SECTION 6

WATER TREATMENT PROCESSES

Section Contents

Private Water Supplies

6.1 Introduction

Larger water supplies are usually treated by point of entry methods based on a full investigation of site conditions. Anyone planning to install or upgrade a water treatment process should seek expert guidance. For small supplies, a disinfection stage should only be dispensed with if the supply can be shown by risk assessment and frequent surveillance to be consistently pathogen-free.

Potential treatment suppliers should be certified, experienced and have references for similar projects. They must also provide adequate training and guidance for the end user.

For some contaminants, several techniques could be appropriate and the choice should be made on grounds of cost, taking into account local circumstances.

6.2 Multiple barriers

Microbiological contamination is generally the most important to human health as this can lead to infectious diseases. All water sources require treatment prior to consumption. Usually, this consists of a number of stages, with initial pre-treatment by settling or pre-filtration through coarse media, and then sand filtration followed by chlorination. This is called the multiple barrier principle, and it extends back from the treatment stage to the catchment.

It requires effective source protection, careful choice of aquifer or water intake and well-designed, well-maintained abstraction structures.

SUMMARY 6.3 – 6.4

6.3 Coagulation and flocculation

Coagulation and flocculation are used to remove colour, turbidity, algae and other micro-organisms from surface waters, as well as iron and aluminium.

The most commonly used coagulants are aluminium sulphate and ferric sulphate, although other coagulants are available. Coagulants such as aluminium sulphate or ferric sulphate are dosed in solution at a point of high turbulence.

Coagulation reduces the time required to settle out suspended solids and is very effective in removing fine particles, as well as many protozoa, bacteria and viruses.

The principal disadvantages for small supplies are the cost and the need for accurate dosing and frequent monitoring.

6.4 Sedimentation

Sedimentation tanks reduce the flow of water to permit suspended solids to settle under gravity. Tank selection is based on simple settlement tests or experience.

They are usually rectangular and designed to both distribute the incoming flow and collect the clarified water as evenly as possible across the full tank width. They should be covered and will require cleaning when performance drops off.

6.5 Filtration

General – turbidity and algae are removed by screens, gravel filters and slow sand (biological) or rapid gravity (physical) filters.

Screens remove particulate material and debris on surface water intakes. Coarse screens remove weeds and debris while band screens or microstrainers will remove smaller particles including fish and large algae.

Gravel filters remove turbidity and algae, and can operate for several years before cleaning is needed. Filter size depends on water quality, flow rate and size of gravel.

Slow sand filters are tanks that remove turbidity, algae and micro-organisms in a simple, reliable process often used for small supplies if sufficient land is available.

The top few centimetres of sand contain the accumulated solids and are replaced periodically. A variant called the ‘Inverness filter’ has been widely used in Scotland.

Rapid gravity filters remove floc (precipitate) from coagulated waters, and turbidity, algae and iron and manganese from raw waters. Granular activated carbon medium can remove organic compounds, and alkaline filters can increase the pH value of acidic water. These filters produce a dilute sludge that must be disposed of properly.

Pressure filters can be used to maintain head and eliminate the need for pumping into supply. Operation and performance are generally as for the rapid gravity filter.

6.6 Aeration

These processes transfer oxygen into water and remove gases and volatile compounds by air stripping. The former is normally done by a simple cascade or diffusion of air into water, and the latter by packed tower aerators.

SUMMARY 6.7 – 6.8

6.7 Chemical treatment

Control of pH – pH may need to be adjusted for several reasons, including quality standards, corrosion and disinfection. Increased pH can be achieved by using alkaline substances or by aeration, and reduced pH by dosing with a suitable acid.

Iron and manganese removal in groundwaters is by oxidation (with care not to cause colloid species) and filtration or coagulation. Surface waters will need filtration.

Taste and odour removal methods include aeration, ozonation and adsorption on activated carbon, depending on the cause.

Nitrate removal is usually by ion-exchange through a column of synthetic resin beads. Nitrate-selective resins are preferred.

Surface waters may require pre-treatment by coagulation to remove organic colour and suspended solids, which would foul the resin.

Nitrate can also be removed by some membrane processes and by biological denitrification, but this is too costly and complex for small water supplies.

6.8 Membrane processes

The most significant are reverse osmosis, ultrafiltration, microfiltration and nanofiltration. Some can remove colour and organic compounds; others can remove *Cryptosporidium, Giardia* and potentially human viruses and bacteriophages, but must not be relied upon as the sole means of disinfection.

6.9 Disinfection

General – contamination by sewage or by human or animal faeces is the greatest danger associated with drinking water. This is because sewage from human or animal sources may contain the causative organisms of many communicable diseases. The use of disinfection to kill or inactivate pathogenic micro-organisms is necessary if the raw water contains such organisms.

Surface waters are more prone to contamination than groundwaters. Disinfection with chlorine is widely used for large water supplies but less so for small supplies. Other methods include ultraviolet irradiation and ozonation.

Ct value can be used to rank relative susceptibilities of micro-organisms to disinfection.

Ultraviolet (UV) irradiation is preferred for small supplies except for certain schemes, but the water must be of good quality and low in colour and turbidity. Pre-filtration is advisable, especially if *Cryptosporidium* is likely to be present.

Low pressure mercury lamps are most commonly used; normally separated from the water by a 'sleeve' to prevent cooling. Typical lamp life is 10 to 12 months after which replacement is required.

For effective disinfection, both the residence time of water in the reactor and UV intensity must be adequate.

UV irradiation equipment is compact and simple to operate, and maintenance is modest but essential. Other advantages include short contact time and no known health risks. However, lamps must be cleaned of scale or replaced regularly, so an appropriate storage tank may be needed.

Chlorine chemistry – Hypochlorous acid is a more powerful disinfectant than the hypochlorite ion and chlorination processes are usually chosen favourable to its formation. These processes need careful control to minimise taste, odour and the formation of THMs. Small water supplies should consider alternatives like UV.

Chlorine sources – liquefied chlorine gas comes in pressurised containers, but chlorine gas leaks are very dangerous and it is not recommended for small supplies.

Sodium hypochlorite solution can be delivered to site in drums or generated on site by the electrolysis of brine, and there is a wide choice of dosing equipment available.

Calcium hypochlorite is stable when dry and several months' supply can be stored, but it will react with moisture in the air to form chlorine gas. Tablets are most commonly used, as their rate of dissolution is predictable.

Chlorination methods – on small supplies, only marginal chlorination would be used in most cases, to produce a suitable residual-free chlorine concentration.

Breakpoint chlorination could be used to remove ammonia but the contact system must not permit short-circuiting or retention in dead zones.

6.9 Disinfection (continued)

Chlorination control – residual control is the most common method, where the water is dosed continuously and the residual is monitored to adjust the chlorine dose.

Ozone gas used with granular activated carbon filters can destroy bacteria and viruses and reduce colour, taste and odour. It cannot be relied upon as the sole means of disinfection for *Cryptosporidium*, however.

It is not widely used because of its complexity, high power requirements and cost.

6.10 Corrosion control

General – can cause structural failure, leaks, loss of capacity and deterioration of water quality, including contamination by metals. Control parameters include calcium, bicarbonate, carbonate and dissolved oxygen concentrations, as well as pH.

Lead corrosion (plumbosolvency) tends to be worst in waters with a low pH and low alkalinity. Pending pipe replacement, the pH should be maintained at 8.0 to 8.5. Dosing with orthophosphate may also help.

Copper – many corrosion problems are associated with new pipe in which a protective oxide layer has not yet formed.

Nickel leaching falls off over time. Increase of pH should also help to reduce it.

Concrete and cement – a pH of 8.5 or higher may be necessary to control corrosion.

Characterising corrosivity – no corrosion index applies to all materials, but the Langelier Index, the Larson ratio and Turner diagrams can all be useful.

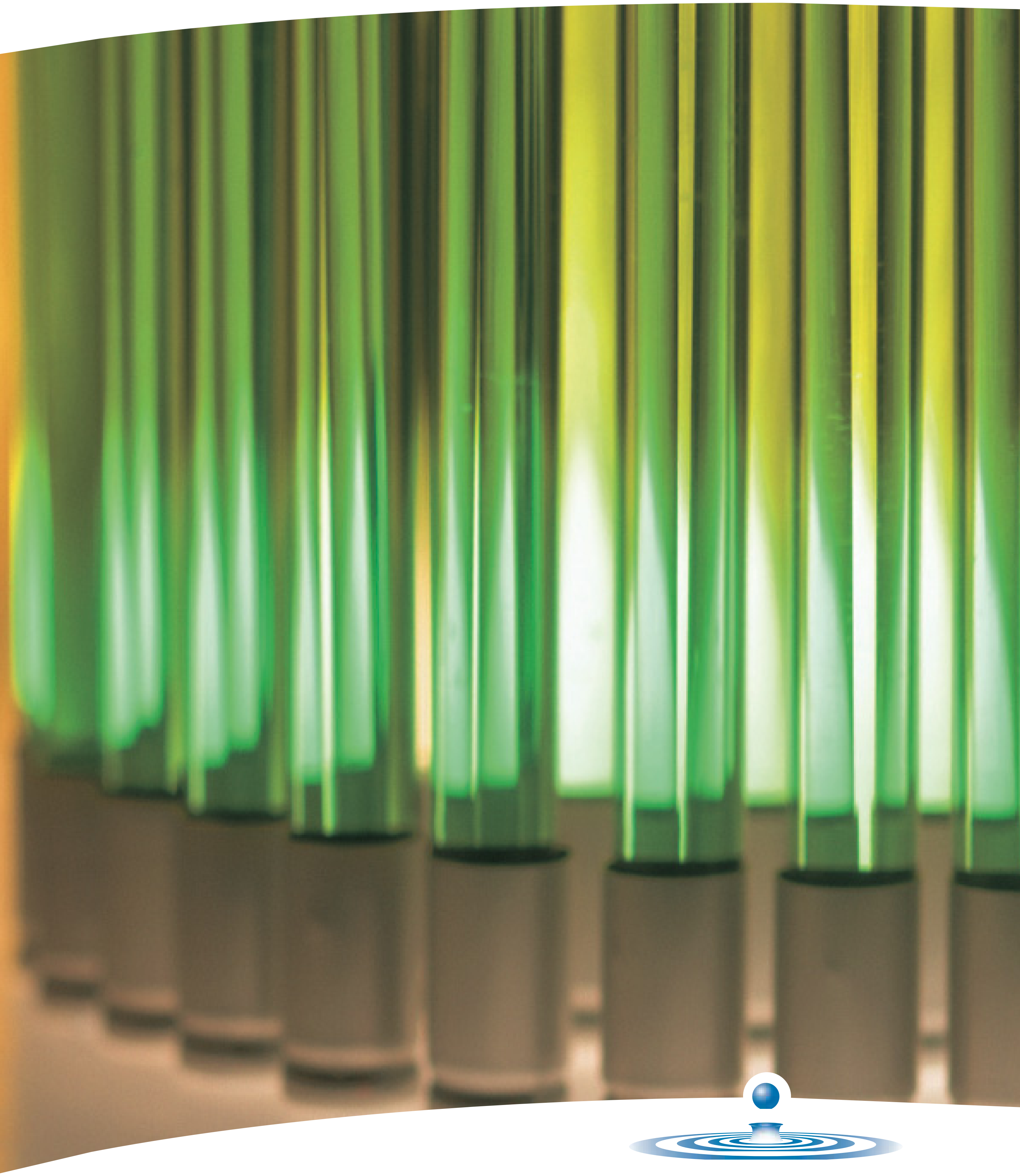
Water treatment for corrosion control – the most common methods are adjusting pH (though this can affect disinfection), increasing the alkalinity and/or hardness, or adding corrosion inhibitors. Wherever practicable, lead pipework should be replaced.

6.11 Treated water storage

The storage tank and other parts of the water supply system should be disinfected before use. Storage tanks must be insulated, lockable (but not airtight), insect-proof, and regularly inspected.

6.12 Maintenance and training requirements

Proper maintenance involves a regular, preventive, programme performed by persons familiar with the equipment. The supplier should provide comprehensive training and supporting documentation.



Private Water Supplies

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6 WATER TREATMENT PROCESSES

6.1 Introduction

Larger water supplies, serving many properties or commercial or industrial premises, are usually treated by point of entry treatment methods, similar in principle to those used at municipal water treatment works. It is essential that the design of any treatment process is based on a full investigation of site conditions, including chemical and microbiological analysis of water and the results of laboratory or pilot-scale tests to determine the effectiveness of the process and the chemical dosing requirements. This chapter provides an overview of the basic principles of water treatment – anyone planning to install or upgrade a water treatment process should seek expert guidance.

For small supplies, for treatment to be truly precautionary it should include a preventive element. In practice this means that treatment of a groundwater supply should automatically include disinfection – a disinfection stage should only be dispensed with if the supply can be shown by risk assessment and frequent surveillance to be likely to be consistently pathogen-free.

It is important to choose equipment suppliers and consultants carefully. Recommendations from previous clients can be useful provided that they relate to similar types of project. Consultants should be members of an appropriate professional institution. Purchasers of water treatment plant and supplies should:

- ensure that potential suppliers are aware of the size and nature of the water supply;
- confirm that potential suppliers can furnish suitable equipment;
- check whether the supplier is certified to the ISO 9000 quality system;
- establish whether suppliers can provide references relating to similar projects;
- if practicable inspect other, similar, installations; and
- establish that the operating and maintenance manual, and training, will be adequate for the end user of the equipment.

A range of water treatment processes is covered here and in the following chapter, which deals with point of use systems for treatment of water at a single tap. Table 6.1 indicates the capability of the various treatment techniques for removing common contaminants. For some contaminants, potentially several techniques could be appropriate and the choice between processes should be made on grounds of cost, taking into account local circumstances. For example, membrane processes can remove a broad spectrum of contaminants but cheaper and simpler alternatives may be just as effective in particular cases. It is likely that a combination of processes will be required to deal with particular waters, for example filtration followed by UV to remove particles and inactivate micro-organisms.

Table 6.1 Overview of treatment methods

	Bacteria	Cysts	Viruses	Algae	Coarse Particles	Turbidity	Colour	Aluminium	Ammonia	Arsenic	Iron & Manganese	Nitrate	Pesticides	Solvents	Taste & Odour
Coagulation/flocculation[1]	+	+	+	+	++	++	++	++		+	++				
Sedimentation					++	+		+			+				
Gravel filter/screen				+	++	+		+			+				
Rapid sand filtration	+	+	+	+	++	+		+			+				
Slow sand filtration	++	++	++	++	++	++		+			+				
Chlorination	++		++	+			+		++						
Ozonation	++	+	++	++			+						++		++
UV	++	+	++	+											
Activated carbon							+						+	+	++
Activated alumina										++					
Ceramic filter	++	++		++	++	++									
Ion exchange									+	+		++			
Membranes	++	++	++	++	++	++	++	++		+	++	++	++		++

+ Partly effective

++ Effective/preferred technique

[1] Pre-oxidation may be required for effective removal of aluminium, arsenic, iron and manganese.

6.2 Multiple barriers

All water sources require treatment prior to consumption to ensure that they do not present a health risk to the user. Health risks from poor quality water can be due to microbiological or chemical contamination. Microbiological contamination is generally the most important to human health as this can lead to infectious diseases. Chemical contamination, with the exception of a few substances such as cyanide and nitrate, tends to represent a more long-term health risk. Substances in water which affect its appearance, odour or taste may make water objectionable to consumers. As micro-organisms can be associated with particles in water, physical contamination may also represent a health risk as it makes disinfection more difficult.

Most treatment systems are designed to remove microbiological contamination and those physical constituents such as suspended solids (turbidity) that affect aesthetic acceptability or promote survival of micro-organisms. A final disinfection stage is nearly always included to inactivate any remaining micro-organisms. When a persistent disinfectant, such as chlorine, is applied this also provides a 'residual' that will act as a preservative during storage and/or distribution in larger systems.

Treatment processes are based on the physical removal of contaminants through filtration, settling (often aided by some form of chemical addition) or biological removal of micro-organisms. Usually, treatment consists of a number of stages, with initial pre-treatment by settling or pre-filtration through coarse media, sand filtration followed by chlorination. This is called the multiple barrier principle.

This is an important concept as it provides the basis for effective treatment of water and prevents complete failure of treatment due to a malfunction of a single process. For instance, with a system that comprises coagulation/flocculation, sedimentation and rapid sand filtration with terminal disinfection, failure of the rapid sand filter does not mean that untreated water will be supplied. The coagulation/flocculation and sedimentation processes will remove a great deal of the suspended particles, and therefore many of the micro-organisms in the water, and the terminal disinfection will kill many of the remainder. Provided that the rapid sand filter is repaired promptly, there should be little decrease in water quality.

The multiple barrier principle extends back from the treatment stage to the catchment, so a key element is to ensure that the source of water is protected and maintained at as high a quality as possible. Proper selection and protection of water sources are of prime importance in the provision of safe drinking water. The subsurface is often an effective medium for attenuating contaminants present on the catchment while the design and good maintenance of the well, borehole, spring or intake can help exclude localised pollution. It is always better to protect water from contamination than to treat it after it has been contaminated. Effective source protection, careful choice of aquifer or water intake and well-designed, well-maintained abstraction structures all constitute effective barriers in the multiple barrier principle.