

Module 5

Drinking Water Treatment and Storage

Summary

This module introduces different types and steps of water treatment at a supplier and a household level. The steps and types presented are: removal of particles and chemical substances and several disinfection methods. Water storage at household level, operation and maintenance of the water supply are also discussed briefly.

Objectives

The module puts teachers and pupils in the position to understand the different options to remove or decrease undesired contaminants of the water. They will be able to make a rough appraisal of the conditions of their water supply and know about different water treatment opportunities and their advantages and disadvantages.

Keywords and terms

Water treatment, sedimentation, coagulation, oxidation, filtration, disinfection, chlorination, household level, storage.

Preparation/material

Materials	Preparation
Questionnaire	Making copies, eventual revising and adding more relevant questions
Excursion to the water supplier	
Paper, pencils	
Sand filter (see module 3)	

Drinking water treatment and storage

Introduction

The treatment of raw water's function is to eliminate undesired substances. Because the treatment process is a rather complex topic, guidance by experts is recommended. A fitting drinking water treatment needs a proper investigation of site conditions including all necessary physical, chemical and biological parameters. It also needs test results of a laboratory to determine all required treatment steps to deliver healthy and safe drinking water. The following chapters give a brief overview on principles of water treatment and several treatment methods.

1. Treatment at the supplier level

Because there are many different types of water contamination, many different types of treatment techniques have been developed. For example, bacteria have to be treated in other ways than turbidity, metals or colour. The following describes the most important treatments of drinking water in brief. The techniques used depend largely on the local contamination of the water and the financial opportunities of the supplier, community and/or users. Before an adequate water treatment can be implemented, an advanced investigation of the site conditions including the chemical, physical and biological analysis of the water has to be conducted. After establishing a treatment process, the effectiveness of the treatment has to be determined. All the mentioned steps should take place under guidance of experts. Equipment suppliers and consultants should be chosen carefully.

Treatment processes are based on the physical removal of contaminants through filtration, settling (coagulation/flocculation, often aided by some form of chemical addition) or biological removal of microorganisms. Usually, a treatment consists of a number of stages, with an initial pre-treatment by settling or pre-filtration through coarse media and sand filtration followed by chlorination. This is called the multiple barrier principle. It is an important concept as it provides the basis for an effective treatment of water and prevents a complete failure of treatment due to a malfunction of a single process.

For instance, if a failure of the coagulation/flocculation should occur within a system that comprises rapid sand filter, the sedimentation and rapid sand filtration with final disinfection could still assure the supply of treated water. Many of the remaining microorganisms in the water will be killed by the final disinfection. Provided that the disorder is repaired promptly, there should be little decrease in water quality.

Water treatment is a purposeful modification of the water quality. It comprises two groups of treatment:

- 1) Elimination of substances from the water (e.g. filtration, sterilisation, softening)
- 2) Addition of substances and adjusting water parameters (e.g. pH, ions, conductivity)

1.1. Coagulation/flocculation

Coagulation and flocculation are used to remove small particles from surface waters that are not removable by simple sedimentation. The addition of aluminium sulphate or ferric sulphate (or other chemicals) as coagulants causes the formation of a precipitate (or flock), which contains different impurities. Some metals like iron and aluminium, humins (e.g. from organic soil, peat), clay minerals and some (not necessarily all) organisms like plankton, protozoa or bacteria can be coagulated. The flocks are then separated by sedimentation and filtration.

Advantage: the coagulation proceeds more rapidly than normal sedimentation and is very effective in removing fine particles.

Disadvantage: higher costs for chemicals and equipment; very exact dosing and frequent monitoring, skilled personnel, disposal of sludge.

1.2. Sedimentation

Simple sedimentation (i.e. unassisted by coagulation) may be used to reduce turbidity and solids in suspension. Sedimentation tanks are designed to reduce the velocity of water flow to permit suspended solids to settle under gravity. There are many different designs of tanks, and tank selection is based on simple settlement tests or by experience of existing tanks treating similar waters.

1.3. Filtration

Particles in water can be removed by different kinds of screens and filters. The applied technology depends on the size of the to be eliminated particles and the treatment concept. Following the most common types of filtration technics are presented.

Screens

Screens are effective for the removal of particulate material and debris from raw waters and are used on many surface water intakes. Coarse screens remove weeds and debris, while band screens or micro strainers remove smaller particles, including fish, and may be effective in removing large algae. Microstrainers are used as a pre-treatment to reduce solids before slow sand filtration or chemical coagulation is carried out. A microstrainer consists of a rotating drum fitted with very fine mesh panels. Raw water flows through the mesh and suspended solids, including algae, are retained and removed by water wash, producing wastewater which may require treatment before disposal.

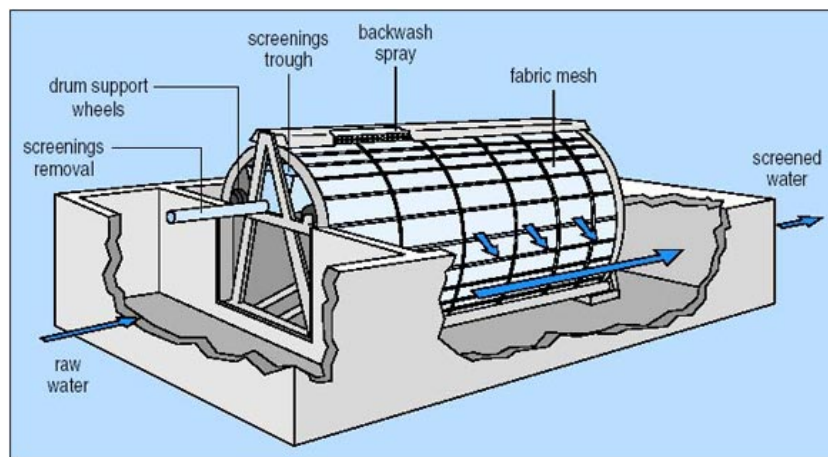


Figure 1: Microstrainer

Microstrainer is a rotating drum with continuous backwash from the top. Screen size openings 10-40 μm , algae removal, to prevent a rapid blocking of sand filters.

Source: Mudde C., Vitens Water Treatment Course (2011), PowerPoint Baku

Gravel filter

Simple gravel (Graded gravel, 4-30mm) filters can be used as a step to remove algae and turbidity. The size of a gravel filter depends on the water quality, flow rate and size of gravel. A filter can be up to 12 m long, 2 to 5 m wide and 1 to 1,5 m deep. The filter should normally be sized for a flow rate of between 0,5 to 1,0 cubic metres per square metre of filter surface area per hour ($\text{m}^3/\text{m}^2/\text{h}$).

Slow sand filter

Slow sand filters provide a biological process in contrast to the later introduced rapid gravity filter, which is more or less a physical filter. Slow sand filters usually consist of tanks containing sand (size range 0,15-0,30 mm) to a depth of between 0,5 to 1,5 m. At the top of the filter a biological active sludge layer develops, which can be active in removing microorganisms. Such kind of filter can be operated as a tandem device - one can be in service

whilst the other is being cleaned. The top few centimetres have to be replaced every 2-10 weeks, depending on the conditions of the raw water.

Rapid gravity filter

Rapid gravity filters are most commonly used to remove floc from coagulated waters and are filled with silica sand (0,5-1,0 mm). Accumulated solids in the upper layers are removed by backwashing the filter with treated water. This should happen every day. The diluted sludge after backwashing needs to be disposed of and/or treated in an appropriate way. Rapid gravity filters may also be used to remove turbidity, algae and iron and manganese from raw waters. Granular activated carbon medium is used to remove organic compounds and filters incorporating an alkaline medium are used to increase the pH value of acidic water.

Membrane filtration

Membrane filters are mechanical filters, which use a permeable membrane to separate gaseous or liquid streams. This technique originates especially from industrial and pharmaceutical applications. Depending on the purpose for the processed water, different types of membranes and techniques are used. Nowadays, some of these processes are applied in the treatment of drinking water too. The most common ones are ultra-, micro- and nano-filtration, and reverse osmosis. They differ in membrane pore size and thus in capability to remove molecules and particles of different size (see table 1). Even though the membrane process can remove protozoa, bacteria or viruses, there is no guarantee of the membrane integrity and safety. Additional disinfection of the treated water should take place.

	Ions		Molecules		Macromolecules		Microparticles		Macroparticles		
Size μm	0.001	0.01	0.1	1.0	10	100	1000				
approx. Molecular Weight	100	200	1,000	10,000	20,000	100,000	500,000				
Relative size of materials in water	Metal Ions	Salts	Viruses	Humic Acids		Clays	Bacteria	Algae	Cysts	Silt	Sand
Separation processes	Reverse Osmosis	Nano - Filtration	Ultrafiltration	Microfiltration				Conventional Filtration			
Pressure	40 bar	10 bar		2 bar				0.1 bar			

Table 1: Overview of separation processes and their effectiveness
 According to http://dwi.defra.gov.uk/research/completed-research/reports/DWI70_2_137_manual.pdf

1.4. Other treatment processes

Aeration

The purpose drinking water aeration is to eliminate iron, manganese or unwanted gases like carbon dioxide (carbonic acid), hydrogen sulphide (sulphuric acid) and methane. The release of carbon dioxide results in a higher pH as well. In addition, oxygen saturated water converts most of the iron or manganese into filtrable

substances. Different technical devices, like passing the water through air fountains, cascades, paddle wheels or cones, can do aeration. The air can also be passed through the water by aeration turbines or compressed air. Although, most aeration work by passing raw water through air in small streams rather than passing air through water (see Figure 2). To ensure elimination of iron and/or manganese, a filtration should be performed to remove the oxidised elements after the aeration. The oxidised elements appear as flocks in the water.

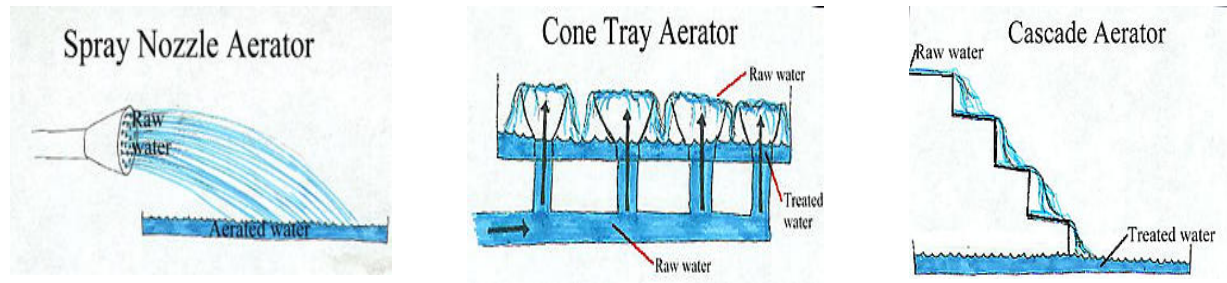


Figure 2: Drawings of different technical devices used for aeration

Source: Mountain Empire Community College. http://water.me.vccs.edu/courses/ENV115/Lesson5_print.htm

pH

The pH value of water may need to be adjusted before water distribution and during treatment for several reasons, including:

- to ensure that the pH value meets the water quality standards;
- to control corrosion in the distribution system and consumers' installations, or to reduce plumbo-solvency;
- to improve the effectiveness and efficiency of disinfection;
- to facilitate the removal of iron and manganese;
- to facilitate the removal of colour and turbidity by chemical coagulation.

Many raw surface waters are slightly acidic and coagulation processes further increase acidity. An increase of pH can be achieved by:

- dosing with sodium hydroxide, calcium hydroxide or sodium carbonate;
- passage of the water through a bed of alkaline medium;
- removal of excess carbon dioxide by aeration.

A reduction of pH can be achieved by dosing with a suitable acid such as sulphuric acid, hydrochloric acid, sodium hydrogen sulphate or carbon dioxide if the pH is too high.

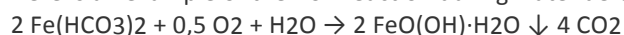
Removal of iron and manganese

To remove dissolved iron from ground waters, it is necessary to oxidise it into the insoluble ferric hydroxide. This can be done by aeration as mentioned above. Afterwards it is possible to remove the oxidised substance by filtration (e.g. sand filter). If the water comes from peaty ground for example, iron is often present as an organic complex. Then it is required to use strong oxidants like chlorine or potassium permanganate to oxidise and remove it.

The removal of manganese is more complicated than the removal of iron. It is a similar method as the removal of iron, but more intensive oxidation is necessary to convert manganese into manganese dioxide; also this step is followed by filtration (sand filter).

When coagulation is practised to remove colour and turbidity, iron removal can be reached simultaneously.

Here is an example of the iron reaction during water aeration:



Removal of nitrate

Natural nitrate concentrations occur usually below 50mg/l, (the threshold value of the EU Drinking Water Directive). If the measured concentration is above this value, it can be an indicator for man-made pollution by agriculture (animals, manure, fertiliser) or sewage. In this case, nitrate has to be removed in order to fulfil legal

standards. Ion-exchange is the most common and easiest technique to remove nitrate. Water passes through columns filled with resin beads that remove anions such as nitrate. See also paragraph 3.3. of this module. During this process, nitrate is exchanged for the equivalent amount of chloride. When the capacity for exchange is exhausted, the resins have to be backwashed and recharged with sodium chloride.

The wastewater contains large amounts of sodium chloride and nitrate. Therefore, the wastewater must be collected for disposal. Other possible removal-processes are filtering via membranes or de-nitrification. The latter one is expensive and one needs experience with such kind of processes.

	Bacteria	Cysts	Viruses	Algae	Coarse particle	Turbidity	Colour	Al*	As*	Fe*/Mn*	NO ₃ *	Pesticides	Solvents	Taste/Colour
Coagulation/flocculation ¹	+	+	+	+	++	++	++	++	+	++				
Sedimentation					++	+		+		+				
Gravel filter/screen				+	++	+		+		+				
Rapid sand filtration	+	+	+	+	++	+		+		+				
Slow sand filtration	++	++	++	++	++	++		+		+				
Chlorination	++		++	+			+							
Ozonation	++	+	++	++			+					++		++
UV	++	+	++	+										
Activated carbon							+					+	+	++
Activated alumina									++					
Ceramic filter	++	++		++	++	++								
Ion exchange								+	+	++	++			
Membranes	++	++	++	++	++	++	++	++	+	++	++	++		++

Table 2: Overview of the removal capacity and effectiveness of several water treatment systems

*Al: aluminium, As: arsenic, Fe: iron and Mn: manganese, NO₃: Nitrate

+ Partly effective ++ Effective/ preferred technique

¹ Pre-Oxidation may be required for effective removal of aluminium, arsenic, iron and manganese

Source: Manual on Treatment for Small Water Supply Systems; http://dwi.defra.gov.uk/research/completed-research/reports/DWI70_2_137_manual.pdf

1.5. Disinfection

Pollution of drinking water by animal or human faeces or sewage is one of the most threatening contaminations. This is because faeces or sewage contains an abundance of pathogenic microorganisms (see also Module 8 and 9). Disinfection is a necessary step to kill or inactivate microorganisms and to prevent spreading of harmful diseases. It is very important to test the raw water for microorganisms, as indicated by the Drinking Water Directive. It determines what kind of treatment is needed and to which intensity. The processed water has to be tested as well to make sure that the disinfection step works sufficiently. Waters from lowland streams are most affected by faecal contamination (some thousand *E. coli* per 100 ml). Upland waters still have some ten *E. coli* per 100 ml. Groundwaters should be less prone to contamination, but they are still threatened depending on site conditions.

The susceptibilities to disinfectants of the different microorganisms vary widely. The effectiveness of the disinfectants depends additionally on its concentration, contact time with pathogens, pH and temperature.

Disinfection can be attained by means of physical or chemical disinfectants. For the disinfection of water the most common means are:

1. Chlorination (chemical disinfectant)
2. Ozonation (chemical disinfectant)
3. Ultra violet radiation (physical disinfectant)

Chlorination

Chlorination is the most common in larger water supplies, but less in smaller ones. The sources of chlorine can be different, as for example, pure *chlorine gas* (from a cylinder), *sodium or calcium hypochlorite* granules or chlorine dioxide. Hypo-chlorous acid is a more powerful disinfectant than the hypochlorite ion.

All chlorine containing substances are very reactive and toxic and should be carefully handled and stored. Additionally, chlorination processes need to be carefully controlled in order to minimise problems with complaints of taste and odour. Chlorination is usually practised at certain values of pH. Therefore, for small supplies, consideration should be given to use alternatives to chlorination, such as UV.

Liquefied chlorine gas is supplied in pressurised containers. The gas is withdrawn from the cylinder and is dosed into water by a chlorinator, which controls and measures the gas flow rate.

Sodium hypochlorite solution can be delivered to the site in drums. Not more than one month's supply should be delivered at one time, as its prolonged storage (particularly on exposure to light) results in a loss of available chlorine and an increase in concentration of chlorate relative to chlorine.. Water disinfection by means of chlorine or hypochlorite affects the taste of water in a negative way.

The World Health Organization (WHO) recommends that for the effective disinfection of drinking water "the pH should preferably be less than 8,0 and the contact time greater than 30 minutes, resulting in a free chlorine residual of 0,2 to 0,5 mg/l".

Chlorine dioxide (ClO₂) is in most circumstances more effective in destroying harmful pathogens than chlorine gas. Especially the cysts of *protozoa* and *legionella* are killed in contrast to hypochlorite. Chlorine dioxide is very explosive and thus used only as an aqueous solution. It builds less chlorinated hydrocarbons with organic components than chlorine gas, but can form chlorite (ClO₂⁻). Chlorite is limited by regulation after disinfection to less than 0.2 mg/l.

Keep in mind that chlorination with chlorine gas or hypochlorite does not affect the cysts of some protozoa (*Giardia lamblia*, *Cryptosporidium*).

Ozonation

Ozone (O₃) is a very strong oxidising agent, which is toxic to most waterborne pathogens, even the cysts of protozoa like *Cryptosporidium*. Ozone has to be created on-site with oxygen and UV light or electrical discharge. It is added to the water by bubble contact with a minimum of 4 minutes of retention time. It can destroy taste and odour as well. Ozone decomposes rapidly and does not leave a persistent residual. Hence a longer lasting disinfectant should be added if necessary. It reacts with all kinds of organic and inorganic material in the water, thus the demand of ozone has to be determined analogously to chlorine. Ozone is regarded as safe in water treatment, even if some oxidation products are not well known. But because ozone is highly toxic, proper handling is indispensable.

Ultra violet irradiation

UV irradiation is the preferred method of disinfection in small-scale water supplies. Special lamps generate light with a wavelength between 250 and 265 nm. This electromagnetic radiation causes direct damage towards biological structures like proteins and DNA. An important prerequisite is clean water with low turbidity and colour. Dissolved organics and inorganics, clumping of microorganisms, turbidity or colour are some factors affecting the effectiveness of UV disinfection method. The dose of applied radiation must be high enough to

ensure a good disinfection. Residence time and UV intensity have to be adequate. A UV lamp can last up to one year.

Advantages: Unlike the treatment with chlorine, there is no taste, odour, colour or health risks left and the cysts of *Cryptosporidium* are inactivated. The handling is simple, maintenance modest and the equipment compact.

Disadvantages: As no residuals are left, the following steps of distribution have to be safe (especially storage). Otherwise, a longer lasting disinfectant like chloramine has to be applied.

1.6. Corrosion control

Corrosion is the partial dissolution of materials constituting the treatment and supply systems, tanks, pipes, valves, and pumps. It may lead to structural failure, leaks, loss of capacity, and deterioration of chemical and microbiological water quality. The internal corrosion of pipes and fittings can have a direct impact on the concentration of some water constituents, including lead, copper and nickel. Corrosion control is therefore an important aspect of the management of a water supply system. See Module 6 and 7.

Corrosion control involves many parameters, including the concentrations of calcium, bicarbonate, carbonate, and dissolved oxygen, as well as pH. The detailed requirements differ depending on water quality and each distribution system material. The pH value controls solubility and the rate of reaction of the metals which are involved in corrosion reactions. It is particularly important for the formation of a protective film at the metal surface. For particular metals, alkalinity (carbonate and bicarbonate) and calcium (hardness) also affect corrosion rates.

2. Treatment at the household level

Besides treating water at a treatment plant, small devices are developed to treat water at the point of use. This means the equipment is able to clean water in small volumes with the distinct purpose to treat water on a household level. This treated water is mostly used only for cooking and drinking. There are treatment units for the household which work very similar to those at larger plants and can produce pure water from raw waters. These units can be taken into consideration if no public water supply and/or adequate treatment are offered. All filters have one common property: they all have to be maintained (cleaned, parts have to be exchanged or regenerated).

Before residents of a household choose a water treatment system, the following questions should be answered:

- Is the system designed to treat a specific water quality problem?
- Are the local conditions, such as eventual needed high pressure, suitable for the system?
- How many litres of treated water does the unit produce per day?
- How much treated water is needed daily for consumption purposes for washing or etc.?
- How will you know if the unit is not working properly? Is there an indicator to show any malfunction of the system if it occurs?
- How high is the total cost and what kind of maintenance is required? Is it manageable?
- Is there a service and warranty for the system?

Filter	Particles	Odour	Microorganisms	Nitrate	Metals, hardness	Pesticides
Ceramic	+++		++			
Active carbon	+	++				+
Anion-exchanger				+++		
Cation-exchanger					+++	
Boiling			++			

Table 3: Different options of water treatment systems for households without adequate drinking water quality

2.1. Ceramic filter

The water has to flow through the ceramic (usually sold as 'candles'), which has a very porous structure. Depending on the pore size, particles up to 0.5 μm can be filtered. Sometimes the filter is impregnated with colloidal silver and will prevent bacteria or fungi from building up on the layers of the candle. Silver is very toxic for many microorganisms as it prevents them from taking oxygen from the water. An active carbon unit can be integrated into the filter. The candle has to be replaced regularly. Ceramic filters remove particles and microorganisms; chemicals like nitrates or calcium (hardness) are not reduced.

2.2. Active carbon filter

Activated carbon is carbon produced from carbonaceous source materials such as nutshells, peat, wood, coal etc. Due to its high degree of microporosity, just one gram of activated carbon can have a surface area in excess of 500 m^2 . Activated carbon is widely used in water treatment processes, while it has a very porous structure and is able to adsorb dissolved organic substances which cause taste or odour. Some pesticides or pharmaceutical residues can be adsorbed by active carbon as well. The more non-polar the substances are, the better they are adsorbed. Ionic substances like minerals, nitrate, salts or lime are not adsorbed and remain in the water.

2.3. Ion-exchange

Many water-softening devices depend on a process known as ion-exchange. Ion-exchangers can exchange certain ions with ions with the same electric charge, for example calcium ions in water are exchanged with sodium ions that are loosely bound to a resin. Ion exchangers have a limited capacity, and after the resin is filled with the removed elements, the exchanger has to be regenerated.

- Anion-exchanger: they can be used to remove nitrate or other negative charged ions or substances.
- Cation-exchanger: they are used in households to soften the water (reduction of hardness) and exchange the positive ions Ca^{2+} and Mg^{2+} with Na^+ .

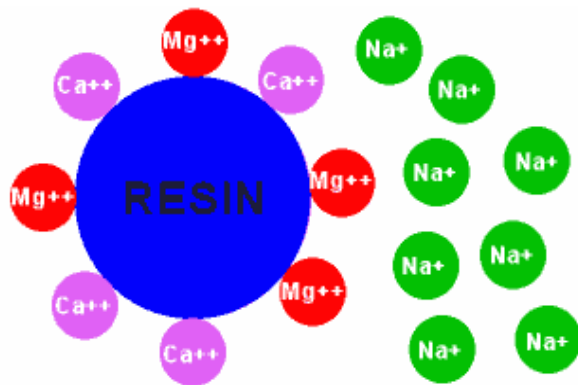


Figure 3: Fully charged resin

Source http://www.healthgoods.com/Drinking_Water_Filter_Buying_Guide_s/150.htm

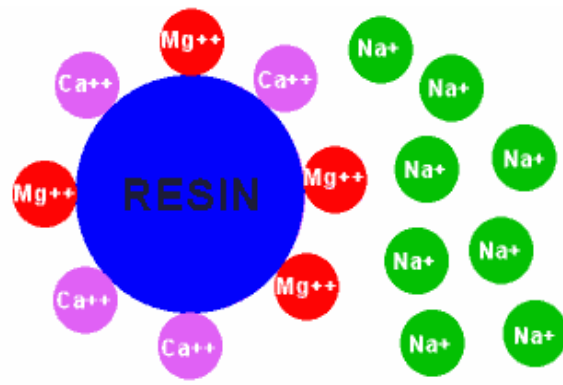


Figure 4: Exhausted resin after ion exchange

2.4. Boiling

Simple boiling of the water (minimum 5 minutes) can destroy microorganisms. It is a common and temporary help until the source of water contamination is determined and/or treatment is adjusted. Chemical contaminations are not at all affected or destroyed.

3. Storage of drinking water

A water supply system should have the possibility to store a certain amount of water in an adequate tank to provide drinking water during times of maintenance, problems with the source or treatment and fluctuating demand. All storage tanks must be insulated to prevent freezing in the wintertime or heating during summer. Light, pollution and insects have to be kept away. Storage tanks have to be built and maintained in a proper manner and inspected regularly. Tanks might be used to maintain an appropriate pressure.

Examples for special water storage tanks are high level tanks, i.e. the water level of an elevated water reservoir is higher than the supply area and the water can follow the natural slope by gravity. It has two functions: storing a smaller volume of water and providing an appropriate pressure at the consumer's tap. These terms can be achieved by using a water tower or by being integrated into a geographical elevated area.

For the storage of drinking water in the household, dispensers with a narrow opening for filling and dispensing are recommended. These kinds of containers protect stored household water especially from contaminations with microbial organisms. Storage containers should furthermore be situated on a stable base so it will not tip over easily, be strong and durable, not be transparent (see-through) and be easy to clean.

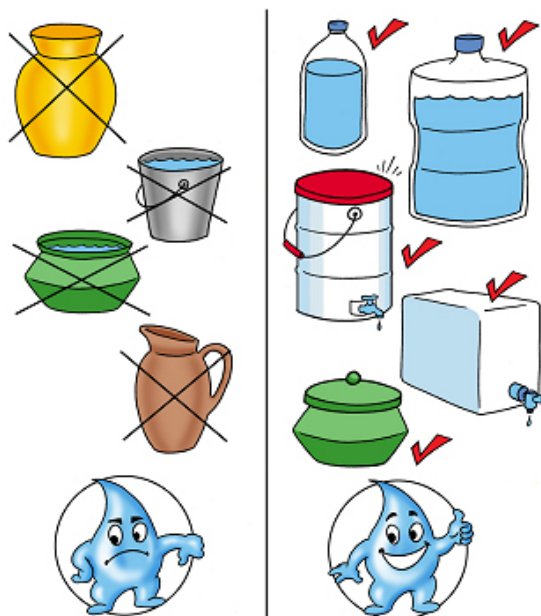


Figure 3: Different types of containers: to the left unsafe, to the right safe storage of drinking water

Source: CAWST (2009)

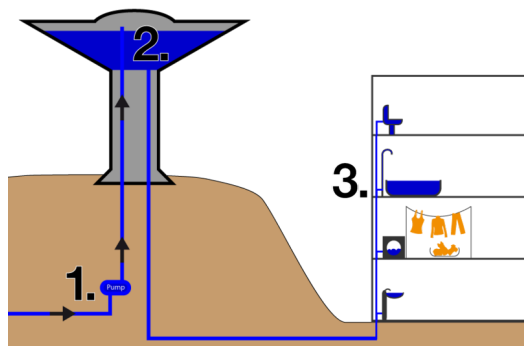
<http://www.sswm.info/category/implementation-tools/water-purification/hardware/point-use-water-treatment/hwts>

4. Transport to Consumer

Drinking water is transported to the consumer and distributed by a more or less extended water pipe network. The water pipes have to fulfil different standards in order to deliver good quality water. Hence, the material of the pipes has to comply with several technical (and legal) aspects. A proper design, assembling and installation from the catchment to the household are essential. For more information about this topic, please refer to module 2 and 6.

A so far neglected issue is water loss in the network. In Bulgaria, around 60% of the water is lost on the way from the suppliers to the consumers. Other countries like Italy (28%), Great Britain (20%) and Germany (8%) have solved this problem in different ways. Broken pipes do not only lead to water loss, but can also be a source of water contamination as organisms and substances can enter the network (see also module 7 and 12).

The supplier has to maintain an appropriate pressure as well. If necessary, pumps have to be installed to provide enough pressure for all consumers. The average flow velocity should guarantee that the retention time of the water does not last too long in order to avoid growing of pathogens and raising temperatures.



1. Pumping of the treated water to the tank
2. Water tank (higher than tap at consumer level)
3. Utilisation of water at consumers' household

Figure 4: Water tower schematic

Source: de.wikipedia.org/wiki/Hochbehälter; Jonathan Cretton

5. Maintenance, training and management

The management, implementation, operation and maintenance of a water supply system require commitment and adequate qualification of all personnel. This is often the most neglected part of a water supply system. The bigger the system, the more consumers are connected, the more water is provided, the more sophisticated the system will get and the more essential is the qualification of managers and workers.

On the management level, planning, collecting data, engineering and communication takes place. In order to manage unforeseen situations, one of the overall tasks is also the elaboration of a local emergency plan for the water supply system. Typical hazardous events are listed in module 2.

The workers take responsibilities to install pipes, operate and maintain treatment plants. For them, it is important not only to fix broken equipment, but also to check it all on a regular base. Devices, chemicals, lamps, and etc. have to be maintained and exchanged preventively. Simple check programmes identify problems in the time necessary to take appropriate measures for fixing.

The checks may include:

- Disinfection, it is most vulnerable and should be checked at least on a daily basis.
- Filters and tanks should be cleaned regularly.
- Site inspection of catchment and water source tapping.
- Regular inspection of the treatment plant, piping system and storage tanks.

Workers should be familiar with the topic and the special equipment used in the local treatment plant. For a proper operation, it is advisable to follow the instructions of the supplier. Suppliers often provide training for their devices. Some may offer contracts on maintenance too. The assistance of experts can be very helpful.

Training of local workers and management personnel should comprise:

- Conducting (or assigning) water analyses and publishing test results according to the regulations.
- Checking that the treatment plant is working properly.
- Protecting the source against contamination.
- Refilling chemicals.
- Conducting routine maintenance and small repairs.
- Clarifying responsibilities (e.g. in case of emergency).
- Documentation.
- Developing mechanisms for the involvement of all stakeholders and developing transparent financial instruments for the operation and maintenance of the water supply.

6. Exercises and questions

- Invite the water supplier to explain how the water system and treatment works.
- Discuss the strong and weak points of the local water supply system with the supplier. Furthermore, ask about the desirable changes, and about the financial, technical and environmental aspects.

- Visit the local water supplier, treatment plant or catchment area.
- Draw a picture (mapping) of the water flow from the catchment area to the households. Which kind of source, source tapping, treatment and storage are included?
- Explain the usage of a sand/gravel filter
- What kind of devices do the pupils use at home for water treatment or storage?

WSP – related activities

Gather information from the local supplier:

- Is the raw water treated? If yes, what kind of treatment is used for the local water?
- Is the water quality monitored during and after the treatment?
- Are the test results of drinking water made public?
- What are the test results of raw and treated water?
- Discuss if the treatment is sufficient enough.
- In what condition is the local piping system and the treatment plant in?
- Are the workers trained adequately and who is responsible for what?
- Is there enough budget available for operation and maintenance of the local water supply system?
- Is there any plan in case of an emergency? If yes, what does the plan look like?

7. Text sources and further reading'

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