Developing a

Water & Sanitation Safety Plan

in a Rural Community

Background information for developing WSSP

Compendium – Part B

Compendium – Part B

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Contents

Foreword

Public health, safe water supply and safe sanitation are very much interrelated and are neglected or in their relevance underestimated, particularly in rural communities. Better protection and management of drinking water sources and sanitation facilities are possible, if weaknesses and strengths are identified. For the identification of possible sources of hazards and risks, the knowledge about an adequate quality of water and sanitation, the pathways of contamination and the associated risks, as well as the prevention of risks are essential. A water and sanitation safety plan (WSSP) can be one way to obtain and maintain safe drinking water and sanitation systems and to minimise related diseases. The management of a safe drinking water supply system, whether it is on a small or large scale, concerns many stakeholders.

On community level, the concerned stakeholders, local authorities, water operators, schools, citizens can play together an important role in improving the management of the local drinking water supplies and sanitation facilities. This compendium gives guidance and background information for managing and planning safe water and safe sanitation for small rural communities in the pan-European countries.

The presented Compendium aims to enable communities to develop a WSSP for small-scale water supplies, e.g. dug wells, boreholes, springs and piped centralised water supply systems, and as well as to assess the quality of sanitation facilities such as school toilets. The users of this WSSP compendium should facilitate them to develop step-by-step a WSSP for their community in a multi stakeholder process and in cooperation with authorities, schools, citizens and other stakeholders.

We hope, that local authorities, water operators and schools will largely use this compendium as a practical tool to improve the public health situation - not only in Macedonia and Romania, but in other countries of the pan-European Region as well!

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Acknowledgements

After the Water Safety Plan (WSP) approach had been created by WHO, the WECF senior water professional Margriet Samwel understood the rich potential of WSP, also for small communities and developed the manual "Developing water safety plans involving schools" and now available in English, Armenian, Azerbaijan, Romanian, Russian and Georgian) especially for small scale water supplies in the pan-European Region. The manual has been applied in the WECF network in 8 countries of Eastern Europe and the Caucasus during the last 6 years.

Some stakeholders had become enthusiastic but requested to provide them with more background information. In addition, the issue of sanitation turned out to be often neglected, although it is of special importance for public health in rural communities as well. The present compendium is thus a consistent further development based on the experience within the WECF network.

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How to Use the WSSP Compendium?

The Water & Sanitation Safety Plan (WSSP) compendium consists of three parts:

Part A: How to accomplish a water and sanitation safety plan?

Part A, consists of 8 modules, explaining the approach of developing water and sanitation safety plans (WSSP) for small-scale water supplies, and provides basic and practical guidance for developing a WSSP. Two modules focus mainly on WSSP for non-piped water supplies and on small-scale piped distribution systems. Furthermore this part introduces the practical activities in 10 steps to be carried out by a WSSP team and leading to a local WSSP. Several forms for the practical activities, doing risk assessments of the water supply or toilets, doing interviews of different stakeholders and processing the collected information and results as well as examples are provided.

The main target groups of part A are local authorities and water operators, but also teachers and NGOs.

Part B: Background information for developing WSSP

Part B, consists of 8 modules, providing technical and regulatory information on for example possible drinking water sources, water treatment and distribution, sanitation and wastewater treatment, water protection and water quality, management of storm water and water related regulations.

The main target groups of part B are persons who appreciate more background information on water and sanitation related issues. These can be local authorities and water operators, but also teachers, NGOs and interested citizens.

Part C: How to involve schools?

Part C, consists of 6 modules, and is an additional part, especially for youth and schools. It includes theoretical lessons on general water issues such as the water cycle, and also specific information on school sanitation, water and hygiene. The development of a WSSP is explained especially in terms of involving pupils and citizens. Exercises and suggestions for practical and interactive actions in combination with the tool box are detailed.

Part C targets mainly teachers, but also youth group leaders, NGOs or local authorities.

Remarks

Most of the modules finish with a list of practical WSSP related activities, the expected results or outputs, and a list with references and further readings.

The contents of the presented WSSP compendium are not definite and can be adjusted and developed according to the local situation and possibilities for implementation.

In part C, the use of the toolbox is also recommended to carry out the exercises.

Module B1

Drinking Water Sources and Abstraction

Authors: Friedemann Klimek, Margriet Samwel

Summary

Water resources are crucial to a sustainable installation and operation of a water supply and to economic development of a community or region. Without access to safe water communities are restricted in many activities such as tourism or growing food. A successfully working water supply, which delivers continuously the whole year through, tasty and healthy drinking water all day, is not self-evident.

The selection of water sources intended for the water supply is crucial and has to fulfil certain requirements.

This module introduces several aspects to take into consideration for the selection of a water source such as groundwater, spring or surface water. An overview of the vulnerability of different types of raw water for possible natural and anthropogenic contaminants is given. The properties and vulnerability for contaminants of the used raw water sources, seasonal fluctuation of quality and quantity, the renewable capacity of the source, as well some aspects of water abstraction are highlighted.
Pros and cons of different water sources and types of water abstraction are discussed.

Objectives

The module puts the readers in the position to understand the criteria for the selection of raw water sources like groundwater, springs or rivers for a drinking water supply. They will be able to make a rough appraisal of the conditions of the water sources used for their water supply, their advantages and disadvantages.

Keywords and terms

Drinking water, aquifer, water source, groundwater, surface water, well, borehole, spring, water abstraction, catchment area, contaminants.

Drinking water sources and abstraction

Introduction

Water resources are crucial for the installation of a water supply and even for economic development of a community or region. Without access to safe water communities are restricted in many activities such as developing tourism or growing food. Furthermore the lack of sufficient and safe water for peoples´ consumption and hygiene will provoke water and sanitary related diseases and economical losses. A successfully working water supply, which delivers tasty and healthy drinking water all day, is not self-evident.

In the pan European region several countries, regions or communities face water shortages, which can have a chronic or seasonal character. Before a water supply network is installed, the properties of the used raw water sources, seasonal fluctuation of quality and quantity, as well the renewable capacity of the source should be known. The size and location of the catchment area, the on-going human activities in the catchment and the water need of the consumers should be identified.

Finally, the abstraction of the raw water from the water body should be in balance with the water recharge.

1. What is drinking water?

According to the Protocol on Water and Health of UNECE and WHO *“Drinking water means water which is used, or intended to be available for use, by humans for drinking, cooking, food preparation, personal hygiene or similar purposes,”* drinking water or potable water is water of sufficiently high quality that can be consumed or used especially for drinking and cooking with low risk of immediate or long term harm. It has to be very pure.

Though our planet is covered by 71% of water, only a fraction can be used as drinking water (table 1). Only 1% of all freshwater can be used as drinking water! This is an equivalent of 0.0026% of the total water volume!

		Water volume [km^3]	**Percentage [%]**	
Total		**1 384 120 000**		**100.**
Saltwater (sea)		**1 348 000 000**		**97.39**
Freshwater (total)		**36 020 000**	100	**2.60**
Freshwater	Water in polar ice, sea ice, glaciers	27 820 000	77.23	2.01
	Groundwater, soil moisture	8 062 000	22.38	0.58
	Water in rivers and lakes	127 000	0.35	0.01
	Water in the atmosphere	13 000	0.04	0.001

Table 1: Water volume of the earth
Source: Marcinek & Rosenkranz 1996, Data according to Baumgartner und Reichel 1975;
bfw.ac.at/300/pdf/globaler_wasserkreislauf.pdf

The following pages give an overview on the different types of raw water sources for water supplies and vulnerability for possible natural and anthropogenic contaminants

2. Source selection and catchment area

There can be various sources depending on local conditions. Drinking water can originate from groundwater (springs, wells), surface water (rivers, lakes, reservoirs, sea), rainwater or even mist. The usage of surface water can be necessary if local groundwater is scarce or non-exploitative. Surface water is much more vulnerable to contamination by anthropogenic and natural activities and should be analysed and always treated adequately.

The recharge of local springs depends largely on the local geology and climate. As aquifers store only a certain amount of water, the local water supply often depends largely on the precipitation received in past weeks or months. If there is less precipitation and/or higher temperatures, the wells and springs could dry up.
On the other hand deep located aquifers can store water of some decades up to some centuries. Water suppliers extracting water of these kinds of aquifers should be aware of the capacity of the aquifer to renew the extracted volumes of the water (see 2.3).

Hence the selection of water sources to establish a water supply depends largely on the hydrological and geological conditions and (local) precipitation in the catchment area as well on the potential hazards in the catchment area. An advanced mapping of the hydrological, geological and land use conditions is very helpful for proper planning and implementation. The management of the catchment area can be essential to minimising problems in water quality and in the treatment of the water.

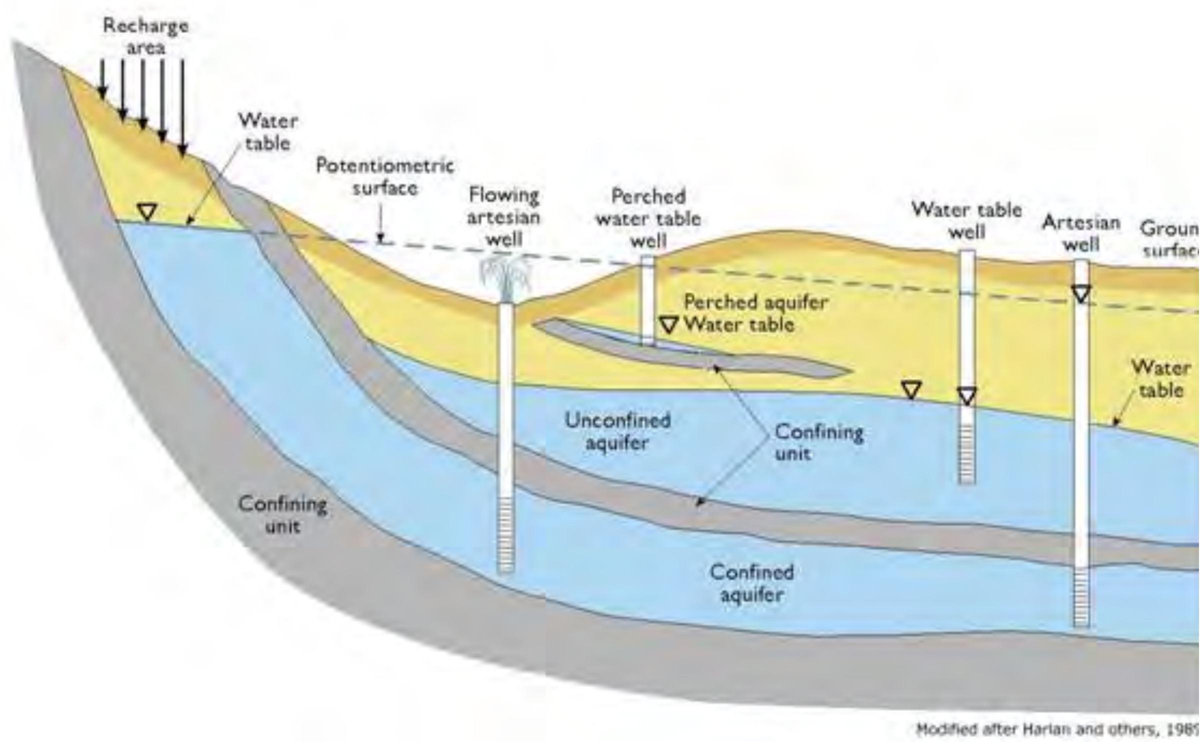

Figure 1: Aquifers and wells

Source: http://www.douglas.co.us/water/What_is_an_Aquifer$q.html

2.1. Surface water

Rivers (e.g. Danube), canals or lakes (natural or artificial) are a frequently used source of water, but they are vulnerable to pollution by man and wildlife. Agriculture (pesticides, fertiliser, grazing cattle) industry and wastewater discharge cause a volatile water quality with higher concentrations of chemicals and pathogenic microorganisms. Algae and their toxins can affect nutrient-rich water too. Furthermore, droppings of wildlife in surface waters are un-avoidable; therefore surface waters without treatment are not safe for drinking purposes. Depending on the catchment area, different measures of preventing hazardous risks have to be undertaken. Because of the potential risk of pollution, surface waters are only considered if other sources (especially groundwater) are not available. Water from an upland catchment area, without agricultural activities and with an acceptable pH, usually shows good chemical quality, but does not necessarily have a good microbiological status! Finally, microorganisms are the main cause of diseases when unsafe water is consumed.

Small rivers are often affected by local human activities and show poor water quality. The community and local administration have the power to change the conditions. Lowland streams are expected to have the worst

water quality, and the local influence to change water quality is at a very low level. In general, this water can change very quickly in its properties, like turbidity (rainfall) or colour (seasons). Natural variability of water quality is common for surface waters, but man-made pollution should be as low as possible.
In the Council Directive 75/440/EEC, 91/692/EEC the requirements concerning the quality required of surface water intended for the abstraction of drinking water are written down. Three categories of surface water are defined and the required standard methods of treatment for transforming the 3 categories surface water into drinking water.

The Danube is a source for drinking water for many villages and cities

If possible water should be collected from the ground in the immediate vicinity of the stream and riverbank. Furthermore, the intake should be situated at a point with low turbulence, during e.g. high rainfalls. If surface water is selected as a source for the drinking water supply, a lot of technical and financial efforts have to be made to deliver safe and proper drinking water to the public. At least a minimum of filtration and disinfection, and monitoring the quality is required. May be lakes are more uniform in their water quality, but not less vulnerable to contamination as mentioned above for rivers.

2.2. Springs

The quantity and quality of water from a spring can vary depending on its source. Springs fed by a deeper aquifer are more reliable and constant, whereas those issued by a perched water table or covered by fissured limestone or granite may dry up. The treatment of spring water is normally less intense because the suspended matter is lower. However, water is not protected against contaminants from agriculture or wastewater from households or communities in many areas. In certain circumstances microorganisms and chemicals can contaminate shallow ground and the spring waters. Soil layers have a certain capacity on adsorbing and filtering pollutants. Hence, deep-water layers are better protected against infiltration than shallow ones in general. The composition of the soil layers has a huge influence on the water quality and its contents. Water passing the soil layers dissolves and transports minerals from the soil into the groundwater. Depending on these layers and the geology, ground waters and springs can contain a varying mixture of several minerals, which can cause technical or health risks. Building a water collection chamber can protect the abstraction point of the spring. The collection chamber can protect the source from pollution, entrance of vermin and debris, and can provide storage for times when there is a higher demand.

2.3. Groundwater

Boreholes and wells are used to explore groundwater of different depths and quality. The quantity of water, which can be extracted, depends on the characteristics of the aquifer. It can be helpful to test it after construction by pumping. Several tests to estimate the suitability of the groundwater body on serving the drinking water supply are developed. The tests should focus on quantitative quality and on chemical status of the water body: are there hazards of saline, surface waters or other intrusions. Does the groundwater abstraction influence terrestrial ecosystems, what is the balance of abstraction and recharge, what is the chemical status and what is the location of the catchment. The recharge tests and groundwater flow tests have to be carried out by experts. Nevertheless for installing a sustainable centralised water supply a basic knowledge of the characteristics of the water body is indispensible.

Shallow wells and boreholes are more at risk to be contaminated than deeper ones, but if sited correctly, they can deliver good quality drinking water. As for springs, the water content and quality is strongly related to the soil layers above the aquifer. Water abstracted from deep wells and boreholes can originate from catchments many kilometres away. Hence, it is important for the water supplier to know the properties and characteristics of the catchment area (see also module B6 – water protection).

A higher quality of groundwater is assured through accurate land use management. This can reduce technical and financial investment by already removing unwanted water contaminants like fertiliser, pesticides, other chemicals or pathogens. A good example is the work of the Munich Water Works (www.swm.de/english.html). Ecological agricultural practice within the catchment area and regional marketing of the products were established. Water suppliers are able to deliver drinking water without practically any treatment.

Most groundwater (aquifers) are renewed naturally by infiltration of water from rain or snow in the recharge area; which, as mentioned above, may be many kilometres away from the abstraction point. However, the water table will subside if the water abstraction for water supply or for irrigation exceeds the natural recharge capacity of the groundwater layer (water mining).

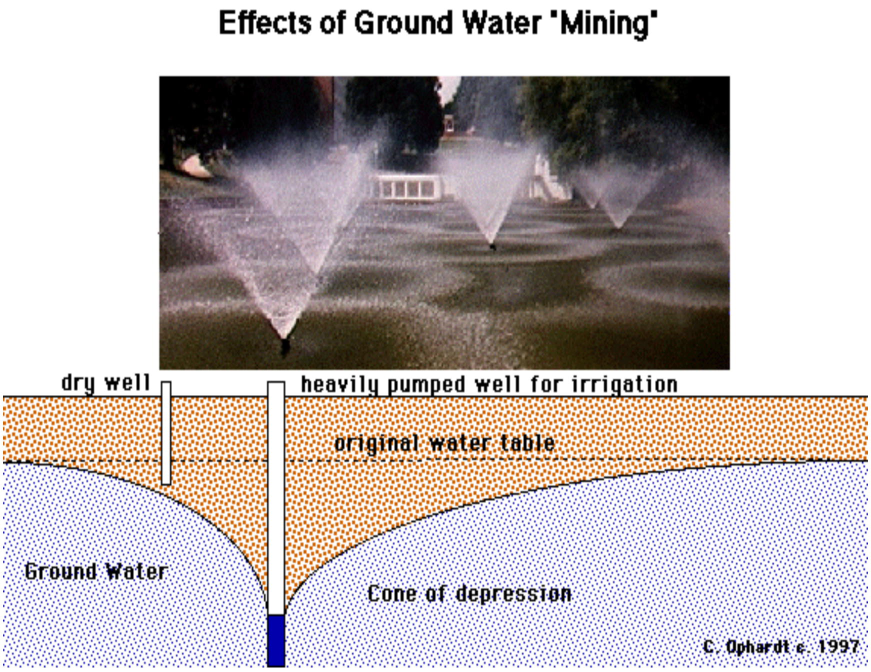

Figure 2: Overexploitation of a groundwater layer
Source: http://www.elmhurst.edu/~chm/vchembook/301groundwater.html

In this case, wells may get dry, water could be sucked from the upper soil layers into the aquifer or coastal salty water could infiltrate into the aquifer depending on the depth. Over exploitation of the groundwater source has to be avoided!

3. Vulnerability of different types of raw water for possible contaminants

The water quality is a matter of type of water source and changes according to geological, land use and weather conditions. The following table gives a rough idea of expected raw water content. For example adequate extracted groundwater will contain no particles, but springs or surface water can contain many particles after heavy rainfalls. In contrast, the groundwater can have high levels of calcium, magnesium and salts depending on the geological conditions. Surface water is less vulnerable for those elements.

Contaminant in raw water	**Ground water**	**Artesian water**	**Spring**	**Surface water**	**Most frequent source**
Microorganism	+	-	++	++	Wastewater, agriculture
Nitrate	++	-	++	-	Wastewater, agriculture
Calcium/magnesium	++	++	+	-	Natural
Sulphate	+	+	+	-	Natural
Iron/manganese	++	++	+	-	Natural
Fluoride	+	+	-	-	Natural
Sodium/potassium (Salts)	++	++	+	-	Natural, infiltration of sea water, inadequate irrigation practice
Particles (sand/loam)	-	-	++	++	Erosion, weather events (rain)
Contaminant during distribution					
Microorganisms	++	++	++	++	Leakages in pipes and connections
Metals: lead, copper	+	+	+	+	Lead or copper pipes, Corrosion
Chlorine-compounds/halogens	+	+	+	+	Chlorination
Phosphates	+	+	+	+	Treatment with phosphates
Salts	+	+	+		Treatment by ion exchanger at household level

Table 2: Different types of raw water sources and their vulnerability for possible natural and anthropogenic contaminants.

- Low vulnerability

+ Vulnerable

++ High vulnerability

4. Water abstraction

Before a water source is selected being to become a drinking water source, the water yield and quality should be tested. A set of chemical and microbiological parameter should meet the established standards, and the potential sources of pollution and, if applicable, the potential treatment methods should be assessed. See module B2 and B4. The technical realisation of water abstraction is different for each type of source and geological condition.
The following descriptions are held simple to be clear and comprehensible.

Boreholes/wells

Boreholes have a small diameter and may vary in depth and are drilled by specialists. Even deeper aquifers are accessible. They are mostly favoured if no other water supply is provided and water is needed in high quantities (e.g. irrigation). Legal aspects have to be taken into consideration. In contrast to boreholes, wells are dug by hand, have a larger diameter of about 1 meter or more, and are in most cases not deeper than 20m. Wells should be drilled or dug in appropriate locations, to avoid pollution by septic tanks, pit latrines or farmyard runoff etc. Furthermore, the used equipment and method should meet certain standards, as well the casing and grout. The wellhead and the direct surroundings of the well should not allow any infiltration of polluted surface or groundwater or runoff.

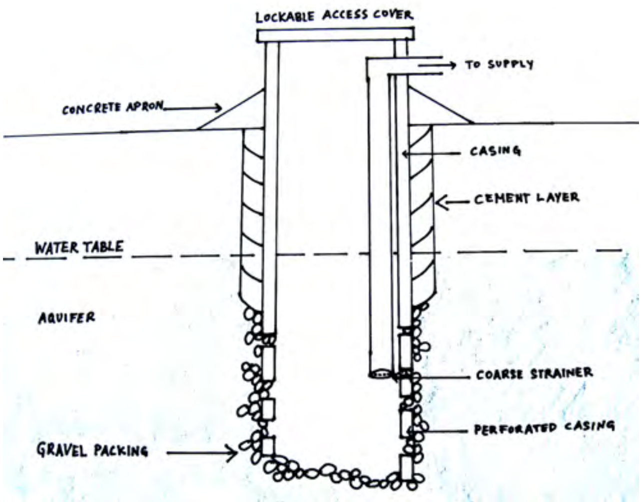

Figure 3: Schematic overview of a well or borehole source
According to Source: DWI: http://dwi.defra.gov.uk/research/completed-research/reports/DWI70_2_137_manual.pdf

Springs

Tapping of a water source can be established where groundwater occurs at the surface or is in less depth water layers. The source is exposed by a dredger or by hand. A filter pipe (PVC pipe with slots) is installed crosswise at the level the water flows. This is covered with silt and gravel. The water collected in the pipe is led to a small chamber or basin from where it goes to the water treatment or straight to the consumer. Springs are protected from pollution and can provide storage for times of higher demand.

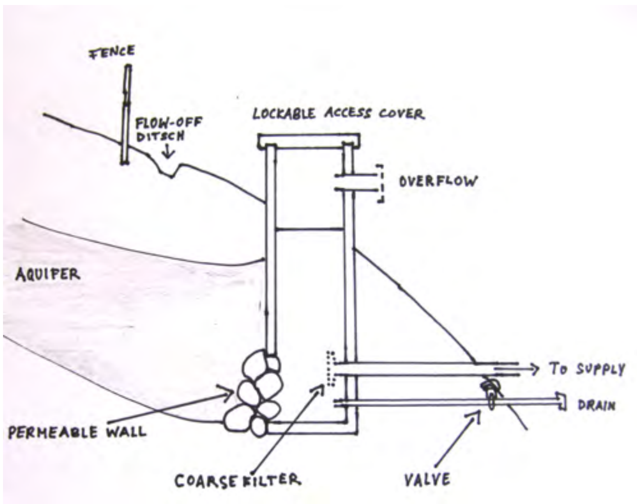

Figure 4: Schematic overview of a spring source
According to Source: DWI: http://dwi.defra.gov.uk/research/completed-research/reports/DWI70_2_137_manual.pdf

Entrance of a spring catchment

Photo source: Bayerisches Landesamt für Umwelt (Bavarian State ofice for Environment); (http://www.lfu.bayern.de/wasser/merkblattsammlung/teil2_gewaesserkundlicher_dienst/doc/nr_219_anlage6.pdf)

Water collection of a spring in Bavaria.
Tapping of the spring can be carried out with several drainage pipes. The basin should be covered and ferment proof.

Photo source: Bayerisches Landesamt für Umwelt (Bavarian State ofice for Environment); (http://www.lfu.bayern.de/wasser/merkblattsammlung/teil2_gewaesserkundlicher_dienst/doc/nr_219_anlage6.pdf

Rivers and lakes

Rivers and lakes can serve as a resource for a drinking water supply. However, the raw water always have to be treated before it is suitable for drinking, food preparation or other domestic purposes. Surface waters are easily polluted by wildlife and infiltration or run-offs by contaminants from wastewater and agricultural activities. Furthermore natural variations of water quality, such as turbidity through water turbulences and weather events, are likely in rivers and streams. Prevention of erosion by appropriate agricultural technics, avoiding grazing livestock in the vicinity of the riverbank and discharge of wastewater are key-elements of protecting the water source.
If possible, water should not be collected from the surface in the immediate vicinity of the stream and riverbank. The intake should be situated at a point with low turbulence and up streams of the community, and sediment traps and screens at the point of abstraction should be installed (see module A3).

5. WSSP related activities and results/ output

WSSP Activities	Results/output
Identify and map the raw water sources used for water supply.	A map with the locations of the used raw water sources is available

Gather geological and hydrological information – identify the water flow directions of the used water sources, the potential water yield and balance of water abstraction and recharge • Identify the location and size of the catchment area • Gather all information about the quantity and quality of the used drinking water sources. • If information about the raw water quality is lacking conduct additional analyses	A report with providing information about the properties and quality of the raw water sources and the location and size of the catchment area(s) is produced. o Analyse of the raw water sources are conducted during several seasons. The results are accessible and assessed.
Investigate if the volume of the water sources and the renewable capacity of the used raw water sources are in balance with the volume of the abstracted water • Identify the average volume of the overall needed water, taking the daily and seasonal fluctuations in consideration	The capacity of the water sources and the volume of the yearly abstracted water are known; the seasonal and daily fluctuations are registered. o The ratio of renewable capacity of the raw water source(s) and the volume of the abstracted water is calculated and assessed
Identify and map the human activities in the catchment and assess the potential hazards. • If applicable, map leakages in the water and sewage system. • Investigate the agricultural and industrial practices within the catchment area.	A report, including a map, with the locations and types of the identified human activities is available. o The potential hazards to the water sources are identified.
Inspect and assess the condition of the abstraction systems.	The condition of the abstraction systems is reported and assessed.
Investigate the raw water treatment methods in use and eventual are needed to transform the raw water into safe drinking water.	An overview of the used treatment method is available. o Eventual lacking steps required for an adequate treatment are identified.
Identify the pros and cons of the used water sources • If required water protection measures are discussed and identified. • Eventual alternative water sources are discussed and identified	An overall assessment report of the used water sources is available. o A list with water protection measures is available o So far required, suggestions for potential alternative water sources are made.

6. Text Sources and further reading

Drinking Water Inspectorate (DWI), (2001). Manual on Treatment for Small Water Supply Systems. Available from http://dwi.defra.gov.uk/research/completed-research/reports/DWI70_2_137_manual.pdf

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Module B2

Drinking Water Treatment, Storage and Distribution

Authors: Friedemann Klimek, Margriet Samwel

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 by several filtration techniques, removal of chemical substances by oxidation or ion exchange. The most common disinfection methods are described.
Furthermore, overviews of the removal capacity and effectiveness of several water treatment systems and separation processes and their effectiveness are given.
A separate chapter covers water treatment and storage at household level. Finally the distribution and operation and maintenance of the water supply, as well the training on water related issues of responsible authorities and operational staff are discussed briefly.

Objectives

The module allows the reader to understand the different options to remove or decrease undesired contaminants of the water. The reader will be able to make a rough appraisal of the conditions of the water supply and know about different water treatment opportunities and their advantages and disadvantages, and the necessity of an adequate training of persons dealing with drinking water supply.

Keywords and terms

Water treatment, sedimentation, coagulation, oxidation, filtration, disinfection, chlorination, household level, storage, distribution, water losses, training.

Drinking water treatment, storage and distribution

Introduction

The function of the treatment of raw water is to eliminate undesired substances. Because the treatment process is a rather complex topic, guidance by experts is recommended. First of all the treatment should target the elements or substances to be eliminated or to be adapted. Therefore, 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.
After the treatment, the drinking water has to be stored, transported and distributed in such a way that at the point of consumption the water is still safe, and minimal water losses occur within the network.
The following chapters give a brief overview on principles of water treatment and several treatment methods. Comprehensive information about distribution and water losses is given.

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 micro-organisms. 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 disinfection. 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 step occurs in a system that comprises rapid sand filter, the sedimentation and rapid sand filtration with final disinfection can still assure the supply of treated water. Many of the remaining micro-organisms 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. The advantage of coagulation is that it proceeds more rapidly than normal sedimentation and is very effective in removing fine particles. The main disadvantages are the higher costs for chemicals and equipment; Further exact dosing, frequent monitoring, skilled staff and disposal of sludge are needed for a proper functioning of the coagulation process

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 particles to be eliminated and the treatment concept. In the following paragraphs, the most common types of filtration techniques 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.

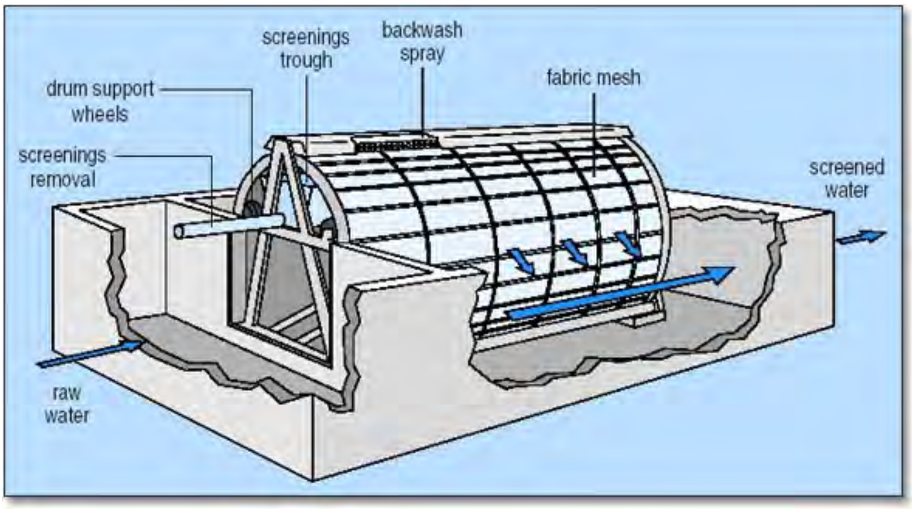


Figure 1: Microstrainer
Microstrainer is a rotating drum with continuous backwash from the top. Screen size openings 10-40 µm, algae removal, to prevent a rapid blocking of sand filters.
Source: Mudde C., Vitens Water Treatment Course (2011), PowerPoint Baku

Gravel filter

Simple gravel (graded gravel 4 to 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 ($m^3/m^2/h$).

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 to 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 micro-organisms. 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 condition of the raw water.

Rapid gravity filter

Rapid gravity filters are most commonly used to remove flock from coagulated waters and are filled with silica sand (0.5 to 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.

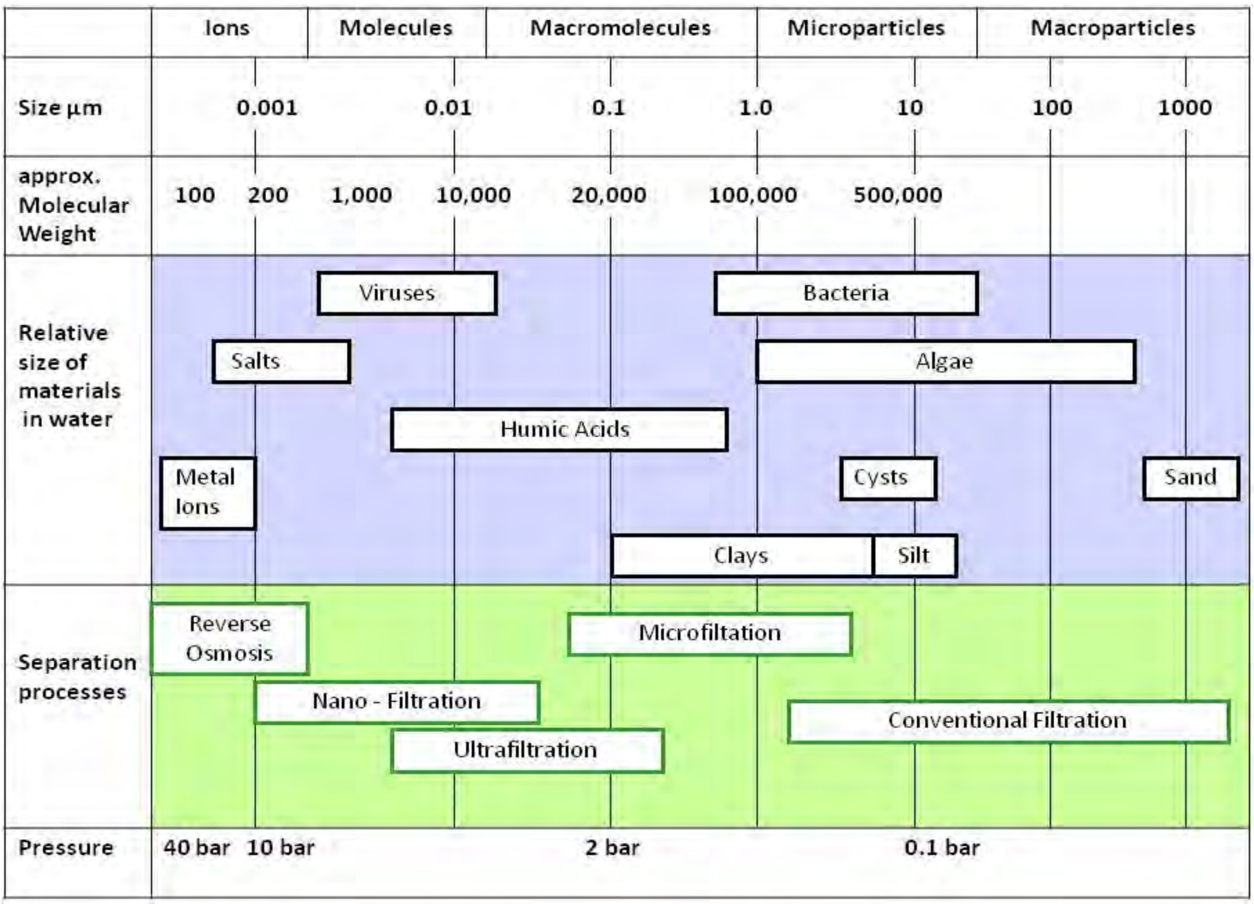


Table 1: Overview of separation processes and their effectiveness
According to http://dwi.defra.gov.uk/research/completed-research/reports/DWI70_2_137_manual.pdf

1.4. Other treatment processes

Aeration

The purpose of 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 filtratable substances. Different technical devices, like passing the water through air fountains, cascades, paddle wheels or cones, can be used for aeration. The air can also be passed through the water by aeration turbines or compressed air. However, most aeration is done 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 carried out to remove the oxidised elements after the aeration. The oxidised elements appear as flocks in the water.

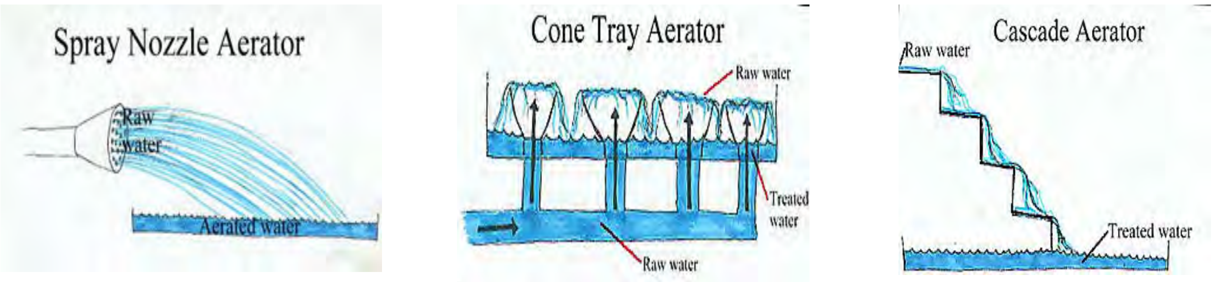


Figure 2: Drawings of different technical devices used for aeration
Source: Mountain Empire Community College. http://water.me.vccs.edu/courses/ENV115/Lesson5_print.htm

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.

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

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. Subsequently, 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. The method is similar, but more intensive oxidation is necessary to convert manganese into manganese dioxide; this step too 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 chemical reaction of iron during water aeration:

$2\ Fe(HCO_3)2 + 0{,}5\ O_2 + H2O \rightarrow 2\ FeO(OH)\cdot H_2O \downarrow 4\ CO_2$

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 requires experience with such kind of processes.

	Bacte-ria	Cysts	Viruses	Algae	Coarse particle	Turbi-dity	Colour	Al*	As*	Fe*/ Mn*	NO_3*	Pesti-cides	Sol-vents	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 or the removal capacity and effectiveness of several water treatment systems

*Al: aluminium, As: arsenic, Fe: iron and Mn: manganese , NO_3: 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 micro-organisms (see also module 8 and 9). Disinfection is a necessary step to kill or inactivate micro-organisms and to prevent spreading of harmful diseases. It is very important to test the raw water for micro-organisms, 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. Ground waters should be less prone to contamination, but they are still threatened depending on site conditions.

The susceptibilities to disinfectants of the different micro-organisms vary widely. The effectiveness of the disinfectants depends additionally on their 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. Ultraviolet radiation (physical disinfectant)

Chlorination

Chlorination is the most common method in larger water supplies, but less common in smaller ones. The sources of chlorine can be different, 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 taste and odour. Chlorination is usually practised for certain values of pH. Therefore, for small supplies, alternatives to chlorination should be considered, 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 exposed 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 (ClO_2^-) 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 (ClO_2^-). 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 lambia*, *Cryptosporidium*).

Ozonation

Ozone (O_3) 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.

Ultraviolet 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 to biological structures like proteins and DNA. An important prerequisite is clean water with low turbidity and colour. Dissolved organics and inorganics, clumping of micro-organisms, turbidity or colour are some factors affecting the effectiveness of UV disinfection. 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 risk, and the cysts of *Cryptosporidium* are inactivated. The handling is simple, maintenance modest and the equipment compact. Disadvantages: As no residuals are left, the subsequent steps of distribution have to be safe (especially storage). Otherwise, a longer lasting disinfectant like chloramine is required.

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 B3 and B4.

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 to guarantee a certain calcium concentration in the water 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 households, 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 have to be maintained (cleaned, parts have to be replaced 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 viable 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 or for washing 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 micro-organisms 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 micro-organisms; chemicals like nitrates or calcium (hardness) are not reduced.

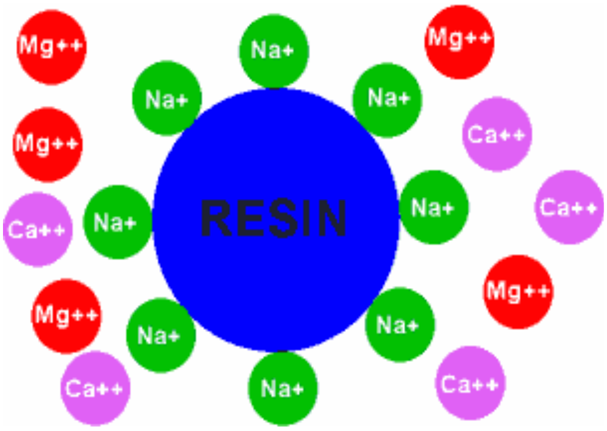
2.2. Active carbon filter

Activated carbon is carbon produced from carbonaceous source materials such as nutshells, peat, wood, coal etc. Due to its high degree of micro porosity, 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, since 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^{+}.



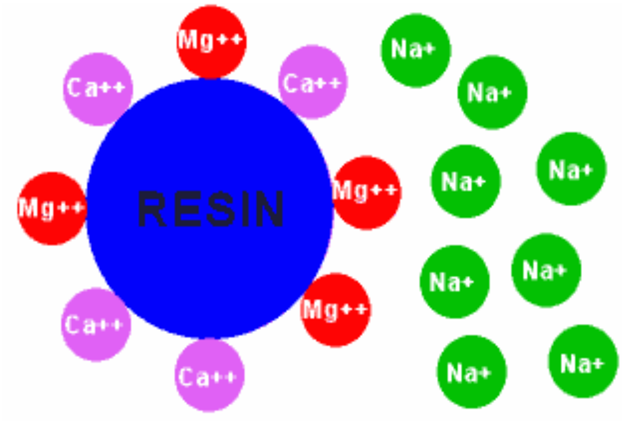


Figure 3: Fully charged exchange resin *Figure 4: Exhausted resin after ion exchange*
Source http://www.healthgoods.com/Drinking_Water_Filter_Buying_Guide_s/150.htm

2.4. Boiling

Simple boiling of the water (minimum 5 minutes) can destroy micro-organisms. 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, and they should be strong and durable, not transparent (see-through) and easy to clean.

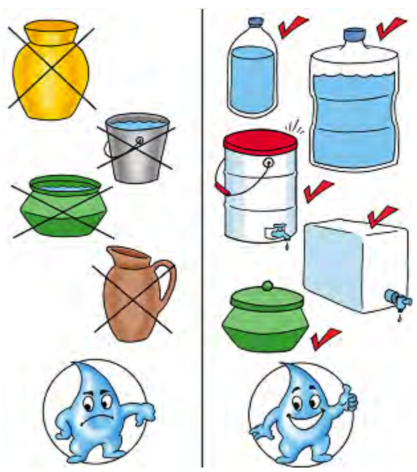


Figure 5: Different types of containers: to the left unsafe, to the right safe storage of drinking water

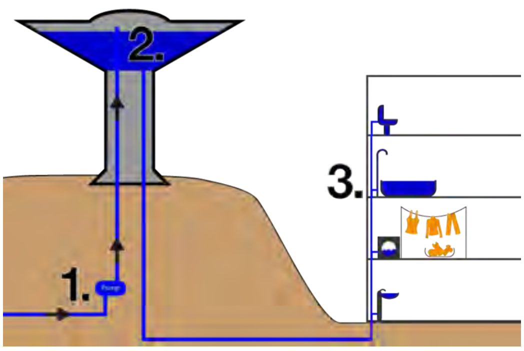
Source: CAWST (2009) http://www.sswm.info/category/implementation-tools/water-purification/hardware/point-use-water-treatment/hwts

4. Water distribution to consumer

Since millennia man has made efforts to make potable water easily accessible to the consumers. In early times water distribution was organised via open clay, tiled or wooden funnels, and later via brass, copper and lead pipes. Experiences, observations and modern analyses demonstrated that drinking water is very sensitive to contaminants and can interfere with materials it is in contact with.
Nowadays, drinking water is transported to the consumer and distributed by special water pipes, which 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 and requirements. A proper design, assembling and installation from the catchment to the household are essential and should be carried out by experts. For more information about this topic, please refer to module B3.

An often-neglected issue are water losses within the network. Due to lack of maintenance and reconstruction of outdated pipes, the losses result in financial damage for the water supplier, and for the consumer in possible lack of sufficient water and deterioration of water quality. 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 B4).
Due to poor maintenance of the network and/or the transport of corrosive water many pan-European countries struggle with broken pipes and high water losses: for example in 2008 in Armenia 80%, in Kyrgyzstan 70% or in Ukraine 45%. Other countries have moderate or low water losses, e.g. in Italy 28%, Great Britain 20% or Germany 8% of the water is lost on the way from supplier to consumer.
Installing water meters within the water supply network and measuring water losses during the water transport is a good indicator of the quality of the infrastructure.

Within the water supply system the supplier needs to maintain an appropriate pressure. If necessary, pumps have to be installed to provide enough pressure to serve consumers living in multi-storage buildings. The average flow velocity should guarantee that the retention time of the water is not too long, in order to avoid the development of pathogens and the rise of 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 6: Water tower schematic
Source: de.wikipedia.org/wiki/hochbehälter; Jonathan Cretton

5. Management, maintenance and training

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 become and the more essential is the qualification of managers and workers.

Planning, collecting data, engineering and communication take place on the management level. 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 A3.

The workers have the responsibility to install pipes, and to operate and maintain treatment plants. For them, it is important not only to fix broken equipment, but also to check all equipment on a regular base. Devices, chemicals, lamps, etc. have to be maintained and exchanged preventively. Simple check programmes identify problems in time to take appropriate measures for fixing. For maintaining and restoring the network on the long term an overall schedule with checks, cleaning, restoring or replacement of the oldest parts of the network should be developed, including a financial plan.

The checks may include:

- Disinfection. As this is the most vulnerable part, it 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, national or regional authorities may provide training for their devices or for specific topics related to the water supply. Some suppliers 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

However not only the workers and management staff should be trained. The water operators and the local authorities responsible for the water supply should have a certain educational background to guarantee an adequate and sustainable water service taking all legislative, financial, technical, chemical and microbiological aspects in consideration. Many countries or institutions offer trainings or developed guidelines for planning, financing, installation, operation and maintenance of water infrastructure, which could be shared.

6. WSSP related activities, results and output

WSP related activities	Results / output
Investigate if the local workers, operators or authorities responsible for the water supply are trained adequately on water management, operation and maintenance of treatment and supply systems. Who is responsible for what (job-description)? • Identify the requested qualifications of the local water supplier and staff. • Identify the available courses and technical guidelines related to the operation of a safe and sustainable water supply. • Are monitoring, operation and maintenance activities regulated, registered and are the results reported? • Is a roadmap for inspection, monitoring and maintenance available? • Is there enough budget available for operation and maintenance of the water treatment and supply system?	An overview of persons dealing with the public water supply is made. o Tasks, responsibilities and the requested educational qualifications are identified. o An inventory of offered courses and technical guidelines is made o A surveillance and reporting system related to operation and maintenance (O&M) of the water supply is available o The financial conditions related to the O&M of the systems are assessed; if needed, alternative financial resources are identified. o A roadmap describing the responsibilities and tasks of staff, frequency of monitoring/inspections, maintenance and recovery of the systems are developed.
Where applicable, identify and assess the water treatment system and the elements to be eliminated or to be adjusted. Find out if water is or should be treated within the households. • If yes, which elements should be eliminated or adjusted and what type of treatment is used • Is the treated water adequately disinfected and safe up to the point of consumption? • What is the frequency of inspection and recovery of the treatment system?	Where applicable, the water treatment system is described and assessed, a design is made; the weak and strong aspects of the system are identified. o The treatment of the water is justified - elements to be eliminated or adjusted are reported. o The disinfection system and its effectiveness are described. o Inspection and maintenance reports are available.
Investigate the water quality before and after the treatment; which parameters are monitored and what are the results? • Are the test results of the public drinking water accessible and shared with the villagers? • Are consumers informed/educated about handling safe or unsafe water?	Analyses reports of the water before and after treatment are available and assessed. o Approach and methods for informing the consumers about the quality and safety of the drinking water is established and implemented. o Consumers are educated how to store water safely and how to handle unsafe water (boiling, filtration)
Investigate if treated or supplied water is stored safely by the operator or households. • Are the reservoirs inspected and cleaned regularly? • Are the reservoirs vermin-proof? • Is the water free from contact with hands, dirty cups or buckets?	The condition of the storage facilities and their safety are assessed at communal and household level and reported. o Frequency of inspection and cleaning is reported. o Where applicable, consumers are informed about safe storage of drinking water at home.

Investigate the condition and the used materials of the local piping system/water supply network. • Are water losses within the infrastructure monitored and locations of water losses identified and registered? • Does the water have corrosive properties? • Are there frequent interruptions and what are the reasons? • Are there any "dead" pipes, backflows and unin-tended cross-connections within the network? • Are there buildings or areas in the community with inadequate water pressure or which are not served at all?	An overview of the condition and the used materials within the piped network and households is prepared. If applicable: o Locations of leakages and the causes are identified and reported. o Unintended water losses are measured o Frequency and duration of interruptions are monitored- o Where applicable, plans for repairs or restoration are discussed, developed and implemented.
In case of emergency, is there an action plan available? If yes, what does the plan look like?	An action plan for emergency cases is available. Responsibilities, tasks, alternative water sources, strategy of providing information and advice for the consumers are described.

7. Text sources and further reading

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Drinking Water Distribution – Pipes

Authors: Bistra Mihaylova, Margriet Samwel, Aglika Yordanova

Summary

When developing a water and sanitation safety plan (WSSP), the important aspects of distributing drinking water must be considered. This module explains these aspects of water distribution and they are:

- the most commonly used types of pipes;
- advantages and disadvantages of different materials used for water supply networks and households;
- the importance of adequately chosen materials and the complexity of the materials.

Some practical tips are given to recognise the different types of metal pipes.
Furthermore the most common damages of pipes occurring within a network are presented and discussed.

Objectives

The reader can describe some types of pipes used for drinking water supply networks.
They know the advantages and disadvantages of the most common used materials and learn how to identify lead, copper and iron pipes. The reader is aware of the causes of the most common damages in the network.

Key words and terms

Metal pipes, cast iron, galvanised iron, copper, lead, plastic pipes, PVC and PE, asbestos cement, corrosion, freezing, damages, maintenance

Drinking water distribution – pipes

Introduction

Pipes used to distribute drinking water are made of plastic, concrete or metal (e.g. galvanised iron or copper). All of them have some advantages and disadvantages, yet the properties of each pipe material should fulfil some specified requirements.

Many water quality factors, including the chemistry and characteristics of the water (e.g. pH, salts that are dissolved in the water), lead to the corrosion of pipes used in water distribution. The corrosiveness of water is principally controlled by monitoring and adjusting the pH and through the concentrations of calcium or phosphates in water. The water supplier should address these factors and eventually treat the water, which will lead to reduce corrosion (see also module B4 and B7). In addition, appropriate and high quality materials for the distribution of drinking water need to be selected.

Pipes for drinking water distribution should be suitable for the transport of water. In many countries norms have been agreed on the minimal required quality of the pipes. When in contact with water or soil, the material should be resistant (corrosion-proof) to possible chemical reactions and the material should not allow toxic substances to be released into the water. Furthermore, the pipes have to be resistant against a specified internal and external pressure and temperatures.

In many countries, the water supplier or the local administration has the responsibility for the quality of the network and water quality that ends at the water meter of the households. Within the house, the owner or costomer carries the responsibility for his/her pipes and other water or treatment tools. The diagram and table below show an example from Scotland, which can be replicable for many countries.

		Water and waste pipes	Water and waste pipes
①	—	The water supply pipe	Homeowner
②	×	Stop valve	Homeowner
③	—	Private drain	Homeowner
④	■	Stopcock/meter	Scottish Water
⑤	—	The communication pipe	Scottish Water
⑥	—	The water main	Scottish Water
⑦	—	Sewer	Scottish Water

Graphic 1. Water supply
Source: www. Scottishwatersupply.co.uk

1. The most common materials used for transporting drinking water

1.1. Metal pipes

Cast iron and ductile cast iron pipes

The use of cast iron pipes has a long tradition. In the 19th and 20th century, they found wide spread use as pressure pipes for the transport of water and gas or as sewage and drainage pipes. Currently, there is hardly any new manufacturing of cast iron pipes. Cast iron is relatively inexpensive but, nowadays, higher quality materials for water networks are available. For example ductile iron, also known as ductile cast iron, spheroidal graphite hardly iron is much more flexible and elastic, due to its nodular graphite inclusion.

For the production of cast iron or ductile iron pipes, minerals and other metals are added to the so-called *pig iron*. Pig iron is an intermediate product of smelting iron ore. The dosage of quantities added depends on the wished properties of the final product. For long-lasting service, corrosion protection of the iron is needed. Often Ductile pipes are somewhat resistant to internal corrosion and very often the surface is covered with Polyurethane (PUR), bitumen or cement mortar.

Galvanised iron pipes

One of the popular materials for transporting water is galvanised iron. Iron has been, and still remains, one of the most popular metals used in large-scale construction. Though due to the instability of the material, iron pipes have to be coated in order to reduce its weak corrosive persistence. By galvanising (zinc-coating) the pipes, the quality increases. Zinc coating contains a mixture of several metals, in which zinc is the main component. In many countries, special requirements for the composition of the metals are established. Galvanised pipes are sensitive to corrosion, such as cast-iron pipes. Therefore, water that comes in contact with galvanised pipes should have non-corrosive properties, and have certain hardness and pH. If drinking water is disinfected with free chlorine, an increase in corrosion of the iron materials can be expected. Elevating the pH of water counteracts the corrosive effect of chlorinated water on iron.
Iron pipes that are in contact with soil are mostly lined with cement (cement-lining). A minimal amount of welding seams increases the stability of pipes. Galvanised iron pipes are rather cheap and easy to handle, but have a relatively short live time.

The purpose of the distribution within the house will influence the selection of the materials

Copper pipes

Experts favour copper pipes mainly because of their universality. They are suitable for plumbing systems and heating, as well as gas pipeline installations. A great advantage is that chlorinated water has no or a very low impact on copper pipes. Furthermore, copper has proven bactericidal properties, which hinder the development of bacteria inside the pipes. International experience from operating with such pipes shows that their flawless use in plumbing and heating systems lasts from 50 to 100 years. Of course, as with all other products, copper pipes also have some limitations in terms of application. They do not tolerate very acidic or very alkaline water, and very soft or very hard water. Hence, the water supplier has to be aware of possible corrosive properties of drinking water towards copper pipes. Brand new installed copper pipes lack the protection layer of limestone (calcium sediments) and release some copper into the drinking water. Depending on the hardness of the water, a layer of limestone develops in the pipes after some months, serving as protection.

Copper pipes are characterised by durability and reliability, but are relatively expensive.

Lead pipes

For many centuries and in many countries, lead pipes were the favourite material for water pipes within the distribution network and for installation within houses. After the early 1900´s, the installation of lead pipes was increasingly substituted by other materials such as copper or galvanised iron, and after the sixties by plastic pipes. The frequency of the appearance of lead pipes within the water distribution systems varies from country to country. Lead pipes can be affected by corrosion and release lead into the drinking water. Besides the drinking water pipes, faucets or fittings of brass, or solder used to seal joints in plumbing, may also contain elements of lead.

Due to the high toxicity of lead, lead pipes are not used any more for the drinking water supply.

1.2. Plastic pipes

The raw material needed to make most plastics comes from petroleum and natural gas. Due to their relatively low costs, ease in manufacture, versatility, and imperviousness to water, plastics are used in a vast and expanding range of products: from paper clips to pipes intended for transporting drinking water. Plastic has replaced many common materials such as cement and metals within drinking water networks.

Plastics are often preferred than metals due to a number of inherent advantages: plastic piping is lightweight and does not require an open flame for joining the flexibility of plastic can simplify the installation. Plastics are typically lower in cost and resist the corrosion and scaling that plague metals in some applications. However, indication of the mitigation of synthetic chemical contaminants from plastic pipe materials to water may exist. These contaminants likely occur at low "safe" levels, but are sufficient to generate odour and taste and can give concern in some cases. Another disadvantage of some types of plastic pipes is that they have a lowered resistance to chlorinated water.

The most common types of plastics used in the drinking water distribution are presented in the following.

PE (Polyethylene) pipes

Depending on the product quality, there are high-density polyethylene (HDPE), medium density (MDPE) and low-density (LDPE) pipes. The level of density expresses the pressure that the pipes can sustain. For locations enduring high pressure or weights, like streets, HDPE pipes are used.


Plastic pipes and fittings are more and more widely used for indoor and outdoor water distribution systems

Performances of PE pipes of different manufacturers show different possible temperature ranges in terms of application and usually range between -20 and +90 °C. Pipes of the PE group are resistant to ultraviolet rays. PE pipes are widely used for water and sanitation systems. High-quality PE pipes have a long lifetime (50 years) and are easy to maintain. They have a high impact strength and show resistance to cracking, even at low temperatures. PE pipes are also stable in water and do not tend to corrode. Nevertheless, due to weak or improper connections, leakages in distribution networks with plastic pipes are not uncommon.

PVC (Polyvinyl chloride) pipes

PVC is the third most widely produced plastic after PE and PP (polypropylene). PVC is widely used in construction because it is cheap, durable and easily workable. This material accounts for 66% of the water distribution market in the USA. In sanitary sewer pipe applications, it accounts for 75%. PVC pipes belong to the cheapest types of pipes, but the material tends to get brittle in the long-term. The usage of PVC is controversial, particularly because of the harmful chemicals (e.g. Dioxins), which may be discharged in the environment during its production and final disposal (burning).

Asbestos cement pipes have been used widely for drinking water distribution and there are many kilometres of them to be found all over the world.

Source photo: the Environmental consultancy; http://www.asbestosguru-oberta.com/A-CMyths&Facts.html

1.3. Asbestos-cement pipes

Asbestos cement is a mixture of cement and primarily *chrysolite*, or e.g. Portland cement and white asbestos. Asbestos cement pipes have been widely used for drinking water distribution and there are many kilometres of it to be found all over the world. According to the results of long-lasting monitoring, no concerns have been reported concerning health by consumers receiving the drinking water from asbestos cement pipes. So far, no programmes have been established to replace asbestos cement pipes. However, nowadays several countries, such as Romania, Germany or the Netherlands, don´t allow using asbestos-cement pipes for new constructions

or rehabilitation of the network.
Staff working within the asbestos industry and working with asbestos pipes are exposed to the inhalation of asbestos fibres, and there is consistent evidence that the inhalation of asbestos fibres is hazardous to health (carcinogenic), Only a few countries still install asbestos cement pipes, primarily because of issues regarding economics.
Very soft water, waters with low concentrations of calcium and magnesium may cause the porosity and permeability of the asbestos cement pipes; once leaking has progressed, it will lead to deterioration and eventual bursting under pressure.

2. Common causes of damage to water pipes

Poor quality of materials and improper installation

Poor quality of pipe materials and improper installation will shorten the pipes lifetime and make them more prone to leakages and bursts. Poor pipe quality may facilitate the infiltration of chemicals into the drinking water and make pipes more sensitive for corrosion. In many countries, the pipe quality conditions for distribution of drinking water include: the size of pipes, the composition, the properties and quality of the materials. The age of the water pipes, their state of maintenance and the quality of water influence their strength, durability and safety. The older the pipes become, the more brittle and more prone they are to fractures. Unsuitable or low-quality materials for plumbing or connecting the pipes can contaminate the drinking water with pollutants such as lead or make the water taste odd.

Installing drinking water pipes and/or connecting households to the network is not a task for unqualified persons, but for professionals. Improperly installed pipes often result in the infiltration of contaminants or a break/leakage within the network.

Besides the quality and installation of the pipes, the arrangement of the network is also a key factor for safety. For example, the installation of valves within the distribution network is essential. Valves can isolate incidents of pipe breakages and contamination events and limit the risk of the surrounding network. Valves can also prohibit the backflow of water within the network.

Another not uncommon occurrence is the installation of tubes/pipes and fittings of different types of metals in a wrong sequence, resulting in (galvanic) corrosion. It is possible to use different types of metals in a network, however the water should follow the sequence of less galvanic/noble metal to more noble metal. For example, water should follow the sequence of the connection: from galvanised steel to lead and finally to copper. An in-proper installation could happen in particular in cases unqualified persons are repairing or extending the network.

Graphic 2. A poor quality of the installed pipes will shorten the lifetime of the pipes and are more prone to leakages and bursts. Source drawing: http://alpharetta.olx.com

Corrosion

Depending on the properties, water can cause chemical reactions with metals and cement pipes, which is called corrosion. Pipes that are corroding release metals into the drinking water. There is also a risk that the pipe will start to leak or crack, increasing the risk of infiltration from microorganisms. Corrosion will cause also aesthetic problems like brown/red or dark or green coloured water, or water with particles or with a metallic taste.

Corrosion control is managing acidity, alkalinity and other water qualities affecting pipes and equipment used to transport water. For corrosion control adequate water tests are indispensible.

Often, the so-called *Langelier Saturation Index* (LSI) is used for indicating the corrosive properties of water. The LSI (LSI = measured pH – pHs) indicates if the water will precipitate, dissolve, or be in equilibrium with calcium carbonate. If the LSI is more than 0, the calcium will precipitate and produce a protecting layer on the interior of the pipes; if the LSI is less than 0, the water is considered corrosive. This corrosion control is a task for the water supplier. Besides the interior corrosion, exterior corrosion of the pipes can also happen, caused by the reaction of soil and water. Therefore, a protection layer, of e.g. bitumen, is often applied on the exterior side of the network pipes.

Freezing

If the temperature falls below the freezing point, there is a risk of the pipes freezing. Because the volume of frozen water increases, frozen pipes will crack and then burst, spilling large amounts of water. In unheated spaces, the pipes should be emptied because the pipes cannot be protected against freezing temperatures. In outside areas with cold winters, water pipes have to be protected against freezing temperatures by digging the pipes deep enough into the ground. The depth of the pipes in the ground depends on the climate and can vary from up to 2 meters down in the ground.

Too much, too low or no pressure

If the pipes or joints are not in good shape, or if the water pump does not function properly, high pressure could result within the water pipes, which could cause rupture and breakage of the pipes. On the other hand the pressure should be regulated in such a way that consumers living in high-located areas are served.

Too low or no pressure in the pipes may occur during major failures such as bursts in pipelines or an increase in the use of the tap (e.g. fire or irrigation of fields). Furthermore a intermittence of the supply system can cause very low or zero pressure in the pipes. Too low or no pressure may provoke ingress of contaminated water or a backflow within the system, causing unsafe drinking water for the consumer (bacteria, undesirable biofilm releases).

An adequate and stable pressure within the water supply system is indispensible for a safe water quality and reliable water delivery to the consumer. Regular control of the condition of the pipes, repairing and cleaning of pipes, avoiding interruptions of the supply, could minimize the occurrence of hazards in many regions.

3. Practical issues

3.1. How to recognise plastic, lead, copper or iron pipes?

Plastic piping is found in newer homes and is distinctive in appearance. It can be blue, black, white, grey or colourless, and can often have glued or threaded joints. Scratching plastic piping will not create a significant mark. Tapping plastic piping will produce a hollow sound.

Copper piping is very common and can be identified due to its bronze/copper colour that resembles the appearance of a one-cent piece or penny. Joints are usually made with copper fittings and solder, or with brass or bronze fittings. When you scratch a copper pipe, a shiny copper coloured line will become visible. A green stain will be visible where moisture or water has been in contact with the copper pipe.

Lead is usually dull grey or silver in colour

Lead piping is used in older homes, usually built before 1950 or 1970 (depending on the country). Lead is usually dull grey or silvery in colour, is relatively bendable and it can be scratched and scraped easily. A good way to identify lead piping is to scratch the surface with a coin or similar object; if it is lead, a grey or silver colour will appear.

Iron piping can be identified by its hardness, black paint, or rusty finish. Iron pipes are usually much more difficult to scratch then pipes made out of other material.

Ductile iron pipes
Source photo: http://images.mitrasites.com/ductile-iron-pipe.html

3.2. Actions to reduce metal intake via drinking water

- Anytime the water in a particular faucet has not been used for six hours or longer, "flush" cold water pipes by letting the water run until it becomes as cold as it will get. The more time water remains in the pipes, the more lead or copper it may contain.
- The only way to be sure of the amount of lead or other metal in the household water is to have it tested by a competent laboratory. The water supplier may be able to offer information or assistance with testing. Testing is especially important for apartment residents, because flushing may not be effective in high-rise buildings with lead-soldered central piping.
- If cases of corrosion within the network or household installation occur frequently, the water supplier should be contacted. Drinking water should be treated at the plant to make it less corrosive.
- If lead pipes release lead into the drinking water, the best way to reduce the lead intake, via the drinking water, is to renew the pipes.

3.3. Maintenance of pipes

Often sediments or bio-films are settled in the pipes and which may release from the pipe wall. Depending on the water and network quality a regular pipe cleaning may be necessary to avoid esthetical or health problems. Skilled persons should assess the frequency, methods and relevance of pipe cleaning. A routine disinfection of the pipes (and eventual reservoirs) should be considered as a part of the network operation and maintenance.

4. WSSP related activities, results and output

WSSP related activities	Results / output
Investigate the type of pipes used within the public network with the support of the water supplier. • Investigate the type of pipes used within the local households (observation, questionnaires, etc.). • How many meters of pipeline are in use • How old are the pipes?	An overview of the used pipes within the network, including households is available. A design of the network is made
How is the distribution network organised? • Are there several zones, branches? • Is it possible to isolate sections of the network in case of repairs or failures? • Are there illegal or inadequate connections within the network?	The flow directions and so far relevant reservoirs, location of the valves, the different zones and branches, illegal connections, dead ends are indicated
Does the provided water provoke corrosion or sediments within the network or at the households? • Is the quality of the provided water treated in order to avoid corrosion? • Carry out a survey on calcification of pipes or pumps or iron/manganese deposits.	The vulnerability of corrosion, deposits in pipes and equipment are assessed and reported o Regular water analyses are carried out
Carry out a survey on leakages within the network, if possible by measuring the water losses (water meters within the network) • Are there branches with losses of the pressure	So far applicable the volume of water losses and/or the location of leakages within the network are identified and reported
Identifying the responsibilities and the practices for operation and maintenance of the network • Is there a program for inspection, cleaning and disinfection of the network (pipes, reservoirs)?	A program for inspection and cleaning pipes and reservoirs is available or developed. o The frequency and the cleaning methods are defined o The responsible persons are identified and listed
If applicable, identify possible improvements, repairs of the network Discuss what should be done in case of doubts about the drinking water quality	The results of the assessments on pipes are discussed with experts, households. o So far needed, actions are planned; pipes are repaired or rehabilitated, water quality is adjusted or water analyses are carried out.

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Module B4

Drinking Water Quality

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Summary

Water is essential for life, but it can and it does transmit diseases in countries on all continents – from the poorest to the wealthiest. Infectious diseases caused by pathogenic bacteria, viruses and parasites (e.g. *protozoa and helminths*) are the most common and widespread health risks associated with drinking water. Water that reaches our home usually comes either from groundwater or surface water (water from small rivers, streams, rivers and lakes). In general most communities use underground water sources for supplying people with drinking water. In regions were groundwater is not exploitable or not suitable for drinking, people rely on surface water. Depending on the original source of drinking water and many other natural and anthropogenic (human-made) factors, raw water or even treated water may show various impurities. A description of the most important contaminants and parameters for drinking water, their sources and related health and technical risks are given in this module. In addition, maximum allowed concentrations of chemical and microbiological parameters, as established by the European Union Drinking Water Directive, are presented.

Objectives

The reader will be aware of the most hazardous microbiological and chemical contaminants in drinking water and the related health or technical risks. The reader will gain knowledge about the causes and/or the source of several natural and anthropogenic hazardous substances in surface water, groundwater and drinking water.

Key words and terms

Contamination, pathogens, health risks, micro-organisms, bacteria, chemicals, corrosion, indicators, parameters, Drinking Water Directive, nitrate, fluoride, arsenic, cadmium, lead, copper, iron, calcium, magnesium, manganese

Drinking water quality

Introduction

Drinking water quality management has been a key pillar of primary prevention for over one-and-a-half centuries and it continues to be the foundation for the prevention and control of waterborne diseases. Water is essential for life, but it can and it does transmit diseases in countries on all continents – from the poorest to the wealthiest. Infectious diseases caused by pathogenic bacteria, viruses and parasites (e.g. *protozoa and helminths*) are the most common and widespread health risks associated with drinking water. The most predominant waterborne disease, diarrhoea, has an estimated annual incidence of 4.6 billion and causes 2.2 million deaths every year. The sources of most of those pathogens (disease-causing micro-organisms) are water contamination with animal or human faecal substances. However, natural and anthropogenic chemical substances in drinking water can also cause different diseases, depending on the geological condition. Furthermore, there are chemical substances without health risks that are nevertheless, unwanted by the water supplier due to technical reasons.

1. Micro-organisms: the most common and widespread disease causes

Life would be impossible without microorganisms. Microorganisms, like the group of coliform bacteria, are indispensable for the proper digestive functioning of human beings and animals. However, the bacteria should not appear in drinking water and can cause diseases in vulnerable persons. They can also cause problems if they enter the body via contaminated food or drinks. Particular pathogens that cause diarrhoea leave the body via the faeces; and they are then transmitted to humans, who can become ill when they ingest the pathogen. This is called faecal-oral transmission. For pathogens transmitted by the faecal–oral route, drinking water is only one vehicle of transmission. Contamination of food, hands, utensils and clothing can also play a role, particularly when domestic sanitation and hygiene are poor. There are several variants of waterborne disease transmission. These include contamination of drinking water catchments (e.g. by human or animal faeces), water within the distribution system (e.g. through leaky pipes or obsolete infrastructure) or stored household water (as a result of unhygienic handling).

1 gram of faeces can contain
10 million viruses
1 million bacteria
1,000 parasitic cysts
100 parasitic eggs

Table 1: Microorganisms in faeces
Source: New Internationalist Issue 414, 2008, http://www.newint.org/features/2008/08/01/toilets-facts/

Table 1 gives an overview of the number of microorganisms that can be present in one gram of faeces and the causes of waterborne diseases. Hence, adequate sanitation measures are required in every step of the drinking water supply system to avoid any drinking water contamination. Hygienic handling of water in all stages of the water supply and personal hygiene (regular hand washing) are essential precautionary measures to minimise water related health risks. Microbial drinking water safety is not only related to faecal contamination. Some organisms live naturally in the water and can become problematic if they grow in large numbers in piped water distribution systems (e.g. *Legionella*), whereas the larvae of others occur in the water source, e.g. guinea worm (*Dracunculus medinensis*), and may cause individual cases or outbreaks. Improvements in the quality and availability of safe water, adequate excreta disposal and general hygiene are all important in reducing faecal oral disease transmission.

Cause	Water-borne diseases
Bacterial infections	Diarrhoea, Typhoid fever, Cholera, Botulism, Paratyphoid fever, Bacillary dysentery, Legionellosis
Viral infections	Hepatitis A and E (jaundice), Poliomyelitis
Protozoa infections	Amoebic dysentery, Cryptosporidiasis, Giardiasis

Table 2: Causes of water-borne diseases
Source: adapted from http://en.wikipedia.org/wiki/Waterborne_diseases

1.1. Contamination of drinking water with faecal matter

As illustrated in Table 1, faeces can contain millions of useful microorganisms, but can also harbour pathogens. Laboratory testing for specific disease causing microorganisms (e.g. *Salmonella typhimurium* and *Vibrio cholerae*) can be expensive, and if the bacteria are present only in low numbers, they may not be detected. Instead, more common bacteria are analysed as an indication faecal pollution of the water, such as coliform bacteria. In many countries, evidence of the faecal coliform bacteria family serves as an indicator for faecal contamination of the drinking water. There are hundreds of coliform bacteria species in the human and animal intestine, and in the environment as well. Contrary to several other bacteria, viruses and parasites, the bacteria *Escherichia coli* and *faecal streptococci* are rather easy to analyse. The presence of those bacteria in water is an indication of recent faecal pollution (see also module B5 and B7). In the following section, some bacteria are presented that are analysed for monitoring the microbiological drinking water quality.

Faecal coliforms

Faecal coliforms are conditionally pathogenic bacteria that are present in the intestinal tract of humans and most mammals. They are called conditionally pathogenic since they can cause diseases only under certain conditions (high concentrations, increased susceptibility and reduced human immune defence). The presence of faecal coliforms in water indicates faecal contamination and most likely the presence of pathogens. The most common health problems that may result from contact with faecal coliform contaminated water are dysentery, typhoid, hepatitis, and gastroenteritis.

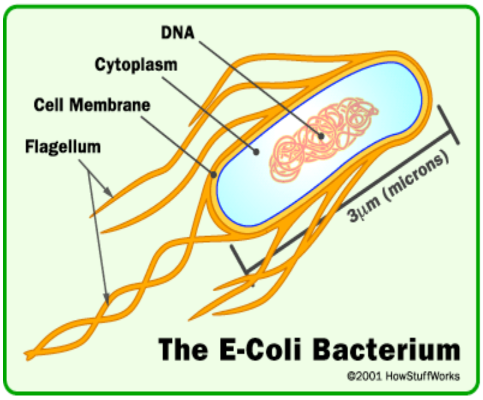

Figure 1: The E-coli Bacterium
Source: ©2001 HowStuffWorks

Escherichia coli (E.coli)

90% of faecal coliforms are types of *Escherichia coli* (E. coli). This bacterium lives in the colon of warm-blooded animals and is necessary for proper digestion of food. Yet this bacterium can cause several infections outside of the colon. E. coli exists abundantly in nature, but the presence of E. coli in water is a sign of faecal contamination. E. coli is the most common cause of urinary tract infections, but can also cause many other diseases such as diarrhoea, pneumonia, meningitis. There are many types (serotypes) of the *E. coli* with different properties. For example, *E. coli* type O157: H7 releases a powerful toxin, leading to severe and bloody diarrhoea with abdominal crampings. It can cause Haemolytic Uraemic Syndrome (HUS) in children, often with fatal consequences. In Canada, a waterborne epidemic caused by E. coli 0157:H7 infected more than 1,500 persons and resulted in 10 deaths during the year 2000.

Faecal Streptococci/ Intestinal Enterococci

Faecal streptococci and *intestinal enterococci* bacteria are normally present in the intestinal tract of warm-blooded animals. Outside the intestinal tract, the bacteria cause common clinical diseases, such as urethra infections, bacterial endocarditis, meningitis and diseases of the colon. Enterococci infection may be the cause of bladder infections and health problems with the prostate and the male reproductive system. They also develop resistances against antibiotics and are sometimes difficult to treat. Wound infections with *faecal streptococci* can result in rapid skin damage and sepsis (blood poisoning), sometimes with fatal outcomes (amputation, death). In the environment, faecal streptococci are more resistant than *E. coli,* and can survive longer in water.

Clostridium perfringens

C. perfringens is a Gram-positive, rod-shaped, anaerobic, spore-forming bacterium. It occurs in the soil, and in the intestinal tract of humans and other vertebrates. In contrast to the aforementioned and easily detectable *E. coli, C. perfringens* is able to survive in a sleeping stage because it forms long-lasting spores. These spores can serve as an indicator for faecal contamination too. For the quality control of drinking water derived from surface waters, it is recommended to test on C. perfringens and its spores. They can serve as an indicator for the occurrence of harmful protozoa like *Cryptosporidium* or *Giardia lamblia. C. perfringens* affects the nervous system and can cause meningitis, Surface water and water catchment areas with intensively grazing livestock are especially threatened by *C. perfringens*. The spores of *C. perfringens* are very resistant to chlorine treatment.

1.2. Contamination of water with Legionella bacteria

The *Legionella pneumophila* bacterium was identified in 1977 as the cause of a severe pneumonia outbreak in a convention centre in the USA. This bacterium is associated with outbreaks of Legionellosis (Legionnaires disease) that are linked to poorly maintained artificial water systems; particularly in cooling towers, air conditioners, hot and cold water systems (showers) and whirlpools. Legionella can be spread by aerosols and infections can occur by inhalation of contaminated water sprays or mists.
The bacterium is found worldwide in aquatic environments, but artificial water systems sometimes provide environments for growing Legionella bacteria. The bacteria colonize in water systems at temperatures of 20 to 59 degrees Celsius (optimal 35^{o}C).

1.3. Microbiological parameters for the quality of drinking water

The EU Drinking Water Directive (90/313/EEC) mentions that member States should take measures to ensure that water intended for human consumption is wholesome and clean. This means that drinking water has to be free of any microorganisms and parasites, and of any substances that cause potential danger to human health! Not a single one of the *Escherichia coli* and *enterococci* faecal bacteria are allowed in 100 ml drinking water. See also module B8.

Frequency of monitoring the quality

The EU Drinking Water Directive also determines the frequency of water sampling and analyses intended for human consumption (used in food-production enterprises too), and how water is supplied from a distribution network (e.g. from a tanker). The frequency depends on the volume of water distributed or produced each day within a supply zone.

Microbiological Parameters	Parametric value (number/100 ml)
Escherichia coli (E. coli)	0
Enterococci	0
Coliform bacteria *	0
Clostridium perfringens*	0

Table 3: Microbiological requirements of drinking water
** Indicator parameter to be measured if the water originated or is influenced by surface water*
Source: According to EU Drinking Water Directive: COUNCIL DIRECTIVE 98/83/EC

Volume of water distributed or produced each day within a supply zone [m3/d]	Check monitoring number of samples per year	Audit monitoring number of samples per year
< 100	The frequency is to be decided by the Member State concerned.	The frequency is to be decided by the Member State concerned.
>100 - < 1,000	4 / year	1 / year
> 1 000 - < 10,000	4 / year + 3 for each 1,000 m^3/d and part thereof of the total volume	1 / year + 1 for each 3.300 m^3/d and part thereof of the total volume

Table 4: Frequency of sampling and analysing the drinking water quality within the supply zone.
Source: EU Drinking Water Directive: COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, Official Journal of the European Communities

2. Chemical contaminants in drinking water

The quality of drinking water can be influenced by several sources:

- Depending on the original source of drinking water, the water may contain various natural inorganic substances, partly wholesome for human health and partly with health concerns. It may contain particles or natural organic substances (decomposing products) originating from forest or marsh areas.
- Due to human activities, agriculture, industry or traffic, the water may contain impurities.
- Drinking water can be contaminated by the contact of the materials within the network, e.g. metal from pipes.

In the following section, the most common chemical contaminants, which can occur in drinking water and originate from the above three mentioned sources, are presented. In addition, the maximum allowed concentration for the respective chemical in drinking water (according the EU drinking water directive) is given.

2.1. Nitrate (NO_3)

Nitrate (NO_3) is a naturally occurring form of nitrogen found in soil. Nitrogen is essential to all life. Most crop plants require large quantities to sustain high yields. The formation of nitrates is an integral part of the nitrogen cycle in our environment. In moderate amounts, nitrate is a harmless constituent of food and water. Plants use nitrates from the soil to satisfy nutrient requirements and may accumulate nitrate in their leaves and stems. Usually plants take up these nitrates, but rain or irrigation water can wash them out due to their high mobility into groundwater. Although nitrate occurs naturally in some groundwater, higher levels are thought to result from human activities in most cases, (see module B6).

Common sources of nitrate include:

- Fertilisers and manure
- Animal feedlots
- Municipal wastewater and sludge
- Septic systems and pit latrines

Nitrate is a natural substance that all plants need for growing

Nitrate in drinking water can aggravate "Blue Baby Disease" (Methaemoglobinaemia) as it is converted to nitrite in the body. Nitrite reacts with haemoglobin of the red blood cells to Methaemoglobin, affecting the blood's ability to carry oxygen to the cells of the body. Infants less than three months of age are particularly at risk. The intake of tea or other baby food prepared with nitrate-rich water can cause the baby to not get enough oxygen and to turn blue. This disease can be lethal, or it can damage the brain or nerves of the child. Older people may also be at risk because of decreased gastric acid secretion. In areas where natural iodine intake by the inhabitants is low, high nitrate concentrations in drinking water can increase the frequency of thyroid problems.

- The maximum allowed concentration of nitrate in drinking water is 50 mg/l.
- The nitrate concentration in most natural water sources is less than 10 mg/l.
- Nitrate levels with more than 25 mg/l indicate a human-made pollution of the water source.

Chemical	**Source**	**Health concerns**
Nitrate	Agriculture/ wastewater	Harmful for new-born babies (Blue baby diseases or Methaemoglobinaemia)
Pesticides	Agriculture	Carcinogenic, mutagenic, effects nervous system
Mineral oil	Landfills, leakages	Carcinogenic
Arsenic	Geogenic	Skin diseases, carcinogenic
Fluorine*	Geogenic	Dental and bone fluorosis
Iron and Manganese*	Geogenic	Suspected relation with nervous diseases
Uranium	Geogenic/mining	Kidney diseases, cancer
Copper*	Copper pipes	Liver damage
Lead	Lead pipes	Effects nervous system
Cadmium	Galvanic pipes	Kidney diseases
Asbestos	Asbestos-cement pipes	Increased risk of developing benign intestinal polyps

*Table 5: Overview of the most common chemical contaminants in drinking water, the related health concerns and its possible sources.; *These chemicals are essential for human health, but harmful in case of increased intake.*

2.2. Pesticides

Pesticides represent a risk factor in all intensive agricultural areas where drinking water is extracted from underground sources or surface waters. Many European rivers are affected by pesticides, and with a seasonal variability. In countries with intensive agriculture, like the Netherlands, river water samples show an average of at least 10 different active pesticide substances. Many of these chemicals are proven or are suspected to be carcinogenic, mutagenic and/or a hormone-disruptor. Some types of pesticides can accumulate in fatty areas of the body; e.g. the breast is composed mainly of fatty tissue. Many of the artificial (synthetic) chemicals are long lasting in the environment and are found in the whole food cycle, for example DDT or Lindan.

Depending on the chemical structure, pesticides can be water-soluble or fat-soluble. Water-soluble pesticides, such as substances of the chemical groups of urea or Triazin herbicides, should not be applied in water sensitive regions, and in particular, not in water protection zones. Some pesticides such as atrazine (a Triazin herbicide), which were used decades ago and caused a widespread contamination of groundwater, are forbidden in many countries since the early nineties. However, they are still present as active substances or as decomposing products in groundwater, thus still being risk factors for human health.

The maximum allowed concentration of pesticides in drinking water for one active substance is 0,1 μg/l.
The maximum allowed concentration of the total amount of active substances is 0,5 μg/l.

Source:http://www.ourbreathingplanet.com/pesticides-and-food-safety/

Source: www.CartoonStock.com

2.3. Fluoride (F)

The presence of fluoride in the groundwater is mostly of geogenic origin, but can also be caused by mining or industrial pollution. In Central Europe, groundwater resources that exceed the fluoride guideline value of 1.5 mg/l are widespread, and effects on health have been reported in areas with high fluoride amounts in the water. Known regions with increased levels of fluoride in groundwater are found, e.g. in Ukraine, Moldova, Hungary or Slovenia.

On the one hand, fluoride is to some extent essential for the development of healthy bones and teeth, but on the other hand, long-term and increased intake of fluoride via water or other sources can cause severe problems with teeth and bones.

The concentration of fluoride should not exceed 1.5 mg/l.

Dental fluorosis is the appearance of spots on teeth that can range from white to brown spots with destruction of tooth enamel.
Source Photo; Oral Health Tips. http://www.oralhealthtips.co.uk/tag/dental-fluorosis-2

2.4. Metals

Metals are substances that occur naturally in geological formations. Some metals are essential for life and are available naturally in our food and water. On the other hand, drinking water may contain metals that, in certain concentrations, cause health risks. Several heavy metals, such as Plutonium or Lead, are not essential for life and can cause severe diseases. Those metals are undesired in drinking water. Copper is a heavy metal that is essential for life, but it is toxic in high concentrations. Other light (alkali) metals, like Calcium and Magnesium, are essential for life and are desired in drinking water for technical reasons. In the following, some metals that are known to be present in drinking water, are described.

Arsenic (As)

Arsenic contamination of groundwater is found in many counties. It is mostly a contamination of natural origin in deeper levels of groundwater. One of the most known cases of large-scale poisoning by the consumption of arsenic contaminated water is found in India. Besides the natural occurrence of arsenic in groundwater, groundwater nearby mines can also be contaminated with *As*.
In Europe, in e.g. Hungary, Romania and Slovakia, exposure of *As* in drinking water has been identified. Arsenic and its compounds have carcinogenic properties. Skin diseases and increased cases of cancer endanger the population in regions where the level of As in their drinking water is too high.

The maximum allowed concentration of arsenic in drinking water is 10 μg/l.

Signs of arsenicosis: spots on the hands

Source: http://www.iwawaterwiki.org/xwiki/bin/view/Articl es/Arsenic

Cadmium (Cd)

Sources of cadmium could be corrosion of galvanised pipes, erosion of natural deposits, discharge from metal refineries, runoff from waste batteries and paints. The release of *Cd* in drinking water due to galvanised pipes depends on the composition of the pipes. Many countries allow a limited percentage of *Cd* in constructing galvanised pipes.

With the introduction of chemical fertilisers, cadmium has been accumulating in agricultural land and therefore in almost all foods (only a very small amount leaches into the groundwater). For example, many natural sources of phosphates are contaminated with *Cd* and other metals. Several developed countries have a regulated limit introduced for the concentration of cadmium in fertilisers. Cadmium can cause kidney, liver, bone and blood damage.

The maximum allowed concentration of cadmium in drinking water is 5μg/l.

Copper (Cu)

Copper is a common, malleable metal that occurs naturally in rock, soil, water, sediment and air. It is used to make products such as coins, electrical wiring and water pipes for household plumbing. The primary sources of copper in drinking water are corroding pipes and brass components of household piping systems. The amount of copper in drinking water also depends on the hardness and pH of the water, how long the water remains in the pipes, the condition of the pipes, the water's acidity and its temperature (see also module 6)

Signs that drinking water may have elevated levels of copper include a metallic taste or blue to blue-green stains around sinks and plumbing fixtures. The corrosion leads to the release of copper ions and their deposit of by-products on the pipe wall. The solubility of these by-products ultimately determines the level of copper at our taps. The only way to accurately determine the level of copper in drinking water is to have the water tested by a certified laboratory.

Healthy water should not be corrosive and contain sufficient calcium (hardness) in order to develop a protective layer of lime scale within the pipes. In the beginning, newly installed copper pipes or other copper equipment release some copper into the water. Therefore, water that was left hours in new copper pipes should not be used for consumption.

Although copper is an essential element for human beings, long-term exposure and increased amounts of copper cause liver or kidney damage. In particular, babies and children are affected.

The maximum allowed concentration of copper in drinking water is 2 mg/l.

Lead (Pb)

Lead is a heavy, soft, and malleable metal found in natural deposits (such as ores containing other elements), and has no characteristic taste or smell. It is used to make pipes, cable sheaths, batteries, solder, paints, and glazes. Where drinking water is concerned, lead has been used to produce service lines and solder (both banned since 1988), and a variety of brass pipes and plumbing devices (see also module 6).

Most lead enters our drinking water through the interaction of the water and plumbing materials containing lead, i.e. through corrosion and the solubilisation of lead-based corrosion by-products. Water chemistry, the age of the piping, and the amount of exposed lead at the surface of the material in contact with the water are the most important factors contributing to lead leaching into our drinking water. Furthermore, corrosion deposits within distribution systems can adsorb trace amounts of certain soluble contaminants, including lead.

Lead is for humans, and in particular for foetuses and children, a toxic metal. Lead can affect delays in physical or mental development in children and infants. Children can show slight deficits in attention and learning activities. Adults can experience kidney problems and high blood pressure.

Taking the recognised health risks of lead into consideration, the EU changed the regulations in 1998.

The maximum allowed concentration of lead in drinking water was reduced from 50 μg/l to 10 μg/l.

A transition period of 15 years was defined to allow replacing of lead distribution pipes.

Lead is a heavy and malleable metal and has been used in previous time to produce service lines and solder.
Lead is a toxic metal for humans.

3. Elements with aesthetic and technical impacts

Consumers do not accept un-aesthetic drinking water. Yet, aesthetic water is not at all a guarantee for safe water. Drinking water can have a sound condition regarding health concerns, nevertheless not being accepted by the consumer due to aesthetic inconsistencies such as colour, taste or odour. Furthermore, drinking water can contain elements in concentrations that affect the pipes or pumps, hence posing in the long-term technical hazards for the network with possible health risks for the consumer. In the following, some aesthetic and technical aspects of drinking water are described.

3.1. Aesthetic aspects

Besides standards for elements with health risks, most countries established also criteria for aesthetic aspects. For example the European Drinking Water Directive established indicator parameters for colour, taste, odour and turbidity. Drinking water should be acceptable to consumers.

Water can have a high turbidity caused by run-off and soil erosion, e.g. after heavy rainfall, or due to corrosion or certain cleaning activities (changing the flow direction) or while the pipes and reservoirs are not regularly cleaned (biofilms). High concentrations of Zinc can cause white coloured water, high concentrations of iron or manganese can colour the water brown/red or dark.
Poor cleaning and stagnation of water in dead ends or pipes can cause bad odour. Using inappropriate materials for plumbing or contamination with oil/petrol can cause an oily odour and taste. Excessive amounts of chlorine will make the water untasty. Water can be naturally coloured by iron or by organic compounds from marshes. Consumers disliking the taste, odour or colour of water will change to other sources of water, which may not always be safer. Therefore, fulfilling the aesthetic requirements for drinking water should be an important part of a water supply.

3.2. Elements with technical aspects

Calcium (Ca) and Magnesium (Mg) / hardness

The hardness of groundwater is very much influenced by the composition of the minerals in soils. Dissolved natural (carbonate) salts of calcium and magnesium cause water hardness, which can cause deposits of hard layers on the surfaces of water pipes or water heaters.
As mentioned earlier, metal pipes can be a source of drinking water contamination. Therefore one of the requirements of the Drinking Water Directive is that drinking water should not have any corrosive properties in contact with metals. That means water should have a certain degree of hardness, although the EU Drinking Water Directive does not specify standards for hardness, composed of calcium or magnesium.

However, too much hardness is unwanted, particularly within households. Heating apparatuses are damaged and the diameter of pipes can decrease. The EU Drinking Water Directive does not advise a minimum or maximum concentration (indicator parameter) for calcium and magnesium, but several countries do so. Water with a very high hardness level may be a problem considering heating installations and household equipment. *Ca*- and/or *Mg*-salts precipitate, in particular, on materials in contact with heated water (water cookers, heating systems). Furthermore, hard water requires more detergents/soaps for cleaning purposes.

Calcium and magnesium are essential elements for human beings. Drinking water with high hardness levels is not considered to be harmful.

Iron (Fe) and Manganese (Mn)

The primary sources of iron in drinking water are natural geological sources, as well as ageing and corroding distribution systems (household pipes). Iron-based materials, such as cast iron and galvanised steel, have been widely used in our water distribution systems and household plumbing.

Undesirable effects are tastes or odours. Iron in quantities greater than 0,3 mg/l in drinking water can cause an unpleasant metallic taste and rusty colour. Iron and manganese are both known to stain the water supply. They can make water appear red or yellow, create brown or black stains in the sink, and give off an easily detectable metallic taste. Even laundry can get brown spots by washing with *Fe*- and *Mn*-rich water. Although these can all be aesthetically displeasing, iron and manganese are not considered to be unhealthy. Fortunately, they can be removed from the water easily. Furthermore, increased levels of iron can appear in the drinking water of galvanised pipes that are corroding and release iron. Because galvanised pipes consist of a mixture of metals, zinc or cadmium levels in the drinking water could also increase. Like iron, zinc is not considered to cause health risks. Please see above for cadmium

Corrosion can cause severe leakages in the distribution system

4. General remarks

Most substances that pose health risks are not visible and do not have a colour or a smell. Therefore, only extended water analyses of the water source and the final drinking water consumed by the people can give information about the quality. If any health-concerned substances exceed maximum levels, the consumer should be informed and advised on taking appropriate precautionary measures.

The EU Directive indicates that the analyses results have to be made accessible to the public. The water supplier is responsible for the water quality of the entire supply system - up to the water meter of the connected household. Water should be free of pathogens, the parameter values of the Drinking Water Directive should be fulfilled and the delivered water should have no corrosive properties. The water quality has to be monitored on a regular basis and according to the delivered quantity of drinking water. But within the household, it is the owner or consumer who is responsible for maintaining the quality of water, the pipes and other equipment in contact with the drinking water. The following Table (Table 6) shows parameters, which are substances that cause health concerns. The concentration should not exceed the set parametric values.

Parameter	Parametric value	Unit
Acrylamide	0,10	µg/l
Antimony	5,0	µg/l
Arsenic	10	µg/l
Benzene	1,0	µg/l
Benzo(a)pyrene	0,010	µg/l
Boron	1,0	mg/l
Bromate	10	µg/l
Cadmium	5,0	µg/l
Chromium	50	µg/l
Copper	2,0	mg/l
Cyanide	50	µg/l
1,2-dichloroethane	3,0	µg/l
Epichlorohydrin	0,10	µg/l
Fluoride	1,5	mg/l
Lead	10	µg/l
Mercury	1,0	µg/l
Nickel	20	µg/l
Nitrate	50	mg/l
Nitrite	0,50	mg/l
Pesticides	0,10	µg/l
Pesticides-total	0,50	µg/l
Polycyclic aromatic hydrocarbons	0,10	µg/l
Selenium	10	µg/l
Tetrachloroethene and Trichloroethene	10	µg/l
Trihalomethanes — total	100	µg/l
Vinyl chloride	0,50	µg/l

Table 6: Chemical parameters and parametric values for the quality of drinking water
Source: EUROPEAN COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, Values of Annex 1, Part B

5. WSSP related activities, results and outcomes

WSSP related activities	Results/ outcomes
Review of the requirements of the national drinking water directive on frequency of monitoring, the parameters to be analysed and the required quality of the supplied drinking water.	List with requirements on frequency of monitoring, the parameters to be analysed and the set values of microbiological and chemical parameters is available.
Find out the quality of the raw water and the supplied water: • What are the locations of sampling? • Are individual water supplies monitored? • Which parameters are analysed at which	Analyses reports of the raw water and supplied water of public, centralised and individual supplies are available and assessed. ◦ Knowledge about risks of metals in the water network and at the households is gathered.

frequency? • Are at least microbiological parameters regularly analysed? • Is the water tasty, odour- and colourless and particle free? • Are lead pipes or corrosive metal materials present within the network or at household level? • If needed, initiate additional water analyses and discuss the results.	o So far, necessary additional analyses are carried out.
Do all connected citizens consume water of the centralised water supply? If not, what are the alternative water sources and what is the quality of that water?	A survey among the citizens on the used drinking sources is carried out. o Knowledge about the quality of the water sources used by citizens is gathered and assessed.
Are any parameters exceeding the set limits indicated by the national regulations or European directive? • Are there any health or technical risks linked to the water quality? • Did outbreaks of water related diseases occur in the past? (is there a local registration system for diseases?) • If yes, what are the measures taken so far to improve the water quality?	So far applicable: o A list of parameters non-compliant with the national standards (parametric values) is available o Health and technical risks of parameters of non-compliance with the national standards are assessed o A report on possible health and technical risks is produced. o An overview with previous occurred water related outbreaks is available. o Recommendations of actions for consumers and health authorities are developed.
Find out if there is an emergency plan in case of calamities. • How would the citizens be informed? • Which measures are taken to guarantee safe drinking water to citizens?	An emergency plan ensuring the citizens an access to a minimum quantity of safe water is available.
Are the results accessible and understandable to the wider public? If not, take adequate and applicable measures for providing information to the citizens and other stakeholders.	Analyses results and recommendations are accessible to the public. Measures are taken to make information accessible and understandable for citizens and other stakeholders.

6. Text sources and further reading

EU Drinking Water Directive: COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption, Official Journal of the European Communities. Available from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1998:330:0032:0054:EN:PDF

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Module B5

Sanitation and Wastewater Treatment

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Summary

Water consumption and usage create wastewater. Unregulated drainage of raw wastewater poses a threat to public health and the environment. Proper wastewater treatment and safe sanitation are key challenges for a healthy environment in urban and rural settings, because the main objective of wastewater treatment is the elimination and/or avoiding contact with pathogens disease-making microorganisms). The main objective of sanitation is the prevention of human contact with pathogens from human excreta.

In the European Union, two main directives address the obligations on wastewater treatment. For a common understanding on wastewater and sanitation issues, definitions are formulated. Furthermore, there are several options presented in this module for the extensive management of wastewater and sustainable on-site sanitation, including the safe re-use of wastewater in agriculture. An example of on-site sustainable sanitation (Ecosan) and extensive management of wastewater, a constructed wetland, is given

Objectives

Awareness of the needs, benefits and possibilities required to provide safe sanitation and wastewater treatment to small communities is obtained. Basic insight into the requirements and options of sustainable sanitation and the properties of domestic and other types of wastewater is gathered.

Key words and terms

Wastewater treatment, domestic wastewater, greywater, blackwater, urban wastewater, toilets, septic tanks, sustainable sanitation, urine diverting dry toilets, re-use

Sanitation and wastewater treatment

Introduction

Proper sanitation and wastewater treatment are key challenges for a healthy environment in urban and rural settings. Unregulated run-off of raw wastewater poses a threat to public health and the environment. Children and vulnerable groups are particularly affected by cases of water borne diseases, but adults are also affected, which can significantly hinder the economic development of a region. The environmental damage due to untreated wastewater is relevant as well. Groundwater, a major resource for drinking water, is under increasing pressure from human activities, and in many regions not suitable for drinking purposes.

EU legislation addresses the topic of sanitation and wastewater treatment through two directives, the Urban Waste Water Treatment (UWWTD) and the Water Framework Directive (WFD). The UWWTD obliges the new Member States to collect wastewater and install treatment plants in agglomerations with more than 2,000 people equivalent (PE). The WFD requires the achievement of good groundwater status and provides for the monitoring of groundwater bodies, as well as for measures to protect and restore groundwater. WFD demands that measures should be adopted to prevent and control groundwater pollution, including criteria for assessing good chemical status. In the pan-European region approximately 200 Million people (my calculation based on the PWH questionnaires) are served by small-scale water supplies, whereof most of them are not connected to a wastewater collection or treatment system.

1. Definitions and characteristics

1.1. Sanitation

Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and faeces. The term sanitation refers also to the maintenance of hygienic conditions through services such as wastewater management and waste collection. Thus, sanitation deals with the toilet or latrine in households, schools and public places, the collection of toilet waste and the management of urban wastewater, and with hygiene practices such as proper hand washing. That is why parts of sanitation are included in other chapters. Please see also module C5, C6, B8.

1.2. Domestic wastewater

Domestic wastewater contains different types of wastewaters, which are produced in the households (see table 1). They have very different characteristics, depending on the source, and are classified accordingly:

Greywater: Water coming from personal hygiene, kitchen and laundry, not from the toilets. The amount of greywater is much bigger than the amount of black water. It is dependent on the living standard within the household and if there are water saving devices installed, e.g. in showers. The volume of greywater can be up to 100.000 liter/person/year.

Blackwater: Water coming from flushed toilets including urine, faecal matter, flush water and toilet paper. See table 1. The volume of black water is around 10.000 – 25.000 liter/person/year, depending on the type of toilet.

The urine is sterile, if the people are not sick, and contains most of the nutrients: approximately 80% of the nitrogen, 55% of the phosphorus and 60% of the potassium.
The average excreted daily amount of nutrients can differ from person to person and from country to country, and depend on the persons diet in particular. In average, people from Sweden excrete more nitrogen than people from India or Africa. The volume of the excreted urine is approximately 500 liter/year per person. At the same time, it constitutes only 1% of the domestic wastewater volume.

The faecal matter is a relatively small amount of wastewater, and it comprises of ca. 50 kg/person/year, which also depends on the diet of the population. People who are vegetarian excrete more faecal matter than people who eat meat. This relatively small volume contains most of the organic matter and a variety of pathogens, which can infect other people if they are not properly collected and treated. 1 gram of faeces can contain 10.000.000 viruses, 1.000.000 bacteria, 1,000 parasite cysts and 100 parasite eggs.

In table 2, the approximate daily amount of Nitrogen and Phosphorus originated from one person and found in urine, faeces and greywater are made visible. As mentioned before, the volume of urine is only 1% of the total daily volume of greywater, however in domestic wastewater, urine is the main source of nitrogen and phosphorus. The volume of faecal matter in domestic wastewater is even less than that of urine, but is the main source of microorganisms and pathogens. Therefore, in order to avoid an intensive treatment of huge volumes of domestic wastewater, modern approaches of wastewater treatment systems focus on a diversion and a safe re-use of the different wastewater streams.

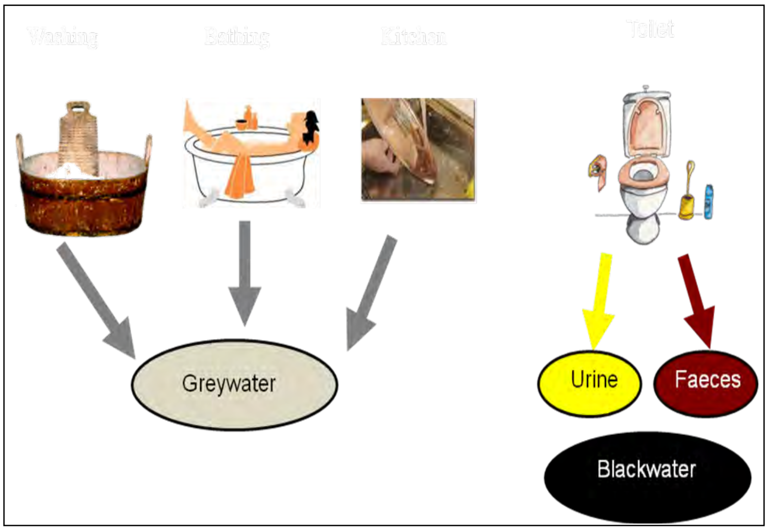

Table 1: Overview of the compounds of greywater and blackwater

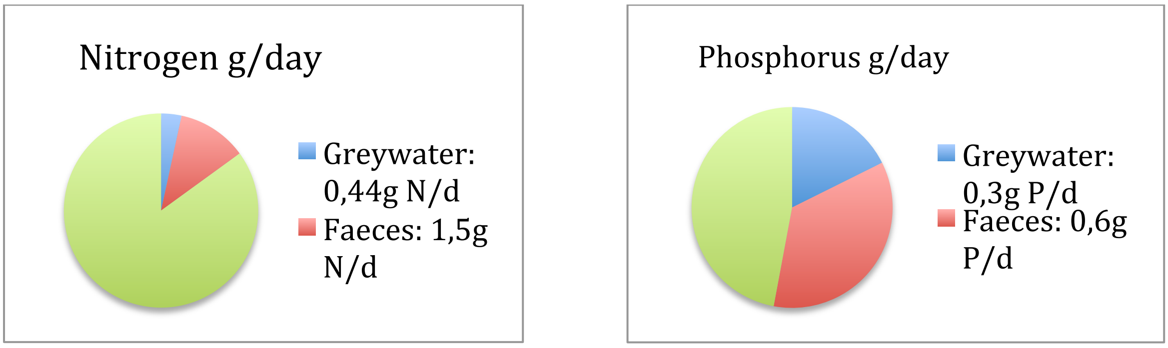

Table 2. Overview of the content of nitrogen (N) and phosphorus (P) in urine and faeces, excreted per person and per day, and the content of N and P in greywater per person and per day.
Source: According data from WHO 2006

1.3. Urban wastewater

Urban wastewater is defined as the mixture of domestic and industrial wastewater and sewer infiltration water. Sewer infiltration water is water that enters the sewer pipes due to broken pipes or illegal connections. The longer the sewer systems are, the higher the probability of having sewer infiltration water. It can significantly increase the quantity of urban wastewater treated in the treatment plant, and it must not be neglected. The solution to keep the volume of infiltration water low is regular proper monitoring and maintenance of the sewage network. Industrial wastewater is included in the urban wastewater stream as well, and should be treated at the source to reduce the amounts and loads of urban wastewater, if possible. The quality and quantity arising from the different industrial sources can vary significantly.

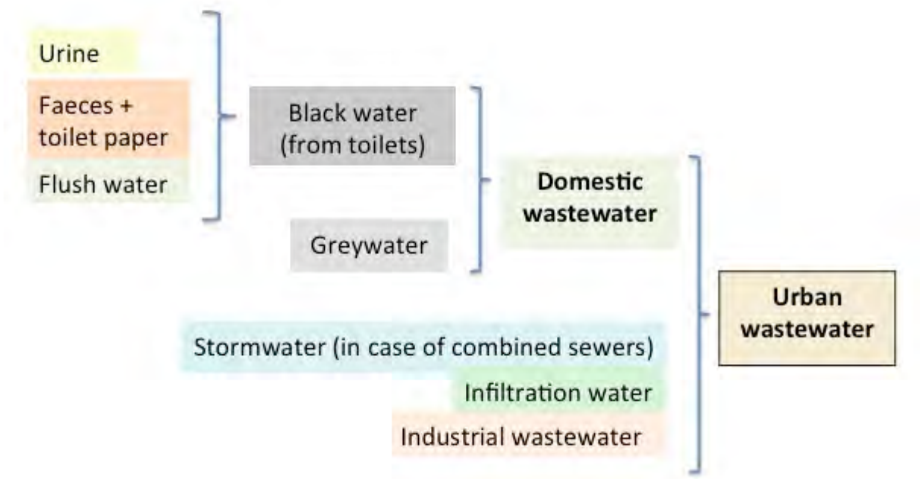

Table 3: Overview of the different types of wastewater

Run-off rainwater or stormwater should be collected separately and treated accordingly. But many old sewer systems collect the rainwater with the wastewater in so-called combined sewer systems.

Urban wastewater			**Sewer infiltration water**	**Storm water, Run-off rainwater**
Domestic wastewater		Industrial wastewater (Annex III of the UWWTD)		
Toilet wastewater (Urine, brownwater (faeces + flush water)	Greywater (Water from personal hygiene, kitchen and laundry, not from the toilets)			
10,000 – 25,000 liter/person/year depending on the type of toilet	25,000 – 100,000 liter/person/year depending on the status of water saving devices in the households	Quantity depends on the industrial activities in the agglomerations and their wastewater management	Quantity is high (e.g. 100% of the domestic wastewater, especially in rural area)	Amount depends on the climate

Table 4: Characteristic and definition of urban wastewater (according to the Urban Waste Water Treatment Directive Council Directive 91/271/EEC)

1.4. Sustainable Sanitation

It is important to implement sanitation and wastewater systems that are sustainable. Sustainability relates to 5 aspects defined by the Sustainable Sanitation Alliance (www.susana.org). In order to be sustainable, a sanitation and wastewater system has to not only be economically viable, socially acceptable, and technically and institutionally appropriate; but it should also protect the environment and the natural resources.

When improving an existing and/or designing a new sanitation system, sustainability criteria related to the following aspects should be considered:

1. Health and hygiene: includes the risk of exposure to pathogens and hazardous substances that could affect public health at all points of the sanitation system from the toilet (via the collection and treatment system) to the point of re-use or disposal.

2. Environment and natural resources: involves the required energy, water and other natural resources for the construction, operation and maintenance of the system, as well as the potential emissions to the environment resulting from use. It also includes the degree of recycling and re-use practiced and the effects of these (e.g. re-using wastewater; returning nutrients and organic material to agriculture), and the protection of other non-renewable resources, for example through the production of renewable energies (e.g. biogas).
3. Technology and operation: incorporates the function/performance and the ease within the entire system; including the collection, transport, treatment and re-use and/or final disposal; can be constructed, operated and monitored by the local community and/or the technical teams of the local utilities. Furthermore, the robustness of the system, its vulnerability against power cuts, water shortages, floods, and etc. are important aspects to be evaluated. The flexibility and adaptability of its technical elements to the existing infrastructure and to demographic and socio-economic developments are also included.
4. Financial and economic issues: relate to the capacity of households and communities to pay for sanitation, including the construction, operation, maintenance and necessary re-investments in the system.
5. Socio-cultural and institutional aspects: the criteria in this category evaluate the socio-cultural acceptance and suitability of the system, convenience, system perceptions, gender issues and impacts on human dignity in compliance with the legal framework and stable and efficient institutional settings.

2. Different types of toilets

The standard toilet is the flush toilet, flushed with different volumes of flush water. Common toilets use up to 10 liter per flush, but new water saving toilets use only 3-5 liter. Toilets, which use less water -only 1l per flush, are vacuum systems, which are common in airplanes or modern trains.

The traditional pit latrines is also still commonly used in mostly rural areas where there is no centralized water supply. They are generally located far away in the garden, because of their bad smell, and are often very unhygienic and pollute the groundwater with excreta substances.

Urine diverting toilet with water flush

Waterless toilets also exist, and modern waterless toilets are equipped with urine diversion, which ensures that the toilet does not smell like the traditional pit latrines do. The urine is collected separately. Instead of using water, these toilets are "flushed" with dry material such as ash, soil or shredded wood after defecating.
Besides urine diverting dry toilets, low-flush urine diverting toilets are more and more used in modern sustainable sanitation systems. The urine can be used for fertilizing agricultural fields and the fecal matter could be used for biogas production or be composted and re-used in agriculture. In all the presented toilet systems, spreading of pathogens and nutrients in the environment should be avoided.

Toilet flushing after use in case of a urine diverting dry toilet in Ukraine

3. Wastewater

3.1. Wastewater collection

There are different technical options in wastewater collection. See table 5.

Centralized wastewater management is the standard approach in many countries. It is characterized by the collection and removal of urban wastewater by a centralized sewage system to a centralized intensive treatment plant where the wastewater and sludge are treated and disposed of under controlled conditions. The overall advantages of this concept are often lower investment and operational costs incurred by a single large treatment plant, as compared to several small-scale plants with regard to more effective control of quality standards and plant operation procedures.

Wastewater collection pipe including a man hole which will be put underground

The centralized standard system also has a number of drawbacks, particularly in rural and peri-urban areas. Increasing attention has been given to modern onsite, decentralized or semi-centralized wastewater management concepts in recent years. These concepts comprise collection, treatment and disposal/re-use of wastewater from small communities (from individual homes to portions of existing communities) integrated in settlement/ village/town development projects. Such approaches consist of many small sanitation/wastewater treatment facilities designed and built locally. Decentralized systems maintain both the solid and liquid fractions of the wastewater at or near the point of origin, and hence, minimize the wastewater collection network. This approach offers a high degree of flexibility, allowing modification of the system's design and operation to fit into various site conditions and scenarios.

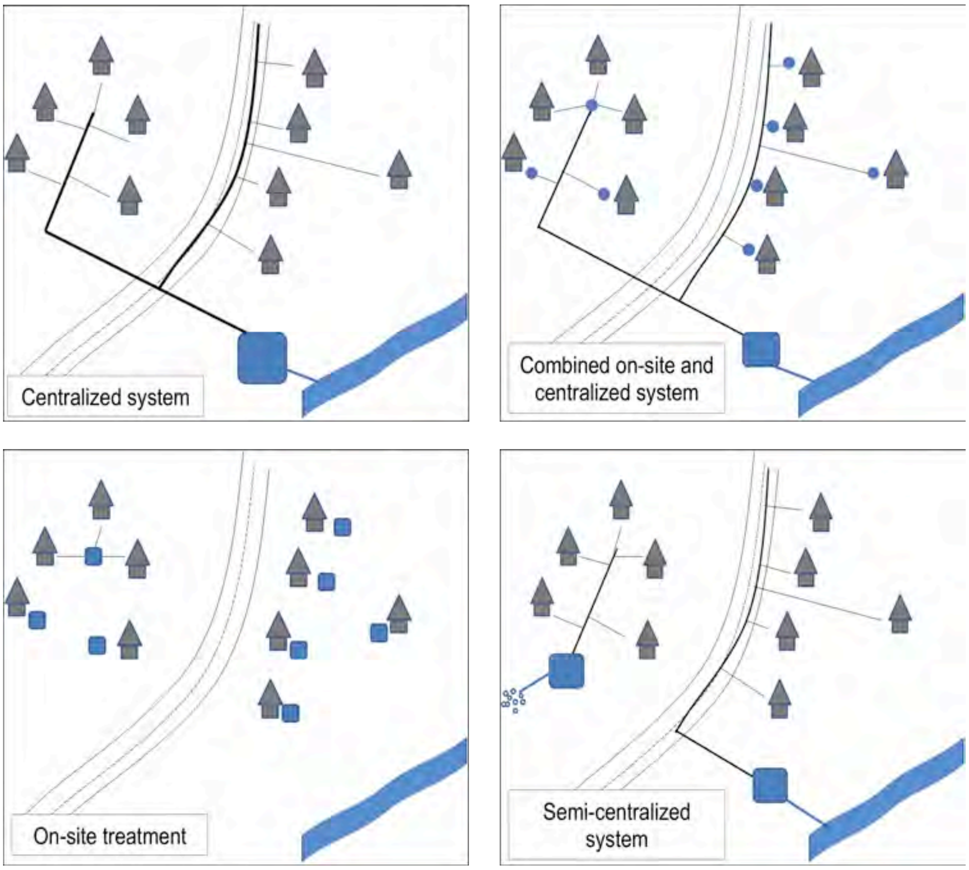

Table 5: Different wastewater collection systems

3.2. Septic tanks

A septic tank is a wastewater collection mechanism and partly a treatment system, which is predominantly applied in rural areas. These are tanks where pre-treatment takes place.

There are two types of septic tanks:

1. Collecting septic tanks, which need to be emptied as soon as they are full (e.g. each month) because they have no outlet.
2. Septic tanks with an overflow outlet where the liquid effluent is infiltrated into the surrounding soil. The settled sludge is supposed to be emptied from time to time (e.g. every five years). The liquid effluent still contains dissolved organic matter, nutrients and pathogens. It needs to be divulged into sandy soil and no close connection to water sources.

The drawback of septic tanks is that it is up to the house owner to take care of the emptying. A certified professional company should carry this out, which might be expensive. In fact many people do not empty their septic tank and the septic tanks overflow if the soil is impermeable and/or highly contaminated sewage is entering the environment.

However, if the septic tank system is operated properly, it is a simple and efficient system. If it needs an upgrade, if for example the water resources are contaminated, an advanced combined onsite and centralized collection system can be applied where the septic tanks on-site are integrated into a full concept (as seen in the scheme above, table 5). The centralized sewage and treatment system then collects and treats only the pre-treated wastewater, which requires a simpler and cheaper system.

A street contaminated by wastewater from over flowing septic tanks

In some rural regions, households discharge their wastewater of the flushed toilets, shower, wash water and kitchen, to a so-called soak away pit. The soak away pit collects the wastewater and directs the wastewater into the soil, or the wastewater overflows due to intensive wastewater production. These collection systems are harmful to the environment and are not considered an adequate wastewater collection and treatment system.

A soak away pit filled with wastewater

4. Wastewater Treatment

There are different types of treatment systems, and they generally comprise of three stages, called primary, secondary and tertiary treatment:

1. Primary treatment consists of temporarily holding the wastewater in a first basin where, on the one hand, heavy solids settle to the bottom, and on the other hand, oil, grease and lighter solids float to the surface. The settled material is the primary sludge that is separated from the liquid and further treated. The sludge might be used in agriculture as an organic fertiliser, if the quality is acceptable otherwise it is disposed off. The floating material is disposed of as solid waste and the remaining liquid goes to secondary treatment.
2. Secondary treatment removes dissolved and suspended organic matter, as well as partly removing the nutrients, especially nitrogen and phosphorus. Secondary treatment is typically performed by indigenous micro-organisms which are also present in the environment. The microorganisms need oxygen, which is provided in technical plants through technical aeration. The microorganisms form a biological sludge which is called activated sludge. In natural systems, the aeration is mostly provided naturally. Secondary treatment requires a separation step to remove the micro-organisms from the treated water prior to discharge, re-use or tertiary treatment. The so-called secondary sludge is separated and can be treated with the primary sludge.
3. Tertiary treatment goes beyond primary and secondary treatment in order to allow discharge into a highly sensitive ecosystem, such as estuaries, low-flow rivers or coral reefs. Treated water is sometimes

disinfected chemically or physically (e.g. by microfiltration, UV treatment) prior to discharge it into a stream, river, bay, lagoon or wetland, or it can be used for irrigation in agriculture, or a golf course or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

View on a huge technical wastewater treatment plant in Hamburg
Source: http://www.vdi.de/2151.0.html

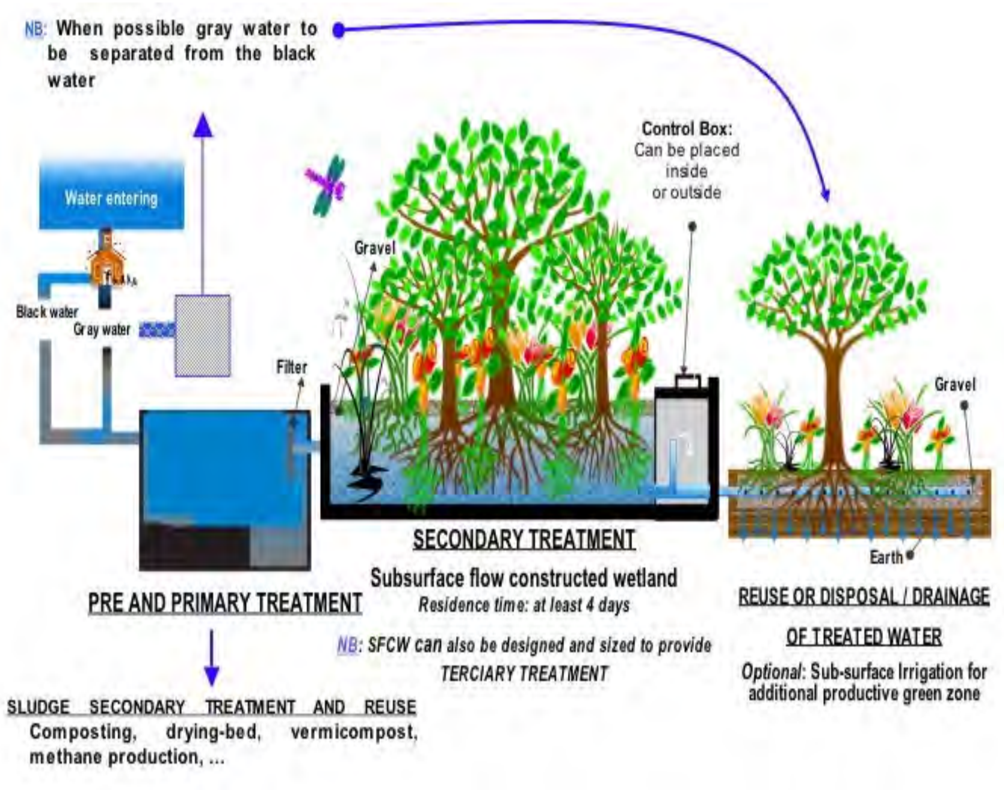

Table 6: Overview of an extensive wastewater treatment
Source: http://en.wikipedia.org/wiki/File:SchemConstructedWetlandSewage.jpg

4.1. Extensive wastewater treatment systems

Wastewater treatment in ponds or lagoons has been a well-known technology for centuries in Europe. The purification is ensured by a long retention time, which requires a lot of space compared to intensive systems. Pond systems are a high-performance, low-cost, low-energy (often zero-energy) and low-maintenance treatment process, especially suitable in warm climates. But they can be upgraded with simple technical aeration as well. Pond systems are widely used in the rural areas of many EU countries. In France, for example, there are more than 2500 waste stabilization pond systems in operation.

Aerated pond in Germany
(Photo: Andrea Albold)

Pond system in Meze, France
(Photo: Francois Brissaud)

Constructed wetlands are natural systems in which the wastewater flows through a planted soil filter where the biological and physical treatment takes place. The bed can have filling material like sand or gravel and is sealed to the ground (by natural soil or an artificial foil).

Constructed wetland in Germany

The treatment relies on the bacterial activity, taking place in the biofilm of the bed, and the physical filter and adsorption effects. To enhance the process, the soil filter is planted with plants, typically reed, and that is why they are often called reed bed filters as well.

4.2. Examples for sanitation and wastewater treatment in rural areas

On-site modern dry sanitation and greywater treatment

Since 2002 in pan European countries many demonstration models for modern sustainable dry sanitation such as urine diverting dry toilets (UDDT or Ecosan) were constructed for households, schools and town halls. The UDDTs were introduced in particular in regions were centralised piped water and/or sewerage systems were lacking, and are in the meantime often replicated. For households mostly seat models, for public places squatting models are used. The WHO guidelines on safe use of human excreta in agriculture (2006) are applied for the treatment and safe re-use of the separated urine and faecal matter.
For schools, e.g. in Armenia, Moldova, Romania, Ukraine, Kyrgyzstan, Tajikistan or Georgia many UDDT toilets attached to the school or in the yard were constructed. The urine is stored during 6 months in reservoirs and according to the WHO, safe for usage as a fertiliser in agriculture; the covered and dry faecal matter is stored for at least one year and used as soil conditioner.
The wash water of the schools is drained off and treated in a simple sand filter.
For more than 10 years Ecosan proved that this system is working well and a considerable improvement for the environment, for the dignity of the users and comfort; particularly in areas with cold winters and for schools and kindergarten.

Exterior of a UDDT facility attached to a school

Interior of a UDDT for a school

School UDDT: chamber for the collection, storage and treatment of faecal matter

School UDDT: basement with reservoirs for the collection, storage and treatment of the urine of 350 use

Constructed wetland for a children´s home in Vidrare, Bulgaria

Collected and stored urine should be used as fertilizer for backyard agriculture. Composted faeces can be used as soil conditioner. The greywater from the sinks is treated in a small horizontal flow constructed wetland. The treated water infiltrates into the ground.

The constructed wetland for the wastewater treatment of a children´s home in the Vidrare, Pravetz municipality was inaugurated in 2011. It comprises of a settling tank of 18 m^3, two pumps, a sand filter with a surface area of 266 m^2 and an inspection shaft for sampling the treated effluent. The design criteria are 76 PE organic load and 95 PE hydraulic load.

Soil filter with planted reed in Vidrare

5. Re-use of toilet products, wastewater and sewage sludge

Toilet products (urine and faecal compost) and sewage sludge contain a lot of valuable substances, organic matter and nutrients, which can be re-used. Treated wastewater can be recycled safely to other water resources. Also, the UWWTD asserts that wastewater and sludge should be re-used whenever possible.
Wastewater re-use can be practiced, for example, in agricultural field irrigation or in urban landscaping. Sport and recreation areas are the largest consumers of treated wastewater.
Other proven applications of re-used treated wastewater are the following:

- Water for manufacturing (cooling and process water) and construction industries.
- Dual water supply systems for urban non-potable use (garden irrigation and car washing).
- Fire fighting, street washing.
- Water for creation or restoration of natural or constructed aquatic ecosystems, recreational water bodies and fish ponds.
- Aquifer recharge through infiltration basins and injection wells for water storage and saline intrusion control.
- Redevelopment of old industrial or mining sites into attractive water parks for the community to increase quality of life and land value

Urine, faecal compost and sewage sludge are suitable for organic fertilizer and soil conditioner. Prior to any re-use, the potential pathogens must be taken into consideration in order to avoid the spread of disease. The level of treatment and the degree of safety measures depend on the purpose of re-use. For example, in case of applying the products in a forest area where there is no sensitive environment and no water protection area, the safety measure can be much lower than applying it on agricultural fields. There are guidelines developed and published by the World Health Organisation (WHO) that explain how toilet products, wastewater and sewage sludge should be handled and re-used in an agriculturally safe way.

Application of dewatered sewage sludge on agricultural field in Germany

6. WSSP related activities and results

WSSP related activities	Results / output
• Are there pit latrines or soak-away pits in the village? If yes, is there danger of groundwater pollution? • Is there a wastewater collection?; if yes, are there leakages in the system affecting the water sources? • Is the wastewater in the village collected and treated, and where is the treated wastewater discharged? • Is the quality of the treated wastewater monitored? If yes, are the values according to the national requirements? • Review of the regulatory requirements of public toilets and wastewater management • If needed, identification of options for sustainable and cost effective sanitary and wastewater treatment systems? • Checking the school toilets and other public toilets including the hand wash facilities; in what state are they, which options are available to improve the situation of the toilets? (using quality assessment form and questionnaire in Modules A7 and A9)	• Sanitation mapping of the village • Action planning for improving the situation if needed

7. Text sources and further reading

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http://www.wecf.eu/download/2009/2009WWF5Sanitationregionaldocument.pdf

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Module B6

Water Protection

Authors: Margriet Samwel, Claudia Wendland

Summary

This module consists of 2 parts:
A. Water protection in general
B. Groundwater protection zones

In many areas, groundwater is used directly as drinking water – this occurs up to 80% of the time in Europe and Russia. It is the most reliable of all fresh-water resources. Its quality and ease of abstraction varies greatly from place to place, as well the possibilities to efficiently treat it. In many countries, small-scale water operators and/or households lack the funding and expertise for the efficient treatment of polluted water.

The most common man-made (anthropogenic) contaminants in ground- and spring water are microorganisms, nitrate and pesticides. These create health risks when found in drinking water, leading, in extreme cases to a complete abandonment of water abstraction.

The lack of measures preventing anthropogenic water pollution contributes to the existence of unsafe drinking water. In general, significant investment is needed for water treatment or for switching to alternative, safer water sources. Experience shows that the effective prevention of water pollution is feasible, manageable and much cheaper than handling polluted ground or spring water.

In this module several aspects of effective water protection are presented:

Part A. Water protection in general, gives an overview of groundwater pollution's most common sources. Regulations on the prevention of water contamination are discussed, and some examples on policies at EU level, like the Water Framework and the Nitrate Directive, as well as measures to prevent water pollution, are described. Contaminants derived from agricultural activities and domestic wastewater are principally targeted. Furthermore, an overview of the common sources of water pollutants is given.

Part B. Groundwater protection zones, defines different water protection (sanitary) zones and the restriction on human activities in these zones. Barriers and mechanisms for implementing restrictions in the sanitary zones are discussed, as well as the contribution households and citizens can make to water protection. Some examples of good water protection measures initiated by communities or water operators are stated.

Objectives

The reader can describe the most common sources of water pollution and is aware of water protection strategies. The basics of different groundwater protection zones of a water catchment area can be described and the aim of the different zones is understood.

Key words and terms

Water pollution, anthropogenic, water protection, directives, agriculture, communal wastewater, animal waste; Water Protection Zones, sanitary zones, catchment area, water quality, hydrogeological conditions

Water Protection

B6-A. Water protection in general

Introduction

In most areas, groundwater is cleaner than surface water. Groundwater is usually protected against contamination from the surface by soil and rock coverage layers. However, depending on geological and hydrological conditions and on rock coverage layers, groundwater can get severely contaminated, in particular with microorganisms, nitrate and pesticides. Polluted groundwater results in unsafe drinking water with a high cost of treatment. In extreme cases, the only feasible solution is to give up the water abstraction. The discharge of untreated or poorly treated wastewater, as well as the infiltration of animal manure, strongly affects the quality of water sources and human life.

A constant decline in ground- and surface water quality has been observed in countries with intensive livestock farming (chicken, pigs) and intensive crop growing which involve the use of chemical weed-killers (herbicides) and over-fertilisation. The runoff and leakage of nitrates, pesticides and phosphorus from agricultural land during rainfall is only one cause of water pollution. However, regions with small-scale farms which fail to safely manage animal manure or other organic waste and household wastewater often contribute to water pollution.

Slope and soil characteristics, erosion, deforestation, farmers' land-use, crop choices and production techniques all contribute to the quality of water.

Besides man-made pollution, natural geological substances, such as fluorine, arsenic or salts can also negatively affect water quality and restrict its use. In this manual, the focus is on explaining anthropogenic water pollution by agricultural practices and the mismanagement of human and animal excreta.

1. What can be done and on which levels?

Often, water pollution is man-made, and can, therefore, be minimised by people.
Experience from many countries shows that water protection policies are attractive and sustainable from an environmental and economic point of view, with a view to the long term. In many cases, costly groundwater treatment for safe drinking water could be avoided. In addition, safe recreational and bathing water are treasured by all people, and untreated wastewater should not be present here. See module B5.

In many countries, local, regional or national regulations have been established which target industries, communities and farmers with the aim of protecting the water sources and basins intended to deliver drinking water to people. For the implementation of these protection measures, stakeholders on all levels (national, regional and local) need to be involved.

A variety of pollution prevention and control measures are needed because water pollution can originate from many different sources.

1.1. Policies and agriculture

For many decades, discharges of nitrogen and pesticide compounds from agricultural activities have posed a problem for groundwater quality - not only across Europe, but the world. Nitrogen is a substance needed for the growth of all plants and is found in mineral fertilisers, manure and slurry. However, only a small proportion of fertiliser applied actually reaches the crops and is taken away with the harvest. A large proportion accumulates in the environment as surplus, for example in the form of ammonia or nitrous oxid. The rest remains in the soil or seeps into the groundwater in the form of nitrate. Nutrients are not the only substances that contaminate our waters, but also heavy metals and pesticides. Around 20 to 40 % of heavy metal discharge in surface waters originating from erosion or drainage outflows, are from agricultural land.

The bulk of pesticide pollution originates from agriculture, from fields to the cleaning of sprayers and other machinery. Pesticides from the *triazin* chemical group, for example the herbicides *atrazin* and *simazin*, are frequently found in ground- and surface water. Other pesticides with considerable potential to pollute groundwater are *diuron* and *bentazon*. Many countries have a pesticide list (active ingredients) with potential groundwater polluting properties. In Germany, around 40 active ingredients with a high importance for water protection were identified.

The legal framework applied to the protection of water resources makes stipulations including the following:

- Obligations of national, regional and local institutions and wastewater/water utilities
- Quality of groundwater and/or surface water
- Monitoring of water quality and quantity
- Type of waste and wastewater treatment
- Adapting and supporting the most sustainable and suitable sanitation systems
- Measures on the restoration and protection of bodies of water
- Human rights regarding access to safe water and sanitation
- Transparency and access to information and public participation

In order to decrease water pollution in the European Union (EU), political actions, particularly in the area of agriculture, were needed and several water-related directives or guidance have been developed and published. The different directives specify minimum requirements and Member States have the obligation to transfer the Directives into their national regulations and are allowed to establish more restrict regulations.

European Water Framework Directive (2000/60/EC)

The purpose of the European Water Framework Directive of 2000 is to establish a framework for the protection of inland surface water, transitional water, coastal waters and groundwaters (see also Module B8). The Water Framework Directive (WFD) explains that further deterioration should be prevented, and promotes sustainable water use based on the long-term protection of available water resources. Member States are expected to protect and enhance all artificial and heavily modified bodies of water with the aim of achieving a good ecological potential, a good chemical status, and ensure a balance between abstraction and recharge of groundwater.

European Nitrate Directive (91/676/EEC)

In 1991, the EU published the Nitrate Directive, concerning the protection of water from pollution caused by nitrates from agricultural sources. This directive tries to control the amount and timeframe of fertiliser application for crops and grasslands, as well the usage of manure from livestock. Also, it requires Member States to designate “vulnerable zones”, which are areas of land that are likely to be vulnerable for nitrate levels exceeding 50 milligrams per litre (mg/l). See module B8 for further information.

European directive on the protection of groundwater against pollution and deterioration (EC Groundwater directive) (2006/118/EC)

Measures to prevent and control groundwater pollution are stipulated in this directive. Quality standards for nitrates, plant protection products and biocides should be set as community criteria for the assessment of groundwater bodies’ chemical status. In consistency with the nitrate directive, the EC Groundwater Directive also relates to human and animal waste. The EC Groundwater Directive sets binding EU-wide limits. (See module B8 for further information.)

1.2. Domestic wastewater

Worldwide, many rural villages rely on decentralised water and wastewater systems for the collection of wastewater, such as dug wells, boreholes, standpipes, pit latrines and septic tanks. These mechanisms usually result in unprotected sources and the mismanagement of human waste. The treatment of communal or individual wastewater is an essential requirement for the long and short-term preservation of water resources. Communal wastewater and excreta from pit latrines or septic tanks must be treated and sanitised before being released into the environment. See also module B5.

Even in regions without a centralised wastewater collection and treatment system, appropriate wastewater treatment or human excreta treatment can be practiced. Modern sustainable and decentralised approaches, such as urine diverting dry toilets, constructed wetlands or wastewater ponds, contribute to the protection of water resources. Communities should be informed about the relationship between communal and domestic wastewater management and the pollution of water resources. They need to select the most appropriate solution, taking the available financial and human resources into consideration. Approaches to the management of wastewater should be investigated and adopted according to local environmental, social and economical conditions. Planning work and the implementation of a wastewater management system should take a holistic approach to wastewater discharge, treatment and re-use.

Particularly in high-density communities without sewage connections or wastewater treatment systems, the infiltration of untreated human excreta into the soil or the discharge of improperly treated wastewater into surfaces waters should be avoided.

Guide on extensive wastewater treatment processes

A guide on the decentralised treatment of wastewater has been produced by the European Union: “Guide on extensive wastewater treatment processes, adapted to small and medium sized communities (500 to 5,000 population equivalent -p.e.)”. This guide comes in addition to the Council Directive decreed on 21 May 1991 concerning urban wastewater treatment (91/271/EEC), which is one of the key parts of the European Union's environmental policy. One of the main measures given by the guide is the obligation for agglomerations with more than 10,000 or more than 2,000 p.e., which discharge their wastewater into a sensitive area, to set up a system for collecting wastewater which is connected to a wastewater treatment plant.

A urine diverting toilet has two outlets and two collection systems, one for urine and one for faeces, in order to keep these excreta fractions separate. Urine and faeces are collected in separate containers, stored or treated, and finally used in crop production.

Constructed wetland used for decentralised treatment of wastewater (Photo Andrea Albold).

1.3. Animal manure

In many rural villages, it is quite common for families to have some cattle, for their own consumption or for commercial purposes. Depending on the culture, solid animal waste is mostly collected and stored outside on a heap, where soil is in direct contact with the manure. Rainwater will partly washout the nutrients and finally infiltrate into the groundwater.

Livestock is often kept in stables, where conditions are not suitable for collecting liquids, resulting in runoff into the soil. In order to avoid these leakages, the manure produced in stables should be collected and stored in a closed concrete platform with borders, such as small walls, from which liquid manure can flow into a reservoir or pit. A watertight layer under the manure heap (manure platform), a covered watertight basin, or tanks for the slurry/liquid manure, should be used to avoid uncontrolled leakages into the groundwater.

In some EU Member States (e.g. Austria, Germany, Netherlands) regulations on handling animal manure are established and promoted by the relevant authorities - for example, the Ministry of agriculture or environment, or local water operators.

To ensure the runoff of leaking liquid, the platform must have a slope of 3-5 %, and a gutter where the liquid is collected and stored in the reservoir. A storage capacity of at least 6 months should be available, in order to ensure a timely and targeted use of the slurry or manure. The application of the manure should be according to the needs of the plants. In general, the rate of animals stocked should be related to the size of the available fields and in balance with the cultivation of crops.

An often neglected aspect of sustainable water protection is the safe storage of animal manure.

Manure should bestored on a closed concrete platform

2. WSP related activities and results / output

WSP related activities	Results / output
Review of existing laws and regulations related to protection of water resources and their local implementation. If no documents are available, detailed research on the Internet may give information	A list with identified relevant laws and regulations applicable for water protection is available. The local implemented and non-implemented regulations are identified.
Assess human and animal waste management in the community and surroundings (see also part b for the water protection zones.) • Assess the management of communal wastewater: how is the wastewater of private households and public places managed, stored, treated and disposed of or re-used? • If there is communal sewerage, what is the level of household connection? Is the wastewater adequately treated, is the quality of the released wastewater monitored? Are there any environmental concerns about the location of the released wastewater? Are there leakages in the sewage system? • Assess the potential sources of other contaminants such as processing plants, fuel stations, laundry or mechanic working places, obsolete or in-use pesticide/fertiliser stockpiles, in and around the vicinity of the village • Interview and/or observe citizens and farmers on the management of animal manure and human excreta • Interview farmers about the usage of pesticides and fertilisers (and about knowledge about the Nitrate Directive)	Locations with possible sources of water pollution in and around village are identified and reported, and a map is provided with the locations. o Agricultural practices and the management of human and animal excreta are inventoried and assessed. o If applicable, an overview of the sewerage, the conditions of the wastewater treatment (including a map with the location of the sewage network),any leakages and the location of the wastewater release is available. o An inventory of households and public institutions without access to adequate wastewater systems is made.

Table 1. Overview of common Sources of Potential Water Contamination
Source: EPA United States Environmental Protection Agency

Category	Contaminant Source
Agricultural	• Fertilizer storage/use • Pesticide storage/use • Manure spreading areas/pits/lagoons • Animal burial areas • Drainage fields/wells • Animal feedlots and storage • Irrigation sites
Commercial	• Metal industry, photography establishments • Auto repair shops, Car washes/gas stations • Laundromats, Paint production/shops • Medical institutions/laboratories • Construction areas, Railroad tracks and yards • Wastewater drainage, storage tanks, landfills
Industrial	• Asphalt plants, wood preserving facilities • Petroleum production/storage • Mining, drainage • Chemical manufacture/storage • Toxic and hazardous spills • Electronic/metal manufacture • Wastewater drainage, pipelines • Wastewater sludge, septic cesspools
Residential	• Sewer lines, septic tanks and pit latrines • Hazardous household products/detergents, • Pharmaceuticals, fuel, oil • Fertilisers/pesticides in households and gardens • Manure leakages and spreading
Other	• Hazardous waste landfills • Cemeteries • Recycling/reduction facilities • Municipal incinerators and landfills • Road de-icing operations • Road maintenance depots • Municipal sewer lines • Storm water drains/basins/wells • Open burning sites • Transfer stations • Salt water intrusion

3. Text sources and further reading

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Water Protection

B6-B. Groundwater protection zones

Introduction

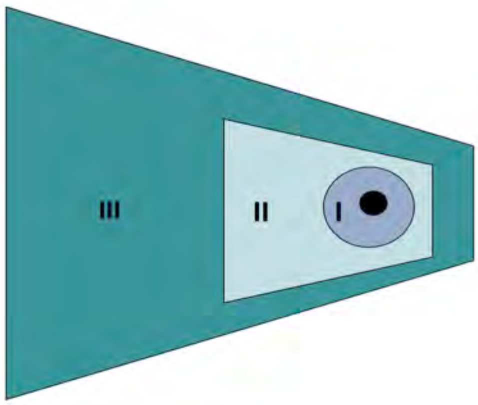
For more intensive protection of groundwater sources, many countries have established national or regional regulations on the protection of water sources intended for the abstraction of drinking water. Generally, water protection areas are divided into several Water Protection Zones (WPZ) with more or less intensive restrictions, addressing diffused water pollution from agricultural activities, for example. Activities in the WPZ, which cause or could cause damage or pollution to the groundwater, are prohibited.

1. How are groundwater protection zones defined?

The shape and size of a protection or sanitary zone depends on the condition and properties of its soil layers, the infiltration of rain or river water and the movement of the groundwater (from which side does the groundwater stream?). Hydro-geological studies define the properties of the ground and the groundwater. For example, the type of soil and its permeability are analysed, as well as the velocity of the groundwater stream.

The division of these zones can vary slightly from country to country. In general, protection zones should include at least the so-called '50 or 60 days' zone. In this zone, the groundwater needs 50 or 60 days to travel from any point below the water table to the abstraction point. During this timeframe, bacteria should be minimised. However, chemical contaminants will hardly be reduced, and up to 3 or 4 protection zones are necessary for preventing chemical pollution. Those zones should be identified by hydro-geological investigation.

The drinking water protection area should consist of the entire subterranean catchment area of a water abstraction point; sometimes, the surface catchment area needs to be considered as well. However, for many reasons, most water suppliers or communities are not aware of this requirement.



Scheme showing water protection zones I-III.

- *Well-field protection (Zone I)*
- *Inner protection zone (Zone II)*
- *Outer protection zone (Zone III)*

1.1. Overview of the defined water protection zones

- Zone I, or the well-field zone, must ensure the protection of the water abstraction point and its immediate environment from all types of contamination. Depending on the regulations, the radius can be established at least 10 meters around the point of abstraction and be surrounded by a stable fence.
- Zone II, or the inner protection zone, must ensure protection from contamination via pathogenic microorganisms (e.g. bacteria, viruses, parasites and worm eggs), as well as other factors posing a hazard, perhaps due to the presence of short flow paths and short flow durations to the water abstraction point. This zone can have a minimum radius of 50 metres.
- Zone III-A, or the outer protection zone, should ensure protection against far-reaching impairments, especially chemical or radioactive contaminants that are either resistant or non-degradable. For some countries, Zone III-A is defined by a 400-day travel time from the point below the water table.
- Zone III-B, or the source catchment protection zone, is defined as the area around the source within which all groundwater recharge is presumed to be discharged at the source.

1.2. Groundwater protection zones and restrictions

In the following table examples of restrictions for different sanitary zones are presented.

	Examples of Restrictions
Zone I	Unauthorised entrance, any kind of agriculture or other usage
Zone II	Setting up of construction sites; Designation of new construction areas; Building new traffic routes; Infiltration of sewage; Fertilisation with solid and liquid manure and mineral fertilisers; Application of pesticides; Deforestation; Discharge of waste for recycling purposes; Handling of substances hazardous to water; Exploitation of minerals; Animal reserves and permanent grazing; Building, extension and operation of industrial facilities handling extremely large quantities of substances that may be harmful to water (e.g. refineries, metallurgical plants, chemical plants, power plants);
Zone III-A	Designation of new industrial estates; Discharge of waste for recycling purposes; Handling of substances hazardous to water; Exploitation of minerals; Building, extension and operation of facilities for the treatment, storage and deposition of waste, residues and mining refuse; Building, extension and operation of industrial facilities handling extremely large quantities of substances that may be harmful to water (e.g. refineries, metallurgical plants, chemical plants, power plants) Usage of mineral fertilizer and water-soluble pesticides;
Zone III-B	Building, extension and operation of facilities for the treatment, storage and deposition of waste, residues and mining refuse; Building, extension and operation of industrial facilities handling extremely large quantities of substances that may be harmful to water (e.g. refineries, metallurgical plants, chemical plants, power plants);

Table 1. Overview of water protection zones and examples of restriction.
Source: According to Deutscher Verein des Gas- und Wasserfaches e.V., DVGW

2. Barriers and mechanisms for implementing the restrictions

Adequate regulations on water protection strategies do not necessarily guarantee the implementation of the regulations. If properties located in the protection zones are not state-owned, or do not belong to the water supplier, problems may arise with the implementation of restrictions. Also, a lack of geological and hydrological information about the catchment zones or monitoring practices of groundwater quality contribute to inadequate water protection. Land-users' lack of awareness about *do's* and *dont's* in protection zones contributes to groundwater pollution.

Sign for a water protection zone in Germany

Successful water protection strategies are carried out in cooperation with the relevant stakeholders, such as farmers and citizens. Mechanisms like forestation, raising awareness, intensive farmer consultation and disincentive taxes for polluting practices have all been proven to be effective to improve water quality.

In principle, experience has shown that water protection can only succeed WITH agriculture, not AGAINST it. Expertise and the provision of competent advice to farmers is an important element of this approach.

Groundwater quality is prone to contamination by e.g. the intensive cultivation of maize. Pesticides and synthetic fertilisers were applied to the field in this picture.

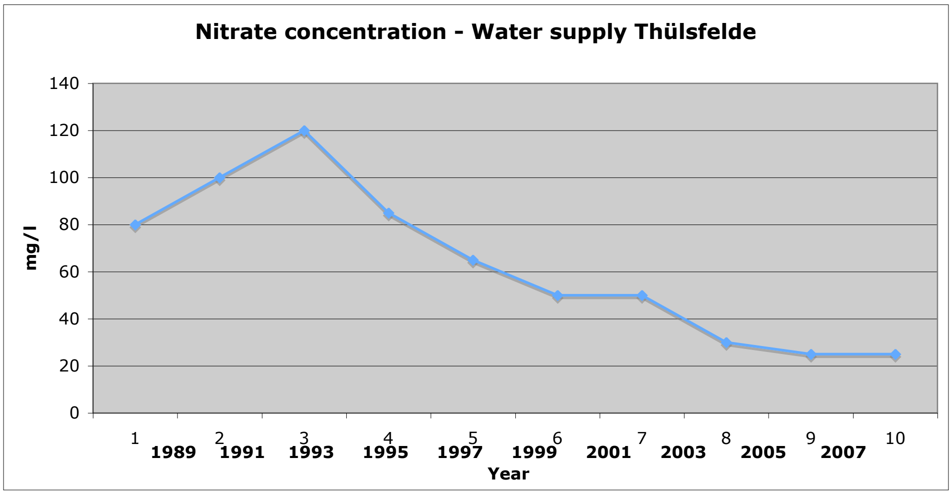
There are some ways of reducing water pollution by adopting modified approaches to farm and land management:

1) Nutrient balance assessment and fertiliser management
2) Crop rotation, appropriate land use, riparian buffer strips
3) Organic farming – restricted amount of livestock per hectare
4) Elimination or restricted usage of synthetic nitrogen fertiliser and pesticides
5) Forestation, termination of grassland ploughing

2.1. Examples of good water protection policy

Since the foundation of the Munich waterworks in Germany around 1900, forest management had been focused on ensuring good water quality. However, in spite of regulations within water protection zones, a slow but constant decrease in water quality had been observed. In 1992, the waterworks decided to cooperate more intensively with farmers. Organic farming was promoted, and farmers were subsidised for not using synthetic fertilisers or pesticides and for working according to the rules of organic farming. Citizens were informed and encouraged to consume organic products grown in the catchment area.
Currently, an area of 4 200 hectare (ha) is managed primarily to maintain water quality: 1 500 ha is forest and an additional area of 2 700 ha is bound to long-term contracts with about 100 local farmers, who have committed to certified ecological/organic agriculture. Due to its strict prevention policy, the Munich water works delivers excellent, completely untreated drinking water to its consumers. For some years, the water has been free from pesticides. Its nitrate concentration remains at the natural level of less than 10mg/l.
Financial experts have calculated that this prevention policy, even counting the consultation and subsidisation of farmers, is less expensive than water treatment.

The following example shows the water supply in Thülsfelde, North-Germany. Due to the intensive livestock-activity in the water catchment area, the nitrate concentration of the shallow groundwater, which was used for the water supply, increasingly exceeded the limit of 50 mg/l. In 1993, the water supplier promoted organic farming in the water catchment areas in close cooperation with the farmers. For marketing the organic-grown products and food processing firms, supermarkets and consumers were mobilised as well. As the graph shows (Graphic 1), the nitrate concentration decreased to the limit of 50mg/l after 6 years of organic farming.



Graph 1: In 1993, the water supplier promoted and realised organic farming in the water catchment areas in close cooperation with the farmers of Thülsfelde, North-Germany.

Source: Data from OOWV, PowerPoint Grundwasserbewirtschaftung, Egon Harms

2.2. Water protection by households and citizens

Communities are also often located in catchment areas from where drinking water is extracted and delivered by a centralised system or individual water sources to the households. Consumers and households can also, undoubtedly, contribute to the contamination of ground and surface waters. For example, car wash runoff flows into rivers, and this oil-contaminated water infiltrates groundwater. Other examples include: excessive pesticides and fertiliser used for gardening; the manure of livestock and human excreta that are not adequately managed; and leftovers from painting or medicination released into the environment or down the toilet. Evidently, water protection starts at a household level and everybody can contribute to keeping water clean. Awareness of water sources and the risks and causes of water pollution can be effective in raising citizens' awareness of the effects of their water handling.

3. WSP related activities and results

WSP related activities	Results / output
Review of regulations or guidelines applying especially to the arrangement of sanitary (water protection) zones of water catchment area(s) and their local implementation, including the defined restriction of human activities in the different zones. If no documents are available, detailed research on the Internet may yield information.	The regulations or guidelines for the arrangement of water protection zones of water sources used for the local water supply are reported and their implementation and the restrictions of activities are assesses.
Identify the location and borders of the several water protection (sanitary) zones. If no information is available, contact relevant experts for a rough estimation.	At least an estimation of the area of the sanitary zones of the water sources used for the water supply is known, and presented in a map.
Assess the potential sources of hazards/water pollutants within the catchment area (3 different water protection zones): • The management of communal wastewater: how is the wastewater of private households and public places managed, stored, treated and disposed or re-used? • The potential sources of other contaminants such as processing plants, fuel stations, laundry or mechanic working places, obsolete or in-use pesticide/fertiliser stockpiles in and around the vicinity of the village. • Interview and/or observe citizens and farmers on the management of animal manure and human excreta . • Interview farmers about the usage of pesticides and fertilisers.	The locations, along with the possible sources of water pollution within the different sanitary zones of drinking water sources, are identified and reported, and a map is included showing these locations. o Agricultural practices and the management of human and animal excreta within the sanitary zones of the catchment area are inventoried and assessed. o The results of the assessment concerning wastewater management from part A are considered for the risk assessment of the catchment areas.
Raising awareness among citizens and communicating with relevant stakeholders about water protection measures and their benefits. • Awareness-raising within the community on available water sources and the benefits of the implementation of protection zones and related restrictions. • Awareness-raising within the community about safe gardening, and the safe management of human and animal excreta. • Provide information to the relevant stakeholders concerning: conditions, risks, challenges and opportunities for the catchment area. • May be a system of farmer consultancy on good agricultural practices and subsidies for good farming practices could be established.	Citizens and relevant stakeholders are aware of the importance of water protection zones, and their related restrictions. o Information is provided to citizens and farmers on safe gardening and agriculture o Information is provided on the safe management of animal and human excreta o So far as it is applicable, a system on farmers' consultancy and the rewarding of good practices within the catchment area is developed.

4. Text sources and further reading

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Module B7

Regulations on Water

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Summary

This module provides information on EU and UN regulations concerning drinking water quality and the human right to have access to clean drinking water and sanitation. A number of international legislative acts and initiatives based on these principles exist. EU legislation is binding for all Member States. The Millennium Development Goals (MDGs) that also concern access to drinking water and sanitation are presented and discussed. People need to know their rights and obligations according to legislation at both a national and international level.

Objectives

The reader should gain insight into the structure of regulations on a national and international level, and gain some knowledge about different directives. The reader should also be informed about the MDGs and the human right to have access to clean drinking water and sanitation.

Keywords and terms

Water Framework Directive, Drinking Water Directive, EU Directives, WHO Guidelines, Protocol on Water and Health, human rights, Millennium Development Goals

Regulations on Water

Introduction

Drinking water is water that is pure enough to be consumed or used with a low risk of immediate or long-term harm. In most developed countries, the water supplied to households, commerce and industry is in accordance with drinking water standards, although only a very small proportion of delivered water is explicitly used for drinking or preparation food.

In many parts of the world, humans do not have adequate access to water of good quality and use sources contaminated with disease vectors, pathogens or unacceptable levels of toxins or suspended solids. Drinking such water or using it in food preparation leads to widespread acute and chronic illnesses and is a major cause of death and misery in many countries. The reduction of waterborne diseases is a major public health goal in developing countries. The quality of drinking water is a powerful environmental determinant of health. Assurance of drinking water safety is fundamental to the prevention and control of waterborne diseases.

1. Water Framework Directive (2000/60/EC)

The European Union (EU) has established a framework for water protection and management in all of its member states. This directive is valid for (European) inland surface waters, groundwater, transitional waters and coastal waters. The Water Framework Directive (WFD) has a number of objectives, such as preventing and reducing pollution, promoting sustainable water usage, environmental protection, improving aquatic ecosystems and mitigating the effects of floods and droughts. Its ultimate objective is to achieve “good ecological and chemical status” in all waters by 2015.

This directive’s management plans for the river basin aim to:

- prevent deterioration, enhance and restore bodies of surface water, achieve a good chemical and ecological state of this water by 2015 at the latest, and reduce pollution from the discharge and emission of hazardous substances.
- protect, enhance and restore the status of all bodies of groundwater, prevent the pollution and deterioration of groundwater, and ensure a balance between groundwater abstraction and replenishment.
- preserve protected areas.

The EU encourages all stakeholders of all Member States to participate in the implementation of this Framework Directive.

2. Drinking Water Directive (98/83/EC)

The European Council Directive deals with the quality of water intended for human consumption. It aims to protect human health by setting health and purity requirements, which must be met in the drinking water provided to consumers. It applies to all water meant for human consumption, except for mineral and table waters, and waters which are used for medicinal products. Mineral, table and medicinal waters are regulated in a separate directive.

Member States’ responsibilities:

- Member States ensure that such drinking water does not contain any concentration of microorganisms, parasites or any other substance that constitutes a potential human health risk and meets the minimum requirements (namely, microbiological and chemical parameters as well as those relating to radioactivity) laid down by the Drinking Water Directive.

- They take any other action necessary to guarantee the health and purity of water intended for human consumption.
- Member States lay down the parametric values corresponding at least to the values set out in the Directive. If parameters are not set out in the Directive, and if they are considered necessary to protect health, minimum values must be set by the Member States themselves.
- The Directive requires Member States to regularly monitor the quality of water intended for human consumption by using the methods of analysis specified in the Directive or equivalent methods. For this purpose, they must determine sampling points and draw up monitoring programmes. Where parametric values are not attained, the Member State concerned ensures that corrective action is taken as quickly as possible in order to restore water quality.
- Regardless of compliance or otherwise with the parametric values, Member States prohibit the distribution of drinking water or restrict its use, and take any action needed where that water constitutes a potential human health hazard. Consumers have to be informed of any such action.
- The Directive presents the Member States a range of exemptions from the parametric values up to a maximum value, in circumstances where:
  - the exemption does not constitute a human health hazard;
  - there is no other reasonable means of maintaining the distribution of drinking water in the area concerned;
  - the exemption lasts for as short a time as possible and does not exceed three years (it is possible to renew the exemption for two further three-year periods).
- From these provisions, Directive Member States may exempt water intended for human consumption from an individual supply providing less than 10 m^3a day as an average, or serving less than 50 persons, unless the water is supplied as part of a commercial or public activity. Whether or not to monitor the quality of those drinking waters has to be decided by the Member States concerned.

EU Member States must ensure that water intended for human consumption does not contain any concentration of micro-organisms, parasites or any other substances which constitute a potential human health risk, and meets the minimum requirements (microbiological and chemical parameters and those relating to radioactivity) as laid down by the Directive.

3. Nitrate Directive (91/676/EEC)

The Nitrate Directive aims to protect waters in Europe by preventing nitrates from agricultural sources from polluting groundwater and surface waters, through the encouragement of good agricultural practices. The Nitrates Directive is an integral part of the EU Water Framework Directive (WFD) and is one of the key instruments for protecting water from agricultural pressures. It was published in 1991.

The Nitrate Directive requests EU Member States to:

- identify surface and ground -water sources affected by pollution, or at risk of pollution, based on procedures and criteria cited in the Directive. These criteria are, specifically, when the concentration of nitrates in ground-water or surface water reaches 50 mg/l, or when surface water is eutrophic, or at risk of being so;
- designate vulnerable zones, which are known areas in their territories which drain into the identified waters. The Nitrates Directive provides a possibility for Member States to be exempted from the requirement to designate vulnerable zones if the action programmes are applied to their entire national territory;
- establish a code of good agricultural practice, to be implemented by farmers on a voluntary basis;
- set up compulsory action programmes, to be implemented by all farmers who work in vulnerable zones;

  These programmes must contain measures aiming to limit the use of mineral and organic fertilisers, which contain nitrogen, as well as manure from livestock

The Nitrate Directive is one of the key instruments for protecting water against agricultural pressures. It regulates the maximal amount of nitrogen fertiliser that can be used, as well as the suitable timeframe of its application on agricultural fields.

4. Directive on the protection of groundwater against pollution and deterioration (2006/118/EC)

This directive is a “daughter directive” of the WFD, and sets out general provisions for the protection and conservation of groundwater. Measures to prevent and control groundwater pollution are stipulated. These include criteria for assessing good groundwater chemical status; for identifying significant and sustained upward trends; and for defining the starting points for trend reversal. Quality standards for nitrates, plant protection products and biocides should be set as community criteria for the assessment of the chemical status of groundwater sources. The nitrate directive requires that consistency be ensured, and this also applies to human and animal waste.

The EC Groundwater Directive sets binding EU-wide limits. The Directive sets "quality standards" of
50 mg/l for nitrate;
0,1 µg/l for individual active pesticide ingredients and biocides and
0,5 µg/l for the overall load of pesticides and biocides.
These levels derive from the EC Drinking Water Directive.

5. Protocol on Water and Health

In the European Part of the UNECE region, an estimated 120 million people do not have access to safe water and adequate sanitation. This results in many cases of water-related diseases such as cholera, dysentery, coli infections, and viral hepatitis A. Safe water and better sanitation could prevent over 30 million cases of water-related disease each year in the region. The 1999 Protocol on Water and Health (PWH) was negotiated with this in mind.

The main aim of the PWH is to protect human health and well-being through better management, involving the protection of water ecosystems and the prevention, control and reduction of water-related diseases. To meet these goals, its parties are required to establish national and local targets for achieving a certain quality of drinking water and discharges, as well as for the performance of water supply and wastewater treatment. Another requirement is the reduction of water-related diseases. Each party is obliged to establish and publish its national targets and respective target dates for each area within two years of becoming a party.
22 countries ratified or accepted the PWH in 1999 and 14 other countries signed it without ratifying. For those that ratified the PWH, the Protocol is binding and obligations should be fulfilled.

5.1. Guide to Public Participation under the Protocol on Water and Health

The Protocol on Water and Health puts great emphasis on access to information and public participation, recognizing public involvement as vital for its successful implementation. In the experience of the different Parties implementing the Protocol, ensuring public participation was usually challenging. This was mostly because the public did not fully understand the process. The Guide to Public Participation under the Protocol on Water and Health is based on experience and good practices in the pan-European region. It clarifies the obligations relating to public participation, and presents case studies from different Parties, as well as other regional instruments. It aims to help improve the planning and carrying out of the public participation process under the Protocol, as well as encourage the taking into account of its outcomes, an important next step being the practical action that will follow (UNECE 2013).
The guide addresses “The Cornerstones of public participation”; Public Participation under the Protocol on Water and Health - General aspects; and Public Participation under specific provisions of the Protocol. It provides several tools for identifying, notifying, informing, consulting and taking into due account the various stakeholders.

6. Human right access to safe drinking water and sanitation

Human rights are the basic rights and freedoms, to which all humans are entitled, and which are essential for human existence; access to water and sanitation are among them. This fact is now officially recognised by the UN Human Rights Council. In the past, human rights discussions have largely ignored water and especially sanitation. But after years of fierce debate, the Human Rights Council adopted the resolution (A/HRC/15/L.14) by consensus on 30th September 2010, affirming that access to safe drinking water and sanitation is a human right.

In order to realise the human right to have access to safe drinking water and sanitation, there are certain criteria to be met:

- **availability**: the UN calls for at least 50 l/p/d of safe water to meet personal needs;
- **accessibility**: services must be available within or in the immediate vicinity of each household, as well as schools, workplaces, health-care settings and public places. Access must be ensured in a sustainable manner;
- **quality/safety**: the human right to water and sanitation means that water and sanitation have to be safe for human health;
- **affordability**: a household’s total expenses for water and sanitation should not be more than 3% (recommendation of the UNDP) of the average income of a household in their geographical area;
- **acceptability**: the technologies offered to the population and ethnic/religious groups have to be culturally acceptable and not contradict their beliefs and values;
- **non-discrimination**: no group of the population should be discriminated against on the basis of origin, religion, gender, age, health status, geographical location or the level of urbanisation of the region where they live;
- **participation**: the entire population has the right to participate in decision-making connected to water and sanitation services; and consumers have the right to information about the quality of services, health and financial effects, etc.;

- **accountability**: water and sanitation suppliers, as well as the respective national and local authorities, must report on their expenses and the effectiveness and safety of their services to tax payers and the general population;
- **impact**: the quality of water and sanitation services directly affects the quality of life and health of the population, especially children; furthermore, it is decisive for the attractiveness of the business environment;
- **sustainability**: water and sanitation services have to be provided to the population and businesses without compromising the prospect of future generations to meet their needs safely; the needs of all living creatures and nature as a whole must be respected.

Mrs.Catarina de Albuquerque is the first UN Special Rapporteur (independent expert) on the right to safe drinking water and sanitation.
Source: http://acnudh.org/en/2012/02/un-expert-on-right-to-safe-drinking-water-and-sanitation-in-first-mission-to-uruguay/

The Special Rapporteur of the UN emphasises the need to use practical solutions when implementing the human right to safe water and sanitation. Further, the resolution calls on States to ensure adequate financing for the sustainable delivery of water and sanitation services.

7. World Health Organisation – Guidelines for Drinking-water Quality

The primary purpose of the guidelines on the quality of drinking water is the protection of public health (WHO 2013).The Guidelines are intended to support the development and implementation of risk management strategies that will ensure the safety of drinking water supplies, through the control of hazardous constituents in water. These strategies may include the development of national or regional standards from the scientific bases provided in the Guidelines. The Guidelines outline the reasonable minimum requirements for safe practice to protect the health of consumers and/or derive numerical "guideline values" for constituents of water or indicators of water quality. In order to define mandatory limits, it is preferable to consider the guidelines in the context of local or national environmental and social, economic and cultural conditions. (WHO 2013)

The guidelines address health-based targets, water safety pans, surveillance, the application of the guidelines in specific circumstances, microbial aspects, chemical aspects, and radiological and acceptability aspects. Several factsheets are provided. The WHO guidelines do not target environmental factors.

8. Millennium Development Goals (MDGs)

In 2002, at the World Summit on Sustainability in Johannesburg, the United Nations adopted 8MDGs. The MDGs, a series of targets for reducing social and economic ills by 2015, include the goals of halving the proportion of people who cannot reach or afford improved drinking water and halving the number who do not have basic sanitation. The term 'access to "improved" water and sanitation' is defined by the UN and does not explicitly mention that the quality of the water and sanitation systems is safe.

Worldwide, some 2,1 billion people have gained access to improved drinking water since 1990. Yet 884 million people still do not have access to improved drinking water. Moreover, in the period of 1990 – 2011, the coverage of drinking water in the rural areas of Caucasus and Central Asia was decreased. Since 1990, even more people living in rural regions use unsafe surface water for drinking (see the table below).

Globally, since 1990, almost 1,9 billion people have gained access to basic sanitation services, such as toilets or latrines. The world remains, however, off-track to meet the MDG sanitation target, which is to reduce the proportion of people without access from 51% in 1990, to 25% by 2015.

Trends of rural drinking water coverage by Caucasus and Central Asia, in the period 1990-2011		
	1990	**2011**
Piped on premises	31%	29%
Other improved	50%	50%
Unimproved	12%	11%
Surface water	7%	10%

Source: Progress on Sanitation and Drinking Water, Update 2013
World Health Organisation and UNICEF, 2013

Although progress was made primarily in rural areas, those areas remain disadvantaged. Globally, eight in ten people without access to an improved drinking water source live in rural areas. For sanitation, the 2015 target appears to be out of reach, since half the population of developing regions lacks basic sanitation.

Kofi Annan, UN Secretary General at Earth Summit, 2002
Source:
http://www2.lse.ac.uk/newsAndMedia/news/archives/2002/Kofi_Annan_at_LSE.aspx

Jan Prank, Secretary-General's Special Envoy for the World Summit on Sustainable Development (WSSD)
Source:
http://berkeley.edu/news/media/releases/2002/08/30_summit.html, Yogi Hendlin photo

At the current rate of progress, the world will not achieve the target of halving the proportion of people without access to basic sanitation, such as toilets or latrines. In 2008, an estimated 2,6 billion people around the world lacked access to improved sanitation. If the trend continues, that number will grow to 2,7 billion by 2015. Wide disparities also exist by region, with sub-Saharan Africa and South Asia continuing to lag behind. Recent data shows 69 per cent and 64 per cent of their populations still lack access to improved sanitation, respectively. The gap between rural and urban areas remains huge, especially in South Asia, sub-Saharan Africa and Oceania.
In 2011, the process of formulating proposals for post-2015 targets and corresponding indicators for water, sanitation and hygiene (WASH) started, in the context of possible goals.

9. WSSP related activities and results

WSSP related activities	Results/ output
• Investigate which regulations, laws, decrees, guidelines or protocols are relevant for communal water and wastewater management and sanitary facilities; which are actively implemented and which are neglected? • Did your country sign or ratify the Protocol on Water and Health? If yes, what does it mean for the community?	o List of the regulatory requirements and guidelines relevant for the operation, maintenance and surveillance of the local water supply and sanitary facilities. o Report on which requirements have been fulfilled or not. If not, the causes are mentioned
• Are the national regulations, laws etc. applicable for water supplies providing less than 10 m^3 a day on average, or serving fewer than 50 persons (very small scale), or for non-piped supplies? • If not, what is the percentage of citizens left out of the regulatory requirements on water intended for human consumption (drinking water)?	o Overview of regulatory requirements applicable for very small-scale water supplies, showing which are implemented or left out. o If applicable, the percentage of citizens provided with non-regular monitored water quality is identified.
• Investigate if the human rights on access to safe water and sanitation are fulfilled for all citizens. If not, what is the reason?	o Inventory of persons within the community not enjoying the human right of access to safe water and sanitation is made and reported. o The criteria not met are identified.
• Investigate if the public participates in making decision on water and sanitation-related issues. Does the public have access to adequate information?	o The process of how the community is involved in decision-making and how the citizens are informed is defined.

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Module B8

Rainwater Management

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Summary

Rainwater management is an important part of the infrastructural management in a community. Rainwater collection and discharge can be managed together with wastewater in the centralized combined sewer system, which has been the common approach during the last centuries. But the combined sewer systems are not only more expensive but pose also a risk to the environment and water resources in case of high rainfall events. Decentralised rainwater concepts have therefore been applied more and more, especially in rural and semi urban areas where there is enough space for rainwater retention and local infiltration. There are different alternative options for rainwater management available, which are explained.

Rainwater harvesting provides an independent water supply and in some countries is often used to supplement the main water supply. The quality of collected rainwater is generally better than that of surface water and locally sometimes even better than groundwater. There are a number of possibilities how to collect and treat rainwater and how to use rainwater in the households and in public areas.

Objectives

The reader should understand the benefits of decentralised rainwater management and rainwater harvesting and which technologies exist to manage the rainwater on public level as well as on household level. The benefits of rainwater harvesting are explained in detail.

Keywords and terms

Rainwater, rainwater management, evaporation, infiltration, rainwater harvesting, discharge

Rainwater Management

Introduction

Rain is liquid water in the form of drops that have condensed from atmospheric water vapor and then precipitated. Rainwater is a major component of the water cycle. People have collected rainwater for their use since ancient times. It is known that the farming communities in Baluchistan (in present-day Pakistan, Afghanistan and Iran), and Kutch (in present-day India) have collected rainwater for irrigation purposes around 3rd C BC. During the Chola period, the Vīrānam tank was built (1011 to 1037 CE) in ancient Tamil Nadu (India) to store water for drinking and irrigation purposes. The tank is 16 km long and has a storage capacity of 41,500,000 m^3. Ruins of other ancient civilizations also witness the usage of rainwater as a water source.

In the middle of the 19th century and with the growing density in populated areas and the large-scale sealing of the soil, urban drainage became a basic problem because of hygienic aspects and later for the benefit of the needs of the citizens: wastewater and rainwater had to be drained as quickly and invisibly as possible. The technical solution, that is a centralised sewerage, resulted in the combined drainage of rainwater and wastewater.

The total amount of collected water was then directed into water basins. However, due to the rapid growth of the population, the increase of traffic and other sources of pollution more and more negative impacts became noticeable, which made measures for the protection of water necessary.

Today both urban wastewater and rainwater have to be managed in such a way that it will form no health risk or damage of the welfare of the citizens.

This is guaranteed through so-called conventional drainage methods, which however involve great financial and technical efforts (construction and maintenance of sewer systems, rainwater retention basins, rainwater overflow tanks and sewage treatment plants). Because of the enormous increase of impervious surfaces in cities as well as in the countryside (so called soil sealing), the rainwater drainage forced the sewer networks at their limits and heir capacity. The treatment performance of the systems is limited and the environment is polluted in case of a lot of rainfall/precipitation at different levels: the aquatic ecology is affected frequently, simultaneous reductions can cause flood events, and the quick run-off of rainwater has a negative effect on the microclimate of the water resources. In response, for the last decades, the professionals have developed alternative approaches and methods: decentralised rainwater management concepts, which bring the rainwater back into the natural water cycle onsite and are cost effective as well.

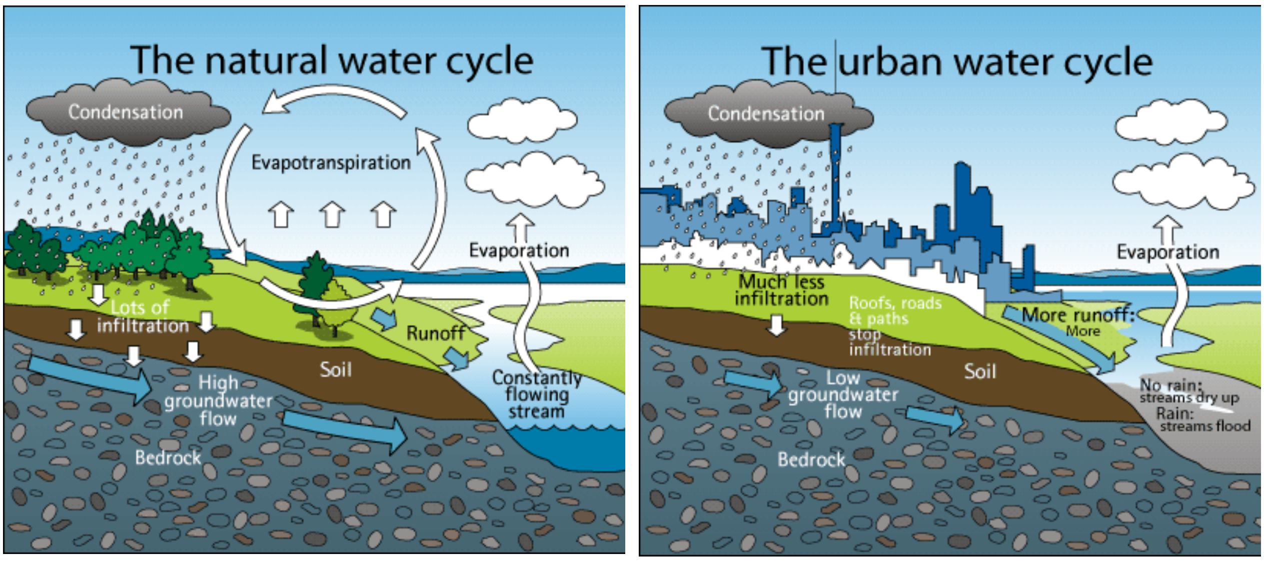

Figure 1. the natural and the urban water cycle (http://www.fo.ucf.edu/stormwater/)

1. Set of issues

Water is in a constant cycle of evaporation, condensation, precipitation and re-evaporation. Rainwater can either evaporate, infiltrate or drain. In its natural environment, vegetated soil absorbs two-third of the rainwater which has penetrated into the topsoil and plants and then will evaporate again (transpiration). About one-fourth gets into the soil through infiltration, and purifies naturally and contributes to the enrichment of the groundwater. It can then be drawn from wells as drinking water or it runs slowly into springs, rivers or lakes. Only a small amount of rainwater flows on the surface (surface runoff).

The average percentage of such processes based on the total annual precipitation in a certain area is described as water balance or water budget. Depending on climate, soil, underground and vegetation it can vary from location to location.

The water balance of natural areas (grassland or forests) can be regarded as ideal. In populated areas in a country the natural environment has been severely affected by continuous development, construction and soil sealing. In this respect, rainwater cannot infiltrate anymore and therefore water, which has to evaporate will be a lot less. The majority of water runs off at the surface.

This causes numerous problems:

- The decreased recharge of groundwater, due to soil sealing, can lead to falling groundwater levels and low water marks of streams, which can have a long-term effect on the drinking water supply.
- The unused storage effect and the direct drainage of rainwater into waters can reinforce floods.
- The natural ecosystem gets damaged (causes: sporadic, jerky and partly polluted rainwater drainage into watercourses; alteration of soils due to air and water shortages; reduction of biodiversity).
- The microclimate changes: humidity declines, temperatures rise, heavy rainfalls and heat waves occur more frequently.
- If the surface runoff flows directly into the sewer system it results into an increased volume and pollutant load in the sewer systems and in the wastewater treatment plants

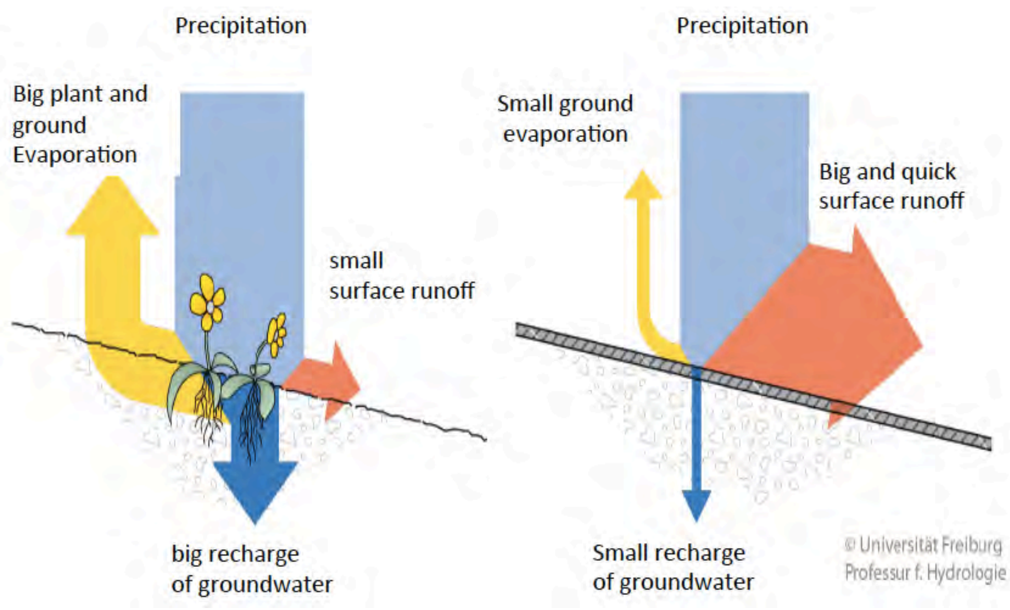

Figure 2. Results of soil sealing on surface runoff in a scheme (Universität Freiburg)

As seen in figures 1 and 2, rainwater management which is close to nature can help impair the natural balance of the water cycle as little as possible.

2. Objectives for a sustainable rainwater management

The main objective of rainwater management is the protection and improvement of ground and surface water, especially regarding the protection of existing and future drinking water resources.

Until a few years ago, urban drainage comprised of fast and complete rainwater drainage in the combined sewer system. Due to the increasing soil sealing due to he construction of roads and buildings in urban areas, the natural water cycle is profoundly disrupted. To prevent this, it is important to “keep the impact on the natural water budget by human activities and soil sealing as low as possible in the frame of technical, environmental and economical feasibility“.

It is necessary to develop environmental friendly systems, which support the natural water cycle and provide a similar advantage like the sewer system. Alternative rainwater management solutions should not lead to a step back compared to the conventional methods.

The objectives of alternative rainwater management systems are as follows:

- Groundwater protection
- Increased groundwater recharge
- Evaporation support
- Decreased pollution of water bodies
- Increase of low-water discharges, which have favourable effects on the aquatic ecosystems impact and their riparian areas
- Avoiding the overloads of sewer networks
- Maintaining and possible upgrading of safety reserves in sewer systems
- Savings in new buildings and renovation of the sewerage
- Savings in construction of rainwater retention volumes

3. Sustainable and natural concepts

In the modern rainwater management, surface runoffs should be reduced and the hydraulic load in the sewer should be decreased. This is mainly done by minimizing soil sealing in new populated areas the unsealing of existing areas and decentralized rainwater management – in this respect rainwater should be managed locally and brought back into the water cycle, or to be managed in an other way. Prerequisite is the separation of sewage and rainwater drainage at the source. Sustainable rainwater management concepts are always dependent on local conditions such as rainfall patterns, water permeability of the soil, existing buildings, existing drainage systems (combined or separate systems) and so on.

In general rainwater is clean, but if it flows off on sealed surfaces it becomes polluted and turns into wastewater. Most land uses (municipal or district roads, roofs, parking spaces) allow a simple infiltration of rainwater, as it is not much polluted and the soil is filtering and thus cleaning the water to protect the groundwater. Highly polluted rainwater should be pre-treated (e.g. the spill of a petrol station) and then infiltrated or it has to be conveyed into the sewer system for further treatment.

There are several possibilities for rainwater management:

- Infiltration into the soil
- Retention, storage and evaporation
- Rainwater harvesting
- Centralized containment for throttled discharge into surface water or sewer

Rainwater management concepts provide combined solutions of the above listed options. Due to legal guidelines and environmental aspects, the following priority levels are defined:

1) Avoidance of runoff and drainage of rainwater
2) Infiltration to the soil wherever possible
3) Retention and storage
4) Discharge

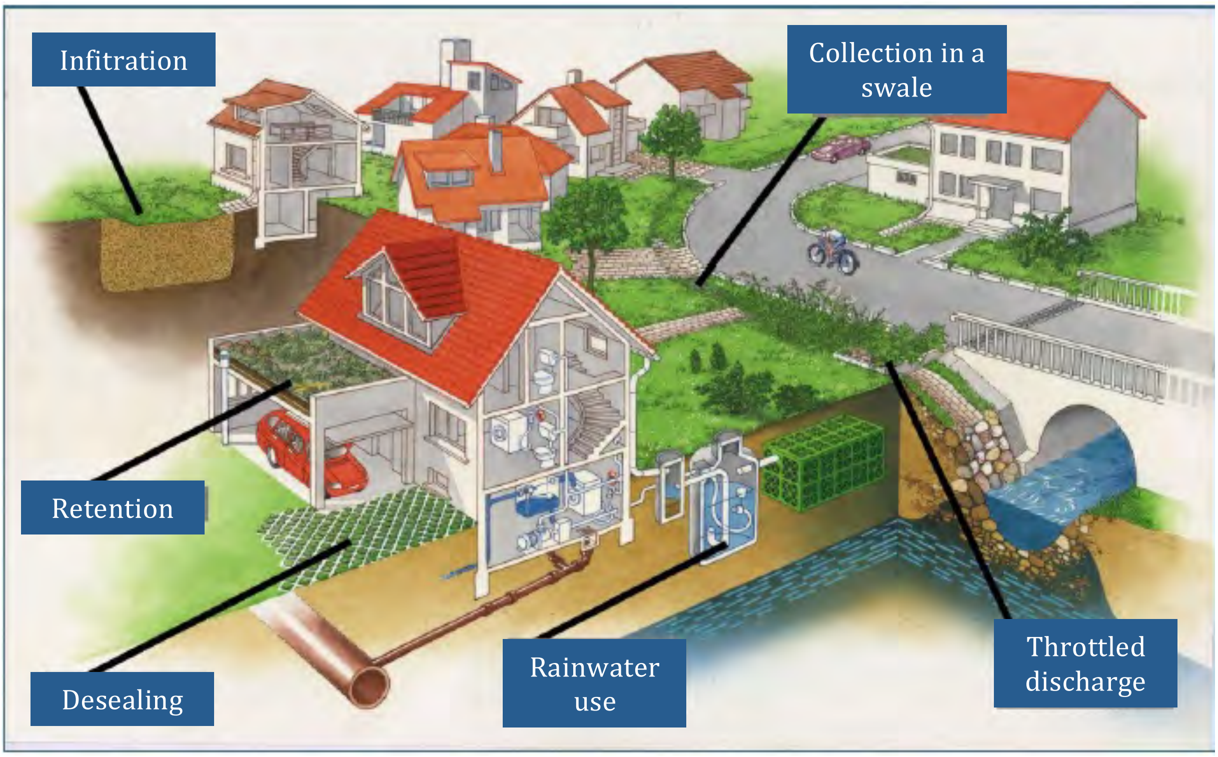

Figure 3: Essential elements of natural rainwater management (http://www.lfu.bayern.de/umweltwissen/doc/uw_88_umgang_mit_regenwasser.pdf)

Avoidance of surface runoff

In populated areas, runoff and drainage of rainwater should be prevented as much as possible. Practically this means on the one hand to check if a full sealing of the soil for construction project is necessary and on the other hand whether existing sealed areas can be unsealed.

3.1. Different types of infiltration

Infiltration to the soil

If the sealing of certain areas is unavoidable, it is better to infiltrate the rainwater. This could be done locally, as close as possible to the source, through e.g. adjacent greenery, trees, bushes or flowerbeds, where the rainwater can infiltrate and evaporate.

Examples of rainwater infiltration

Surfaces where sealing is unavoidable should be designed as permeable as possible, especially in areas with low traffic (service roads, paths, car-parks, land and garage driveways, yards and patio areas), water permeable surfaces can be used as a way of rainwater drainage. Several applications are available: Gravel, gravel cover, grass pavers, paving with joints or perforated portion, water permeable asphalt, see photos.

Example of rainwater infiltration in a lawn

Swale infiltration

In contrast to direct infiltration, rainwater can be contained in swales, often grassy, where it is stored before infiltrating or evaporating. The required area for the swale infiltration is 15 to 20 % of the connected sealed surface area. Due to the retention effect large amounts of precipitation can be absorbed. The depth of the swale should be a maximum of 50 cm. This insures that even after a stronger or long lasting rain event the water infiltrates completely within a maximum of two days. To make the swales visually inconspicuous into the landscape, a swale depth of 15 cm is recommended.

Different swale infiltration systems
Photo´s: Münchener Stadtentwässerung

Rigole infiltration

Rigole infiltration or so called French drain infiltration are man-made underground infiltration systems which catch the rainwater and gradually seeps into the ground, and is especially used for low-drained soil conditions. A rigole Infiltration consists of gravel or a perforated pipe string where rainwater is supplied through pipes above and below ground. Rigole systems, which are made of plastic elements have predominantly horizontal expansion and have about three times larger storage volume. Because of the lack of filtering of the rainwater through the topsoil prior treatment by swale infiltration, sedimentation tanks, soil filter or wells is needed.

Rigole infiltration system in construction
Photo: Arnd Wendland

Soakaway infiltration

The soakaways are prefabricated components like a shaft and made out of concrete or plastic without a bottom plate and with water permeable walls. Rainwater is directed to these soakaways, which collect the water and later discharged into the subsoil. The soakaways have a large volume, but need a little surface area. As it is a point infiltration source and there is usually no additional soil treatment, they provide the least groundwater protection. Therefore the soakaway infiltration should only be applied when there are grounded reasons for excluding the other specified types of infiltration. The soakaway infiltration is not allowed to be used in drinking water catchment areas, but only for areas where the groundwater has a large depth.

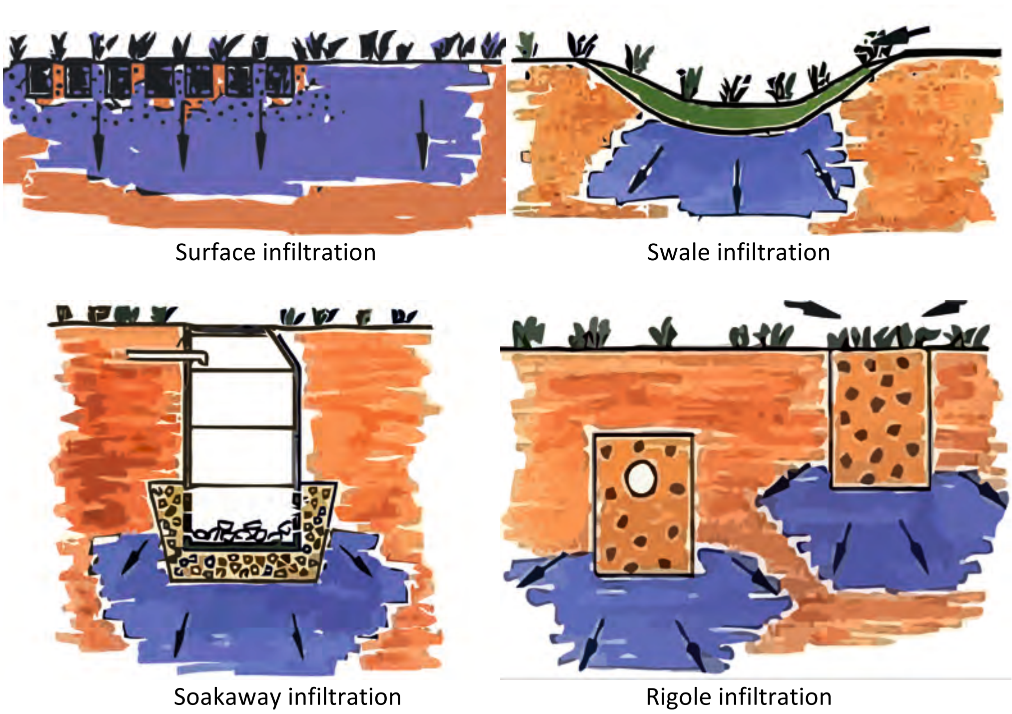

Figure 4. Different types of rainwater infiltration:
(http://www.lfu.bayern.de/wasser/niederschlagswasser_umgang/versickerung/index.htm)

3.2. Retention

In the decentralized concepts of retention, there is a basic distinction between the water retention for evaporation, infiltration or usage, and the water retention prior to the discharge into watercourses or sewer systems. The retention might be realised by green roofs, retention reservoirs, and cisterns or ponds onsite.

Greening the roofs

The green roofs provide an important contribution to rainwater management. They bring back a part of nature to the urban environment, minimize the drainage peaks of rainwater due to the water intake capacity and contribute to the balanced microclimate. 60 to 90% of the rainwater can be retained due to roof greening.

We can distinguish two types of green roofs: extensive and intensive. Extensive green roofs are close to nature-based forms of vegetation, which can stand severe droughts and no special care is needed (different types of grass, moss, wild herbs and low growing perennials). They are suitable both for flat roofs and pitch roofs higher than <30°. Intensive green roofs are green spaces on flat roofs with trees suitable for walking, as well as ornamental plants, sometimes even artificial ponds with soil filter plants. The green roofs can be described as "Roof gardens" in literature and can be seen as complete garden landscapes. Due to their weight those intensive green roofs require a high carrying capacity of the roof construction, because of this they are not suitable for reinstallation.

Due to the large storage volume of the substrate layer the retention of the rainwater occurs. The water discharge is delayed and minimized due to transpiration (evaporation through plants) and evaporation (evaporation from soil surface). As a result of these processes, green roofs have remarkable moisture and a temperature regulating function. Especially, in densely populated urban areas where the consequences of strong sealing are clearly noticeable, green roofs can also help to improve the air quality.

Example of an extensive green roof of a public building

The advantages of green roofs include:

- Longer life time of the roof sealing
- Improved thermal insulation in winter
- Cooling effect in summer
- Improving of the microclimate through evaporation and transpiration
- Increased noise protection
- Attractive/Aesthetic effects by improving the working and living environment for the people
- Rainwater retention
- Minimizing drainage peaks of rainwater
- Dust suppression
- Filtering of pollutants in rainwater discharge
- Reduction of electro-smog
- Lower sewage charges

- Save money on roof repairs
- Flood mitigation
- Savings in the construction of wastewater treatment plants

Therefore green roofs are strongly recommended in terms of ecological, technical, drainage and economical point of view.

Rainwater retention space

If there is no direct infiltration, rainwater can be directed through channels or swales into retention areas, from where throttled discharge takes place into the watercourses. In the natural rainwater management open basins with or without infiltration are implicit and they have a specific storage volume. Depending on their location in rural or urban areas, these might be ponds with sealing or without, artificial watercourses, up to permanent retention basins.

Simple pond scheme for rainwater retention (http://www.lfu.bayern.de/umweltwissen/doc/uw_88_umgang_mit_regenwasser.pdf)

Instead of discharging rainwater of their property into the public sewer system, the population should decide for a pond as a refreshing landscape element if possible.

Artificial retention pond

Artificial water course/trench for rainwater retention

3.3. Discharge into surface waters

There are some areas where no infiltration is possible and rainwater is directly throttled or discharged into surface water. In this case medial retention areas are of great importance, because rainwater discharge can cause considerable damage in hydraulic and environmental terms. At any rate surface water has to be

maintained. Whether to have pre-treatment of the rainwater discharge or not, and can be decided depending on the origin area of the rainwater discharge and the sensitivity of the water basin in which it will be discharged.
When it rains, the rainwater from certain areas, such as roof and terrace surfaces or in non busy traffic areas (walking and biking trails), are not highly polluted and do not pose major problems.

Concerning busy roads, metal roofs, car or truck parking places, especially in industrial and commercial areas, rainwater has to be pre-treated or directed to wastewater treatment plants. Depending on the type of treatment, the following methods can be used:

- Sedimentation, e.g. in septic tank or sealed ponds
- Filtering, e.g. through soil passages
- Chemical – physical treatment processes in special treatment systems for rainwater treatment

4. Rainwater harvesting

Water consumption of people varies between 25 to 500 litres per day, depending on water availability and the state of the water supply systems in each country. In the European countries, the consumption is between 120-270 litres per day, mostly pure drinking water. However, for 30-50% water usage, the use of rainwater can be applied instead and is for free.
Rainwater is free of charge and there is no need to treat it or transport it over long distances.

The possibilities for using rainwater as service water are diverse:

a) Domestic use
- Toilet flushing
- Washing machine
- Garden irrigation
- Cleaning purposes

b) In the public sector
- Toilet flushing in schools
- Community centres and other public buildings
- Irrigation of sports fields , gardens and green spaces
- Water supply from wells
- Sewer cleaning

c) In the commercial sector
- Process water, (e.g. water for cooling, raw water)
- Irrigation
- Replenishing of cooling water
- Water for fire fighting
- Toilet flushing
- Cleaning purposes
- etc.

Graph: www.regenwassernutzen.eu

The main benefits of rainwater harvesting are:

- Saving of drinking water as a resource
- Retention of rainwater
- Reduction of rainwater drainage

The usage of rainwater in rainy areas does not change the balance of dry areas in remote places and is not an advantage for them. Nevertheless, rainwater usage is considered as an environmental protection measure as it decreases the local water consumption and the groundwater extraction.

Further positive side effects of rainwater harvesting are:

- No urine deposits in the toilet
- Soft rain water means better washing performance which requires smaller amounts of detergents
- No lime in the washing machine (as rainwater does not contain any lime)
- Optimal for irrigating plants as they better absorb minerals
- Central retention basins can be smaller in design
- No burden of sewer system, wastewater treatment plants and rivers because of reduction and delay of peak flows during heavy rainfall
- Cost savings in drinking water and wastewater fees
- Contribution to flood protection if additional retention volume is available

Rainwater collected from the roof area for the purposes of usage should be collected by a rainwater collector, purified by filters and collected in underground or above ground rainwater reservoirs, e.g. such as rain columns, rain cisterns or rain barrels. However, there are some exceptions – extremely dirty roofs, as well as uncoated copper, zinc and lead roofs are not suitable due to their potential source of pollution. The above ground tanks are mostly used for garden irrigation, which contributes to an increased evaporation and infiltration of rainwater. The underground cisterns usually have a much larger storage and are used for public and commercial sectors but also for the washing machine and toilet flushing in the private sector.

The quality of rainwater is still under discussion, although numerous studies have proved the safety of rainwater collecting. A properly built rainwater system allows unrestricted use of the collected rainwater.

The following factors must be taken into consideration:

- Suitable and well-maintained roof surfaces and gutters without any specific dirt
- Introduction of a filtering system between the collecting area and rainwater storage
- Sedimentation in the storage tank through a non turbulent inflow
- No light should enter the storage tank
- Protecting the overflow of the storage tank against backflow of wastewater from the sewer
- Outlet of rainwater above the bottom of the rainwater storage tank
- Regular inspection and maintenance of the rainwater harvesting system

Under these circumstances, rainwater can be stored for a longer period without any concerns and can be used for each of the above-mentioned factors, because it will meet the recommended requirements of the microbiological quality for bating water of the EU Directive for Bathing Water.

Different types of rainwater storage tanks for household use

The long-term usage of rainwater can reduce the consumption of household drinking water usage by 30-50%, which in fact means a significant reduction of drinking water costs because the drinking water will be replaced by rainwater for free. However, the use of rainwater is not always economical, because the energy consumption of the pump is always larger than the energy required for the provision of drinking water from the public network.

Each individual case should be estimated considering individual needs, which include: investment costs and subsidies, operational costs, the amount of drinking water and wastewater fees.

5. WSSP related activities and results

WSSP related activities	Results/ output
• Identify the amount of precipitation there in the region. • Identify how the rainwater of public areas is managed and how? Is there a problem with the rainy weather (e.g. flooding)? • Identify if the groundwater level is affected by an unbalanced water abstraction and the renewal of the abstracted groundwater. • Find out how rainwater can be collected from streets, roofs of public buildings and sealed soil in the community! • Discussion with stakeholders about benefits and barriers to rainwater management and collecting. • Identify to what extent the population collect and use rainwater. • Identify options under which conditions it is feasible and beneficial to collect and use rainwater in the community. • Identify the main barriers not to collect rainwater?	Report on benefits and barriers of rainwater harvesting o Draft feasibility study of rainwater harvesting in public places o Action plan for increased collection and usage of rainwater in the community o If applicable, action plan on increasing the water retention and/or infiltration into the soil

Text sources and further reading

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