which these waters may be put; for example to their potential agricultural, industrial, recreational, transport or potable water supply uses – or they may relate to the social and cultural significance of the waters or to their ecological significance. These waters may have certain potential uses or attributes that make them special.

Environmental values are not just confined to aquatic environments, and the above is not an exhaustive list. Value (or is it beauty?) is certainly in the eye of the beholder. In many societies throughout the world ecological communities, ecosystems, locations or non-living characteristics of our surroundings are also thought of as having cultural or spiritual worth (e.g. Hindu reverence of the River Ganges). Environmental values may also be contested by differently interested groups in society. The support and opposition that dam construction proposals have the ability to generate in Australian society (and elsewhere) are classic examples of this.

The worth or value attributed to any environmental characteristic may also change over time and location. To most of us a tin opener is worth about two dollars. You can buy one at any hardware store. To a person marooned on a desert island with no other provisions save a year's supply of tinned food, a tin opener is worth considerably more. While our aquatic environments appear to be able to dilute our wastes and while we have not perceived this as an issue, they have had little environmental value. It is when our aquatic surroundings become overwhelmed by our 'watery interactions', that they suddenly have greater worth.

Many different values may be held for our aquatic environments. That's O.K. Environmental values are subjective constructs. But those of us who find comfort in 'objective facts' may find this disturbing. Nevertheless, knowing what we, as a society, collectively value about our

'Vera! How wonderful to see you again,' said Watter. `Did you get tired of being in the wetland?'

'It was a delightful, soothing experience. The drops stay there for a couple of months – by that time the plants have absorbed most of their pollutants. I decided to come into the river and do some consulting but the quality of the water in the river is so unbelievably bad I don't know where to begin.'

'How did it get to be like that?' asked Watter.

'About half of it is effluent from the STP below the town. It's a trickling filter plant so the effluent is only Grade Two and contains a full compliment of nutrients. They chlorinate it because they think the kids might go for a swim in it, but this has poisoned the fish. It joins the other half of the water in the river which flows through an irrigation area. They overwater the crops so the runoff carries all their expensive fertiliser and some of the pesticides and weedi-

cides they use too.'

'Sounds awful,' said Watter. 'I'm glad I'm not a river drop.'

'It's quite difficult to breathe too,' said Vera. 'The dissolved oxygen levels are way down because of all the organic matter in the water.'

She changed the subject. 'What happened to you? Did you get to be drinking water?'

'No,' replied Watter, 'I'll tell you about it.' He related his sorry tale and his encounter with Sir Genghiz. Vera was sympathetic.

'Such hypocrisy,' she said. 'But I'll tell you how to beat them. Just come in the river with me because there is a weir only a mile downstream from here and they take drinking water out of that.'

'But they never make drinking water out of effluent,' said Watter, 'And the river is at least 50% effluent.'

'No it's not,' said Vera, 'Once effluent has been in a river it turns into water. Just as soon as it gets

surroundings can help when planning how we might go about maintaining and/or improving their quality and the nature of our interaction with them.

The Australian Water Quality Guidelines for Fresh and Marine Waters is based on five environmental values that represent a broad-brush attempt to capture what we collectively **hold** and **assign** as worthwhile about our aquatic environment. They represent a good starting point for our discussion.

The guidelines describe environmental values for our fresh and marine waters. They are mostly related to the uses to which water may be put. As such, they are a mixture of held and assigned values. The values considered are:

- protection of aquatic ecosystems
- recreational water and aesthetics
- raw water for drinking water supply
- agricultural water use
- industrial water quality.

How are these environmental values influenced by our treatment of the wastewater that occurs as a result of our everyday use?

ENVIRONMENTAL VALUES

Protection of Aquatic Ecosystems

Water quality and ecosystem health are very important and have a bearing on all other values. If the ecosystem is in good health then other environmental values will also be met.

An ecosystem can become polluted from point sources, most often sewage treatment plants, and non-point – diffuse – sources such as stormwater and agricultural run-off.

Point Source Pollution

Two decisions affect how sewage effluent will impact on aquatic ecosystems: its quality, which depends on its original composition and the treatment it has received, and how we then manage it. We could simply dispose of it into a receiving water such as a creek, river, lake, estuary, coastal marine water or via an ocean outfall. Alternately, we could reuse it in some way. The justification for the disposal of effluent into a waterway has been based on the notion that receiving waters have 'assimilative capacity' and they can absorb and modify wastes without any adverse effects on the receiving ecosystem. This assumption has certain problems!

Some toxic substances found in poorly treated sewage effluents are cumulative pollutants (e.g. chlorinated hydrocarbons, heavy metals). Rather than being rendered harmless by the receiving ecosystem, they are accumulated, often with disastrous consequences. For example, animals at the bottom of the food chain accumulate these compounds; they in turn become the food for higher animals in the chain, such as carnivorous fish and birds and humans; the pollutants gradually increase in concentration in the organisms further up the food chain.

Sewage effluent also contains nutrients which may cause eutrophication of the waterway (see page 10).

Eutrophic waters generally have:

- lower overall dissolved oxygen levels and big differences between day and night-time levels
- larger quantities of living things (larger biomass of plants and animals)
- lower biological diversity, different plant and animal species from non-eutrophic waters, higher nutrient levels
- overall poorer water quality.

The variations in dissolved oxygen are caused by increased photo-

around the first bend, it looses its identity and becomes just water. It's called the Miracle Mile because it can turn even the lowest quality of effluent into water. It's because of the absorptive capacity of the river and the dilution factor – so they say.'

Watter was almost at a loss for words.

'But the river doesn't have any absorptive capacity – it's overloaded with pollutants. And it's being diluted with water that is even dirtier than it is! I suppose it would be alright if it were raining – there'd be more water.'

'No,' said Vera, 'It wouldn't necessarily be any better. Urban run-off can be quite disgusting – grease, dog poo – the number of pathogens in urban stormwater can be even more than in sewage.'

'It doesn't make sense,' said Watter, 'It just doesn't make sense.'

'Doesn't have to be logical,' said Vera, 'It's perceptions that count these days.'

synthesis and respiration of the larger plant biomass. This causes higher dissolved oxygen levels during the day and extremely low dissolved oxygen levels as night progresses. Carbon dioxide levels may rise as dissolved oxygen levels drop. This may cause a decrease in pH (the water becomes more acidic).

The organic matter produced as a result of eutrophication dies and decays, causing even further declines in dissolved oxygen levels.

In marine and estuarine waters, eutrophication may also cause algal growth on seagrass making it more vulnerable to disease and infection, leading eventually to its death. The 'slimes' that result are not an ecological substitute for seagrass nor are they an alternative food source for the organisms dependent on the seagrass.

Non-Point Source Pollution

Non-point source pollution – the runoff from urban, industrial, commercial and agricultural land uses – contributes as much, or even more, to the state of health of an aquatic ecosystem as point source pollution.

Runoff from land contains suspended and dissolved material – the pollutants are similar to those from point sources – but non-point source pollutants may also include litter and rubbish. The amounts of sediment and nutrients in runoff from various land uses vary. Runoff from forested areas usually contains fewer pollutants than runoff from other areas. Urban runoff is also called 'stormwater'; it is highly polluted, especially the first flush after a prolonged dry period. It contains a large number of pathogens, grease and oil.

Sediment is significant in a variety of ways. In agricultural areas, high levels of sediment in runoff represent a loss of soil which may affect agricultural production. In bad cases soil losses of over 100 tonnes per hectare per year are reported. High sediment levels in receiving waters may shade out and kill aquatic plants. Sediment particles may also have phosphorus, heavy metal and pesticides chemically 'attached' to them – these pollutants affect the receiving ecosystem.

Unfortunately, non-point source pollution is not as easy to identify and manage as point source pollution. Consequently, it is often conveniently overlooked.

Rainfall Events and Floods

Everything looks clean after rain – the dirt and litter from our backyards, parks and streets are washed into our creeks and rivers.

The health of our waterways is related to rainfall events and floods. The pollution loads we place on our waterways come in 'slugs' – most of the pollutants that find their way into our waterways do so in times of flood. In wet weather, the effect of non-point source pollution is much greater than point source, but in dry weather point sources may be more significant. The monitoring and management programmes we put in place need to take this into account.

Biological Indicators

In freshwater, estuarine and marine situations, pollution causes changes in species occurrence and diversity. If the load of nutrients, for example, is more than the receiving ecosystem can sustain, overall water quality declines so that fewer, more tolerant and adaptable species of plants and animals eventually dominate. Monitoring the occurrence of certain sensitive species and changes in species diversity helps to warn us if environmental health is being compromised. Such monitoring is a useful addition to the 'snap-shot' provided by physical and chemical monitoring as it gives a 'fuller picture' of the health of the ecosystem.

Environmental Flows

The water we use to transport our wastes may come from reticulated town water supplies, rain water from the roof or from bores or wells. Whatever the source, the large quantity we use affects the natural flow regime in our waterways.

Many native fish (e.g. golden perch, Murray cod) need changes in water levels and water temperatures to trigger breeding. The building of a dam changes the flow in the river below it; there are fewer floods and, consequently,

VIRIDIAN VIRULENCE

As they rounded the bend in the river, Watter could see the weir. The water behind the wall was bright green.

'Hey, Vera, you'd better come out of the river. The water ahead looks very strange. It's bright green – looks positively poisonous.' Watter helped Vera up onto the bank. He found himself holding her hand just a little longer than was necessary.

'Look,' he said, 'do you see how coloured it is?'

'Heavens above – they've got an algal bloom. Not surprising considering the amount of phosphates there must be in the water. Yes, it is poisonous.The algae cells contain toxins and when the cells die they leak out into the water. It's very expensive to treat – they have to use activated carbon and sometimes they have to stop taking water from that source altogether. I suppose the people in the town will have to manage with very little water – that's

going to be hard; they normally each get through at least 440 litres a day.'

They stared in thoughtful silence at the vivid water in the weir.

'Vera,' said Watter slowly, 'One day somebody is going to realise that effluent from the sewage plant is better quality than this river water and a better source of drinking water than one with an algal outbreak. At least all the pollutants in it are manageable, whereas the toxins from the algae present a real threat to public health.'

'What's more,' said Vera, 'The treatments are becoming better understood and more affordable.'

'I wonder how we can persuade people to change their minds about their attitude to water quality,' mused Watter. 'Obviously it's no good telling the Government, they have a vested interest in not doing anything about it. And the engineers seem to have so little confidence in their own technology.'

fewer fish. The fish and animals in a river can also be seriously affected by unnatural discharges of water from deep down in a dam because the water is much colder than the river water and contains less oxygen.

Many Australian urban areas are near estuaries. Sewage effluent from them, being fresh water, may affect the salinity in the estuary. Mangroves, which require frequent inundation by salt water to survive, may die out and the fisheries that depend on them will also suffer. Mangroves also suffer if they are starved of fresh water, such as when there is no environmental streamflow in a river system which is over-regulated by dams.

Minimising the Effects

Much can be done to reduce the damage to the environment caused by non-point source pollution. Modifying agricultural practices (excluding inappropriate land-uses, timing cultivation, using minimal tillage practices, contour ploughing and banks) helps to minimise soil loss. Protection of the vegetation in the riparian zones along creek and river banks assists in preventing erosion and provides a buffer to stop pollutants entering the water. In urban areas, gross pollutant traps (physical barriers which intercept litter in stormwater drains) and wetlands may also be used to keep receiving waters healthy. They must be maintained if they are to work effectively. Minimising the exposure of bare soil, the use of sediment traps, silt fences, grassed swales and drains are all ways to improve urban stormwater quality. Education and awareness campaigns, combined with legislative approaches, are also needed to improve the quality of agricultural and urban runoff.

Water and Nutrient Re-use

The re-use of sewage effluent that has been traditionally poured into streams, estuaries and coastal waters via our sewerage systems, is good news for the environment. Fewer dams need to be built; estuarine salinity regimes are less likely to be affected and eutrophication can be kept under control. Nutrients which previously polluted the waterways can be used to advantage to encourage the growth of the right plants in the right place.

Recreational Water and Aesthetics

For many of us in Australia our first memories are of the interface where land meets sea – the beach! We live mostly in cities, in close, coastal groups. The beaches, rivers, and estuaries in proximity to the cities come under the most pressure from recreation.

The Australian Water Quality Guidelines for Fresh and Marine Waters identifies three different categories in relation to this value: primary contact (swimming), secondary contact (boating) and no contact (visual appreciation only).

Healthy aquatic ecosystems are generally more attractive and safer places in which to recreate. The points raised in the previous discussion on the protection of aquatic ecosystems generally apply to recreational water and aesthetics.

The microbial condition of waters can be affected by the discharge of sewage effluent. How much it is affected will depend on the quality of the effluent and its volume in comparison to the flow of the receiving waters. It is not necessary to drink water in order to become infected with pathogens – they can penetrate our defences when they come into contact with our mucous membranes when we swim or inhale them in very fine aerosol droplets. Cases of infection from contact with polluted water are difficult to prove but often do happen, especially if effluent has not been adequately disinfected. Re-use of the effluent would obviate this concern and improve this environmental value.

Raw Water For Drinking Water Supply

This environmental value has usually been discussed in terms of its quality or 'Is this water safe to drink?' However, with the increasing adverse effect of human activity on water quality, it is now more appropriate to ask the question, 'Can this water be made safe to drink?'

The answer is 'Yes'.

In many parts of the world, river water, which receives many pollutants as it passes through urban and industrial areas, is highly treated and supplied as reticulated drink-

'If we were to explain it to the community and they learned what treatments and barriers and safeguards are available, they would be happy to accept it. Certainly in this town – they're going to be very short of usable water for a while,' said Vera.

Watter was enthusiastic. 'I could explain to them the effect of water quality on their own health and you could tell them about its effect on the health of the environment.'

'We could show them around the institute.' Vera was bursting with ideas. 'And if the community accepts recycled water, the engineers will enjoy the challenge of modern technology. There would be much more job satisfaction in reliably producing such a quality product rather than just meeting an inadequate licence standard some of the time. Come on, Watter. Let's get going. They need us in this town.'

THE NONEBETTER NEWS SOCIAL EVENTS

The wedding of Nan Vera Mantle and Watter Cecil Quandary, which took place at Nonebetter Water Reclamation Plant, was attended by a record number of guests.

This popular couple was given a rousing send-off by the entire population of Nonebetter who were delighted to have the opportunity to show their gratitude to their local heroes.

A toast to the couple was proposed by the Mayor of Nonebetter, Councillor I. van Guard.

'Watter and Vera, the people of Nonebetter thank you from the bottom of their hearts for your devotion to recycled water which has enabled us to survive in these difficult days of drought,' said Cr. van Guard.

The toast was drunk in gourmet recycled water, specially produced at the plant for the occasion.

The bride wore a dress of the palest aqua lace and was attended by the two year old twins, May and Willy Wee.

After the reception the couple evaporated off for their honeymoon which is being spent on Cloud Nine.

ing water (see page 28). It really depends on whether or not it is economically feasible. It is preferable to protect our drinking water catchments from human and animal activity, as this provides an initial barrier against pollution and minimises the cost of treating the water. However, pressures from urbanisation, agriculture and industry in the catchments of our water supply dams are causing concern. Low grade, nutrient rich waters (e.g. from urban septic tank seepage) are having an increasing chance of finding their way into town water storages. As the quantity of available water decreases, waters previously not considered suitable as raw water for the drinking supply will become so.

The quality of our drinking water supply is a very important environmental value. The unintentional, unplanned re-use of sewage effluent is ignorant, unhealthy, dangerous and should be a concern to us all.

The planned re-use of water can help to obviate both the health and ecological problems that arise because of the current values we have assigned to water. These values are best summed up with phrases like: 'Don't worry, there's plenty more where that came from' and 'Dilution is the solution to pollution'.

Agricultural Water Use

Irrigation accounts for around 70% of all water used in Australia. Agriculture is economically important. In 1992–93 gross agricultural production in Queensland alone was valued at just under five billion dollars (Queensland Department of Primary Industries, 1996).

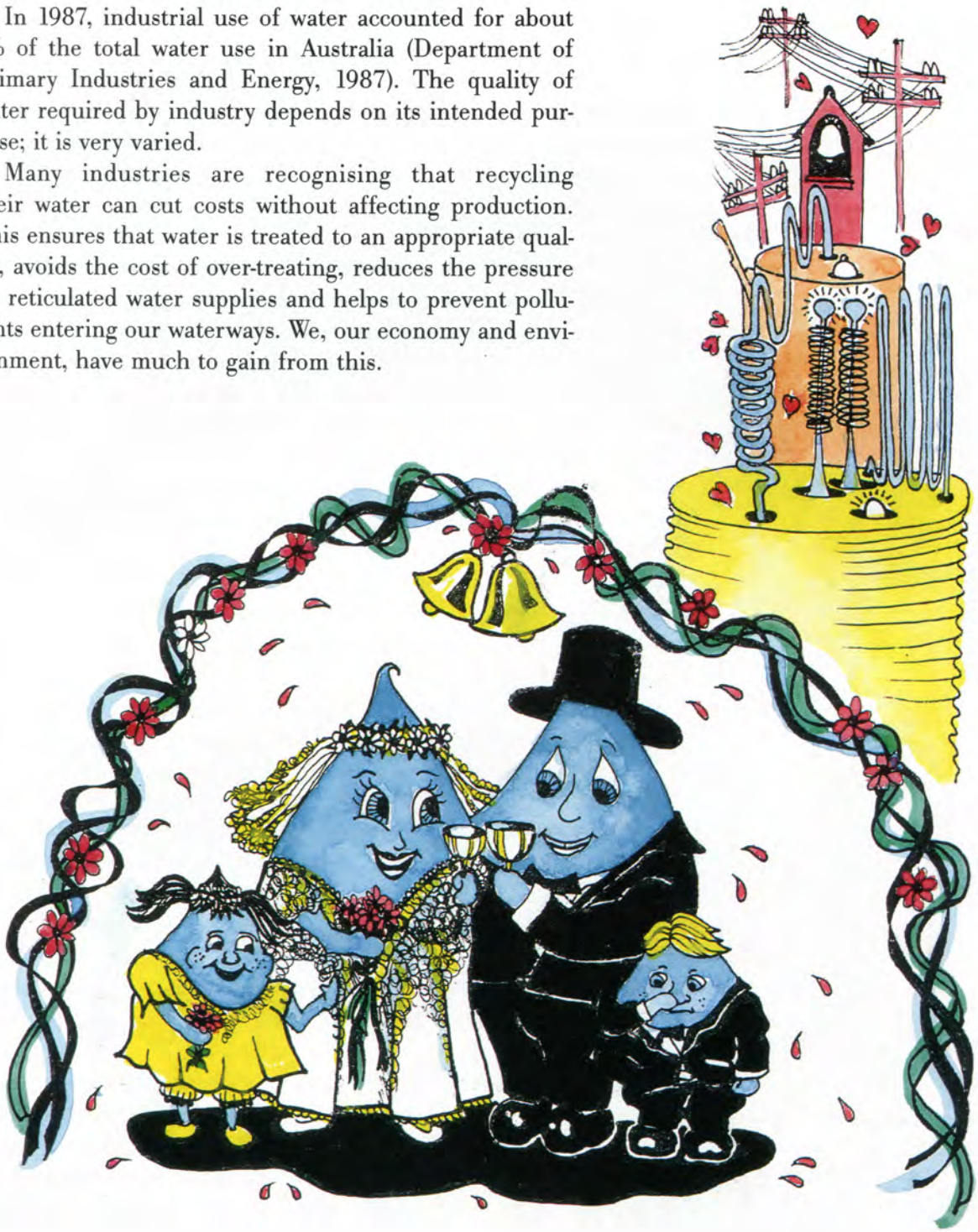
High levels of production have not been achieved without an impact on water quality. Increases in nutrient and salt loadings, coupled with decreased flow rates, have caused significant environmental problems.

This is one of the easier values to meet. However, specific issues include high levels of dissolved salts for sensitive crops, high salinity in stock water and high levels of suspended solids which have a tendency to block irrigation jets.

Industrial Water Quality

In 1987, industrial use of water accounted for about 5% of the total water use in Australia (Department of Primary Industries and Energy, 1987). The quality of water required by industry depends on its intended purpose; it is very varied.

Many industries are recognising that recycling their water can cut costs without affecting production. This ensures that water is treated to an appropriate quality, avoids the cost of over-treating, reduces the pressure on reticulated water supplies and helps to prevent pollutants entering our waterways. We, our economy and environment, have much to gain from this.



NO MORE BUSINESS AS USUAL

Australians are a coastal people living on the driest inhabited continent on earth. Many of the values that we hold regarding water and the way we use it have come from other places and other times. We must recognise this. We have acted as if we have an inexhaustible supply of water, and as if streams, estuaries and coastal marine waters would always be able to endure our water borne wastes without ecological degradation. We have not properly recognised the consequences of these actions in terms of our health and social well-being, our long-term economic prosperity and the maintenance of the ecological integrity of the ecosystems with which we must interact.

A 1950s European life-style conducted on the ever-crowding fringe of a desert continent is not sustainable economically, ecologically or socially. The time has come to assign and hold new values in relation to our interactions with the water cycle.

We have the opportunity to learn from the experiences of others. In 1994, the Netherlands Government hosted an international Ministerial Conference at Noordwijk entitled '*Drinking Water and Environmental Sanitation – No More Business as Usual*'. Over 250 participants from 64 countries and 12 international organisations met to discuss the topic. They approved a political statement, which says in part:

Explosive growth of urban centres, unsustainable exploitation of natural resources, uncontrolled industrialisation, increasing water demand for food production and expanding populations lacking proper environmental sanitation have led to progressive depletion and degradation of freshwater resources. Many current patterns of water use are not sustainable. Rising costs of developing evermore distant freshwater resources threaten economic development, while both the visible and less visible effects of reckless waste disposal and inadequate environment sanitation spread squalor, disease and death. Water scarcity, and the tensions which it engenders, especially in competing claims to transboundary water resources, are a potential threat to peace.

At present in Australia we don't have 'competing claims to transboundary water resources' on an international scale but already we are starting to question the advisability of inter-basin transfers of water. We have other water problems, from 'increasing water demand for food production' to 'progressive depletion and degradation of fresh-

water resources', which we are not recognising and acting upon. Because of our smaller population, we may be further removed from the crisis being experienced by other nations, but it would be fair to say that 'many current patterns of our water use are not sustainable'.

The solution to our water problems will require a variety of approaches from education and engineering through economic incentives and disincentives to legislation and regulation. Water conservation, demand management and the re-use of water will all help to provide solutions to our growing 'watery' dilemma.

We need sound understanding of our interactions with the water cycle; how much water we use, what quality it is, how we use it, what waste we put in it, how we treat it, what we do with it when we have finished with it, and how this use, treatment and 'disposal' affects our surroundings and ourselves.

We need to hold and assign environmental values for water and match this with understanding.

We need to act upon these values if we are to sustain ourselves, our society, our economy, and the ecosystems on which we all ultimately depend today and in the future.

A properly integrated, holistic and sustainable way of managing our relationship with the water cycle will look very different from what we do now: it is vital that we start now to consider how to achieve it.

POST SCRIPT

'Vera, I didn't see Sir Genghiz at the reception, did you?' asked Watter, as they drifted in heaven on their fleecy bed.

'He wasn't there,' said Vera. 'Didn't you hear? He was so hung up about recycled water that he wouldn't drink it. So he went to Noneworse to get his water and caught crypto. They say he's quite inconvenienced.'

'Oh, I ***am*** *sorry,' said Watter.*

'Watter, you're lying!' said Vera sternly. 'You're as bad a hypocrite as he is.

* * * *

And they lived happily ever after.

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Water is one of the essential ingredients of life yet we take so little care of its quality. Because of our increasing population, we can no longer assume that there will be plenty more where the last drop came from or that we need not worry so long as our waste is 'out of sight and out of mind'. A basic understanding of water quality is essential if we are to have informed input into the urgent question of how to manage this precious resource sustainably.

This book explains simply the factors we should take into account when planning how to manage our water. It will take us from wastewater – to drinking water – to even better.

