# Module 8

# Sanitation and Wastewater Treatment

## Summary

Water consumption and usage create wastewater. Unregulated run-off 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. 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 sanitation, including the safe re-use of wastewater in agriculture.,.

## 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 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, re-use

## Preparation/material

| Materials | Preparation |
|---|---|
| Questionnaire | Making copies, eventual revising and adding more relevant questions |
| Excursion to wastewater treatment plant | |
| Paper, pencils | |

# 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. 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 Bulgaria, 1.8 Million people live in settlements where there is not any wastewater collection or treatment.

## 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 11, 12, and 14.

### 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 reuse of the different wastewater streams.

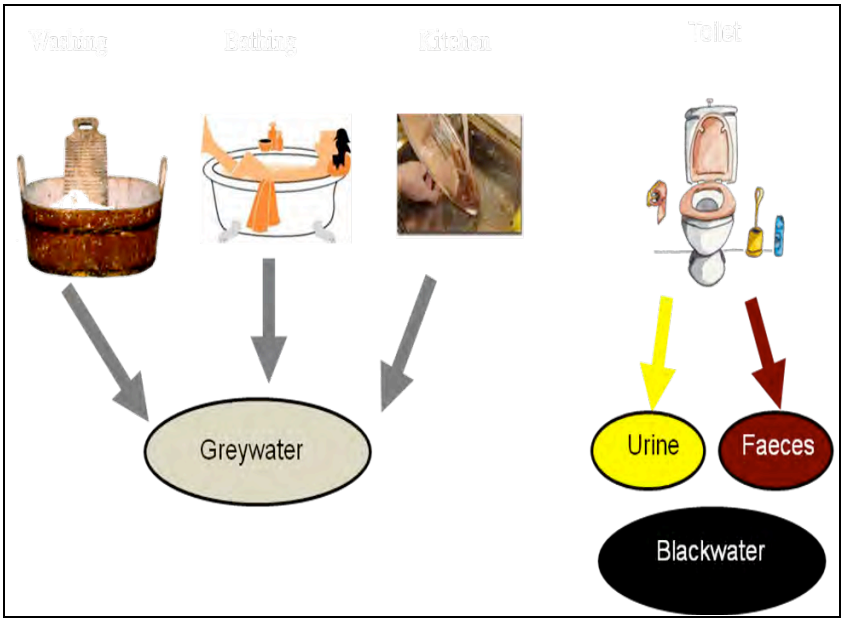


*Table 1: Overview of the compounds of greywater and blackwater*

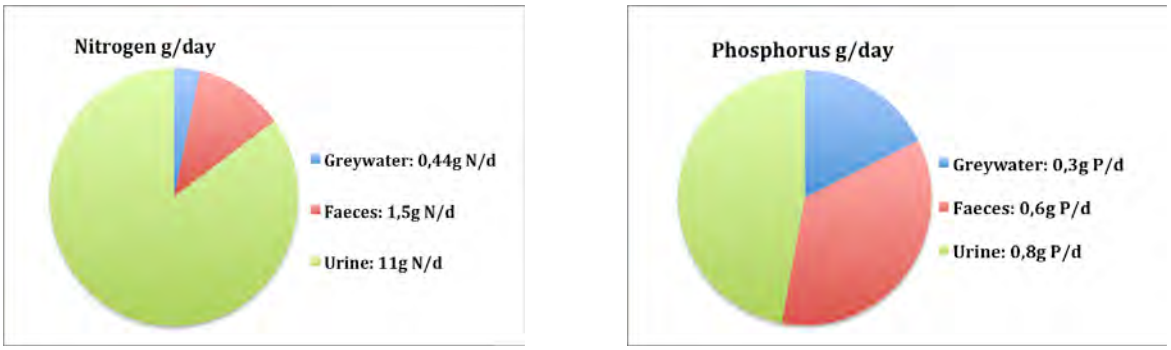


*Table 2. Overview of the content of nitrogen (N) and phosphorus (P) in urine and faeces, excreted per person and per day, and the content of N and P in greywater per person and per day.*
*Source: According data from WHO 2006*

## 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 flow if possible. The quality and quantity arising from the different industrial sources can vary significantly.

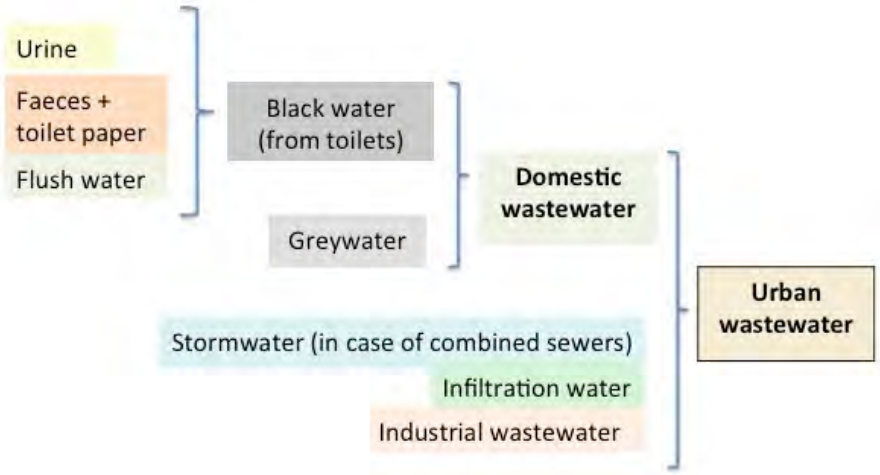


*Table 3: Overview of the different types of wastewater*

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. reusing 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 functionality and the ease with which 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 towards 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 reinvestments in the system.
5. Socio-cultural and institutional aspects: the criteria in this category evaluate the socio-cultural acceptance and appropriateness 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 1 l per flush-, are vacuum systems which you might know from the airplane or a modern train. You might also know the traditional pit latrines, which are commonly located far away in the garden, because they smell bad, are often very unhygienic and pollute the groundwater.
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 in 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 reused in agriculture. In all the presented toilet systems, spreading of pathogens and nutrients in the environment should be avoided.

*Urine diverting toilet with water flush*

*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.

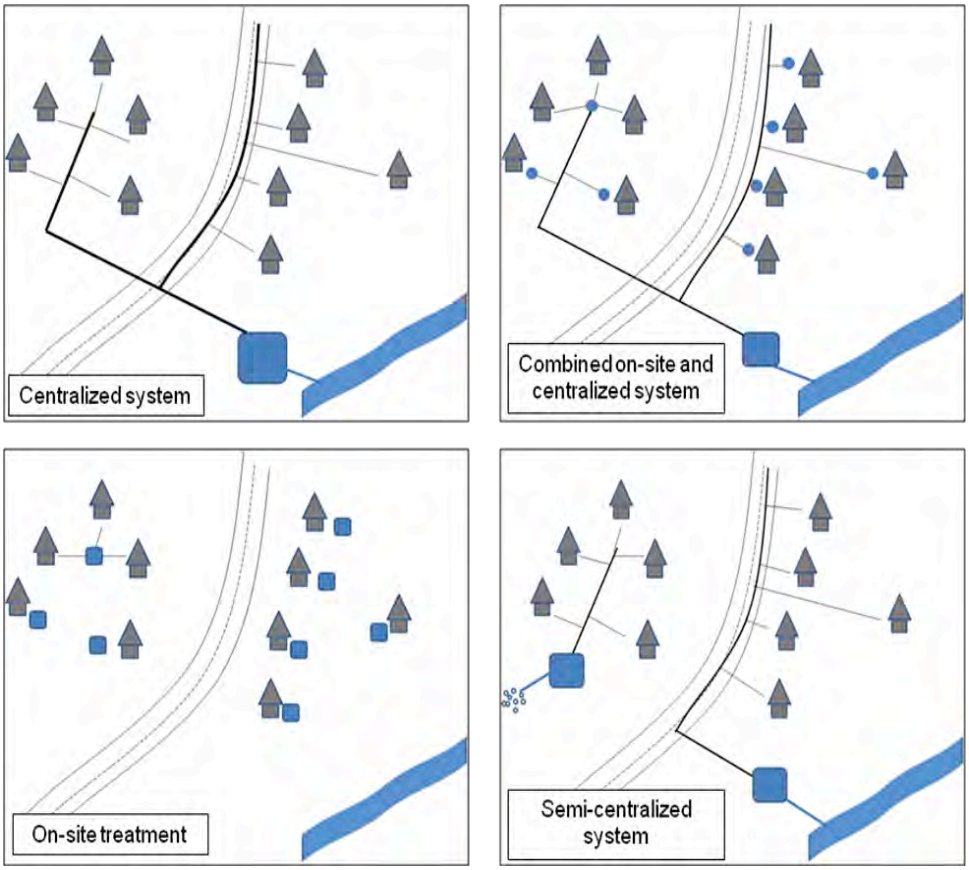


*Table 5: Different wastewater collection systems*

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 in regards to more effective control of quality standards and plant operation procedures.
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.

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

## 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. That is why many people do not empty their septic tank in reality, 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, but 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 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 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 into a stream, river, bay, lagoon or wetland, or it can be used for irrigation in agriculture, of 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*

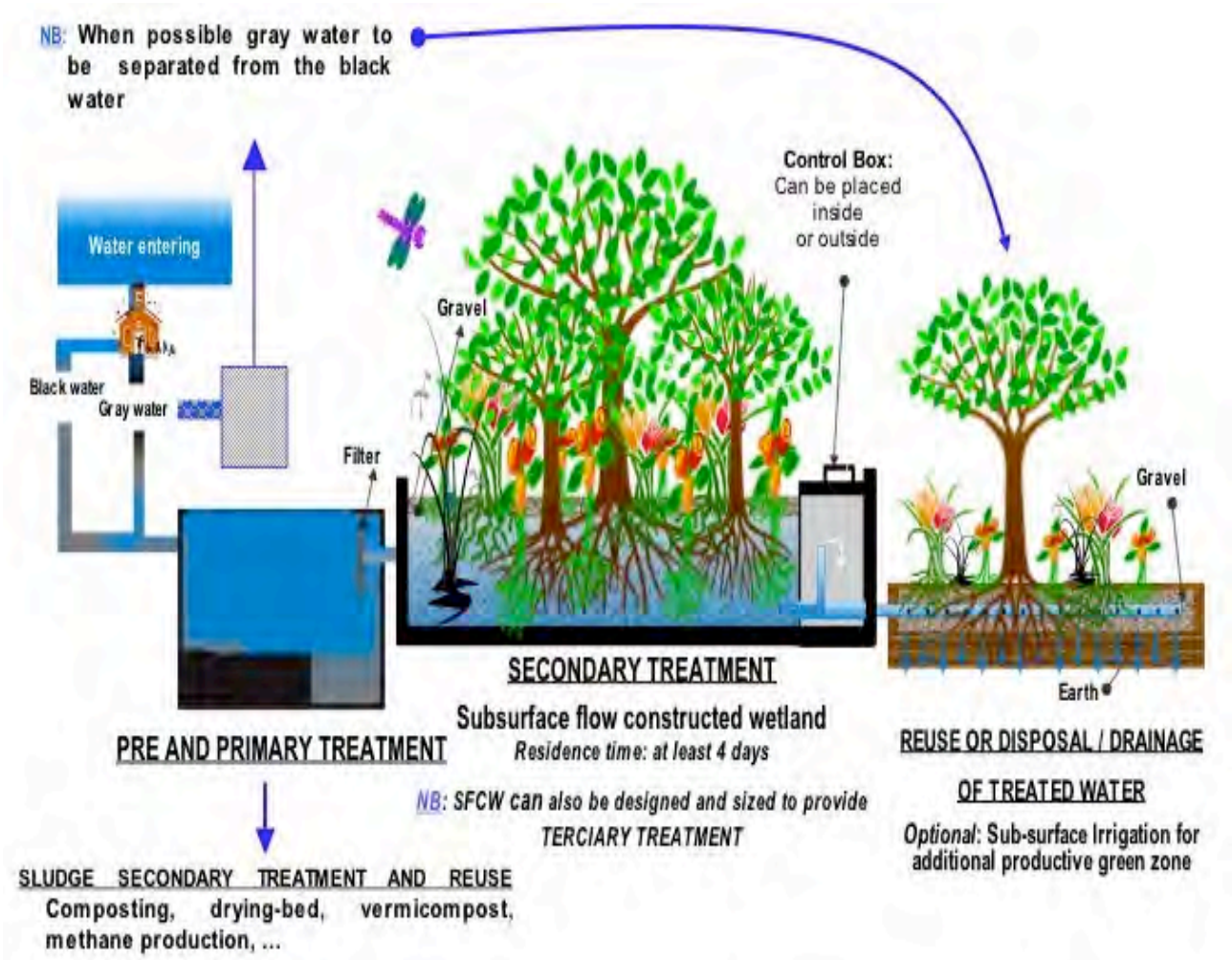


*Table 6: Overview of an extensive wastewater treatment*
*Source: http://en.wikipedia.org/wiki/File:SchemConstructedWetlandSewage.jpg*

## 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, Sulitsa, Bulgaria

In Sulitsa, Bulgaria, there is a community centre where village meetings, celebrations, amateur activities and other initiatives take place. Because of water shortages, it was decided to build dry toilets with urine separation. Two toilets and two waterless urinals have been installed.

*Urine and the faecal matter of the urine diverting dry toilet are separated and collected in different containers, and treated for safe reuse in the garden of the community centre in Sulitsa*

### 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 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*
*Photo: Bistra Mihaylova*

## 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 says 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 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 reused in an agriculturally safe way.


*Application of dewatered sewage sludge on agricultural field in Germany*

## 6. Exercises and Questions

- Why does the issue of sanitation not stop at the toilet?
- What type of toilets do you know?
- What is the volume of greywater and blackwater per person per day? How can the volumes be reduced?
- What is the difference between technical and natural wastewater treatment systems?
- Why and how can wastewater be re-used?
- Visiting a wastewater treatment plant nearby

## WSP related activities

- Checking the school toilet, how is the state, what are options to improve the situation of the school toilet
- Are there pit latrines or soak away pits in the village? If yes, is there danger of groundwater pollution?
- Is the wastewater in the village collected and treated, and where is the wastewater released?
- Are there any drinking water sources affected by the infiltration of wastewater?
- Is the quality of the treated wastewater monitored? If yes, are the values according to the EU requirements?
- Questionnaire of a sewage utility

# 7. Text sources and further reading

Sanitation: A continuous challenge for the European Region, Chapter of the European Document for the European Regional Process of the 5th World Water Forum (2009). Available from http://www.wecf.eu/download/2009/2009WWF5Sanitationregionaldocument.pdf

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