Treatment Options for Small Drinking-water Supplies

Resources for the Drinking-water Assistance Programme

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1 Introduction

This booklet and the accompanying DVD *Making it Safe* provides information about the supply of safe drinking-water to small water supplies serving fewer than 5000 people. For more information, contact your regional Technical Assistance Programme (TAP) Facilitator or see the draft *Guidelines for Drinking-water Quality Management for New Zealand* (Ministry of Health 2005), available online at http://www.moh.govt.nz/moh/water.

Untreated water can be a major health risk as it can contain harmful chemicals, protozoa, bacteria and viruses. Drinking-water that may contain contaminants should be treated to ensure it is safe. This booklet describes the principles and methods of water treatment for small supplies.

The quality of the water and the need for treatment will depend on the source that is chosen. Water sources can generally be described as groundwater, surface water or rainwater.

Most **groundwater** is naturally filtered as it passes through layers of the earth into underground reservoirs known as aquifers. Water pumped from wells in these aquifers may not need to be treated at all. Note, however, that springs are often fairly shallow so the Drinking-water Standards consider springs to be surface water.

Surface water, which comes from lakes and rivers, often contains dirt and organic matter (see Figure 1), as well as small amounts of other contaminants. It generally requires treatment to be safe and pleasant to drink.

Rainwater in New Zealand is relatively pure as it falls from the sky but it is often contaminated by micro-organisms as it flows over roofs or when it is kept in storage tanks.

2 Why Should We Treat Water?

The water used by a household is divided among a number of activities, which have different requirements for quality, as summarised in Table 1.

Table 1: Water quality required for different household activities

Type of use	Main requirements
Drinking, cooking, food preparation	Biologically and chemically safe
Bathroom	Biologically safe, chemically safe for skin contact
Laundry, toilet flushing	Should not cause stains or damage clothing
Outdoor (eg, irrigation, car washing)	No special requirements but safe for skin contact

Ideally, all of the water supplied to households in New Zealand should be treated to be biologically and chemically safe. This is because it is costly to provide multiple water supplies of different quality, and minimises the risk of incorrect use.

One of the most effective ways of deciding what treatment is required is to write a public health risk management plan. This is a simple way of identifying the public health risks in a water supply. Treatment options that will manage these risks can then be selected.

Public health risk management plans can be straightforward for small supplies.

1. They outline what could go wrong in the water supply that would lead to contamination of the water; eg, high river levels leading to dirty water in the catchment.
2. They identify what would indicate that something has gone wrong; eg, water becomes turbid (cloudy).
3. They identify and prioritise any improvements that are needed; eg, use of stored water when the river water is dirty.

The Drinking-water Standards for New Zealand provide a yardstick for determining whether water is safe to drink. The standards set out maximum allowable values for things that can contaminate drinking-water and the monitoring that is required to demonstrate that the water is safe to drink. They include a section especially for small supplies serving fewer than 500 people. Drinking-water suppliers should try to comply with the drinking-water standards.

Figure 1: Water contamination from animals

2.1 Micro-organisms

Waterborne organisms cause many sporadic cases of illness each year. Because instances of these illnesses are usually not reported, the level of illness is likely to be more than the people of a community realise. Many people who live in an area also build up some resistance to the micro-organisms in their water; however, visitors to the area can still become ill.

Illnesses from water can be very serious, particularly for those with weakened resistance like the young, elderly or people who are already sick.

2.2 Chemical contaminants

All natural water contains some minerals. As water flows in streams, sits in lakes, and filters through layers of soil and rock in the ground, it absorbs some of the substances that it comes into contact with. Many of these substances are harmless. In fact, some people buy 'mineral water' because the minerals give it an appealing taste.

Substances found in water can also result from human activity such as discharges from factories, chemicals applied to farmland, or products used by people in their homes.

At certain levels, chemicals are considered to be contaminants that can make water unpalatable or even unsafe.

2.3 Prioritising treatment

The sources of these microbiological and chemical contaminants might be in your local area or they could be a long distance away, depending on the path the water takes.

In New Zealand, because of the large number of farm animals and low levels of heavy industry, the risks of microbiological contamination are far greater than the risks of chemical contamination. For this reason, microbiological contaminants are given a greater priority than chemicals in the Drinking-water Standards and should be the first priority for water suppliers. The World Health Organization recommends that all countries give priority to microbiological contaminants.

3 Minimisation, Removal and Inactivation

There are three key principles of water treatment for microbiological safety.

The first principle of water management is **minimisation**. Minimisation means selecting and managing a water source to reduce the risk of contaminants entering the supply. To achieve this, you need to know what activities are happening in a catchment area, what risks there are, and how those risks can be managed. For example, the number of pathogens entering the water supply may be reduced by keeping animals out of the catchment. Alternatively, another source with less contamination could be used.

The second principle is **removal**. That is, if pathogens cannot be entirely prevented from entering a water supply, they need to be removed once they get there. This can be done by a number of processes including filtration, coagulation and settlement. The aim here is to physically remove bacteria, viruses and other contaminants from the water.

Generally, you cannot remove all the pathogens from a water supply. In this case, you need to apply the third principle of water treatment; **inactivation**. This is where you use disinfection such as chlorine or ultraviolet light to inactivate pathogens.

Ideally, these three principles – **minimisation, removal** and **inactivation** – should be used together. This is a multi-barrier approach: it uses not just one barrier but a range of methods to make the water safe to drink.

4 What are the Options for Water Sources?

The quality of water from different sources varies. The quality of a particular water source also may change from one day to the next. Such variation can be important in deciding what treatment is needed to make the water fit to drink.

If you are deciding where to get your water from, here are some questions you need to ask.

- What are the available catchments like? Does the water flow through farmland? If it is a bore, is it deep? Is the bore head secure? Is it going to be safer or cheaper to find another source?
- What treatment will the water need? Is the water turbid? Is there significant faecal contamination?
- How much does the water quality vary? Is there activity in the catchment that can affect the quality? Does the weather affect quality? For example, does the water quality deteriorate after rain?
- Is the water flow reliable? Will there be enough water when it is needed? Otherwise, can enough water be stored for when the inflow is low or when you need extra water? In what ways may water availability change in the future? Consider the timeframe over which the supply will be used.
- What is the environmental impact of taking the water? Will someone else be affected? Is permission needed to use it?

Obviously some water sources are better than others. Table 2 lists characteristics that are generally true for the different categories of water source.

Table 2: Characteristics of different water sources

Water source	Microbiological quality	Chemical quality	Acceptability to consumers	Possible sources of contamination
Roof water	Often poor	Usually good	Usually good	Birds and other animals on roof or entering storage tanks.
Shallow bore or shingle aquifer	Often poor	Can be high in chemicals coming from the surface, such as nitrate	Variable. Can be turbid and discoloured	Infiltration from surface or dissolved from soil and rocks.
Deep bore	Usually good	Often high in iron, manganese, carbon dioxide, or ammonia	May be hard, or corrosive to plumbing	Infiltration from surface many years previously, or dissolved or picked up from soil and rocks. Infiltration at the bore head.
River	Usually poor	Variable	Can be turbid and discoloured	Wildlife, farm animals, decaying vegetation, algae, wastewater and other human activities, soil and rocks in catchment.
Stream	Variable	Usually good	Can be turbid and discoloured	Wildlife, farm animals, decaying vegetation, algae, wastewater and other human activities, soil and rocks in catchment.
Lake	Variable; algae can be an issue. Internal and external seiches can cause quality fluctuations	Usually good but can contain nutrients and cyanobacteria	Usually good, but can be warm	Wildlife, farm animals, decaying vegetation, algae, wastewater and other human activities, soil and rocks in catchment.

5 How Much Water Do We Need?

An important decision that should be made early in the process of considering treatment options is how much water will need to treated. This information will allow you to determine the size of water treatment equipment that is needed and what storage capacity is required. The rate of water use can vary significantly between water supplies depending on household, commercial and industrial activity. Most of a small community's water use will be by households unless the supply is also used for rural purposes.

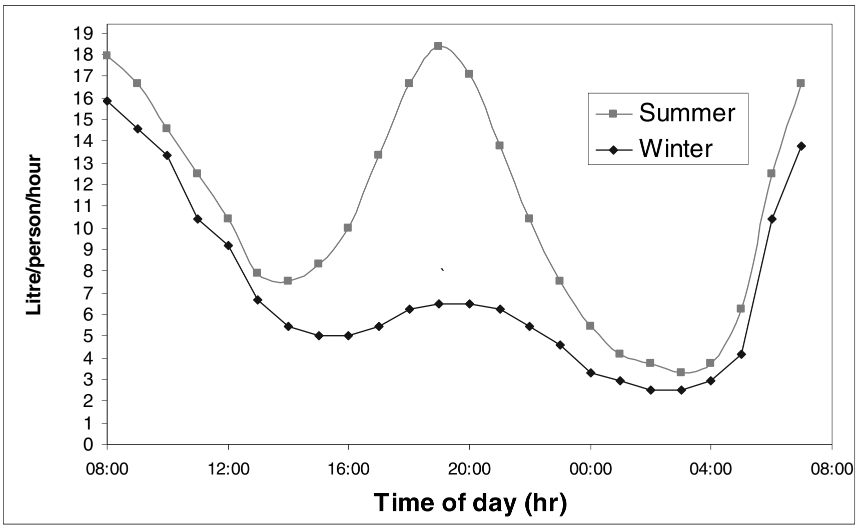
When calculating treatment and storage requirements, it is necessary to take account of:

1. minimum, average and peak water demand at present
2. expected future increases in demand
3. demand for fire fighting
4. variations in availability of source water
5. how quickly problems with the treatment process can be fixed.

If an existing system is in place and requires extra capacity due to foreseen increases in demand, such as through a rising population, usage figures can be scaled based on the existing population or activity – that is, based on how much water each person uses per day at the moment. If the water supply is completely new, there may be no existing flow information to use for design. In this case, typical figures must be used along with an estimate of the population. Consumption invariably increases when a community switches from a roof water to a piped supply.

Water use can vary a lot through the day, week and year. Figure 2 gives an example of water use over 24 hours, in summer and winter, and where the vast majority of water connections are to households and there are no major commercial users.

Figure 2: Typical water usage during winter and summer periods



As you can see from Figure 2, the amount of water used in summer is more than in winter and there is a clear increase in demand on summer evenings. In very cold places (eg, Central Otago) people sometimes leave taps running on frosty nights to stop pipes bursting. In this case winter usage can be high too.

Generally, in New Zealand, water used per person in a day averages around 150–200 litres in winter. However the amount can be highly variable because it depends on the individual's lifestyle and approach to water efficiency.

In practice, the amount that must be supplied is often much greater than the average would suggest due to factors such as leakage from the network and use by commercial, industrial and farming consumers.

In addition, water demand on a peak day commonly increases to very high values in summer due to outdoor use. This demand is affected by local factors such as a hot dry climate and the consequent watering of gardens and lawns. In some communities, consumption in the order of 2000 litres per person in a day is regularly recorded. Values around 600 litres per person in a day are more common. The Ministry of Health considers that the minimum amount of water desirable to maintain sanitary conditions is 50 litres per person per day where showers are available and 90 litres per person per day where only baths are available.

Water use can vary under different weather patterns or at different times of day. If the weather gets particularly hot and dry, people tend to use more water. Hot and dry weather can also dry up the water supply. Often it is at this point that water restrictions are imposed.

Water use at night, when people are asleep (say 11 pm to 6 am), drops to low levels. There may still be some water going into the supply network, of which a high proportion is water leakage (leakage happens at much the same rate, day and night).

In general, the best way to cope with variation in demand is to store treated water. A good guide for small water supplies is to store enough water to cover the highest expected demand over two days in summer. Another reason to store water is to have a supply available for fighting fires. If fire fighting is one of the functions of the storage tanks, then there are rules for the minimum amount of water stored for gazetted fire areas.

6 What are the Options for Treatment?

6.1 Introduction

When preparing to provide a new water supply, consider all the likely water sources and the costs of bringing the water from each source up to a safe standard. Treatment costs and overall safety are greatly improved by choosing sources well away from potential contaminants. For example, shallow bores should be well away from septic tank soakage areas, landfills, offal pits etc.

Water testing is almost always used to see what the problems are. When testing the water, it is important to think about the range of water conditions that may occur. What land use, activities or situations can affect the water quality? Some examples of activities that can have an intermittent effect on water quality are rainfall, land slips, excavation, tree felling and cows crossing streams.

The water should be tested at the times when the quality is poor (and needs more treatment), and also under normal conditions.

The most common drinking-water treatment is disinfection. Most water suppliers add chlorine or another disinfectant to kill bacteria and viruses. Other treatment might also be needed, according to the quality of the source water.

Table 3 indicates the treatment that may be needed for various contaminants. Only common contaminants are shown. The need for treatment will depend on their concentration.

Table 3: Treatment needed for various water contaminants

Contaminant	Description	Sources	Likely treatment methods
Micro-organisms			
Bacteria	Bacteria are a type of micro-biological contaminant, some of which are capable of causing waterborne disease. Bacteria are very small. They cannot be seen with the naked eye. They are capable of multiplying quickly and are responsible for such waterborne diseases as cholera, typhoid and campylobacteriosis or symptoms of gastroenteritis.	Disease-causing bacteria from farm animals, birds, possums, sewage discharges, treated effluent. Also backflow and other recontamination in the network.	Bacteria are usually killed by dosing with chlorine. This has the advantage of remaining in the water as protection against recontamination. Some other chemicals are effective but are less common. Sometimes UV light is used. Other methods are boiling, and physical removal (eg, reverse osmosis).
Viruses	A virus is an extremely small particle capable of causing waterborne disease. Disease-causing viruses that are capable of being transmitted through water include hepatitis A and norovirus.	Human disease-causing viruses from sewage discharges, treated effluent. Also backflow and other recontamination in the network.	Viruses are usually controlled by dosing with chlorine. This has the advantage of remaining in the water as protection against recontamination. Some other chemicals are effective but less common. Sometimes UV light is used, but it is not very effective against some viruses. Other methods are boiling, and physical removal (eg, reverse osmosis).
Protozoa	Protozoa are single-celled animals, some of which can cause waterborne disease in humans. Problem-causing protozoa are: *Entamoeba histolytica*, *Giardia lamblia* and *Cryptosporidium parvum*. Protozoa are very small but larger than bacteria and viruses. They are found in the environment in cyst form. When inside a person, the cyst can become a mature protozoan, which is then able to multiply and may cause disease.	Disease-causing protozoa from wild and farm animals, sewage discharges, treated effluent. Also backflow and other recontamination in the network.	Protozoa are not readily inactivated with chlorine but they can be inactivated with UV light, ozone, and chlorine dioxide (although a high dose is required). Physical removal can be achieved, chiefly through filtration. Ideally more than one treatment method (the multiple barrier approach) is used. Boiling is also effective.

Contaminant	Description	Sources	Likely treatment methods
Other contaminants			
Aggressiveness or plumbosolvency	Water tends to corrode pipes and fittings, releasing metals into the water supply and eventually damaging metal and concrete pipes. Sometimes heavy metals are released, which is a health hazard.	All rainwater and common in surface water. Groundwater that is high in carbon dioxide can be very corrosive.	The most that is normally done in small systems is to increase the pH slightly by adding sodium hydroxide or lime solution. A granular dolomite filter can be used in some situations. Carbon dioxide levels are often reduced by aeration and/or reaction with lime.
Boron	The element boron is an essential plant nutrient and a trace mineral for animals but it is toxic at high concentrations.	Common in geothermal areas.	An ion exchange process is normally used but this is very expensive and difficult. Usually a new source is found.
Colour	Colour is an indicator of dissolved organic material in the water that comes from decaying vegetation and certain inorganic matter. A colour above 10 degrees Hazen can make the water appear 'tea stained'. If high levels of organic matter are in the water when chlorine is added, then undesirable disinfection by-products can form.	Decaying vegetation.	Colour is usually removed by coagulation and filtration. In many circumstances, colour can also be removed by chemical oxidation, adsorption on to activated carbon, and some membrane filtration systems.
Fluoride	At low concentrations, fluoride is beneficial to teeth, but at higher levels it can be damaging to health.	Dissolved from rocks and soil, particularly in geothermal areas.	In most NZ source waters, fluoride concentrations are too low to be beneficial and some communities adjust the fluoride level.
Hardness	Hard water is water that contains high levels of calcium and magnesium ions. It becomes difficult to lather with soap, and scale can form on the inside of kettles and hot water cylinders. It is not a health concern but can make the water less palatable. New Zealand waters are not usually hard. This is why they are often aggressive.	Dissolved rocks (usually limestone) and soil.	If any treatment were to be undertaken, a small water supply would probably use the ion exchange process.

Contaminant	Description	Sources	Likely treatment methods
Iron	Iron is an element whose compounds can cause reddish-brown coloration of the water and can give it a metallic taste. Iron can be present in the source water and it can also dissolve out of steel pipes when the water is aggressive. Often water coming from a bore source is low in oxygen and, when it comes into contact with air, the iron oxidises and forms reddish brown particles in the water.	Dissolved rocks, especially in bore water.	Aeration followed by filtration is usually effective in removing iron. Sometimes increasing the pH, chemical oxidation followed by filtration, greensand filters or ion exchange is used.
Manganese	Manganese is an element whose compounds can cause brown/black stains on laundry and can give water an unpleasant taste. High levels of manganese can be harmful to health.	Dissolved rocks and soil.	Normally, chemical oxidation followed by filtration, greensand filters or ion exchange is used.
Nitrate	At high levels nitrate can cause methemoglobinemia, a disease that is particularly toxic to babies. Surface waters are usually low in nitrate but high levels can occur in groundwater.	Fertilisers, animal run-off, raw sewage or treated effluent.	The ion exchange process is normally used but this is very expensive and difficult. Usually a new source is found.
pH	pH is a measure of how acidic or alkaline a solution is: a pH less than 7 is acidic; a pH more than 7 is alkaline. A low pH causes water to be corrosive to pipes and fittings. A pH in the range of 7–8 is desirable. A high pH reduces the effectiveness of chlorination.	CO_2 from the atmosphere, decaying plant matter, dissolved rocks and soil.	Water in NZ is normally too acidic so the pH needs to be increased rather than reduced. This is generally done by adding sodium hydroxide or lime solution. A granular limestone filter can be used in some situations. Removing CO_2 also increases the pH.
Taste and odour	Taste and odour in water can be caused by organic or inorganic materials, or dissolved gases from many sources. Sometimes only tiny amounts of a chemical are the cause, as with 2-methylisoborneol (MIB) and geosmin released from algae.	Examples are algae, decayed organic matter, and hydrogen sulphide in some groundwaters.	Depending on the cause of the problem, a combination of aeration, chemical oxidation, filtration and absorption on to activated carbon may be appropriate.

Contaminant	Description	Sources	Likely treatment methods
Other metals that can be toxic include antimony, arsenic, barium, cadmium, chromium, copper, lead, lithium, mercury, molybdenum, nickel, selenium, silver.	Potentially toxic metals are chemical elements for which excessive amounts can be harmful. However, some of them (eg, selenium) are needed in small quantities as trace minerals.	All of the metals may be dissolved from rocks and soil. Arsenic is common in geothermal areas. Cadmium, chromium, lead and nickel can leach out of plumbing fittings and pipe solder. Lead is of particular concern in water supplies.	These metals rarely reach nuisance levels in NZ source waters, other than in geothermal areas. If the contaminants are being leached from pipes and fittings, a less aggressive source should be used or the water treated to reduce the aggressiveness.
Toxic organic chemicals	Toxic organic chemicals include a range of compounds that might be used as pesticides, plasticisers, fuel (or its combustion products), or for many other purposes.	Farming, horticulture, industrial activity and creation during the disinfection process. They can also form as by-products of disinfection.	They can often be removed by absorption on to activated carbon. Disinfection by-products are usually addressed by removing the organic precursors before chlorination and controlling the chlorine dose rate.
Turbidity	Turbidity is a measure of how particles in the water scatter light and is normally measured in nephelometric turbidity units, NTU (or formazin turbidity units, FTU, which is an equivalent unit). Water with turbidity above 5 NTU will look cloudy. More importantly, the presence of turbidity can interfere with disinfection by shielding the organisms. The presence of suspended material such as clay, silt, finely divided organic material, plankton and other material is indicated by turbidity.	Dirt.	Turbidity can be removed by filtration. Some pre-treatment may be needed, such as settling tanks or coagulation and settling.

6.2 Pre-treatment

Pre-treatment processes are designed to reduce the load on the main treatment process. The degree to which bacteria, viruses and protozoa are removed by pre treatment is very limited. However, because some treatment processes need low turbidity water, some form of pre-treatment to reduce suspended solids load may be advantageous. Storage, pre-settlement, pre-filtration and aeration are examples of pre-treatment.

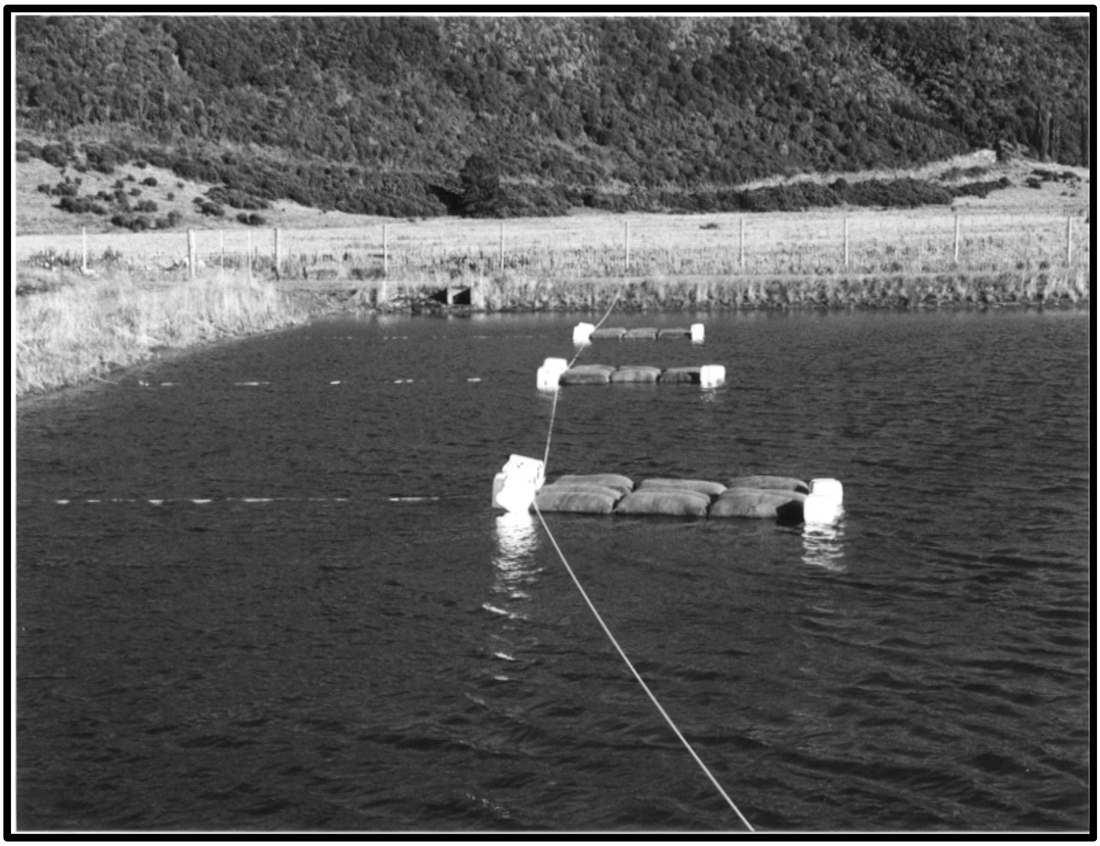
Storage

Raw water storage allows the treatment process to be shut off when the source water quality is poor. This approach can save money on treatment costs (such as the cost of replacing cartridge filters), and may reduce the risk of producing substandard treated water. Raw water storage can also act as pre-settlement, as discussed below.

Storing nutrient-rich raw water exposed to sunlight may result in excessive growth of phytoplankton (algae) which can cause taste and odour problems, or if blue-green algae (cyanophytes) grow, toxins can be produced.

Final water storage (not really pre-treatment but dealt with here for convenience). In small supplies, water can usually be stored fairly cheaply in ready-made tanks. As a result, it can make sense to install extra storage so that there is more time to fix any problems that arise in the treatment plant. Water storage also has a role in smoothing flows through the plant, which improves the treatment performance, and allows smaller treatment units to be used.

Figure 3: Raw water reservoir

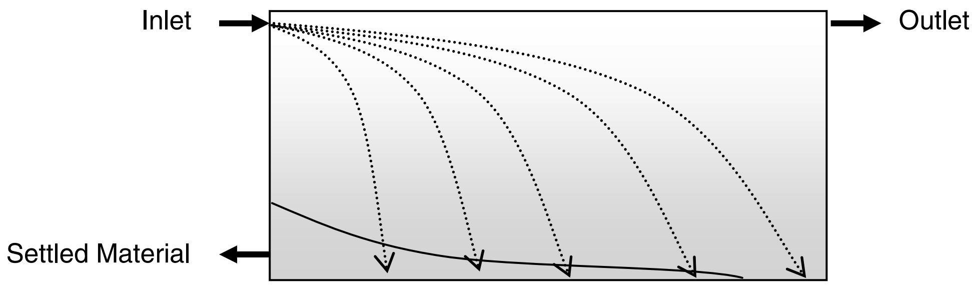


Pre-settlement

If water is left in a tank for long enough, particles will settle to the bottom (or, in some cases, float to the top). In the pre-settlement process, water is passed through a tank at a slow rate and suspended solids fall out of suspension to the bottom of the tank (Figure

4). The outlet of the settling tank should be near the top of the structure so that the clear water is removed.

Figure 4: Pre-settling basin



The solids are removed by either draining the tank or by suction from the bottom. In a small system, a swimming pool vacuum system could be used.

A common problem with settling in tanks and ponds is 'short-circuiting', where water effectively takes a short cut. To avoid this problem, consider:

- placing the inlet and outlet as far apart as possible
- introducing the water to the tank as gently as possible to avoid turbulence
- installing baffles to direct the flow.

Simple settling will not remove very fine-grained particles (including micro-organisms) because they settle extremely slowly. Therefore the water can still be cloudy after treatment. Nevertheless, settling reduces the load on downstream treatment processes.

Pre-filtration

Pre-filters can be worthwhile because they do not require chemicals, have few working parts and are robust. Unfortunately they need frequent cleaning and do not remove fine particles such as silt and clay.

It is common to install coarse steel screen and plastic disc filters to remove large particles such as small animals, leaves and sand (Figures 5 and 6). Gravel or coarse sand filters are sometimes used to reduce turbidity enough for the downstream processes to work effectively. Infiltration galleries (or bankside filtration) can work in this way (see Figure 7). When the media becomes blocked, the filter is backflushed or drained, depending on the design.

Figure 5: Infiltration gallery

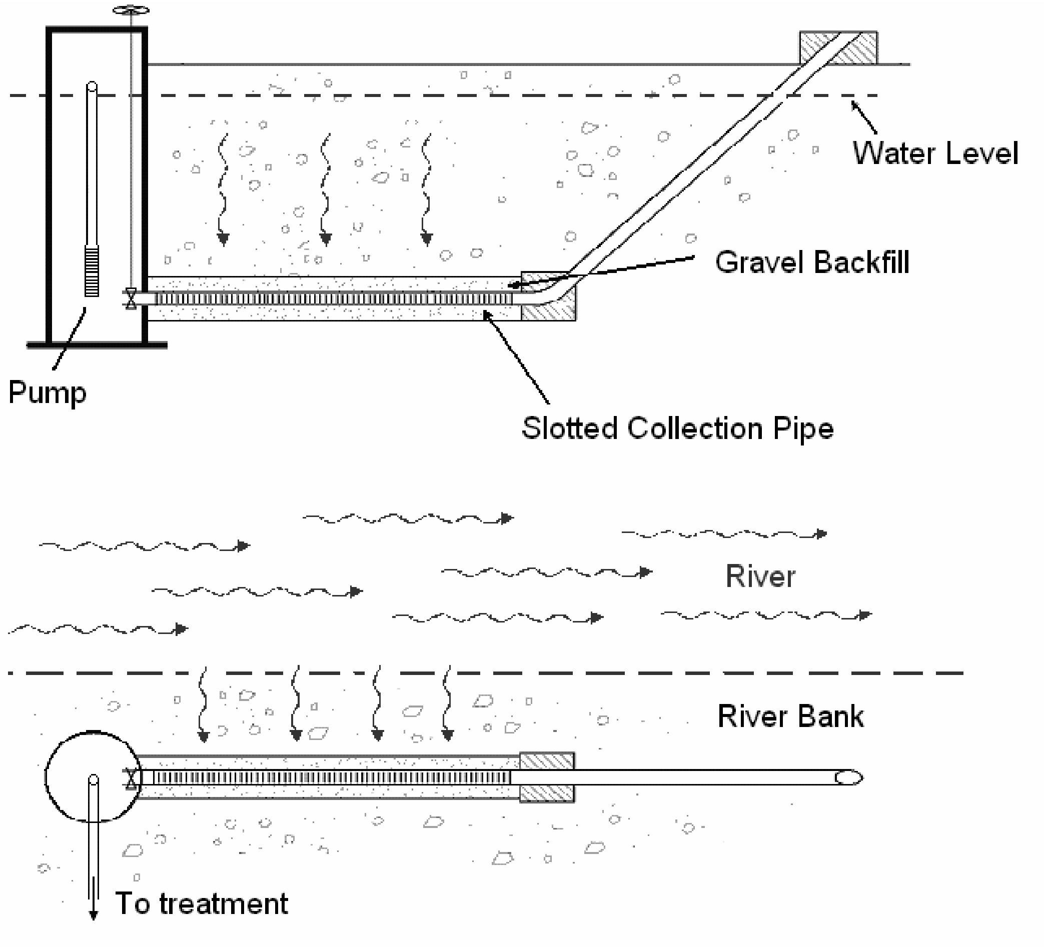


Figure 6: Disc filter

Figure 7: Infiltration gallery

Aeration

Aeration is the process of forcing air through water. It is often used to treat water that is devoid of oxygen (such as groundwater) to:

- oxidise iron or manganese in groundwater to make it insoluble so that it can be filtered out
- reduce the carbon dioxide content if it is very high (carbon dioxide can make water acidic and corrosive to pipework and fittings)
- expel volatile organics or odours from the water.

One of the simplest forms of aeration consists of spraying the water on to a tower of criss-crossed slats, as shown in Figure 8 (in some cases, bread crates have been used for this purpose). Many other configurations are possible.

Figure 8: Simple aeration unit

Chemical coagulation

To overcome the very low settling rate of the fine particles suspended in the water, the settling process is often improved through adding **coagulants**. Coagulants are chemicals that carry an electrical charge and therefore attract charged particles. When coagulants are added to the water, the charged particles clump together to form **flocs**. These flocs settle more quickly to the bottom of the settling tank; sometimes the coagulated water can be fed directly to a sand filter. The chemical coagulation process was used by the ancient Egyptians, who used a chemical they called alum to coagulate their water, followed by sand or charcoal filters. They discovered that adding alum made the water less cloudy and better tasting.

Experimentation will confirm whether sufficient pre-settlement can be achieved without using coagulants and, if they are needed, which coagulants will be effective, and at what dosage.

6.3 Filtration

Particles are removed from water as it passes through pores or gaps between grains of sand or other filter material.

Simple filters only remove particles by straining, so if a contaminant is dissolved in the water, it will pass through the filter. Dissolved material such as organic compounds can be reacted with a coagulant to form particles that can then be removed by filtration.

6.3.1 Cartridge filters and membranes

Membrane filters and some cartridge filters are made with pores that are smaller than protozoa (*Cryptosporidium* is about 4–6 microns long, ie, 4–6 millionths of a metre) so they provide an excellent barrier as long as the filter is not damaged. Bacteria that pass through the filter can be inactivated by chlorine or UV light, and viruses can be inactivated using chlorine; UV light inactivates some types of virus.

(a) Cartridge filters are often used in small supplies because they are cheap to install, simple to operate and compact.

Cartridge filters act as simple strainers. As particles become lodged in or on the cartridge, it gradually blocks. The amount of use that is possible depends on the solids content of the water. Once cartridge filters block they have to be thrown away, so they are expensive to use on dirty water. You might choose to use a cartridge with a larger pore size, say 20 micron, upstream of the finer cartridge. This will reduce the load on the downstream cartridge so that it does not block as quickly.

Cartridge filters usually contain pleated fabrics, membranes or strings tightly wound around a filter element. A large variety of filters is available, with different pore size ratings and materials (Figures 9a and 9b). When choosing a cartridge filter, it is important to know whether the pore size is being quoted as 'nominal' or 'absolute'.

Figure 9a: Cartridge filter system

Figure 9b: Used cartridge filters

The **nominal** size means that 90 percent of the particles of the quoted pore size will be removed by the filter. In other words, some pores will be bigger than the quoted size so some of the particles you are aiming to remove could go through.

An **absolute** pore size means that all of the holes are smaller than the quoted size. These filters are the best choice as a barrier to protozoa.

Cartridges should be certified for 3 log *Cryptosporidium* removal. That is, they should remove 99.9 percent of all *Cryptosporidium* oocysts in the water.

Bag filters are a variation on cartridge filters. These function in the same way as cartridge filters but rely on a flexible fabric bag instead of a cartridge. Short circuiting around the bags can be a problem. Bag filters are not usually recommended.

The longer a filter remains in service, the more blocked it becomes. This lowers the downstream pressure, so that it eventually becomes much lower than the pressure upstream of the filter. This difference in pressure is called **head loss**. A pressure gauge is used to measure the rate of solids accumulation and to ensure that the filter has not failed. Pressure gauges can be installed on each side of the filter, or the difference in pressures can be measured directly using a differential pressure instrument. Cartridges must not be used outside the manufacturer's specifications.

Slow opening valves should be used to avoid sudden changes in flow, which can dislodge solids that have been collected so that they pass through the filter.

When choosing a cartridge system, it is important to trial the treatment method using a small filter unit to see how well it will work before installing the full size system. Treatment plant designers call this sort of test a pilot trial. It will indicate the likely time between cartridge replacements and show whether the cartridges will remove sufficient contamination.

(b) Membrane filters remove contaminants using a plastic membrane containing extremely fine pores. The water can either be pushed through the membrane (pressure type) or sucked through (vacuum type). For a small system, they come as a packaged unit complete with controls.

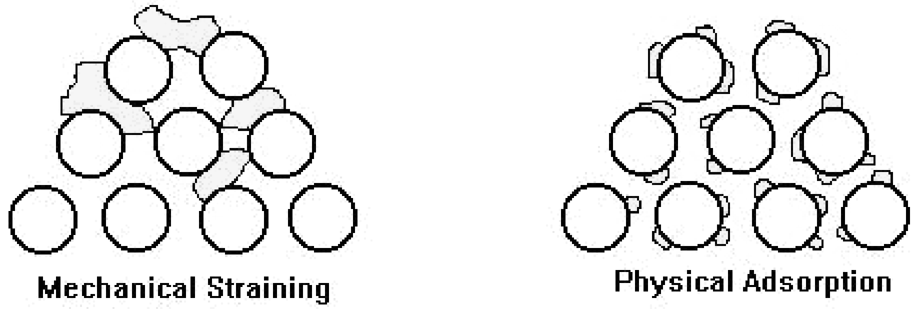
Membrane filters are split into categories depending on the size of the pores. In decreasing order of pore size, the categories are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). All of these systems will remove protozoa, and reverse osmosis can even remove salt.

Some small supplies might consider microfiltration or ultrafiltration to remove protozoa and turbidity. These systems can be useful because the process is automated and, when they are not damaged, the membranes form an absolute barrier to protozoa; they can be backwashed. However, for a small supply, they are a sophisticated method of treatment, which can be daunting if the person operating them is inexperienced. They are also a relatively expensive form of treatment for small systems, although the cost has been steadily reducing.

6.3.2 Rapid sand filters

Rapid sand filters operate by filtering water through grains of sand (or other granular material). They remove suspended particles by mechanical straining (like a sieve) and by attachment (adsorption) to the surfaces of the sand (Figure 10).

Figure 10: Methods of particle removal through rapid sand filters

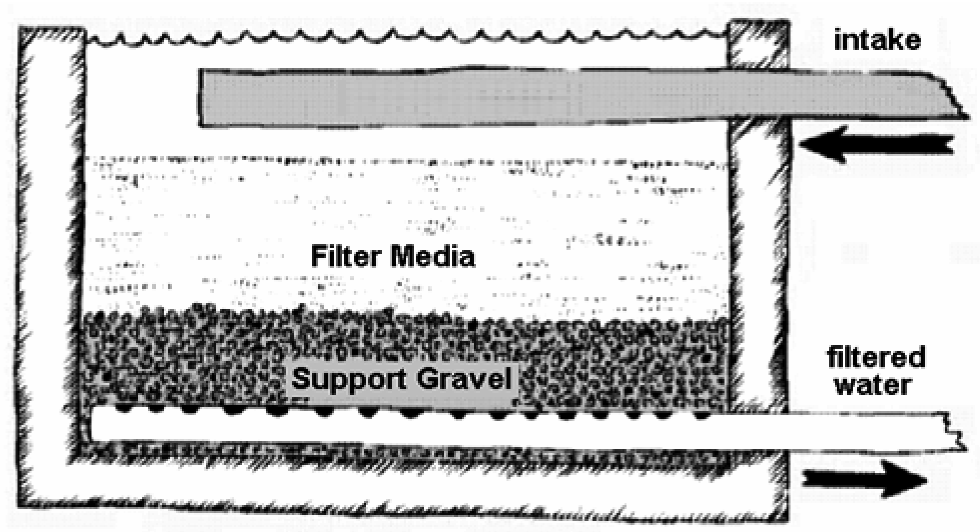


With careful operation and the use of a chemical coagulant, rapid sand filters can be used to remove protozoa, despite the mean pore size being larger than the organism.

There are two main types of rapid sand filters.

First, **rapid gravity filters** consist of an open tank containing a layer of sand (Figure 11). The sand depth varies depending on the size of the sand grains but is typically 1–2 m deep. Water flows into the tank above the sand, through the sand and out through nozzles in the base of the tank. Rapid gravity filters are very common in medium to large water treatment plants.

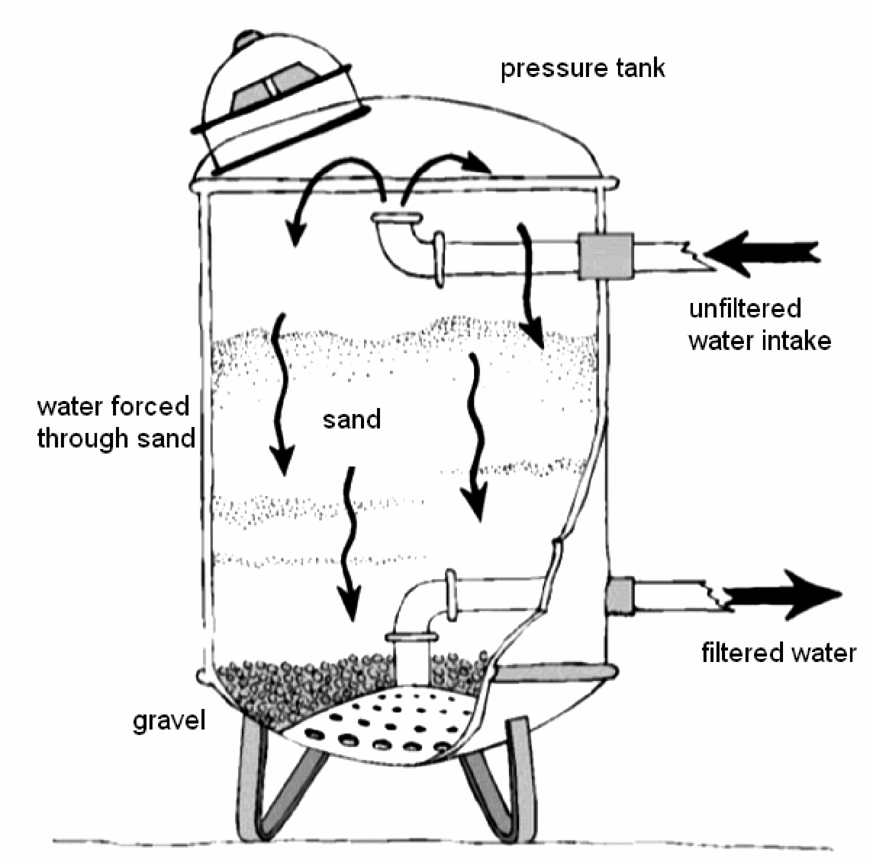
Figure 11: Rapid gravity filter



Second, **pressure filters** are the most common filter type for small supplies. They are the same as rapid gravity filters except that the filter is inside a sealed tank (Figure 12). Because the tank is sealed, the water pressure from upstream is not lost (apart from frictional losses) as the water is filtered.

Pressure filters have some advantages, particularly for small supplies. They are compact and they can carry the flow through the filter and up to a storage reservoir or tank without having to pump again. In addition, the water is not exposed to the atmosphere, which may be an advantage where contamination is a concern, such as with secure groundwater supplies where the water is not going to be disinfected, but needs filtration.

Figure 12: Pressure filter



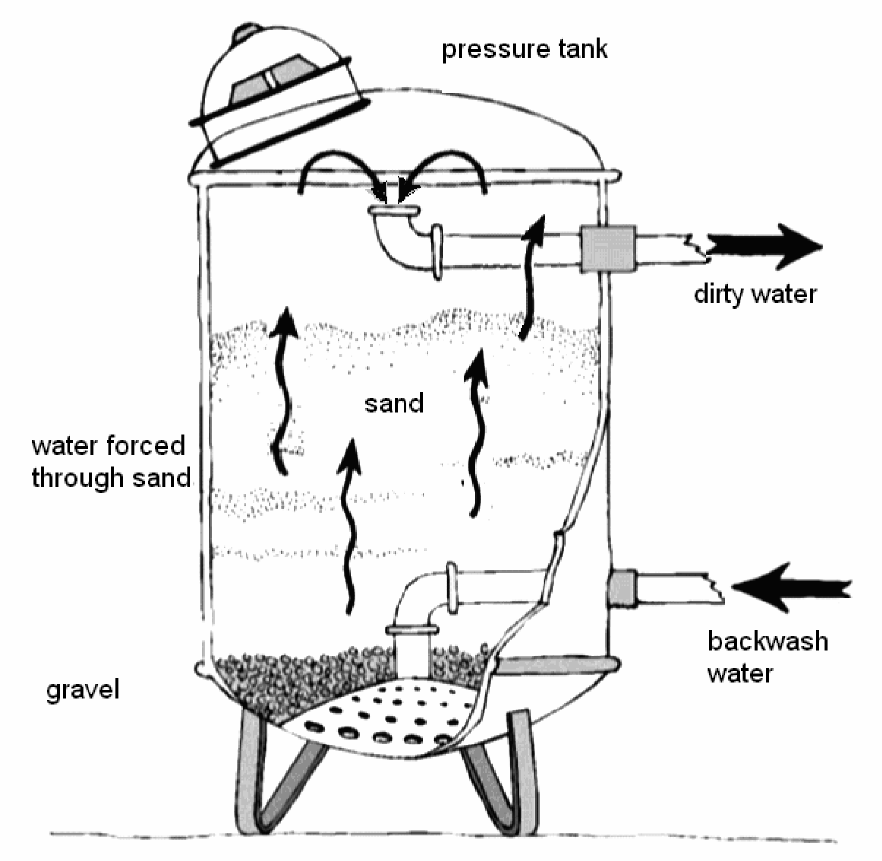
Pressure filters also have some disadvantages. You cannot see the filter sand or watch the filter backwashing (Figure 13), which can make solving problems with performance more difficult.

When either type of filter needs to be cleaned, water is forced into the filter from the bottom to stir up the sand and carry away the dirt. This process is called backwashing. Sometimes air is pumped through the bed to assist with backwashing. This cleaning process only takes a few minutes and the filter can be used again straight away. Often, in a process called **filtering to waste**, the filtered water is diverted to waste for the first few minutes after backwashing, to allow the turbidity to improve.

As for other filter types, the water may need pre-treatment to reduce the solids load. Sand filters are normally used with a coagulant, except where they are used for manganese and iron removal.

The media does not have to be sand, and sometimes there are layers of more than one material. For example, sometimes a larger media is placed in a layer above the sand. This coarse layer is often made of anthracite (a durable type of coal). The coarse layer removes the larger particles, which reduces the load on the fine sand below. Consequently, the filter can cope with a higher solids load and operate for longer between backwashes. A filter media called ‘greensand’ can be used to remove iron and manganese.

Figure 13: Pressure filter during backwash



To perform effectively, a rapid sand filter must be able to operate without sudden increases in flow that would dislodge the particles that have been collected. It is important to have a backwashing frequency that is high enough to avoid carry through of particles as the filter clogs up. You can tell when the filter needs to be cleaned by:

1. the build-up in water level above a rapid gravity filter or (depending on how the filter is controlled) how far open the flow control valve is
2. the decline in downstream pressure after a pressure filter
3. an increase in ‘differential pressure’ across either type of filter
4. increased load on the feed pump (increased current draw)
5. an increase in turbidity of the filtered water.

Ideally the filter will be washed well before the turbidity starts to increase, as greater turbidity indicates an increase in contamination.

Operators of sand filters need appropriate training.

6.4 Disinfection

As mentioned in Section 3, the third principle of water treatment is **inactivation**. This is where disinfectants like chlorine or ultraviolet light are used to inactivate pathogens.

6.4.1 Chlorine

The most common chemical used for disinfection is chlorine. Chlorine is preferred over other disinfectants because of its cost, availability and effectiveness.

One of the advantages of chlorine is that it remains active in the water for some time after it has been dosed into the water. This gives some protection against recontamination that may occur in the distribution network from events such as backflow or pipe breakage. For a secure bore that is free of risk from micro-organisms, water can often be provided in an untreated form direct to consumers. However it is still a good idea to add chlorine as protection against contamination in the network.

Typically the target concentration of chlorine in the distribution system is at least 0.2 mg/L of free chlorine residual. However, the amount that must be dosed varies, depending on how much chlorine the water absorbs through reactions with the contaminants that have not been removed by treatment. A higher dose of chlorine is required where there is a high organic or ammonia content. Other contaminants that can use up chlorine are iron, manganese and hydrogen sulphide. The difference between the chlorine dose and the chlorine residual is called the **chlorine demand**.

If chlorine is dosed to waters with high colour (colour is linked to the organic content), then undesirable disinfection by-products can be formed. For this reason, this organic matter should be removed if possible before chlorine is added.

In a small water supply, chlorination may be achieved using a chlorine gas cylinder, on-site generation, or by using sodium hypochlorite or calcium hypochlorite.

1. **Chlorine gas** is liquefied using high pressure and is delivered in steel cylinders. Normally a 75 kg cylinder is used by small supplies. Because the gas is highly dangerous and under pressure, it must be handled with care. While chlorine gas is the least expensive form of chlorine, it may not be desirable for small systems for safety and maintenance reasons and because the operator must be specially trained.

   The chlorine supplier will offer advice on the safe use and maintenance of the system.

2. **Sodium hypochlorite** is normally added by dosing tiny amounts as a liquid using a small dosing pump. The active ingredient is the same as for household bleach. Sodium hypochlorite is normally purchased at 15 percent strength in various container sizes and in bulk. It should not be stored for long periods because it can lose 2–4 percent of its available chlorine content per month, and more of the solution would be needed as the strength lessens. If the solution is stored at more dilute concentrations, dosing can be easier to control.

   Sometimes sodium hypochlorite is made at the treatment plant by electrolysing a salt solution. The equipment costs more to buy than for other systems but operating costs can be lower. The costs for raw materials, electricity and electrode replacement need to be considered when comparing this method to the alternatives.

3. **Calcium hypochlorite** (also can be called HTH) is most commonly used in swimming pool chlorination. It is delivered as a white powder and as tablets, with available chlorine comprising about 65 percent of the substance. Normally it is dissolved into water and then used in the same way as sodium hypochlorite. Calcium hypochlorite is particularly reactive in the solid form and should be kept dry and away from organic materials such as rags and oil to avoid fire.

   A chlorine dosing system can be as simple as a tank with a dosing pump that starts when the treatment plant pump starts. If the treatment plant pump runs at only one flow rate, then the dosing pump could also run at a single flow rate (as long as both the chlorine concentration and the chlorine demand of the water do not change).

   When the water flow rate varies, the rate at which chlorine is added can be either changed in proportion to the flow rate or controlled by a meter that measures the amount of chlorine in the water after the chlorine has been added. The meter measures 'free available chlorine'.

   After the chlorine is added, the water should be stored for a period in a contact tank (or a clear well) to allow the chlorine to act. The contact tank should be designed so that the chlorinated water will remain in the basin for at least 30 minutes and preferably longer. This design is achieved by baffling the tank so that the water will not 'short-circuit' and enter the distribution system too early.

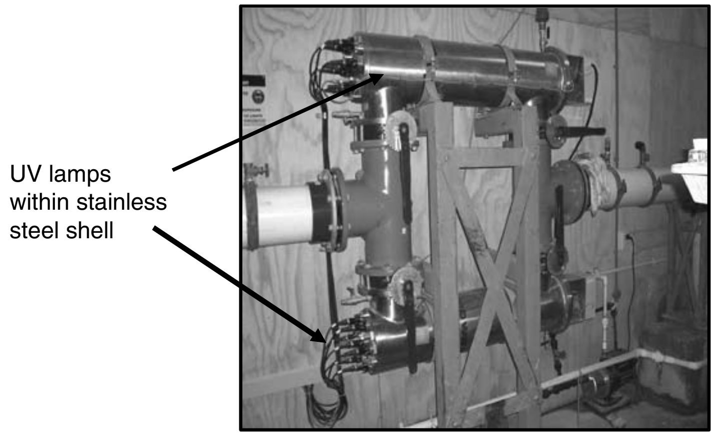
6.4.2 Ultraviolet light

The energy from an Ultra Violet (UV) lamp can be used to inactivate pathogens, including protozoa.

UV disinfection is only installed where the water is of a high quality because the light needs to transmit through the water with enough power to be effective. So for UV disinfection to be cost-effective, the water must have a **high transmissivity**. Contaminants such as organic material in the water can absorb the UV light and reduce the effectiveness of the disinfection. Suspended particles can also shade the microbes inside them so these particles must be removed before UV disinfection. The UV transmittance of the water should be greater than 80 percent and the turbidity should be less than 1 Nephelometric Turbidity Units (NTU).

The main parts of a UV unit are shown in Figure 14. Either the UV lamp or the water flow is inside a clear quartz tube. Flow is controlled so that the time the water spends inside the unit is always long enough to kill the micro-organisms. A UV sensor is required to measure the UV dose. If the dose falls too low, then the sleeve may need cleaning or the lamp may need replacing.

Figure 14: UV disinfection system



The advantages of UV disinfection are that it is simple, cheap and takes up very little space. One disadvantage of using UV light is that water with elevated turbidity, or low UV transmittance, is not properly treated. Also, because UV is not a chemical agent, it does not leave a residual of disinfectant and therefore does not protect against recontamination of the system later. Access to electricity at a reasonable price is another consideration for UV.

6.5 Control of aggressive or plumbosolvent water

When aggressive (corrosive) water stands for a period in a household plumbing system, metals are likely to leach into the water. For example, corrosion of household plumbing can cause lead, copper, nickel, zinc and other metals to enter drinking-water. Water that tends to cause lead to dissolve out of plumbing fittings such as brass taps is described as **plumbosolvent**. Warmer temperatures increase corrosion rates, which can cause hot water cylinders to fail.

The aggressiveness of water is often managed by adjusting the pH and alkalinity of the water or by aerating the water to reduce carbon dioxide levels. However, the most common way to deal with plumbosolvent water is to flush a cupful of water from a tap to clear out dissolved metals before using it for drinking or food preparation. This process is only necessary if the tap has not been used for a long period, such as overnight.

Water with a pH below 7.0 can cause corrosion. It is therefore normal practice to make sure the pH is within the 7.0–8.0 range. Sometimes chemicals such as lime or sodium hydroxide (also called caustic soda) have to be dosed to achieve this. Dolomite media filters can also be used if good accuracy is not essential. The dolomite media has to be recharged from time to time.

Most water in New Zealand has very low alkalinity, which makes it corrosive. (**Alkalinity** is the capacity of water to neutralise an acid solution, and should not be confused with 'alkaline', which means having a pH greater than 7. Water with a low alkalinity could actually have a pH less than 7, and often does.) Sometimes chemicals are added to increase the alkalinity of the water while keeping the pH in the preferred range. This method is not particularly common with small supplies due to the cost of chemicals and equipment.

7 General Equipment

Some equipment is common to most treatment plants. Almost all plants include pumps, pipes and valves.

7.1 Pumps

Pumps are used to bring water up to points higher than the point it is being taken from, or to boost the pressure through a system so that sufficient flow can be carried over flat gradients. Elevated pressures also ensure that any leaks force contaminants out of the system rather than allowing them into it.

The most common type of pump used for small water systems is the centrifugal pump.

A pump supplier can advise you on the type of pump required as long as you have supplied all the information they need to make their calculations. This information includes the:

- height difference between the pump and the water surface from which the water will be carried higher
- height difference between the pump and the place where the water is to go, or the highest point along the way
- maximum flow rate required through all possible outlets and the minimum pressure required at the outlets
- internal diameter and type of the pipes
- total length of the pipes on both the suction (inlet) and discharge (outlet) sides of the pump.

When operating a distribution system, it may be necessary to pump to a high-level tank, which will then gravity feed water through the distribution system. Alternatively, you can operate a pressurised line with a pressure switch to control the pump speed.

Particular care needs to be taken with the inlet pressure on a pump. If inlet pressure is too low, it can lead to a loss of flow or even pump damage.

7.2 Pipework and connections

Pipes should be selected according to cost, availability of the size required, strength, flexibility, ease of laying, ease of connection and resistance to frost (or sunlight). An experienced master plumber or plumbing goods supplier should be able to give you useful advice. Outdoor pipes should be buried to protect them against mechanical damage and exposure to the elements. Indoor pipes should be supported and protected against accidental damage.

8 Places to Get Information

Table 4 below lists some people and places that can provide more information.

Table 4: Sources of further information

Source	Expertise	Listing in phone book
TAP facilitators	All aspects	District Health Board – Public Health Unit
Water testing laboratories	Water analysis and interpretation of results	Analytical laboratories
Local water treatment plant operators	Operational advice	District councils and other water treatment plant owners
Regional council	Local water sources and likely contaminants, resource consents, restrictions on water take	Regional council
Specialist water treatment equipment suppliers	Capabilities of their equipment	Water treatment
Treatment plant designers	All aspects, especially system design	Environmental consultants
Master plumbers	System installation cost	Plumbers

For extra detail, see also the *Guidelines for Drinking-water Quality Management for New Zealand* (Ministry of Health 2005), which is held by public libraries, local authorities and the public health service, and available online at http://www.moh.govt.nz/moh.nsf/indexmh/drinkingwaterinnz-assistanceprogramme.

9 Conclusions

Every community differs in its needs and water source. The choices made about the type of treatment need to reflect these differences.

Although it may not be possible to simply adopt a design used elsewhere, it can still very helpful to talk to other water suppliers about their systems. They can tell you what they are using, how well it works and what it costs to run. They can describe their mistakes, and the good decisions they have made.

Remember the three key principles of water treatment:

1. **minimisation** – management of the catchment to keep the water as clean as possible before treatment
2. **removal** – methods for cleaning the water, such as filtration
3. **inactivation** – the use of chlorine, ultraviolet light or other methods to disinfect the water.

All three principles help to make drinking-water free of pathogens.

10 Worked Examples

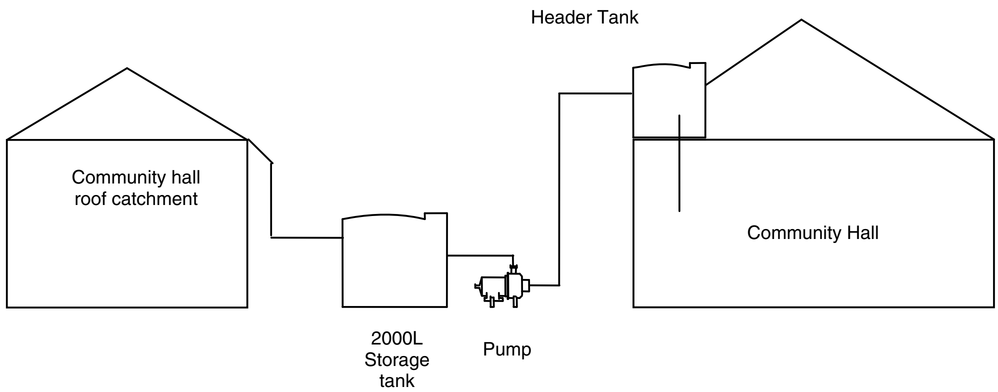
The following worked examples indicate some of the solutions that may be available in making decisions about treatment options. They do not constitute a complete list, nor will they be appropriate in every situation. In most cases, water testing and a pilot trial are needed to make sure that local conditions are suitable for a particular treatment method.

Part of the process of considering treatment options is to calculate the costs of the alternatives. Develop the costings for your particular plant using up-to-date and local costs. An important element to include is the effect of the long-term operating costs. Sometimes an option that looks cheap initially can cost a lot more in the long term.

10.1 Scenario 1: Shorthop Community Hall

Community:	A community hall uses up to 2000 litres per day. There may be little or no water use for many days at a time.
Water source:	Rainwater is taken from a roof catchment and stored in a 20,000-litre tank (Figure 15).
Existing treatment:	None
Water quality issues:	There is no chemical contamination, but water quality testing is finding faecal coliforms in the water. The roof is the source of the contamination.

Figure 15: Existing water supply system at Shorthop Community Hall



Option 1: Add a second storage tank

Trimming overhanging branches around the building would reduce the tendency for birds to rest above the rooftop and would prevent access by possums. This measure therefore minimises source contamination.

A screen on the gutter outlet is useful to divert debris such as leaves (Figure 16). Self cleaning designs are available.

When it rains, **the first flush of water from the roof may contain most of the pathogens** from bird and animal droppings and other debris. It may also contain sediments, waterborne heavy metals and chemical residues that have collected on the roof. **A first flush diversion unit** will divert this first flush of contaminated water to waste rather than to the storage tank.

A calmed inlet will prevent the contents of the first tank from being stirred up when water enters the tank. A floating outlet allows the cleanest water to be taken from the top of the tank.

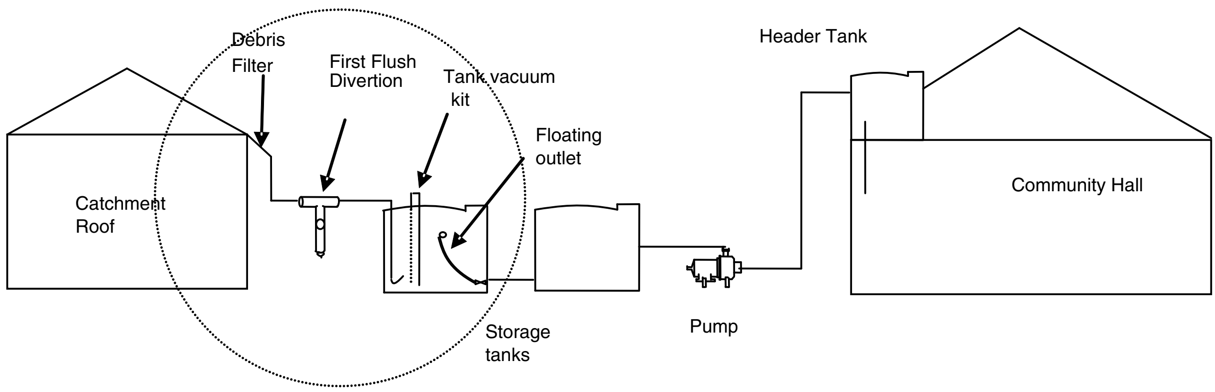
Storage tanks should be drained and cleaned annually (at different times to ensure that water supply is maintained). A tank vacuum kit, which operates like a siphon, can do this automatically. When the tank reaches the overflow level, water is drawn from the dirty bottom layer rather than the surface.

Another way to minimise contamination in the tanks is by using two individual tanks connected in series. This arrangement is better than one large tank for enabling pathogen settling and die off.

The water from the second tank can then be pumped to the header tank as supply water storage.

In this way, several barriers to contamination are provided.

Figure 16: Adding another storage tank (Option 1)



Note: While this option would improve drinking-water quality, it would be insufficient to meet the Drinking-water Standards.

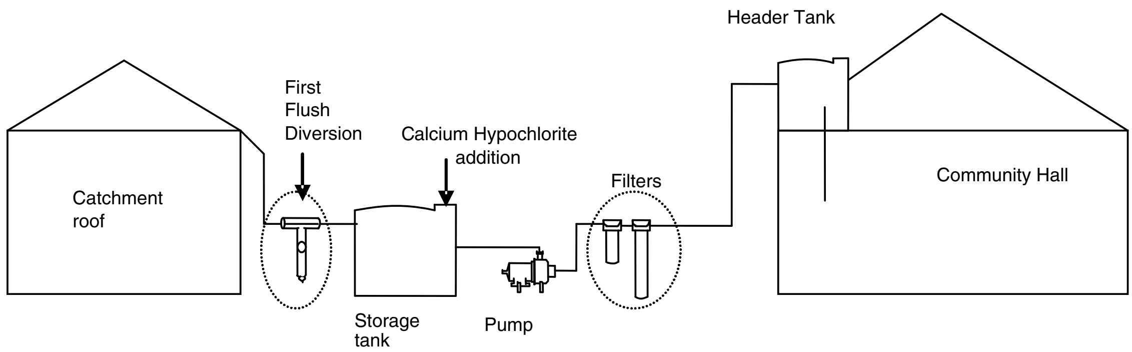
Option 2: Cartridge filters and calcium hypochlorite

Option 2 is similar to Option 1 but uses a filtration system and regular calcium hypochlorite dosing.

In this case, as Figure 17 shows, there is a first flush diversion unit but an additional storage tank has not been installed. Calcium hypochlorite is added to the storage tank for bacteria and virus disinfection at regular intervals to top up the chlorine level.

The water is pumped through cartridge filters to remove particulate matter, including protozoa.

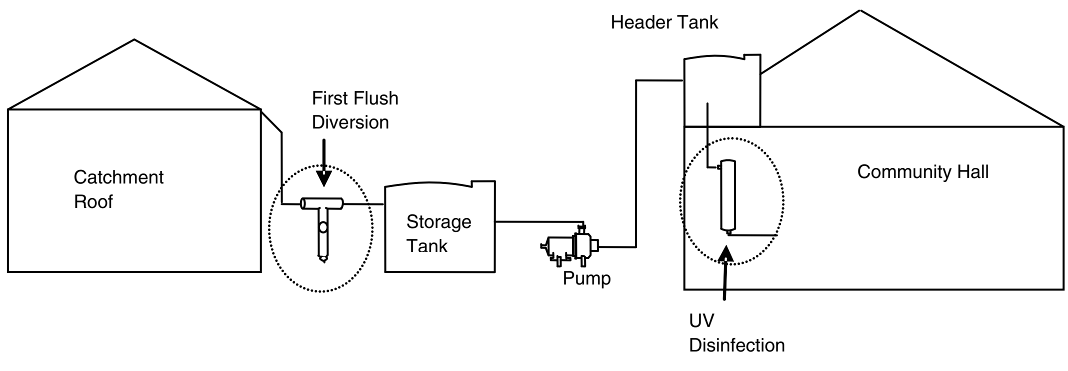
Figure 17: Using cartridge filters and dosing with calcium hypochlorite (Option 2)



Option 3: UV disinfection

Option 3 uses a UV system to disinfect the water as it leaves the header tank (Figure 18). The first flush diversion unit has been retained as a further barrier to contamination. Small UV units are often supplied along with a cartridge filter upstream to further improve their performance.

Figure 18: Disinfecting with a UV system (Option 3)



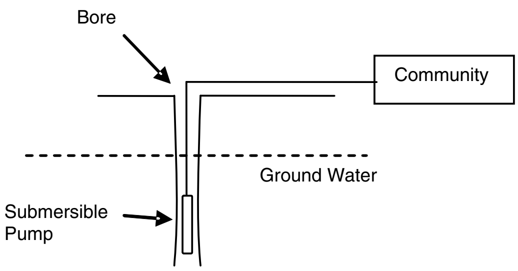
Option 4: Treating part of the water supply

Option 4 would be to treat only the water that may be drunk, ie, water in the kitchen, and bathroom, using any of the above options, or an approved point-of-use device. The point of use device should meet the bacterial quality requirements of AS/NZS.

10.2 Scenario 2: Smalltown water supply

Community:	A community of around 500 people uses approximately 200,000 litres of bore water per day.
Water source:	Water from a non-secure bore is pumped directly into a distribution system (Figure 19).
Existing treatment:	None
Water quality issues:	It has been decided to pass the water through a pressure diatomaceous earth filter to remove fine sediment and protozoa, and to dose chlorine to inactivate bacteria and viruses, and to provide a disinfectant residual as protection against contamination in the distribution system.

Figure 19: Existing water system for the Smalltown community



Option 1: Diatomaceous earth filtration

Diatomaceous earth (DE) filtration involves adding to the raw water a small amount of tiny particles (DE) that are trapped on a septum. As the water passes through the septum, particulate matter is filtered out. It is widely accepted that this process will remove protozoa.

Two small diatomaceous earth pressure filters are installed into the line between the borehead and the chlorine dose point. One filter will be in use while the other is being washed and recharged. Vacuum diatomaceous earth filters may be more suitable if the supply requires pumping.

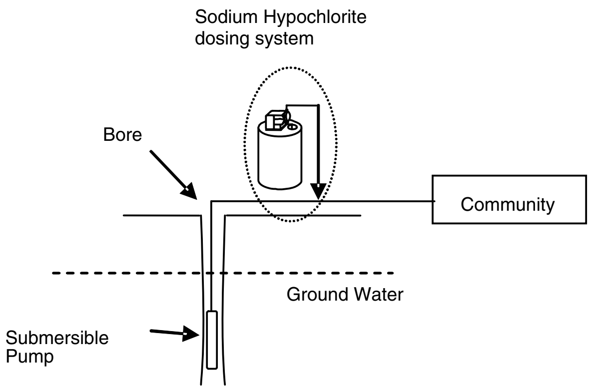
Being a groundwater, a minimal diatomaceous earth dose rate will be required, and quite long filter runs should be achieved.

Option 2: Sodium hypochlorite disinfection

A form of chlorine that is well suited to small supplies due to its simplicity and relative safety is sodium hypochlorite. It is delivered as a liquid, and can be dosed directly into the water supply using a dosing pump (Figure 20).

If the bore pump flow rate is constant, then the dosing pump could start and run at a fixed rate when the bore pump runs. Otherwise flow control is required on the dose rate.

Figure 20: Disinfecting with sodium hypochlorite (Option 2)



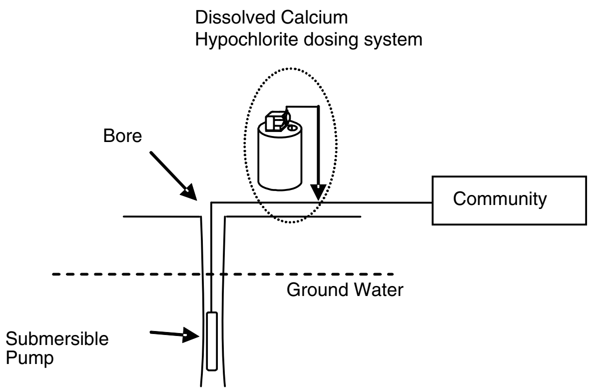
Option 3: Calcium hypochlorite disinfection

Calcium hypochlorite is bought as a solid, of which 65 percent is available as chlorine. It has to be dissolved in water prior to use. The dissolved solution can then be dosed into the water using a dosing pump (Figure 21), in the same way as sodium hypochlorite.

If the bore pump flow rate is constant, then the dosing pump could start and run at a fixed rate when the bore pump runs. Otherwise flow control is required on the dose rate.

To apply the correct dose, it is essential to make up the solution accurately.

Figure 21: Disinfecting with calcium hypochlorite (Option 3)

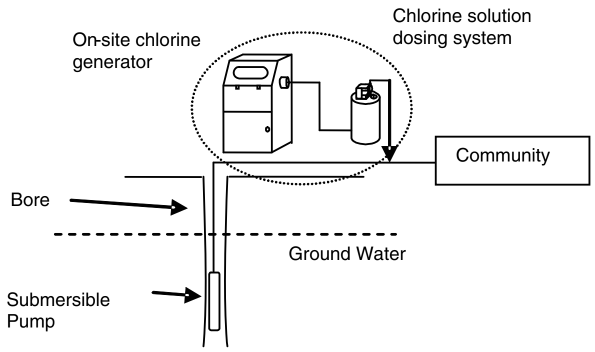


Option 4: On-site sodium hypochlorite generator

An on-site generator can be used to produce sodium hypochlorite or a **mixed-oxidant** (eg, MIOX) solution for water disinfection. Because the system uses salt as a raw material, it is not associated with any serious chemical safety issues. However, the process will produce hydrogen gas, which is flammable and must be vented directly to the outdoors. The unit will include a water softener because it has an electrode that is sensitive to water quality.

The chlorine solution produced by this on-site generator would be dosed into the water line using a dosing pump (Figure 22), in the same way as for the first two options. Electrodes and salt solution pump components need to be replaced occasionally.

Figure 22: Using a sodium hypochlorite generator (Option 4)



Consideration of operating costs

Each of the three chlorination options above will provide similar protection against bacterial contamination. The final selection will depend, to a considerable extent, on both the initial capital cost and the ongoing operating costs. It will also depend on factors such as ease of use, skill level of operators, and operating hazards.

The main operating cost to consider for chlorination systems is the cost of the chemical. This cost will vary according to the location and the amount that is purchased. In most situations, chlorine gas will be slightly cheaper but, as there are significant operating hazards associated with it for small systems, its use has not been included as an option. Of course, some small supplies successfully use chlorine gas. Normally, however, sodium hypochlorite or calcium hypochlorite will be very cost-effective and the associated hazards are much less severe.

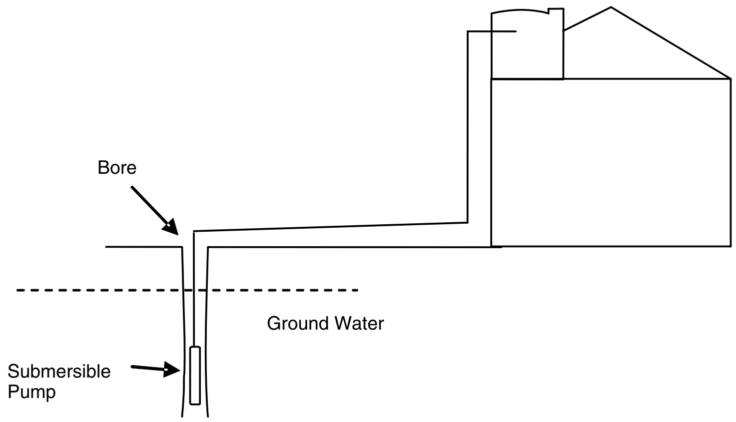
Although there is a high installation cost for on-site generation of sodium hypochlorite, this option may be cost-competitive once the long-term operating costs are considered. Because these systems use electricity to convert salt to sodium hypochlorite, the cost and availability of the electricity is important.

10.3 Scenario 3: Buttercup School

Community:	A rural school with 100 pupils uses approximately 5000 litres per day in winter and, due to irrigation of sports fields, 10,000 litres per day in summer.
Water source:	Non-secure groundwater
Existing treatment:	None. Water is pumped from the groundwater source directly to the school distribution system's header tank

	(Figure 23). There is room in the existing buildings for the treatment units.
Water quality issues:	The water has been proven to have no chemical contamination that needs treatment, apart from low pH that makes the water aggressive to plumbing. For example, the copper pipes are corroding and blue stains are forming under taps on the sinks around the school. However, there is no need to treat the water being used for irrigation.

Figure 23: Existing water system at Buttercup School

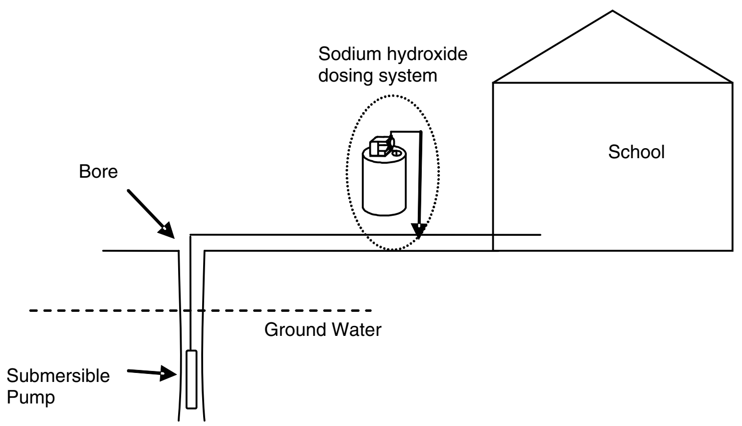


Option 1: Raising the pH

One way to make the water less corrosive is to raise the pH of the water by dosing with sodium carbonate (soda ash). In this scenario, the dosing pump would operate at a constant speed and run only when the bore pump runs (Figure 24). The speed of the dosing pump would be adjusted so that it can give the target pH. A meter to test the water pH would be needed to ensure that the dosing system is dosing the right amount, and turn off the dosing pump if there is a problem.

Sodium hydroxide would be a cheaper chemical but it requires great care when handling as it can cause chemical burns and serious damage to eyes.

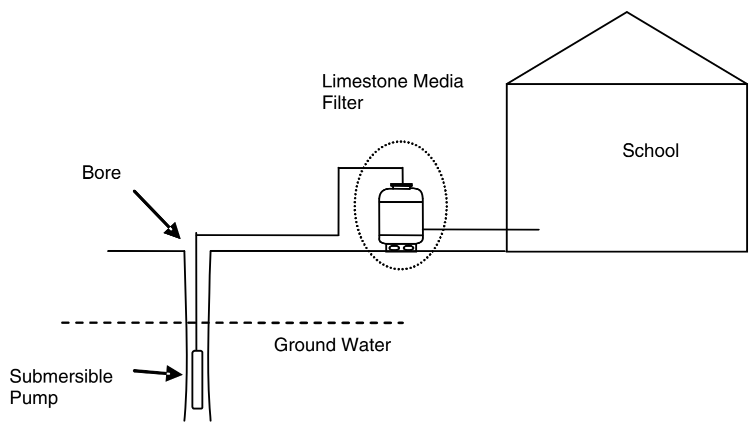
Figure 24: Dosing with sodium hydroxide or soda ash (Option 1)



Option 2: Dolomite media filters

Another way to raise the pH is to use dolomitic limestone or a similar material as a filter media (Figure 25). The dolomite will raise the pH of the water but the exact increase cannot be precisely controlled. The dolomite is gradually consumed so it will need to be inspected at regular intervals and replaced as required.

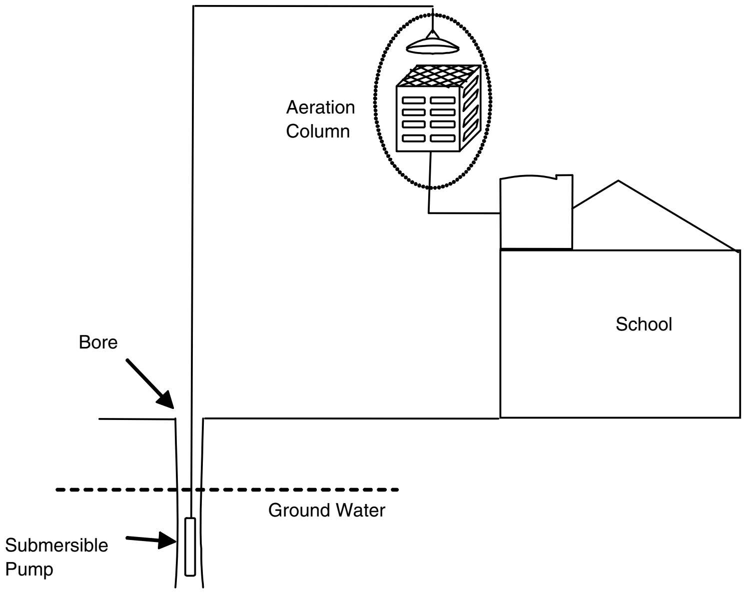
Figure 25: Using dolomite media filters (Option 2)



Option 3: Aeration to remove excess carbon dioxide

A common source of acidity in water is dissolved carbon dioxide. Aeration can be used to reduce the carbon dioxide content in water by evaporation to the atmosphere (Figure 26 and Figure 8). This process will increase the pH but the effectiveness would have to be tested on a small scale beforehand. Often this technique would be combined with others, particularly when there are other reasons to aerate, such as to reduce sulphide levels. Lifting the water to a higher level may require a bigger pump.

Figure 26: Using aeration (Option 3)



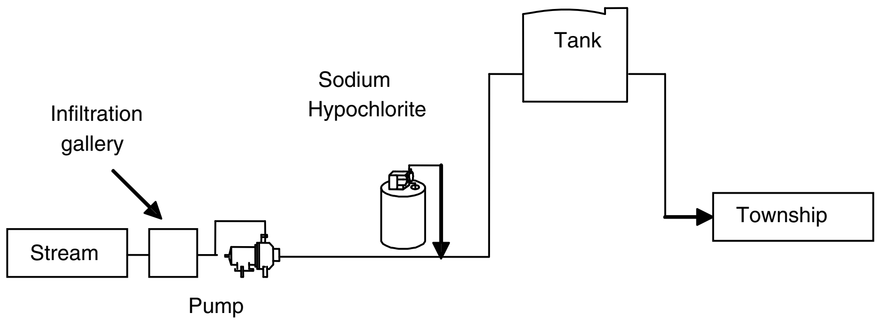
Option 4: Disinfection

Options 1-3 do not address the microbiological quality of this water. UV disinfection will inactivate any protozoa and bacteria in the water, and most viruses. See Option 3 in 10.1 Scenario 1.

10.4 Scenario 4: Slipville

Community:	A small township uses approximately 90,000 litres per day.
Water source:	Water is taken from a small stream in a native forest using an infiltration gallery (Figure 27 and Figure 5).
Existing treatment:	Sodium hypochlorite is dosed for disinfection. The water is pumped up to a reservoir on a hill, which gives the water the required pressure.
Water quality issues:	Water has moderate colour and dissolved organic matter levels from broken-down leaf litter but turbidity is consistently low. The sodium hypochlorite is reacting with organic matter producing disinfection by-products. The dissolved organic material needs to be removed. Additional protection against protozoa is also needed.

Figure 27: Existing water system in Slipville



Option: Coagulant dosing, pressure filter and UV unit

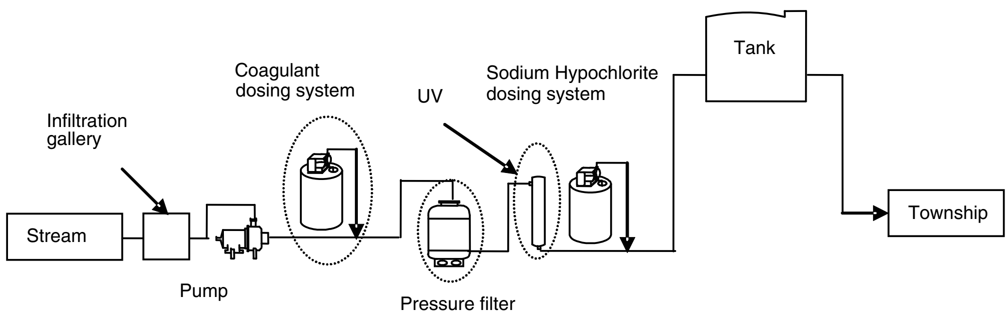
One way to reduce the colour level is to dose coagulant into the water upstream of a pressure filter (Figure 28). The filtered water is then passed through the UV unit to kill bacteria, viruses and protozoa. Sodium hypochlorite can be dosed downstream of the UV unit to provide protection against recontamination in the network.

Coagulant dosing and filtration comprise the normal method for removing colour in large water treatment plants. With this system, the coagulant dose has to be regularly adjusted by a skilled operator. In addition, many coagulants are sensitive to pH, which has to be adjusted within a narrow range. If the dose is too small, the filtration stage is not as effective. Dosing too much can cause the filters to block or lead to carry-through of the coagulant. Chemical coagulation is not normally practical for small supplies.

The effectiveness of the direct filtration process shown in Figure 28 is highly dependent on the performance of the infiltration gallery. If the turbidity were to become high, then pre-treatment would be needed.

Other methods for colour removal include oxidation by ozone, or nanofiltration; these processes would be very expensive for small water supplies.

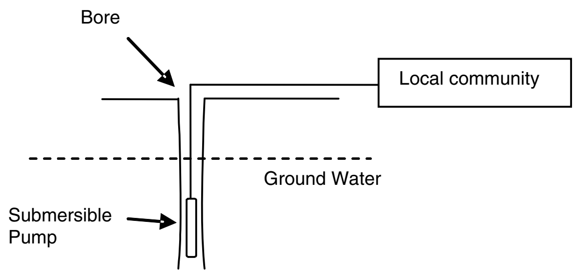
Figure 28: Using coagulant dosing and filtration



10.5 Scenario 5: Greenacres Resort

Community:	A community uses approximately 20,000 litres per day.
Water source:	Water from a secure bore is pumped directly into a distribution system (Figure 29).
Existing treatment:	None
Water quality issues:	Iron and manganese levels require treatment. Residents have noticed brown/black stains on their laundry and an unpleasant taste from the drinking-water.

Figure 29: Existing water system at Greenacres Resort



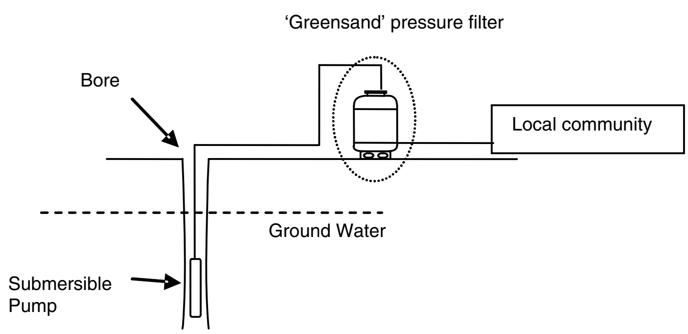
Option and cost

This scenario involves a secure groundwater. Proving security can be very expensive. It is possible for a small water supply to operate a bore in an aquifer that a larger water supplier has proved to be secure.

The water could be pumped from the bore to a pressure filter filled with 'greensand' media for removing iron and manganese (Figure 30). The filter requires regular backwashing and the waste must be disposed of. The filter must be regenerated either continuously or intermittently by dosing with potassium permanganate or with chlorine, or a combination of the two, to restore the media.

Particular care must be taken when handling potassium permanganate as it is a very strong oxidiser.

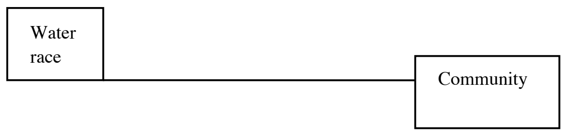
Figure 30: Using a 'greensand' pressure filter



10.6 Scenario 6: Kaupapa Marae

Community:	A small community of about 200 people uses 40,000 litres per day on average and 70,000 litres per day when there is an influx of people.
Water source:	The water supply is sourced from a water race located above the community. The height of the source is sufficient to give the required water pressure. The water becomes cloudy after rain.
Existing treatment:	Water is collected from an intake at the water race and there is no treatment processes (Figure 31). No pumping is needed.
Water quality issues:	Turbidity levels can be high after rain. The high turbidity is also an 'aesthetic' issue for the community as their water looks very cloudy.

Figure 31: Existing water system at Kaupapa Marae

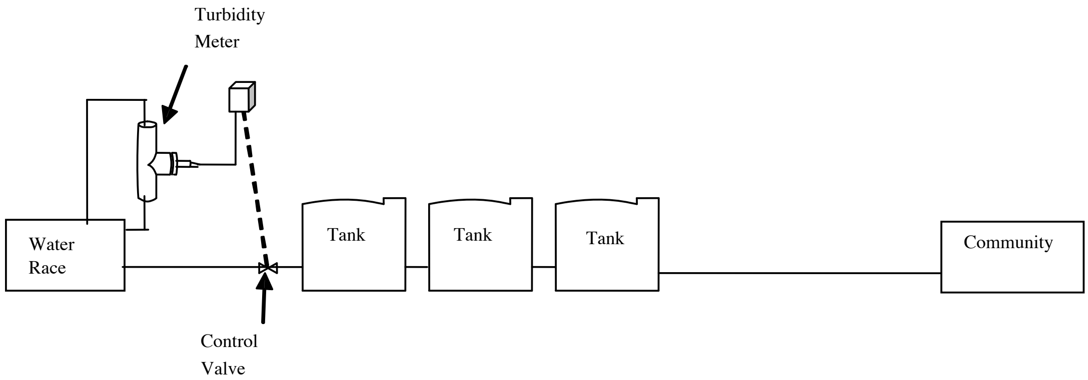


Option 1: Storage

A simple solution would be to stop extracting water from the water race when the water quality is poor. In order to do this, a turbidity meter can be installed prior to a storage system (Figure 32). Inflow can be shut off automatically when the turbidity exceeds a set level, say, 1 NTU. Once the turbidity level falls, the flow can start again.

30,000-litre storage tanks can be added upstream of the treatment process to maintain a two-day supply (the longer the better) during a high turbidity event. Floating outlets can also be installed to further improve water quality by settling out the heavy particles. This sediment will have to be flushed out from time to time.

Figure 32: Using a storage system



Note: These options can be adjusted to meet the Drinking-water Standards if UV disinfection and possibly cartridge filters are added; see Option 2 of Scenario 6 and Option 3 of Scenario 1.

Option 2: Pre-filtration and cartridge filters

This option uses cartridge filters to remove turbidity and UV light to protect against protozoa (Figure 33). To reduce the frequency with which cartridge replacements are required, a roughing filter is installed upstream. This filter contains either sand or a fine artificial media and must be backwashed regularly.

This system needs to be tested first using smaller filter units to make sure it can give the necessary performance. It is possible that the pressure filter may not remove enough of the material in the water, which would lead the cartridge filters to become blocked very quickly. The performance of the cartridge filters also depends on the size of the particles in the water. Very small particles could pass through and the water could still be turbid.

A UV unit is included as a way to provide multiple barriers against protozoa and other pathogens.

Figure 33: Using pre-filtration and cartridge filters