Aalto University
School of Engineering

Water and wastewater treatment

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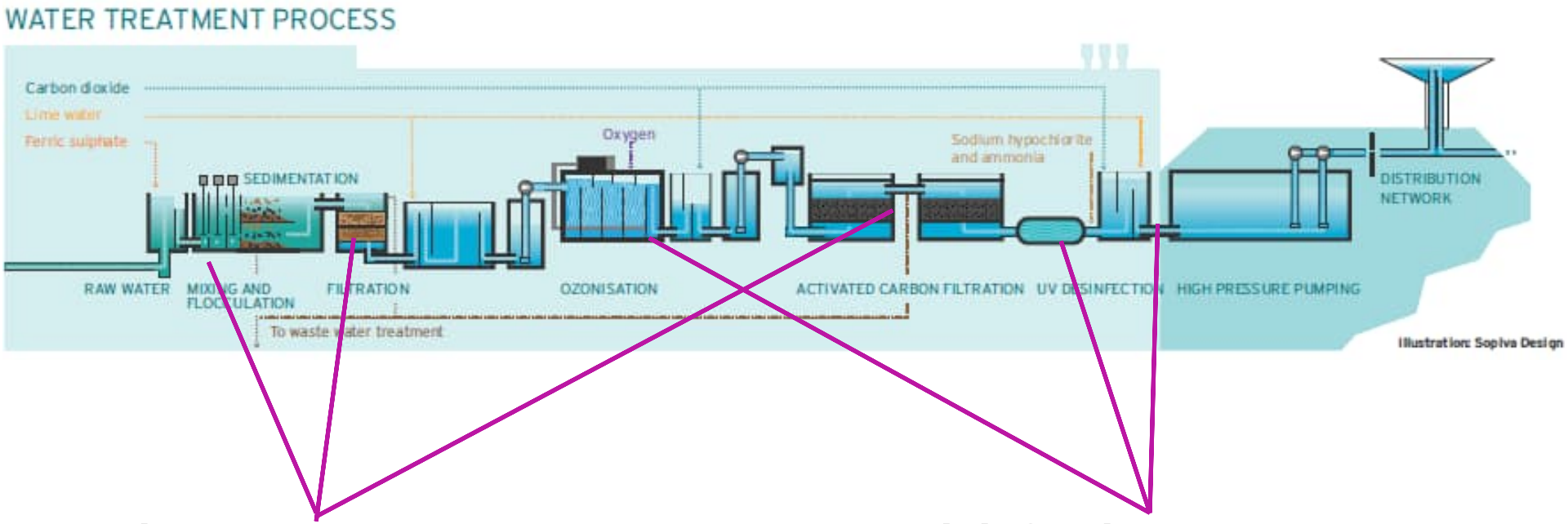
Why do we need good quality water?

- **Human health impacts**
  - Long-term health effects
  - Waterborne diseases from microbiological contamination
- **Food production needs**
  - Animal farming
  - Food processing industry
  - Irrigation
- **Industrial needs**
  - Varying requirements for quality

What and why do we typically treat?

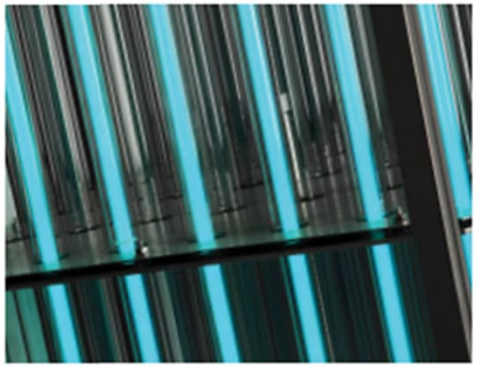
Raw water sources	
- Groundwater or Artificial groundwater/bank filtration	Iron and manganese pH, corrosivity Pesticides Other persistant organic micropollutants (Microbiological quality)
- Surface water (lake or river)	Natural organic matter Taste and odor Turbidity and color Microbiological quality
- Sea water	Desalination

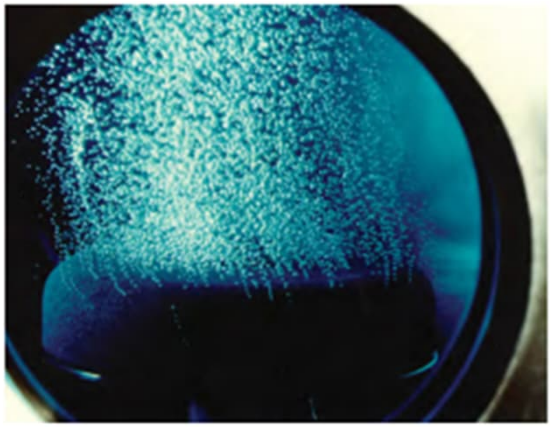
Multi-barrier approach in drinking water production



Organic matter removal treatment steps **Disinfection treatment steps**

Examples of water treatment processes





Discussion in groups (10 min.)

You have all been drinking a lot water. Water is treated very differently in Espoo, in your summer cottage and e.g. in Berlin. What do you know about the purification processes of the water that you drink in different places?

Sometimes water receives a lot of treatment and sometimes very little?

What do you prefer? And why?

Why do we treat wastewater?

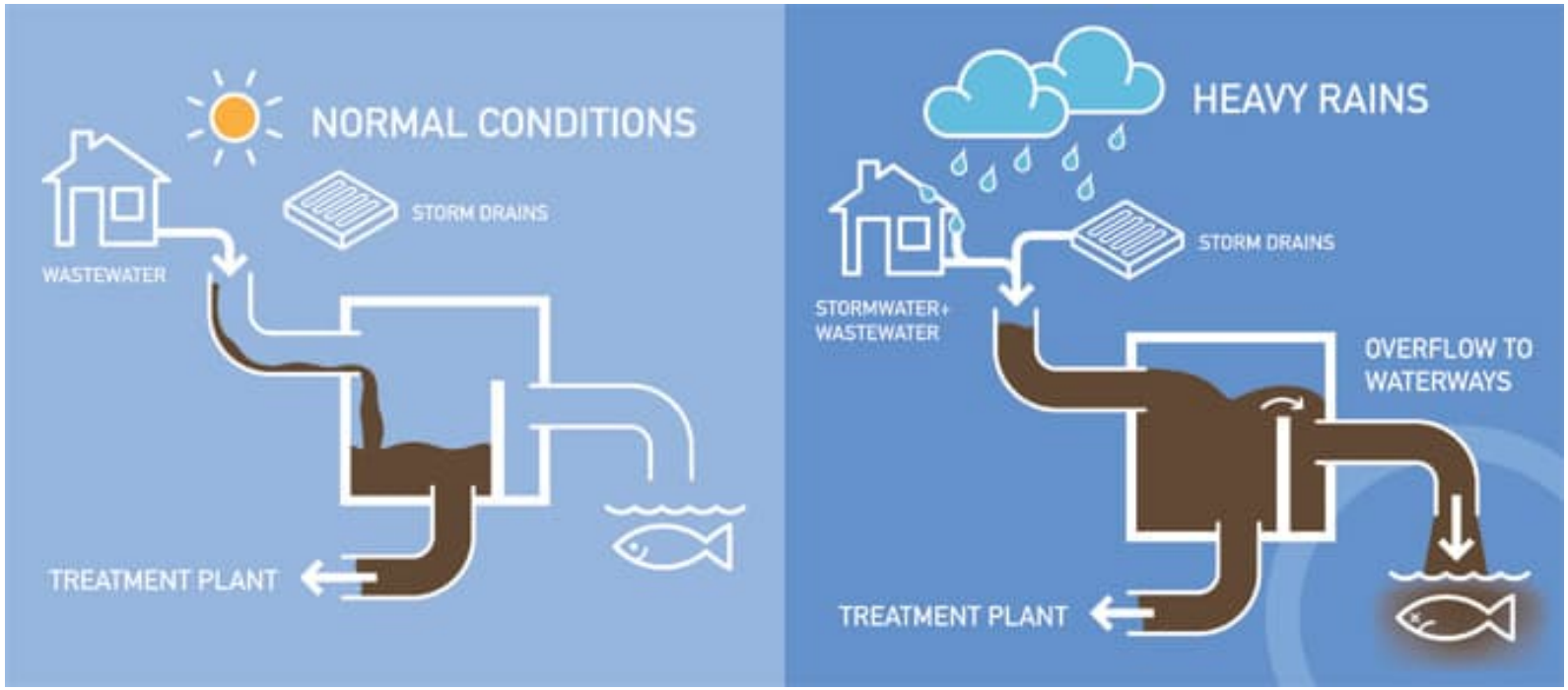
- **Improve public health and safety**
  - Decrease of pathogenic microbes
- **To avoid the negative effects in the receiving water body**
  - Oxygen depletion
  - Eutrophication
    - *Nitrogen and phosphorus*
    - *Limiting nutrient*
  - Toxic substances e.g. heavy metals, micropollutants
  - Microplastics
- **To recover valuable resources**
  - Energy
  - Nutrients
  - Water
- **Requirements from the legislation**
  - Waste framework directive ”polluter pays”
  - Water framework directive
  - (New) urban wastewater treatment directive

Quality of wastewater

- **Households and services**
- **Industries**
- **Rural areas (loading to the WWTP from septic tanks)**
- **Rain and storm water**

- **Everything you put to the sewer system ends up in the wastewater treatment**
  - Feaces, urine
  - Paper, fiber, plastic
  - Food waste (grease, carbohydrates, proteins, sugars)
  - Drogs, solvents, cleaning agents, beauty products
  - Heavy metals, toxic compounds,...

Combined sewer overflow



http://wayworks.net/illustration/tech_illus_06b.jpg

What are the advantages and disadvantages of separate and combined sewers?
Discussion in groups 10 min.
Wrap-up 5 min.

BREAK 10 min

Current requirements for wastewater treatment (PE > 10 000)

EU minimum requirements (will be soon updated)

Nitrogen >70%
Phosphorus >80%, <1,0 mg/l
Suspended solids <35 mg/l
BOD >70%, <30 mg/l
COD >75%, <125 mg/l

Environmental permit typically in Finland

Nitrogen >70%
Phosphorus >95%, <0,2 - 0,3 mg/l
Suspended solids <15 mg/l
BOD >95%, <10 mg/l
COD >80%, <75 mg/l

BOD = Biological oxygen demand
COD = Chemical oxygen demand

Suggested requirements in the new urban wastewater treatment directive

- **More stringent requirements for nitrogen and phosphorus removal**
  - Impact in Finland: P no impact, N big impact
- **New requirements for removal of pharmaceuticals**
  - 80% removal of selected compounds
  - Extended producer responsibility – principle introduced to finance the upgrades
- **Energy neutrality in wastewater treatment**
  - Energy audits
  - Gradually 100% of energy consumption produced by wastewater resources or other renewable sources
- **Enhancement of water reuse**
  - Mainly for irrigation

Development of the wastewater treatment

1900 1920 1940 1960 1980 2000 2020

Solid removal, hygienic quality

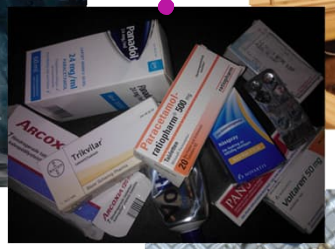
Nutrient removal

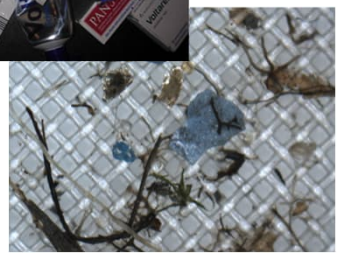
Micropollutants
Microplastics

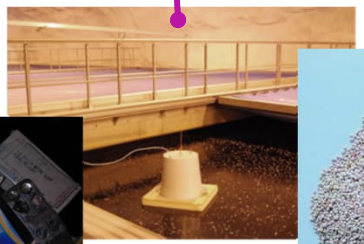
GHG emission control

Resource recovery

Water reuse







The basic principle of wastewater treatment

- Suspended solids →
- Colloidal matter →
- Soluble matter

- Mechanical treatment
- Chemical treatment
- Biological treatment

- Nutrients mainly soluble
- Phosphorus removal biologically or chemically by precipitation
- Nitrogen biologically
- Micropollutants & water reuse: different biological and chemical treatment processes; similar processes already in use in drinking water treatment

Emerging needs in water and wastewater engineering

- **Removal of micropollutants**
- **Resource recovery**
  - Nutrients
  - Energy
  - Water reuse
- **Global warming mitigation and carbon sequestration**
- **Circular economy implementation**
  - Leakage and waste minimization
  - Use of recycled chemicals and materials
  - Production of different products from wastewater (bioplastics and other biopolymers,...)

Removal of micropollutants

- **Removal of pharmaceuticals**
  - Enhancement of existing biological processes
  - Advanced oxidation processes
  - Activated carbon treatment

- Mitigation of antibiotic resistance risk

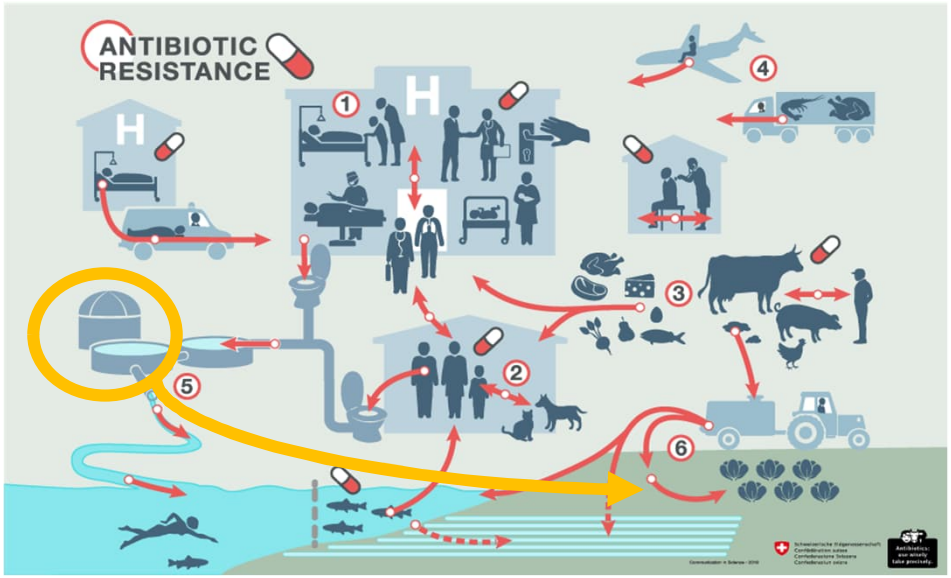
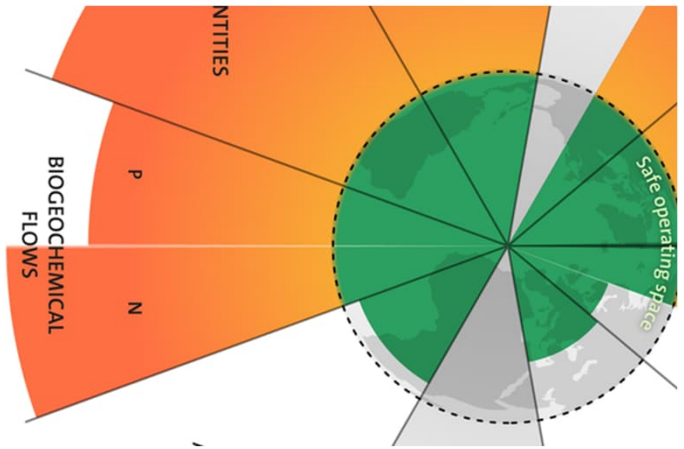


Figure: FOPH, https://www.use-wisely-take-precisely.ch (29.4.2022)

Nutrient recovery

- **Nutrient recovery can replace 40% of the mineral fertilizers for phosphorus and 6% for nitrogen**
- **P classified as a critical resource in 2014 (EU) but Russian attack in Ukraine woke us up about the benefits of local nutrient recycling**
  - *Food prices are volatile in politically unsteady world*
  - *Most of the P and N are imported to Europe*
- **China, Russia, the US and India produce most of the world's ammonia with mainly fossil resources**
  - *Significant contribution to climate change through fossil Haber-Bosch*



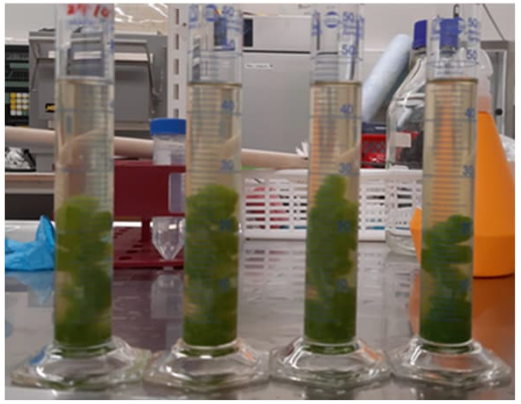
Planetary boundaries are exceeded!

Examples of solutions for nutrient recovery

- **NPHARVEST**
  - A process developed in our research group
  - Recovery of nitrogen based on selective gas permeable membrane
  - Recovery of phosphorus based on ballasted sedimentation with calsium

- **Phosphorus recovery as vivianite**
  - Suitable for processes where iron is dosed to remove phosphorus

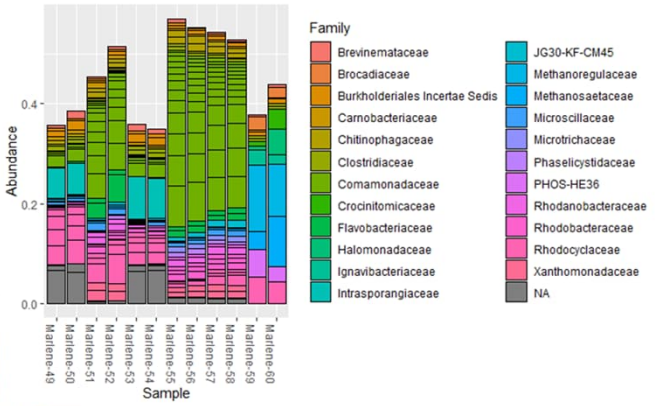
- **Nutrient recovery using algae**



Energy carbon neutrality in water and wastewater sector

- **Energy consumption optimization**
  - Aeration monitoring
  - Advanced process control
- **Energy production optimization**
  - Heat recovery
  - Optimization of the carbon balance

- **Direct greenhouse gas mitigation**
  - Nitrous oxide and methane emissions



DIGICARBA research project

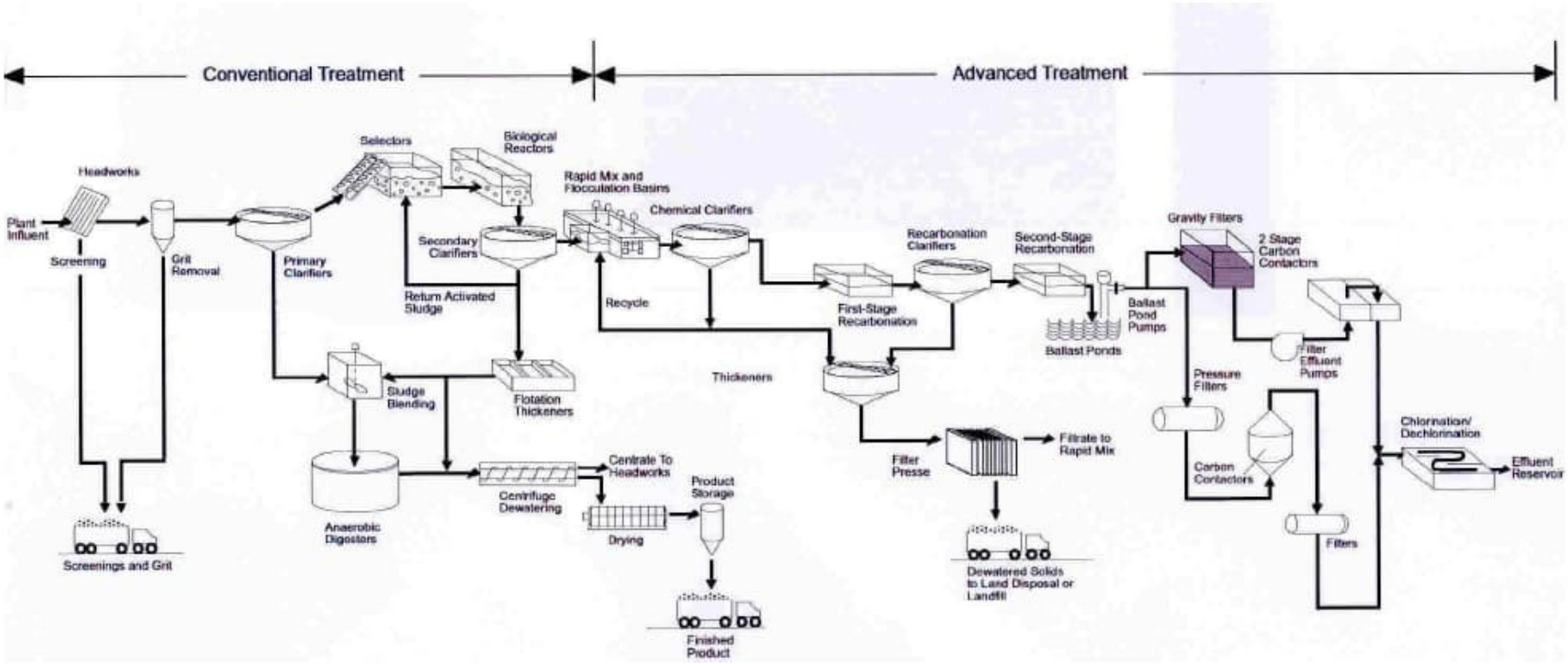
aims to mitigate greenhouse gas emissions and assist wastewater treatment process control.

Main contributors

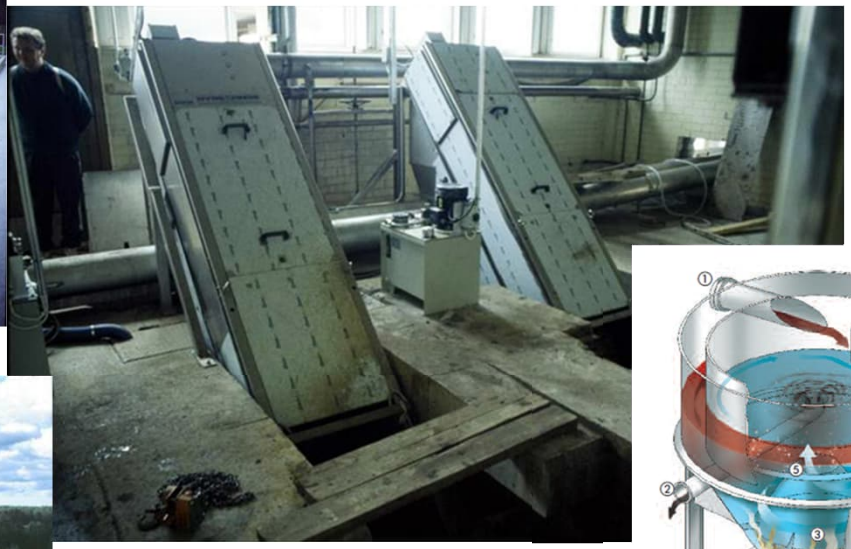
Digital twin development — Aalto University — HSY — End-user of digital twin Wastewater treatment process optimization

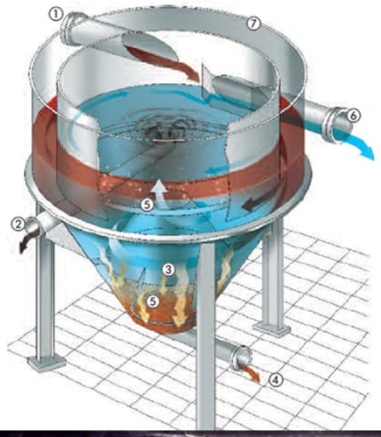
Example: Kalteva Hyvinkää

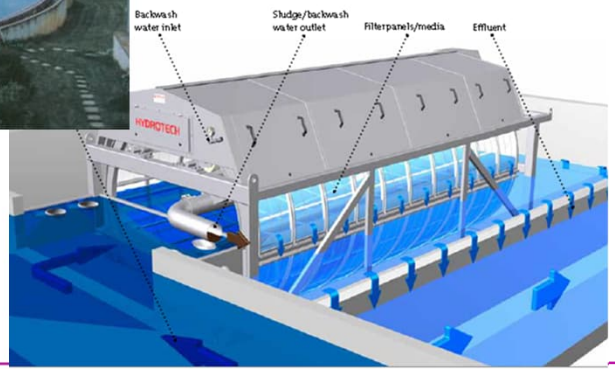
Example: UOSA WWTP



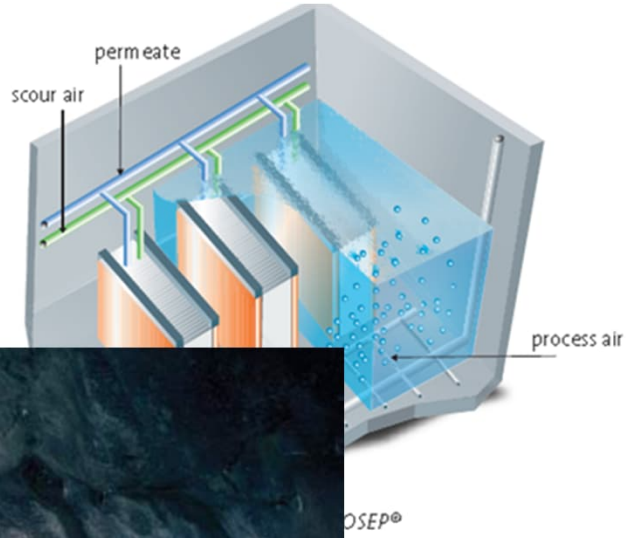
Examples of primary treatment processes

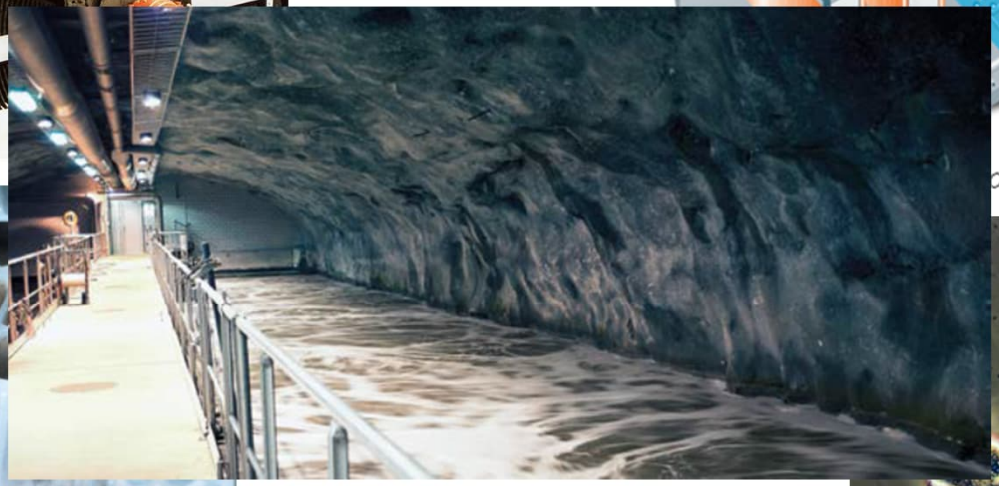


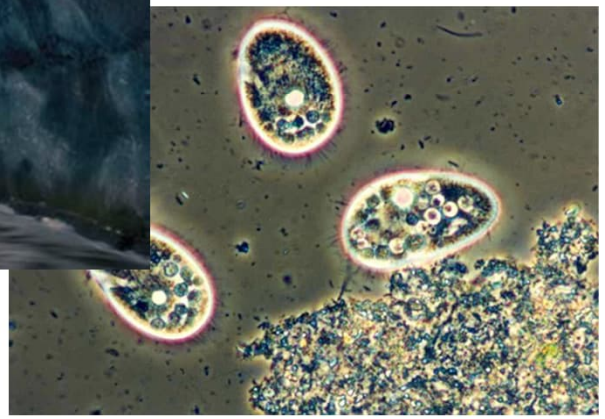




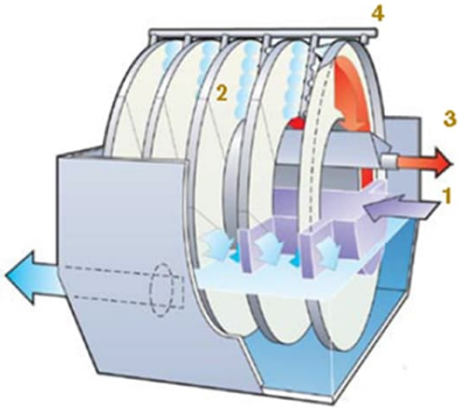
Examples of secondary treatment (biological treatment)

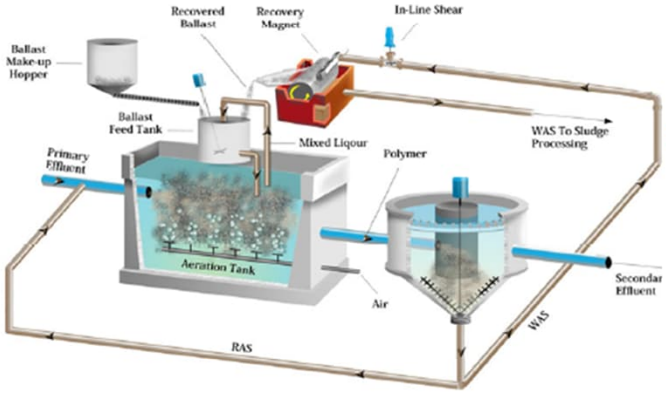


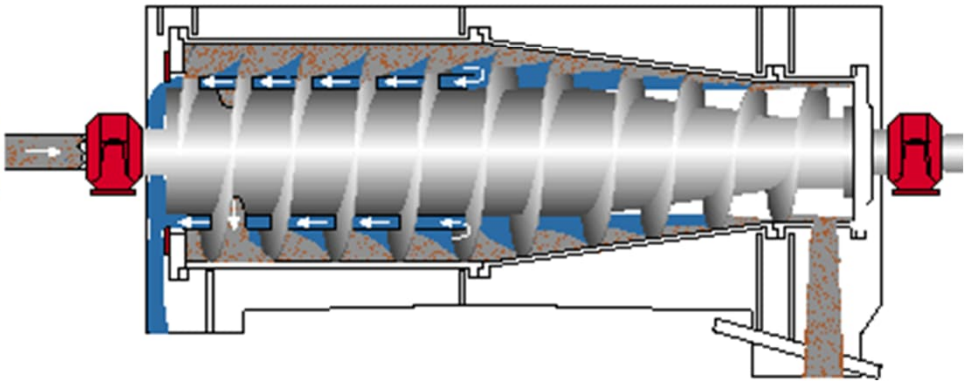




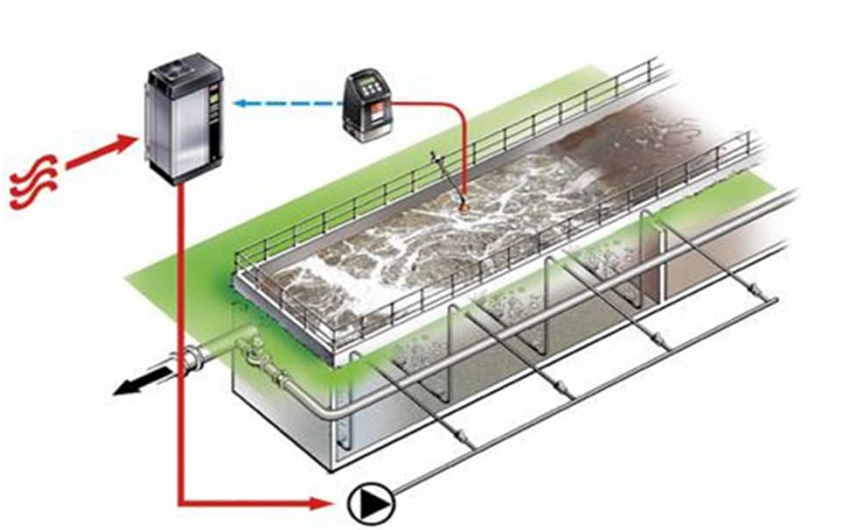
Examples of solid separation processes



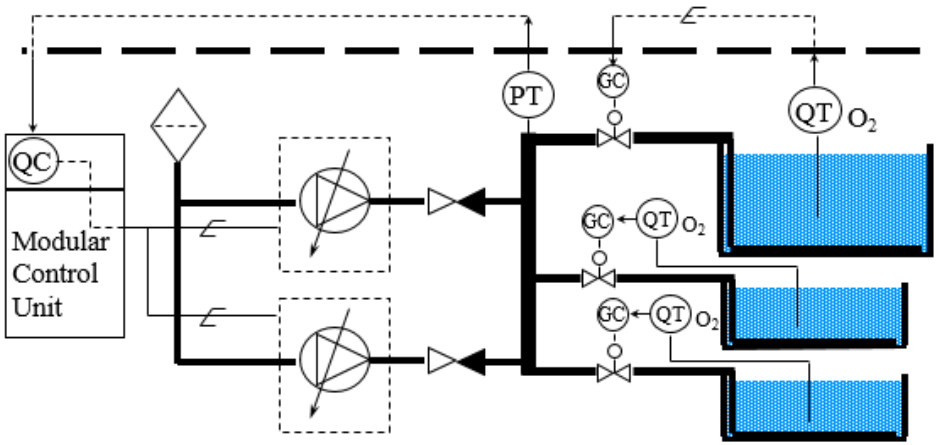




Process monitoring and control



Plant control automation



Water and wastewater treatment is a multi-disciplinary engineering task that saves human lives and protects the environment