Hundreds of small water cooperatives in Finland have arranged their water supply utilizing shallow groundwater wells. The operators of such utilities are seldom qualified experts and hence in need of practical guidance. This guidebook, written and published originally in Finnish and in Swedish, aims to give information and advice to operators of small groundwater utilities.

Even though many of the problems encountered at small waterworks are different due to local circumstances, especially water resources and geology, many risks and problems as well as many solutions are common throughout Europe and Asia. In order to serve wider audiences, especially in the context of the United Nations ECE and WHO, and distribute the knowledge and experience gained in Finland, the Finnish Environment Institute and The Finnish Ministry of Social Affairs and Health decided to publish this guidebook also in English language.

The authors and publishers wish that the content of this book is useful for many operators of small waterworks and helps them in their efforts to further develop safe water abstraction and distribution.
Operation and maintenance of small waterworks

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FOREWORD

In 2004 the Finnish Environment Institute SYKE started a project aiming to study the state of and problems encountered at small waterworks utilizing shallow groundwater aquifers. The main aim was to collect experiences of their operation, maintenance, monitoring and control procedures, as well as to do some research on the water quality. In connection of the project activities it became soon evident that there was a clear need for a special, practically oriented guidebook focusing on these subjects. At the same time the need for educational material increased also due to the newly introduced national requirement of a proven knowledge and understanding of hygienic aspects for operators and other staff working at waterworks. This guidebook was then compiled based on the results of the project and other knowledge and experience from various sources.

This guidebook was written by Ms. Eija Isomäki, Mr. Matti Valve and Ms. Anna-Liisa Kivimäki from SYKE and Ms. Kirsti Lahti from the Water Protection Association for the River Vantaa and Helsinki Region. Ms. Isomäki is civil engineer specialized in water supply, Mr. Valve is specialist of water chemistry and water treatment, Dr. Kivimäki is hydrogeologist and Dr. Lahti microbiologist. Also several other water quality, water treatment, microbiology and water resources management experts from the Ministry of Agriculture and Forestry, Ministry of Social Affairs and Health, National Public Health Institute, National Product Control Agency for Welfare and Health, Helsinki University/Department of Food and Environmental Hygiene, Finnish Water and Waste Water Association and Haume Consulting participated in the project. In addition, some specialists from the companies FCG Planeko, Hyxo, Watman and Prizztech/Finnish Institute of Drinking Water gave valuable help to the authors. Leading expert Erkki Santala from SYKE acted as a responsible leader for the project.

This book was originally written and published in Finnish and in Swedish languages aiming to give information and advice to operators of small groundwater utilities in Finland. Even though many of the problems encountered at small waterworks are different due to local circumstances, especially water resources and geology, many risks and problems as well as many solutions are common throughout Europe and Asia. In order to serve wider audiences, especially in the context of the United Nations ECE and WHO, and distribute the knowledge and experience gained in Finland, SYKE together with the Finnish Ministry of Social Affairs and Health decided to publish this guidebook also in English language.

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1 Groundwater

Groundwater bodies are formed when precipitation water infiltrates through the soil surface and percolates further through unsaturated porous deposits. Groundwater bodies can be found in loose deposits, porous sedimentary rocks and fractured crystalline bedrock. Water quality changes during the underground passage: a variety of harmful compounds (and pathogenic micro-organisms) attach to the fine-grained particles and organic matter in the subsurface deposits, while ion composition changes due to dissolution of minerals present in the rock debris. The flow routes of groundwater are determined by a relief of the bedrock surface underneath the loose deposits and impermeable layers of fine-grained deposits such as clay soil.

Figure 1: Groundwater formation
The saturated zone, i.e. water-bearing strata in which all interconnected pores, voids and cracks are filled with water extends from the groundwater table down to top of the impermeable layer. In Finland, the groundwater table is usually encountered at the depth of 2 to 4 metres below the ground surface, although in places, for example in esker ridge areas, it may lie at the depth of more than 30 metres bgs. Groundwater is discharged from aquifers via springs, wetlands or surface water bodies. The groundwater reservoir stored in an aquifer may become exhausted if groundwater yield of the aquifer is limited and volume of groundwater continuously abstracted from the aquifer exceeds the yield.

In Finland, the aquifers with the highest exploitation potential are commonly found in glacifluvial sand and gravel formations. Groundwater aquifer areas are formations with defined groundwater recharge zones from where groundwater can be abstracted for water supply purposes. Finnish environmental authorities have grouped Finnish aquifers into three classes, based on the potential to be exploited for municipal water supply. Class I aquifers are those considered vital for water supply, Class II are aquifers considered suitable for water supply, and Class III aquifers need to be further investigated to define their usability in water supply. There are about 6,600 classified aquifers in Finland.

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Of the water supplied by waterworks in Finland, surface water accounts for about 37%, groundwater for about 52% and artificial groundwater for about 11% of the total. Over three million Finns rely on groundwater for their water supply. Some 500,000 of this total are rural dwellers maintaining their own well or sharing a communal well as members of a water cooperative.

Groundwater quality is impacted by the following factors:

- volume of precipitation
- pH in precipitation water
- dissolved ions in percolating water
- groundwater storage and underground retention time
- mineralogical composition of bedrock and loose deposits
- thickness of overburden and grain size composition of loose deposits
- microbial activity in unsaturated and saturated zones
- a range of human activities within the groundwater recharge zones
Groundwater aquifers can be (see Figure 1):

- **unconfined aquifer**: water-bearing formation with a free groundwater table, overlain by unsaturated zone consisting of strata with high hydraulic conductivity.
- **confined aquifer**: water-bearing formation overlain by impermeable stratum. The latter is also known as an artesian aquifer, where groundwater occurs under greater than atmospheric pressure. Due to high pressure groundwater level will stand above the top of the aquifer if the confining layer is punctured. In some cases the piezometric surface of groundwater will settle above the ground surface and groundwater gushes to the surface; and
- **perched groundwater**: thin separate body of groundwater, accumulated on the top of impermeable stratum, located above the water table of the main groundwater body.

The yield of a groundwater aquifer can be increased by artificial groundwater recharge, i.e. infiltration of surface water into subsurface via basins, wells, sprinkling etc. The surface water to be injected to an aquifer can be pre-treated to ensure high quality of artificial groundwater.

When a groundwater aquifer borders a lake or a river, its yield can also be improved using bank filtration, in case there is a good hydraulic connection, i.e. deposits in a shoreline consist of coarse-grained sand and gravel. The groundwater level is lowered by pumping water from water intake wells, and when the groundwater table falls below the lake water level, the surface water infiltrates into the aquifer.
2 Quality control of the drinking water supply

2.1 Water supply companies and operator qualification requirements

Water supply companies range from large municipal water utilities serving thousands to small water cooperatives providing water to a few households. The quality of the drinking water distributed by the water supply companies is supervised by the municipal health authorities.

A water supply company must apply for certification from the municipal health authorities no later than three months before beginning operations. (The amendment to the Finnish legislation concerning the certification process entered into force on 1 March 2006.) If the water supply company was in operation before the amendment entered into force and the health authorities have been notified of its operations, no application is necessary. In this case, an application for certification is only necessary if changes are made to the waterworks operations, i.e. if the water intake or distribution is expanded or there are changes in water treatment methods.

Under the Finnish Health Protection Act, all persons working at a waterworks distributing drinking water and employed in tasks in which they may be in position to influence the quality of drinking water must prove their qualifications. Operators must pass a qualifications test managed by the National Product Control Agency for Welfare and Health (STTV) and organized by STTV-authorized testing facilities such as the Finnish Water and Waste Water Works Association, the Centre for Technical Training (AEL), and polytechnics and other educational institutions. The locations at which the examination can be taken several times throughout the year are listed at the STTV website, and further details can be supplied by municipal health authorities. The material covered in the examination is listed in Appendix 9. The deadline for qualification is 30 June 2008. No previous qualifications are required.

In the future, the number of waterworks operators is expected to decrease, although managing waterworks will become more demanding and requires more resources.
For this reason, it may be easier for small waterworks to join larger utilities or to outsource their maintenance and service operations to professionals.

2.2 **Surveillance of the drinking water supply by health authorities**

Drinking water is not allowed to contain anything that may pose a hazard to human health. This includes pathogenic bacteria, viruses and protozoa. To eliminate these health hazards, statutory quality requirements for drinking water have been enacted. There are also regulations that prohibit distributing water that may cause hazardous precipitates in the water distribution system or is highly corrosive. The relevant quality requirements and guidelines are set in the relevant Decrees of the Ministry of Social and Health Affairs (461/2000 and 401/2001), issued pursuant to the Health Protection Act. (Appendix 1)

**Quality of drinking water is to be monitored on a regular basis.** Water supply companies providing water to 50 or more people or in quantities of 10 m$^3$ or more per day must have a monitoring programme which outlines its regular monitoring protocol, including e.g. the number of monitoring samples taken. The number of samples depends on the volume of water distributed by the waterworks; the minimum requirements concerning the number of samples are given in the aforementioned Decrees of the Ministry of Social and Health Affairs (Table 1). The waterworks draws up the monitoring programme in cooperation with the municipal health authorities. The authorities are usually responsible for collecting the samples. Should a waterworks operator take the samples, the results must be sent to the authorities as soon as they are available. Samples are usually taken from customer taps.

The operations at the waterworks determine how it is to be monitored. Depending on the type of operations, the municipal health authorities may require the waterworks to carry out analyses beyond those required by the law. Special conditions, such as the intake being located in a sensitive area, must therefore be considered when the monitoring programme is drawn up. Every waterworks must monitor the water quality parameters regulated in the quality requirements and guidelines, and water quality has to fulfil the set quality standards. Samples must be analysed in an accredited and certified laboratory. A laboratory is considered certified if it has been certified by the Finnish Food Safety Authority (Evira). A list of certified laboratories can be found at the Evira website. Municipal health authorities can also provide more information.

A copy of the monitoring programme must be sent to the State Provincial Office and the regional environment centre. The programme must be updated at least every five years and whenever there are changes in capacity, technology or treatment methods used at the waterworks.
Table 1: Statutory monitoring of drinking water for waterworks with fewer than 100,000 customers:

<table>
<thead>
<tr>
<th>Volume of water [m$^3$/d]</th>
<th>Customers</th>
<th>Continuous monitoring [analyses/year]</th>
<th>Periodic monitoring [analyses/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>under 10</td>
<td>&lt; 50</td>
<td>every third year – 1</td>
<td></td>
</tr>
<tr>
<td>10 – 50</td>
<td>50 - 250</td>
<td>1</td>
<td>every second year</td>
</tr>
<tr>
<td>50 – 100</td>
<td>250 - 500</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>100 – 1,000</td>
<td>500 – 5,000</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>1,000 – 10,000</td>
<td>5,000 – 50,000</td>
<td>6 - 32</td>
<td>1 – 4</td>
</tr>
<tr>
<td>10,000 – 20,000</td>
<td>50,000 – 100,000</td>
<td>32 - 64</td>
<td>4</td>
</tr>
</tbody>
</table>

2.3 Supplementary monitoring of drinking water quality

In addition to the statutory monitoring samples, the waterworks must also monitor its own operations, especially the quality of the water that is distributed and the quality of the raw water abstracted from groundwater wells. This is essential because the waterworks is primarily responsible for the quality of its water supply. This type of monitoring, called routine operational monitoring, must be on a regular basis and much more frequent than statutory monitoring. Only comprehensive routine monitoring of operations enables the waterworks to identify water quality deterioration quickly enough. The routine operational monitoring protocol must be described in the monitoring programme.

Routine operational monitoring can be quickly carried out in-house at the waterworks’s facilities with simple analysis and measurements. The parameters included in routine monitoring are dictated by what kinds of water treatment methods are in use at the facility.

An important means of protecting the groundwater resources is a groundwater area protection plan. The plans are normally drawn up or commissioned by the municipality and waterworks together, in cooperation with the regional environment centre. The protection plan involves the examination of the hydrogeological characteristics of the groundwater area and the mapping out of potential hazards and risk areas that could affect water quality. This information is used for drawing up recommendations for measures concerning risk sites in the area, determining groundwater quality monitoring requirements and planning measures in case of accidents. A protection plan is not legally binding, but is used as background material for such matters as supervision of groundwater protection, land use planning and the preparation of environmental permits and permits for the extraction of land resources. Environmental authorities can provide more information about groundwater protection plans.

Each waterworks supplying drinking water must draw up a contingency plan for accidents and other emergency events. This includes a detailed plan about what to
do in emergency situations. Under the Health Protection Act, the municipal health authorities must, in cooperation with the waterworks and other authorities, make preparations regarding what to do in emergency situations.

- Before a waterworks can begin operation, it must obtain approval from the health authorities. The authorities must also be informed if there are any changes in the operations;
- Operators of waterworks distributing drinking water must pass a qualifications test;
- The quality of drinking water must be examined on a regular basis, at the very least as required by law under the Health Protection Act;
- Municipal health authorities must oversee the operations of waterworks and monitor the quality of drinking water. Municipal health authorities are usually also responsible for collecting monitoring samples; and
- Routine operational monitoring as performed by the waterworks is as important as statutory monitoring programmes in terms of quality analysis.
3 Water quality

3.1 General information

Potable water is water that is used for drinking, cooking and other household consumption. Sources of drinking water can be either groundwater or surface water that has been treated with a variety of chemicals. In several cases also groundwater must be treated before it is suitable for domestic use.

Groundwater quality is impacted by mineralogical composition of the bedrock and loose deposits. In Finland, pH in groundwater is usually low and concentrations of cations such as calcium, magnesium are also low. In limestone areas (Lohja, Parainen and Lappeenranta), elevated pH as well as concentrations of calcium and magnesium are detected. In rapakivi-granite areas (southeastern Finland, southwestern Finland and Åland), fluoride concentration in groundwater can be high. In areas where bedrock contains sulphide minerals (Tampere-Vammala-Pori and Lake Ladoga – Bay of Bothnia), groundwater has a low pH and high sulphate concentration. Radioactive radon restricts the use of groundwater – especially groundwater abstracted from deep drilled wells - in some granitic areas. Arsenic may occur in areas such as Pirkanmaa, Kittilä and Åland. Ancient marine sediments in coastal areas result in high chloride and sulphate concentrations in the groundwater. In western Finland and the coastal areas of southwestern Finland, there are clay-covered aquifers with a very low oxygen content and high iron and manganese concentrations.

Water quality affects human health and the technical functioning of the water supply network. Poor-quality water may cause illnesses, precipitates in the water pipes and the corrosion of equipment. It may also enhance microbial growth in different parts of the water supply network.
In aquifers that have been classified as vital or suitable for water supply purposes, the quality of the groundwater is usually good. Contamination of groundwater is often localised, and only in few cases the entire aquifer is found so seriously contaminated that groundwater can not be abstracted in any parts of the aquifer. Nevertheless, groundwater quality can be deteriorated by a range of geological and hydrogeological factors or a large variety of anthropogenic contaminants. The most important means to guarantee high groundwater quality are restriction of risk activities, preventive protection measures in groundwater areas and regular monitoring of groundwater quality.

In Appendix 2 a summary of ground-water quality of private wells in Finland is presented. Due to human activities, the quality of well water may differ substantially from the quality of pristine groundwater.

Groundwater can be contaminated by any activities that include handling, storage, use, transport or production of harmful substances in groundwater recharge areas. Generally there are a variety of human activities in groundwater areas, meaning that there are a large number of risk sites and the risk of releases of contaminants to aquifers is very high. Occasional and random leaks of contaminants are difficult to detect, and the migration pathways of harmful substances with varying transport characteristics are difficult to predict. Occurrence of thick layers of deposits and fine-grained stratigraphic units with low permability slows down the migration of harmful substances from the unsaturated zone to the saturated zone, and it may take years or even decades before contaminants are detected in the groundwater. In some cases contaminants have not been detected before they have reached the water abstraction wells. It is regrettably common that the occurrence of pathogens in groundwater at the waterworks is detected through epidemic of diarrhoea.

Figure 3. The varying mineralogical composition of bedrock and deposits results in local specific groundwater quality problems. Reference: Geochemical database of the Geological Survey of Finland.
3.2

Hygienic quality of drinking water

3.2.1

Indicator bacteria

When hygienic quality of drinking water is monitored, a number of specific indicator bacteria in the water are determined. Indicator bacteria are used to determine faecal contamination, because comprehensive analysis of pathogenic micro-organisms is expensive and time-consuming. Discovery of indicator bacteria in the water shows that the water may be contaminated by faeces and thus it may contain pathogenic bacteria, viruses or protozoa.

Coliform bacteria are the most commonly used indicators of hygienic groundwater quality. With the exception of Escherichia coli, they can also originate from sources other than human and animal faeces. Coliform bacteria are present in plants, soil and industrial wastewater. In fact, they often simply indicate that surface water has entered a well. Even if no coliform bacteria were detected in the effluent water leaving the waterworks, they may still multiply in precipitates found in the water supply network and taps of private households, weakening the quality of the network water.

Escherichia coli is considered the best indicator of faecal-based contamination, but usually it is not considered pathogenic. If E. coli bacteria are detected in drinking water, the waterworks and the municipal health authorities must immediately take joint measures to identify the cause of the contamination and prevent any imminent health hazards. Customers must be issued with a recommendation to boil their drinking water, and water chlorination must be initiated (Emergency situation instructions are detailed in Section 8).

Intestinal enterococci occurring in well water may indicate faecal contamination. If they are detected in the water, urgent measures must be taken to determine the cause of contamination and to prevent health hazards. Faecal streptococci (presumptive enterococci) are not necessarily intestinal, as they may be of environmental origin, and therefore they are not a direct indicator of faecal contamination.

3.2.2

Examples of pathogens in well water

Campylobacteria are the most common bacteria causing stomach diseases in Finland. They are normally spread by poultry and beef cattle, which means they are particularly common in the surface water of areas with cattle farming and other agricultural activities. If campylobacteria are transported to groundwater wells during periods of heavy rain or melting snow, they may survive in the water for several days. Symptoms of diseases caused by campylobacteria include diarrhoea,
heavy stomach pains and fever. Other bacteria found in water that can cause disease include EHEC and salmonella.

**Noroviruses** cause the most water-transmitted epidemics and can occur in foodstuffs such as berries and oysters. Noroviruses can reach well water as a result of a wastewater leak, or in periods of heavy rain or melting snow. In cold water, noroviruses may survive for up to a year. Symptoms of patients with norovirus illnesses include fever, vomiting, diarrhoea, and headache. Contamination can be caused by an extremely small number of noroviruses (fewer than 10 viruses). Well water can also be contaminated by other viruses, e.g. rotaviruses.

**Protozoa** occur naturally in surface water and wastewater. If they reach groundwater, their cysts may survive for long periods in groundwater environments. Cysts are cocooned protozoa shielded by a protective cover which allows them to survive unharmed in extreme conditions for long periods. They may even survive chlorine treatment, which means that protozoa-contaminated water must be purified with special filters and/or UV treatment. A single protozoa is enough to cause an illness characterized by diarrhoea, strong stomach pains and nausea.

**Mould fungi and actinomycetes** are particularly common in soil and nutrient-rich surface waters. Moulds and actinomycetes may migrate to well water during artificial groundwater recharge or bank filtration, or as a result of surface water runoff. Actinomycetes may reproduce as the water percolates through the soil layers and thus they may enter a well. Actinomycetes may also grow in sand filters. Mould fungi are most likely to be found in the raw water of groundwater waterworks, while actinomycetes are more commonly found in the water supply network. Mould fungi and actinomycetes can result in a foul odour or taste in the water, e.g. the fusty smell of earth in well water may be caused by moulds. Moulds and actinomycetes thriving in warm environments may also cause a cough, shortness of breath and fever.

Groundwater contamination scenarios that can result in drinking water induced illnesses:

- Clogged or damaged sewers result in wastewater entering the subsurface and a well through the well’s overflow tube.
- Surface water flows into a well through the well’s overflow tube. This could happen during the spring thaw, for example.
- Microorganisms enter a well or tank through the well ventilation pipe.
- A septic tank overflows, wastewater enters the soil and percolates through the permeable deposits to the groundwater.
- Surface water seeps through the unsealed concrete mantles of a well during periods of melting snow or heavy rain.
- The network has a damaged pipe, causing runoff to enter the network when the pressure in the pipe falls.
- The amount of groundwater has been increased using bank filtration, which unintentionally introduces surface water pathogens into the aquifer.
• If there are gaps or holes in a water tank, rainwater including faeces of birds or other animals that move about on the roof can leak into the tank. Small animals may even enter the tank and contaminate it.
• In winter, the water is colder, and chlorine treatment is less effective. As a result, pathogens may survive in the water for long periods if there is an insufficient dosage of chlorine.
• Mould fungi and actinomycetes may survive and grow in sand filters that are not cleaned frequently enough.
• Wastewater soil infiltration allow bacteria and viruses to enter the soil and deeper deposits and possibly enter the aquifer. If a water intake well is located near a leaching bed, pathogens may enter the well water.

Bacteria and viruses that have entered the water supply network may survive there for long periods of time, particularly if they are attached to biofilms. They may even survive shock chlorination. Biofilm formation can be prevented by flushing the network regularly, which also removes weakly attached precipitates from the pipe walls.

3.3 Threats to groundwater quality

Heavy rain and floods
Heavy rain, melting snow and floods may deteriorate the microbiological quality of the groundwater in the abstraction wells. Floods have been a frequent cause of quality issues in the groundwater waterworks located in the flood-prone areas of Ostrobothnia. Surface water and runoff water may enter well water and pipes as a result of poor well construction or through leaks in the water distribution system, resulting in transport of pathogenic microbes to the well water.

Drought and bank filtration
Exceptionally long periods of drought may create problems at the water intake units located within small aquifers. During a drought, groundwater levels at groundwater intake units may drop 1-5 metres below the long-time average. Drought affects both water availability and water quality. The most common groundwater quality change resulting from periods of drought is an increase in dissolved iron and manganese concentration due to oxygen deficiency. High iron concentration in the water causes technical and aesthetic problems: iron leaves rust stains on sanitary fittings and clothing and causes water to taste rusty.

In waterworks relying on bank filtration, hygienic problems may occur during dry periods if the groundwater level sinks and leads to an increase in the filtration of lake water into the aquifer, especially if the retention time is short. For bank filtration waterworks that have been operating at maximum capacity for long periods, dryness
can lead to high dissolved iron and organic carbon concentrations in the well water, as
the purification ability of the soil has been undermined by the intensive water intake.
Increases in bank filtration can be detected easily by measuring the groundwater
temperature. Groundwater temperature in an aquifer usually varies between +2.3
and +8.9 °C. Larger fluctuations indicate that surface water is migrating to and mixing
with the groundwater. The temperature of bank-filtered water in a well close to shore
may vary between +1 and +20 °C throughout the year.

The groundwater of a bank filtration waterworks may also be threatened by a
sudden discharge of harmful compounds in the surface water or by toxins produced
by the blue-green algae (cyanobacterial toxins) that appears in the surface water on a
seasonal basis. This is complicated by the fact that the bank filtration process cannot
be swiftly shut down when a hazard is recognized.

**Wastewater in rural areas and municipal sewerage systems**
The hygienic quality of groundwater can be affected by both privately-owned septic
tanks and filtration facilities and municipally-run wastewater treatment facilities and
faulty sewer systems. Pathogenic microbes transported into an aquifer as a result of
a wastewater leak may survive and remain infectious for up to a year. A wastewater
leak often also causes a rise in the concentration of nitrogen compounds, chloride
concentration and electrical conductivity.

**Agriculture**
In agricultural areas, the groundwater quality is affected by the use of fertilizers,
pesticides and liquid manure. The most common groundwater quality problem
in areas with crop and livestock production is a rise in nitrate concentration.
The microbiological quality of groundwater may also be affected by agricultural
activities.

**Sand and gravel excavation**
In sand and gravel formations, extensive sand and gravel excavation areas are
considered a risk to the groundwater, especially in cases where there is no restoration
of topsoil layers after the excavation activities have ceased. In sand and gravel
excavation areas, the uppermost deposits protecting the aquifer have been removed.
The handling and storage of fuels, potential fuel oil leaks from off-road machinery,
dust-binding in operating areas and the sludge resulting from wet sieving are all a
threat to groundwater quality in excavation areas.

**Traffic and road maintenance**
Road maintenance can also affect groundwater quality. Use of de-icing chemicals
(sodium chloride or other salt compounds) has in places contaminated water in wells
located adjacent to roads. As a consequence, chloride concentration in well water
has exceeded the taste limit. At small waterworks, the guideline for the maximum
chloride concentration is 100 mg/l, as laid down by the Ministry of Social Affairs and
Health. To avoid corrosion problems, however, the chloride concentration should be less than 25 mg/l. The use of road salt has been significantly cut down in all parts of Finland, and, to avoid deteriorating the groundwater quality, alternative de-icing chemicals (such as potassium formate) have been tested.

Significant amounts of pesticides were earlier used to kill weeds and brush on roadsides, traffic islands and railway areas. Their active ingredients degrade very slowly in the subsurface. The transport of hazardous materials poses a risk to the groundwater in the case of accidents.

**Service stations and oil tanks**

One of the most common sources of groundwater contamination in identified and reported contamination cases in Finland are mineral oil hydrocarbons. Contamination of groundwater at service stations often occurs in connection with accidents or other human errors, such as overfilling a tank. Oil hydrocarbons biodegrade slowly in subsurface deposits and aquifers, and a range of the oil compounds degrade so slowly that they can be considered virtually permanent.

**Old landfills**

In addition to solid household waste, old landfills also contain sludge, solid industrial waste and contaminated soil materials, some of which can be classified as hazardous waste. Contaminants such as heavy metals, volatile halogenated hydrocarbons and other organic compounds can usually be found in landfills. High concentrations of PAH and PCB compounds, lead, zinc, mercury, copper, cyanide and oil compounds have all been found in the soil of old landfills.

**Sawmills and wood impregnation plants**

Sawmills use preservatives to ward off wood rot and blue staining on the wood. The contaminants contained in these preservatives infiltrate into soil in connection with the watering of the timber, the storage and transport of the preservatives and their careless handling. The most commonly used preservatives contain chlorophenols, but dioxins and furans have also been found in the soil at sawmills. Ky5, which was widely used as anti-blue-stain agent in Finland until 1988, contains chlorophenols and is now categorized as class I toxic substance.

**Dry cleaner’s**

Chlorinated solvents such as tetrachloroethylene and trichloroethylene have been widely used at dry cleaner’s. These dense, Free-phase organic liquids can coalesce in an immiscible layer at the bottom of a saturated geologic unit, and slow dissolution of solvents into groundwater may continue up to several decades. The biodegradation of chlorinated solvents is extremely slow, and incomplete degradation may result in the carcinogenic by-product vinyl chloride.
**Commercial gardens and greenhouses**
Commercial gardens and greenhouses store and use fertilizers and pesticides which may leach into groundwater. Greenhouse production discharges much more contamination per surface area unit than ordinary crop production. Contaminants such as pesticides, metals, arsenic and oil compounds have been detected in the soil of commercial greenhouses.

**Shooting ranges**
Lead is the most common contaminant detected in the surroundings of shooting ranges. Shells and bullets also contain other contaminants such as antimony, arsenic, copper, zinc and nickel. At shooting ranges for shotguns, PAH compounds contained in clay pigeons also may contaminate the soil.

**Golf courses**
The fertilizers and pesticides used at golf courses for growing grass and the management of greeneries may end up being flushed into the groundwater. Other golf course operations, such as roads, parking places, storage of hazardous substances and the treatment and discharge of wastewater may also affect groundwater quality.

**Mining**
Mines have an environmental impacts both during their induction and during their operations. In discontinued mines with no land restoration or aftercare, the environmental impact may continue for decades after operations have ceased. The greatest environmental hazards are connected with quarrying of sulphide ores and the storage of tailings and country rock. Microbial oxidation of sulphide minerals and acid mine drainage may result in leaching of water with high sulphate and metal concentrations into the groundwater. As a consequence, pH in groundwater may drop to exceptionally low levels.

During mine operation, groundwater quality can also be affected by the storage of waste oils and chemicals, explosive residues and the maintenance and repair of the machinery used in the quarrying processes.

### 3.4 Groundwater investigations and assessment of groundwater contamination

The party causing groundwater contamination is responsible for determining the extent of the contamination and for the remediation of the contaminated soil and groundwater. The contaminated area is investigated to delineate the contamination, the groundwater flow regime and any factors that might cause limitations during remediation work. The main stages of a Phase II groundwater contamination investigation are as follows:
1. compilation and assessment of previous geological mapping information, groundwater investigations and groundwater quality data,
2. determination of the thickness of loose deposits, stratigraphy of geologic units and strata with high hydraulic conductivity with borehole drillings, soil sampling and geophysical surveys,
3. determination of bedrock fractures,
4. installation of groundwater monitoring wells,
5. collecting groundwater samples, measurement of groundwater levels and water quality measurements.

Delineation investigations are often expensive and time-consuming. The investigation requires collaboration of experts from a number of fields. If there are contaminants in the groundwater that are not included in the routine monitoring programmes of the waterworks, it may take years before the contamination is even detected. Different contaminants behave differently in the soil and groundwater. Most of the contaminants migrate in dissolved phase along groundwater flow, whereas a range of contaminants may be present as a free-phase liquid on the top of impermeable strata, from which they will later slowly dissolve into the groundwater (e.g. chlorinated solvents). A range of oil compounds form a low-density plume on the top of the saturated zone. Pathogenic micro-organisms may be transported further in the aquifer attached to fine-grained suspended solids, such as small clay particles.

3.5 Preventing contamination and measures in cases of contamination

Groundwater contamination can be prevented with appropriate land-use planning, thorough protection measures (see Groundwater protection plans, page 6) and groundwater quality monitoring. It is essential to provide local residents with information on activities threatening groundwater, and protection measures aimed at eliminating risks.

All groundwater intake units must have a contingency plan. The following information is essential when preventing groundwater contamination (the body providing the information is mentioned in brackets):

- hydrogeological maps of the groundwater area (municipal environmental authorities and regional environment centres);
- information on the factories, production plants and other activities in the groundwater recharge area that may pose a contamination risk (municipal environmental authorities and regional environment centres);
- use of de-icing chemicals on local roads (Finnish Road Administration);
- oil tanks and their conditions (rescue departments);
• existing groundwater investigation reports and protection plans that are available (regional environment centres, planners).

Water intake units must also measure the groundwater level on a regular basis, at a minimum once a month, from abstraction wells and groundwater monitoring wells potentially installed in the area. The dominant groundwater flow direction can be estimated by measuring elevation of groundwater table at three monitoring wells, at the minimum. In extensive aquifers with complex groundwater flow regime, measurements in 6 - 9 monitoring wells are required.

Groundwater contamination may be detected in a range of ways: an accident or some kind of damage, anomalous finding in routine groundwater monitoring, a finding of groundwater investigation in a potential area of environmental concern, suspicious epidemic in a region of water users, or an unusual odour or taste in the water. Any groundwater contamination detected must be immediately reported to the municipal health authorities.

If faecal pathogenic bacteria are detected in well water, immediate measures must be taken to detect the source of contamination, to delineate the groundwater contamination and to prevent any health hazards. The measures required are described in more detail in section 8: “Special situations at small waterworks”.

Table 2: Results of a questionnaire submitted to small waterworks abstracting groundwater. The table shows the number of waterworks (245 in all) in which the distance to the risk factors listed in the Table is less than 50 or 100 metres.

<table>
<thead>
<tr>
<th>Risks</th>
<th>Max distance 50 m</th>
<th>50-100m</th>
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</thead>
<tbody>
<tr>
<td>Septic tank</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>Private well</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Soil filter</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Wastewater treatment plant</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Wastewater pumping plant</td>
<td>2</td>
<td>7</td>
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<tr>
<td>Sewer pipe</td>
<td>7</td>
<td>10</td>
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<tr>
<td>Landfill</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Livestock farm</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Cultivated field</td>
<td>46</td>
<td>30</td>
</tr>
<tr>
<td>Salted road</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>River/lake</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Oil tank</td>
<td>4</td>
<td>14</td>
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<tr>
<td>Ditch</td>
<td>54</td>
<td>23</td>
</tr>
<tr>
<td>Sand and gravel excavation area</td>
<td>33</td>
<td>11</td>
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</tbody>
</table>

More information on the size and characteristics of the groundwater aquifer area used by the waterworks is available at the regional environment centre.
• The risk activities within the groundwater area should be mapped out, and the monitoring of water quality should be planned in accordance with these risks.
• There may be several risk factors in the area, which means that all potential activities of environmental concern in the groundwater area must be secure and well-managed.
• There are three important methods for securing groundwater quality: reducing risks, preventive protection measures in the groundwater area, and regular monitoring of groundwater quality.
• Hygienic water quality must be monitored with indicator bacteria.
• A single pathogenic microbe in the water may be enough to cause an illness.
4 Waterworks technology

4.1 Water intake

Water intake may employ dug wells, perforated-casing wells or drilled wells.

In a **dug well**, the water enters the well from the bottom, which is filled with filtering sand. The purpose of the sand is to keep small organic particles from infiltrating the well. The area at the bottom of the well from which the water is taken is proportioned to the amount of water required. Dug wells are either built from concrete well rings or cast *in situ*. Dug wells are normally between 5 and 20 metres deep and are best located on sandy or gravel-rich soil.

**Drilled wells** are drilled deep into the bedrock. They are used in areas in which water supplies would otherwise be scarce (such as the archipelago). A drilled well is normally between 20 and 150 metres deep. Unfortunately, the quality and supply of water cannot be guaranteed before drilling. Water in drilled wells often contains larger quantities of dissolved substances (such as fluorides, sodium, chlorine and radon) than water from a dug well.

For water supply on a larger scale, **wells equipped with a perforated casing** are used, where part of the well tube is a screen. The well is normally 5 to 50 meters deep.

There are also **spring wells** in Finland, which utilize a natural spring. There are a variety of spring well types in use in Finland, but establishment of a new spring well is now prohibited.

**A well must be kept in good condition.** The seams between the concrete mantles must be sound and
secure, so that the water only enters the well from the bottom. There should be no such risk factors in the vicinity of the water intake unit that could potentially contaminate the water. If there are any such activities near the water intake unit, they must be monitored and water must be analysed regularly for contaminants. (For more information, see Section 7 – Routine operational monitoring and Section 3 – Groundwater quality.)

The lid of the well must fit tightly and prevent litter, animals and surface water from entering. The well lid must have a sealed service hatch or be otherwise constructed in such a way that water samples can be taken. The well must also include a screened ventilation tube and the screen must prevent litter and small animals from entering the well. The well should be located in a place where no surface runoff water can enter the well. It is also important that the well be properly heat-insulated and that its construction allows for inside maintenance. Appendix 7 contains a checklist for risk assessment of small waterworks. The checklist should be gone through once a year.

If a well is in poor condition, it must be renovated or a new well must be built. Joining a larger water utility could be the easiest option. Renovation is a reasonable option if the well is located away from any risk factors, the mantles are in good shape, if it is not possible for surface water to enter the well and water is of good quality. There are a number of companies specializing in well renovation in Finland, and further information is available at regional environment centres.
• Well structures must be sealed and secure
• The well must be regularly maintained
• The condition of the well must be regularly monitored

4.2

Materials suitable for the distribution of drinking water

The materials used in facilities treating and distributing drinking water must be selected with particular care. The products used must be classified as suitable for the distribution of drinking water, and the suitability must be ensured when the materials are acquired. No substances or materials used in drinking water treatment and distribution may cause hazardous amounts of impurities to enter the water.

Careful consideration must be given to the type and suitability of materials used in distribution networks. Solvents, for example, are able to permeate certain types of plastic if the water mains happen to be located in an area with contaminated soil. Some coating materials such as bitumen may also result in unusual smells and tastes. Untreated groundwater is also inherently corrosive to metal pipes, making it possible for metals such as copper and zinc to dissolve from the pipes into the water. Concrete pipes and concrete coatings can also affect water quality by raising the pH level.

It must also be ensured that all dry-installed metal parts are properly protected at the water intake. Metal parts rust easily if the air at the intake unit is warm and humid. Equipment and materials last longer if they are properly selected and protected. There must be proper ventilation at the intake unit, and temperature fluctuations should be minimized.

Many of the materials used for analysis and maintenance of the water supply should be disinfected before use. If the pump is lifted from the well for inspection, for example, the parts that will be exposed to water should be disinfected before the pump is reinstalled (see page 21).

Materials used for the distribution of the drinking water supply must meet the requirements laid down in the SFS-EN standards. Substances may not contain hazardous compounds, and the chemical supplier should always be consulted about the acceptability of any chemicals used. For example, the lime used in water alkalisation must be lime that is intended for treating drinking water. For more information about chemicals used in drinking water treatment, see Appendix 3.

Material used for drinking water fittings include:
• the metals copper, brass, cast iron and steel,
• organic materials such as plastic and rubber, and organic coating materials, and
• cement-based materials like concrete, mortar and asbestos cement (no longer used for new construction).
The European Union is preparing a harmonized product approval procedure for construction products that come into contact with drinking water. The procedure, known as the European Acceptance Scheme (EAS), is expected to become effective in 2010. To ensure that materials and products used in water distribution cannot harm the quality of the drinking water, the same standards will apply to all EU countries for the examination of product safety and suitability.

- Materials used for the distribution of drinking water must be classified as suitable for this purpose.
- Whenever a waterworks purchases new products and materials that will be in contact with the water, they must first ensure that these are suitable for use with drinking water.

4.3 Water treatment

If a waterworks finds that the quality of its influent groundwater is not in accordance with the limits laid down in the water supply decrees 461/2000 and 401/2001, there are four options: the waterworks can either join a larger waterworks, construct a new well, treat the water or step up its current water treatment. Water treatment is required if the water is found to contain harmful substances that are not listed in the decrees but may be harmful to water users.

In difficult cases, small waterworks may have to resort to treating water with chemical precipitation and consequent filtering. The more complicated the treatment required, the more important it is to consult experts in the treatment planning. It is also necessary that those in charge of the waterworks possess the necessary skills.
Table 3: Methods suitable for addressing water quality issues at small groundwater works

<table>
<thead>
<tr>
<th>Treatment method</th>
<th>sand</th>
<th>slow sand</th>
<th>VYR</th>
<th>catalytic media</th>
<th>granulated iron oxide</th>
<th>activated carbon</th>
<th>nanofiltration</th>
<th>reverse osmosis</th>
<th>anionic resins</th>
<th>cationic resins</th>
<th>mixed resins</th>
<th>aeration</th>
<th>oxygen (air)</th>
<th>potassium permanganate</th>
<th>chlorination</th>
<th>UV radiation</th>
<th>alkali- sation</th>
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<td>Substances or organisms</td>
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<td>** commonly used for removing the compound or improving water quality</td>
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<td>Microbes</td>
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<td>* suitable for removing the compound or for improving water quality, but should not be used as the primary method</td>
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<td>Iron</td>
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<td>Hydrogen sulphide</td>
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<td>Pesticides</td>
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<td>Uranium</td>
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</tbody>
</table>
4.3.1 Disinfection

The purpose of disinfection is to eliminate any pathogens occurring in the water. Small waterworks use chlorination and/or UV radiation for disinfection. Chlorination is carried out as a final stage in the process just before the water is fed into the mains.

4.3.1.1 Chlorination

Chlorination is a process in which a chlorine chemical is added to the water. Small waterworks commonly use sodium hypochlorite for this purpose. The chlorination of tanks and pipes (known as shock chlorination) may be carried out by using a calcium hypochlorite powder specifically suited for use in water distribution systems.

Chlorine is added to the water using a simple membrane or piston pump, in some cases directly from the sodium hypochlorite transport tank. Polypropylene (PP) or Teflon (PTFE) are both suitable pump materials. An example of chlorination with sodium hypochlorite is shown in Figure 7.

Figure 7. An example of a hypochlorite chlorination process.
If there is only a small need for sodium hypochlorite, it is recommended that it be diluted to a one per cent solution, for example, before adding it to the water, so that the dosage is as accurate as possible. Chlorine is added before the water enters the pressure tank or storage basin so that the tank and the basin are also protected and the chlorine effectiveness can be extended before the water is fed into the mains.

**Chlorination maintenance**

Hypochlorite chlorination causes precipitates in both the pipes and the pumps which must be removed with regular flushing of the network and cleaning of the pump head. Particular attention should also be paid to the valves and their operability. The foot valve and screen on the hypochlorite tank must also be checked and cleaned regularly.

The hypochlorite tank should be placed in a protective basin in case of leaks. Any hypochlorite solution that has leaked into the protective basin may not be discharged into sewers or thrown out, but instead should be pumped back into the chlorine feeding system or dechlorinated (i.e. decomposed). Sodium bisulphite or sodium metabisulphite can be used for dechlorination; both compounds can be added with a membrane pump and the dechlorination process is quick. Sodium tiosulphite may also be used, but it reacts fairly slowly with chlorine. Wastewater treatment plants can allocate permission to discharge small amounts of chlorine into sewers.

Before chlorination can begin, a laboratory must determine the required chlorine dosage. If the waterworks has the necessary equipment, this can also be done on site. The chlorine dosage should be checked at least three times a week with free chlorine residue measurements.

The chlorine dosage may not exceed 5 mg/l. Any excess will cause an unpleasant odour and taste, and may cause irritant reactions among the water users. After chlorination, the residue chlorine content at the remote branches of the network must be at least 0.05 mg/l for the disinfection properties of the chlorine to be sufficient. The bound residual chlorine content in the water leaving the waterworks is normally set at 0.5-0.7 mg/l. A 30 minute retention time before the first consumption point allows the chlorine to produce the required reaction in the water and thus the desired disinfection process. Chlorination is only effective if the pH level of the water is 6.5-7.5. Section 4.3.2 Alkalisation, covers adjusting the pH level in more detail. It should be remembered, however, that chlorination does not remove all the pathogens from the water; for example, it is not effective against some viruses or protozoa.

Sodium hypochlorite must be stored in a cool, sheltered place not exposed to sunlight in order to remain usable for long periods. Sodium hypochlorite crystallizes at a temperature of –30°C, and diluted solutions crystallize at higher subzero temperatures. Protective structures must be used to prevent chemicals from leaking into the soil and groundwater.
Chlorine chemicals must be used with the utmost care. Chlorine causes irritation and damage to eyes and mucous membranes and pain, redness and blisters on the skin. The chemical safety data sheets must be read carefully and observed. Sodium hypochlorite spray causes irritation in the nose and the throat, and a solution of more than five per cent may cause corrosive damage to skin.

Water customers are not always in favour of chlorination, because it can cause an unpleasant smell and taste. Chlorine is still commonly used, however, and chlorination is the only disinfection method that can ensure sufficient disinfection throughout the water distribution system.

**Shock chlorination**

Water distribution networks and water tanks or wells may occasionally have to be subjected to cleaning chlorination, or what is known as shock chlorination. This may become necessary for instance when indicator bacteria are detected in the water. In such a situation, the equipment must first be flushed carefully. Soft cleaning elements may have to be used in large-diameter pipes, and sometimes it may also be necessary to carry out a preliminary wash of the well or the water tank. Washing equipment suitable for this purpose can be rented. After flushing, the facility must be filled with water from the water distribution network and a dose of chlorine chemical, whether calcium hypochlorite tablets/grains or liquid sodium hypochlorite, is added so that the chlorine content in the water is 10 - 50 mg/l. The chlorine solution is left to disinfect the water for 1-3 days, after which the water should contain at least 5 - 25 mg of free chlorine. The chlorine is removed by flushing, and then samples are taken to ascertain whether the disinfection was effective. The sample must be examined at a certified water laboratory, which determines on the basis of analysis whether the disinfection was a success. Any repeat disinfection required must be carried out in accordance with special instructions from the laboratory.

Different types of equipment may also be disinfected as required. A pump that has undergone maintenance may be disinfected before being put back into place by immersing it for one half hour in water with a chlorine content of 10 mg/litre.

4.3.1.2

**UV disinfection**

UV disinfection occurs when water is exposed to ultraviolet light radiation. In the UV equipment, water flows through a pipe-shaped chamber with one of more horizontally placed UV lamps (Figures 8 and 9).

In the right conditions and when done properly, UV disinfection is very effective, but it does not prevent the water from becoming contaminated later as it moves through the network. To ensure the quality of the water throughout the network, it is best to add a small amount of chlorine or chloramine.
Table 4: Factors influencing UV treatment effectiveness.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation source intensity and wavelength</td>
<td>The best wavelength is 240 – 280 nm, the smallest radiation intensity required is 400 J/m².</td>
</tr>
<tr>
<td>Depth of the water layers</td>
<td>The thicker the water layer, the poorer the result.</td>
</tr>
<tr>
<td>Colour and turbidity of the water</td>
<td>Any colour or turbidity in the water makes the UV treatment markedly less effective. Iron and calcium create deposits on the surface of the protective pipe.</td>
</tr>
<tr>
<td>Mixing conditions</td>
<td>Weak mixing, caused for instance by a weak water flow, leads to poorer effectiveness.</td>
</tr>
<tr>
<td>Time lapse</td>
<td>Normally a sufficient reaction time is a matter of a few seconds, at the most one minute.</td>
</tr>
<tr>
<td>UV lamp operating life</td>
<td>The effectiveness of a UV lamp weakens as it ages. A general rule of thumb is that after a year of continuous use, the radiation effectiveness is only 50% of its original capacity.</td>
</tr>
</tbody>
</table>

Figure 8. Diagram of UV radiation equipment
Maintenance of UV equipment
The UV equipment is easy to maintain, but it does require a few maintenance measures:

- The runtime counter must be read once a week.
- The radiation intensity meter must be read once a week. If the equipment is not attached to an automatic alarm system, it must be read every day.
- When the UV-intensity decreases and becomes less effective, the protective pipe must be cleaned. In some models, this function is automatic, but in simpler models, it must be done manually. If the water contains contaminants, the entire radiation unit must be cleaned. The radiation chamber is usually cleaned four times a year. The built-in cleaning systems should be cleaned every six months. If it becomes necessary to use chemical cleaners, the equipment must be rinsed out thoroughly before being attached to the network again.
- The lamp must be changed after a certain number of hours of use, according to the manufacturer’s instructions, or when the effectiveness has decreased to 50% of full capacity.
- The radiation meter must be checked annually.

![Figure 9: The UV lamp can be mounted in the radiation chamber in several different ways.](image)

The following replacement parts should be available at the waterworks at all times:

- UV lamp
- Protective pipe and sealing
- Relay for the UV lamp
- Warning lamp/bulb
- Spare parts for the measurement and warning alarm systems

**Waterworks employing UV disinfection equipment should check the UV equipment daily, or at least once a week.**

During UV maintenance, it is important to avoid looking directly at the UV lamp when it is on. The effect of UV radiation can only be seen and felt after a few hours have passed. Symptoms include a feeling as if there were ‘sand in the eyes’ and, in the worst cases, temporary or permanent blindness.
• Each of the waterworks should be prepared to carry out disinfection.
• It is recommended that water be disinfected in all waterworks. UV disinfection and chlorination with sodium hypochlorite are both appropriate methods for small waterworks.
• Sodium hypochlorite is distributed with a simple pump straight into the water. The chlorine levels and effectiveness of the equipment must be checked on a regular basis, however.
• UV disinfection is a very straightforward, trouble-free method for disinfection. For optimal operation, however, the water must be completely clear and the equipment must be maintained regularly.

4.3.2
Alkalisation

The purpose of alkalisation is to lower the acidity of water, i.e. increase its pH level. In most cases, this also raises the water’s buffer capacity (the ability of water to keep the pH stable). Alkalisation binds excess free corrosive carbon dioxide in the water.

Alkalisation adjusts the water’s pH so that it will not be corrosive for example in the pipes. Depending on the hardness of the water, the pH level is normally set between 7.5 and 8.5. If the water is harder, the pH is set as close as possible to 7.5 to avoid calcium scaling in the hot water systems.

The following chemicals are used for alkalisation:
• Lye or sodium hydroxide (NaOH)
• Soda ash or sodium carbonate (Na₂CO₃) and
• Hydrated lime or calcium hydroxide (Ca(OH)₂).

Alkalising media used:
• Limestone containing calcium carbonate (CaCO₃) and
• Dolomite containing calcium and magnesium carbonate (CaMg(CO₃)₂).

(Information about chemical properties can be found in Appendix 3)

Lye and soda ash are added to the water as a solution using a membrane pump. The lime can be added either as lime milk, in which the lime particles have not dissolved, or as lime water, a saturated lime solution. Small waterworks use lime rarely, as it is difficult to handle. Dosage is controlled either by the flow rate or by using a pH meter that continuously measures the pH level. Flow rate adjustment may be based on pump operation or flow rate measurement.

Alkalising media is a simple method for controlling alkalinity. In open filters, the water is pumped over the surface of the media. In closed pressure filters, the flow direction can be down flow or up flow. The alkalising media is depleted as the carbon dioxide is neutralized, and more should be added to the filter on a regular basis. Suspended matter and iron in the water can also clog the filter, because iron precipitates on the surface of the filter and thus inhibits its use. Should the water contain any iron, it should be removed before alkalisation.
When using alkalising media, a preliminary rinsing of the media is recommended. During transport, the media tend to crumble, and therefore it should be rinsed off before being taken into use.

If the water is soft, alkalisation should favour calcium-rich materials that make the water harder. Hardness and raised pH levels can lead to detrimental deposits in hot water systems, however.

**Determining the correct dosage so as to avoid both unwanted corrosion and lime deposits in hot water systems is very demanding, and it is recommended that such matters be left to professionals. An overdose of lime or soda is hazardous to human health.**

- Alkalisation lowers the acidity of water, i.e. increases its pH level. It is the most common water treatment method at small waterworks.
- Alkalisation is the process of adding an alkalising chemical to the water or conducting the water through an alkalising filter.
- Because the groundwater in Finland is usually acidic, alkalisation is recommended at all waterworks.
- The appropriate alkalisation chemical depends on the quality of the water.
- Each waterworks should have a pH meter, and it should be calibrated regularly.

### 4.3.3 Aeration

Aeration adds air to water. Its purpose is either to oxidize a certain compound with the oxygen contained in the air or to remove saturated gases such as carbon dioxide, radon and hydrogen sulphide from the water. Certain other volatile compounds that create smells and tastes can also be removed with aeration.

Aeration can be carried out by either breaking up the water into droplets, by leading the water through airflow, or by dispersing fine bubbles through the water. Other methods are based on the trickling down of water, in which shallow water is led over layers made of different materials in either an enclosed tower or open pools. The simplest models of this kind are angled pools filled with gravel, others includes ‘cascade aerators’ which can be either step-like or towers (Figures 10a and 10b). Other kinds of water-feed systems and ejectors also cause aeration.

The most important parameter for an aerator is the air-to-water ratio, i.e. how much air is needed for the amount of water to be treated. This is then dependent on where the aeration will occur and what type of aeration equipment is being used. Information on the settings are available from the equipment manufacturers.
All aerators become clogged over time. A bacterial growth (biofilm) accrues on the surface that can add disturbing tastes and cloud the water when it peels off. Iron and magnesium deposits can also accumulate in the aerator and the nozzles, and fillers and other parts can become clogged, decreasing the aeration efficiency. The nozzles, cascades and other parts must be washed regularly and disinfected if necessary with chlorine or hydrogen peroxide. Washing intervals are dependent on the water quality, varying from once a month to once a year.

- **Aeration brings the water into contact with air so that the oxidable components can either be oxidized further and coagulate or take on a less harmful form, and so that dissolved gases in the water can be removed.**

### 4.3.4 Sand filtration

Sand filtration is used in groundwater works together with aeration to remove iron and manganese from the water. Sand filtration is used in almost all waterworks treating surface water to remove leftover impurities from the chemical deposits that passed through sedimentation. Small waterworks tend to use combined sand and limestone filters, among others.

The simplest filter is a sand filter composed of just one layer, a container filled with sand through which water trickles down. The sand is 0.5-2 metres thick, and the grain size of the sand is 0.5-1.5 mm. At the bottom of the filter is a supporting nozzle plate containing the nozzles through which the water flows. In between the filter sand and the base there can be a layer of coarse sand or gravel which evens out the water flow and prohibits the fine sand from clogging the drains.
Other forms of filters in use include the multi-layer sand filter and the up flow filter. The filter can be either open, in which case the flow is enabled by gravity, or an enclosed pressurized filter, in which the water flow is directed by a pump. Outline diagrams are presented in Figures 11 and 12.

The deposits caught by the filter are removed regularly by backwashing. Use of the filter is affected by the rate at which the filtration takes place, the pressure loss, the intervals between washing, the washing method, and the wash water velocity. The effectiveness of the filter can be observed with pressure loss measurements, a continuous meter measuring turbidity and a laboratory test for suspended solids.

Filter operation is often automated so that the backwash is activated once the pressure loss reaches a certain level. In smaller waterworks, the washing interval can be linked to the amount of water that is treated or to a fixed period of time. In larger treatment plants the turbidity measurement can also trigger a wash cycle, along with pressure loss.

When a clean sand filter is started, suspended matter tends to pass through the system at first. After some time in use, however, it will run at optimal efficiency. Over time, the filter will accumulate suspended matter, and the filter resistance will grow, i.e. the filtration rate will decrease. At some point, the filter will become saturated, and the suspended solids will no longer be captured. Normally, the filter resistance will have increased by this time so that the backwashing will have begun (or needs to be carried out). In a pressurized filter, the backwash is activated when pressure loss reaches 15-25 kPa. In an open filter, pressure loss becomes apparent when the filtration rate tapers off. In enclosed filters, an increase in pressure and a slower filtration rate is observed. The filtration rate in a one-layer filter is normally 5-10 m/h, and in a multi-layer filter it is 10-20 m/h (Figures 11 and 12). Even if no pressure loss were apparent, the filter must be washed regularly, according the manufacturer instructions.

The filtration rate [m/h] is calculated by dividing the flow rate [m$^3$/h] by the cross-section surface area of the filter [m$^2$].

The backwash takes place from the bottom up with either just water or with a combination of water and air (only applicable to one-level filters), according to certain procedures. The objective is to mix the filter bed in such a way that the scouring forces created will loosen the suspended matter attached to the filter and wash it away. During the wash, the filter bed grows by 30-50 per cent. The wash water velocity should be adjusted so as to not dislodge any filter material in the washing process. Multi-level filters require particular care, as one must avoid mixing the different layers together. After the wash, it is recommended that the water be discharged to the sewer for a short period, to ensure the quality of the effluent filtered water.
In a multi-layer sand filter, the materials are chosen so that the upper layers consists of a material that is coarse but light (anthracite), while the lower levels are composed of material that is fine and heavy. They are graded in order, according to level, after the wash is complete. Because the wash is done with clean water, the waterworks should have a clean water tank reserved for this purpose. In cases where the washing of a one-layer filter is followed by an air wash, the amount of wash water can be significantly reduced. In exceptional cases, e.g. if the waterworks does not have a reserve clean water tank of its own, the wash can be done with influent water instead.

Filters with continuous washing mechanisms can also be found on the market, e.g. Dynasand®. With this method, the sand bed moves down against the water flow, and a small amount of sand is continuously extracted with an airlift pipe to a separate washing cycle, after which it is returned to the filter. Advantages of the filter include its compact structure, continuous operation and the fact that it has no moving parts. The effectiveness of the filter can be adjusted according to the amount of water to be filtered and the required airlift pipe capacity.

- Groundwater works use sand and air filtration to remove iron and manganese from groundwater.
- There are several kinds of sand filter, most of which are maintained with regular backwashing.
4.3.5

Slow sand filtration

Slow sand filtration is similar to ordinary sand filtration, but the process is mainly biological. The filtration rate of slow sand filtration is normally a maximum of 0.15 m/h. **Slow sand filtration removes numerous water impurities, including compounds that create smells and tastes, as well as ammonia, iron and manganese. To some extent, the filter can also remove organic matter, such as that found in groundwater produced with bank filtration.**

The fill material for the filter is sand, and the filter bed is approximately one metre thick. **Over time, a biologically active growth (biofilm) forms on the surface of the filter, and this is where most of the water purification takes place.** As a rule, the filter is not washed; rather, the surface of the filter is scraped clean. When the filter bed has been reduced by 30 per cent, new filter sand is added onto the filter.

The filter must be left to ‘re-ripen’ after the surface of the filter has been cleaned. It may take anywhere from a few days to a several weeks for a film of biological growth to reform on the filter surface, and it may take several months before a biofilm that is strong enough to oxidize manganese can form. For this reason, it is recommended that waterworks have at least two filters in operation at all times to ensure that the effluent water supply is constant. Any breaks in the filter use dry out the biofilm. The cleaning interval for the filters is dependent on the water properties and the amount of water to be treated. Normally, the surface is cleaned every 6 to 12 months.

It is recommended that filters be roofed over. A roof prevents algae growth and bird and animal contamination and makes winter maintenance easier. It is in any case necessary to disinfect the water after slow sand filtration.

- In large, roofed slow sand filtration tanks, biological growth that has formed on the surface of the sand removes organic compounds, smells and tastes from the water.
- The surface of the filter is scraped regularly, and more sand is added when needed.
- Slow sand filtration is always followed by disinfection.
4.3.6

Biofiltration (dry filtration) and VYR

Biofiltration or dry filtration removes iron and manganese and some of the organic material from groundwater. A biofilm made of primarily iron and manganese forms on the surface of the fill material of the filter. The filter is of the same structure as the rapid sand filter, but air is also introduced to the process. The iron bacteria oxidize the reduced iron and manganese, which then precipitate. The filter must be washed regularly.

In the VYR Method, the biological reaction occurs underground in the soil. The water to be treated is pumped up from the ground, aerated and sucked back down into the ground through pressurised wells. Oxidation and precipitation of the iron and manganese occurs underground in the soil, after which the treated water is pumped back up from a collecting well to be treated further.

4.3.7

Activated carbon filtration

An activated carbon filter removes compounds creating smell and taste and other matter, e.g. pesticides, from the water. In special cases, activated carbon can also remove radon from the water.

Activated carbon is used in water treatment in either a powder or granular form. powdered activated carbon tends to be used in waterworks treating surface water to prevent unpleasant tastes and smells that appear from time to time. The powder is added to the water to be treated and prohibited from entering the network by a filter. In exceptional cases, the method could be used in groundwater works in situations where a significant amount of pesticides are suddenly found in the water.

The following discussion only applies to activated carbon filtration using granular activated carbon. Filtration with granular activated carbon takes place in an open filtration tank or in a pressurized closed tank, utilizing added pressure or relying on gravity for the filtering process.

Pre-treatment preparations and method application

The activated carbon filter unit should be placed after the iron, manganese and uranium removal in the water treatment process, but before disinfection. Iron and manganese removal before the activated carbon filtering can double the useful life of the carbon.

The ability of the activated carbon filter to remove harmful substances from the water is largely dependent on the quality of the carbon. Carbon should always be chosen on a case-by-case basis according to the quality of the raw water. The carbon supplier should supply test results about the applicability of the carbon to the raw water of the waterworks and its ability to remove the harmful materials that are present in the water. In association with the purchasing agreement, the carbon supplier must
also provide an operation guarantee for the filter. **If the activated carbon is also to be used for removal of radon, the filter must be shielded to avoid emitting radiation. In this case, it is recommended that the filter be situated in a separate building.**

The normal retention time for filter operation is 5-20 min. Material removal improves as the retention time is increased. It is not always necessary to dimension the filter according to the total water flow. If the concentration of harmful material is small enough, it is enough to filter only part of the water and then mix it with the remaining unfiltered water afterwards.

**Use and maintenance of the filter**

Normally, the activated carbon filter must be rinsed occasionally to remove any suspended matter, to ensure that the filter hydraulics stay operational and to control the possible growth of microbes. The need to rinse the filter usually becomes apparent when the pressure rises as the pores of the filter become clogged. The filter cannot be rinsed too often, however, as it could weaken the capacity of the carbon. On the other hand, a filter that has not been rinsed can give rise to microbe growth, which can cause suspended matter to enter the water. The need for rinsing is also determined by the quality of the raw water, the quality of the carbon, and the pre-treatment of the water. The rinse frequency should be discussed with the carbon supplier. At some waterworks, there is no need to rinse the filter at all.

The effectiveness of the filter should be assessed regularly to avoid exceeding the carbon capacity. When the capacity of the carbon is exceeded, the compounds that have been trapped in the carbon pores can become dislodged from the carbon and dissolve in the effluent water, causing the concentrations in the water to become higher than the concentrations in the raw influent water. It is recommended that, upon implementation, measurements for harmful substances are carried out monthly until the carbon capacity has been confirmed, i.e. the filter rinsing frequency has been established. As the service life of the carbon ends, it may be necessary to make the harmful substance measurements more frequent again. If a carbon of a different quality is adopted, the capacity of the new quality must be investigated. An exceptional water quality can also affect the filter, e.g. a sudden change in the pH level of the water can cause harmful substances to detach from the filter.

The useful service life of the filter can be extended by raising the filter volume and lowering the flow rate. In those Finnish waterworks that use carbon to remove pesticides, the carbon is usually changed approximately once a year. Used carbon can be reactivated by removing the harmful substances from the carbon pores with incineration. At least one carbon reactivation plant (Silcarbon Finland Oy) is operative in Finland. Larger water treatment plants send their carbon abroad to be reactivated. If the carbon is not sent to be reactivated, new carbon is procured for the filter and the old carbon is delivered to a landfill. Although the activated carbon filter collects harmful substances, used carbon is not classified as hazardous waste. At any rate, the disposal of used activated carbon must be considered on a case-by-case basis. **If the activated carbon has been used to remove radon, the used filter must be stored**...
for three weeks before it can be brought to a landfill, to allow time for the residual radiation to decay.

- Activated carbon filtering should always be followed by disinfection. The activated carbon filter can itself be disinfected by heating it with water vapour, for instance. Activated carbon filters remove compounds that create smells and tastes from the water, along with e.g. pesticides and radon.
- The activated carbon must be changed regularly and rinsed from time to time.
- Activated carbon filtration should always be followed by disinfection.

4.3.8

Catalytic filtration

Catalytic filters are filters for specifically removing iron and manganese, where the filter content is a media made up of certain characteristics. Catalytic filters are also useful for removing hydrogen sulphide.

While most forms of iron removal use aeration and sand filtration, the catalytic filter does not require separate aeration. In the catalytic filter, the oxidation, coagulation and filtration of the iron (and manganese) all takes place on the surface of the catalytic media, in one unit. The media can be activated with either a continual chemical feed (e.g. greensand with potassium permanganate) or with periodic feeds. For some media, activation is triggered if the influx water contains a certain amount of oxygen. The oxidation of iron and manganese takes place 10-100 times faster for catalytic media than with aeration. The oxidation of manganese in particular is effective, as the pH level is a more favourable 7.8-8.3 with catalytic media, as opposed to 9-11 pH for sand filtration. Catalytic filters can be run 2-4 times faster, up to 20 m/h, than sand filters.

Technically, catalytic filters function in the same way as sand and multi-layer filters. The manufacturer constructs the filter to meet customer needs.

- Catalytic media is a simple method specialized in removing iron and manganese.
4.3.9

Membrane filtration

Membrane filtration is a water treatment method where water is forced through a thin membrane. Depending on the porosity of the membrane, membrane filtration can be divided into four categories: micro filtration (MF), ultra filtration (UF), nanofiltration (NF) and reverse osmosis (RO). Each filter type can remove particles of different sizes, down to molecules and ions.

Nanofiltration and reverse osmosis are most suitable to small waterworks, where they are used to remove chlorine and fluoride (as well as arsenic) from the water. They can also be used to remove pesticides. The differences between nanofiltration and reverse osmosis are as follows:

- Reverse osmosis requires a higher pressure, 2,000-8,800 kPa, while nanofiltration requires only 500-2,000 kPa.
- Reverse osmosis removes smaller molecules than nanofiltration, which is particularly apparent in the removal of chlorides and sodium.

Membrane filtration units for treating drinking water are normally plate & frame spiral membrane modules. Some tubular, hollow fibre modules are also in use. Only a part of the water fed into the membrane passes through the membrane. Treated water that has passed through the membrane is called permeate, and the water that has not passed through the membrane is called concentrate or reject. The yield, i.e. the ratio of the treated water to the total water fed into the filter, is 65%-75% for reverse osmosis and nanofiltration, and 95% for ultra filtration and micro filtration.

![Figure 13. The principle of membrane filtration.](image-url)
Pre-treatment and raw water quality requirements
For purposes of groundwater treatment, nanofiltration does not necessarily require pre-treatment of the water. The influent water is usually pre-treated, however, to cut down on the frequency of membrane clogging, fouling and degradation. At its most simple, the pre-treatment can simply be filtration with either micron-sized cartridge filters or large-pored membranes (microfiltration). Dependent on the quality of the raw water, some pH adjustment or iron and manganese removal may also be necessary. Iron and manganese can be removed with membrane filtration if they are in their reduced, dissolved state.

Use and maintenance of the filters
Filters must be mechanically or chemically cleaned from time to time. Units are always equipped with either integrated or attachable cleaning equipment. In mechanical cleaning, the membrane is rinsed with a large amount of water at a low pressure. If the mechanical wash does not remove the clogs, the membrane must be washed again with a chemical cleaning solution during the mechanical wash. Cleaning intervals vary anywhere from one month to a year, dependent on the quality of the raw water and pre-treatment practices. Usually membranes are cleaned when the membrane output has declined by 10%-15%, or if there is a corresponding increase in pressure.

Membranes are normally replaced every 3-5 years due to clogging, but at their best they can last 10 years. The intervals between membrane replacements depend on the quality of the water that is treated and the pre-treatment practices. An automated electro conductivity measurement monitors the ion density of the water. An abnormal rise in electro conductivity indicates filter malfunction, e.g. a filter break.

The water that does not pass through the membrane (concentrate) creates a problem for the membrane filtration unit. The percentage of concentrate in the pumped raw water is about 5% for micro filtration and ultra filtration and 24%-35% for reverse osmosis and nanofiltration. It contains the matter removed from the treated water in inflated concentrations. There is no clear protocol for disposing of the concentrate. The effects of the matter concentration must be assessed before the concentrate can be treated or flushed into the sewer or water systems. Authorities make the final decision about the acceptability of the proposed option. The pH of the cleaning water can be anything from 1 to 13, and it can contain large concentrations of organic matter. For this reason, the cleaning water must either be neutralized or led to the sewer.

Post-treatment
In practice, membrane filtration removes all particles larger than the pores of the membrane. Exceptions include gases, such as carbon dioxide. Because the treatment effectively removes the salts that cause water hardness (99% removal in reverse osmosis, 90%-98% removal in nanofiltration), the hardness and alkalinity of the water must be adjusted in post-treatment. Some non-treated water could be mixed into the membrane-filtered water in order avoid the expense of chemicals for inducing water hardness. Nanofiltration and reverse osmosis normally remove all of the microbes
that spread disease, so there is no real need for water disinfection. There can be
gasket leaks, however, and so the situation needs monitoring and there must be a
preparedness for disinfection. If only a part of the water is filtered, the water must
be disinfected. The state of the water network also dictates the disinfection needs of
the system.

• Membrane filtration is the pressurized forcing of water through a
  membrane. Nanofiltration and reverse osmosis, for removal of sodium,
  fluoride and, in some cases, pesticides, are the best option for small
  groundwater works. Membrane filtration usually requires pre-treatment
  and post-treatment. The membranes must be cleaned regularly and
  inspected for breaks.
5 Water distribution system

5.1 General information

Water distribution systems are comprised of main water pipes, distribution pipes (and their components, such as valves, fittings, fire fighting water supply points and fire hydrants), domestic water connections, water containers, water towers and pump stations. The water supply provider maintains the water network. Maintenance includes the use of the water distribution system, repair of damages, servicing, cleaning and testing.

5.2 Collection of network data

All waterworks must have comprehensive maps and appendices of their entire water distribution network and everything connected to it. If parts or equipment are repaired or replaced, these changes must be documented. In addition to a daily use log (see page 39), the following information about the network must be recorded:

- material and coating of the water pipes
- dimensions
- location and installation depth
- installation time
- repairs
- location of leaks
- valves, fire fighting water supply points and fire hydrant locations
- pressure meters and pump stations

Figure 14: Network maintenance work
There should also be location markers on the ground showing the course of the water mains, as necessary.

**Waterworks must maintain precise mapping data about their water distribution network.**

Even if the waterworks does not bill for water consumption by volume, it is recommended that a water meter be installed at every customer connection. It is useful to take a reading from the customer water meters once a year. Network leaks can be pinpointed by comparing the volume of water exiting the waterworks with the total customer water use at the connections. For some waterworks, the amount of water lost through leakage can be large. Leakage can cause significant damage, such as water damage at domestic connections or even sinkholes on roadways.

Data regarding any damage of water pipes must be assessed and documented in writing. Pictures taken during construction, maintenance and repair work can store useful information about the underground networks.

5.3 **Maintenance and renovation of the network**

Old water pipes and water distribution units must be renewed as needed. Renovation includes renewal of the water distribution system and general repair and improvement. Water supply networks over 50 years old are rarely in good condition. The condition of the water pipes influences the quality of the water, the costs of the waterworks and the reliability of the water supply. Several factors weaken the condition of the water pipes and the water quality, including water standing in the pipes, microbe growths in the network, clogged water tanks, old and weak pipe materials, and impurities remaining in the pipes after installation. Network maintenance includes such tasks as the thawing of frozen pipes and network flushing. Pipes that are rarely used must be flushed periodically to avoid deposits, the development of microbe growths (i.e. biofilms) and pipe clogging. Water stagnant in a pipe for a long time also smells and tastes bad.

There are several reasons why water pipes need renovation, some of them being:

- deterioration of the pipe materials and structures: degeneration of the gaskets, subsidence, settling, corrosion, and carelessly installed pipe connections
- changes in water use: a decrease or increase in network capacity and water volumes that are too high or low
- quality of the old pipes and faultiness in installation
- other factors, such as construction and changes in land use.
Renovation is essential if there are serious disruptions such as disturbances in the operation, a threat of collapse, reduced capacity or a weakening of the quality of the water exiting the network.

Networks can be renovated using several techniques (Table 5). The method of choice is determined by technical and financial factors and the inconvenience imposed by the work, among other things.

Table 5: Common methods for water pipe renovation

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>The old water pipe is dug up, and new water pipes and fittings are laid in place of the old. Alternatively, new pipes are laid next to the old pipes, which are left intact under the ground.</td>
</tr>
<tr>
<td>Sliplining</td>
<td>A new pipe is inserted into the defective pipe, instead of excavation.</td>
</tr>
<tr>
<td>Pipe bursting</td>
<td>An expanding device, pneumatic or hydraulic, is inserted into the defective pipe, shattering the old pipe and drawing the new line behind it.</td>
</tr>
<tr>
<td>Deformed pipe lining</td>
<td>Before insertion, the lining pipe is made smaller by running it through a compressor or bending it into a u-shape. The pipe is inserted into the defective pipe, where it regains its shape and expands to give a tight fit against the inside of the old pipe.</td>
</tr>
<tr>
<td>Pipe lining</td>
<td>A plastic pipe is threaded into the defective pipe. The old pipe then serves as a protective pipe against earth pressure.</td>
</tr>
<tr>
<td>Relining</td>
<td>Metal water pipes can be relined with a spray-on material (e.g. cement mortar). Before the relining, the pipes must be cleaned carefully.</td>
</tr>
</tbody>
</table>

Checklist for network renovation and construction:
- drafting and recording inspections, reports and documentation of all work
- pinpointing location of cables, possible need to move them, etc.
- obtaining permits required (private and corporate property, roadways, railways, waterways)
- making arrangements for any disruptive traffic arrangements or water service interruptions required during repair work
- informing authorities and customers
- planning excavation work and water services work
- gaining official assessment and approval of plans, quality monitoring
- planning finishing work
- entry of completed project information in the mapping and network system

5.4 Construction and implementation of the water distribution system

Only materials approved for use in drinking water distribution may be used in water distribution systems. Pipes and fittings must withstand network pressure (4-7 bar); 10 bar pipes are the most commonly used. Currently, plastic pipes are prevalently used (PVC, PEH, PP and PEL). Cast iron is also used if the pipes need to be extremely
durable. Pre-stressed reinforced concrete pipes are used for large diameter water mains pipes.

When choosing pipes, the following factors need to be considered: the estimated useful life, pipe diameter, resistance to pressure and pressurized impact, resistance to corrosion, the soil type, and pipe durability in terms of traffic load.

Comprehensive directions for water pipe installation have been compiled by Finland’s Building Information Foundation (RTS).

A new water distribution network must be flushed before it can be taken into use. During the flush, the pressure resistance is tested to make sure that the pipe is secure. Tests for watertightness of plastic pipes are carried out according to SFS 3115 standards.

It is recommended that water distribution pipes always be disinfected before being taken into use. The cleanliness of the network is checked with laboratory tests of the network water and analysis of indicator bacteria. Directions for chlorine flush, or shock chlorination, are found on page 21. The chlorine-rich water used for the chlorine flush must be dechlorinated after use.

Water lines to property and fire hydrants must be equipped with a cut-off valve. One-way valves prevent water backwash. A sufficient number of cut-off valves should be installed in order to make repair work on the network easier and to prevent shutdowns of large areas in case of leaks. User points that are at an unusually high elevation may require their own water pressure boosting.

In addition to maintenance and renovation, the waterworks must also carry out the following: map drafting, leak assessment, monitoring of network condition and assessment of reasons for damages, assessment of network equipment functionality, and monitoring of network pressure conditions (the water pressure should be kept as stable and sufficient as possible).

In any work on the network, as with any work in water services, particular attention must be paid to hygiene. No humus material may be allowed to enter the water pipes. The ends of the water pipes must be sealed during storage and during water service maintenance or construction work. Water pipes must be flushed before they are taken into use and often disinfected as well. If something happens during water service maintenance or construction work that could potentially affect the water quality, the event must be reported to the health authorities.
Water tanks

Water tanks are an essential part of any water distribution system. There are several kinds of water tanks, from elevated water towers and ground level reservoirs to pressurised water tanks. The purpose of a water tank is to:

- act as a storage tank to make water available in times of water intake fluctuation,
- ensure a sufficient time delay after chlorination,
- provide a sufficient, balanced hydrostatic pressure that will convey the water to the customers, and
- act as a storage space in times of malfunctions (e.g. an electric outage for the pump or large, temporary spikes in use during leaks).

For smaller waterworks, water tanks are usually groundwater tanks located in the vicinity of the water treatment plant, at the same elevation. A ground level reservoir can also act as a backwash water storage tank.

Elevated water tanks or water towers are often a part of large waterworks, but some small waterworks also have them. Water towers are built very high, in order to create enough pressure by gravity to serve the entire distribution area.

The difference between ground level and elevated water tanks is that the ground level water storage water is always pumped through the network with a pump, while the water pressure created by an elevated water tank is caused by the elevation difference between the user points and the tank.

Water tanks may be made of cement, steel, plastic or fibreglass.

Pressure vessels are regularly used in small waterworks. Pressure vessels contain an airspace that can be portioned off from the water space with a rubber bag (bladder tank). The bag keeps the air from dissolving into the water and cuts down on the frequency with which new air must be added. (In vessels with no bag, air must be added regularly.) In addition, the quality of the water in a bladder tank remains better. A pressure vessel is made of either steel or fibreglass. A pressure vessel is used to equalize water flow and maintain water pressure in the network. It works on a small scale as a storage tank in between pumping intervals. Pumping can be interrupted when there is no water use or when there is very little water use, e.g. during the night. A pressure vessel thus allows for intervals in pump use. A pressure vessel equalizes pressure and buffers the pressure impact that occurs during on and off stages or fluctuations in use, acting as an air pocket or shock absorber (Figure 15). Pressure vessels must be inspected and approved according to regulations.
Keep in mind the following factors when working with elevated water towers and ground level reservoirs:

- There should be working ventilation.
- Ventilation openings should be protected with a grate or net to keep animals from entering the water. Dust protection will keep the water quality better.
- The watertightness of the vessel must be inspected to avoid unnecessary leaks and the entry of rainwater, surface water and animals into the water.
- Deposits form in the water tanks, which require regular washing and disinfection. The cleaning interval is dependent on the water quality and can be anything from once a year to once every several years.
- Water tanks must be protected from vandalism.

If the tank is large in proportion to the volume of water use and the retention time of the water is long (several days), there must be water turnover. This can be done by adjusting the pumps so that the tank will empty sufficiently. There should always be enough reserve water on hand, however.

- The condition of the water pipes affects the quality of the water, the costs of the waterworks and the reliability of the water supply. Construction and maintenance of the water pipes must be carried out according to instructions, so that they will stay in good condition and the water quality will remain satisfactory.
6 Waterworks maintenance

6.1 General information

Maintenance of waterworks is important for both the water supply providers and the customers. When waterworks are maintained properly, the distributed water is faultless, and major repairs can be avoided. Prevention is usually much less costly than repairs.

A waterworks distributing water for domestic use must be maintained in such a way that the water it produces is not harmful to customers’ health and is in every other way suitable for domestic use. Careful maintenance prevents damage and problems. Systematic maintenance improves the operational reliability and condition of the equipment, reduces the costs caused by repairs and decreases the amount of damage. The waterworks should be inspected regularly (preferably weekly or even daily – the more frequently the more complex the process is and the more customers are being served). The operation and effectiveness of the waterworks must be made optimal, and the condition of the equipment must be maintained. Drawing up a maintenance plan is particularly important for small waterworks, as they are often dependent on just one waterworks operator.

An assessment of the effectiveness of the waterworks is part of the maintenance programme. The waterworks is comprised of the water intake unit, the treatment system and the distribution system and storage, but the larger picture includes the entire groundwater area and all of the customers. All of these elements are connected, and they must be managed and assessed together. Water quality, water supply performance and customer health can all be affected through each element of the...
system. The waterworks is responsible for the water up until the point where the pipe connects to the customer’s property. It also has a responsibility to provide information on the quality of the water, along with other matters.

*The waterworks in its entirety can be illustrated with the following continuum:*  
**Groundwater area (factors in the area) ↔ well ↔ water treatment system ↔ distribution system ↔ customers**

A waterworks usually names one person as the principal officer: the responsible operator of the waterworks. His or her job is to ensure the objective care and maintenance and adequate inspection of the waterworks. The operator should have comprehensive knowledge of the water treatment facility and the skills necessary to maintain it. According to the Health Protection Act, waterworks operators must prove their operator credentials (see page 3). The deputy operator must also possess sufficient knowledge of the water treatment process. The appointment of a deputy operator can be agreed upon with other waterworks or provided for as an outsourced service if necessary.

The contact information of the primary operator and deputy should be made available to all of the waterworks customers. If a problem with the water arises, customers can contact them directly.

The department can also enter into a maintenance agreement with an external party (e.g. a maintenance company). In this case, the external party must also show proof of professional competence. It is recommended that all work to be carried out and maintenance costs be listed in the maintenance agreement.

6.2 **Waterworks documents**

It is recommended that the waterworks have the following documentation available at all times, in separate folders:

- General information about the waterworks
  - data about the system (e.g. the groundwater area, influent water intake data and treatment system data, maps of the network and pipe sizes)
  - occupational safety plans
  - inventory of material and equipment in storage
  - safety information for chemicals
  - equipment cards and user manuals
  - maintenance plans
- dosage instructions and other process control and adjustment instructions

• Operational data
  - daily log
    * flow rates
    * operating data on the various process units
    * chemical consumption
    * energy use
    * readings from runtime counters of pumps
    * readings from meters and calibrations
    * other observations and analysis results from routine monitoring
  - readings from customer water meters and waterworks meters
  - completed maintenance work and other maintenance tasks
  - information on the water source, groundwater levels, amount of water pumped, water flow velocities, information from units measuring water pressure,
  - network maintenance protocol (flushing, cleaning, lining, leak assessment)
  - information about repair of leaks (time and place and possible assessment of reasons for the leak)

• Monitoring data
  - results of monitoring inspections by the authorities: water quality sampling points and results, with particular note taken of abnormal data
  - customer feedback: comments received by the waterworks, reasons for the comments, investigations into the comments and measures taken as a result.

All of the information that would be useful to the primary operator of the waterworks, his/her deputy and other employees should be entered into the daily log. The log is useful in the assessment of accidents and anomalies.
6.3

**Waterworks maintenance procedure**

Good maintenance of the waterworks requires expertise. In some cases, the experience of the waterworks personnel is insufficient, and it becomes necessary to turn to a professional. The waterworks should have a list available of professionals who can be of assistance (Appendix 5):

- electricians
- pipe and plumbing experts
- electronics and control experts
- equipment experts and network experts
- authorities, such as the public health inspectors, environmental authorities and rescue services

By drawing up and adhering to a thorough maintenance programme, the waterworks can avoid unanticipated water supply interruptions and unnecessary repairs and thus ensure a longer useful life for the system. All of the waterworks tasks and their scheduled times are entered in the maintenance programme, including all other aspects of the waterworks: from the groundwater area to all of its customer units and equipment. The maintenance programme must also take into account the potential responsibilities that may be included as part of the water intake permit. An example of the listed tasks in a maintenance programme is found in Appendix 5. Maintenance practices are specific to each waterworks, however, and this must be considered when drawing up new maintenance programmes.

All maintenance procedures must be documented in writing. This helps with maintenance when e.g. a replacement operator is substituting for someone at the waterworks. The documents may also be of use in the future when working out a problematic situation. The following content should be included in any maintenance programme:

- operational framework, i.e. what is done at the waterworks and how often (examples listed in Appendix 5),
- equipment maintenance statistics, e.g. calibration of monitoring equipment,
- schedules,
- duties and persons with primary responsibility,
- functional variables, i.e. the values by which the waterworks operation is managed (e.g. pH), and
- information about the facilities and equipment.

The water intake unit and all of the equipment of the waterworks must be inspected and serviced regularly. The manufacturer instructions that accompany the equipment should act as the primary data source. For larger waterworks and complicated systems in particular, the equipment cards are effective tools for keeping equipment up to date.
A reminder calendar can serve as a summary of the maintenance programme tasks, making maintenance of the equipment and machines easier. In any case, it is beneficial to jot down reminders (e.g. on the equipment card, the equipment user instructions or a separate means of data storage) about when machines were purchased, when and how they have been serviced, when they will need inspection next, where to find replacement parts and replacement part storage and availability data. Along with the acquisition of new equipment, it is recommended that the waterworks request information about use and maintenance. Irregular use may mean, however, that more servicing than that which is recommended is required.

Other maintenance considerations
Chemical storage units must be secure and appropriate for the storage purposes. The storage space must be dry and safely locked. The floor or storage levels must be smooth and easy to clean. Several chemicals have particular storage requirements, such as the need for a protective tube encasement or proper ventilation. For example, the lime storage area needs to be partitioned off from the rest of the area with a wall because of dust. Chemicals may not be stored in the service well. When purchasing chemicals, information must be obtained on the safe storage methods, and the limitations on storage time must be taken into account. Moisture creates problems for some chemicals (lime tends to cake, for example) and can even create a hazardous situation (reactions with chlorine).

Chemical dosages must be exact. If too little chlorine is added, harmful microbes that are hazardous to human health will remain in the water. If too much is added, the water will become unpleasant for users and potentially dangerous to their health.

When using pumps for the distribution of drinking water, manufacturer guidelines must be adhered to. A general instruction for all pumps is that their operation must be monitored and meter readings recorded regularly. The cleanliness of the pump must also be ensured, as this adds to the pump’s service life and reliability. Anything unusual must be noted: strange sounds in the equipment, pump failure during power failure, etc. Even if the anomaly does not necessarily affect the pump’s operation and requires no response, everything out of the ordinary must be documented. (see also Appendix 5).

It is easier to ensure good water quality if the components of the drinking water production chain are well managed. This includes the choice of a clean water source, protecting the water source from contamination, choice of a suitable treatment method, disinfection, continuous maintenance of the water distribution system, water quality surveillance, personnel training and preparedness for emergency situations.
Information distribution

Waterworks must distribute a sufficient amount of information about the quality of the drinking water and what components the water fees consist of.

Results of monitoring inspections must be sent to the municipal health protection authorities, but a waterworks must also remember to inform its customers about the water quality. This information can be made available on the Internet or through a mailing sent to all customers, for instance along with the bill. It is recommended that waterworks inform their customers about the quality of the water at least once a year. Any changes affecting water quality must be reported immediately, and any serious changes must be reported to the health authorities without delay (see 8.5 Informing during emergency situations).

- Thorough maintenance and effective routine monitoring of waterworks promote their performance and improve the water quality.
- The expertise of the waterworks operator is the key to successful maintenance.
- The waterworks must maintain a daily log, a maintenance programme, a routine monitoring programme and, if possible, equipment cards.
- Waterworks maintenance covers the entire system: the groundwater area, wells, the water treatment system and the distribution network.
7 Routine operational monitoring

7.1 Routine monitoring at the waterworks

The routine monitoring programme is a programme carried out by the waterworks itself to identify potential threats to waterworks operation and to monitor water quality continuously.

Waterworks must continuously monitor the quantity and quality of the raw water being used and the amount of water loss in the water distribution network. A thorough routine monitoring programme – an ‘internal inspection’ carried out regularly by the waterworks itself – is an essential part of waterworks operations. Only regular, comprehensive monitoring of operations can ensure the quality of the water begin distributed to a sufficient degree of reliability. The routine monitoring programme should include a sufficient amount of raw water testing to enable the waterworks to assess the effectiveness and overall need for water treatment and to analyse changes in water quality in the network. The number of routine monitoring samples is not determined by legislation, but it is recommended that the raw water be examined at least four times a year for potential factors that would have an effect on the quality of water. For groundwater works, the raw water samples are taken from the influent water entering the water treatment system.

The routine monitoring programme of the waterworks should include the following measures:

- An operational assessment – an evaluation of the functionality of equipment and processes, including data collection for purposes of process management and control.
- Water quality monitoring – assessment of the microbiological and physical-chemical quality of the water to ensure its suitability for customer use.
• Assessment of customer satisfaction – recording customer comments and complaints to detect any problems as quickly as possible.
• Other research and surveillance – identifying other potential problems and planning risk management.

Routine monitoring programmes promote the independent quality assurance of drinking water by the waterworks. This does not include the statutory requirements for water quality analysis. In practice, even just reading and documenting the volume of water leaving the waterworks, as measured at the main water meter once a week, constitutes a routine monitoring programme. When the recorded numbers remain stable and are consistent in annual inspections with the amount of water sold to customers, it can be assumed that there are no significant leaks in the network.

The minimum number of analyses required by the municipal health protection authorities (official samples) is laid down in the Decree on water intended for human consumption. More information on this matter can be found in Section 2. In the case of the waterworks routine monitoring programme, however, the results of the water analysis are checked as soon as they arrive. The results are compared to the previous findings and changes are detected. The results are also compared with the values set by the Decree (Appendix 1).

The routine monitoring programme also includes an assessment of the treatment methods of the waterworks, such as the regular measurement of chlorine concentrations, if the system uses chlorine. Regular inspection can include different volumes of water and different indicators describing the water quality at the waterworks, such as:
• the total volume of water pumped through the network
• the groundwater level in the wells and in the observational pipes located in areas affected by the water intake unit
• in-house or laboratory analysis of indicator bacteria (e.g. coliform bacteria and E.coli)
• continuous monitoring of the influent water quality with a field meter: water temperature, pH, conductivity, turbidity, dissolved oxygen content, colour, hardness, alkalinity, or water quality testing in the laboratory.

Several different kinds of analysers, field meters and sensors are on the market, but it is also important to monitor the water quality organoleptically, i.e. with the human senses (i.e. smell, taste, colour and turbidity). Inspection rounds in the vicinity of the water intake unit and of the water intake unit itself (specifically chemical feed and pump operation) are also an important part of the routine monitoring programme.

It is recommended that each waterworks acquire a pH meter, so the waterworks operator can measure and record the water pH at each visit. If the water at the waterworks is not treated, the pH level can help to assess that the water quality is stable and problem-free. If the water is treated, it is necessary for most of the treatment methods to adjust the pH level of the water so as to be suitable to the treatment method (or vice versa). The pH meter can be a on-line meter, in which the sensor is
attached to a point in the water line or to a separate unit where water is conveyed from several points in the process, so that one meter can assess several areas. The importance of monitoring is accentuated if the risk factors are considerable. It is particularly important to document everything clearly. If meters (especially the pH meter) are to be considered reliable, they must be calibrated and serviced according to instructions. The availability of a chlorine meter must be ascertained in anticipation of an emergency in which the waterworks would need to commence chlorination of the drinking water. Another situation requiring careful monitoring of water is when the groundwater level is extraordinarily high after heavy rains or extraordinarily low during dry periods.

When planning routine monitoring and risk management, the following matters must be taken into consideration:

- Are the most probable water problems of a microbial or chemical nature?
- Which hazards threatening water quality are near the water intake unit?
- Can the water treatment chemicals cause some kind of danger?
- How can the facilities be monitored to ensure their performance?
- Where are water samples taken and how often?
- Where are the samples analysed?
- How can the monitoring material best be used to eliminate risks and guarantee customer health?

The more complicated the water treatment system is, the more important it is that it be monitored carefully. Some of the equipment that is useful in terms of system monitoring are continuous measuring devices, automated control equipment, monitoring system and automated alarm systems, auxiliary systems, monitoring of the variables during chemical feeds, and functioning mixing systems.

If the routine monitoring reveals concentrations of harmful substances that exceed limits or recommended levels, the health authorities must be immediately contacted. If faecal indicator bacteria counts exceed the limits, customers must be notified and measures must be taken to correct the situation. Repeat samples must also be taken for these kinds of cases.

If the groundwater is not treated, an analysis of the groundwater, along with network sampling, usually suffices. The raw water sample from the groundwater works is primarily taken from the effluent water exiting the waterworks or the pumping station. If this is not possible, the sampling can be taken from a well, utilizing different kinds of lifts and pumps. If the treatment is straightforward (i.e. simple alkalisation), an analysis of the raw water and the treated water should be enough to provide a comprehensive description of the water quality. The effluent water sample also shows the combined influence of the cleaning effectiveness and treatment. If the treatment is comprised of several stages or chemicals, the operation of each process unit should be monitored for suitable parameters. Samples taken from the treatment process must provide a comprehensive picture of the performance of the treatment system. Official samples for the inspection are taken from the network water, often
from the taps of the consumers. The waterworks can take their own auxiliary samples from the network water. The sampling points for network water are chosen so that they optimally reflect the system conditions. Sample locations are usually agreed upon with the health authorities. If the network is expanded, it is good to ensure that the sample locations are still sufficient and that the routine monitoring programme is suitably extensive.

7.2

**Water sampling**

7.2.1

**Official control samples**

When taking official inspection samples, only approved, standardized sampling methods are allowed. Official samples are taken by inspectors or certified environmental samplers. The instructions included here are primarily for the waterworks’ own use. The instructions from the laboratory must first be followed. When it comes to regular sampling, the waterworks should arrange that a health inspector or someone else certified to take samples, e.g. a laboratory sample taker, comes to take the samples. However in cases requiring a quick response, i.e. if there is a suspicion that the water is contaminated and could be a health hazard to customers, the waterworks must be able to take the samples on its own.

A sample that is taken incorrectly, taken from the wrong point, placed in the wrong container or stored improperly gives an incorrect result.

Remember the following when taking samples:

- Determine which parameters you want to test for with the sample in question. The objective may be to determine the quality of the raw water, the suitability of the water for drinking, the quality of the water in terms of health properties or an assessment of the water treatment performance.
- The tests on the water must be based on the parameters in question. The number of samples should be based on the research objective as well.
- For some measurements, the samples cannot be stored for examination in a laboratory; rather, the measurements must be performed as soon as the sample is taken. A preservative is added to some of the samples so they may be examined in a laboratory later. The sample taker must be aware of the order in which samples should be taken: which samples need to be tested immediately, which need preservation, and which can be sent to the lab as they are (Table 6).
- Remember to bring the correct sampling equipment, e.g. the proper sampling containers. Very clean, sterilized bottles are required for microbiological tests. Chemical analysis requires plastic or glass bottles, dependent on
the tests in question. The proper sampling equipment should be requested directly from the laboratory to which the samples will be sent.

- Some of the qualifications can be met with measurements that can be done in-house. Personnel should learn the proper protocol for these measurements beforehand, not when the samples are about to be taken.
- The sampling points and protocol should be up to standard. For example, if a sample is taken from a well, it should not be taken from the surface of the well water.
- The first samples that are taken are those for bacterial tests, before any other samples are taken.
- When taking a sample, careful notes about the sampling should be recorded in the sampling log. The log should contain information about all of the measurement results taken at all of the sampling points.
- Samples must be stored correctly. They should be kept cool (2-8 °C), but not allowed to freeze. Normally, samples are stored in a refrigerator or in a cooler equipped with a cold pack.
- Any samples that are to be sent to the laboratory should be sent immediately. Measures must be taken to ensure that the samples remain cool during shipment. It is recommended that a copy of the sampling log be sent along to the laboratory with the samples.

7.2.2

Sample containers

The kind of sample container to be used is contingent on the type of tests that are to be carried out. For this reason, it is good to use several kinds of containers that have been treated in different ways. Different kinds of samples should be taken in their own dedicated bottles.

The best choice is to ask the laboratory for the required containers before testing. Sterile bottles for microbiological testing in particular should come directly from the laboratory.
If the laboratory does not have bottles available, the following directions should be followed:

- Glass bottles should always be used when examining gases and organic compounds that have dissolved into the water. Table 6 explains when a glass bottle is necessary.
- Samples are usually taken in polythene bottles in cases where the water will be subject to physical or chemical analysis. The screw top should be colourless and have a Teflon seal.
- Nalgene bottles, made of polycarbonate and polypropylene, should be used as containers for samples to determine metal concentrations (e.g. iron and manganese).

Sample containers should be clean. For samples taken to determine physical and chemical analysis, the containers should be washed with a brush and cleaning solution. Containers should then be rinsed at least five times with tap water and two more times after that with distilled water. Table 6 shows which samples require special cleaning, e.g. acid cleaning.

Sample bottles used for microbiological tests need to be sterile. Sterile bottles can be sent from the laboratory. If this is not possible, sterilisation can be carried out by submerging the clean, open bottle in boiling water for one half hour. After boiling, the bottle must be emptied and sealed immediately with a sterile, sealed top. The bottle must then be wrapped in clean paper and left to cool. The bottle can also be disinfected in an oven set at 125 °C for 30 minutes.

If the sample is taken from chlorinated water, the sample for microbiological testing must be taken in a bottle to which 1 ml of sodium sulphate solution (35 g $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5 \text{H}_2\text{O}$ litres) for every litre of sample water has been added before sterilisation. The sodium sulphate prevents the chlorine from affecting the bacteria analysis.

Table 6 show the sample amounts that are needed, the bottle filling protocol, when samples bottles are to be completely full, the sample preservation protocol and preservation periods with regards to the different analysis.
Table 6: Storage of water samples, sample volumes required and preservation requirements.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Sample size, ml</th>
<th>Preservation K = in-house L = in the laboratory</th>
<th>Storage</th>
<th>Remarks</th>
<th>K, M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkalinity</td>
<td>100</td>
<td></td>
<td>1 day</td>
<td>Sampling bottle must be filled completely, with no air left in the bottle</td>
<td>K, M</td>
</tr>
<tr>
<td>Bacteria</td>
<td>250</td>
<td></td>
<td>poor, 8-18 hours</td>
<td>Sterilized glass bottle</td>
<td>M</td>
</tr>
<tr>
<td>KMnO4 consumption</td>
<td>100</td>
<td>1 ml 4 M sulphuric acid / 100 ml</td>
<td>5 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>100</td>
<td>1 ml MnSO4 and 2 ml NaJ / 100 ml</td>
<td>1 day</td>
<td>Screw top glass bottle, titration method</td>
<td>K</td>
</tr>
<tr>
<td>Calcium, hardness</td>
<td>100</td>
<td></td>
<td>7 days</td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>Chlorine</td>
<td>2*100</td>
<td>poor</td>
<td></td>
<td></td>
<td>K, M</td>
</tr>
<tr>
<td>Chloride</td>
<td>100</td>
<td></td>
<td>7 days</td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>pH</td>
<td>100</td>
<td>poor</td>
<td></td>
<td></td>
<td>K</td>
</tr>
<tr>
<td>Total iron</td>
<td>100</td>
<td>1 ml 4 M sulphuric acid / 100 ml (L)</td>
<td>6 months</td>
<td>Sample bottle that has been washed with acid</td>
<td>M</td>
</tr>
<tr>
<td>Iron, reduced</td>
<td>100</td>
<td>1 ml 4 M sulphuric acid / 100 ml (K)</td>
<td>poor</td>
<td>Screw top glass bottle. Analysis on site or immediately upon arrival at the laboratory</td>
<td>K, M</td>
</tr>
<tr>
<td>Turbidity</td>
<td>100</td>
<td></td>
<td>1 day</td>
<td>Glass bottle</td>
<td>M</td>
</tr>
<tr>
<td>Conductivity</td>
<td>100</td>
<td></td>
<td>1 day</td>
<td>Polyethylene bottle</td>
<td>K, M</td>
</tr>
<tr>
<td>Total organic carbon (TOC)</td>
<td>250</td>
<td></td>
<td>1 day</td>
<td>Screw top glass bottle filled completely with water</td>
<td></td>
</tr>
<tr>
<td>Ammonium</td>
<td>100</td>
<td>poor</td>
<td></td>
<td>Immediate analysis recommended</td>
<td></td>
</tr>
<tr>
<td>Nitrites</td>
<td>100</td>
<td></td>
<td>5 hours</td>
<td>Immediate analysis</td>
<td>M</td>
</tr>
<tr>
<td>Nitrates</td>
<td>100</td>
<td></td>
<td>3 days</td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>Colour</td>
<td>100</td>
<td></td>
<td>1 day</td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radon</td>
<td></td>
<td></td>
<td>1 day</td>
<td>Liquid scintillation bottle from the laboratory</td>
<td></td>
</tr>
<tr>
<td>Fluorides</td>
<td>100</td>
<td></td>
<td>7 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>100</td>
<td>1 ml 4 M sulphuric acid / 100 ml (L)</td>
<td>6 months</td>
<td>Sample bottle that has been washed with acid</td>
<td></td>
</tr>
<tr>
<td>Uranium</td>
<td>100</td>
<td></td>
<td>7 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>100</td>
<td></td>
<td>7 days</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

KM-column: ‘K’ indicates testing that is preferably done in-house and ‘M’ denotes a test that can be either done in-house with quick procedures or at the laboratory. Tests with no letter given must be performed at the laboratory. See also Appendix 4 Measurements and analysis.
7.2.3

**Sampling protocol**

Hands must be carefully washed and disposable sanitary gloves must be applied before drawing samples for microbiological analysis. Microbiological samples are always taken first, before any other samples.

**Samples from the tap** are taken by first running the water from the tap for 4 to 5 minutes at a medium velocity. The insides of the bottle and the part of the cork that will come into contact with the water may not be contaminated. They may not be touched with the hands or come into contact with the tap. The bottle is not filled completely, and it is sealed tightly.

**Samples from a well** can be taken with a bailer or a container that is normally used to draw water from the well.

**Samples from a pump well** are taken in the same way as if the sample would be taken from the tap.

If a bailer is used, the bailer line must be decontaminated just before use — flamed with a propane blowtorch, for instance. The bailer is quickly submerged head first to a depth of 20-30 cm below the water surface. The bottle should not be filled completely.

The necessary field analyses, i.e. water temperature, pH level, conductivity, acidity, ferric iron and sample turbidity assessment based on appearance and smell, should all be carried out during the sampling. All of these observations must be recorded in the field log.

Table 7 is a summary of sampling methods in different situations.
Table 7: How water samples are taken in different situations.

<table>
<thead>
<tr>
<th>Water sample point</th>
<th>How water sample is taken</th>
<th>Should the water be allowed to run before taking the sample?</th>
<th>Is it necessary to remove the filters and mixers?</th>
<th>Is it necessary to disinfect for microbiological analysis?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground-water</td>
<td>With a pump (submerged pump, peristaltic pump, inertia pump) observation tubing or with a decontaminated bailer from the source.</td>
<td>Yes, water must be purged before the sampling until the temperature and conductivity is consistent, at least three times the capacity of the observational tubing.</td>
<td>Yes, if the sampling tubing has been connected to filters.</td>
<td>The submerged pump is disinfected by submerging it in a solution of 10 mg of Cl₂/l hypochlorite for 30 minutes, the tubes and line are also rinsed with a hypochlorite solution.</td>
</tr>
<tr>
<td>Well water</td>
<td>With a pump installed in the well or straight to a sample bottle (or into a sterilized bottle, using sterilized gloves, for samples needing microbiological analysis) or a disinfected line.</td>
<td>No need to run water or just enough to change the water in the pump.</td>
<td>Yes, well tap filters must be removed.</td>
<td>Yes, the well pump tap must be flamed with a torch. (70% ethanol or hypochlorite solution, if the tap cannot be flamed.)</td>
</tr>
<tr>
<td>Water container</td>
<td>From the tap or directly into the bottle (or into a sterilized bottle, using sterilized gloves, for samples needing microbiological analysis).</td>
<td>If the water container has a tap, a short run of water to ensure that the water to be tested is from the container.</td>
<td>Yes, the water container filters must be removed.</td>
<td>Yes, the water container tap must be flamed with a torch.</td>
</tr>
<tr>
<td>Network water</td>
<td>Taps designated for water sampling</td>
<td>Yes, water is run until the temperature has stabilized. The water cannot run too heavily, however (turn the tap only halfway).</td>
<td>Yes.</td>
<td>Yes, water sampling taps must be flamed.</td>
</tr>
<tr>
<td>Consumer tap water</td>
<td>Taps on the property.</td>
<td>5-10 seconds or not at all.</td>
<td>No.</td>
<td>No.</td>
</tr>
</tbody>
</table>
7.2.4

Storage and transportation of water samples

Water samples must be delivered as quickly as possible to the laboratory, as extended storage can change many of the water properties. During transportation, the samples must be stored in a dark place at a temperature of 2-8 °C, e.g. a cooler. During the summer months, several cold packs must be added to the cooler. In the winter, the samples need to be insulated from the cold, as the samples must not freeze. Basic information should be sent along with the samples: the name of the sampling operator, the sampling point and time, the sampling method and an explanation of which samples are to be analysed. Any organoleptic observations (smell, colour, turbidity) should also be recorded in detail. If the samples need to be stored overnight before being sent to the laboratory, the storage temperature must be recorded and sent to the laboratory. Clean samples may not be stored in the same place with contaminated samples during transportation.

- Routine monitoring is the waterworks’ own independent monitoring programme, acting as an important supplement to the inspection programme of the authorities.
- Routine monitoring can be implemented with the help of different meters and analysis, in addition to inspection rounds and human observation. Routine monitoring observations should always be documented in writing.
- The waterworks operator should know the proper procedure for taking water samples.
8 Emergency situations at small waterworks

8.1 Waterworks must be prepared for emergency situations

According to the Act on Water Services, the water supply provider is obliged to ensure their customers’ water service in all situations.

How water supply providers operate in emergency situations must be taken into account in agreements between the customer and the water service provider. According to the Health Protection Act, the waterworks must, along with the municipal health protection authorities, be suitably prepared to prevent, investigate and remove any health hazards created by emergency situations.

Waterworks can be confronted with several kinds of different problems. It is important that everyone at the waterworks is well prepared. Disruptions at a waterworks can be caused by accidents, vandalism, mistakes, technical faults, unusual weather conditions and natural hazards. Preparedness begins with an assessment of the potential risks. After this, actual processes can be put in place to reduce the probability of problems and to help avoid them. Not all disruptions can be prevented with advance measures. For the problems that are the most likely to occur, plans can be made for how to act when the problem arises.

The best way to avoid problems is good, thorough maintenance.
Table 8: Water service risks and their prevention (Arosilta 2005, as revised by the author).

<table>
<thead>
<tr>
<th>Risks</th>
<th>Prevention and management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural phenomena</strong></td>
<td></td>
</tr>
<tr>
<td>Drought</td>
<td>• The well should be located and built properly.</td>
</tr>
<tr>
<td></td>
<td>• Plan for where to gather auxiliary water, should the well in use dry up.</td>
</tr>
<tr>
<td></td>
<td>• Long-term drought can affect water quality, which means the water would need to be treated. Drought can also cause the well bottom to crack.</td>
</tr>
<tr>
<td>Flooding and torrential rains</td>
<td>• The structure of the well should be sound. Well components above ground should be placed high enough so as not to be submerged.</td>
</tr>
<tr>
<td></td>
<td>• The ground around the well should be shaped so that it slopes away from the well.</td>
</tr>
<tr>
<td></td>
<td>• The well must be located in such a way that the surface of the waterway will not reach the well, even in times of flooding.</td>
</tr>
<tr>
<td>Sub-zero temperatures and ground</td>
<td>• The well, water pipes and pumps must be protected from ground frost.</td>
</tr>
<tr>
<td>frost</td>
<td>• If the ground frost ruptures the well or a water line, repair work must begin immediately. Microbes can enter the water at the site of the break, especially in cases where the wastewater line has also been damaged.</td>
</tr>
<tr>
<td><strong>Technical hazards</strong></td>
<td></td>
</tr>
<tr>
<td>Land use</td>
<td>• When planning land use in a groundwater area, steps must be taken to guarantee that the groundwater is not contaminated.</td>
</tr>
<tr>
<td></td>
<td>• Construction work needs to take account of water and sewer lines in the area.</td>
</tr>
<tr>
<td>Fire</td>
<td>• Building and forest fires can harm the groundwater (in particular the chemicals used for extinguishing the fire, should they infiltrate the groundwater).</td>
</tr>
<tr>
<td></td>
<td>• All units of the waterworks, including the water towers, must be protected from fire.</td>
</tr>
<tr>
<td></td>
<td>• The waterworks should have smoke alarms, and waterworks should utilize a remote fire alarm system if possible.</td>
</tr>
<tr>
<td>Electricity distribution</td>
<td>• Storms and high winds can cut off the electricity supply.</td>
</tr>
<tr>
<td></td>
<td>• The waterworks should have an alternative power source in case there is a power outage.</td>
</tr>
<tr>
<td></td>
<td>• It is good to ensure the re-starting of the pump after a short electricity outage with a frequency converter, for example.</td>
</tr>
<tr>
<td></td>
<td>• Water is still used after the pump has been cut off, the resulting loss of pressure can mean that microbes will be sucked into the water distribution system or that dirty water may enter the network from a part of the works that is located at a high elevation. The surface water in the valve well can enter the network through the two-way air removal valves.</td>
</tr>
<tr>
<td>Agriculture and forestry</td>
<td>• In agricultural areas, the waterworks must confirm that no field fertilisation or animal manure can contaminate the groundwater.</td>
</tr>
<tr>
<td></td>
<td>• It also must be established whether anyone has ever used pesticides in the groundwater area.</td>
</tr>
</tbody>
</table>
### Risks

<table>
<thead>
<tr>
<th>Business areas</th>
<th>Prevention and management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Neglect by industry has ruined many aquifers. Today, permit regulations severely restrict the activities of industrial facilities, but, as a rule, industry is a potential risk to groundwater areas.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Residential areas</th>
<th></th>
</tr>
</thead>
</table>
|                   | • Individual wastewater treatment systems are a significant risk to groundwater areas. All waste that is stored on private property (trash, oil, fertilizers, poorly maintained outhouses and composts) can pose a threat to groundwater.  
• Maintenance neglect. |

<table>
<thead>
<tr>
<th>Traffic</th>
<th></th>
</tr>
</thead>
</table>
|         | • In groundwater areas, alternative methods for de-icing roads should be found, to avoid salting.  
• If the well is located near a road that is regularly salted, the salt content of the well must be checked regularly.  
• The waterworks should be aware of any transport of hazardous materials in the groundwater area. |

<table>
<thead>
<tr>
<th>Radiation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• The well should be built as a sealed structure, to avoid radioactive fallout entering the well water. Groundwater is less vulnerable to fallout than surface water.</td>
</tr>
</tbody>
</table>

### Social factors

<table>
<thead>
<tr>
<th>Inadequate maintenance</th>
<th></th>
</tr>
</thead>
</table>
|                        | • Good maintenance is the primary preventive measure against risks in water service.  
• The cost of repairs due to inadequate maintenance usually far exceed what would have been the cost of regular maintenance |

<table>
<thead>
<tr>
<th>Availability problems</th>
<th></th>
</tr>
</thead>
</table>
|                       | • The availability of chemicals, replacement parts and professional services can be problematic at times, e.g. during industrial action or due to the peripheral location of the waterworks.  
• To avoid the problem, waterworks personnel must know at all times where certain services can be found and how quickly.  
• Stockpiling of the most important chemicals (disinfectant chemicals in particular) should be arranged for with the chemical distributor. |

<table>
<thead>
<tr>
<th>Vandalism and criminal actions</th>
<th></th>
</tr>
</thead>
</table>
|                               | • Ventilation vents of the well should be equipped with screens. The water treatment facilities, wells, containers and chemical storage facilities must all be locked.  
• Effective lighting in the facility area discourages trespassing (e.g. lights triggered by a motion detector). Excess vegetation must be removed from the waterworks area.  
• Extortion is very unlikely in Finland.  
• Terrorism is very unlikely in Finland. |

<table>
<thead>
<tr>
<th>Changes in water demand</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Population growth, a rise in the amenity levels in residences and changes in the economy may create problems in water sufficiency. A decrease in water consumption could cause financial or technical problems for the waterworks.</td>
</tr>
</tbody>
</table>

The severity of a disruption at a waterworks is dependent on several factors. For example, the probability of well water contamination depends on not only the properties of the soil, the location and condition of the well, weather conditions, etc., but also the presence of hazardous materials or other possible degenerative measures in the area near the raw water intake point.
8.2

Preparing for emergency situations

Not all emergency situations can be prevented, but some kind of preparation can be made for every possible scenario. A written preparedness plan should be drawn up. It should also be located in a place where everyone who would need to refer to it could find it easily. On the other hand, it must also be protected from outsiders, as it is not a public document. Each waterworks should have more than one person who is aware of the general waterworks issues and who is familiar with the preparedness plan in particular. Preparedness plans should be drawn up in association with the health authorities, or, at the least, a copy of the completed plan should be sent to them.

A few examples of matters that must be considered in a preparedness plan are given here. Local conditions (water sources, water treatment methods, personnel, location, etc.) have a significant effect on how the preparedness plan is shaped. The plan must also be clear and unambiguous. All of the local conditions and essential cooperative partners must be considered. The plan should be checked once a year and updated accordingly. Any changes in the water treatment process, operating area or personnel may require changes in the preparedness plan.

The preparedness plan for emergency situations must contain the following information at the very least (model in Appendix 8):

- description of the waterworks: the water intake unit, water treatment and water distribution;
- potential threats to the waterworks and the effect their realization would have on the customers and facilities. Threat probability and preventive measures that are in place;
- Protocol in case of an emergency: things to be done immediately (stopping water distribution, water analysis, etc.), things to be done in due course (chlorination, repairs to the facilities), and documentation of the events;
- information distribution in case of emergency (important contact information); and
- the role of the personnel in emergency situations and their contact information.

Smaller waterworks may not have the resources to draw up a comprehensive preparedness plan. It is still a good idea to inventory all of the vulnerable parts of the waterworks and to consider solutions in case of complications. (Appendix 7 is a checklist for determining the weak points of the waterworks.) The existence and easy availability of good maps and a list of contact persons is very important, especially for a small waterworks.
8.3

**What to do in an emergency situation**

The emergence of a problem requires quick decisions. Does the situation present a danger for the water customers? Should water distribution be stopped? Who needs to be informed of what has happened? How can the information be distributed? Are repairs necessary? Who should be called in to help? The preparedness plan assists the waterworks with these quick decisions. When problems arise, the waterworks should first contact the health authorities, and they, in turn, are responsible for informing the public. The health authorities can also assist in finding a suitable solution.

Companies providing services vital to society are bound by a public service duty: even if waterworks operations were disrupted by force majeure, water distribution must still be managed so as to provide the amount required. **Each waterworks should have a plan concerning auxiliary water sources.** Water can be drawn from a reserve well or from another waterworks. Temporary water distribution can be arranged for easily if the waterworks is connected to the network of another waterworks, although this is no help if the problem is in the network. Some cases may require water to be brought in with container trucks. Plans for temporary water distribution and the feasibility of its implementation should be made and checked ahead of time.

In emergency situations (e.g. the flooding of neighbouring waterways), the quality of the drinking water should be monitored closely. Water quality monitoring should be made more frequent until the threat to water quality has been removed (e.g. the level of the waterway has returned to normal).

Usually an explanation can be found to water quality problems. There is a good probability that a bad smell or taste, for example, can be traced to contamination of the groundwater or well. For this reason, a water samples must be sent to the laboratory for analysis immediately. In laboratory testing for quality, the water is usually checked for indicator bacteria, pH, turbidity, colour, permanganate level, iron, manganese, nitrogen compounds, alkalinity, hardness, acid, and chlorine. Inform the laboratory of the problems, and they can suggest appropriate analysis of the water sample. Water samples must be taken from the raw water, the treated water and/or the network water, dependent on what the analysis is meant to determine. The results can be used to determine what caused the contamination. The health authorities can help with the investigation. The well may be broken, pipes may be worn, or there may be polluting factors in the groundwater area. Emergency situations can lead to a variety of scenarios at the waterworks. A well or equipment may require repair. It is a good idea to contact a professional in the field before any repair work begins.

**Each waterworks must be prepared for disinfection of the water.** This means that the waterworks must be able to connect a disinfection unit to the process at any time. The disinfection equipment does not necessarily need to be at the waterworks facility itself, but the waterworks personnel must all know where the equipment and chemicals can be found so they can be retrieved quickly in need.
8.4 Who does what in emergency situations

The municipal health protection authorities play a crucial role in emergency situations. According to the Health Protection Act, they are charged with monitoring the quality of the drinking water delivered by the waterworks and the thorough inspection of the waterworks. The health protection authorities must take immediate action upon being informed of a problem or suspicion, and it is their responsibility to decide whether the drinking water supply should be interrupted. Preventive measures are divided among the health centres, the health protection authorities and the water service providers. The health protection authorities are responsible for drawing up a preparedness plan along with the waterworks. This plan is drawn up specific to the area in question.

Municipalities are responsible for the development of water services and their proper maintenance. The need to provide water to an extensive population in cases where the water has been contaminated is mentioned in the Water Services Act, and local authorities are charged with offering their assistance. Municipalities and waterworks must prepare a plan for temporary water distribution, but the municipality may also receive payment for their services rendered. As per the Preparedness Act, the municipality must draw up a preparedness plan for emergency situations. The plan should include water service preparedness. In practice, however, each line of business (including water service providers) is liable for the creation of their own preparedness plan.
**Waterworks** are responsible for purity of the water delivered to their customers. A waterworks must identify the risks associated with water services, do their best to prevent them and prepare for them. The task of the waterworks is therefore to prepare a preparedness plan and maintain a maintenance plan. In water service emergencies, the waterworks is responsible for informing the persons concerned and making provisions for temporary water distribution from an auxiliary source. The waterworks can suggest limitations of water use if suspicions are well founded. The waterworks must agree with the health authorities as to how to inform the public.

In certain water service emergencies, it may be necessary for a **rescue services authority** to coordinate the necessary measures, e.g. in the case of considerable flooding. In cases like these, the rescue services authority may found a command centre, with representatives from the various authorities and water service providers participating.

**Property owners** are responsible for water services on their property. A property owner connected to the waterworks network is responsible for the water service equipment on his/her property, i.e. the water pipes and sewers and various associated materials, all the way up to the mains connection. The property owner is also responsible that the activities on the property and the equipment therein do not cause problems for waterworks operation.

### 8.5 Informing the public during emergencies

It is primarily the waterworks management that informs others about the quality of the water during normal operations and of changes that may have come about due to emergency situations. If the quality of the water is substantially weakened (e.g. a water quality disruption or epidemic), the municipal health protection authorities are usually responsible for informing the public. In other serious emergencies, the rescue service handles public information services.

When water quality deteriorates, there should be clear lines of communication available whereby all those using the water can be informed of the situation. This can take place by phone, using a pre-planned call chain for informing the customers, or by mail. Announcements can also be made on the local radio, in newspapers and via the Internet. **There must be a plan in place for the best means of informing the public, considering the local circumstances.** In this way, an unexpected situation can quickly be brought under control. The waterworks can write up and save a sample letter informing its customers of an unusual situation which can quickly be changed to suit the occasion and sent out. Creating a sample letter ahead of time can also guarantee that no important information is left out of the message in the case of a real emergency.
• **Suspicion of a water epidemic:** Do not wait for confirmation of a water epidemic from the laboratory.

• Together with the health authorities, inform all of the water customers immediately of the potential water contamination.

• Decide with the health authority whether it is necessary to announce a ban on drinking water or instructions for boiling water before use.

• Begin necessary arrangements for procuring auxiliary water, should the need arise. Begin disinfection of drinking water to prevent spread of the epidemic.

• Assist the authorities in their efforts to determine the extent of the epidemic.

Problems at the waterworks can cause an emergency situation that requires assistance from other parties. For this reason, it is vital that the waterworks and the waterworks operators have the contact information of the most important parties easily available at all times (Appendix 5). These parties include:

• emergency centre
• health protection authorities and environmental authorities
• health centre
• local environment centre
• police and rescue services
• local radio and other media channels
• companies dealing in foodstuffs, hospitals and key players responsible for security measures or special units to which water is delivered.

• The waterworks should be well prepared for emergency situations, as it is responsible for the quality of the water. The best way to avoid problems is to perform careful, thorough maintenance.

• In disruptive situations at the waterworks, or in case of an epidemic, the health authorities are usually responsible for informing the public.

For further information on the maintenance and supervision of groundwater works, contact any of the following: the municipal health protection authorities, the local environment centres, the Finnish Environment Institute, the National Product Control Agency for Welfare and Health, and the Social Insurance Institution of Finland (KELA).
The Finnish literature is omitted in this list but can be found in the original Finnish version of this publication Pienten pohjavesilaitosten ylläpito ja valvonta, ISBN 952-11-2531-4 (pdf at www.environment.fi)


Appendix 1. Requirements and recommendations for the quality of potable water and its most commonly measured substance concentrations and characteristics

In Finland the quality requirements and recommendations for potable water conform with the EU Concil Directive 98/83/EC (implemented as Decrees 461/2000 for waterworks serving more than 50 persons and 401/2001 for facilities serving less than 50 persons). The parameters for potable water from waterworks serving more than 50 and less than 50 persons are as follows:

<table>
<thead>
<tr>
<th>Microbiological parameters</th>
<th>&gt; 50 pe or &gt;10 m³/d</th>
<th>&lt;50 pe or &lt; 10 m³/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Parametric value</td>
<td>Parametric value</td>
</tr>
<tr>
<td><em>Escherichia coli</em></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Enterococci</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical parameters</th>
<th>&gt; 50 pe or &gt;10 m³/d</th>
<th>&lt;50 pe or &lt; 10 m³/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Parametric value</td>
<td>Parametric value</td>
</tr>
<tr>
<td>Acrylamide</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Antimony</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Arsenic</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Benzene</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Boron</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bromate</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cadmium</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Chromium</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Copper</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Cyanide</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>1,2-dichloroethane</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Epichlorohydrin</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluoride</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Lead</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Mercury</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Nickel</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Nitrate</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Nitrite</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Pesticides</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Pesticides - Total</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Polycyclic aromatic hydrocarbons</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Selenium</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Tetrachloroethene and trichloroethene</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Trihalomethanes - total</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Chlorophenols, tot.</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Parameter</td>
<td>Parametric value</td>
<td>Parametric value</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Aluminium</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Ammonium</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Chloride</td>
<td>250</td>
<td>100</td>
</tr>
<tr>
<td>Clostridium perfringens (including spores)</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>COD₅₅O₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidisability</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Colour</td>
<td>Acceptable to consumers and no abnormal change</td>
<td>5</td>
</tr>
<tr>
<td>Conductivity</td>
<td>2500</td>
<td>&lt; 2500</td>
</tr>
<tr>
<td>Hydrogen ion concentration</td>
<td>&gt;6.5 and &lt; 9.5</td>
<td>6.5 – 9.5</td>
</tr>
<tr>
<td>Iron</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Manganese</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Odour</td>
<td>Acceptable to consumers and no abnormal change</td>
<td>No clear foreign odour</td>
</tr>
<tr>
<td>Sulphate</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Sodium</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Taste</td>
<td>Acceptable to consumers and no abnormal change</td>
<td>No clear foreign taste</td>
</tr>
<tr>
<td>Colony count 22 °C</td>
<td>No abnormal change</td>
<td></td>
</tr>
<tr>
<td>Coliform bacteria</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total organic carbon (TOC)</td>
<td>No abnormal change</td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>Acceptable to consumers and no abnormal change</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### RADIOACTIVITY

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parametric value</th>
<th>Parametric value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritium</td>
<td>100</td>
<td></td>
<td>Bq/l</td>
</tr>
<tr>
<td>Radon</td>
<td>300</td>
<td></td>
<td>Bq/l</td>
</tr>
<tr>
<td>Total indicative dose</td>
<td>0,1</td>
<td></td>
<td>mSv/year</td>
</tr>
</tbody>
</table>

Because the ground water in Finland is usually very soft with low alkalinity it is also recommended that the chloride concentration should be less than 25 mg/l and sulphate concentration less than 250 mg/l. The water may not be corrosive.
**Escarichia coli**

*Escarichia coli* or *E.coli* is a faecal indicator bacterium. One of its types (EHEC) is pathogenic. The Ministry of Social Affairs and Health has determined the maximum admissible concentration of *E.coli* in potable water to be 0 cfu/100 ml.

**Intestinal Enterococci**

The Ministry of Social Affairs and Health has determined the maximum admissible concentration of intestinal Enterococci in potable water to be 0 cfu/100 ml. In the event that Enterococci is found in well water, immediate measures should be taken to determine the cause and extent of the faecal contamination and to prevent health hazards (boiling of water before use, disinfectants, decontamination of the network).

**Arsenic**

Arsenic occurs naturally in the bedrock groundwater in the Tampere Region, Salla, and few other areas in Finland. The highest concentrations are approx. 1000 µg/l. Arsenic is a poisonous metallic element and potential carcinogenic.

**Fluoride**

Fluoride is naturally present in the groundwater, mainly in rapakivi granite areas in the regions of Kymenlaakso and Finland Proper, both in soil and bedrock. Excessive intake of fluoride can cause staining of teeth and fragility of bones.

**Nitrate nitrogen**

The Ministry of Social Affairs and Health has determined the maximum admissible concentration of nitrate nitrogen to be 11 mg/l (50 mg/l measured as nitrate). Nitrate can enter the water from fertilizers and as a result of dispersion and oxidation of nitrogenous substances. The median concentration of nitrate in natural state groundwater is 0.2 mg/l. In sand and moraine areas, the median is 2.5–5.2 mg/l in well water.

**Nitrite nitrogen**

The Ministry of Social Affairs and Health has determined the maximum admissible concentration of nitrite nitrogen to be 0.15 mg/l (0.5 mg/l measured as nitrite). Nitrite is formed as a result of incomplete oxidation of nitrogen compounds, and its presence in potable water always indicates bacterial activity either at the water intake unit or in the water pipes.

**Alkalinity**

Alkalinity normally originates from bicarbonate in water. It affects the buffer capability of water i.e., its ability to resist changes in pH. The higher the alkalinity, the better the ability to resist changes in pH. In Finland, the alkalinity of groundwater is normally low (less than 0.6 mmol/l) but in the limestone areas it can be over 3 mmol/l. The unit of alkalinity is mmol/l. Low alkalinity adds to the risk of corrosion.
Aluminium
Aluminium most commonly occurs in the solid matter present in clay minerals but can also be found in solution and colloid forms in acidic sulphate soil. Aluminium has not been proven to pose health risks. It can taint the taste of water and is often present in cases of clay turbidity.

Chloride
The Ministry of Social Affairs and Health has determined the maximum admissible concentration of chloride to be 250 mg/l. This level is based on the assessed threshold concentration above which tainting of the taste of water is likely to occur. To prevent corrosion problems, it is recommended that the concentration is less than 25 mg/l. Due to the effect of the sea, high chloride concentration occurs in coastal areas. Other causes of high chloride concentration include the use of salt for de-icing of roads in winter, and wastewater emissions. In its natural state, the chloride concentration of groundwater varies between < 1 and 60 mg/l. In sand and moraine areas, the median of chloride concentration is 4.5–9.0 mg/l in well water.

Ammonium nitrogen
The Ministry of Social Affairs and Health has determined the maximum admissible concentration of ammonium nitrogen in potable water to be 0.4 mg/l (0.5 mg/l measured as ammonium). Ammonium enters water as a decay product of nitrogenous organic substances and due to fertilizers, industrial operation, and wastewater. In its natural state, the ammonium nitrogen concentration of groundwater is 6 µg/l.

Manganese
The Ministry of Social Affairs and Health has determined the maximum admissible concentration of manganese to be 50 µg/l. Relatively high manganese concentration is common in Finnish groundwater, often co-occurring with iron. In its natural state, the manganese concentration of groundwater varies between < 0.02 and 3.9 mg/l while the median is < 0.02 mg/l. In sand and moraine areas, the median of manganese concentration is < 0.02 mg/l in well water. High manganese concentration taints the water and causes staining of bathroom and kitchen equipment and laundry.

Iron
The Ministry of Social Affairs and Health has determined the maximum admissible concentration of iron to be 200 µg/l. Dissolved iron occurs commonly in Finnish groundwater, especially in clay-covered ridges with low oxygen concentration and bank filtration plants. The iron concentration of natural-state groundwater varies between < 0.02 and 77 mg/l while the median is 0.035 mg/l. In sand and moraine areas, the median of iron concentration is 0.2 mg/l in well water. The problems caused by high iron concentration in potable water are technical and aesthetic: iron forms rust layers in bathroom and kitchen equipment, leaves rust stains in laundry, and taints the water.
Sulphate
The Ministry of Social Affairs and Health has determined the maximum admissible concentration of sulphate to be 250 mg/l but, in order to prevent corrosion problems, the recommended target level is 150 mg/l. High sulphate levels are observed in the groundwater particularly in coastal areas, which reflects the influence of salts in the ancient sea water. Geological factors and airborne sulphur deposition also cause increased sulphate concentration in certain areas. In its natural state, the sulphate concentration of groundwater varies between 0.1 and 280 mg/l while the median is 3.8 mg/l. In sand and moraine areas, the median of sulphate concentration is 10–16 mg/l in well water. In anoxic conditions, bacterial activity can lead to the reduction of sulphate to hydrogen sulphide, which is observed as bad smell and taste.

$\text{KMnO}_4$ value
$\text{KMnO}_4$ value (permanganate value) is primarily used to determine the amount of organic matter, mainly humus, in water. A high $\text{KMnO}_4$ value is normally reflected as a high degree of colouration.

$\text{COD}_{\text{Mn}}$, $\text{O}_2$
The same as permanganate, but measured as oxygen content.

Coliform bacteria
The presence of coliform bacteria indicates faecal contamination. Except for $E.\text{coli}$, coliform bacteria can originate from other sources than human or animal excrement, including plants, soil, and industrial wastewaters. Therefore, the presence of coliform bacteria in water does not always mean that faecal contamination has taken place but simply reflects the general pollution level of the water, resulting from the leakage of surface water into the groundwater, or similar.

Radon
Radon is a radioactive gas that is found especially in the granite areas of Southern Finland. Excessive exposure has been linked to the development of lung cancer.

pH
pH is used to measure the acidity of water. The lower the pH, the higher the acid content of the water. According to quality recommendations, the targeted pH level is 6.5–9.5. The pH of groundwater varies between 3.6 and 9.0 inside Finland due to geological factors and the load caused by human activities. In sand and moraine areas, the average pH is 6.3–6.5.

Electrical conductivity
Electrical conductivity indicates the salt content of the water. Substances that cause increased conductivity include chloride, sulphate, sodium, hardness salts, and bicarbonate. The Ministry of Social Affairs and Health has determined the targeted...
level of conductivity of potable water to be under 2500 µS/cm. In its natural state, the conductivity of groundwater varies between 3 and 590 µS/cm while the median is 42 µS/cm. In sand and moraine areas, the median level of conductivity is 140–200 µS/cm in well water.

**Turbidity**
The turbidity of water is often caused by clay, iron, or colloidal compounds, and does not in itself have negative health effects. In well water, the median of turbidity is 1 FTU.

**Colour**
The Ministry of Social Affairs and Health has determined the maximum admissible intensity of colouration of potable water to be 5 Pt mg/l. The colouration of water is generally caused by organic compounds such as humus acids, but metals such as iron and manganese can also cause increased intensity of colouration.

**Total organic carbon (TOC)**
Although measured differently from the KMnO₄ value, TOC is also used to indicate the organic matter content of water. TOC provides a more exact measurement of water’s organic matter content than KMnO₄, because the latter may also take into consideration the oxidation of inorganic compounds, such as iron. No actual limit value has been set for drinking water’s TOC content but an unofficial target value of concentration is < 2 mg/l. The TOC concentration of Finnish lake water is normally between 5 and 15 mg/l. The TOC concentration of uncontaminated groundwater is normally 0.5 – 1.0 mg/l. In the event that surface water is mixed with groundwater, for example as a result of bank filtration, the TOC concentration of the groundwater can be 3.0–5.0 mg/l.

**Uranium**
Uranium normally occurs in the same areas as radon. It is a radioactive compound but the negative health effects of the concentrations found in Finland are related to its chemical characteristics. Uranium can obstruct the normal operation of the kidneys. The WHO’s guideline value for uranium is 15 µg/l on the basis of its toxicity and 110 µg/l on the basis of its radioactivity.

**Dissolved oxygen**
The concentration of oxygen dissolved in the groundwater varies greatly due to geological and other environmental factors. In addition, in the event that biologically decomposing matter leaks into the groundwater basin, microbes quickly consume the dissolved oxygen in the water. In sand and gravel formations such as ridges, groundwater’s oxygen content is normally between <1.0 and 12.0 mg/l, and between 0–5.0 mg/l in clay and silt covered sand formations. Under anoxic conditions,
the concentration of iron, manganese, and similar dissolved in the groundwater increases.

**Redox**
Redox potential or reduction/oxidation potential is used to indicate whether the conditions of the groundwater basin are reducing or oxidising. When the redox potential is low, the conditions are reducing and the elements occur in their reduced forms (e.g., iron is present in soluble Fe$^{2+}$ form). In sand and gravel formations such as ridges, groundwater’s redox potential is normally -320 - +800 mV, and -320 - +460 mV in clay and silt covered sand formations.

**Hardness**
The hardness of water is principally due to calcium and magnesium in the water, but iron and manganese also cause hardness. In Finland, groundwater is most often soft, but in limestone areas the level of hardness can be quite high. High levels of hardness can lead to the formation of boiler scale in hot water systems, while low levels of hardness add to the risk of corrosion. The unit of hardness is mmol/l but in water services, degrees of German hardness (°dH) are also used.
Appendix 2. The quality of well water in Finland

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dug wells</th>
<th>25 - 75% = the middle 50% of investigated water samples.</th>
<th>Bedrock wells</th>
<th>25 - 75% = the middle 50% of investigated water samples.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>median</td>
<td></td>
<td>median</td>
<td></td>
</tr>
<tr>
<td>Requirements</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Escherichia coli [cfu/100 ml]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Enterococcus (faecal) [cfu/100 ml]</td>
<td>0</td>
<td>0-1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Arsenic, As [µg/l]</td>
<td>0.14</td>
<td>0.35</td>
<td>0.16</td>
<td>1</td>
</tr>
<tr>
<td>Fluoride, F [mg/l]</td>
<td>&lt;0.1</td>
<td>&lt;0.1-0.2</td>
<td>0.37</td>
<td>&lt;0.1-1</td>
</tr>
<tr>
<td>Nitrate, NO₃ [mg/l]</td>
<td>5.2</td>
<td>0.8-16</td>
<td>1.1</td>
<td>0.4-8</td>
</tr>
<tr>
<td>Nitrite, NO₂ [mg/l]</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Uranium, U [µg/l]</td>
<td>0.09</td>
<td>0.85</td>
<td>0.64</td>
<td>13</td>
</tr>
<tr>
<td>Quality recommendations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coliform bacteria [cfu/100 ml]</td>
<td>6</td>
<td>0-34</td>
<td>1</td>
<td>0-4</td>
</tr>
<tr>
<td>Aluminium, Al [µg/l]</td>
<td>30</td>
<td>&lt;10-100</td>
<td>10</td>
<td>&lt;10-30</td>
</tr>
<tr>
<td>Ammonia, NH₄ [mg/l]</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Chloride, Cl [mg/l]</td>
<td>7</td>
<td>3-15</td>
<td>10</td>
<td>4-21</td>
</tr>
<tr>
<td>Manganese, Mn [µg/l]</td>
<td>20</td>
<td>&lt;20-60</td>
<td>20</td>
<td>&lt;20-100</td>
</tr>
<tr>
<td>Iron, Fe [µg/l]</td>
<td>180</td>
<td>70-510</td>
<td>130</td>
<td>50-390</td>
</tr>
<tr>
<td>Sulphate, SO₄ [mg/l]</td>
<td>16</td>
<td>9-25</td>
<td>17</td>
<td>10-27</td>
</tr>
<tr>
<td>Potassium permanganate value [mg/l]</td>
<td>5</td>
<td>3-10</td>
<td>4</td>
<td>2-9</td>
</tr>
<tr>
<td>Radon, Rn [Bq/l]</td>
<td>12</td>
<td>38</td>
<td>138</td>
<td>311</td>
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<tr>
<td>pH</td>
<td>6.6</td>
<td>6.3-6.9</td>
<td>7.2</td>
<td>6.5-7.9</td>
</tr>
<tr>
<td>Conductivity [µS/cm]</td>
<td>190</td>
<td>120-290</td>
<td>280</td>
<td>260-380</td>
</tr>
<tr>
<td>Conductivity [mS/m]</td>
<td>19</td>
<td>12 - 29</td>
<td>28</td>
<td>26 - 38</td>
</tr>
<tr>
<td>Turbidity [NTU]</td>
<td>1</td>
<td>0.44-3.4</td>
<td>0.7</td>
<td>0.3-2.1</td>
</tr>
<tr>
<td>Colour</td>
<td>&lt;5</td>
<td>&lt;5-20</td>
<td>&lt;5</td>
<td>&lt;5-15</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkalinity [mmol/l]</td>
<td>0.7</td>
<td>0.41-1.3</td>
<td>16438</td>
<td>0.77-2.5</td>
</tr>
<tr>
<td>Dissolved oxygen [mg/l]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total hardness [mmol/l]</td>
<td>0.65</td>
<td>0.4-0.97</td>
<td>0.67</td>
<td>0.46-1</td>
</tr>
<tr>
<td>Corrosion index</td>
<td>1.32</td>
<td>3.35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3 Chemicals in water treatment

- sodium hypochlorite
- potassium hypochlorite
- lye or sodium hydroxide
- soda ash or sodium carbonate
- sodium hydrogen carbonate
- lime or calcium hydroxide
- limestone
- dolomite
- activated carbon

Only chemicals which are suited for potable water treatment may be used for the treatment of water. When ordering chemicals always mention that it will be used at waterworks.

When using chemicals read carefully the directions on the packages and eventual other directions. These directions should be strictly followed. The chemicals should be stored in their original packages and directives of storage should be followed. The packages must be carefully sealed.

Sodium hypochlorite
Sodium hypochlorite is used for disinfection of potable water (page 30). Its chemical formula is NaClO.

Sodium hypochlorite is delivered as a water solution. The active chlorine content in Finland is 10, 13 or 15 %. The solution is yellowish, basic (pH 12-14) and has a tangy smell. It contains sodium hypochlorite, sodium hydroxide and often also sodium chloride. It is a strong oxidant, corrodes weakly metals, dissolves leather and some plastics, textiles, steel and concrete. Sodium hypochlorite increases the pH and alkalinity of water.

Sodium hypochlorite is always dosed as an aqueous liquid. Piston and membrane pumps are suitable.

If too much sodium hypochlorite is dosed to the water it causes strong irritation, damage and inflammation to the user. Caustic solutions weaker than 5 % do not usually cause severe damage to tissues. During vomiting the chemical may enter the lungs causing inflammation and pulmonary edema.

If too little sodium hypochlorite is dosed to the water, it won’t be able to disinfect the water.
During storage sodium hypochlorite is gradually decomposed. Its stability decreases at higher concentrations, pH less than 11, by effect of light, by increased temperature and if the solution contains iron, manganese, copper, nickel or cobalt. When the product is correctly stored and it has not been diluted the active chlorine concentration decreases at a temperature of 20 °C as follows:
- 10 % solution – approximately 0.5 percentage units/week
- 15 % solution – approximately 0.7 percentage units/week

At 5-10 °C the concentration decreases in both solutions approximately 0.3 percentage units/week. Figure 1 presents the decrease of the active chlorine concentration in a sodium hypochlorite solutions as a function of time.

The concentration of the sodium hypochlorite solution should be checked when taken into use. Only the need for 2 – 3 months of the chemical should be stored. Sodium hypochlorite should be stored away from organic material.

When planning for the chlorination system it is important that the dosage pump is stopped automatically if the water flow is stopped, e.g. when the main pump stops.

Inhaling sodium hypochlorite irritates the nose and throat. Even droplets of week solutions can irritate the skin. It is important to take care of the safety of the personnel according to the manual of the chemical.

When storing sodium hypochlorite note:
- It should be stored in clean vessels and the feed tank should be placed in a protective vessel.
- It should be stored in a cool place and protected from light.
- The ground should be protected against leaks.
- Acids and chemicals which react like acids may not be stored in the same space with sodium hypochlorite.
- In wintertime it should be noted that sodium hypochlorite crystallizes at -30 °C. Concentrated solutions stand freezing better than week solutions.

Figure 1. The active chlorine concentration in a sodium hypochlorite solutions as a function of time at 10 and 20 °C. Two different initial concentrations (200 g/l and 120 g/l) are shown.
**Calcium hypochlorite**
Calcium hypochlorite is mainly used for occasional disinfection of pipes, pools and vessels. Its chemical composition is Ca(ClO)$_2$.

Calcium hypochlorite is delivered as a powder or tablets. The free active chlorine content is usually 60 - 70%.

Calcium hypochlorite is usually not used at waterworks as it should first be dissolved into water, but it could be used for instances at swimming pools and in instances when certain volumes of water is disinfected occasionally. Dosing of calcium hypochlorite directly into wells is not recommended because it should be slowly dissolved and the circumstances in wells are not suitable for this. The tablets should be dissolved in warm flowing water. (Calcium hypochlorite dissolves poorly in water at temperatures below 5 ℃.)

Calcium hypochlorite is a very powerful oxidant and should be stored in a sealed container in a dry and cool place. If it comes in contact with organic matter, e.g. oily rags, it can cause a fire.

Calcium hypochlorite solutions are corrosive and should be stored in corrosive resistant materials like glass, titanium, ceramics and most plastics. The solution has usually 1-2 % free chlorine.

In higher concentrations calcium hypochlorite is harmful for humans and should be handled carefully. It can cause burns and is dangerous inhaled.

The shelf time of calcium hypochlorite is approximately six months after the container has been opened. It is very unstable when stored as a solution.

Calcium hypochlorite used in potable water treatment is markedly different from the product used for whitening.

**Calcium hypochlorite used for swimming pools may contain cyanides and may not be used in potable water treatment.**

**Markings for sodium and calcium hypochlorite:**

- **Figure 2. Corrosive (C)**
- **Figure 3. Environmentally harmful (N)**
Lye or sodium hydroxide

Lye is used for neutralizing acidity. Its chemical composition is NaOH.

Lye is a white, odourless and non volatile solid substance. As a 50 % solution it is liquid at room temperature. It does not burn but reacts strongly with water and many other compounds. The reactions produce so much heat that inflammable materials nearby may ignite. Lye is very corrosive and corrodes metals like aluminium, magnesium and zinc liberating hydrogen gas which can explode.

When lye is dissolved into water much heat is developed. The solution may start to boil and cause splatter, so much care should be taken when lye is dissolved.

Lye should be stored in a well ventilated, cool and dry space. The building material should be of sufficient strength. Lye should be stored separated from acids, water, metals, organic halogenated compounds and inflammable materials.

Lye is usually fed as a 1 – 10 % solution with a piston or membrane pump. The strength of the solution should be such that over dosage is prevented. The lower the flow the weaker the solution should be. A strong solution is diluted by pouring the strong solution into water, not vice versa.

When handling lye, protective gloves and goggles with face shield should be used. The strong solution burns the skin and is dangerous when inhaled.

Much care should be taken when using lye because excessive dosage may be very harmful to the health. The pH meter should be calibrated and checked regularly and the lye pump may never stay on if the water pump is stopped.

Markings for lye:

![Figure 4. Corrosve (C).]

Soda ash or sodium carbonate

Soda ash is used for neutralizing acidity and increasing alkalinity. Its chemical composition is Na$_2$CO$_3$.

Soda ash is a white, dusting, odourless powder. It dissolves easily in water and forms a caustic solution. It is very hygroscopic and clods easily and should not be stored more than six months.

Soda ash is not as corrosive as lye and it is recommended to be used instead for lye for safety reasons. Also over dosage is not as detrimental as over dosage of lye. It is, however, a more expensive chemical.
Good ventilation is needed when handling soda ash. Dust formation should be avoided and the eyes should be protected. Soda ash irritates the eyes. It should be stored in a dry place. It may not be stored together with acids or metals (aluminium and zinc).

Soda ash is dosed as a 1 – 10 % solution with piston or membrane pumps.

When handling soda ash protective gloves and goggles with face shield should be used.

**Hydrosodic carbonate or sodium bicarbonate**

Hydrosodic carbonate is used for neutralizing acidity and increasing alkalinity. Its chemical composition is $\text{NaHCO}_3$.

Hydrosodic carbonate is a white, dusting, odorless powder. It dissolves readily in water and forms a caustic solution. It is less caustic than soda ash and thus safer to use but more expensive.

- It is sold in 25 kg bags and 1000 kg on pallet.
- It is dosed similarly to soda ash.

When handling hydrosodic carbonate protective goggles should be used.

**Lime or calcium hydroxide**

Lime is used for neutralizing acidity and increasing alkalinity. Its chemical composition is $\text{Ca(OH)}_2$.

Lime is a almost white, strongly dusting and smearing powder. It is sold in bulk and sacks. It is relatively poorly soluble in water and is usually fed as lime milk or as a saturated solution (lime water) at waterworks.

The feeding equipment is rather complicated and expensive. In waterworks it comprises either of a lime silo or bag feeding unit, mixing vessel, saturator and head tank. In small groundwater plants it is not recommended to use lime for alkalization.

Calcium oxide or quicklime reacts violently with water. When dissolving it should be slowly added to the water (slaking of lime). It is not used at small water works.

When handling lime protective gloves and goggles with face shield should be used.

**Limestone**

Limestone is calcium carbonate. It is used as grains or coarse-ground grist at waterworks for neutralizing acidity and increasing alkalinity. Its chemical composition is $\text{CaCO}_3$.

The grain size classes used at water works are: 2-5, 3-5, 5-8 and 8-16 mm. The finer the grain the more effective it is but there is a risk of clogging if the water contains iron.

It is safe to use limestone for alkalisation because the pH is automatically set to 7.5 – 8.5 at equilibrium.
During transportation limestone is somewhat crushed. It should be backwashed before taking into use. In some cases this can be rather tedious. Limestone grains should also be disinfected before taking into operation either with a hydrogen peroxide or sodium hypochlorite solution. The solution should contain either 0.5 g of hydrogen peroxide per litre or 10 mg chlorine per litre. The treatment time is 3-6 hours after which the grains are carefully flushed. The limestone used at water works in Finland should comply to standard SFS-EN 1018.

**Dolomite**

Dolomite is calcium magnesium carbonate and is used similarly to limestone. Its chemical composition is CaMgCO$_3$.

Dolomite reacts slower and has higher capacity for carbon dioxide removal than limestone. It increases the calcium concentration less than limestone. In other respects it is handled similarly to limestone.

**Activated carbon**

Activated carbon is produced by heating organic material. It contains mainly carbon and is very adsorptive. It is sold as granules or powder. It has a very large internal surface because of its porous structure and is thus very adsorptive.

The quality, i.e. its origin (peat, wood, coconut), specific surface, pore distribution, chemical surface properties (depending on the burning process) and ash content effect its ability to remove harmful compounds. The activated carbon should always be chosen with respect to the water quality and the compounds to be removed because of the differences between different carbons.

Activated carbon is a staining compound but otherwise handling does not pose any risks.
Appendix 4. Meters and analytic instruments

A number of meters and on-line instruments are needed for the self control of water works. The most important measurements the operator easily can perform without any specific training are:

- pH
- chlorine concentration
- temperature
- alkalinity
- turbidity
- colour
- iron concentration
- conductivity
- COD (permanganate number)
- Flow

pH
The pH or acidity can be measured in many ways. The most simple is the pH-paper, which is dipped in the water to be examined and its colour is compared to a colour scale.

pH can also be measured with a comparator. A small vial or cuvette is filled with a water sample, a indicator chemical is added and the colour thus formed is compared to a colour scale or colour of a colour disk. The specific colour of the water may disturb the measurement. A colorimeter measures the colour electronically and is thus more exact and the specific colour of the water can be compensated.

Measurements with an electric pH probe is the most exact method and is used whenever continuous measurements have to be performed, e.g. for control and regulation of alkalisation. There are many kinds of meters from simple pen-type devices to very exact laboratory meters and process meters. If the pH do not need to be regulated at the water works a simple device is enough, provided that it is maintained carefully according to the manual.

The choice of the electrode is important because potable water needs a different electrode from the kind used at wastewater treatment plants. The producers of electrodes give advice in that respect. The maintenance and storage of the electrode should be strictly made according to the manual. Over 90 % of faulty results are due to mistreatment of the electrode.

When measuring especially clean samples one should not wait too long for the results to equalize as carbon dioxide from the atmosphere dissolves into the sample and changes its pH.

It is very important to calibrate the meter in order to achieve correct results. For calibration a solution with a known pH is needed. The best way to calibrate the meter
is to use two standard solutions with a pH on both sides of the pH of the sample. Usually pH 5 and 8 or 9. The calibration solutions should be fresh and may be used only once for each calibration.

Because the pH value depends on the temperature, the temperature of calibration solutions should be the same as the sample temperature. Some pH probes have a temperature probe to compensate for the temperature difference but the result is not as exact as when both the sample and calibration liquid are at the same temperature. Some meters have a separate dial for temperature compensation. The probes are nowadays combined with an internal reference electrode. Some laboratory meters use a separate reference electrode.

*Calibration and cleansing and inspection of the probes of continuous measurement devices should be done regularly.*

It is necessary to have pH measurement in the alkalinisation process. When alkalinisation is automatically performed, the pH-meter is on-line and follows the pH of the alkalinized water. A signal from the pH-meter goes to the regulation unit, which regulates the dosage device, e.g. the frequency of the membrane stroke of the pump or the position of the regulating valve.

**Chlorine**

The residual chlorine concentration has to be measured to assure the hygienic properties of the water when chlorination with sodium hypochlorite or chloramine chlorination is adopted. The measurement should be made as soon as possible after sampling, in less than one our.

The device can be a simple colour comparator, colorimeter, spectrophotometer or electronic meter. The strength of the chlorination solution (sodium hypochlorite) can also be measured in the laboratory by titration, but special skill is needed.

For small water works a colorimeter and ready-to use powder pillows or ampoules of reagents or hand held electronic meters are very suitable. When performing the measurement it is very important to follow the instructions: temperature and reaction time. If the result is very near or exceeds the upper limit of the measuring range the sample should be diluted with distilled water. The result is then multiplied with the dilution factor.

**Temperature**

The temperature can be measured with a digital measurement device. This is used when analyzing for concentrations in which the temperature affects the colour formation or other reactions (e.g. residual chlorine, in some cases pH). Many pH and conductivity probes include a temperature probe. The result should occasionally be checked with a precision temperature indicator.
For on-line measurements electronic temperature probes are used. An electric signal is fed to a display unit. Also these should be controlled occasionally.

**Alkalinity**
Alkalinity can be measured by titration. A colour indicator is added to the sample and a basic solution is added by a precision pipette or burette until a colour change occurs. According to the amount of basic solution and its strength added the alkalinity can be calculated. There are ready-to-use packages on the market, which contain a measurement cylinder, indicator solution, alkaline solution and precision pipette. By counting the number of alkaline solution droplets added to the sample until the colour change occurs the alkalinity can be read from a table. During the procedure the sample should be stirred effectively.

There are also continuous measurement instruments for alkalinity measurements but these are rarely used on small water works.

**Turbidity**
Turbidity is measured electronically by either measuring the optical scattering of the sample or the reduction in light intensity through the sample. The unit of turbidity is FTU or NTU. 1 FTU = 1 NTU. There are both laboratory instruments and continuous on-line instruments for turbidity.

Continuous measurement of turbidity – together with pH and residual chlorine - can be considered as one of the most important measurements for monitoring the water treatment process and the quality of the treated water. Much consideration should be given to the maintenance and calibration of the instrument. Fouling of the probe should be checked regularly and the instrument calibrated with standard solutions. Modern probes have often two beams and detectors for the compensation of errors caused by fouling. The probes can also include wipers or other mechanical cleaning devices which should be monitored.

Turbidity measurements can be disturbed by air bubbles. One time measurements could be made in such a way that the reading is always taken after a certain time (e.g. 30 seconds). In this way the readings will be comparable to each other.

**Colour**
The colour is easily measured with a colorimeter or comparator. The colour indicates often the amount of humic acids but also iron affects the colour value.

**Iron and manganese**
Iron and manganese can be measured with general colorimeters or photometers. Also specific testing instruments are available. In all cases the iron (or manganese) will react with a colour forming reagent and the colour intensity is measured. If the result is very near or exceeds the upper limit of the measuring range the sample should be diluted with distilled water. The result is then multiplied with the dilution factor.
Conductivity
The specific conductivity measures the free ion (salts) concentration in water. These ions are chloride, sulphate, bicarbonate, sodium, potassium and magnesium. The increase of conductivity can mean leakage in reverse osmosis (RO) devices. The main use of conductivity measurement is at RO or nanofiltration plants.

The instrument comprises of an electric resistance meter and a probe. It is important to clean the probe regularly. Because conductivity depends on temperature, the instruments often incorporate temperature probes with which the temperature compensation can be made either manually or automatically.

Conductivity measurement can be combined with pH measurements in a common unit.

Flow
The water flow at the water works can be measured with mechanical and electronic devices. Especially the magnetic flow meter is simple, reliable and exact. Depending on the placement of the probe it can be fouled in time and should be cleaned. Especially when there is iron in the water and the probe is situated before the iron removal unit, the measurement should be inspected occasionally.
Appendix 5. Disquisition of waterworks and manual of maintenance

Disquisition of waterworks

<table>
<thead>
<tr>
<th>INFORMATION ON WATERWORKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name and id-code of plant</td>
</tr>
<tr>
<td>Name of water intake</td>
</tr>
<tr>
<td>Building and reparation years of water intake</td>
</tr>
<tr>
<td>Number of connections</td>
</tr>
<tr>
<td>Number of water users</td>
</tr>
<tr>
<td>Other users than households and their number</td>
</tr>
<tr>
<td>☐ farms _______</td>
</tr>
<tr>
<td>☐ cattle farms _______</td>
</tr>
<tr>
<td>☐ schools _______</td>
</tr>
<tr>
<td>☐ nursing homes and comparable _______</td>
</tr>
<tr>
<td>☐ hotels and comparable _______</td>
</tr>
<tr>
<td>☐ food industry / production _______</td>
</tr>
<tr>
<td>☐ other industry _______</td>
</tr>
<tr>
<td>☐ military areas _______</td>
</tr>
<tr>
<td>☐ camping sites or comparable _______</td>
</tr>
<tr>
<td>☐ restaurants or comparable _______</td>
</tr>
<tr>
<td>☐ others _______</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual flow to the network [m³/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily average water consumption [m³/d]</td>
</tr>
<tr>
<td>Maximum production capacity [m³/yr]</td>
</tr>
<tr>
<td>Types and depth of wells</td>
</tr>
<tr>
<td>Name and number of groundwater basin</td>
</tr>
</tbody>
</table>

Information on water works operator

<table>
<thead>
<tr>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
</tr>
<tr>
<td>Zip code and post office</td>
</tr>
<tr>
<td>Phone(s)</td>
</tr>
<tr>
<td>E-mail address</td>
</tr>
<tr>
<td>Name of deputy operator</td>
</tr>
<tr>
<td>Address</td>
</tr>
<tr>
<td>Zip code and post office</td>
</tr>
<tr>
<td>Phone(s)</td>
</tr>
<tr>
<td>E-mail address</td>
</tr>
</tbody>
</table>

When have the operator passed the qualification test ___________________________
Other personnel who have passed the qualification test __________________________
The water works should have
- Drawings and descriptions of the waterworks including
  - Wells
  - Water treatment system and its operation
  - Water treatment units (e.g. equipment cards)
  - Units of the water pipe network
- Permit for water abstraction and control program
- Copy of groundwater protection plan (if made) and follow-up reports of protection plan
- Hydrotechnical maps of groundwater basin (if available)
- Data on other possible measures to protect the groundwater basin
- List of risk factors at the groundwater basin with a map where they are indicated
- Copy of security plan
- Results from official control samples for at least the ten preceding years
- Results from the control analyses made by the plant for at least ten preceding years
- User complaints given in writing
- Information on water treatment: chemical dosages, dilutions and guidelines for dilution
- Information on chemicals used and their security instructions
- Instructions for start-up of plant and measures in case of grave malfunctions
- Information of maintenance ordered from external operators and maintenance contracts
- Contact information for maintenance and repair and information on maintenance performed to equipment
- Information on spare parts in stock and spare parts suppliers
- Information on maintenance of the network with dates
- Information on auxiliary power
- Information of planned maintenance and reparation

Maps and their annexes should include:
- Operation area
- Groundwater basin
- Sizes and materials of water pipes and their year of installation
- Valves, purge valves, air release valves and fire hydrants
- Volumes, placement and building years of water tanks and reservoirs
- Connections to other systems
- Placement of booster stations and pressure (normal/maximum)
- The most critical users when considering water pressure
- Sampling and control points

Are there other wells or water intakes at the same groundwater basin? How are the nearest wastewaters treated (preferably also on the map)
Contact list in case of problems

<table>
<thead>
<tr>
<th>TITLE</th>
<th>NAME</th>
<th>PHONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator in charge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deputy operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance person for network/ person responsible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rescue department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Police</td>
<td></td>
<td></td>
</tr>
<tr>
<td>emergency exchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health authority in the municipality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Person responsible of wastewater treatment in the area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designer of waterworks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrician</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plumber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reparation of pumps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals provider</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water laboratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterworks expert (e.g. from other plant)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power plant and its on-call duty</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pharmacy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Person responsible for equipment (e.g. UV-equipment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment suppliers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurseries, schools and corresponding institutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other waterworks in the neighbourhood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local press and radio</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**General operation and maintenance instruction for water works**

In the following examples of the operations which should be included in the maintenance program, are presented. The maintenance operations vary from plant to plant which should be taken into consideration when planning the program. The responsible persons should also be noted in the maintenance plan if there are more persons performing the maintenance.

The information on the maintenance protocol and results could be useful also in the future and should be written down carefully. Official control information should be carefully saved and should be easy to find and understand.

**When a control visit to the plant is made:**
- Check the process operation
- Check all the equipment
- Check all the meters
- Note possible disturbances and correct them
- Write down all findings and measures in an operation diary.

### Things to be checked weekly

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Organoleptic check of water: clearness, odour, taste and colour (weekly or daily)</td>
</tr>
<tr>
<td>2.</td>
<td>Read main water meter at each visit. For controlling water leakage also the nocturnal water consumption can be used. It should be checked during a couple of consecutive nights.</td>
</tr>
<tr>
<td>3.</td>
<td>Read all water meters at each visit to the plant.</td>
</tr>
<tr>
<td>4.</td>
<td>Measure water temperature. It is useful to measure the temperature weekly but it is beneficial to examine the long term variations too. A marked difference between autumn and spring indicates that surface water can leak into the groundwater.</td>
</tr>
<tr>
<td>5.</td>
<td>Check the network pressure.</td>
</tr>
<tr>
<td>6.</td>
<td>Note the chemical feed. (Always when adding chemicals)</td>
</tr>
<tr>
<td>7.</td>
<td>Check the operation of the pumps and write down the flows and/or runtimes.</td>
</tr>
<tr>
<td>8.</td>
<td>Check the operation of the equipment: chemical pumps, filters, valves…</td>
</tr>
<tr>
<td>9.</td>
<td>Clean and calibrate pH probes and other probes according to manual.</td>
</tr>
<tr>
<td>10.</td>
<td>Read runtime counters (e.g. UV-equipment).</td>
</tr>
<tr>
<td>11.</td>
<td>Check the disinfection process.</td>
</tr>
<tr>
<td>12.</td>
<td>Check the pressures in the plant, e.g. sand filtration units.</td>
</tr>
<tr>
<td>13.</td>
<td>Check and if necessary clean the interior of the plant.</td>
</tr>
<tr>
<td>14.</td>
<td>In wintertime keep the well lids free of snow and assure that ventilation of the wells is safe.</td>
</tr>
<tr>
<td>15.</td>
<td>Lock the door every time when leaving the plant.</td>
</tr>
<tr>
<td>16.</td>
<td>Secure the operation of the alarm systems and the locks.</td>
</tr>
<tr>
<td>17.</td>
<td>Check the surroundings of the water works. Risk factors as abandoned vehicles and household appliances should be removed immediately</td>
</tr>
</tbody>
</table>
Things to be checked more often than once a year

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>18.</td>
<td>The water quality should be controlled at least annually but at least according to the Decree. The health authority takes the official control samples. It is good practice to have own quality control or operational control at the plant.</td>
</tr>
<tr>
<td>19.</td>
<td>The power consumption should be written down.</td>
</tr>
<tr>
<td>20.</td>
<td>The groundwater level should be controlled at least monthly, during draught even more often. The level can be measured from the wells and groundwater pipes</td>
</tr>
<tr>
<td>21.</td>
<td>If the plant has a standby well it should be tested at least twice a year.</td>
</tr>
<tr>
<td>22.</td>
<td>The constructions of water reservoirs or tanks should be checked 3 – 12 times a year. Also the inside of the tanks should be controlled occasionally.</td>
</tr>
<tr>
<td>23.</td>
<td>In autumn and early spring one should control that rain water and melting water is led away from the well and do not seep directly into it.</td>
</tr>
<tr>
<td>24.</td>
<td>Check the water analysis and compare them to earlier results. When achieving the results one have to look at the whole picture of the water quality. Does it comply to the quality requirements and recommendations? Is it necessary to enhance water treatment?</td>
</tr>
<tr>
<td>25.</td>
<td>The suitability of the chemicals for potable water treatment has to be controlled when ordering and receiving them.</td>
</tr>
<tr>
<td>26.</td>
<td>The pumps have to be served at certain intervals. The suitable interval is stated in the service manual.</td>
</tr>
<tr>
<td>27.</td>
<td>The dosing equipment and other equipment should be cleaned according to the manuals. (Usually either weekly, monthly or annually)</td>
</tr>
<tr>
<td>28.</td>
<td>The surface of slow sand filters should be scraped after 6 to 12 months.</td>
</tr>
<tr>
<td>29.</td>
<td>The backwashing or flushing of activated carbon filters, membrane filters and other filters according to manuals and needs.</td>
</tr>
<tr>
<td>30.</td>
<td>The time used for flushing and backwash water amount and time should be written down.</td>
</tr>
<tr>
<td>31.</td>
<td>The dosing equipment should be controlled periodically.</td>
</tr>
<tr>
<td>32.</td>
<td>The deposits formed during hypochlorite chlorination should be removed and the pump heads, screens and foot valves cleaned. Deposits are formed especially in the pipes and pumps. The operation of valves must also be controlled. The sieve and foot valve in the hypochlorite tank should be controlled. It is good practice to regularly clean the system (according to the instructions of the designer).</td>
</tr>
</tbody>
</table>
## Things to be checked annually

33. The condition of the well should be checked.  
The lids, insulation, inside seaming and seals have to be in good condition, the concrete well ring may not fissure and they have to be correctly in place and no sediment at the bottom is allowed. No water may flow into the well between the well rings. The water should enter the well from the bottom.

34. The water meters in the houses should be read annually although invoicing does not take place then.  
How much on-revenue water (water pumped into the system minus invoiced amount of water) is observed?  
Increase of non-revenue water may indicate leaks in the system. The amount of lost water should not exceed 5 – 10 per cent from the produced amount of water.

35. Check the number of users.  
If the number increases the capacity of the water works must be checked. If it diminishes the need for flushing of pipes and tanks should be checked.

36. It is good to evaluate the need for cleaning and disinfection of the water tanks.  
If significant amounts of sediments have formed on the bottom of the tank it should be cleaned. The tank has to be disinfected after cleaning.

37. The valves and other equipment of the network should be checked annually or twice a year.  
The valves suffer more if they are not used than of overuse.

38. The operation of fire hydrant should be checked annually.  
At the same time it is possible to flush away stagnant water from the area.

39. Check the surroundings of the water intake annually and clean the surroundings thoroughly.  
No such factors which may contaminate the groundwater are allowed in the vicinity of the groundwater basin. If, however, there exist such factors one has to take care that they do not pose any risk of contamination of the groundwater.

40. If there is industry or agriculture in the area, chemicals used at the facilities should be monitored in the water (e.g. pesticides, if they are used at the fields nearby)

41. The pipes should be flushed annually or when needed.  
If the network is not in complete use, sediments and slurries may form. This can be prohibited by flushing the network.

42. Complaints against the waterworks have to be inspected annually and corrective measures taken considered.

43. Check the safety equipment and constructions.

44. Check the safety plan.

45. Maintenance of pressure sewer systems, e.g. pumps according to manuals.  
If the wastewater plant is not in normal use it may be necessary to shorten the period between service.

46. The list of risks at small waterworks must be checked.

47. When renewing equipment, materials or chemicals, their suitability to potable water use have to be assured.
Appendix 6  Calculations and examples

Some unit conversions

<table>
<thead>
<tr>
<th>1 kg = 1000 g</th>
<th>1 m³/h = 1000 l/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 g = 1000 mg</td>
<td>1 l/h = 16.7 ml/min</td>
</tr>
<tr>
<td>1 m³ = 1000 l</td>
<td>1 % of something = 100th of something</td>
</tr>
<tr>
<td>1 l = 1000 ml</td>
<td>1 mg/l = 1 g/m³</td>
</tr>
</tbody>
</table>

Solution of solid compounds in water

When a solid compound (e.g. lye, soda ash) is dissolved a solution is formed. Its concentration can be given as weight percentage or units g/m³, mg/l, kg/m³, g/l.

The equation is

\[ C = \frac{m}{V} \]

\( C \) is concentration
\( m \) added compound
\( V \) volume of solution

or

\[ p = \frac{m}{m + M} \times 100 \]

\( p \) concentration in per cent
\( m \) amount of dissolved compound (mass)
\( M \) amount of water (mass)

Example:
1.5 kg of lye is dissolved in 100 l of water. If the increase of the specific gravity or density is not taken into account or the density of the solution is taken for 1 kg/l, the concentration will be

\[ 1.5 \text{ kg/100 l} = 0.015 \text{ kg/l} \text{ or } 15 \text{ g/l}. \]
As weight percentage it is:

\[
1.5 \text{ kg}/(1.5\text{ kg} + 100 \text{ kg}) \times 100\% = 1.48\%
\]

At increased concentrations the specific weight of the solution must be taken into account.

When 15 kg of lye is added to 100 l of water, its weight percentage concentration is \(15 \text{ kg}/(15 \text{ kg} + 100 \text{ kg}) \times 100 = 13\%\). If the volume of the solution doesn’t increase, the density of it will be 1.15 kg/l.

Specific weights of different solutions are often indicated in the fact sheet of the product.

**Dilution calculations**

In dilution calculations one calculates how much water should be added to a concentrated solution to get a solution suitable for feeding. The calculations can be made as follows:

\[
v = \frac{V \times R \times P}{r \times p}
\]

- \(v\) is amount of concentrated solution (volume)
- \(r\) is specific weight (density) of concentrated solution
- \(p\) is weight percentage of concentrated solution
- \(V\) is amount of diluted solution (volume)
- \(R\) is specific weight (density) of diluted solution
- \(P\) is weight percentage of diluted solution

**Example:**

To get 100 litres of 1 percent solution of a concentrated solution of 13 % with a density of 1.24 kg/l the following volumes should be added:

Concentrated solution \(v = \frac{100 \text{ l} \times 1\text{ kg} / \text{l} \times 0.01}{1.24 \text{ kg} / \text{l} \times 0.13} = 6.2\text{ l}\)

Dilution water \(V - v = 100 \text{ l} - 6.2 \text{ l} = 93.8 \text{ l}\)
Batch feed
When a certain concentration of chlorine is needed for disinfection of a certain volume like a vessel or pipes the amount of concentrated solution can be calculated as follows:

\[ v = \frac{V \times C}{0.01 \times p \times r} \]

- \( v \) is amount of concentrated solution (volume)
- \( r \) is specific weight (density) of concentrated solution
- \( p \) is weight percentage of concentrated solution
- \( V \) is volume of diluted solution
- \( C \) is concentration of diluted solution

**Example:**

A basin with a volume of 1000 m\(^3\) shall be filled with a chlorine solution of 5 mg/l. The sodium hypochlorite stock solution has 13 % of active chlorine and its density is 1.240 kg/l. The amount of this solution to be added is

\[ v = \frac{1000 \ m^3 \times 5 \ g / m^3}{0.01 \times 1.24 \ kg / l \times 13 \% \times 1000 \ g / kg} \approx 31 \ l \]

(The factor 0.01 in the nominator comes from the conversion 1\% = 0.01. 1000 g/kg is to balance the units)

If potassium hypochlorite powder with 65% of chlorine is used, the amount needed is:

\[ \text{Potassium hypochlorite added} = \frac{1000 \ m^3 \times 5 \ g / m^3}{0.01 \times 65 \%} \approx 7700 \ g \]
Continuous feed
Some chemical as sodium hypochlorite must continuously be dosed to the water. To calculate the feed rate you need to know the target concentration in the water and the density and concentration of the feed solution. It can be calculated as follows:

\[ q = \frac{Q \times c}{0.01 \times p \times r} \]

- \( q \) is feed of solution
- \( Q \) is water flow of waterworks
- \( c \) is targeted concentration
- \( p \) is weight percentage of concentrated solution
- \( r \) is specific weight (density) of concentrated solution

Example:
The flow of the water works is \( Q = 2.6 \text{ m}^3/\text{h} \) and the chlorine need is \( 1 \text{ mg/l} \) (\( 1 \text{ g/m}^3 \)), the chlorine concentration of the solution is \( 1\% \) and density \( 1 \text{ kg/l} \). The dosage is:

\[ q = \frac{2.6 \text{ m}^3/\text{h} \times 1 \text{ g/m}^3}{0.01 \times 1\% \times 1 \text{ kg/l} \times 1000 \text{ g/kg}} = 0.26 \text{ l/h} = 4.3 \text{ ml/min} \]

(The factor 0.01 in the nominator comes from the conversion \( 1\% = 0.01 \). \( 1000 \text{ g/kg} \) is to balance the units)
Alkalisation

Table 1. Calculated consumption of alkalizing substances for each gram of carbon dioxide to be neutralized

<table>
<thead>
<tr>
<th>Product</th>
<th>Specific consumption</th>
<th>Change in hardness</th>
<th>Change in calcium</th>
<th>Change in bicarbonate alkalinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lye (NaOH)</td>
<td>0.9</td>
<td>0</td>
<td>0</td>
<td>0.023</td>
</tr>
<tr>
<td>Lime (Ca(OH)₂)</td>
<td>1.0</td>
<td>0.01</td>
<td>0.45</td>
<td>0.023</td>
</tr>
<tr>
<td>Sooda ash (Na₂CO₃)</td>
<td>2.4</td>
<td>0</td>
<td>0</td>
<td>0.046</td>
</tr>
<tr>
<td>Limestone (microcrystalline)</td>
<td>2.5</td>
<td>0.02</td>
<td>0.9</td>
<td>0.046</td>
</tr>
<tr>
<td>Limestone (grains)</td>
<td>2.7</td>
<td>0.02</td>
<td>0.9</td>
<td>0.046</td>
</tr>
<tr>
<td>Dolomite</td>
<td>1.3</td>
<td>0.016</td>
<td>0.3 + 0.2 magnesium</td>
<td>0.031</td>
</tr>
</tbody>
</table>

Example: For evaluation of daily consumption of alkalizing materials

When the free carbon dioxide concentration to be neutralized is 100 mg/l and water flow is 90 m³/d, the daily consumption is:

Total consumption = specific consumption*carbon dioxide concentration*flow

Lye: Total consumption = 0.9 g/g* 100 mg/l * 90 m³/d = 0.9 g/g * 0.1 g/l * 90 000 l/d = 8 100 g/d

Summary:
Lye 8.1 kg/d (100%)
Lime (calcium hydroxide) 9 kg/d
Soda ash 21.6 kg/d
Limestone (microcrystalline) 22.5 kg/d
Limestone (grains) 24.3 kg/d
Dolomite 11.7 kg/d
Appendix 7. Check list for assessing the vulnerability of a small waterworks

This list was made to act as an auxiliary for the assessment of the vulnerability of small waterworks. However, the list is not exhaustive but the special features of each waterworks must, as far as possible, been taken into account in the assessment.

A "Yes" answer means that the matter in question has been paid attention to. In the "Explanation" column (next to the "No" answers) there is information on the significance of the risk concerned and its prevention. Vulnerability mapping must be conducted by waterworks personnel using expert assistance when necessary. The document contains delicate information as regards the safety of the plant and therefore it must not be shown to unauthorised persons.

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater intake units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has a protection plan been drawn up for the groundwater basin?</td>
<td>Yes</td>
<td>In the protection plan, the risk factors affecting water intake are mapped and means for their management are presented.</td>
</tr>
<tr>
<td>Have the groundwater basins been marked on the terrain and on maps?</td>
<td>No</td>
<td>The marking of groundwater basins promotes the protection of groundwater against pollution caused by carelessness. On the other hand, the marking may expose the groundwater basins to vandalism or intentional damage. As to maps, in particular, the possibility for misuse and vandalism must be taken into account and it must be carefully considered in which cases marking is necessary.</td>
</tr>
<tr>
<td>Have the inhabitants and businesses of the area been informed of groundwater protection?</td>
<td>No</td>
<td>Not all inhabitants necessarily know that they live in a groundwater area and may therefore unconsciously cause risks to groundwater.</td>
</tr>
<tr>
<td>Has the sufficiency of groundwater been appropriately determined?</td>
<td>No</td>
<td>Dry spells are a factor that most easily depletes the surfaces of small groundwater basins. Besides the scarcity of water, the depletion of surfaces may negatively affect the water quality. Likewise, the rise of the water surface back to normal levels may cause unexpected variations in quality.</td>
</tr>
<tr>
<td>Does the plant observe the land use planning for the groundwater area?</td>
<td>No</td>
<td>The plant must observe land use planning and seek to actively influence matters so that the factors posing a risk to water intake are paid attention to in the planning of land use and in the granting of permits.</td>
</tr>
<tr>
<td>Has it been ensured that the following factors do not pose a risk to water intake?</td>
<td>No</td>
<td>The risk for groundwater contamination may be caused by all those activities connected to how compounds harmful to the quality of groundwater are treated, stored or generated. Certain activities, such as soil extraction or ditch drainage, may also cause changes to groundwater flow conditions. It would be ideal if these kinds of operations are not located in groundwater areas. However, it is often the case that these kinds of operations and water intake activities compete over the same areas. Consequently, the waterworks must, together with environmental authorities and operators, seek to ensure that these operations do not pose a threat to water intake.</td>
</tr>
<tr>
<td>QUESTION</td>
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</tr>
<tr>
<td>- road salting</td>
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<tr>
<td>- the road and rail transport of oil or chemicals</td>
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<td>- anti-ice measures at airports</td>
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<td>- railway yards</td>
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<tr>
<td>- industry (power plants, the metal and chemicals industry)</td>
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<tr>
<td>- business activities (wood impregnation plants, sawmills, dry cleaners)</td>
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<tr>
<td>- service stations and scrap yards</td>
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<td></td>
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<tr>
<td>- graveyards</td>
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<tr>
<td>- municipal waste water treatment plants</td>
<td></td>
<td></td>
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<tr>
<td>- sewers</td>
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<tr>
<td>- releasing waste water into the ground on properties</td>
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<tr>
<td>- on-site oil tanks</td>
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<tr>
<td>- landfill sites, the storage and treatment of waste</td>
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<tr>
<td>- fertilizers and pesticides</td>
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<td></td>
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<tr>
<td>- animal shelters (piggeries, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- liquid manure tanks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- fur farms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- greenhouses, nurseries and market gardens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- soil extraction and auxiliary activities (e.g. crushing), quarrying and mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- contaminated soil areas, shooting ranges, etc.</td>
<td></td>
<td></td>
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<tr>
<td>- golf courses</td>
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<td></td>
</tr>
<tr>
<td>- motor-racing tracks and sports fields</td>
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<tr>
<td>- loading via air</td>
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<td></td>
</tr>
<tr>
<td>- ditch drainage, other groundwater intake activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- old wells which have been removed from use but which are unfilled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has it been ensured that rain water cannot enter directly into the water intake wells?</td>
<td>Yes</td>
<td>The water intake units must be located so that surface water cannot contaminate raw water during heavy downpours. The sections around the well must be shaped so that they slope away from the well. The well structures located above the groundwater layer must be tight and secure.</td>
</tr>
<tr>
<td>QUESTION</td>
<td>ANSWER</td>
<td>EXPLANATION</td>
</tr>
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</tr>
<tr>
<td>Has it been ensured that floodwater or a rise in the surface of a body of water will not flood the water intake unit?</td>
<td></td>
<td>The water intake units must be located so that surface water cannot contaminate raw water during floods. If the well structures have been equipped with drainage pipes, it must be ensured that surface water cannot flood through them into the well in any circumstances.</td>
</tr>
<tr>
<td>Have the water intake structures been planned so that a sufficient amount of water can also be obtained during periods of exceptionally low water surface levels?</td>
<td></td>
<td>In perforated-casing wells, the lowest filters are sometimes located so high that water cannot be obtained from the groundwater basins when the water level is significantly lower than normal. The structures should also be checked for exceptional droughts.</td>
</tr>
<tr>
<td>Has it been ensured that surface water (lakes, rivers, mires, etc.) is not infiltrated into the ground close to the water intake wells?</td>
<td></td>
<td>If the distance between the recharge area and water intake is too short, water will not be sufficiently purified. Bank filtration does not usually purify surface water to a sufficient degree unless infiltration has been specifically planned. Because of a flood risk, water intakes must be located at a sufficient distance from bodies of water and never in low-lying, flood-sensitive areas.</td>
</tr>
<tr>
<td>Has the water intake area been fenced off?</td>
<td></td>
<td>It is a good idea to fence the area in order to prevent vandalism and thefts and, above all, to keep animals roaming in the area away. Animal faeces often contains pathogens, which may, when entering into drinking water, make a large number of people ill.</td>
</tr>
<tr>
<td>Are the ventilation holes in the wells such that small animals cannot enter the well through them?</td>
<td></td>
<td>The entering of animals into ventilation holes can be prevented with the help of grating.</td>
</tr>
<tr>
<td>Are the well structures in a good condition?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has the well been protected against ground frost?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Has water quality been comprehensively studied?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are all materials utilised (water intake, water treatment, networks) intended for potable water use?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water treatment plants</td>
<td></td>
<td>There are also often impurities in groundwater that may cause health risks. If groundwater that has not been disinfected is released into the network, you must be absolutely certain about the microbiological quality of the groundwater in all circumstances. Surface water must always be effectively treated before it can be used as potable water.</td>
</tr>
<tr>
<td>Is the treatment process sufficient for removing the impurities from water?</td>
<td></td>
<td>In order to prevent an epidemic in a contamination situation, the plant should, at a minimum, be prepared to start disinfection measures. The disinfection method must be chosen beforehand and it must also be examined in advance what equipment and chemicals are needed. Additionally, the plant must obtain the necessary disinfection know-how.</td>
</tr>
<tr>
<td>QUESTION</td>
<td>ANSWER</td>
<td>EXPLANATION</td>
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</tr>
<tr>
<td>Have the changes in the microbiological quality of water been studied in connection with melting snow or heavy rains, for example?</td>
<td>Yes</td>
<td>Groundwater works often have water quality problems particularly during the melting of snow and heavy rains though these problems are often not visible in the normal monitoring of water quality. It would be useful to investigate whether the treatment process utilised by the plant is also effective enough at such times.</td>
</tr>
<tr>
<td>Can the exposure of consumers to hazardous chemicals be prevented in cases where, for example, a dosing error takes place?</td>
<td>Yes</td>
<td>A dosing error should be detected prior to consumers accessing the water. Particularly those small groundwater works that use alkalisation as the only method of water treatment have occasionally had a problem with the lye overfeeding.</td>
</tr>
<tr>
<td>Has the monitoring programme for potable water been updated?</td>
<td>Yes</td>
<td>The monitoring programme required by the decree on water intended for human consumption must be updated every 5 years, at least, and always when there is a change in the conditions that may possibly affect water quality.</td>
</tr>
<tr>
<td>Is there a sufficient amount of routine operational monitoring in addition to the monitoring programme?</td>
<td>Yes</td>
<td>Pursuant to the decree on water intended for human consumption, information on routine operational monitoring conducted by the plant must be collected in the monitoring programme. Routine operational monitoring must contain sufficient monitoring of raw water quality in order to ensure the appropriate treatment of water in all situations. The routine operational monitoring should also include the necessary analyses of the internal processes and of the water released from the plant.</td>
</tr>
<tr>
<td>Is the monitoring of the treatment process or the water released from the plant implemented on-line?</td>
<td>Yes</td>
<td>It is important to quickly detect a water quality failure in order to prevent health risks. With the help of on-line monitoring, information on a change in water quality or on a process failure is swiftly conveyed to the personnel of the plant. For example, on-line measuring of turbidity may lead to a timely alarm of problems dealing with water quality.</td>
</tr>
<tr>
<td>Have measures been agreed on in a situation where there are deviations in water quality?</td>
<td>Yes</td>
<td>The plant should have written operating instructions for situations where they note, by means of on-line monitoring or analyses conducted in accordance with the monitoring programme, that limits have been exceeded or insufficient water quality is notified by the customer.</td>
</tr>
<tr>
<td>Are there parameters referring to risks analysed from groundwater (nitrate, chloride, pesticides...)?</td>
<td>Yes</td>
<td>In routine operational monitoring, even more effective measures than those required by statutory obligations should be taken in order to monitor those quality parameters that refer to the activities that cause the most probable risks to water quality. Attention should be paid to the observation of acute, hazardous changes (e.g. toxic substances).</td>
</tr>
<tr>
<td>Is the quality of process chemicals monitored or has quality assurance been agreed on with the chemicals supplier?</td>
<td>Yes</td>
<td>Impurities in chemicals may cause negative effects which are difficult to detect in the quality of potable water. Chemicals may also be contaminated during transportation or storage.</td>
</tr>
<tr>
<td>Are there stockpiles for critical chemicals and materials?</td>
<td>Yes</td>
<td>During a transportation or chemistry strike, for example, there is a risk that the disinfection materials that are needed in water treatment run out. Access to critical materials and chemicals can be ensured by stockpiling and by means of cooperation with the other waterworks in the area.</td>
</tr>
<tr>
<td>QUESTION</td>
<td>ANSWER</td>
<td>EXPLANATION</td>
</tr>
<tr>
<td>----------</td>
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</tr>
<tr>
<td>Are the personnel at the plant supervising the reception of chemicals?</td>
<td>Yes</td>
<td>The plant personnel must ensure that the right chemicals are appropriately delivered to the right object of utilisation. The risk of a chemical entering into the wrong tank can be reduced by means of technical arrangements.</td>
</tr>
<tr>
<td>Have the hazardous chemicals been stored safely?</td>
<td>No</td>
<td>Careless storage of chemicals may cause occupational safety risks to the plant's personnel. The storage of chemicals must be kept outside the flood area. A flood that statistically takes place every 100th year must be taken into account in all cases. If the stores are difficult to move, the plant must be prepared for clearly more rarely occurring floods.</td>
</tr>
<tr>
<td>Are the instructions for the dosage and dilution of chemicals clearly on view? And are the necessary warning signs on view?</td>
<td>Yes</td>
<td>If a substitute has to carry out the adding of chemicals, it is essential to have clear instructions for the addition of the required chemicals.</td>
</tr>
</tbody>
</table>

The potable water network

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>ANSWER</th>
<th>EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the network regularly flushed?</td>
<td>Yes</td>
<td>The network should be regularly flushed in order to remove loosely established deposits and to maintain the condition of the network. As regards more effective methods than water flushing, pigging and the combination of water and air can be used.</td>
</tr>
<tr>
<td>Is the network pressure supervised and has keeping it within appropriate limits been assured?</td>
<td>Yes</td>
<td>The positive pressure in pipelines protects water quality, and a fall in water pressure exposes the water to contamination due to waste water that has leaked into the ground. In addition, pressure surges may also cause damages and force the water around the pipes into the tap water through the leaking points.</td>
</tr>
<tr>
<td>Is there enough elevated water tank volume in the network?</td>
<td>Yes</td>
<td>During a power failure, for example, the water is distributed from elevated water tanks enabled by gravity. The tank volume should, at a minimum, provide 12 hours of water consumption.</td>
</tr>
<tr>
<td>Are the water towers and tanks regularly cleaned?</td>
<td>Yes</td>
<td>With time, precipitate accumulates on the bottom of water tanks. This precipitate may start moving, thus posing a threat to water quality. The tanks must be planned so that they can, if necessary, be quickly isolated from the other parts of the water distribution network and emptied safely. The swift isolation and purification of the tank is critical particularly in a water contamination situation. It must also be ensured that small animals cannot enter the water tank.</td>
</tr>
<tr>
<td>Has the back flow been blocked in the network?</td>
<td>Yes</td>
<td>The use of check valves in properties prevents the water returning to the distribution network. A check valve must always be installed in connection with the installation of a water meter.</td>
</tr>
<tr>
<td>Are there back-up connections for the main water pipes?</td>
<td>Yes</td>
<td>During a breakdown of a pipe in the main line it should be possible to deliver water to users via an alternative route.</td>
</tr>
<tr>
<td>Can the water tank be bypassed?</td>
<td>Yes</td>
<td>If there are structural problems in the tank or it causes water contamination, it must be possible to remove the tank from the system.</td>
</tr>
<tr>
<td>QUESTION</td>
<td>ANSWER</td>
<td>EXPLANATION</td>
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</tr>
<tr>
<td>Is the part of the network concerned always chlorinated in connection with repairs and the construction of new pipelines?</td>
<td>Yes</td>
<td>In conjunction with construction work as well as pipe breakdowns and repairs impurities that may contaminate the water enter into the pipeline. The general specifications for municipal engineering tasks contain instructions for the measures to be taken after the repairs.</td>
</tr>
<tr>
<td>Is a sufficient standard of hygiene adopted in connection with the repairs?</td>
<td>No</td>
<td>In repair work, different tools, clothing and greases should be used, as far as possible, than those used in waste water sites. Personal hygiene must be taken care of in order to prevent pathogens from entering the water distribution network due to carelessness in connection with the repair and maintenance work.</td>
</tr>
<tr>
<td>Have the water distribution networks been renovated at the pace required by their condition?</td>
<td>No</td>
<td>Along with the aging of networks, the number and probability of damages grow.</td>
</tr>
<tr>
<td>Is there a renovation plan that is being followed for water distribution networks?</td>
<td>No</td>
<td>Along with the aging of networks, the number and probability of damages grow. Leaks may also cause weaker water quality.</td>
</tr>
<tr>
<td>Has the network been replaced to a sufficient extent / when necessary?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Is the network located below ground frost level?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Personnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have the backgrounds of new employees been checked in connection with recruiting?</td>
<td>Yes</td>
<td>With the consent of the applicant concerned, it is possible to obtain a concise security clearance of the backgrounds of new employees from the local police authorities.</td>
</tr>
<tr>
<td>Have the competence and security of the outsourced service providers been ensured?</td>
<td>Yes</td>
<td>There must be a reserved attitude towards the outsourcing of critical activities. Equal standards must be placed on the providers of external services as on own personnel. A concise security clearance may also be required for employees of outsourced services who have access to critical objects or who acquire important information.</td>
</tr>
<tr>
<td>Can it be ensured that outgoing employees return the plant’s possessions?</td>
<td>Yes</td>
<td>The employees leaving the employ of the plant have a great amount of know-how in dealing with plant operations. It must be ensured that the employees return all the belongings (such as keys and maps) of the plant at the end of their employment.</td>
</tr>
<tr>
<td>Does the plant have a stand-by system?</td>
<td>Yes</td>
<td>The waterworks should always have some people on stand-by in order to be able to react quickly to exceptional situations taking place outside of working hours. Small plants may agree on this arrangement with other waterworks, for example. Naturally, the parties concerned must ensure the mutual familiarisation of matters concerned.</td>
</tr>
<tr>
<td>Are the plant personnel sufficiently educated and competent in carrying out their tasks?</td>
<td>Yes</td>
<td>A qualification test for waterworks operators is being prepared. The professional execution of tasks and the prevention of exceptional situations require experience and profound competence. It is only through continuous training that sufficient competence can be maintained in this changing operating environment.</td>
</tr>
<tr>
<td>Have the personnel received security training?</td>
<td>Yes</td>
<td>The training given by security professionals motivates personnel and commits them to promoting security matters.</td>
</tr>
<tr>
<td>Are there enough personnel?</td>
<td>No</td>
<td></td>
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<tr>
<td>QUESTION</td>
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<td>EXPLANATION</td>
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</tr>
<tr>
<td>Access control and security</td>
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<td></td>
</tr>
<tr>
<td>Has access to critical objects (such as water intakes, pumping stations, water towers) been restricted to personnel only?</td>
<td>Yes</td>
<td>External parties (such as contractors) must not gain access to areas that are not necessary for their work tasks. As regards the keying of the series of locks, the needs for different groups of people to enter different premises should be taken into account.</td>
</tr>
<tr>
<td>Have the vehicles, equipment and work clothes been marked with the symbols of the plant? Are identification cards used?</td>
<td>No</td>
<td>With the help of symbols, external parties can easily recognise the personnel of the plant. Access to the critical objects of the plant can be supervised, for example, by using identification cards equipped with a photograph. Smaller plants have a smaller need for this but, however, when replacing the water meters in properties, the person conducting this task needs to have an identification card showing his/her authorisation.</td>
</tr>
<tr>
<td>Are the critical objects locked?</td>
<td></td>
<td>Locking in particular prevents vandalism and thefts committed on impulse. At the very least the water intake wells and valve wells, water treatment plants, pumping stations, water towers and the groundwater observation pipes should be locked.</td>
</tr>
<tr>
<td>Have alarm systems or motion detectors been installed in the critical objects?</td>
<td></td>
<td>A property alarm system should be installed at least in the buildings where water intake and water treatment activities take place. Trespass is prevented by effective illumination of the object or with the help of motion detectors; the lights that are lit up by motion may be effective enough to drive away trespassers. The most central premises can be supervised by means of video surveillance systems.</td>
</tr>
<tr>
<td>Are regular visits paid to the plants? Does a guard service company patrol the objects?</td>
<td></td>
<td>Daily visits to critical objects improve security and possible visits by unauthorised parties or other problems can be immediately detected.</td>
</tr>
<tr>
<td>Is a record kept of the keys? Are the keys stored in a controlled way? Have measures to be taken in case a key is lost been agreed upon?</td>
<td></td>
<td>You should keep a record of the use of keys, and the series of locks must be re-keyed at least when keys are lost. Door codes should be changed often enough.</td>
</tr>
<tr>
<td>Has the security of the IT systems been ensured?</td>
<td></td>
<td>The use of all computers at the plant should be protected with a password. Passwords must be changed on a regular basis; at an interval of 2 months, for example. The Internet connection must be protected with antivirus measures, a firewall and anti spyware.</td>
</tr>
<tr>
<td>Is the plant's control system separate from the Internet?</td>
<td></td>
<td>The most secure systems are those that are separate from the Internet. In practice, different computers and systems can be used for the control of the plant than for the other tasks.</td>
</tr>
<tr>
<td>Are the back-up copies made of important files?</td>
<td></td>
<td>The most important files must be regularly backed-up and the back-ups must be stored in another building in case of a fire or theft.</td>
</tr>
<tr>
<td>Has it been ensured that the plant's website or the websites of other parties do not contain any such plant-specific information that can be misused (e.g. for causing damage)?</td>
<td></td>
<td>The plant must avoid giving sensitive or too detailed information on its website. The plant must also occasionally check by means of search engines that there is no incorrect or sensitive information concerning the plant on any websites administered by other parties.</td>
</tr>
<tr>
<td>QUESTION</td>
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</tr>
<tr>
<td>Is the security concerning the storage of maps and other physical information attended to? Is it ensured that they are returned?</td>
<td>Yes</td>
<td>The provision of map information to external parties, such as contractors, should be limited to only absolutely necessary information. External parties are only given the information that they need for their work tasks. The returning of maps must be controlled and their storage must be paid attention to in order to prevent other parties than own personnel from gaining access to them.</td>
</tr>
<tr>
<td>Has it been ensured that there is sufficient illumination at different points of the system?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Is there enough information on the condition and security of all parts (wells, pipes, water tanks) of the system?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Has the plant taken sufficient measures to ensure thermal insulation?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Operating instructions and plans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Does the plant have an updated preparedness plan?</td>
<td>Yes</td>
<td>The waterworks ensures that the municipality’s preparedness plan contains an updated section for water services.</td>
</tr>
<tr>
<td>Does the plant have an updated contingency plan or have the risks concerning normal conditions been sufficiently dealt with in the preparedness plan?</td>
<td>Yes</td>
<td>Previously, preparedness planning was focused on operations in extraordinary circumstances. However, preparations for exceptional situations that take place in normal conditions must be at least as comprehensively planned.</td>
</tr>
<tr>
<td>Has a rescue plan been drawn up for the buildings of the plant?</td>
<td>Yes</td>
<td>The primary purpose of the rescue plan referred to in the Rescue Act is to be prepared for the rescue of people inside a building or on a property in hazardous situations.</td>
</tr>
<tr>
<td>Have the plans been delivered to the authorities concerned?</td>
<td>Yes</td>
<td>Information on water services development plans and groundwater basin protection plans must be provided as extensively as possible. On the other hand, the preparedness and contingency plans must be kept in secrecy and their distribution must be limited. However, information is delivered, when necessary, on some sub-entities of these plans e.g. to the municipal health protection authorities and the rescue department in order to ensure smooth cooperation in emergency situations.</td>
</tr>
<tr>
<td>Have plans been drawn up for possible water contamination incidents?</td>
<td>Yes</td>
<td>It is necessary to draw up detailed plans for information provision and other activities in advance in order to prevent health risks. The plans must be documented in the plant’s contingency plan as well as in a municipal emergency situation plan for environmental health.</td>
</tr>
<tr>
<td>Have information provision plans been drawn up for epidemics and other emergency situations?</td>
<td>Yes</td>
<td>It is necessary to plan in advance the responsibilities dealing with information provision and the channels and objects of information provision. Information distribution is most critical in water contamination incidents. Information provision and alarm measures must be agreed on with the municipality’s health protection authorities and the rescue department.</td>
</tr>
<tr>
<td>QUESTION</td>
<td>ANSWER</td>
<td>EXPLANATION</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Have emergency situations (epidemic, flood situation) been rehearsed in practice?</td>
<td>Yes</td>
<td>The functionality of the contingency and preparedness plans of the waterworks and the municipality requires that responsible parties have been well trained for their tasks and that the situations have been practised.</td>
</tr>
<tr>
<td>Has cooperation in emergency situations been agreed with different authorities (e.g. the municipal health protection authorities)?</td>
<td>No</td>
<td>The situation must only be headed by one party. The division of responsibilities is agreed in advance and the responsibilities are additionally determined, for example, by phone in a real situation. The cooperation preparedness of different authorities and other participants in emergency situations must be practised. Water services are often only one sub-sector in comprehensive cooperation training events organised by the State Provincial Offices, the rescue department or some other parties.</td>
</tr>
<tr>
<td>Has the contact information that is needed in emergency situations (e.g. water epidemic) been updated?</td>
<td>Yes</td>
<td>The plant must update the contact information of critical water users (such as hospitals, old people’s homes, quarters that are critical from the perspective of security of supply, dairy cattle farms) and the authorities (such as municipal health and environmental protection, the technical department, the rescue department, and environment centres). The plant must also update the contact persons’ names and phone numbers once a year, for example.</td>
</tr>
<tr>
<td>Is an announcement delivered to the Emergency Response Centre in emergency situations?</td>
<td>No</td>
<td>People often phone the Emergency Response Centre though the matter would be one of the tasks of the waterworks. The Emergency Response Centre should therefore be instructed in advance in assessing the calls for help and in contacting the waterworks. In an emergency situation the plant should deliver an announcement and instructions for the situation to the Emergency Response Centre.</td>
</tr>
<tr>
<td>Do the water consumers know whom they must contact if they detect problems in water quality or they note some suspicious activities close to the water intake, for example?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Have all the re-starting functions been ensured after power failures, for example?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Have financial preparations been made for problematic situations?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Are the causes of disruptive situations examined?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Back-up systems</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Does the plant have a back-up water source or a contract with the neighbouring municipality on water distribution?</td>
<td>No</td>
<td>In a groundwater contamination incident, for example, you must use a back-up water source located in a different groundwater basin. The plant may also make a contract on purchasing water from another plant. When calculating the distribution capacity, the capacity of the plant’s own network, the capacity of the connection pipes and the delivery contracts must be taken into account.</td>
</tr>
<tr>
<td>QUESTION</td>
<td>ANSWER</td>
<td>EXPLANATION</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Does the back-up water source have the capacity to provide a minimum of 50 l / 24 hours / inhabitant for household use?</td>
<td></td>
<td>When using a back-up water source, it has been estimated in several contexts that the sufficient volume of water be 50 l / 24 hours / inhabitant after the critical water users’ minimum need for water has been deducted from the available capacity.</td>
</tr>
<tr>
<td>Can the back-up water source be quickly put into action?</td>
<td></td>
<td>The water intake must be regularly tested and the quality of water must be monitored. It must be ensured that there are the necessary water intake permits.</td>
</tr>
<tr>
<td>Has a regional general plan for water services been drawn up for the area?</td>
<td></td>
<td>Regional cooperation, such as the connection pipes between the plants, promotes the security of the supply of potable water in exceptional situations in case there are water intakes of several plants available.</td>
</tr>
<tr>
<td>Has the implementation of temporary water distribution been planned?</td>
<td></td>
<td>The implementation method for temporary water distribution (tank trucks, pick-up points, private wells), capacity, the use of necessary equipment and the monitoring of water quality should be planned in advance.</td>
</tr>
<tr>
<td>Has the use of external equipment required in emergency situations been agreed on with the service providers?</td>
<td></td>
<td>Written contracts should be made in advance on the use of external equipment (such as tank trucks and sewage trucks).</td>
</tr>
<tr>
<td>Is there stand-by power equipment for critical functions or a possibility for a stand-by power connection?</td>
<td></td>
<td>Through the use of stand-by power supplies of pumping stations and water treatment plants the negative effects caused by power failures can be prevented. A failure that takes longer than 12 hours may cause a serious disruption to supply when, for example, the elevated water tank may become empty.</td>
</tr>
<tr>
<td>Are there sufficient stockpiles of chemicals and critical spare parts, or have contracts been made with goods suppliers on keeping stockpiles?</td>
<td></td>
<td>It is possible to make a contract with suppliers on maintaining stockpiles for the customer. However, the stockpile is not safe from disruptions, such as strikes, in the delivery chain. A large part of the plant processing equipment is imported, so the availability of spare parts is not necessarily guaranteed in an international conflict situation.</td>
</tr>
<tr>
<td>Can the network and the plant be controlled by manual operation?</td>
<td></td>
<td>In case the automation system breaks down it is important, in order to prevent an interruption to water distribution and sewerage functions, that the equipment is able to function by means of a local logic system or by manual operation. The manual operation should be further practised.</td>
</tr>
<tr>
<td>Have the information technology systems (such as remote control systems and operating systems) been protected with UPS equipment?</td>
<td></td>
<td>UPS equipment protects the computer from voltage failures and enables a controlled shutdown of the information systems in the case of a prolonged failure.</td>
</tr>
</tbody>
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Appendix 8. A model for a contingency plan of a small waterworks

The contingency plan of the Kytövainio waterworks

1. Description of the waterworks

The Kytövainio waterworks is responsible for the supply of potable water in the municipality of Kytövainio within the operational area (appendix a) approved by the municipal council, and the collection and processing of waste water within the sewage plant’s operational area (appendix b), as approved by the municipal council.

2. Risks

The known risks in the groundwater area of Santakangas include:

- 19 fuel tanks
- 12 residential properties, which have an on-site waste water treatment system
- 4 cattle farms
- A landfill site that has not been in use for 18 years
- A gravel pit that is no longer in use but which has been used as an unauthorised dump
- Santakankaantie road, the traffic along which includes heating oil distribution traffic
- Increasing cross-country traffic.

Other potential risks include observation pipes, which can convey impurities into the groundwater, and the pressure to start the extraction of gravel in the southwest part of the area. An aeroplane accident is an unlikely but feasible risk, as the groundwater basin is located under the landing area of Kivikylä airfield’s new runway. During exceptionally dry seasons, the level of groundwater has lowered, though not alarmingly. A long-lasting drought and subsequent decrease in the level of groundwater may, however, increase the likelihood of risks relating to water quality, as it may change the flow of water in a manner that allows for harmful substances to enter the groundwater from the old gravel pit.

In the event that microbiologically or chemically hazardous substances enter the groundwater or the water pumping station’s tail-water tank, they may cause an epidemic or a varying level of poisoning symptoms.

At the water intake unit, the risks include power failure (the unit has a stand-by power system in place), fire at the unit or in its vicinity, operational disturbance caused by thunder, and vandalism (the unit is enclosed but has no surveillance). No alternative source of water exists in the event that water pumping needs to be suspended.
The water distribution network has operated reliably with only 2–4 pipe breaks a year. During the pipeline repair work, the quality of the water has suffered at times due to impurities that have entered the system. During hard winters, freezing of the upper extension of the pipe network and the connection pipes to the properties poses a risk. No hydrants have been connected to the network. Drains are located in the same canal as the water pipes and therefore negative pressure in the water pipes can lead to the contamination of water.

In the sewerage system, operational disturbance of pumping stations can lead to the flooding of the drains and inspection wells located closest to the pumping station. During extensive power failures, pumping stations are out of operation. The same is true of the waste water treatment system.

Oil, solvents, and other substances that may seriously disturb waste water treatment can get into the drains. This is an unlikely risk in Kytövainio, because it principally collects and treats normal domestic waste water.

The waterworks has only a few staff members and they are all about to retire in the near future. A significant part of technical and operational information concerning the plant has been insufficiently documented and may be lost with the retirement of the current staff. Another threat is that no skilled, motivated, and reliable people can be found to replace them. The aforementioned risks and threats are the most critical ones in terms of the continuation of the plant’s operations.

3. Securing of the operations at the current level

3.1 Need for water and the amount of waste water

On average, the waterworks supplies a total of 215 m$^3$ of potable water to 850 residents and other customers every day. The water distribution network includes the following special institutions and establishments:

- health centre ward, 16 beds (8.8 m$^3$/d);
  address................., telephone number.................
- Vaarila old people’s home, 30 beds (8.3 m$^3$/d);
  address............... , telephone number............... 
- Kurkkulan Vihannes Oy’s greenhouses (3.3 m$^3$/d);
  address............... , telephone number............... 
- 11 dairy-stock farms (a total of 4.5 m$^3$/d);
  address............... , telephone number............... 

Natural water resources are used for the needs of fire-fighting (appendix c).

The waterworks collects the waste water of 470 residents and other customers. On average, 140 m$^3$ of waste water is treated daily at the water treatment plant. Of the aforementioned special institutions and establishments, the health centre and old people’s home are part of the sewerage system.
The amounts of water and waste water are expected to remain at the current level despite the plans to extend the networks.

3.2 Raw water procurement

All raw water used by the waterworks is taken from the Santakangas groundwater basin, where it has one water intake unit with an estimated productiveness of 1 800 m$^3$/d. The water does not need to be treated but is ready for use as potable water. The plant has no back-up water intake or securing connection pipes. The supply of water has been secured relatively well at the water intake unit: the water is taken from two wells and the tail water tank is connected to two pumps. The power supply of all electrical devices has been secured by a diesel-powered generator. The water intake unit is remote-controlled and its data transfer uses a dial-up telephone network.

Because securing the quality of the raw water is vital for the plant, a protection plan will be prepared for the Santakangas groundwater basin by the end of 2006 (responsible person: N.N). The objective is to convince the environmental committee of the municipality of the risks posed by any future extraction of gravel. (N.N.) In addition, restricting the use of motor-powered vehicles outside the trafficable areas in the southwest part of Santakangas will be investigated.

During 2005, negotiations will be launched with Mesijärven Vesihuolto Oy concerning the construction of a connection pipe and supply of water in exceptional situations (N.N. and P.P.)

3.3 Water treatment facilities

The water does not need to be treated but is ready for use as potable water. To secure water quality, the means of disinfecting the system will be prepared for in case of a microbiological contamination. The availability of disinfecting equipment in the event of contamination will be settled by the end of 2005. (N.N.).

3.4 Water distribution, regulation, and storage space

A diagram of the water distribution network can be found in appendix d. The length of the distribution network is approx. 31 km and it includes one pumping station in Yläkylä for increasing the pressure, which is powered by one feeding line. In the main population centre, the supply network uses eyelet mounting, which means that damage to one pipe does not cause severe disruptions to the general supply. Outside the centre, the network is tree-shaped, due to which a disruption along one line prevents the supply of water to all customers beyond that line. The network features no connections with other networks. In the north, the closest pipeline of Mesijärven Vesihuolto Oy is located approx. 2.5 km from the plant’s pipe network.

The water intake unit has a tail-water tank, the capacity of which is 600 m$^3$; the plant has no other water storage facilities.
Intensified supervision and documentation will be used to improve the application of work instructions in the repair of pipe damage (R.R.).

3.5 Water quality control

Raw water control samples are taken twice a year from both wells, and network water samples six times a year from five different points at varying points within the distribution network. This regularity of control provides a picture of the long term development of water quality but cannot, naturally, guarantee the quality of water in the network at all times.

In the preparation of the groundwater basin protection plan, the developmental needs of groundwater quality control and the need for visual inspection at the drainage area will be considered. (N.N.)

3.6 Sewerage

A diagram of the sewerage network can be found in appendix e. The length of the sewerage system is approx. 13 km and the network features two pumping stations. They have two power supply lines. The main population centre features a 3.1 km long storm sewerage system. In other areas, rain water is directed into open ditches.

No special measures are required concerning sewerage system in the near future. The flow to the waste water treatment plant is continuously monitored and compared to the amount of pumped potable water to estimate the condition of the sewerage network. (O.O.)

3.7 Waste water treatment

Waste water is treated at the Ruskearanta waste water treatment plant with a biorotor. The plant features two power supply lines and the area has been fenced. The sludge is transported to the treatment plant of the town of Kivikylä.

No special measures are required concerning waste water treatment in the near future.

The water treated at the Ruskearanta waste water plant is forwarded to Tuuliselkä in Lake Ruskeajärvi through a 1.2 km long discharge pipe. Any waste water that does not go to the treatment plant is forwarded into the same discharge pipe. The operation of the discharge system does not depend on the power supply.

The forwarding of waste water into the discharge water system does not require special measures in the near future.

3.8 Critical materials used

The plant does not use chemicals or other daily consumed materials. The water intake unit has double pumping capacity, which in practice means back-up pumps.
The pumping station in Yläkylä for increasing the pressure features only one pump. The pumping station is only needed during periods of high consumption. The plant does not have the spare parts needed for the maintenance and repair of the pumps in stock.

For the maintenance of the networks, valves, pipes, pipe parts, and repair tools are kept in stock at the plant. The current stock is sufficient for at least three years of normal maintenance. A list of the stocked items can be found in appendix f.

No special measures are required concerning the material stock in the near future.

3.9 Power procurement and use

The plant purchases electricity from Kivikylän Energia Oy. Except for the Santakangas water intake unit and the pumping station in Yläkylä for increasing the pressure, the power supply of the pumps has been secured by two feeder lines. In Santakangas, a diesel-driven generator is used as a back-up.

Kivikylän Energia Oy has agreed to inform the plant of any developments during disruptions and to secure the power supply to the plant before household customers if required.

No special measures are required or feasible to secure power supply in the near future.

3.10 Assessment of computer preparedness

The staff have been instructed to change their personal passwords monthly. The server of the plant updates the database of the antivirus programme and firewall automatically and makes back-up copies of all working files daily. The plant has a long-term contract for computer and software maintenance with an external service provider. All information systems have been secured with a UPS.

Data transfer of the remote control system relies on the operation of the general telephone network. In the event that data transfer is disrupted, water intake is controlled locally by manual operation. For this, the plant features two VHF radio telephones.

The plant’s computer preparedness is adequate and requires no special measures in the near future.

3.11 Vehicles and mobile machinery

The plant has no special vehicles that would be critical for the continuation of operations.

In the event of disruptions of water distribution, a written contract has been signed with XXX concerning the distribution of water by using their transport company’s tank truck.
3.12 Cooperation contracts concerning materials and spare parts

The pumping station in Yläkylä for increasing the pressure features only one pump. Kivikylän Vesi has two similar pumps in its stock and they have agreed to lend one of them if required. Kivikylän Vesi can also lend back-up pumps for the waste water pumping stations if required.

3.13 Radiation safety plan

The plant’s radiation safety plan is provided in appendix g and does not require new measures.

3.14 Improving the level of preparedness

The central contingency planning measures are listed in sections 3 and 4.

The plant’s water transportation plan for a situation in which water cannot be supplied by using the distribution network can be found in appendix i. Priority will be given to the special institutions and establishments listed in paragraph 3.1.

4. Organisation and personnel

The plant employs one part-time manager (municipal engineer) and three full-time staff members: secretary, waterworks operator, and mechanic. The ages of the staff members varies between 55 and 63. Excavation and similar tasks have been outsourced. The current staff members have worked at the plant for all of their working life and know both the plant and its clientele in detail.

The undocumented data concerning the plant will be written down during 2005 (N.N., O.O., and R.R.). In addition, a new waterworks operator will be employed while the current one starts working part time in preparation for retirement.

The areas of responsibility and contact information of the personnel have been listed in appendix h, which also includes the contact information of the main contractors’ contact persons (power plant, computer company, and others).

5. Management

The head of the plant will be responsible for the management in all situations apart from emergencies. In the event that he is unavailable, the waterworks operator will be responsible for the management of the plant. He will report directly to the mayor.

The control centre will be responsible for the management in an emergency as defined in the Emergency Powers Act.
6. Emergency communication

The plant’s information practices depend on the nature of the emergency.

In the event that the contamination of potable water is suspected, the health inspector (contact information: ) and health centre should be contacted immediately.

Following the instructions provided by the health inspector, a decision is made on the possible discontinuation of pumping into the network or its continuation and intensified taking of water samples. The rescue department should be called for to remove contaminated soil and groundwater (contact information: ). The regional environment centre (contact information: ) and municipal environmental secretary (contact information: ) should also be informed. The health inspector assumes main responsibility for informing consumers about the situation. The manager of the plant is responsible for the plant’s external reporting and delegates tasks according to his best judgement. The information channels include the press, local radio, and the Internet as well as announcements made to consumers. Special institutions and establishments are informed directly either by phone or mass text messages or emails (contact information: ).

In the event that vandalism against the plant is detected, the health inspector should be contacted if there is a reason to suspect the quality of water. In all cases, the police should be informed (contact information: ).

In the event of radiation, the regional emergency centre (contact information: ), State Provincial Office (contact information: ), rescue department, health inspector, and environmental secretary should be informed.

In the event of disruptions to the water distribution and sewerage systems, the special institutions and establishments listed in paragraph 3.1 should be informed before other customers.

7. Preparative training and practice

The entire staff of the waterworks have participated in first aid training. The contingency training plan and related practices will be prepared in cooperation with the rescue department, health inspector, and the regional environment centre by the end of 2005 (N.N.)

8. Maintenance of the plan and distribution of responsibilities

N.N. is responsible for the maintenance of the plan. The plan should be updated when the need arises: therefore, whenever any of the responsible or contact persons or their contact information changes, as well as in other similar situations, the plan should be updated and the new versions distributed to all responsible persons immediately.

The implementation and impact of the measures included in this plan will be controlled and the contingency issues reassessed in their entirety by the end of 2006.
Appendix 9. Areas of expertise required in the qualification test

THE PLANT TECHNICAL AND POTABLE WATER HYGIENE -RELATED COMPETENCE REQUIREMENTS OF PERSONS WORKING IN A POTABLE WATER SUPPLYING PLANT

1. Water procurement

The person should be familiar with
- the most common impurities occurring in raw water and their significance to the need of water treatment
- the protection of the water intake unit area and the groundwater protection plans
- the activities that cause contamination of raw water such as waste water conduction, farming, soil extraction, and industrial operations
- the most common water intake unit structures
- the general principles of groundwater formation at groundwater plants
- the water intake permit and raw water quality control

2. Water treatment

The person should be familiar with
- the most important water treatment chemicals and related safety issues, feeding methods, maceration and diluting methods, and the purpose of feeding
- the significance of over- and under-dosage of chemicals and its prevention
- the most important water treatment methods and their impact on water quality
- the operational practices during disturbances (preparation for exceptional situations)
- the impact of water treatment on the quality of potable water
- the basics of operational monitoring

3. Water distribution network

The person should be familiar with
- the general principles of installation hygiene and connecting domestic water connections into the network
- the parts and materials of the network
- the implementation of the unit processes relating to the maintenance and installation of the network and tanks, such as flushing, cleaning, draining, and disinfecting
- the prevention of back flow
- the hygiene risks relating to water tanks and their prevention
4. Legislation and monitoring the quality of potable water

The person should be familiar with
- the legal requirements for the quality and quality control of potable water
- the instructional content and meaning of the monitoring programme

The person should be able to
- take a sample for the purpose of chemical and microbiological analysis
- choose the sampling point that best serves the objective of the sampling
- assess the quality of potable water on the basis of taken measurements and the appearance of the water
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Operation and maintenance of small waterworks

**Publication series and number**  
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**Abstract**  
This guide is aimed for small waterworks operators. The guide includes information on groundwater recharge, the risks of the groundwater resources and risk management procedures, guidelines and regulations relating to water intended for human consumption as well as maintenance and self-monitoring of small waterworks. Water distribution networks are also briefly covered in this guide. The purpose of the guide is to give help and advice on maintenance of the waterworks and at the same time serve as a handbook of water hygiene issues for small water supply operators, expected to be certified by passing an official examination designed for water works personnel.

**Keywords**  
Waterworks, maintenance, groundwater, well, water intake, self-monitoring, water quality, water distribution network, sampling

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Hundreds of small water cooperatives in Finland have arranged their water supply utilizing shallow groundwater wells. The operators of such utilities are seldom qualified experts and hence in need of practical guidance. This guidebook, written and published originally in Finnish and in Swedish, aims to give information and advice to operators of small groundwater utilities.

Even though many of the problems encountered at small waterworks are different due to local circumstances, especially water resources and geology, many risks and problems as well as many solutions are common throughout Europe and Asia. In order to serve wider audiences, especially in the context of the United Nations ECE and WHO, and distribute the knowledge and experience gained in Finland, the Finnish Environment Institute and The Finnish Ministry of Social Affairs and Health decided to publish this guidebook also in English language.

The authors and publishers wish that the content of this book is useful for many operators of small waterworks and helps them in their efforts to further develop safe water abstraction and distribution.