Methods of pollution control and waste management

# Lecture 3

## Sewage (wastewater) treatment methods

# Categories of Sewage

Sewage is water carried waste in solution or suspension which should be removed. If consists >99 % of water is also called wastewater.

- Municipal Sewage
- Industrial sewage
- Agricultural
- Surface runoff (overland flow)

# Ingredients in typical municipal sewage

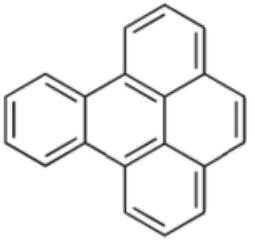
- Oxygen –demanding materials
- Sediments
- Grease
- Oil
- Scum
- Pathogenic bacteria
- Salts
- Nutrients
- Pesticides
- Heavy metals

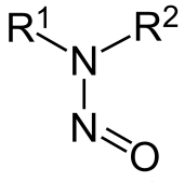
# General Categories of Sewage Pollutants

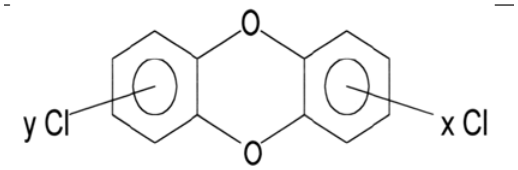
- Oxygen Demanding Waste (Biodegradable Organics)
- Disease Causing Agents (pathogens and parasites)
- Nutrients
- Synthetic Organic Compounds (SOCS)
- Inorganic Compounds and minerals (IOCS)
- Sediments
- Radiation
- Heat

# Non – biodegradable pollutants

- Heavy metals (Cd, Hg, Pb, Cr, Zn)
- Pesticides
- Polycyclic aromatic hydrocarbons
- Nitrosamines
- Radioactive elements
- Dioxins

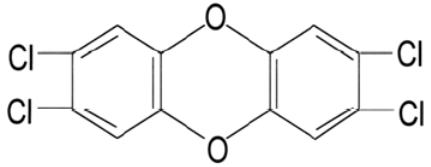





PCDD

Polychlorinated dibenzodioxins




2,3,7,8-tetrachlorodibenzo-*para*-dioxin (TCDD)

# Characteristic of sewage (wastewater)

- Biological oxygen demand BOD (j. pol. BZT)
- Chemical oxygen demand COD (j. pol. ChZT)
- Total solids TS
- Suspended solids SS
- Total phosphorus TP
- Total nitrogen TN
- pH

# Oxygen demanding substances in water

- Organic matter

$$CH_2O + O_2 \xrightarrow{\text{microorganisms}} CO_2 + H_2O$$

- Biooxidation of nitrogeneous material

$$NH_4^+ + 2\,O_2 \xrightarrow{\text{microorganisms}} 2H^+ + NO_3^- + H_2O$$

- Chemical oxidation of chemical reducing agents

$$4\,Fe^{2+} + O_2 + 10\,H_2O \longrightarrow 4\,Fe(OH)_3 + 8\,H^+$$

$$2\,SO_3^{2-} + O_2 \longrightarrow 2SO_4^{2-}$$

Unless the water is rearated efficiently is rapidly becomes depleted in oxygen and will not support higher forms of aquatic life.

# Biological (biochemical) oxygen demand (BOD)

- The parameter to measure organic matter content in water, the degree of oxygen consumption by microorganisms –mediated oxidation of contaminants in water. This parameter is information about purity of water.

very clean < 1mg/L ($O_2$)
fairly clean 1-3 mg/L ($O_2$)
doubtful purity 3-5 mg/L ($O_2$)
contaminated > 5 mg/L ($O_2$)
typical sewage 200-500 mg/L ($O_2$)

Analysis is done by adding appropriate heterotrophic microorganisms to a measured amount of water sample, saturating it with air, incubating for usually 5 days ,and then determining the oxygen that remains in the water ( change in pressure or electrochemical measurements).

# Chemical oxygen demand (COD)

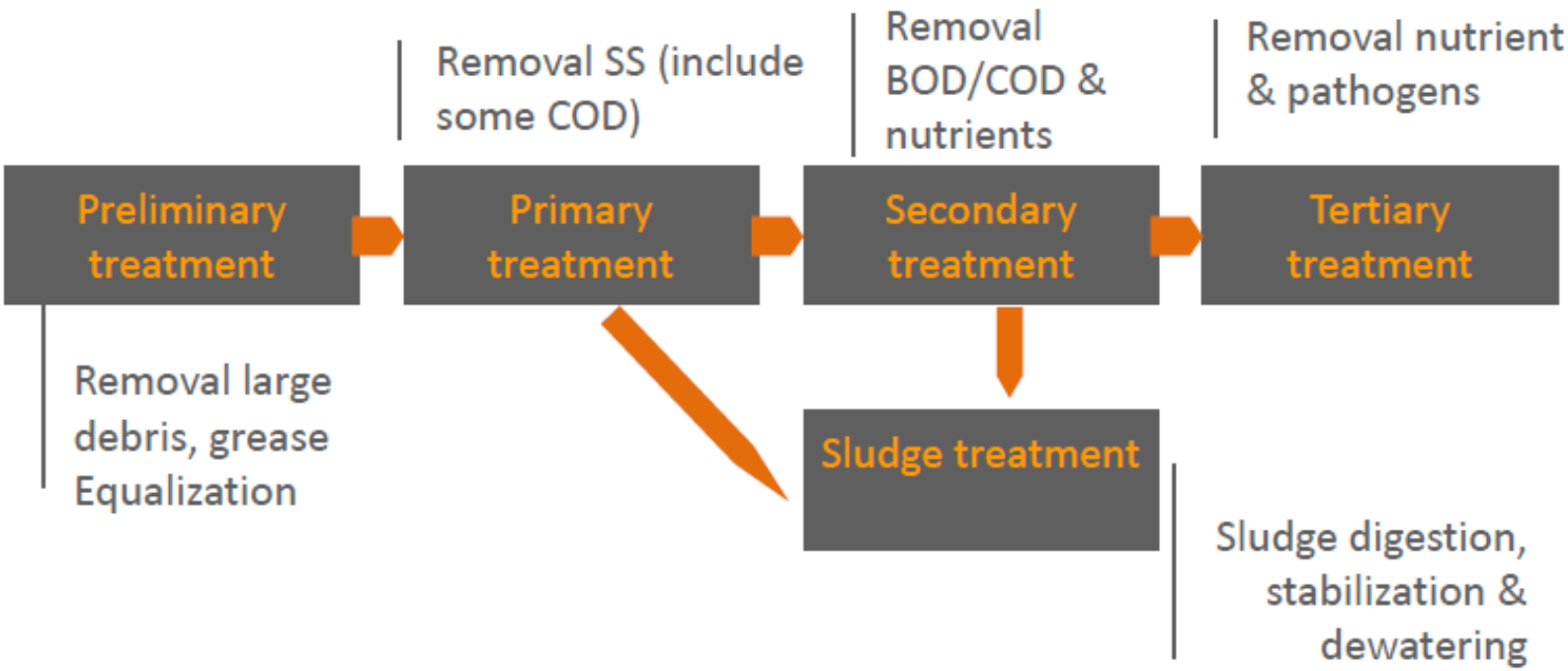
- The degree of oxygen consumption determined by oxidation of contaminants in water by chemical oxidant e.g. acidified potassium dichromate (with addition 50% $H_2SO_4$).

$$3\ CH_2O + 16\ H^+ + 2\ Cr_2O_7^{2-} \longrightarrow 4\ Cr^{3+} + 3CO_2 + 11\ H_2O$$

After oxidation material in water the unreacted dichromate is determined by titration with standard reducing agent.

Another oxidant used in COD determination is potassium permanganate $KMnO_4$

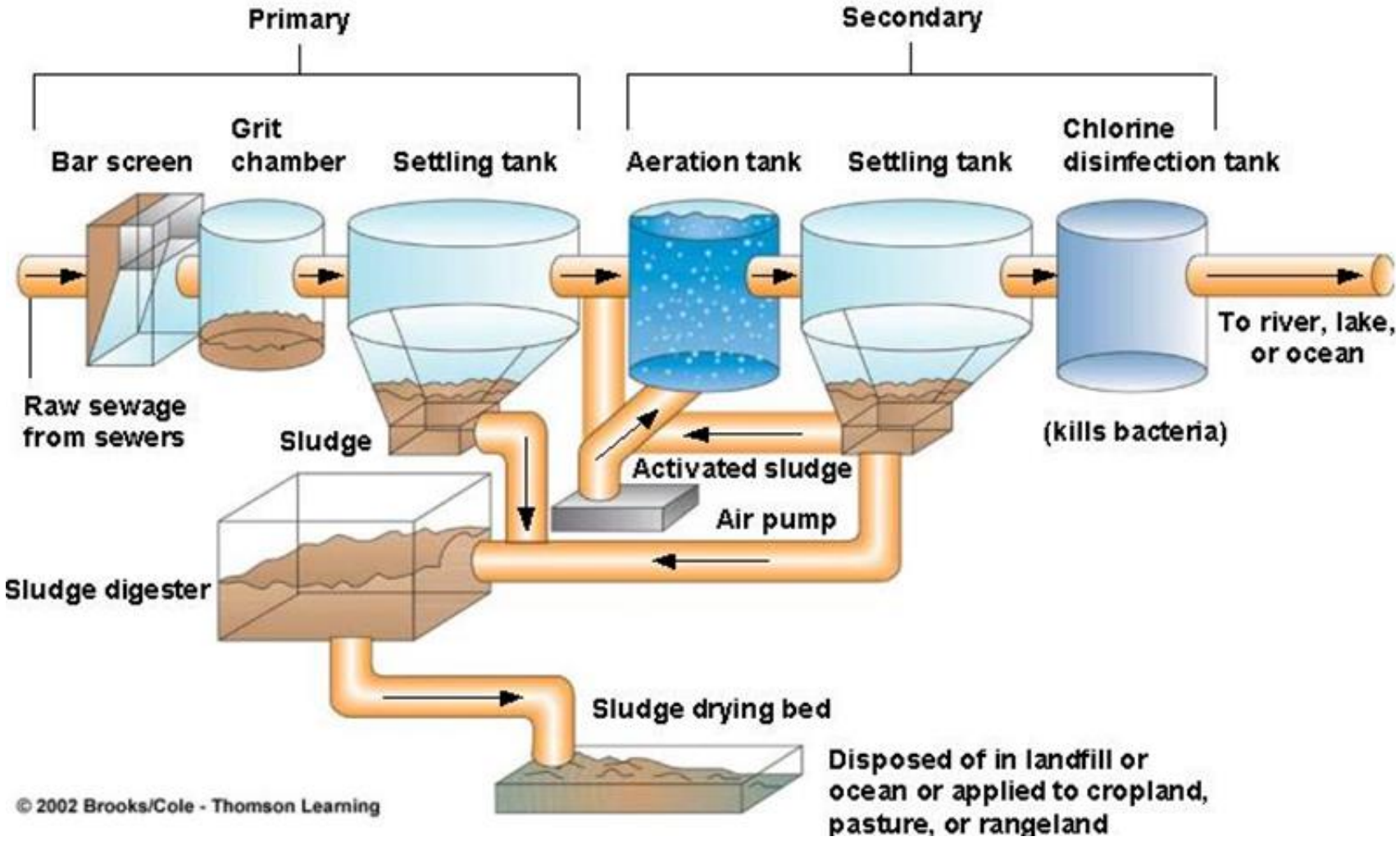
# The main stages of sewage treatment process




Typically:
Preliminary and Primary treatments are based on physical mechanisms
Secondary = biological
Tertiary = specialized

Equalization provides a more uniform effluent to downstream processes

# The main stages of sewage treatment process



# Primary stages of sewage treatment

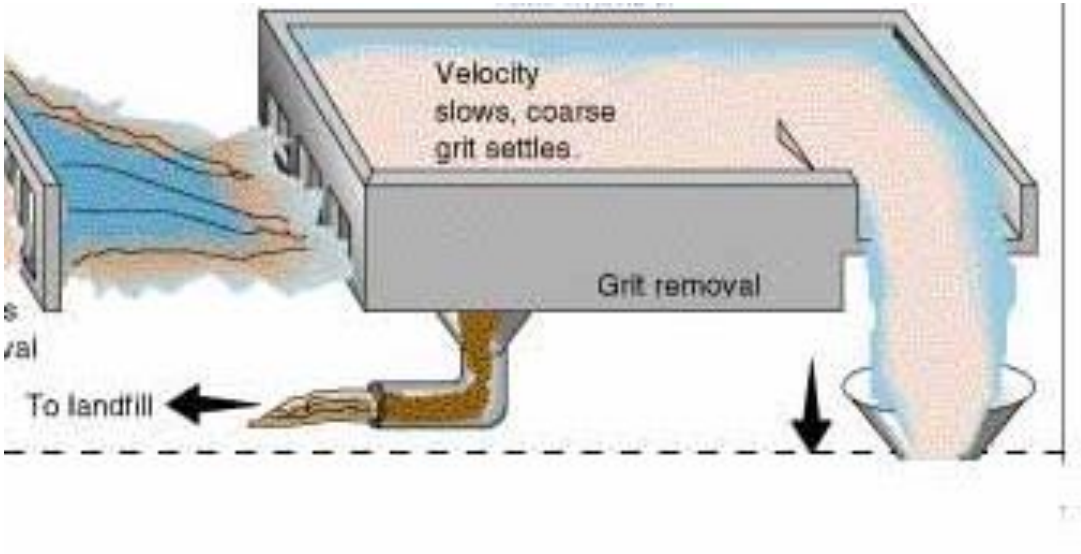
## Bar screens

Typically a set of inclined parallel bars, fixed at a certain distance.

Goal: removal of insoluble matter such as grit, grease, and scum from water. Screening removes or reduce the size of trash and large solids that get to the sewage system.

# Primary stages of sewage treatment

## Grit chamber




Long, narrow tank; Goal: removal of grit, sand, gravel, cinders or other inert solid materials - particles settle out of the water. A grit causes excessive wear and tear on pumps and other plant equipment.

# Primary stage of sewage treatment

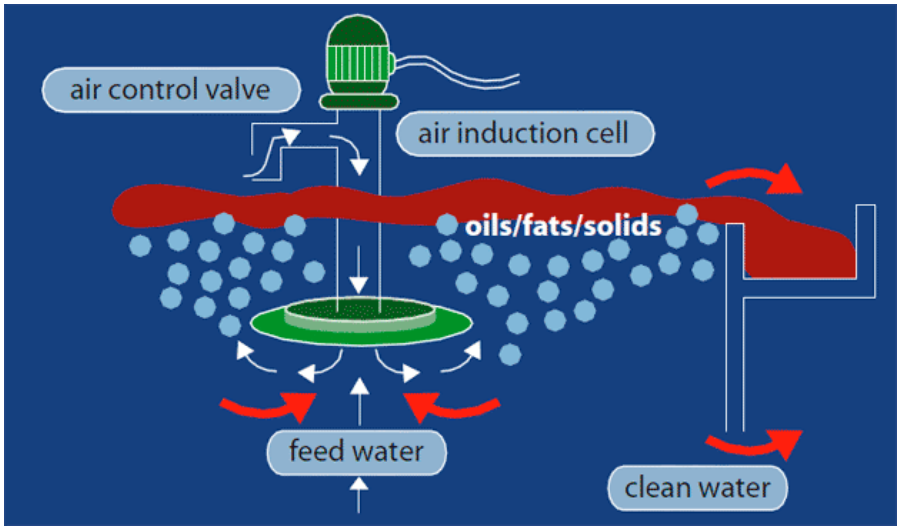
## Primary settling tank

Large tank in which solids settle out of water by gravity
Goal: removal of solids using coagulation process.

Sewage are introduced from the bottom of tank and coagulants are added and after this solids fall on the bottom of tank and here are removed as a primary sludge.

# Primary stage of sewage treatment

## Skimming tank

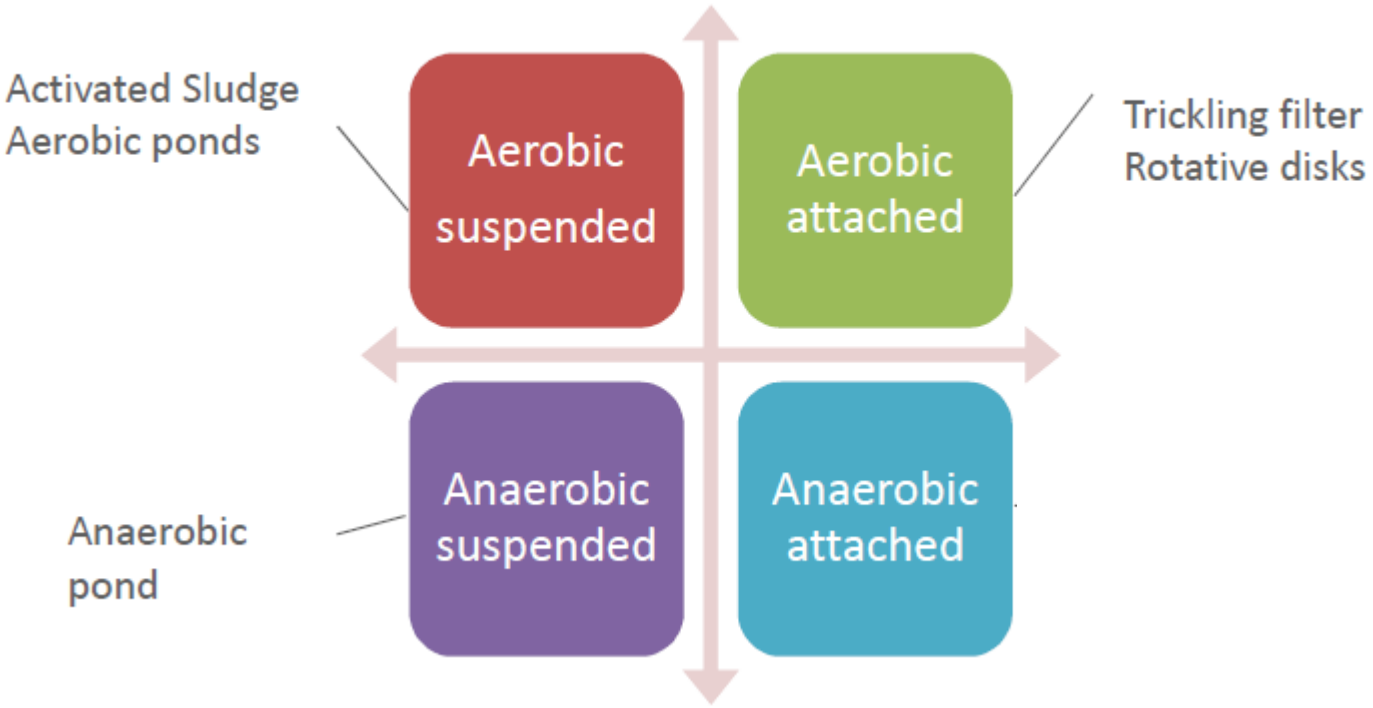



A chamber so arranged that the floating matter like oil rise and remain on the surface.

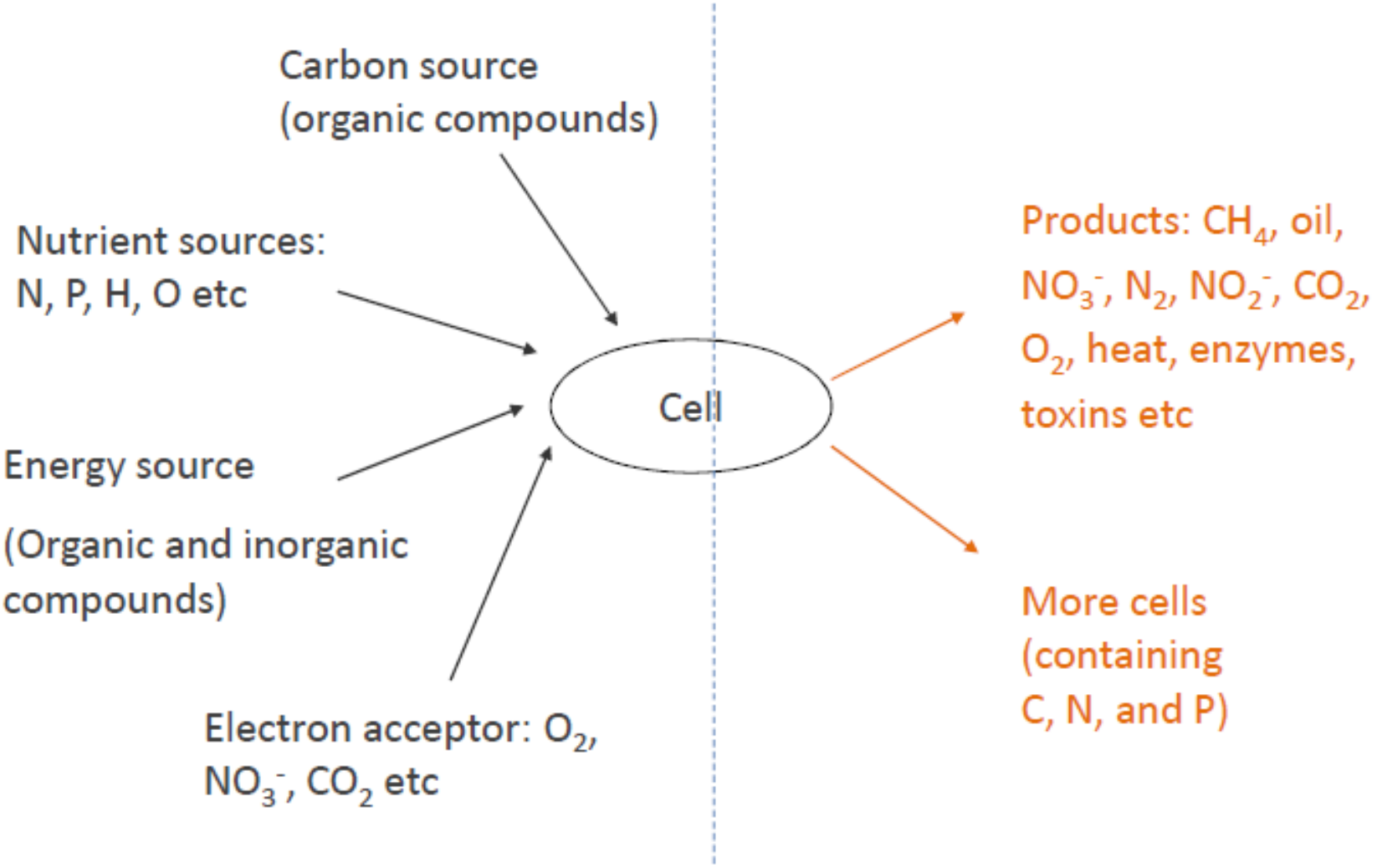
Goal: removal of grease - material that floats using flotation process. The removal is achieved by dissolving air in the water. Tiny bubbles of air adhere to the suspended matter causing the suspended matter to float to the surface

# Secondary wastewater treatment

- Biological process – microorganisms are allowed to degrade organic material in solution or in suspension in the presence of added oxygen, until BOD of waste has been reduced to acceptable level



# Main principle of biological removal:
# Food + organisms = Products + biomass



# Secondary wastewater treatment

- Fixed bed –biological filter that operates under (mostly) aerobic conditions

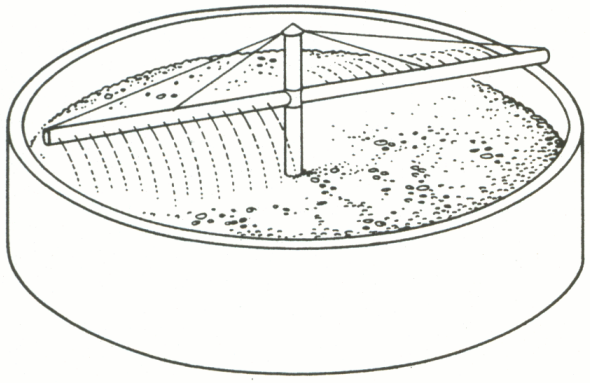


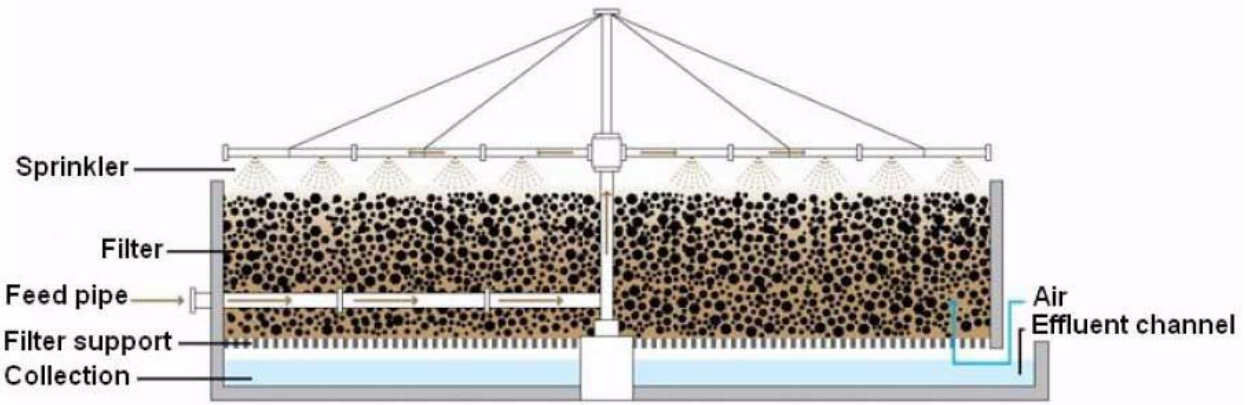
**FIGURE 8.5** A trickling filter waste-treatment system.

Wastewater is sprayed over rocks or other solid support covered with microorganisms. The biological layer consists of aerobic and anaerobic partitions.

Treatment occurs as the wastewater flows over the microorganisms film attached to some inert material such as rocks or plastics.

*S. E. Manahan „Environmental Chemistry" Brooks/Cole Publishing Company , 1984

# Trickling wastewater filter




The trickling filter is used in WWTP but there are some operational problems (clogging) the large surface is required for this type of reactor.

# Secondary wastewater treatment

- **Activated sludge process ASP- the most versatile and effective of all waste treatment processes.**

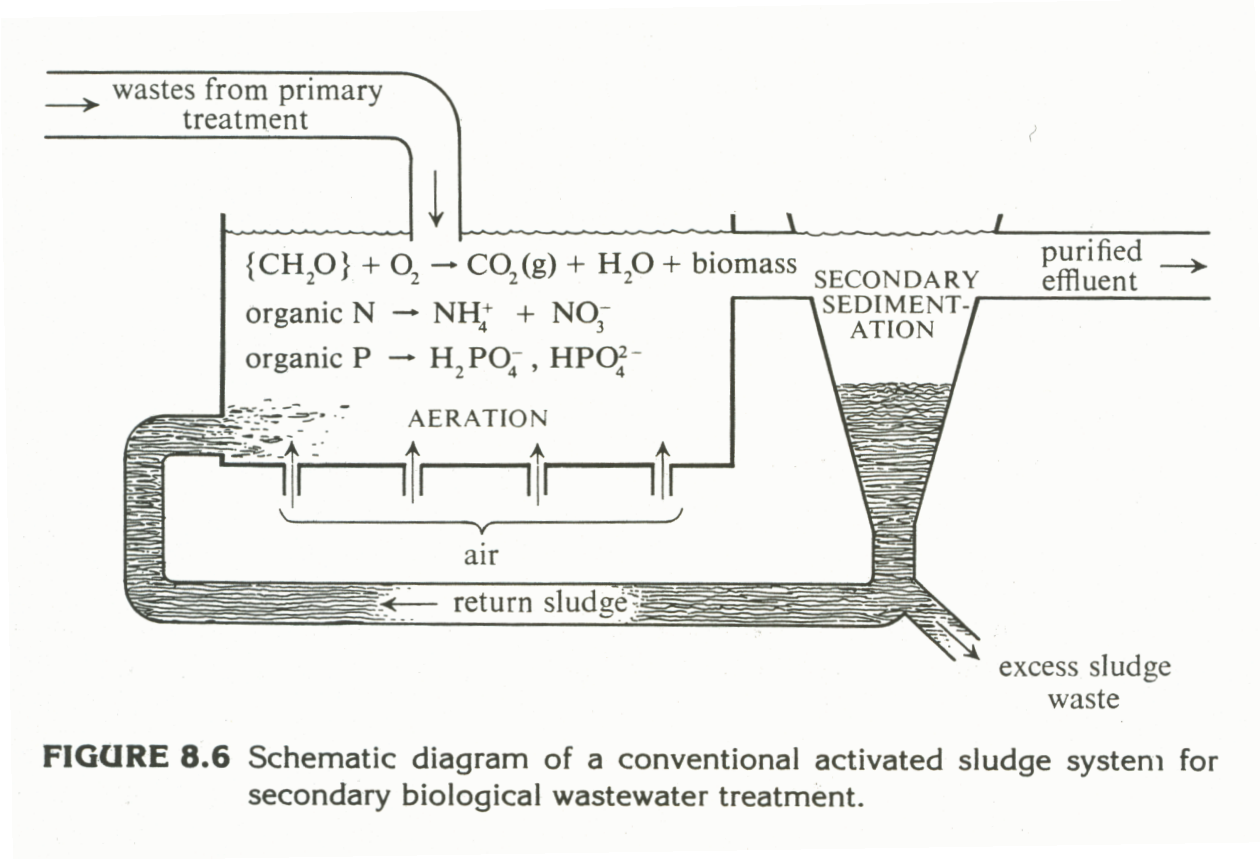
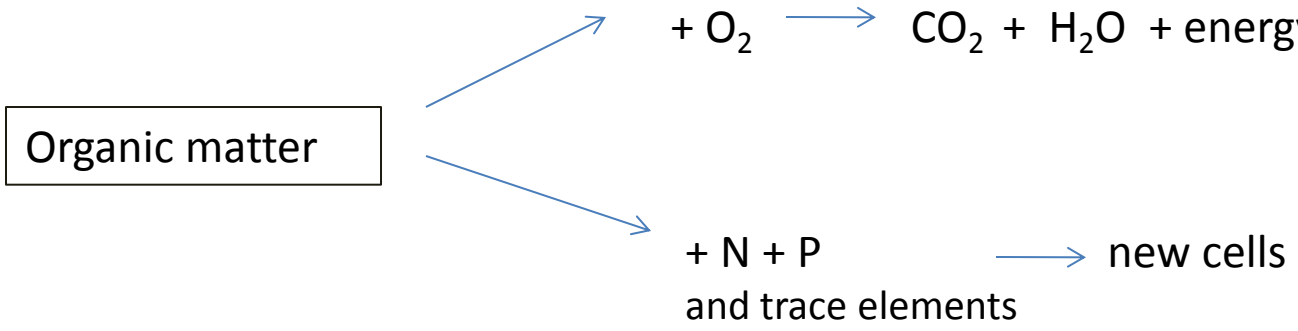



**FIGURE 8.6** Schematic diagram of a conventional activated sludge system for secondary biological wastewater treatment.

*S. E. Manahan „Environmental Chemistry" Brooks/Cole Publishing Company , 1984

# Secondary wastewater treatment

**The activated sludge process provides two ways for removal of BOD**



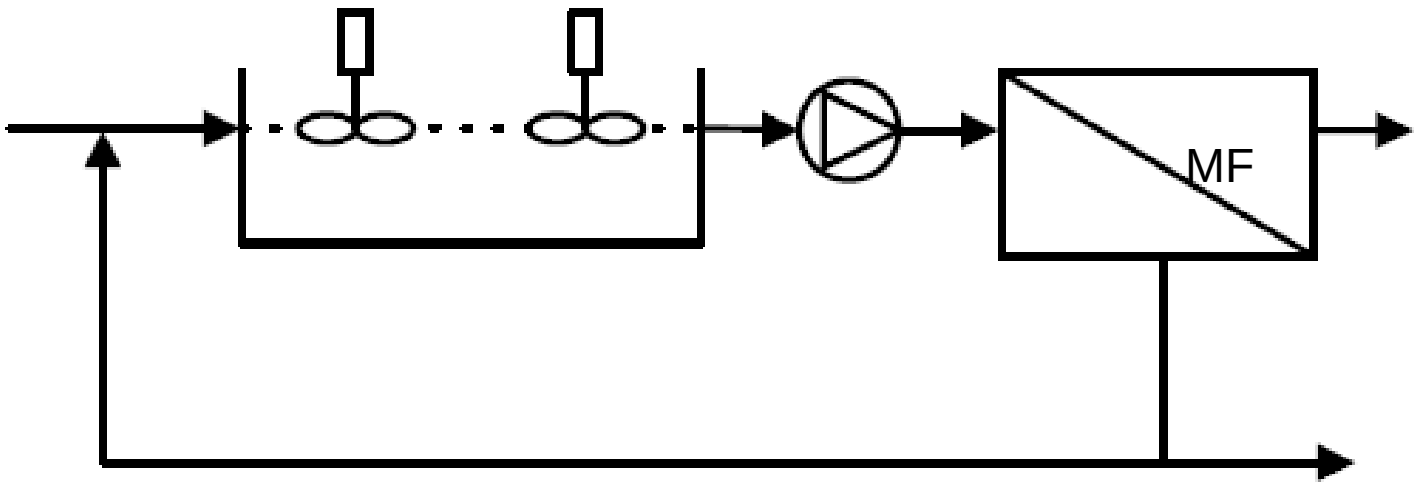

- Oxidation (40% of carbon) carbon is converted to $CO_2$ is vented to atmosphere and does not present disposal problem
- Synthesis (60% of carbon) incorporation of the organic matter into cell mass. The disposal of waste sludge however is a problem, the dewatered sludge may be incinerated or landfilled, may be digested to produce biogase

$$2CH_2O \xrightarrow[\text{bacteria}]{\text{Anaerobic}} CH_4 + CO_2$$

# Activated Sludge Reactor and Settler

http://www.ztch.umcs.lublin.pl/admin/materialy/Ocz_sc_BCh.pdf

# Membrane Bioreactor (Crossflow membrane filtration)




Settleability of the sludge, which is a problem in conventional activated sludge, has absolutely no effect on the quality of the treated effluent. Consequently, the system is easy to operate and maintain.

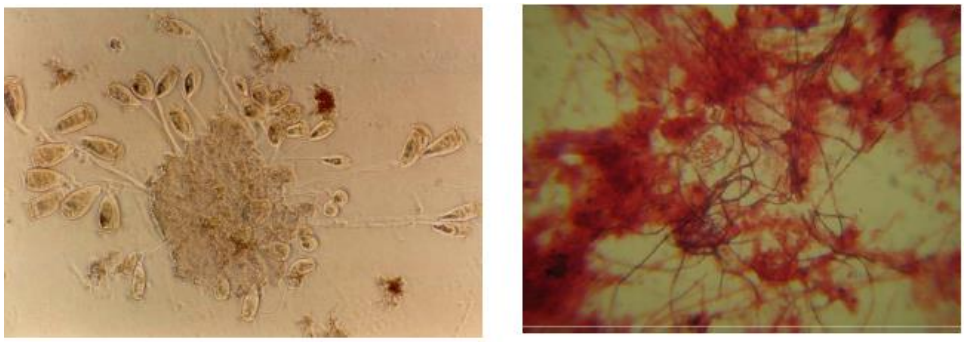
C. Visvanathan and R. Ben Aim Membrane Bioreactor Applications in Wastewater Treatment, article

# Activated sludge

- **Bacteria:** *Pseudomonas*, *Acinetebacterium*, *Zooglea*, *Aeromonas*, *Enterobacteriare*, *Flavobacterium*, *Achromobacter*, *Micrococcus*

- **Ciliata:** *Paramecium*, *Vorticella*, *Aspidisca*, *Suctoria*

- **Flagellates:** *Tetramitus*, *Trigomonos*



*Kolonie mikroorganizmów w osadzie czynym*

http://www.ztch.umcs.lublin.pl/admin/materialy/Ocz_sc_BCh.pdf

# Secondary wastewater treatment

Nitrification in the aeration tank of the activated sludge favored by long time, low organic loadings, high temperature

$$2\ NH_4^+ + 3\ O_2 \xrightarrow{Nitrosomonas} 4\ H^+ + 2\ NO_2^- + 2\ H_2O$$

then to nitrate:

$$2\ NO_2^- + O_2 \xrightarrow{Nitrobacter} 2\ NO_3^-$$

Anoxic conditions
(absence of dissolved oxygen but presence of nitrates)
If there is nitrate available in the liquid medium the organisms that are capable of using nitrate in their respiration converting the nitrate to nitrogen gas (denitrification).

$$4\ NO_3^- + 5\ \{CH_2O\} + 4\ H^+ \rightarrow 2\ N_2(g) + 5\ CO_2(g) + 7\ H_2O$$

**Table 16.5** Typical concentrations of wastewater contaminants during the wastewater treatment process[a].

| | Concentration / mg $L^{-1}$ | | | |
|---|---|---|---|---|
| | Raw influent | Primary | Secondary | |
| | | | Biological | Chemically assisted |
| BOD | 250 | 175 | 15 | 10 |
| SS | 220 | 60 | 15 | 10 |
| TP | 8 | 7 | 6 | 0.1–1 |

[a] BOD, Biological oxygen demand; SS, suspended solids; TP, total phosphorus.

Trickling filter ≅ 80 % reduction of BOD concentration.
Activated sludge process > 95% reduction of BOD concentration.

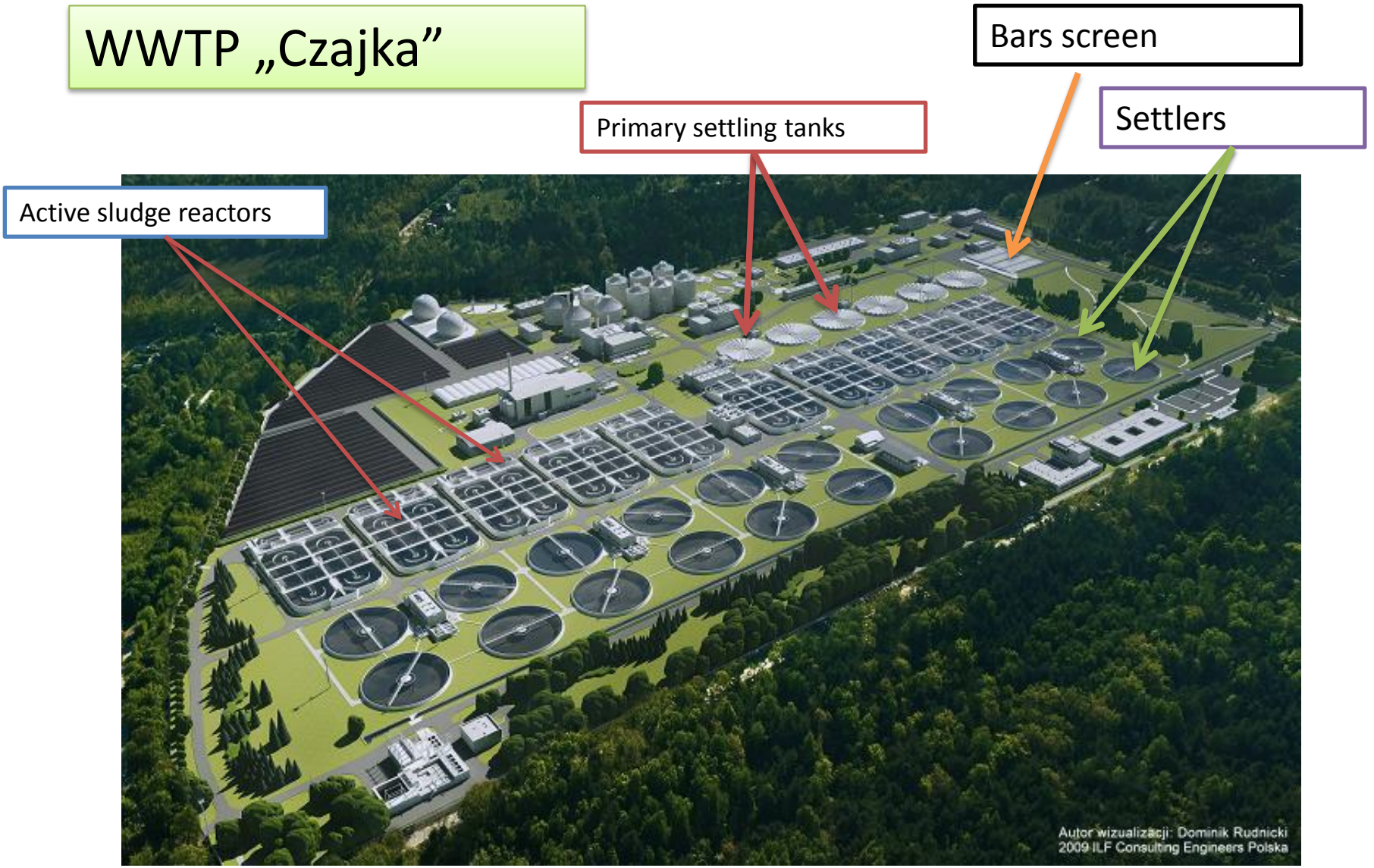
G. W. vanLoon, S. J. Duffy Environmental Chemistry, Oxford Press, 2011

# Tertiary (advanced) wastewater treatment

**Contaminants removed by this process:**

- Suspended solid
- Dissolved organic compounds
- Dissolved inorganic compounds
- Bacteria and viruses

# WWTP „Czajka”




**This plant was buit in 1991 and currently receives a sewage from area located of left and right sides of Wisła, capacity: 240 000 $m^3$/d**