Understand the wastewater treatment process

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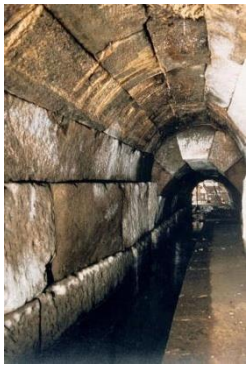
How does wastewater get to the treatment plant?



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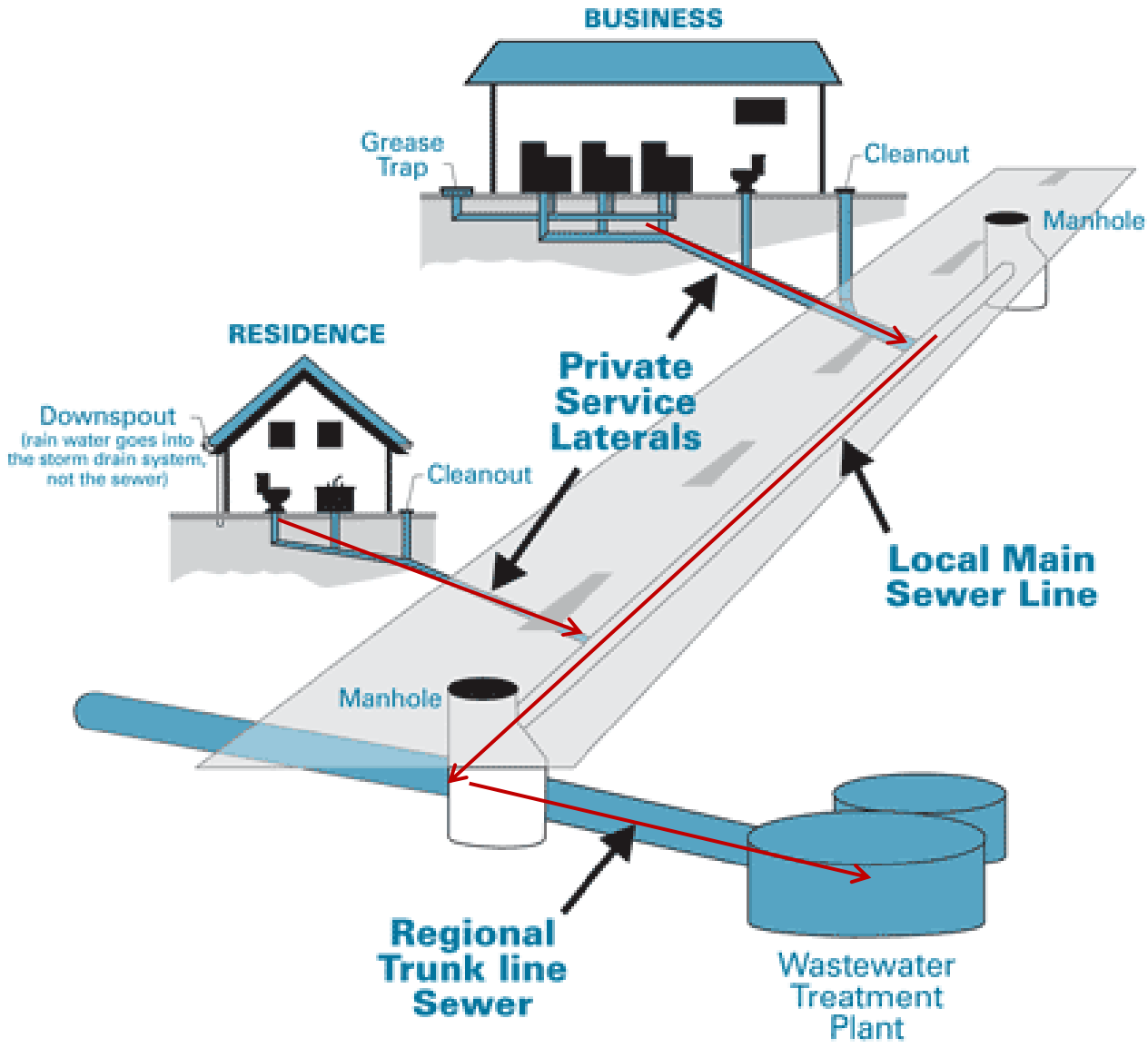
General lay out of a modern sewer system



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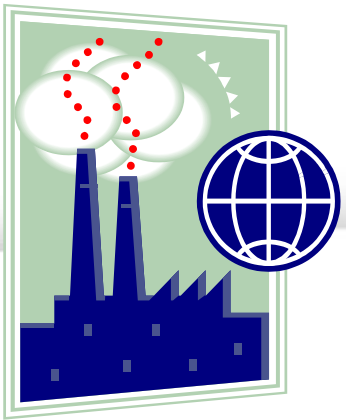
Types of water to be transported

- **Storm water**
  - Rain water and surface runoff
  - Can be highly polluted, especially when the rain begins to fall (rain-out of atmospheric fumes, wash off from roads and roofs)

- **Domestic wastewater**
  - Black water from toilets, household sewage from kitchens or bathrooms
  - Biodegradable and mineral matter ; dissolved or in suspension

- **Industrial wastewater**
  - Characteristics are variable and linked to the type of industry
  - May be mixed with domestic wastewater if it does not constitute a risk for the network or the treatment plant



Why do we need a sewer network?

- Are there alternatives?

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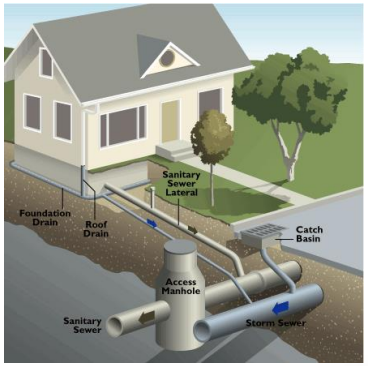
How are sewer systems built-up?



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General principle of a sewer system

- **The pipelines have a certain slope downhill**
  - The water flows by gravity to the treatment plant
  - Sewers are gravity powered!
  - If the water velocity is high enough: Sewers are self cleaning

- **If the natural lie of the land demands this, pumping stations and/or vacuum lines are added**

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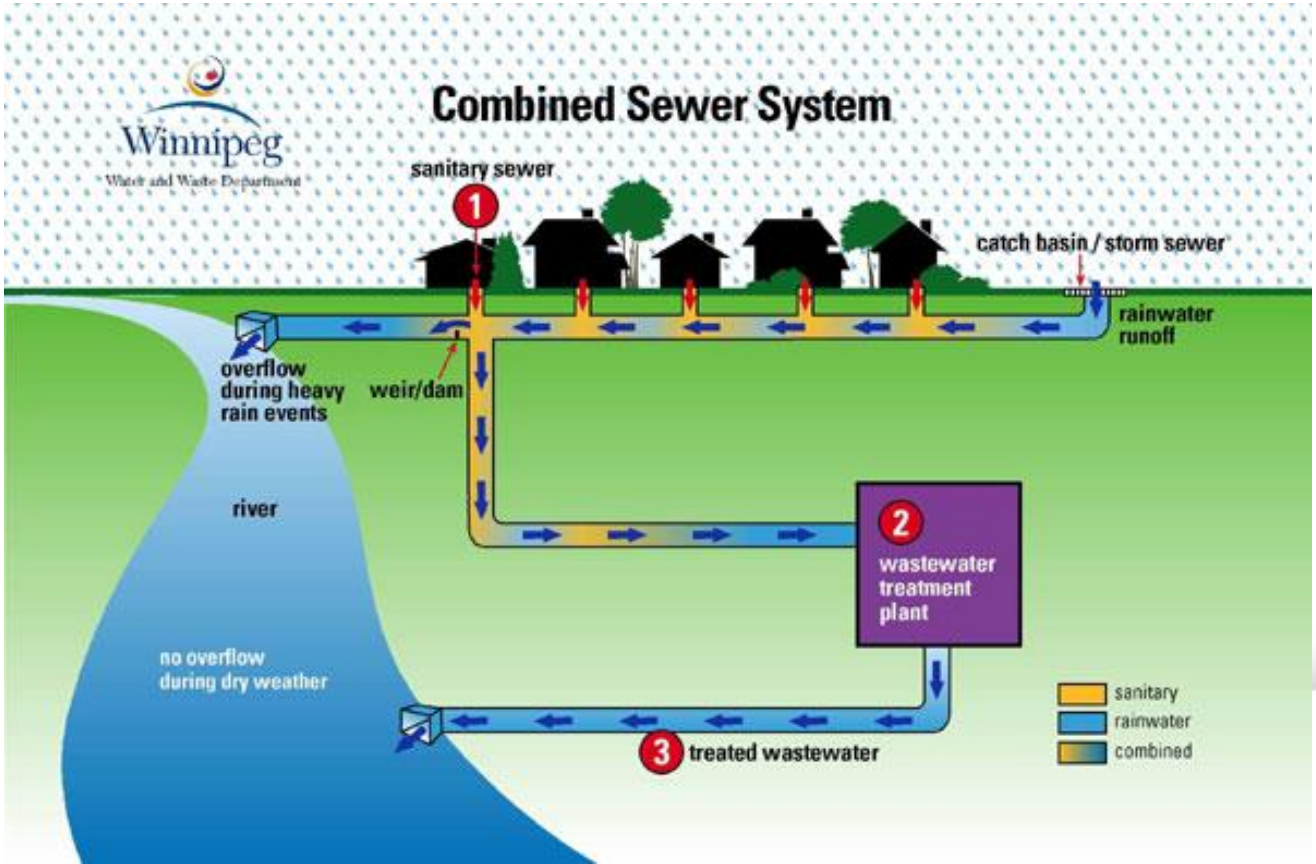
Types of sewer systems

- **The combined system**
  - Removing all waste and storm water using one single network
  - Usually equipped with storm water outfalls
    - in the event of a storm: discharge some of the water by overflow, directly into the environment.



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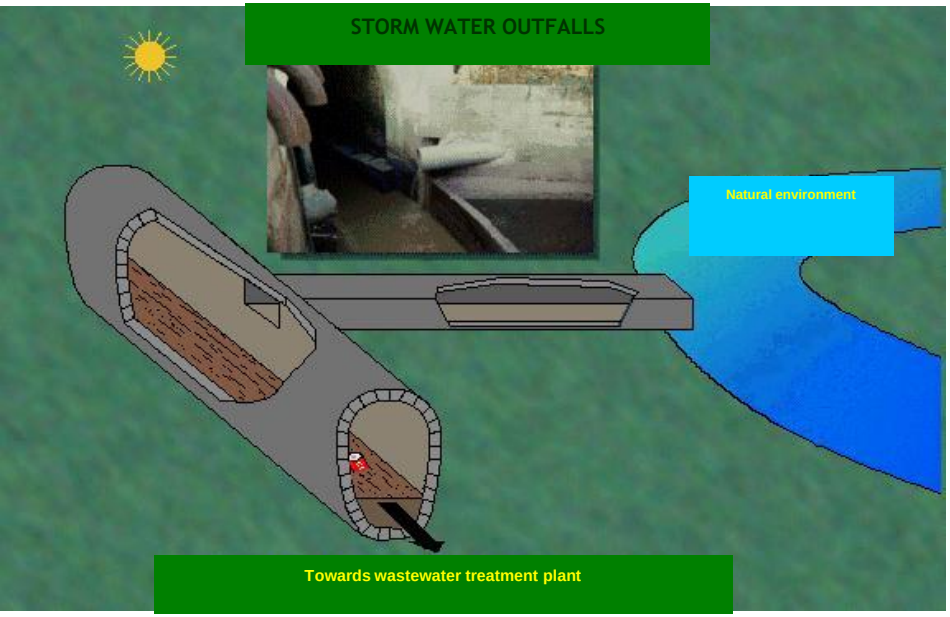
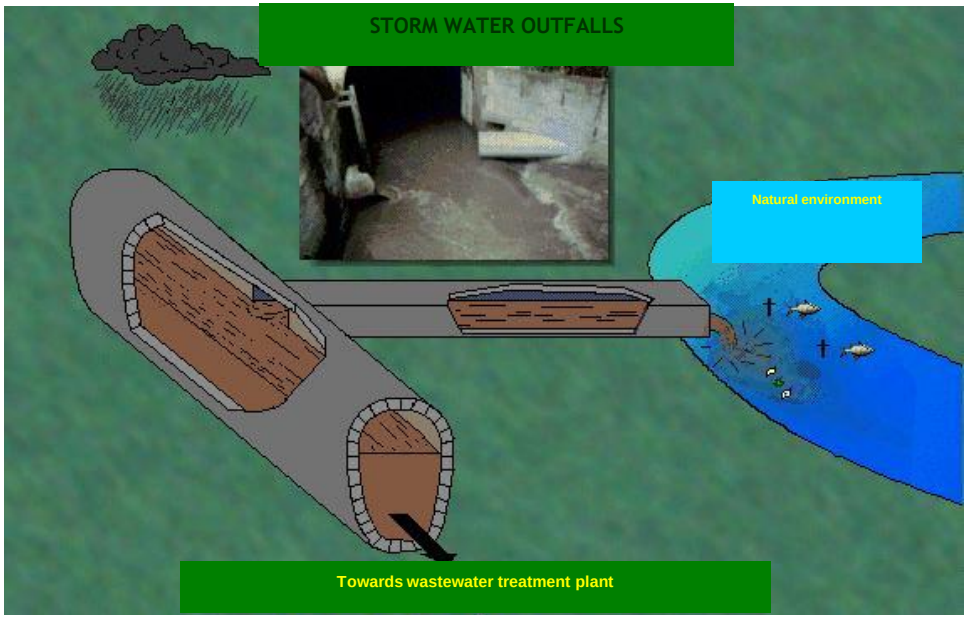
Combined sewer systems: stormwater outfalls





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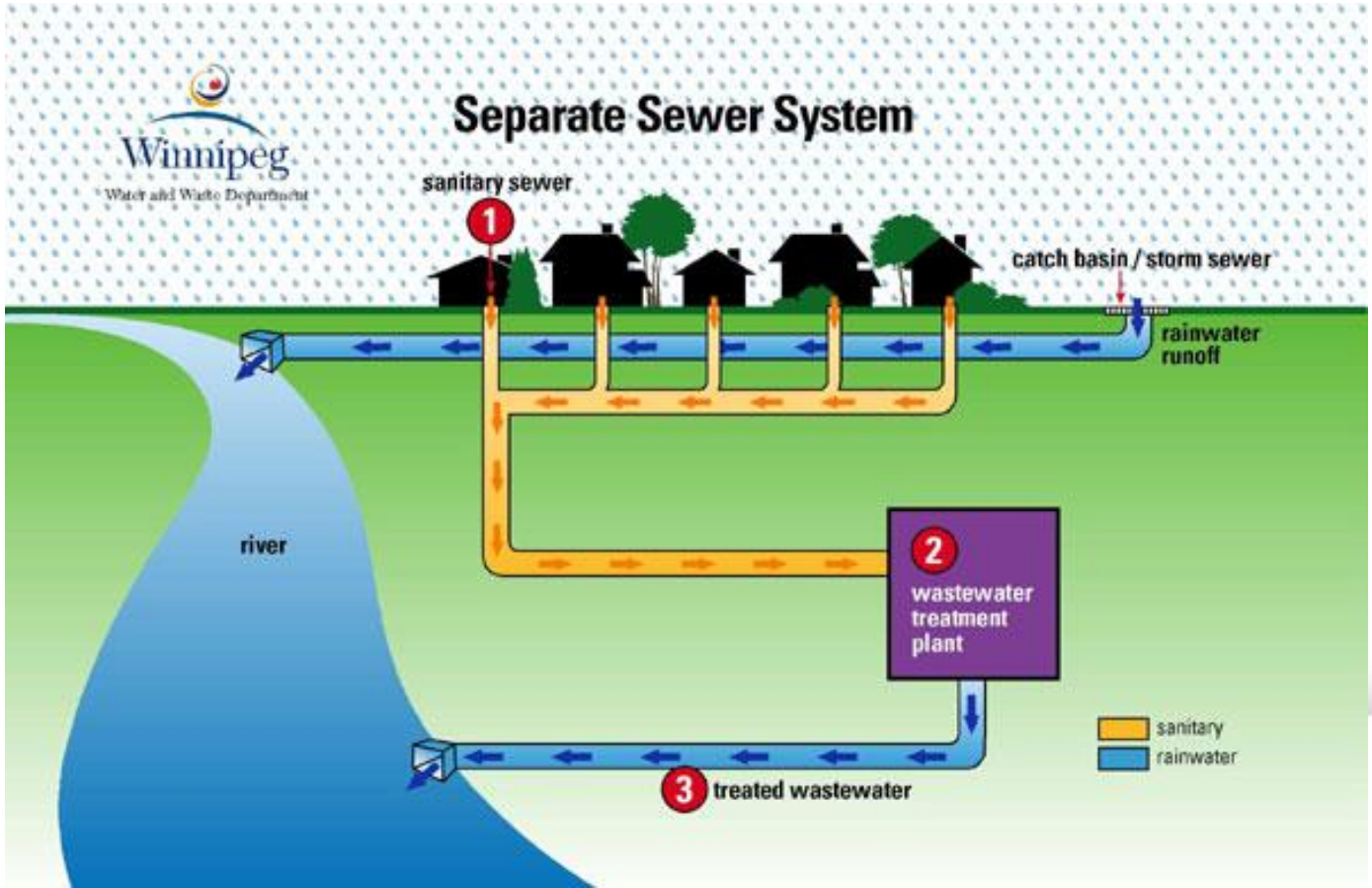
Types of sewer systems

- **The separation system**
  - One network to remove domestic wastewater (black water and household sewage) and some industrial effluent.
  - Another network to remove storm water



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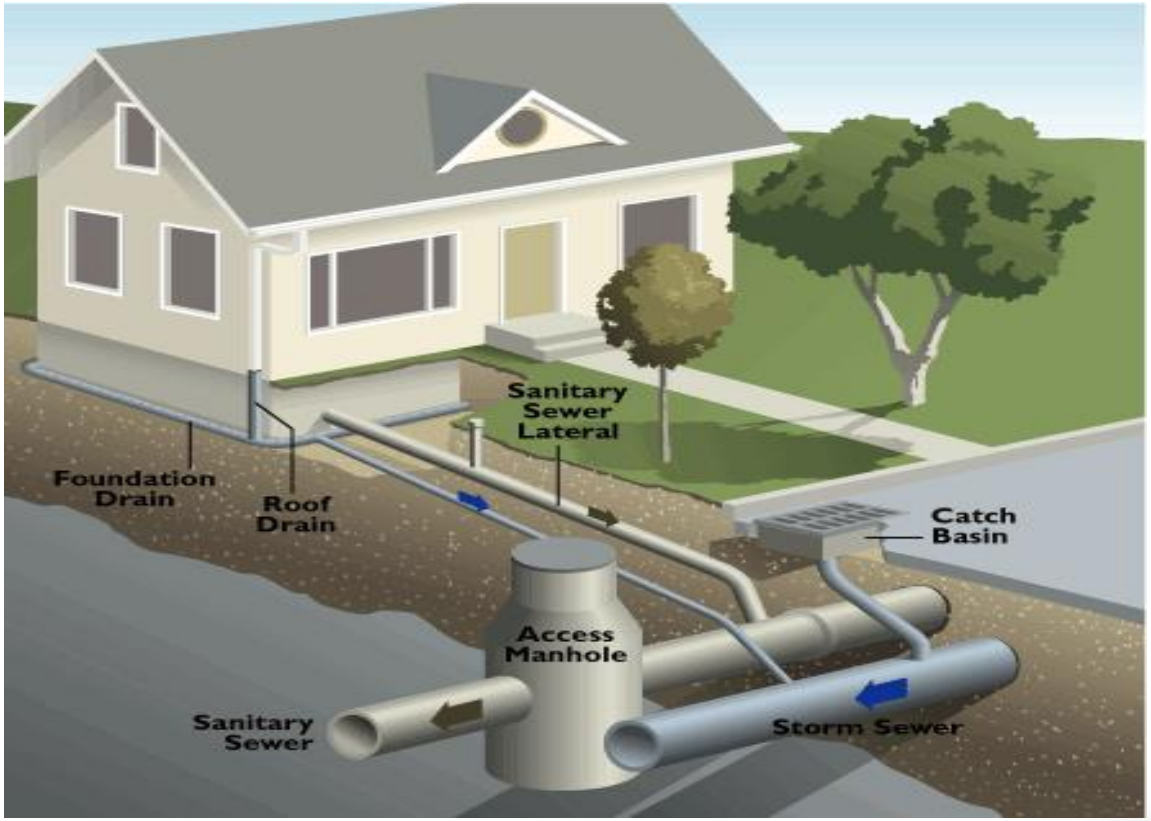
Separation sewer system

- Sanitary sewer (smaller)
  + Storm water sewer (larger: Θ 200 mm – 3000 mm)



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Types of sewer systems

- **The partial separation system**
  - Similar to the separation system, this network allows some storm water in (from courtyards or roofs) which increases the flow rate, and therefore facilitating the self-cleaning of the pipe in cases where there is only a slight slope.

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Understand the wastewater treatment process
TRAINING MODULE WWP002-2

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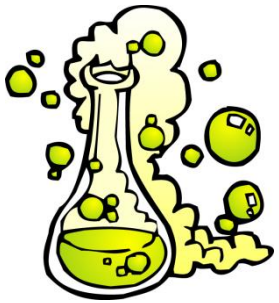
How to decide what type of treatment process to select?



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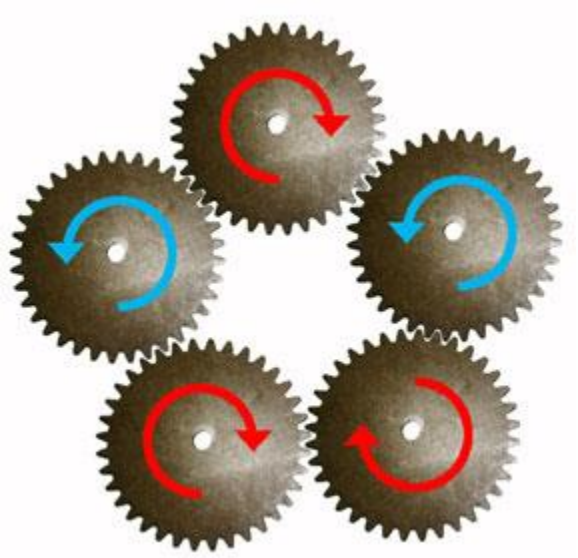
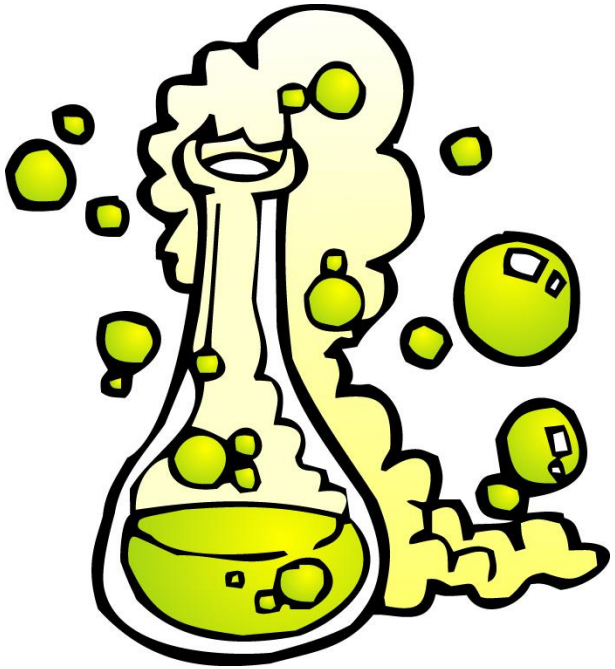
Possible types of processes



PHYSICAL PROCESS



CHEMICAL PROCESS

BIOLOGICAL PROCESS

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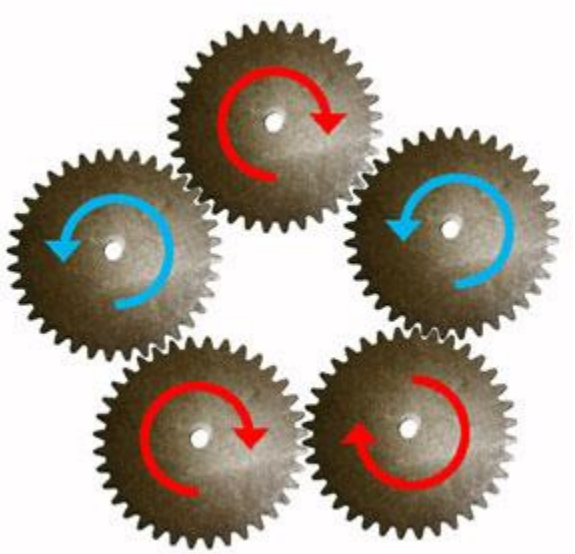
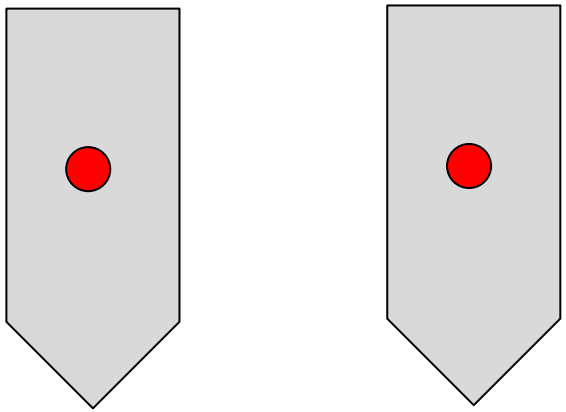
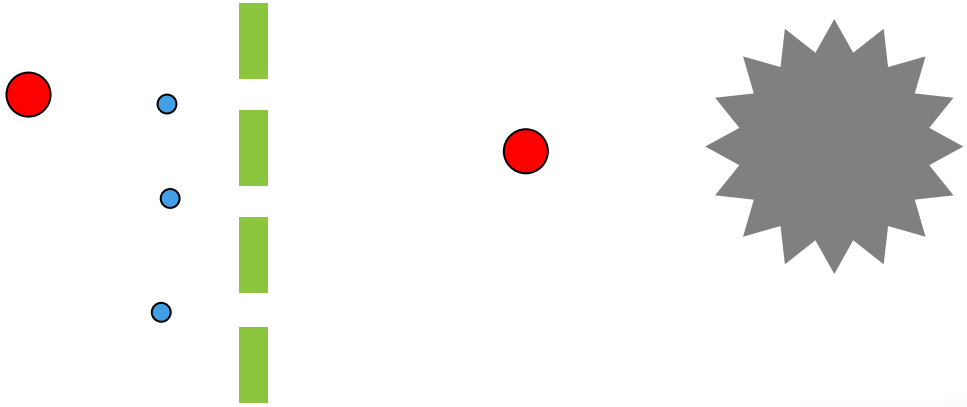
Possible types of processes



Physical processes

- Settling
- Flotation
- Filtration
- Adsorption





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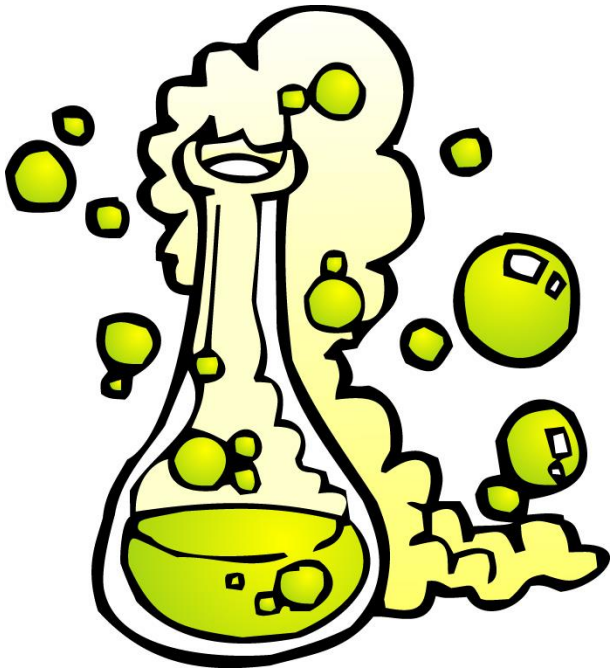
Possible types of processes



Chemical processes

- Different types of chemical reactions : precipitation, oxidation/reduction, neutralization
- Consuming chemicals
- Nothing disappears, never! Transformation of matter

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Possible types of processes

Biological processes

- or BIOCHEMICAL processes
- Are chemical reactions which are facilitated using ENZYMES in living organisms
- Reactions that would not happen without the help of the enzymes. However, the enzymes are not involved in the reaction
- Mostly bacteria are used

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How is a treatment process selected?

Technical issues

- Characteristics of incoming water
- Process efficiency
- Final quality to reach
- Process stability

Economical issues

- Investment cost
- Operational cost

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How is a treatment process selected?

Environmental issues

- Quality of treated water
- Environmental impact of the process : generation of other problems : use of chemicals, energy consumption, production of waste, odour, ...

WASTEWATER TREATMENT IS NOT AVOIDING ENVIRONMENTAL IMPACT, IT IS REDUCING ENVIRONMENTA IMPACT !

Other issues

- Safety

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Wastewater treatment processes use physical, chemical and biological principles for the treatment of wastewater

Processes are selected based on technical, economical, environmental and other concerns

How can we characterize municipal wastewater?





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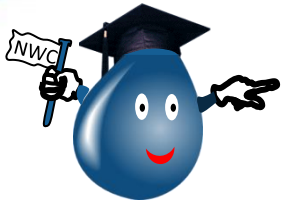
Characterizing wastewater

- **By origin**
  - toilet water (black water)
  - other water (grey water)
    - laundry
    - bathroom
    - kitchen
    - cleaning activities
- **By composition**
  - Organic/inorganic
  - Soluble/insoluble
  - Nitrogen, phosphate
  - Oil/grease
  - (Heavy) metals
  - Toxic compounds (antibiotics, pesticides, hormonal substances, ...)

Example



Link the following compounds to their characteristics

Sugar

Salt

Rice

Sand

	Organic	Inorganic
Soluble		
Insoluble		

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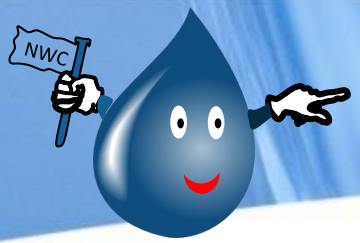

Organic and inorganic compounds

- **Organic compounds**
  - Made by living organisms
  - Made by chemists
  - Basic compound is carbon
  - Serves as energy source and building block for living organisms (consumers and decomposers)
  - Examples : wood, paper, sugar, food in general, acetic acid, ...
- **Inorganic compounds**
  - Minerals
  - Examples : salt, limestone, sand,

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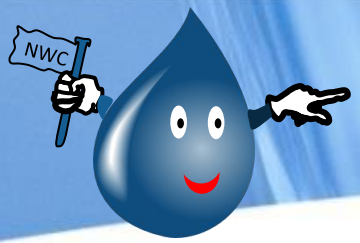

Dissolved versus suspended compounds

- **Dissolved compounds**
  - Forms one entity with the water, cannot be separated by normal physical processes (settling, flotation, filtration)
  - Examples : sugar, sea salt, acetic acid, alcohol, ...
- **Suspended compounds**
  - Stays in a suspended form in the water
  - Separation is normally possible by settling, flotation of filtration
  - Examples : sand, pieces of plastics, hair, tissue, paper, oil, ...

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Can you combine the pollutants and the separation techniques?

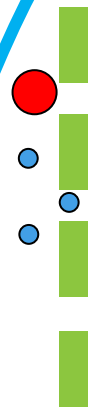
Sugar

Oil

Sand

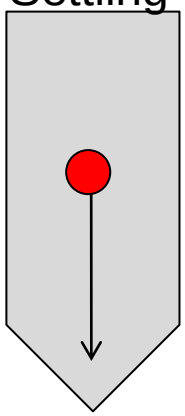
Salt

?

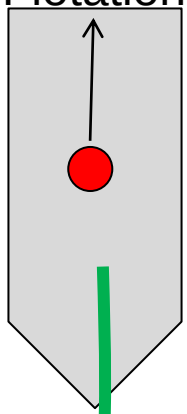


Filtration

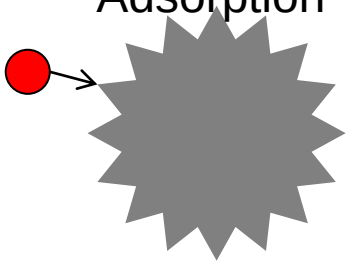
Settling

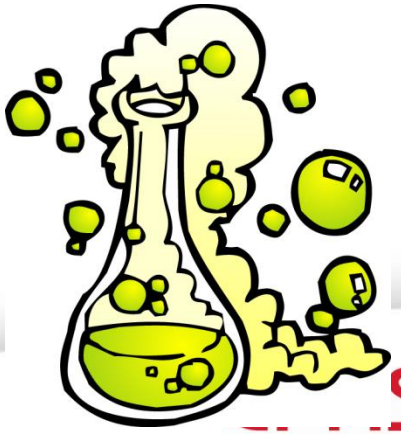


Flotation

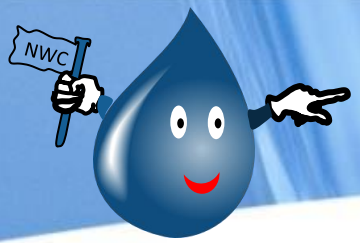


Adsorption





ECO PROCESS ASSISTANCE



Nitrogen and phosphate

- **Necessary elements for construction of cell material (organic matter)**
  - examples : proteins, cell wall (phospholipids)
- **When organic matter decomposes, nitrogen and phosphate are released**
- **Sources of eutrophication**

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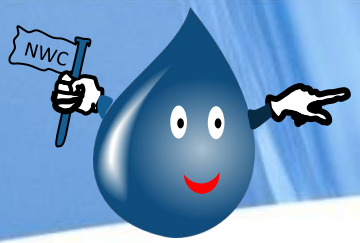

Other pollutants

- Other pollutants are present in very small quantities
- Although their presence is limited, they may be very important due to environmental/health effects at low concentrations or due to their ability of bioaccumulation
- Examples : heavy metals, substances coming from drugs (antibiotics, contraceptives), pesticides used for growing corps, ...
- Communal wastewater treatment plants are in general not conceived for removing this type of pollution. However, part of these pollutants are removed, mainly due to adsorption processes.

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Example: composition of domestic wastewater

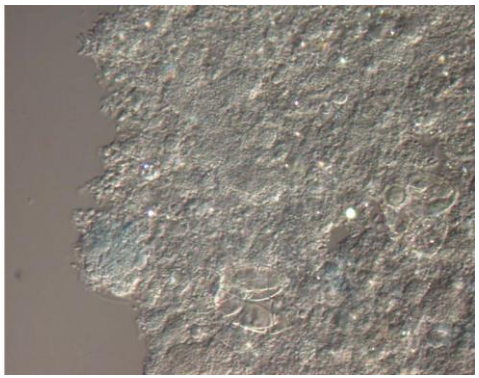
- **Daily water consumption: 150 – 200 liter water per person**
- **Average pollution by day**
  - 90 g SS (suspended solids “particulate pollution”) (70% organic)
  - 60 g OM (organic matter, carbonated pollution)
  - 15 g N (ammonium and organic nitrogen)
  - 4 g P (phosphorus)

Source	Type of discharge	Composition
Kitchen	Cleaning vegetables Washin-up water Cleaning electrical equipment	Organic and mineral matter Grease Detergents
Washing machine	Washing clothes	Detergents Phosphorus
Sanitary installations	Bathroom Toilet	Organic matter Nitrogen and phosphorus Biological material

The origin of the pollutants of municipal wastewater is found in all household activities like bathing, cooking, toilet, laundry, ...

The state of the pollutants, whether they are organic or inorganic, whether dissolved or suspended, determines the possible treatment principles

What is the general lay out of a wastewater treatment plant?

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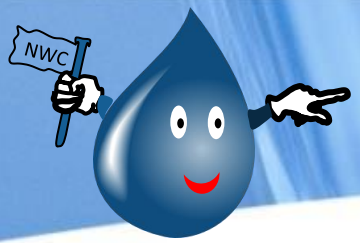

Cleaning water in 3 steps

Primary treatment

- Removing pollutants that may harm the installations
- Preparing the water for further treatment
- Mainly physical processes

Secondary treatment

- Core of the treatment process
- Removing major types of pollutants : organics, nitrogen and phosphorus
- Biological process

Tertiary treatment

- Polishing steps
- Preparing water for reuse or discharge into environment
- Physical and chemical processes

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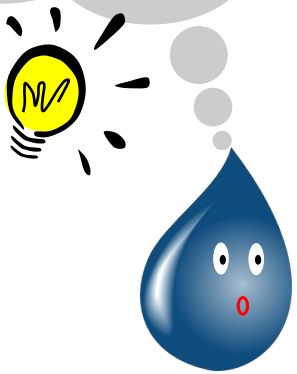
Law of conservation of misery

Wastewater treatment is only a partial solution to an environmental problem



Wastewater

Wastewater treatment plant

Odour
Off gasses

Treated water

Waste

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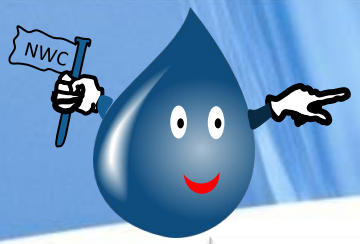
Total process



Water treatment

- Primary treatment
- Secondary treatment
- Tertiary treatment

- Odour treatment
- Waste treatment

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How is primary treatment functioning?




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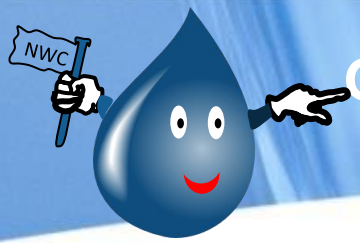
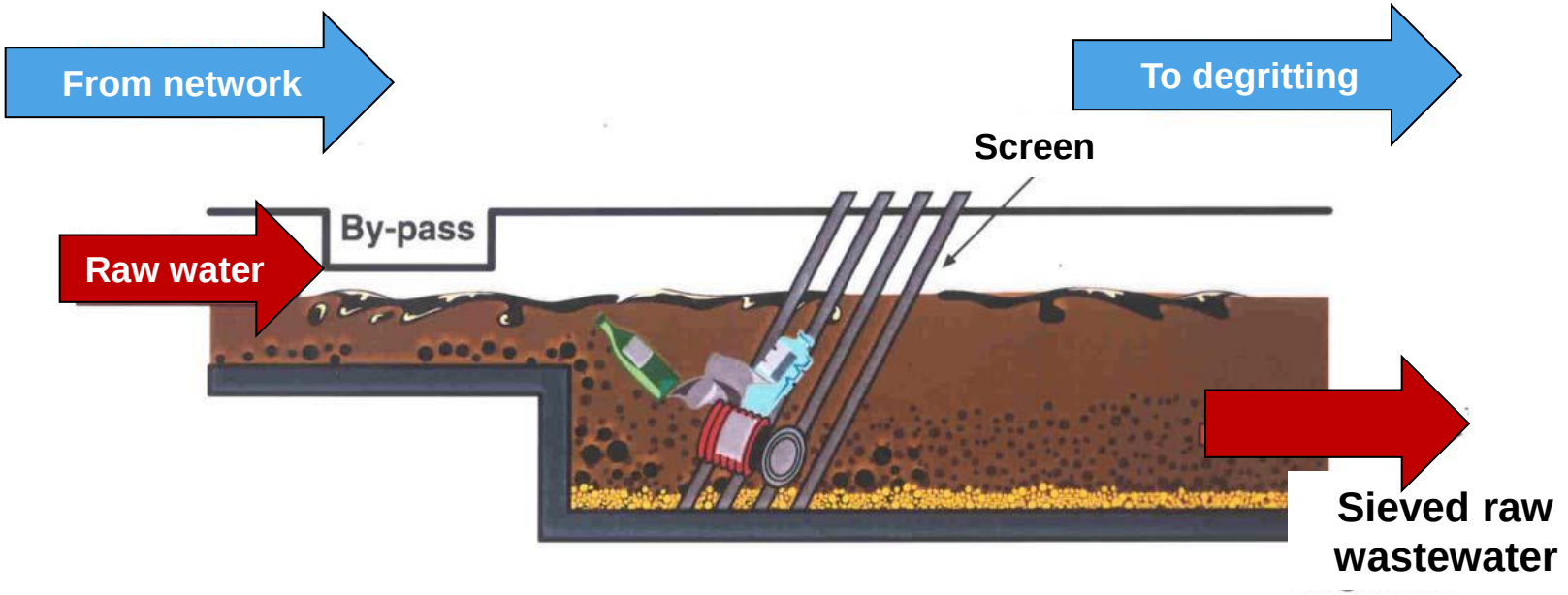


Goal of primary treatment

Goal	Process
Protecting mechanical equipment and pipes from blocking and damaging	screening & sieving Degritting, settling Oil removal
Protecting the good functioning of the biological treatment	oil removal neutralisation
Prevent the plant from overflow and overload	balancing

Screening



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Screening

Sieving : rotary drum sieves

mesh sizes : 1 – 3 mm

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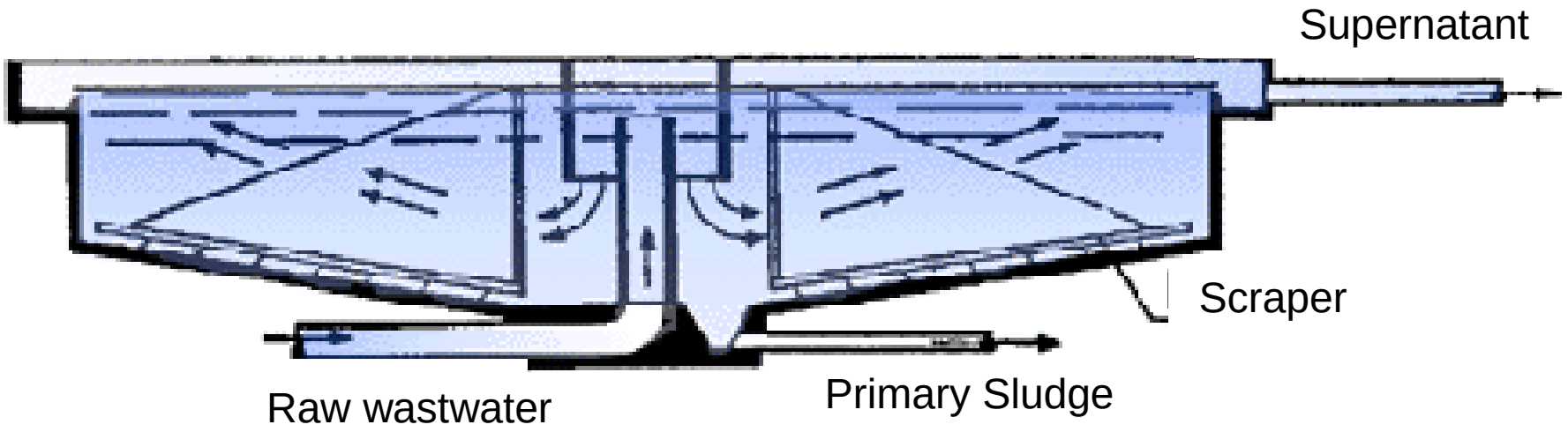
Pretreatment : Degritting

- **Goal :**
  - removal of sand and other heavy material
  - protect system from abrasion = erosion
  - prevent accumulation of deposits in pipes and tanks


Combined sand and grease removal

Pretreatment: Primary settling

- Goal : Settling particles that sink slower than the sand



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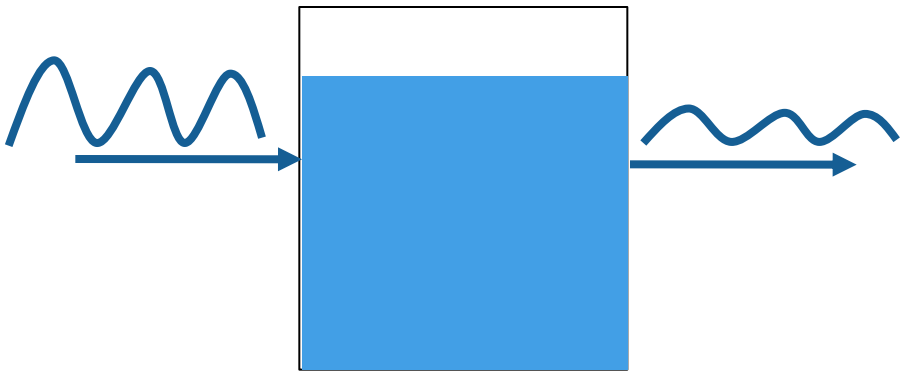
Pretreatment : Balancing of wastewater

- **The balance tank is in between the inflow and the wastewater treatment plant itself**
- **When needed?**
  - Reduce hydraulic peaks
  - Reduce differences in composition of the wastewater



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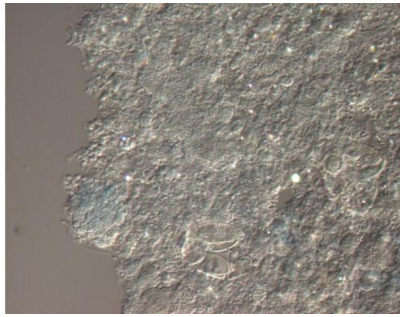
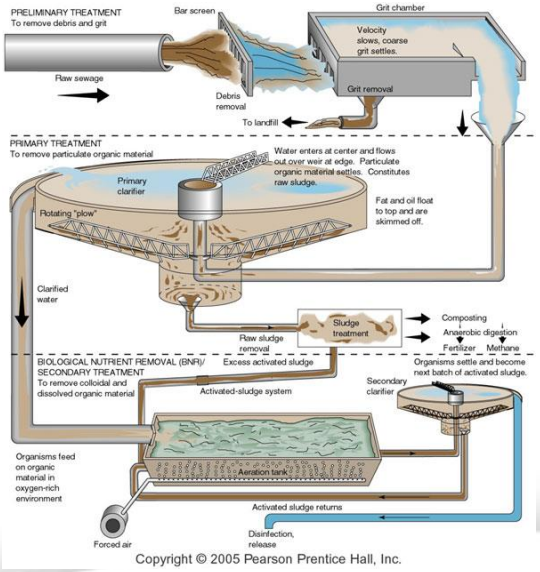
How is biological treatment functioning?





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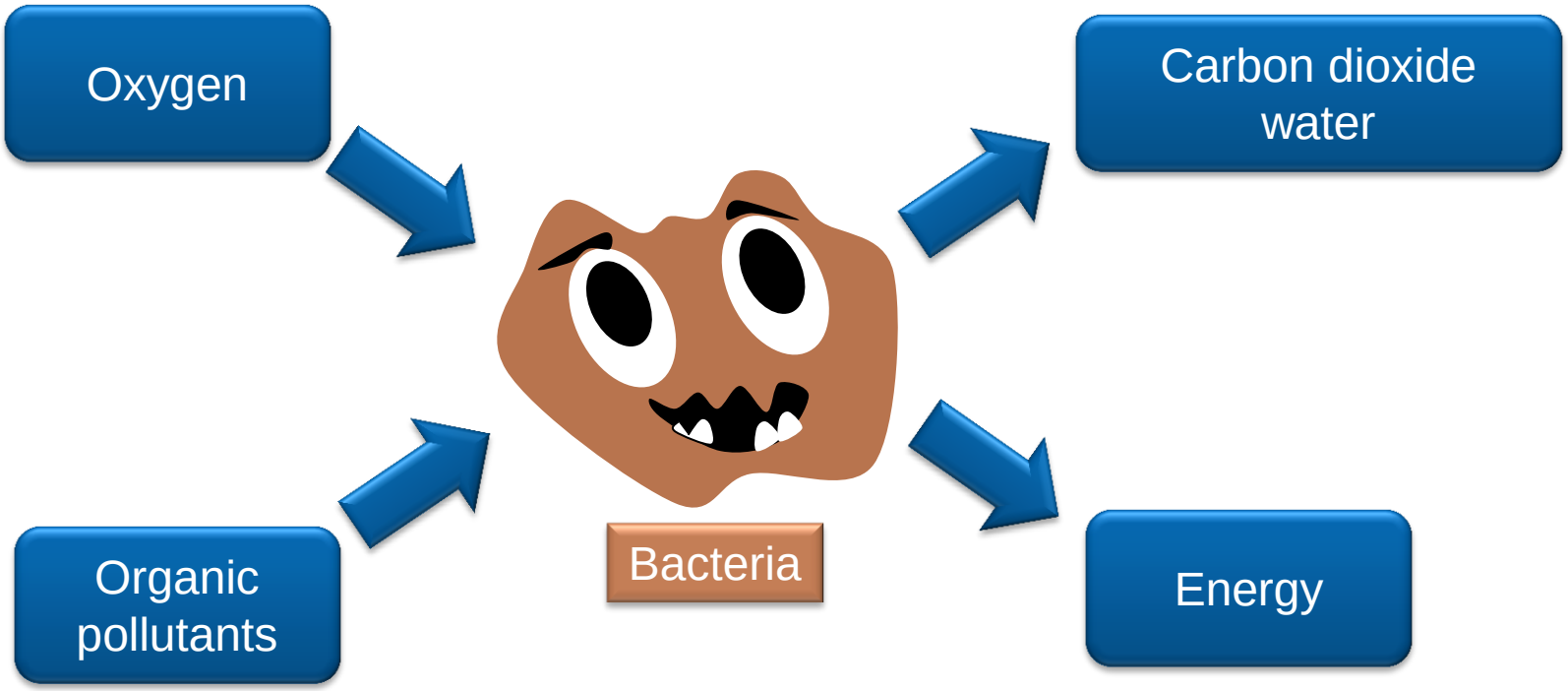
Basic principle...

Oxidation process



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...is pretty common

Oxidation process

Oxygen

Organic food

Carbon dioxide water

Energy

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Oxidation process

Oxygen

Fuel

Carbon dioxide
water

Energy

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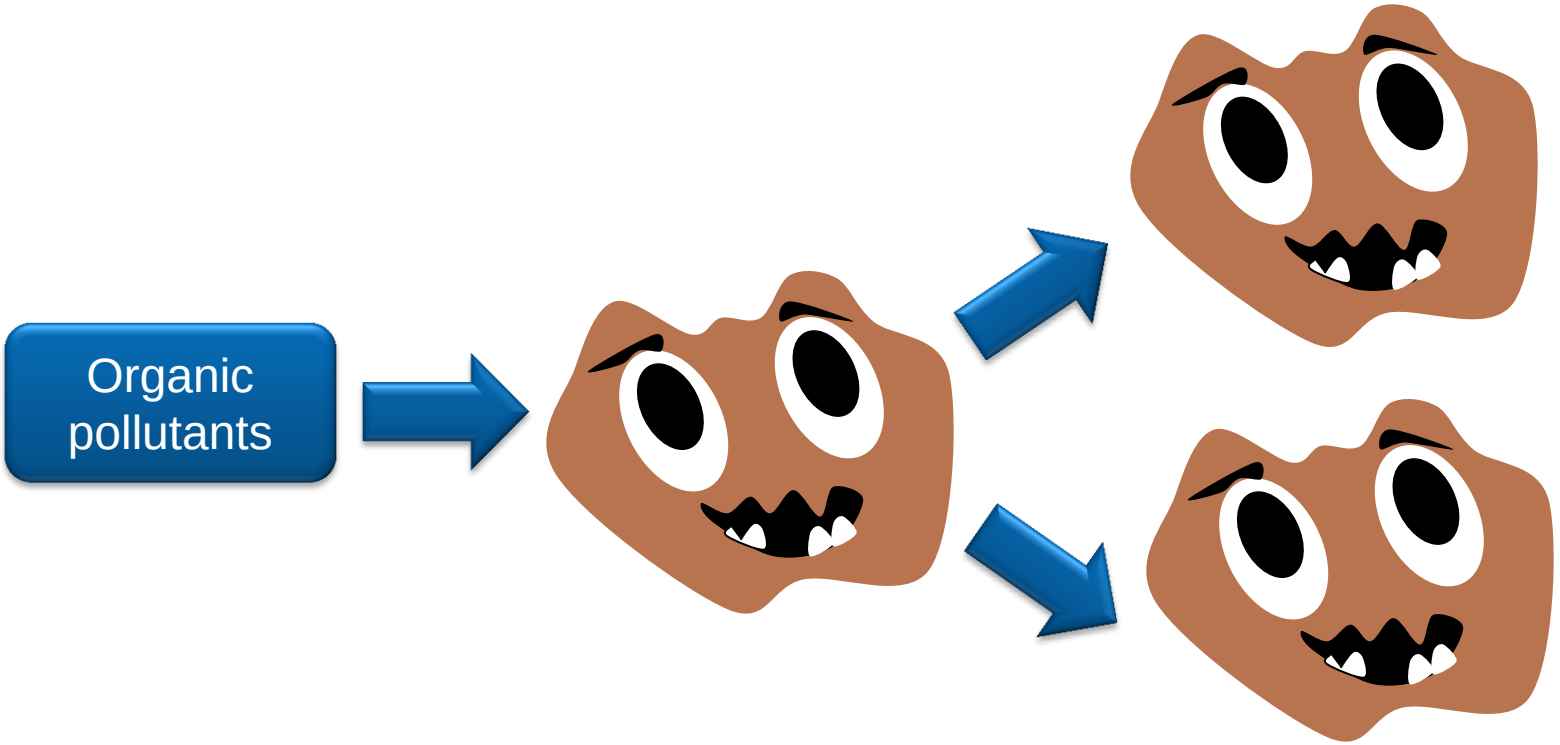
Second process : growth

Growth



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The basic process is copied from nature and concentrated

Self purification river

- Few bacteria
- Few oxygen
- Low capacity

Wastewater treatment plant

- Many bacteria
- Much oxygen
- High capacity

ACTIVATED SLUDGE SYSTEM

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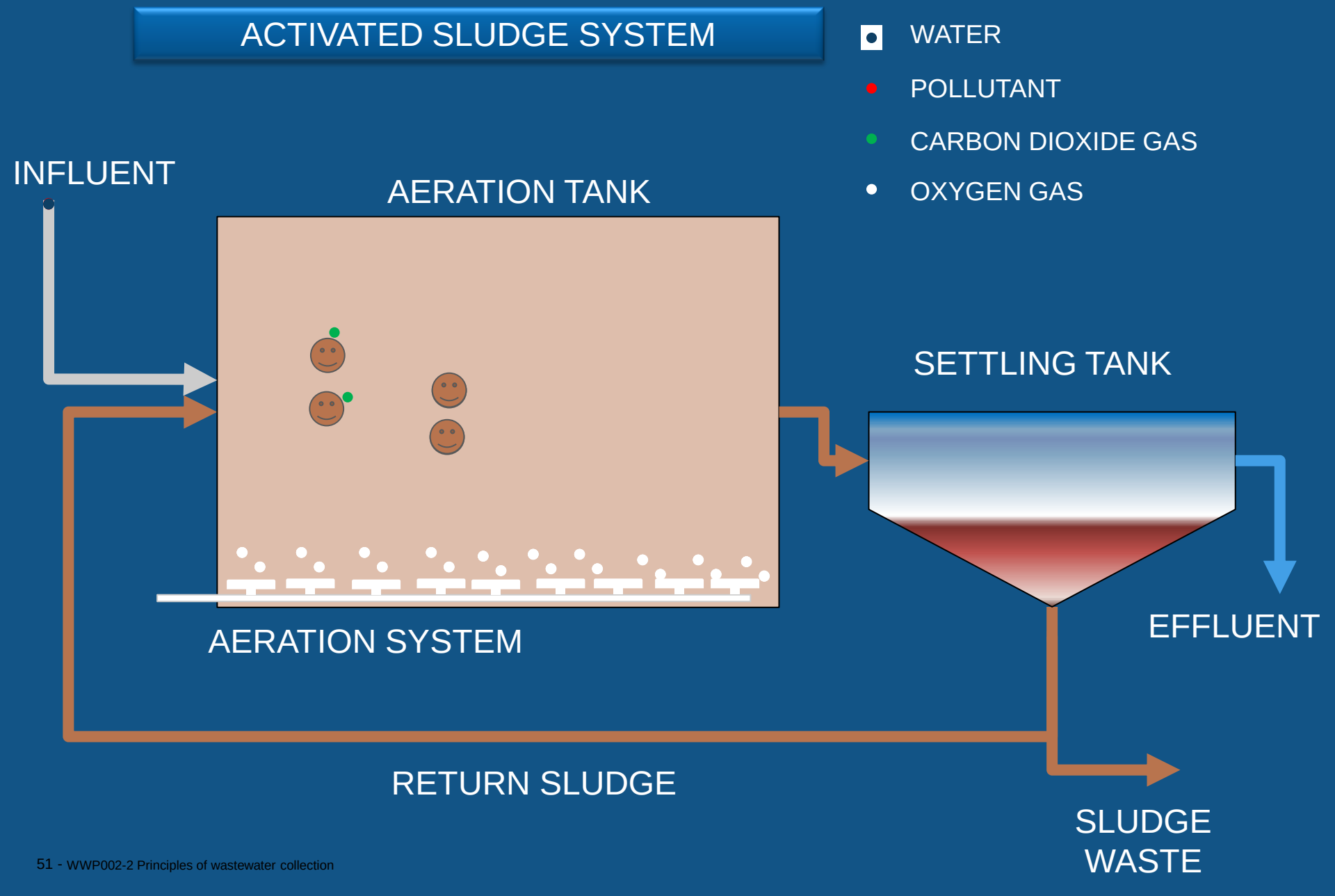
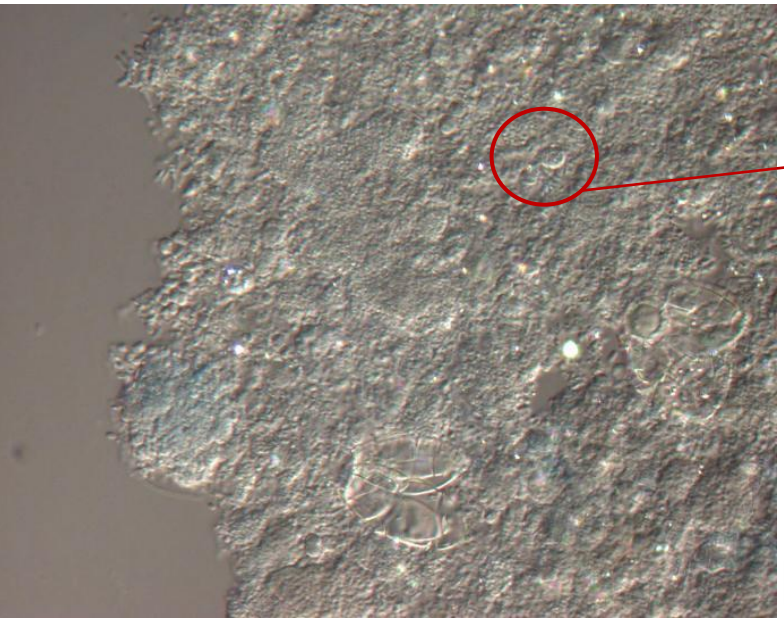
Lay out of a biologicial wastewater treatment plant



What organisms live in the activated sludge system?

- Most of these organisms are BACTERIA
- Bacteria are small organisms with sizes of about 1 µm (1000 bacteria = 1mm)
- Live together in “sludge flocs” : clumps of bacteria



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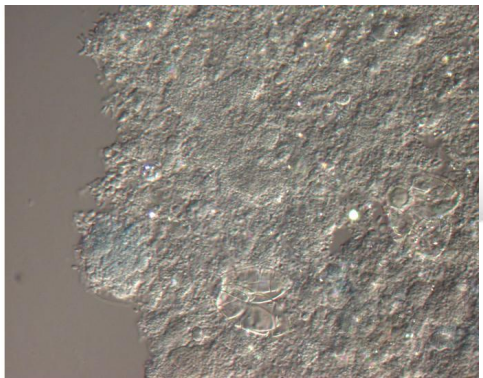
What organisms live in the activated sludge system?

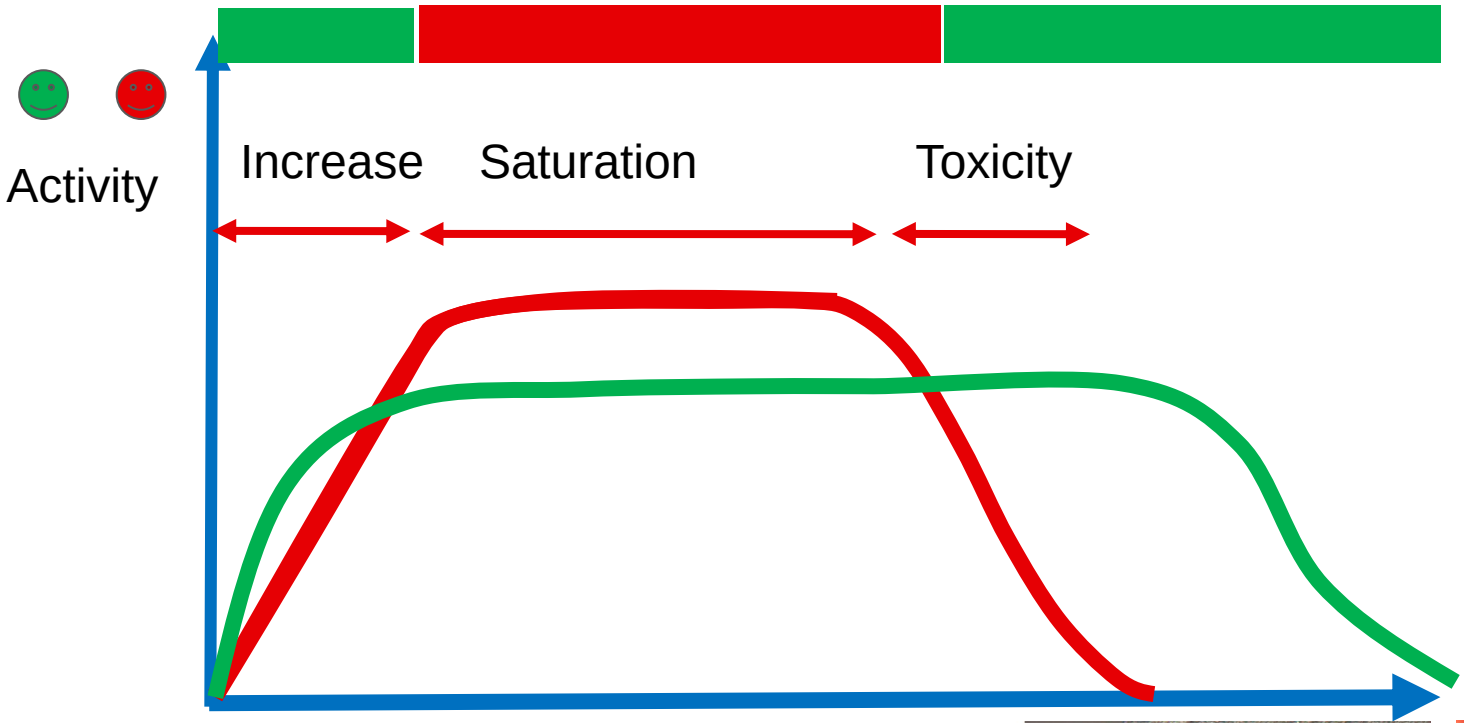
- **Bacteria**
  - Lot of different types
  - Different ecological functions : e.g. used in wastewater treatment plants (reducers), food digestion, food processing, cause diseases
  - The types of bacteria we find in wastewater treatment plants depend on the conditions
    - type of food (pollutants)
    - quantity of food
    - presence and level of oxygen
    - presence of other elementary nutrients
    - temperature
    - salt concentration
    - acidity

→ control the process

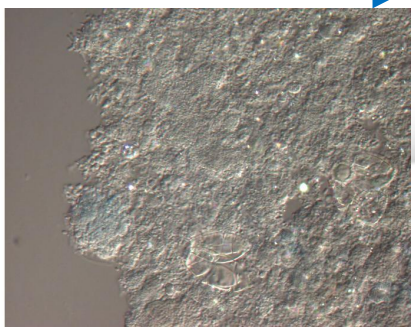


What organisms live in the activated sludge system?

- Bacteria : example of behavior of bacteria = possibility for process control

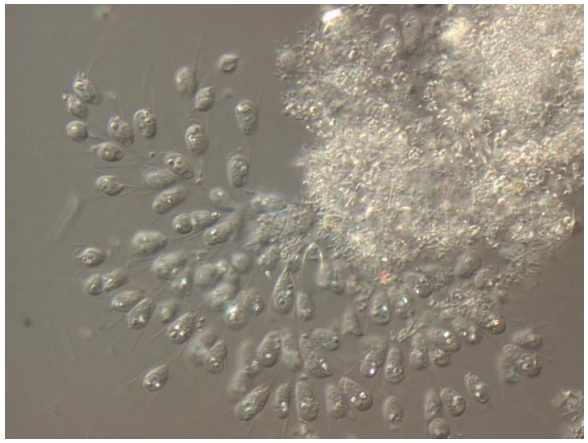


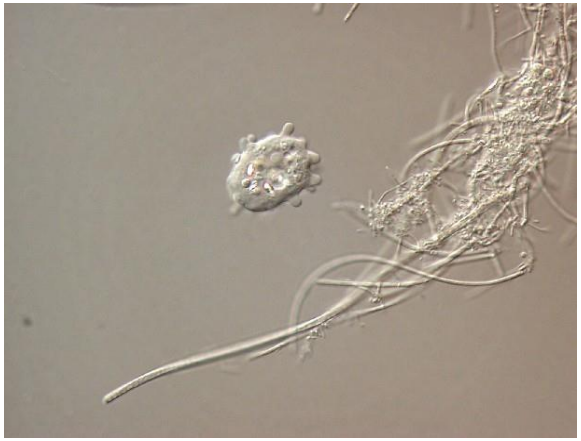
Amount of food
Amount of oxygen
Temperature
...



What organisms live in the activated sludge system?

- Protozoa: eat the flock forming bacteria and particular organic pollution
- Used as indicator organisms for the quality of the environment

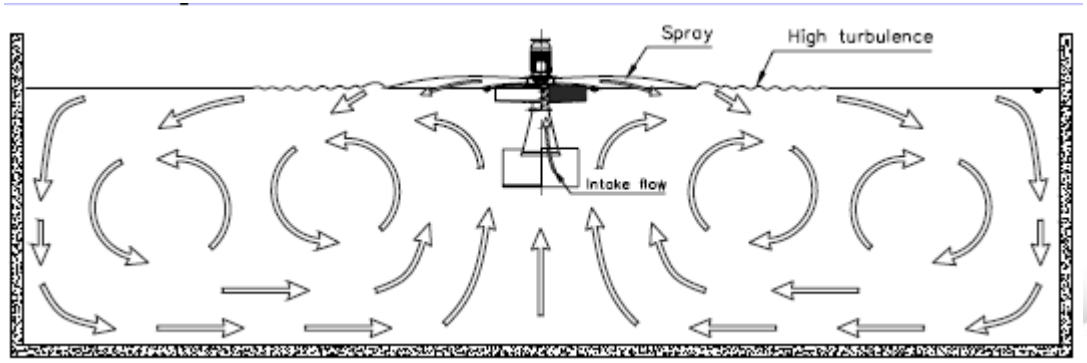




Aeration

Surface aeration

- **Aeration of the water is a critical process**
  - Keeps the process going on
  - Major part of energy consumption



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Aerator systems
Fine bubble aeration

Sludge separation

- Two main types of sludge separation
- Classic system : settling tank
- Newer installations : membrane system

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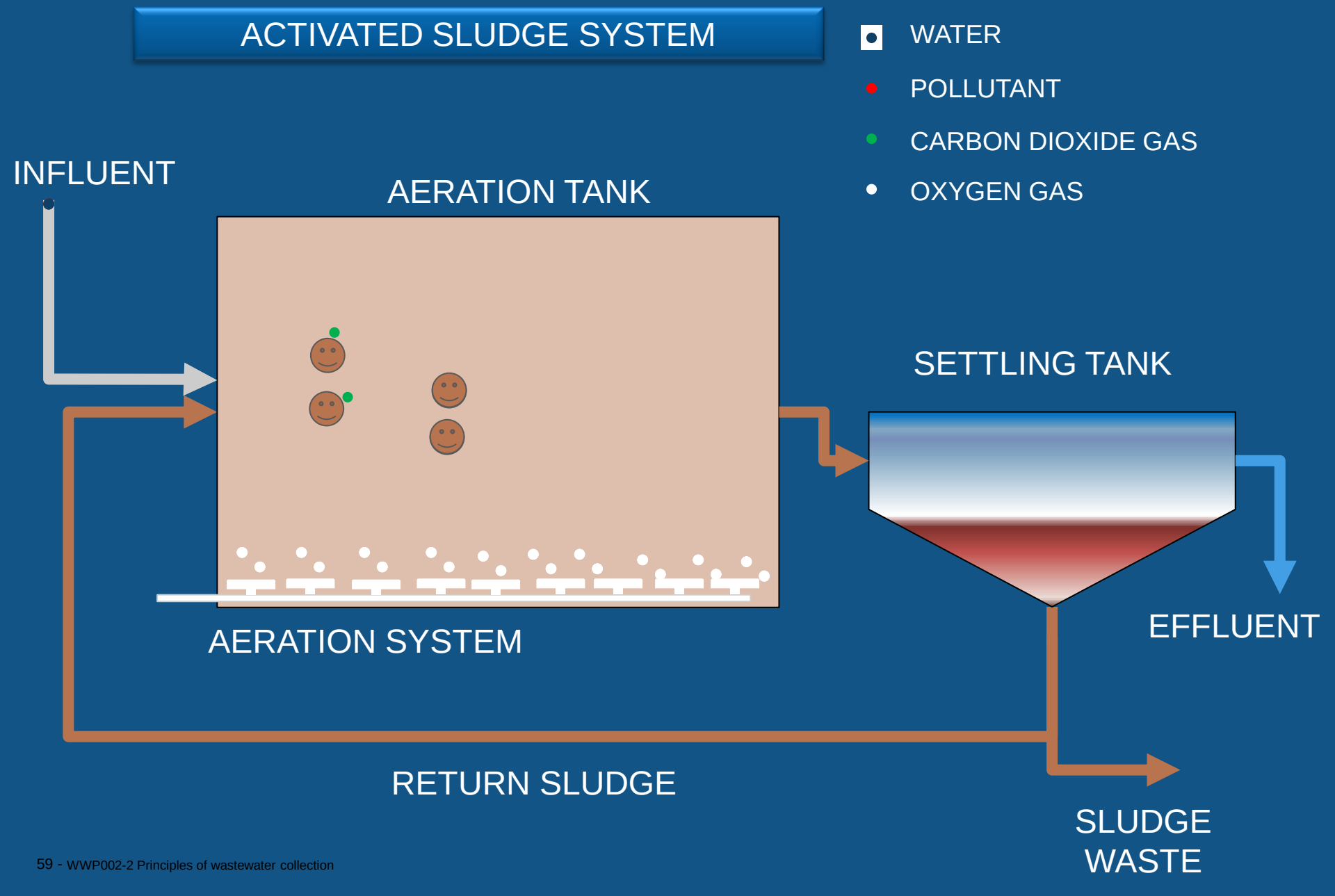
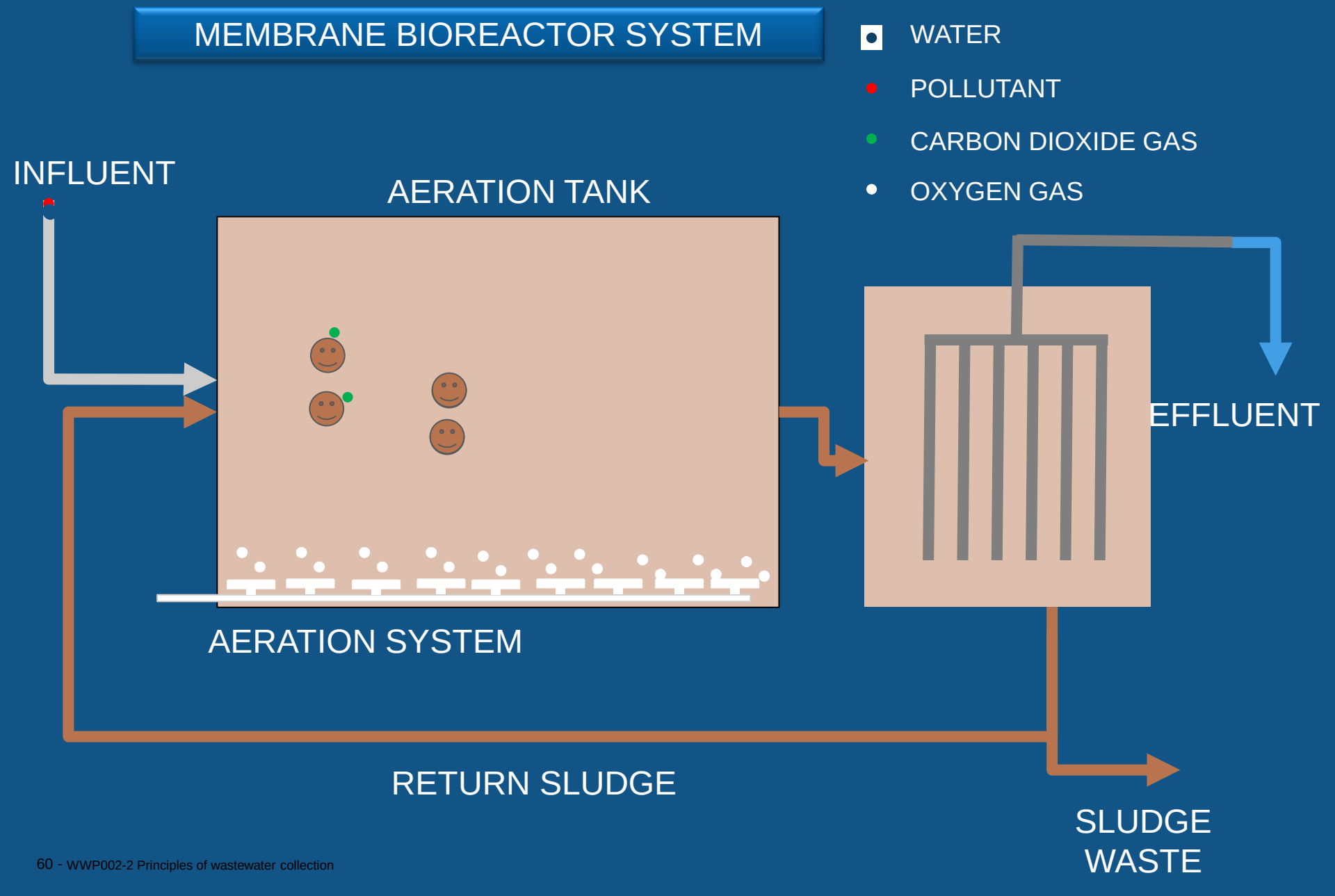
Lay out of a biologicial wastewater treatment plant



Lay out of a biologicial wastewater treatment plant



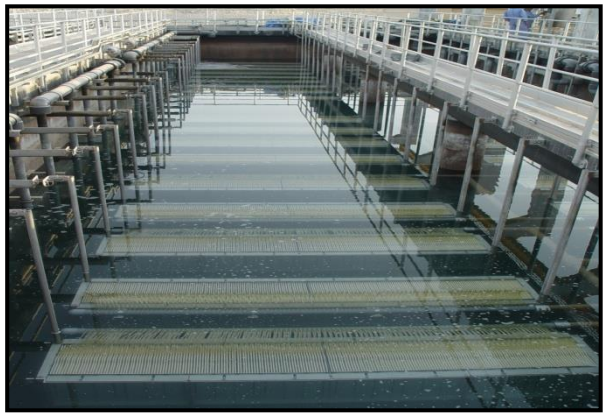
Membrane system

Sludge separation

System with settling

- Sludge separation from effluent by settling
- Technically simpler system
- More settleable solids in the water

Membranes in MBR



- Sludge separation from effluent by filtration
- Technically advanced system
- High quality water : very low settleable solids in the water

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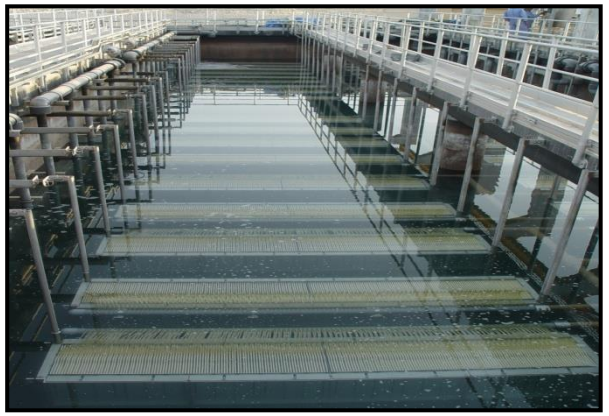
Sludge separation

System with settling

- Key parameter : sludge settleability
- More space needed
- Most of the times lower investment cost
- Low operational cost

Membranes in MBR



- Sludge separation from effluent by filtration
- Reduced footprint
- High investment cost
- Important operational cost

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What is done during post or tertiary treatment?

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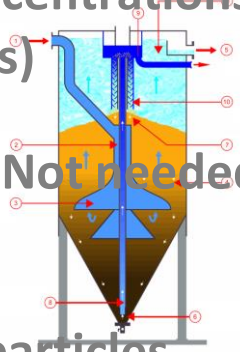
Sand filtration

- Used for removing low concentrations of remaining particles (normally small sludge flocs)
- Used after a settling tank. Not needed after membrane separation
- Sand is used to retain the particles



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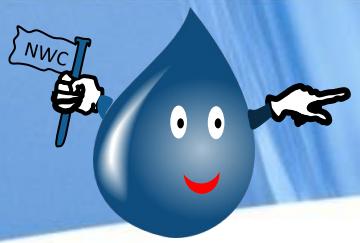

Disinfection

- After the biological process, bacteria and other micro-organisms are present in the water in small amounts.
- This poses little problem when discharged into surface water.
- However care should be taken when water is re-used for irrigation
- Basic process: chlorination
- Less chemicals needed in case of membrane system compared to settling tank

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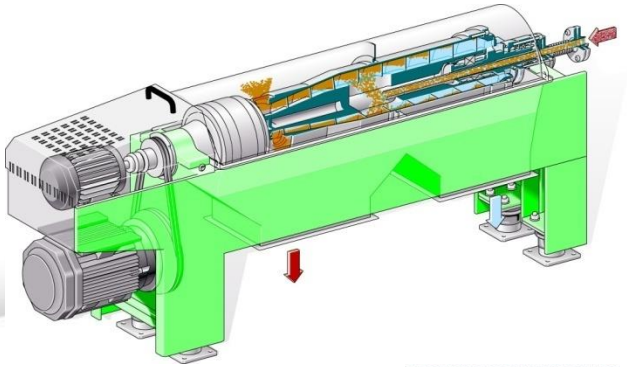
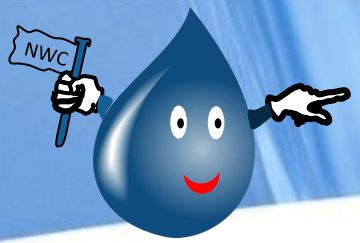
What do we do with the wasted sludge?





Different types of sludge...

Primary treatment

Primary sludge

- Contains original pollutants
- Treated as waste

Secondary treatment

Secondary sludge

- Contains mainly the micro-organisms of the activated sludge system
- Treated as waste or re-used for land application

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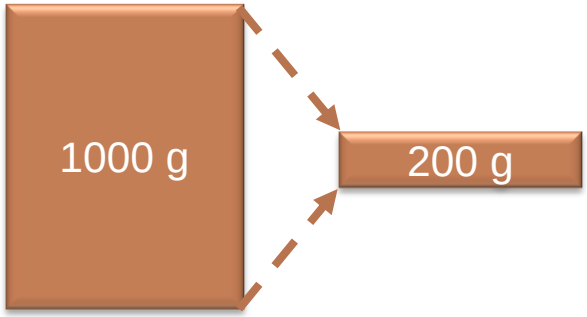
How many sludge is produced?

- 1 kg of organic pollutants in water results in about 200 g of sludge (dry matter)



During 1 year...

1 Person

55 m³ wastewater

37 kg organic pollution

8 kg sludge

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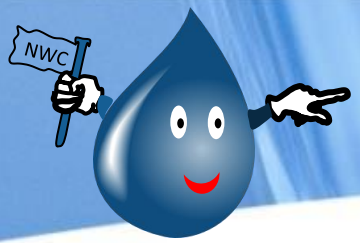

What is the goal of sludge treatment on-site?

- The main goal is to reduce the volume of the wasted sludge
- Most of the treatment plants use thickening and dewatering

100 m³ from settling tank	1% Dry matter
Thickening	
25 m³ from thickener	4% Dry matter
Dewatering	
5 tons of sludge	20% Dry matter

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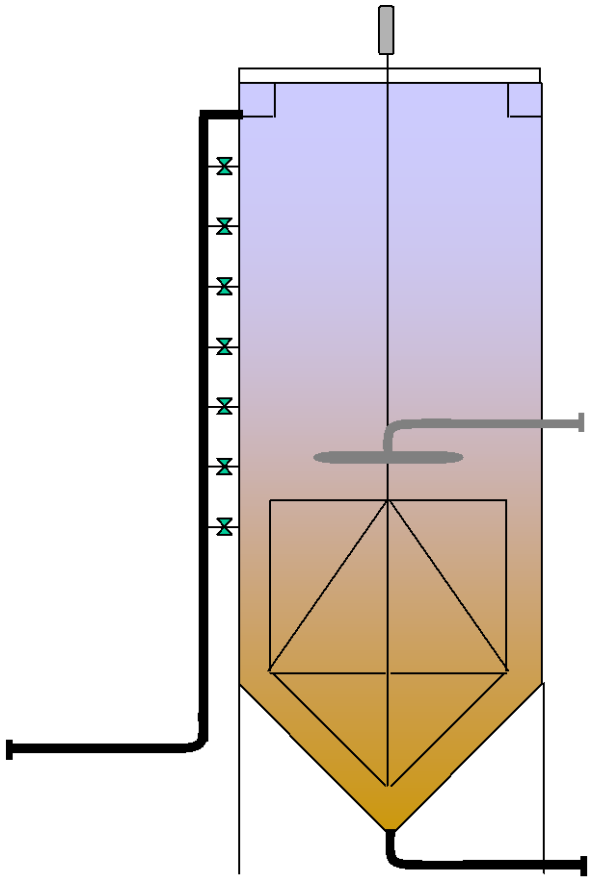
Thickener

- Static thickener: principle is settling during a longer period (1 day)



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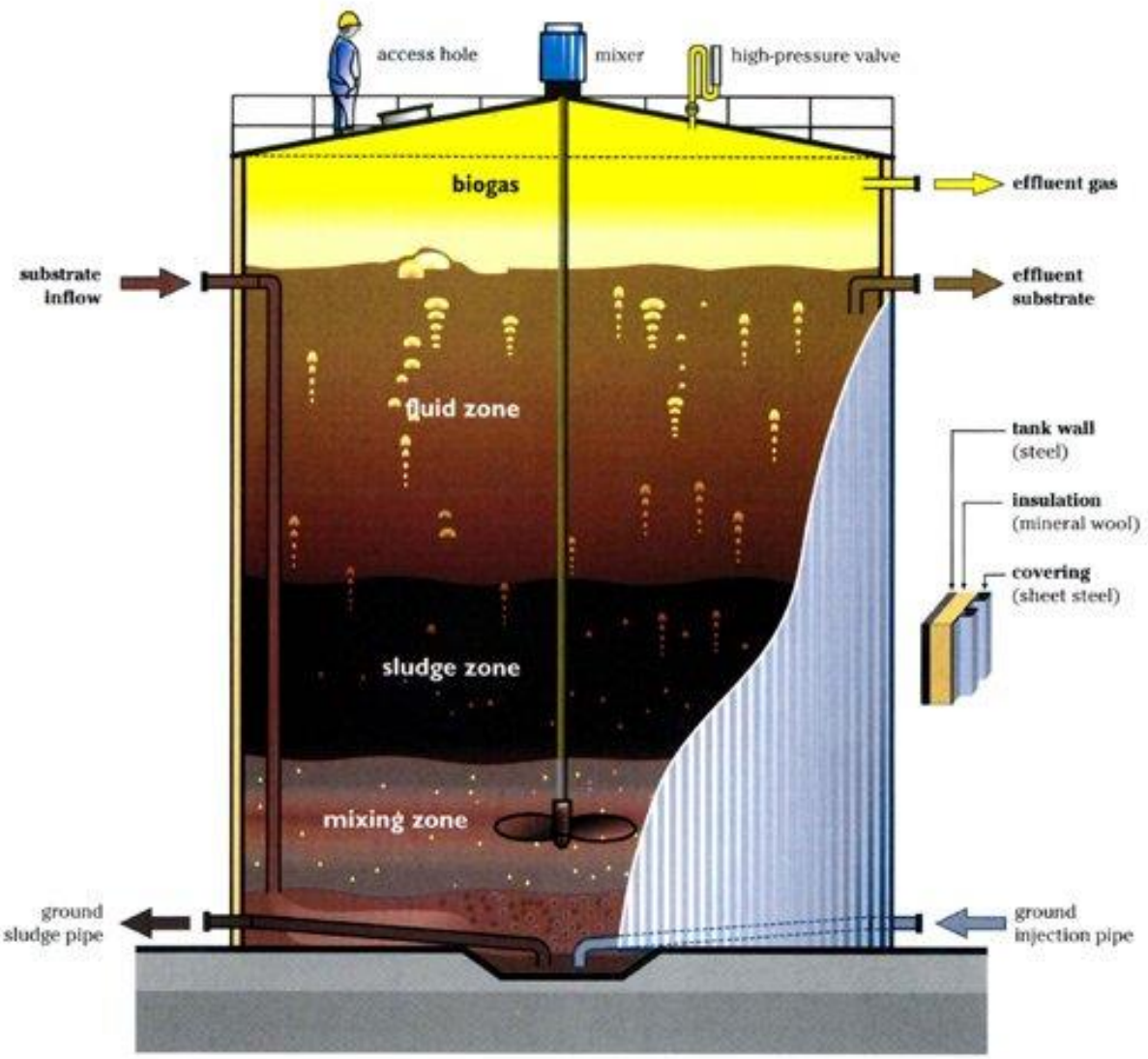
Sludge digestion : intermediate treatment

- **Intermediate treatment: sludge digestion**
  - Biological degradation
  - Anaerobic (without air)
  - Methane production : energy source



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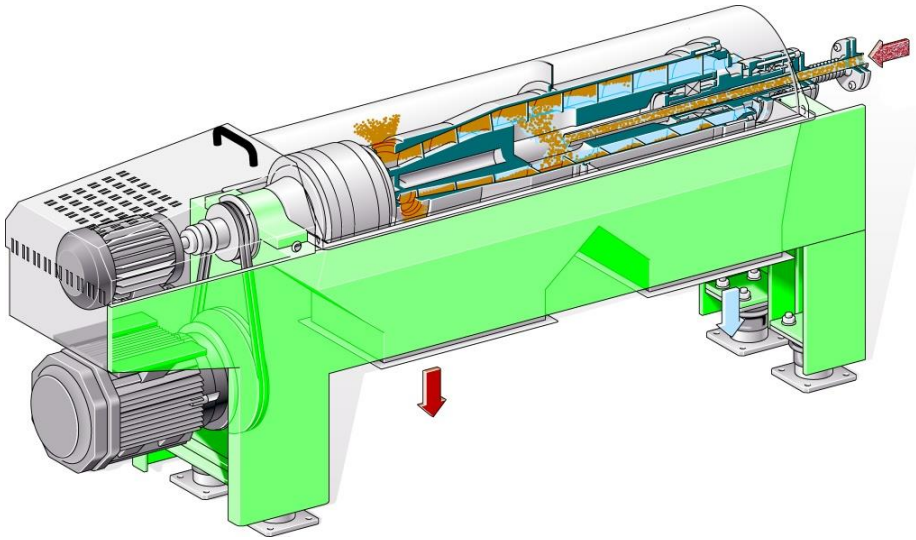
Dewatering

- Uses pressure or centrifugal forces to separate the water and the sludge
- Three main techniques :
  - Centrifuge
  - Plate filter
  - Belt filter



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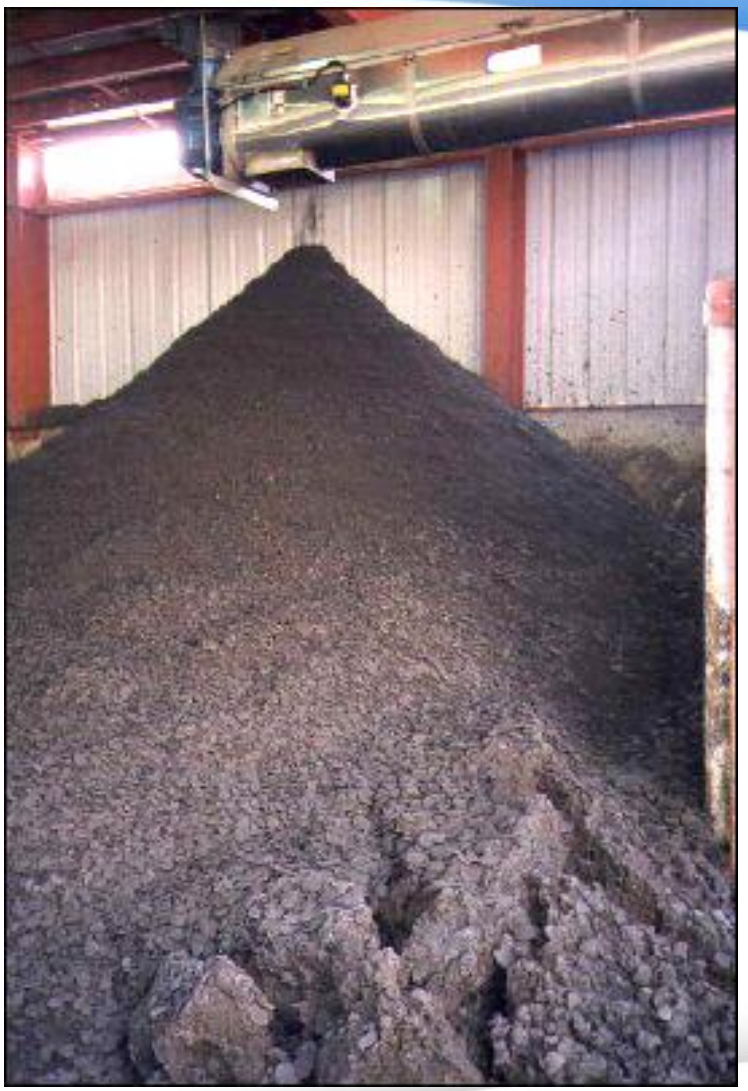
Dewatered sludge



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What happens with the sludge after treatment?

FINAL DESTINATION

- Drying and incineration

- Landfill

- Reuse : land application

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Why land application?

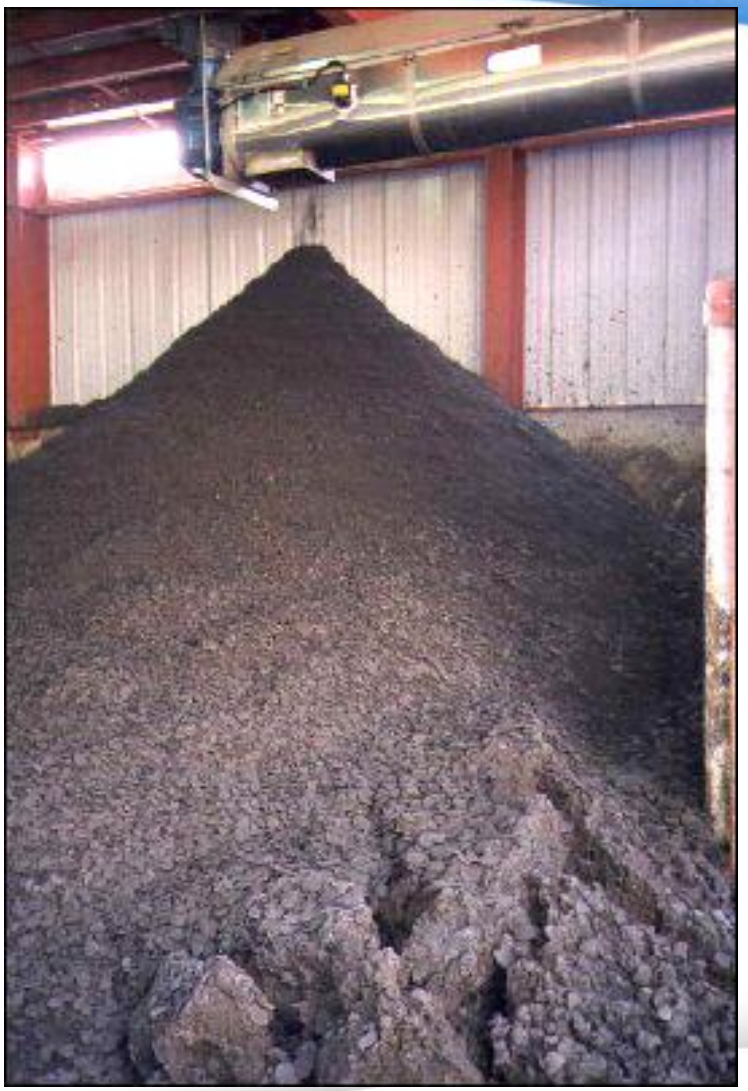
- **Sludge contains :**
  - organic matter from bacteria : serves as a soil conditioner (compost)
    - improves water holding capacity of the soil
    - improves air exchange
    - improves mineral holding capacity of the soil
  - nutrients : nitrogen and phosphate
    - slow fertilizer
    - improves plant growth

What are the risks of land application?

- **Some pollutants accumulate on the sludge**
  - Heavy metals and some other compounds are toxic and easily adsorb to the sludge
  - They accumulate in the soil
  - May be harmful for living organisms or can re-enter the food chain

What are the risks of land application?

- **Sludge = micro-organisms**
  - Bacteria, viruses, ... may survive
  - Harmful for people coming in contact with the sludge
  - Can contaminate vegetables and return in the food chain



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What do we do
with the off gasses?

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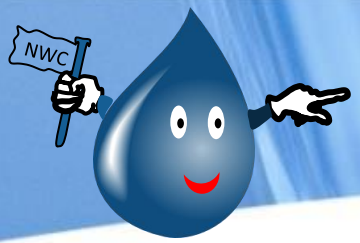

Off gasses and odour problems in a WWTP

- **Where do odour problems come up?**
  - All places where untreated wastewater comes in contact with air
    - pumping and lifting stations
    - inlet constructions, aerated balance tanks
    - pre-treatment
  - Aerated tanks : when the treatment process functions well : no odour problem
  - Sludge treatment : when sludge is stored, digestion starts and odour problems may arise again
- **How can odour problems be treated?**
  - Washing off gasses in different steps : acid scrubber, alkaline scrubber, scrubber with oxidizing substances
  - Activated carbon
  - Biofilter

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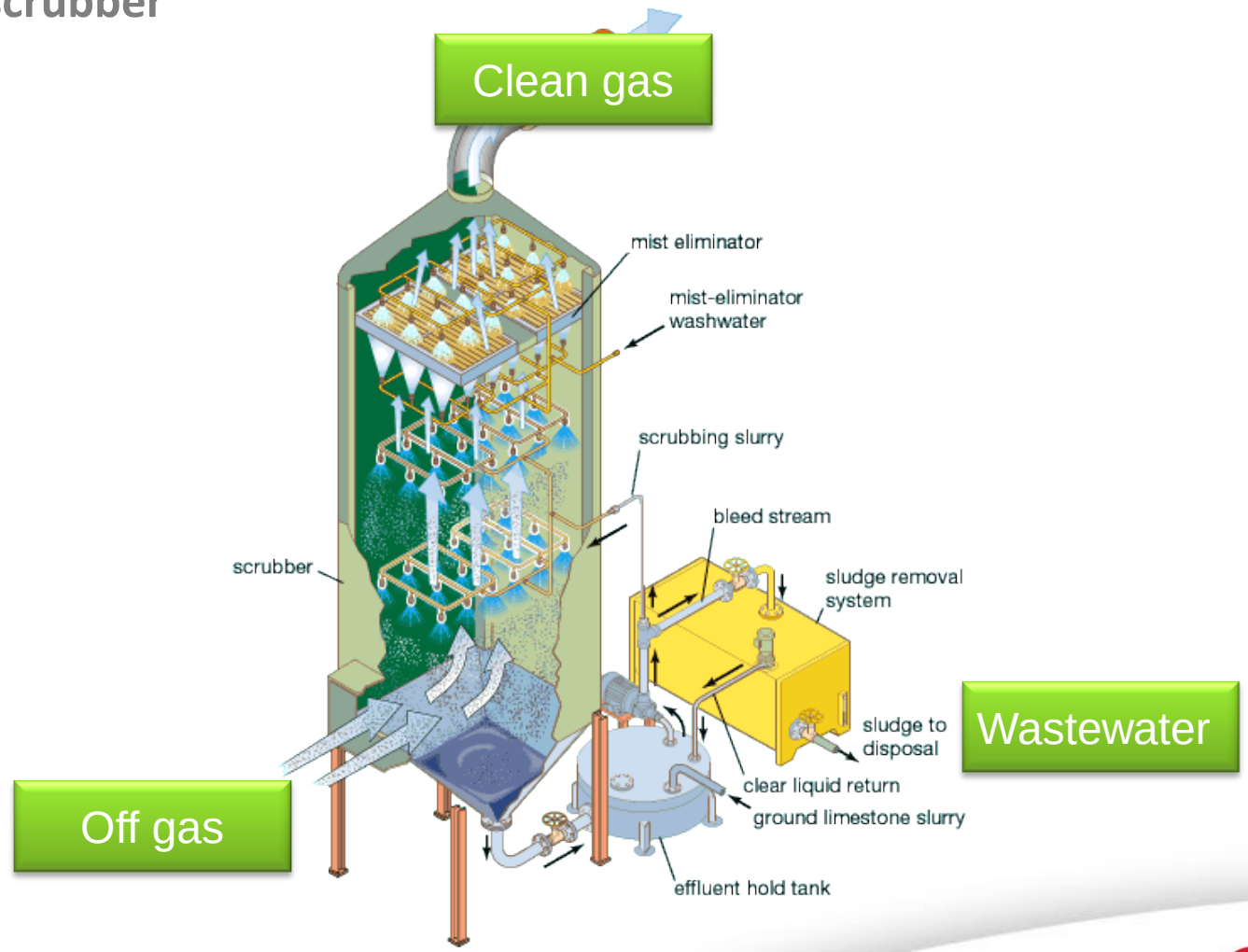
What do we do with odour off gases?

- Gas scrubber



Odour treatment by air scrubber

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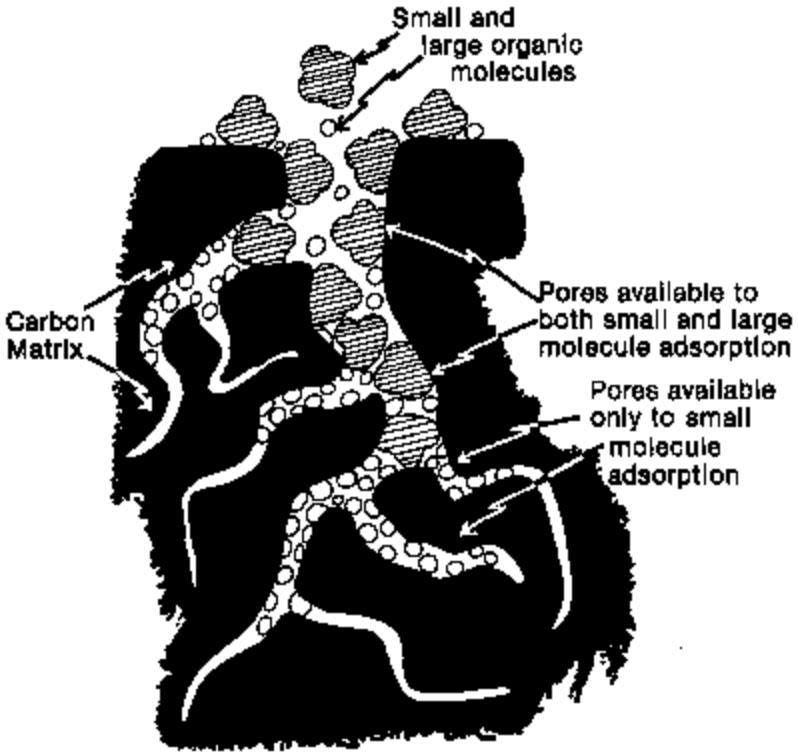
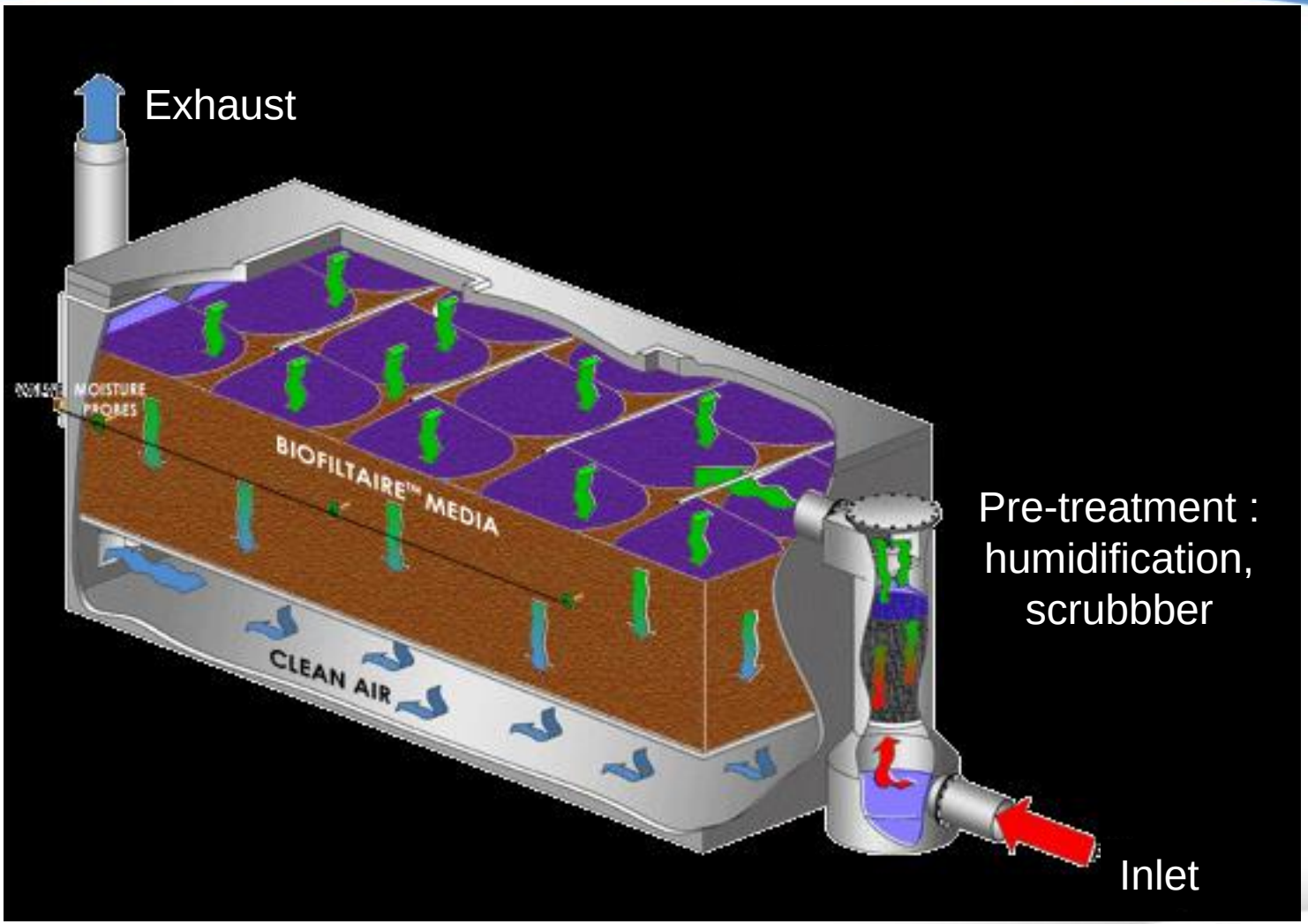
Odour treatment by carbon adsorber



Odour treatment by biofilter



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Odour treatment by biofilter

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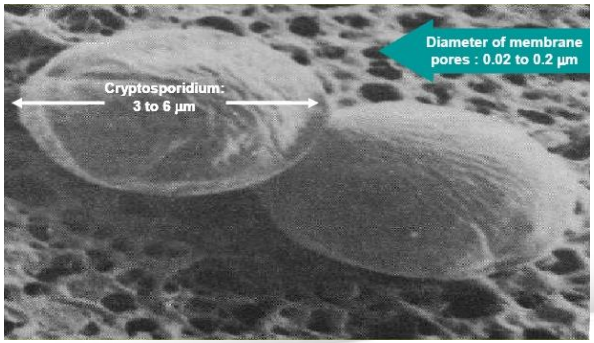
What is the final destination of the treated water?



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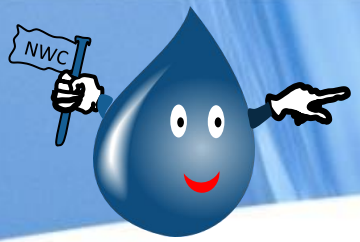

The quality of treated water

- **Wastewater treatment processes are not 100% efficient**
- **The effluent contains still some pollutants**
  - Salts in the water were not removed, and even salts may have been added
  - Small amounts of organic pollution is present in the water
  - Small amounts of nutrients (nitrogen and phosphate) are present
  - Small amounts of metals and toxic compounds can be present
  - Micro-organisms from the treatment process or from the raw wastewater
- **What is the final destination?**

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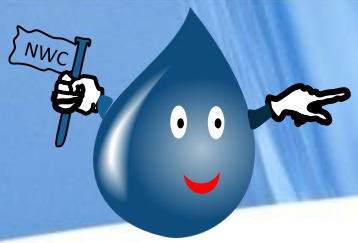

Final destination of water

Treated effluent

Discharge in natural eco-system

Re-use after disinfection for irrigation, construction

Re-use after further treatment : high quality water for industry and public consumption

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Final destination of water : discharge in the natural environment

- **Water enters the natural water cycle again**
- **Discharge standards to protect the natural environment**
- **Examples for new plants :**
  - Biodegradable organic matter < 15 mg/L (BOD)
  - Suspended solids < 15 mg/L
  - Nitrogen < 15 mg/L

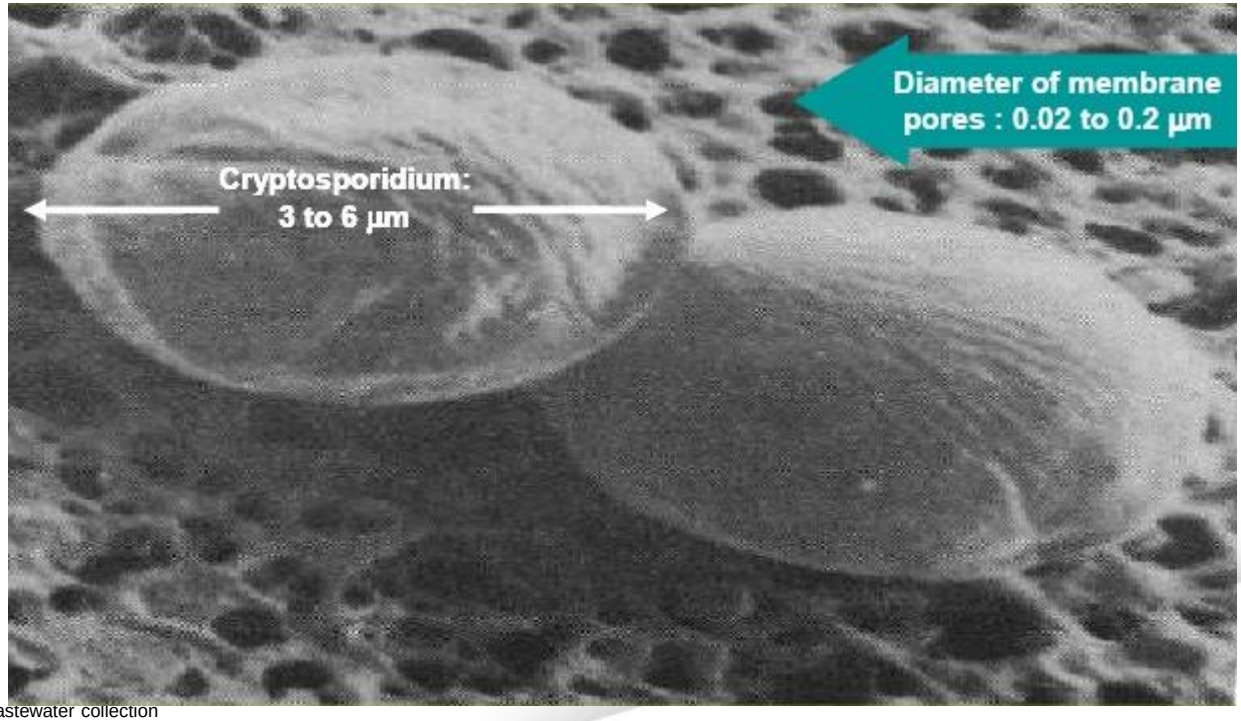
Final destination of water : irrigation

- Irrigation for plant growth
- Mainly in arid regions
- Gardens / crop growth
- Disinfection needed to reduce risks for human health
- Remaining impurities should be low

Drip irrigation

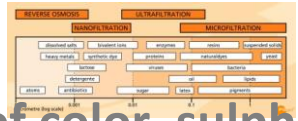
Water reuse: membrane technology

- **Water is forced through a selective membrane by pressure:**
  - All pollutants larger than the pore size are removed
  - No chemicals needed
  - Different types of membranes have different pore sizes
  - Separation in a clean water flow (permeate) and concentrate flow



Water reuse: different types membrane technology

- **Microfiltration:** Clarification treatment, microbial removal, water reuse
- **Ultrafiltration:**



- **Nanofiltration:** Removal of color, sulphates, nitrates, micropolluents
- **Reverse osmosis:** Desalination, water reuse, process water treatment

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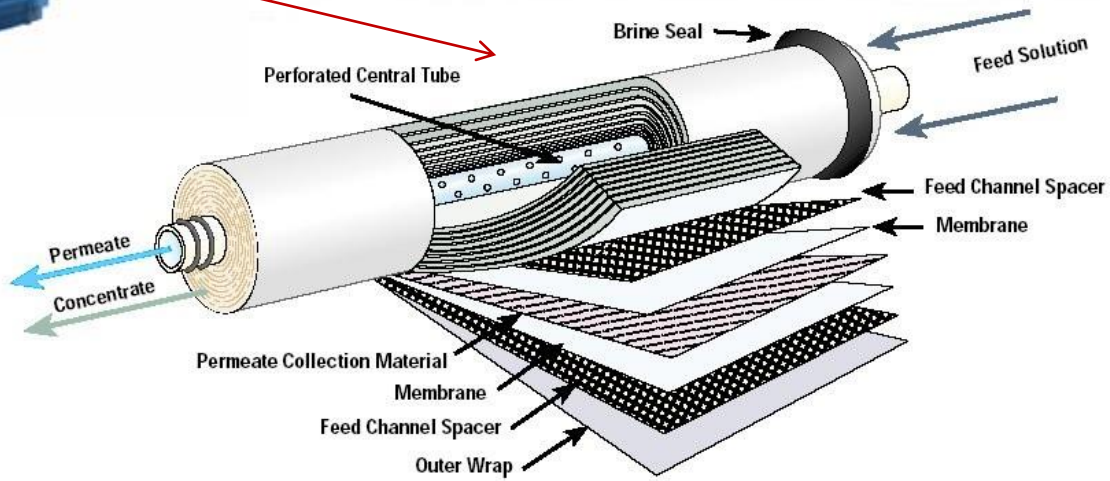
Water reuse: membrane technology



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