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Faculty of Chemical and Bioengineering
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Biology, biotechnology

Biological wastewater treatment

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I. Biodegradation and its environmental importance

Biodegradation in the nature

Domestic wastewater

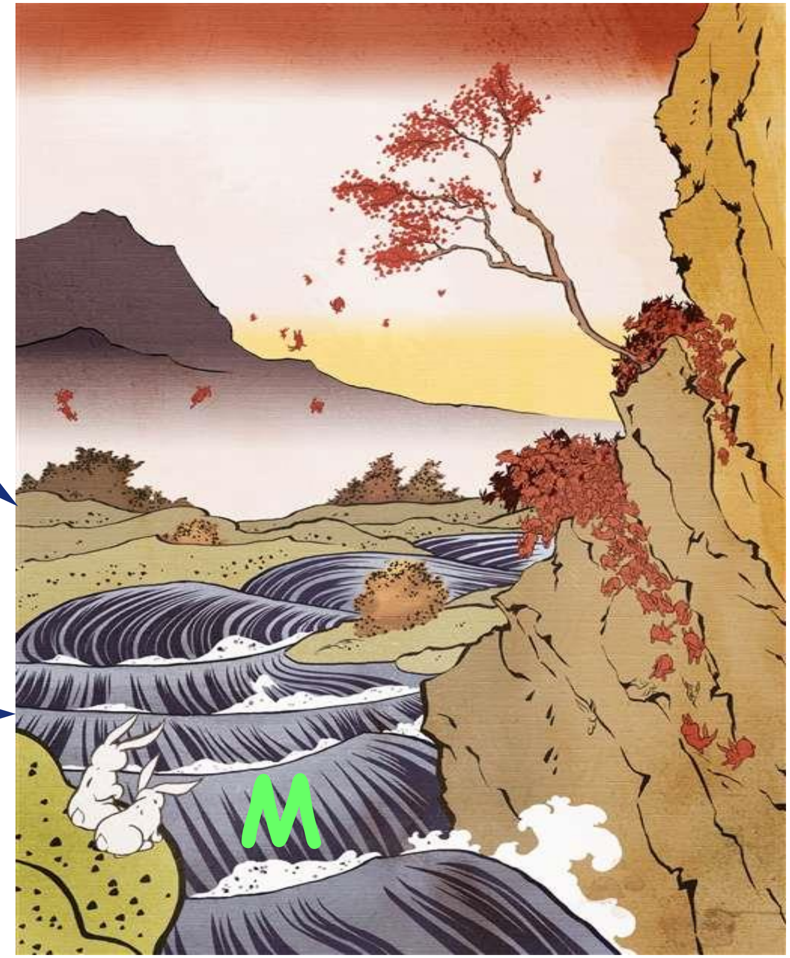
Readily biodegradable (O_2 consumption)

Treatment

Industrial wastewater

Readily or poorly biodegradable (accumulation)

Treatment



Receiving body

Biodegradable: microbial elimination / transformation is possible

Biodegradation - definition

„Biodegradation means the biological transformation of an organic chemical ***to another form****, no extent is implied."*

C. P. Leslie Grady Jr.

Biodegradation is the biological transformation of an organic chemical to another form resulted in molecular size reduction.

Importance

Definitions

- Mineralisation: results CO_2, H_2O, inorganic compounds (pl.: ammonium) and new biomass (no remaining soluble organic carbon)

  Firstly „biogenous” compounds

- Acceptable/appropriate biodegradability:
  The pollutant looses its toxic / harmful effect on environment
  (eg.: foaming, toxicity)

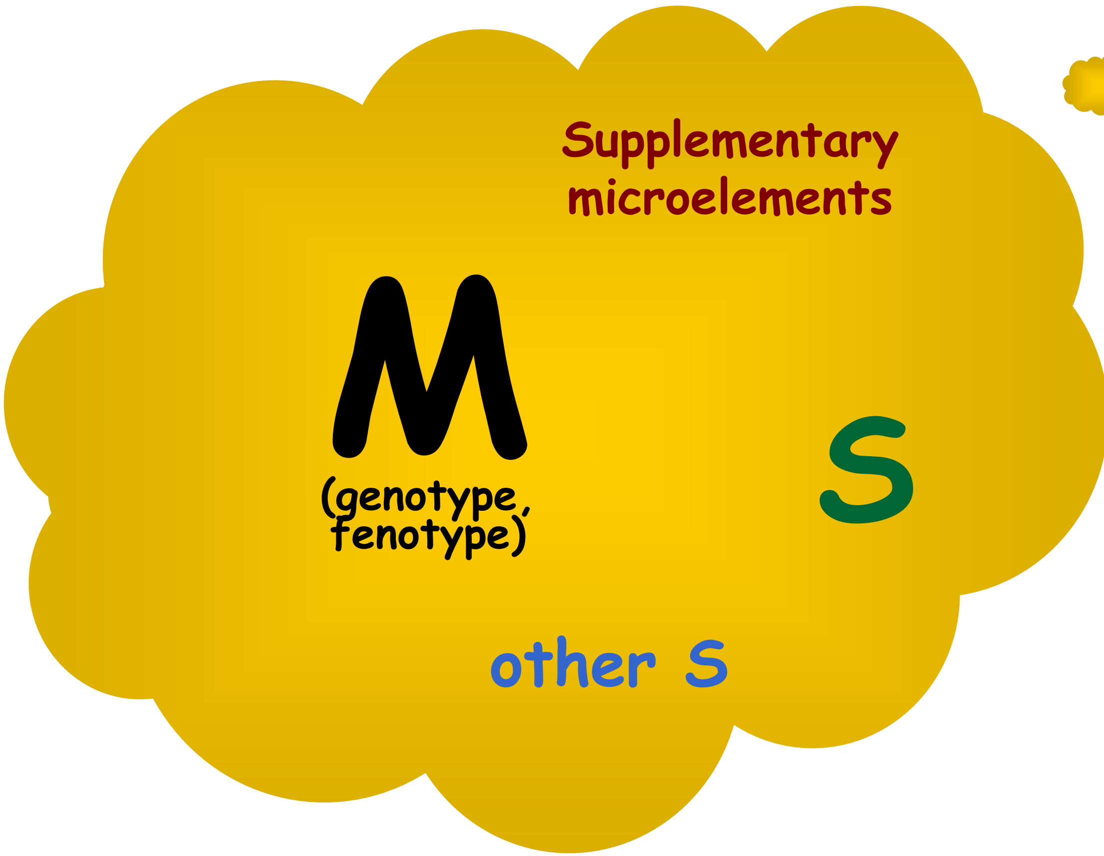
- Primary / partial / full biodegradability

II. Influencing factors of biodegradation

Main influencing factors of biodegradation

- Compound to be eliminated (potential substrate)
- Presence of other substrate (co-metabolism)
- Microorganism, microflora
- Environment
- Technology (eg. bioreactor arrangement)

Influencing factors



M : microorganism

: environment

Components:

- **S** : substrate (available for microorganisms)
- **other S** (co-metabolism)
- **electron acceptor:**

  O_2, NO_3^-, SO_4^{2-}, stb.
- **supplementary microelements:**

  N, P, minerals

Electron acceptors in different environments

- *Aerobic*: dissolved oxygen is available
- *Anoxic*: no oxygen, but presence of NO_3^- and/or NO_2^-
- *Anaerobic*: no oxygen, no NO_3^- and NO_2^-, but presence of eg. H_2, CO_2, SO_4^{2-}

III. Biodegradation kinetics

Biodegradation

Elimination of pollutants:

Substrate (C,H,O and N, P) + inorganic compounds $\xrightarrow{M}$

new biomass + CO_2 + H_2O + metabolites

In appropriate environment / conditions

Monod kinetics (valid for biodegradable but non-toxic substrates)

$$\frac{dx}{dt} = \mu \cdot x$$

where: **x – microorganism concentration [g/l]**

μ – specific growth rate [d^{-1}]

Specific growth rate: $$\mu = \mu_{\max} \cdot \frac{S}{K_S + S}$$

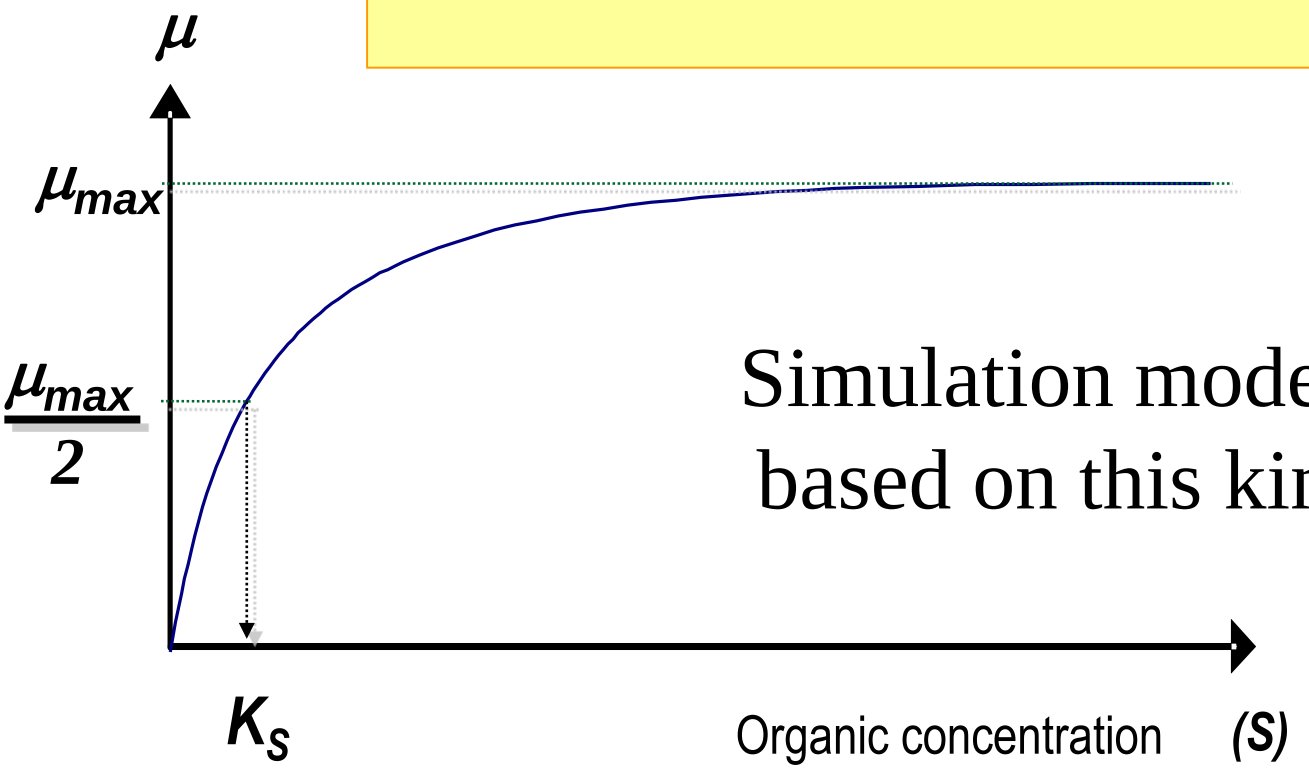
ahol : **μ_{max} – maximum specific growth rate [d^{-1}]**

S – substrate concentration [mg/l]

K_S – half-saturation coefficient [mg/l]

Monod kinetics

Specific growth rate: $\mu = \mu_{\max} \cdot \dfrac{S}{K_S + S}$



Simulation models are based on this kinetics

IV. Activated sludge wastewater treatment

Qualifying of wastewater

S – szubstrate, organic material

Parameters for organic content characterization:

- COD – Chemical Oxygen Demand : Oxygen needed for the total chemical oxidation of the organic content of the sample [mg O_2/l sample]
- BOD_5 – five-day biochemical oxygen demand: Dissolved oxygen needed for microbial oxidation of organic content of the sample in given conditions (at 20 degree C, for 5 days) [mg O_2/l sample]
- TOC – Total Organic Carbon content [mg/l]

Qualifying of wastewater

- Total Suspended Solids (TSS) concentration: mass of solids retained by membrane filter with pore diameter of 0,45 μm for a given sample volume filtered [mg/l]
- Special components
- N forms (NH_4^+,NO_3^-,NO_2^-, organic-N, TN) [mg/l]
- P forms (PO_4^{3-}, TP) [mg/l]
- Other components (pl.: anions, cations, etc.) [mg/l]

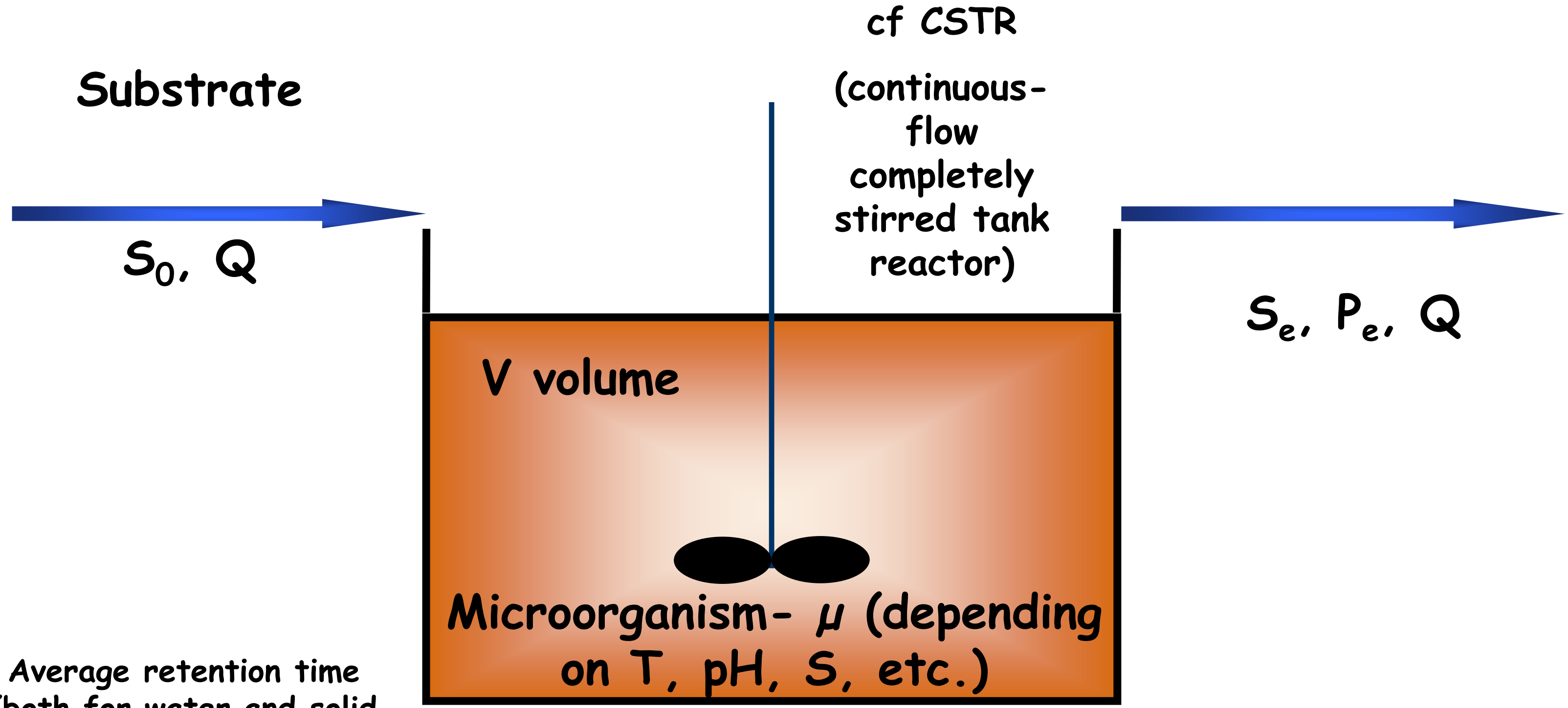
Classification of wastewater regarding its origin

Domestic **Industrial**

↓

„design parameter"

Chemostate (eg. fermentation in pharma industry) – criteria of stable operation



Average retention time (both for water and solid phases)

$$\tau[\mathrm{h}] = \frac{V[\mathrm{m}^3]}{Q\left[\frac{\mathrm{m}^3}{\mathrm{h}}\right]} = \frac{1}{D\left[\frac{1}{\mathrm{h}}\right]}$$

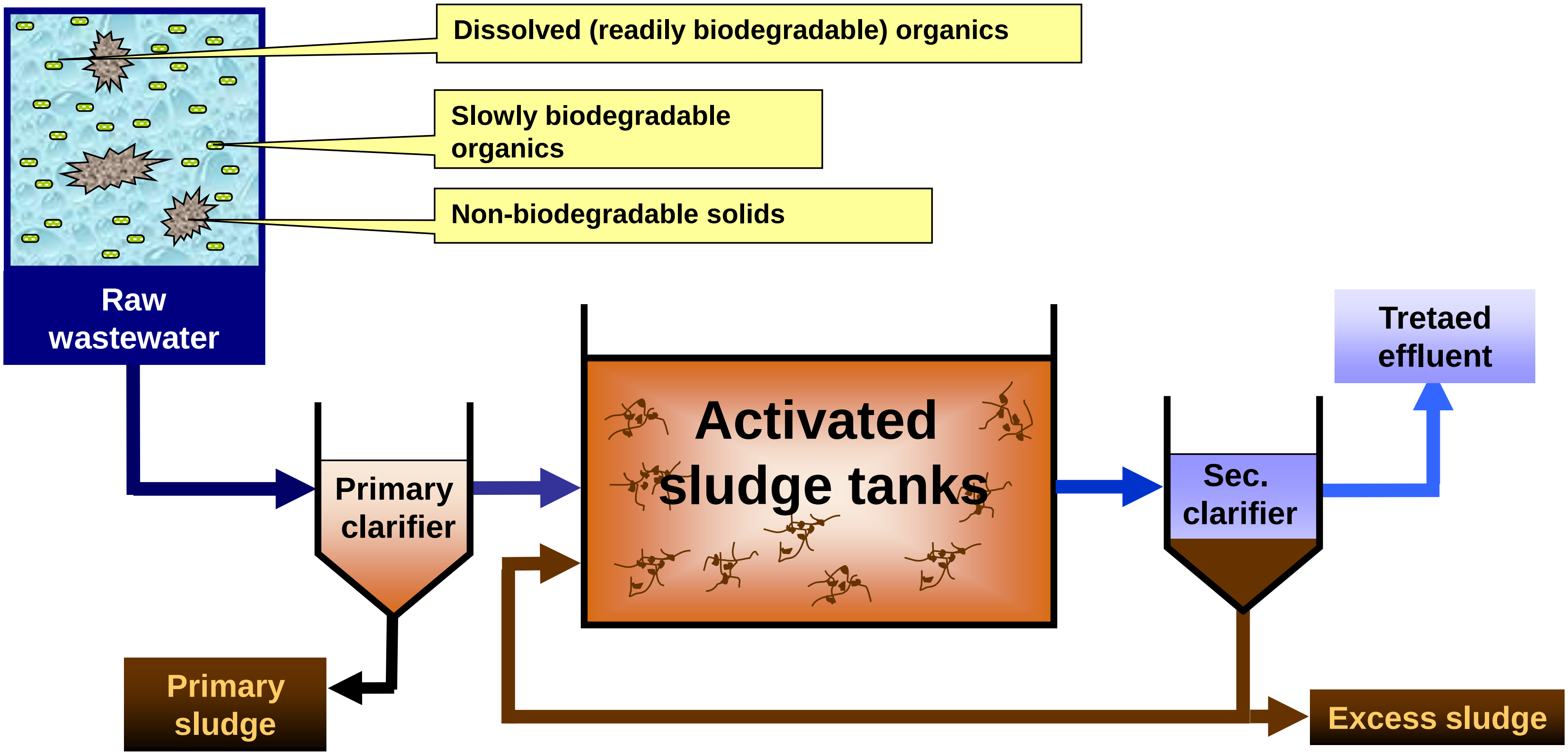
Stable operation if: $D \leq \mu$

It is not possible (could not be maintained) in wastewater treatment

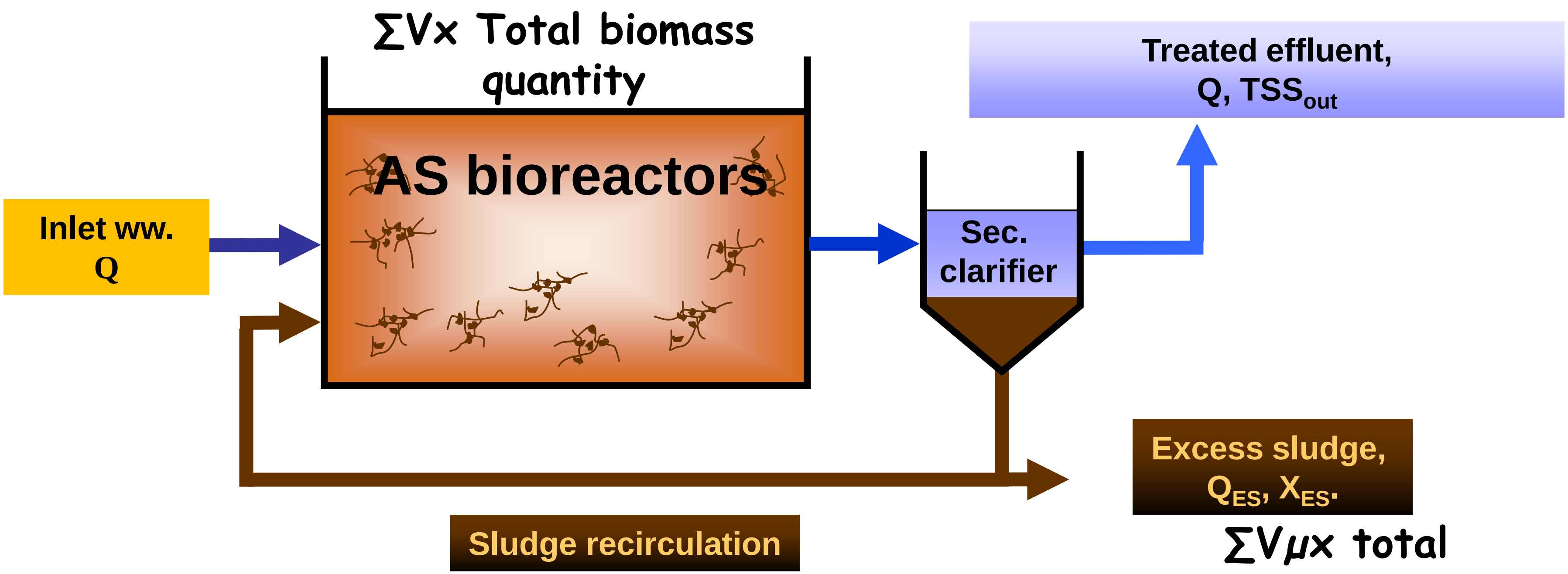
This technology is to be modified

(Ardern and Lockett, 1914)

Conventional Activated Sludge (CAS) technology – world-wide the most common applied system in wastewater treatment



CAS as modified chemostate



ΣVμx total biomass removal
(equal to the quantity of new biomass grown)

Hydraulic Retention Time
(valid only for water phase)

$$HRT[\mathrm{h}] = \frac{V[\mathrm{m}^3]}{Q\left[\frac{\mathrm{m}^3}{\mathrm{h}}\right]}$$

Sludge Retention Time, sludge age
(valid for solid phase)

$$SRT[\mathrm{d}] = \frac{\sum X\left[\frac{\mathrm{kg}}{\mathrm{m}^3}\right]\cdot V\left[\mathrm{m}^3\right]}{\sum V\cdot\mu\cdot X\left[\frac{\mathrm{kg}}{\mathrm{d}}\right]} \equiv \frac{1}{\mu} \equiv \frac{\sum V\cdot X}{Q_{ES}\cdot X_{ES} + Q\cdot TSS_{out}}$$

SRT and the criteria for CAS stable operation

$$\frac{1}{\mu\left[\frac{1}{\text{d}}\right]} \leq SRT[\text{d}] = \frac{X\left[\frac{\text{kg}}{\text{m}^3}\right] \cdot V\left[\text{m}^3\right]}{Biomass \cdot removal\left[\frac{\text{kg}}{\text{d}}\right]}$$

Total biomass in bioreactors

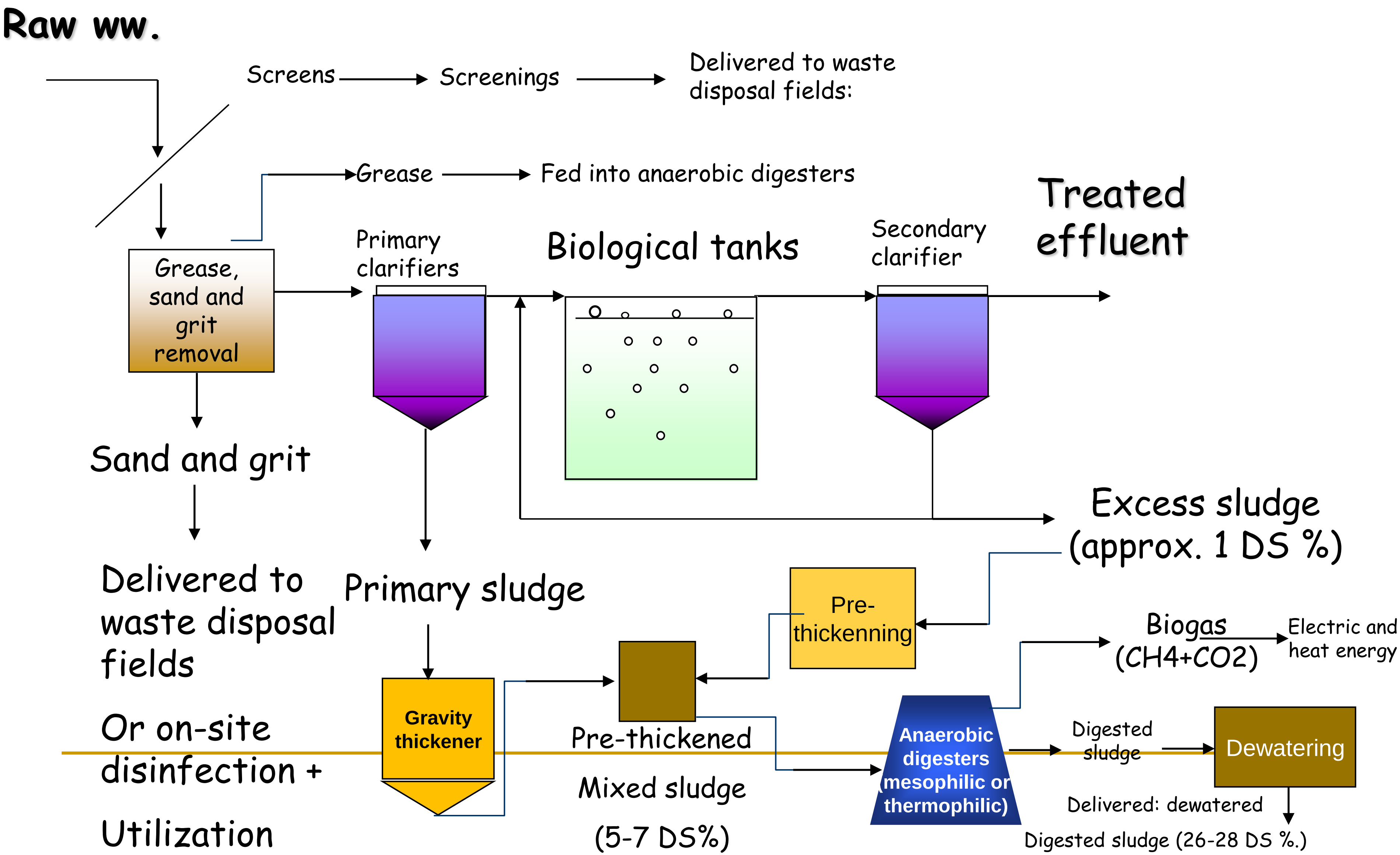
Specific growth rate of microorganisms

namely:

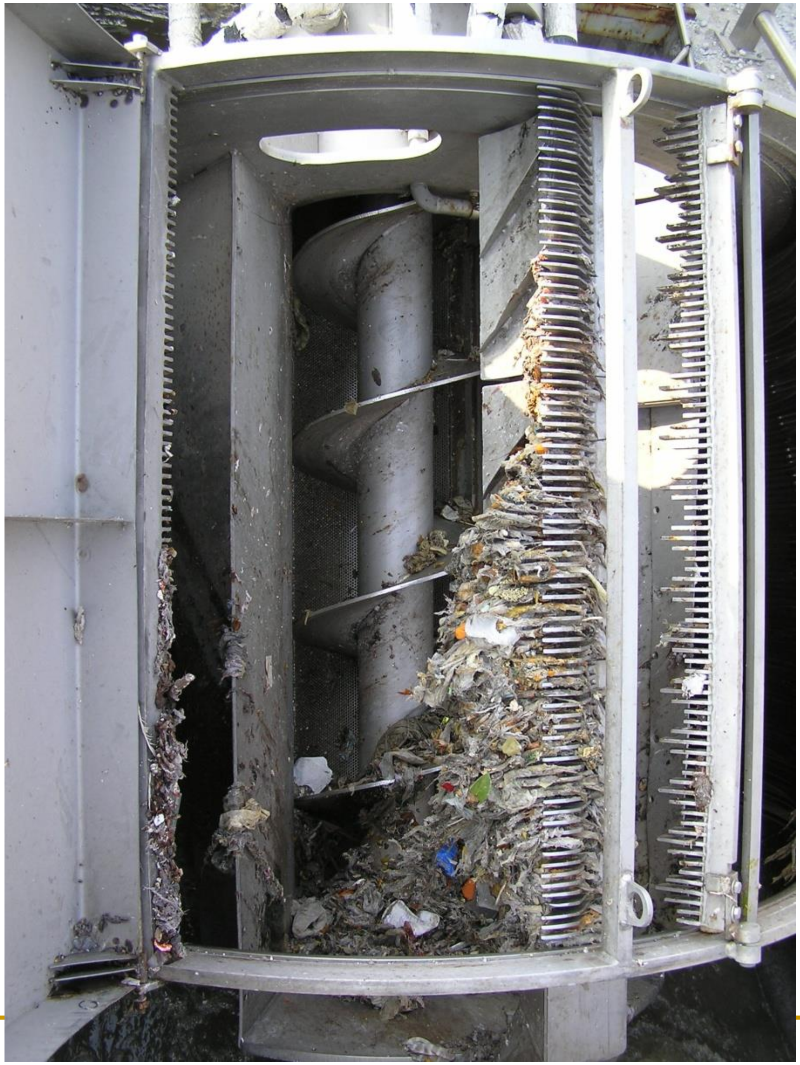
$$\mu_A \geq \frac{1}{SRT}$$

μ_A: autotrophic specific growth rate (μ the slowest microorganismes (generally autotrophs) should be taken into consideration in order to avoid their wash-out.

CAS process flow scheme
(water and sludge treatment lines)



Screens



Grit, sand and grease trap

Primary calrifier (Dorr-type)

Biological basins

(activated sludge tanks)

Secondary clarifier (Dorr-type)

Treated effluent