Content - Questions to be answered

Waste- (water) Treatment

- What is it? From Where & How Much? (quantity & quality)
- Why must wastewater be treated? (Environmental Protection & Legal Framework)
- How to collect wastewater? (drainage system & other concepts)
- How does a treatment plant work? (conventional, large treatment plants = aerobe intensive systems)
- What to do with the sludge? (sludge treatment & disposal)
- Any other possibilities of wastewater treatment? (extensive systems)
- Are these sanitation concepts available & appropriate for all over the world? (alternative concepts)

Sludge Treatment – Sources & Quantities

Sources / Quantities / Consistence

Upcoming with the advanced biological treatment are 3 sources:

- **Mechanical** pre-treatment primary sludge
- **Biological** treatment surplus sludge
- **Chemical** treatment precipitation sludge

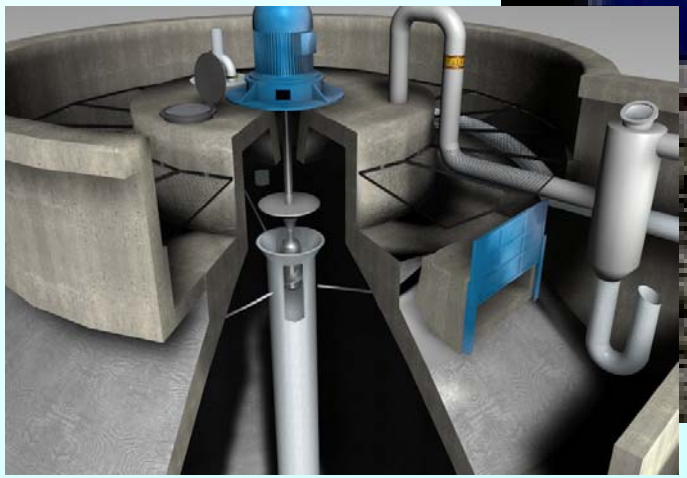
➢ primary sludge	13 kg_{SS} / (P*y)
➢ surplus sludge	6 kg_{SS} / (P*y)
➢ precipitation sludge	5 kg_{SS} / (P*y)
Total:	24 kg_{SS} / (P*y)

Sludge Treatment –
Specific (per capita) daily load (SS)

Process	daily load (SS) mech. + biol.	daily load (SS) simultaneously precipitation	daily load (SS) storm water treatment	Total SS (raw sludge)
1	2	3	4 (=20% of 2)	5 (=2+3+4)
	$SS_{m+b\ raw\ spec}$	$SS_{simprec\ raw\ spec}$	$SS_{rain\ raw\ spec}$	$SS_{tot\ raw\ spec}$
	[g/(P.d)]	[g/(P.d)]	[g/(P.d)]	[g/(P.d)]
Activated sludge				
Without Nitrification	78	10	16	104
With Nitrification	67-75	10	13-15	90-100
With Nitrific. and Denitrification	72-74	10	14-15	96-99
With N + D + partial biological aerobic sludge stabilisation	60 partial stabilisation sludge age 25 d, T > 15°C	10	12	82
Trickling filter				70

Sludge Treatment

- **Thickening** (conditioning)
- Sludge **stabilization**
  - aerobic stabilization e.g. composting,
  - anaerobic stabilization = digestion
- **Dewatering** (natural or mechanical)
- **Decontamination**



Sludge Treatment - Thickening

- Depending on the source, sludge has water contents from **93 % to 99.5** %.
- Thus any sludge treatment starts with a **separation of water and sludge**.

The separation starts with a **conditioning** step.

- Chemicals are added to the raw sludge, enabling a better separation of water (supernatant) and sludge:

Agents:

- Inorganic chemicals = precipitants (lime, iron salts, aluminum salts)
- Organic chemicals = polyelectrolytes (anionic or cationic) or polymeric substances or ashes or coal

Sludge Treatment - Sludge stabilization

- Major requirement: **reduce the organic matter**
  … to a quantity that will **not enable digestion** processes any more.

Aerobic stabilization

Simultaneously (@ AT) or **separated** or **composting**

- Reduction of organic matter by the **metabolism** of the MO and higher organism.
- Principle: Further aeration of the sludge without or with only **minimal nutrition**.

Anaerobic stabilization

High concentrations of organic matter of sewage sludge enable **digestion processes**.

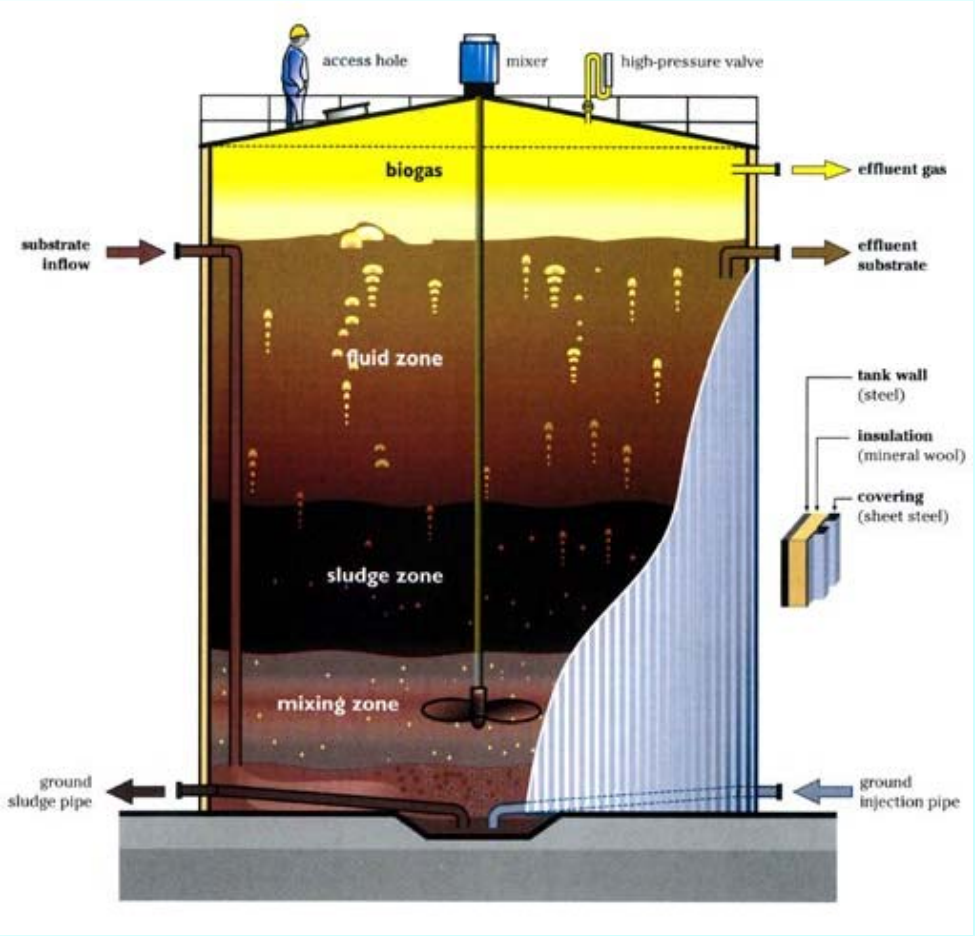
- Under anaerobic conditions (storage without aeration) further degradation (digestion) processes will take place (together with a very bad odor!).

Sludge Treatment - Anaerobic Sludge stabilization

The biodegradation of organic substances by methane-forming bacteria is called **anaerobic stabilization** (= **digestion**).

- Methane and carbon dioxide is gained (70% CH_4 + 30 % CO_2)
- Digestion usually takes place in heated (about 35 °C), mixed tanks.
- Digestion time is about **20 days**.

- Unheated digesters used at small scale treatment plants are usually built as Imhoff tanks (situated at the bottom of the primary clarifier).



Sludge Treatment - Sludge dewatering

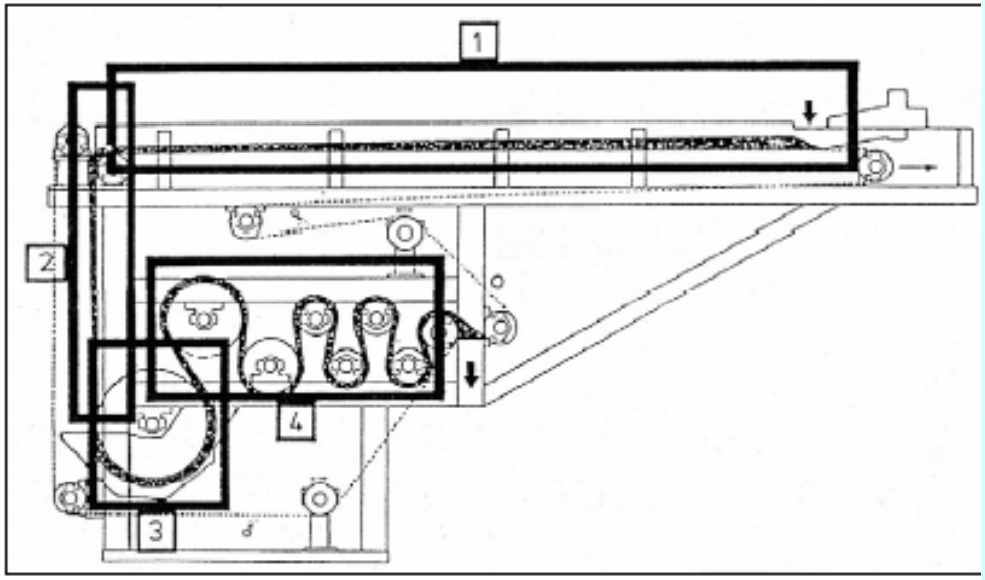
Natural dewatering

… is the oldest process used to treat stabilised sludge

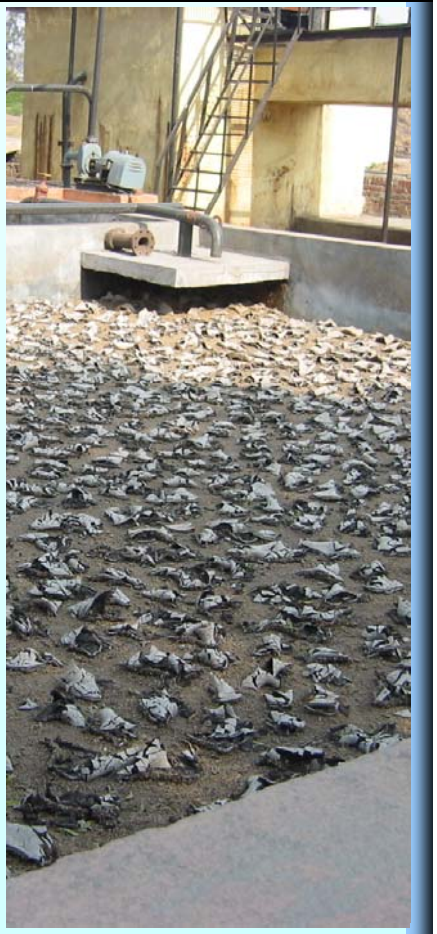
- Sludge is applied to drying beds
- Effects used are: **gravity-dewatering**, **evaporation** and storage of sludge.

Mechanical dewatering

- **Belt filter press** (continuously operation)
- **Centrifuges**
- **Filter press** (pressurised sludge is filtered through several filter compartments; driving force is a feed pump; principle: cake filtration)



Belt filter press



Sludge Treatment - Decontamination of sludge

- Especially for **agricultural use** the decontamination of sludge is very important.
- Health risks have to be avoided
- Pathway of contamination:
  - **Humans – Wastewater – Sludge – Soil – Crops – Animals - Humans**

This pathway of potential infection has to be cut by decontamination of the sludge.

Decontamination of liquid sludge

1. Addition of hydrated lime	pH = 12,5 ± 0,3	≥ 3 Month
2. aerobic-thermophilic stabilisation	T_1 = 50°C T_2 = 55°C T_3 = 60°C	$t_1 \geq$ 23h $t_2 \geq$ 10h $t_3 \geq$ 4h
3. aerobic-thermophilic pre-treatment with anaerobic stabilisation	T_1 = 60°C T_2 = 65°C T_3 = 70°C T_4 = 80°C	$t_1 \geq$ 60 Min. $t_2 \geq$ 30 Min. $t_3 \geq$ 25 Min. $t_4 \geq$ 10 Min.
4. pasteurising of sludge	T_1 = 65°C T_2 = 70°C T_3 = 80°C	$t_1 \geq$ = 30 Min. $t_2 \geq$ = 25 Min. $t_3 \geq$ = 10 Min.

Decontamination of dewatered sludge

5. Addition of burnt lime (CaO)	T = 55 to 70°C and pH ≥ 12,5	T ≥ 24h
6. Composting	T = 55°C	t ≥ 3 weeks
7. Composting in Bioreactors	T = 55°C + T = 65°C	10 days +2 days

Sludge recycling / disposal / incineration

Agricultural use of sludge

- utilization as a fertilizer is an alternative to disposal or incineration

The basic conditions for an agricultural use are:

- Adequacy of the soil and
- Pollutants contained in the sludge

Sludge or disposal at a landfill

- … was commonly used for a long time
- Nowadays the disposal at landfills is decreasing because of new European guidelines, forbidding the disposal of waste with more than 5 % TOC

Sludge incineration

- Economical way with a **heat and energy recovery** system.
- Liquid incineration (Vienna Main WWTP)

- Rotary furnace
- Rotating multilevel furnace
- Fluidised-bed furnace

Biological Wastewater treatment: overview

Aerobe intensive system

- **Biological film (biofilm) reactors**
  - Trickling filter
  - Rotating biological contactor
  - Biofilter
- **Activated sludge process**
- **SBR**

Aerobe extensive system

- **Constructed wetlands**
  - Horizontal flow
  - Vertical flow
- **ponds**

Anaerobe system

Pretreatment for very high organic loads

- fixed bed reactors
- floating bed reactors

Extensive Processes for WWT

Common features of extensive processes are:

- **Simple** process and design
- Little control technology
- **Low surplus** sludge accumulation
- Much space required
- Low maintenance
- **High stability and high buffering capacity**

Designs:

Wastewater ponds

Constructed Wetlands

Extensive Processes for WWT - Wastewater ponds

Classification:

- Sedimentation Ponds
- Stabilization Ponds (non aerated oxidation Ponds = without artificial aeration)
- Aerated Wastewater Ponds

Advantages & Problems:

- Low tech - Low cost – solution
- Simultaneously stabilization of the settled sludge

- High specific space required
- Only little controllability
- Treatment performance is affected by seasonal changes

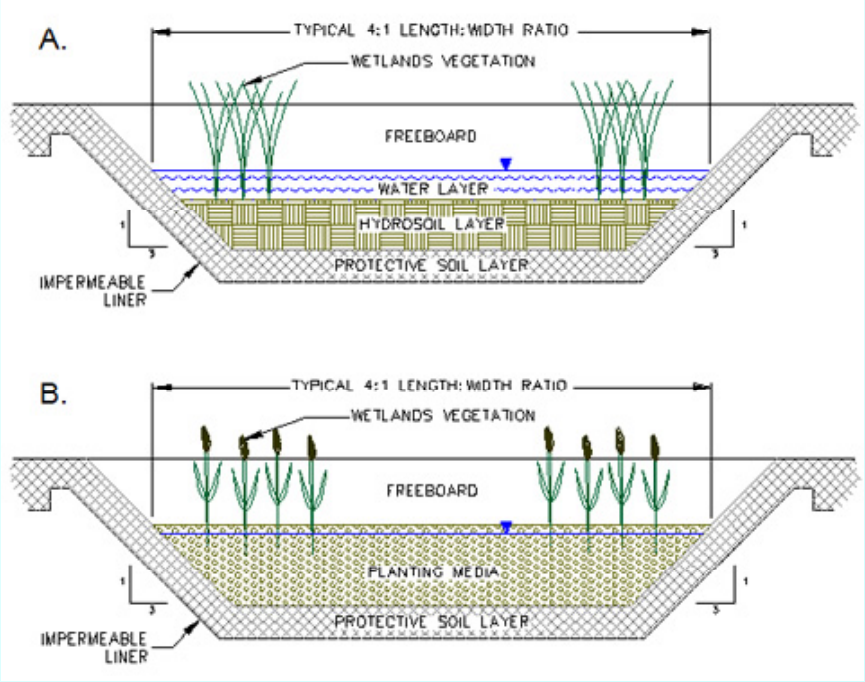
Extensive Processes - Constructed Wetlands (CWs)

CWs are used successfully with

- **different quality of the influent and**
- **under various climatic conditions**

CWs are effective in treating or

- organic matter, nitrogen, phosphorus,
- Additionally: adsorption of heavy metals,
- organic chemicals, and pathogens.



Designs of CWs:

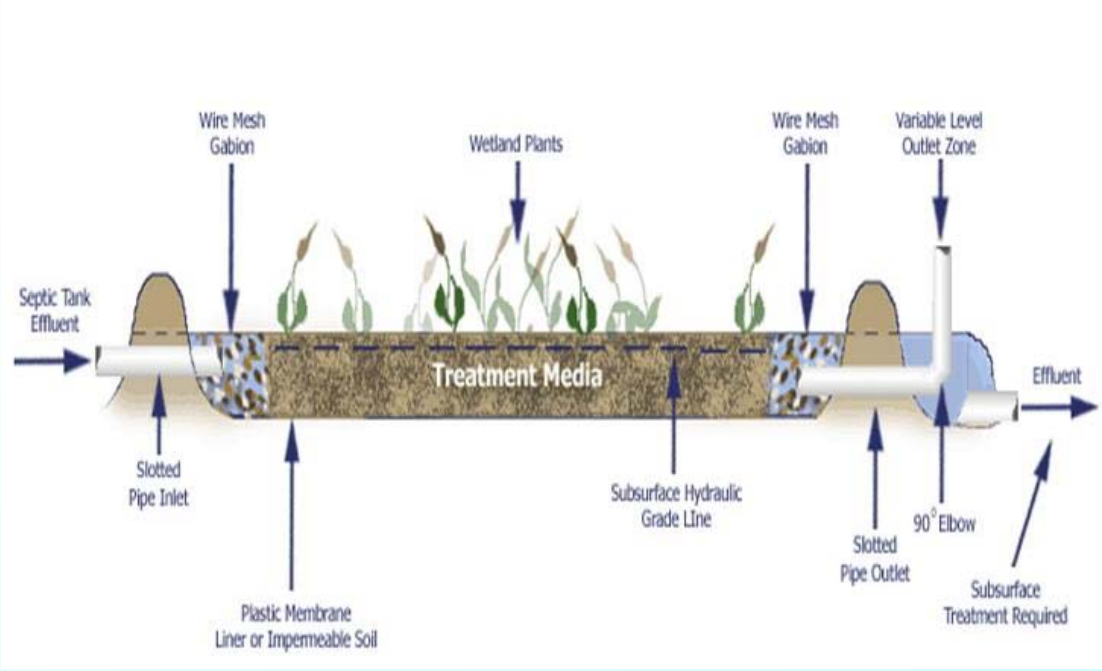
- **Surface** flow constructed wetlands (A.)
- **Subsurface** flow (B.) constructed wetlands with **horizontal** flow
- **<u>Subsurface flow constructed wetlands with vertical flow</u>**
- **single stage or multi stage** treatment plants.

Extensive Processes - Constructed Wetlands (CWs)

Major part and responsible for the biological treatment is

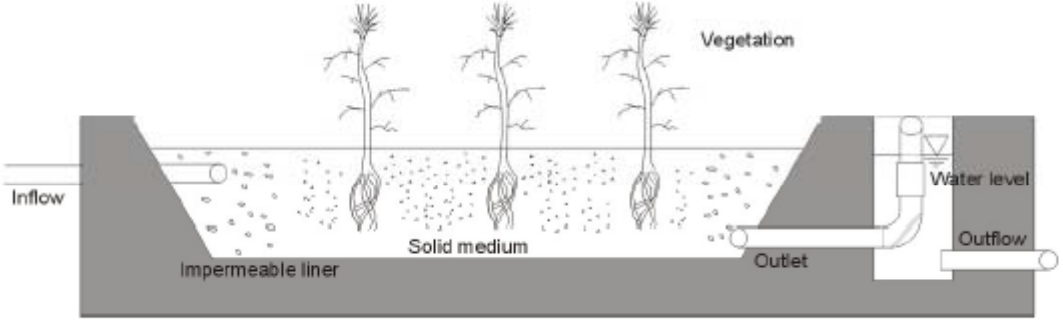
a **basin filled with soil or sand** (higher hydraulic conductivity).

- The basin is sealed (most common design: plastic liner (HDPE) basin) and
- filled with substrate
- includes **plantings** of reed or similar plants.

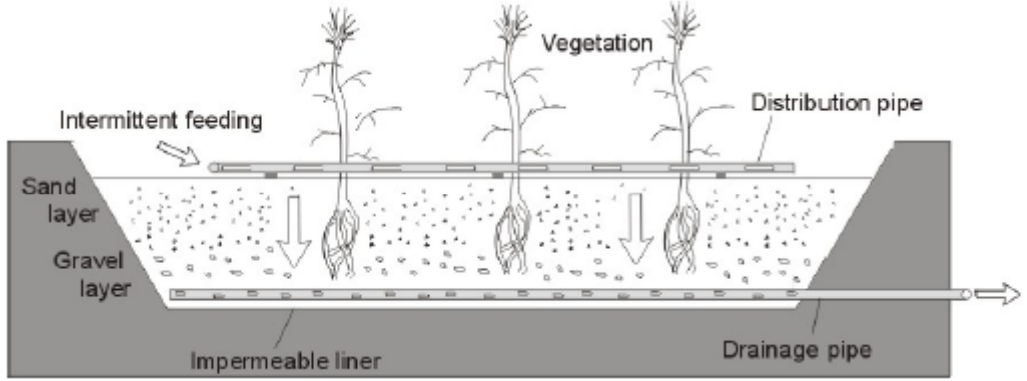


Extensive Processes - Constructed Wetlands (CWs)

Surface Flow Constructed Wetlands



Subsurface Flow Constructed Wetlands – Horizontal flow



Subsurface Flow Constructed Wetlands – Vertical flow

Extensive Processes - Constructed Wetlands (CWs)

Principle & basic components of CWs:

- Mechanical **pre-treatment** (settling compartment, filter bag)
- **Inflow distribution** (pipe and sprinkler system)
- **Substrate** (mostly sand fraction) with hydraulic conductivity of kf = 10^{-3} - 10^{-4} m/s;
- adsorption capacities
- **Plants** (helophytes): different species according to the regional location
- **Oxygen supply** of the substrate by **vertical flow & intermitting load**
- **uptake** of several substances (nutrients), **insulating layer** (winter season).

- **MO:** play the **major roll in degradation** of organic carbon and nutrients in wastewater
- areas with **aerobic** and **anaerobic** conditions within the substrate contain differently adapted MO

Extensive Processes - Constructed Wetlands (CWs)

Operation of CWs:

- **Intermittent loading** of vertical flow plants
- 4 to 8 times / day → **aeration**

Required space of CWs:

- Specific required space of **vertical flow, intermittent loaded CWs = 4 m² / person**
- **Multistage** CWs even less m²
- Oxygen supply mainly induced by intermittent loading
  → important for **Nitrification**

- Specific required space of **horizontal flow CWs = 6 m² / person**
- **Nitrification not possible** (too low Oxygen supply – only by diffusion through water surface)
- Multistage CWs can fulfill the same treatment performance with less space

Extensive Processes - Constructed Wetlands (CWs)

The contribution of the plants

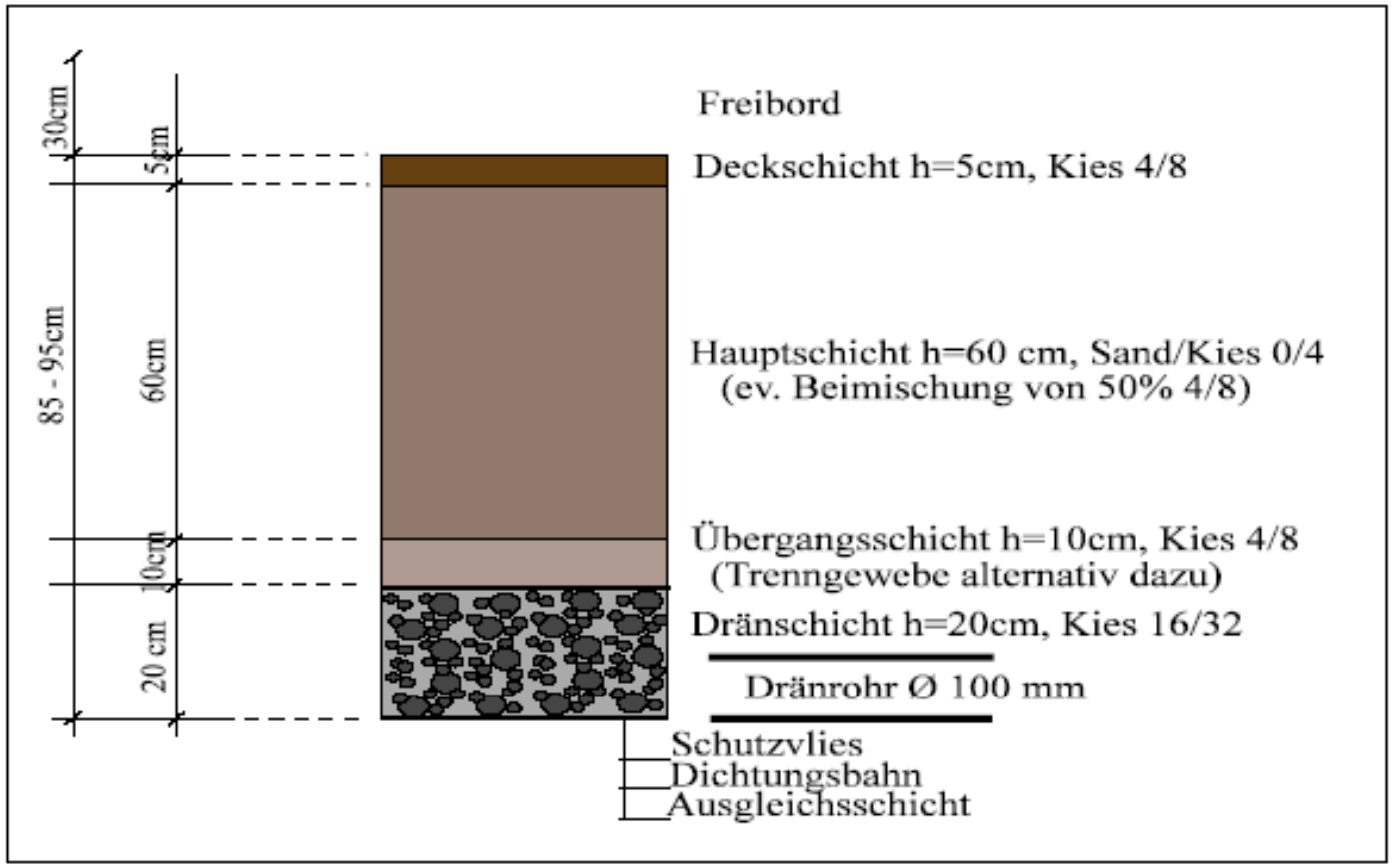
- Roots → positive influence on the structure of the substrate → **prevent clogging**
- Shadowing (**prevent algae growth**) & **Thermal insulation** in winter
- uptake of nutrients (only if plants are harvested – up to 3 % of the total N load)
- **Habitat forming for MO &** Aesthetical aspects

CW for 8 PE (Farm in Upper Austria)

Distribution system of a 40 PE vertical flow plant

Extensive Processes - Constructed Wetlands (CWs)

Profile of a subsurface vertical flow CW (ÖNORM B 2505, 1997).



Freeboard

Covering Layer (5 cm, gravel 4/8)

Main Layer (60 cm, sand/gravel 0/4 + 4/8)

Intergradation (10 cm gravel 4/8, if necessary with fleece web)

Drainage Layer (20 cm, gravel 16/32, drainage pipe DN 100)

Extensive Processes - Constructed Wetlands (CWs)

Construction of CW with impermeable synthetic liner

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Anaerobic Wastewater Treatment

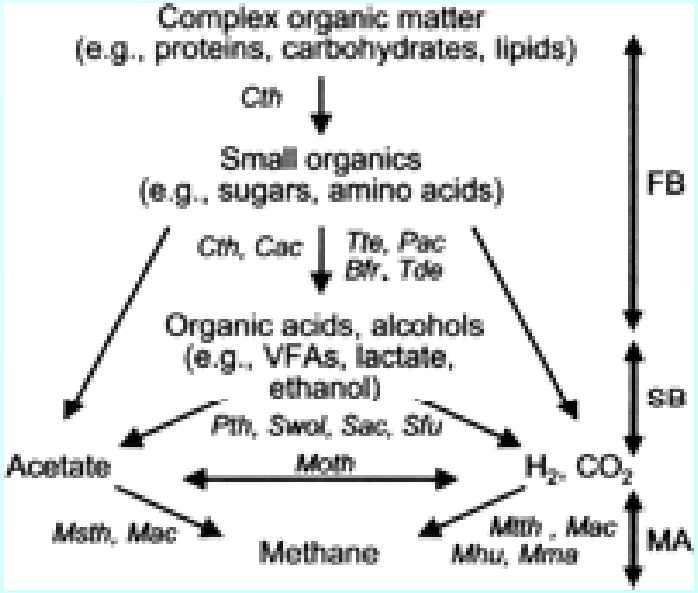
Used for: (pre-) treatment of **wastewater** with high organic carbon concentrations.

- Anaerobic degradation of organic matter is a **multi-stage process**.
- Every stage is accomplished by a certain group of bacteria.
- During every degradation step the bacteria are emitting several by-products.

Anaerobic degradation-model shows **4 stages** for the transformation of

- **carbohydrates, fats** and **proteins** into
- **methane** and **by-products**

1. Hydrolysis
2. Acidification
3. Acetic Phase
4. Methane formation



Anaerobic Wastewater Treatment - Summarization

Characteristics of the anaerobic degradation:

- No additional energy required; energy is recovered by the anaerobic degradation
- No complete degradation
- Bad odor
- Strongly affected by temperature

Comparison of anaerobic and aerobic process:

- Lower energy demand
- Higher remaining pollution
- Lower biomass growth
- Lower nutrient uptake (C:N:P = 1000:5:1)
- Unstable biologic process