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DENITRIFICATION

Wastewater Treatment Technology- course
Faculty of Environmental Engineering, Wroclaw
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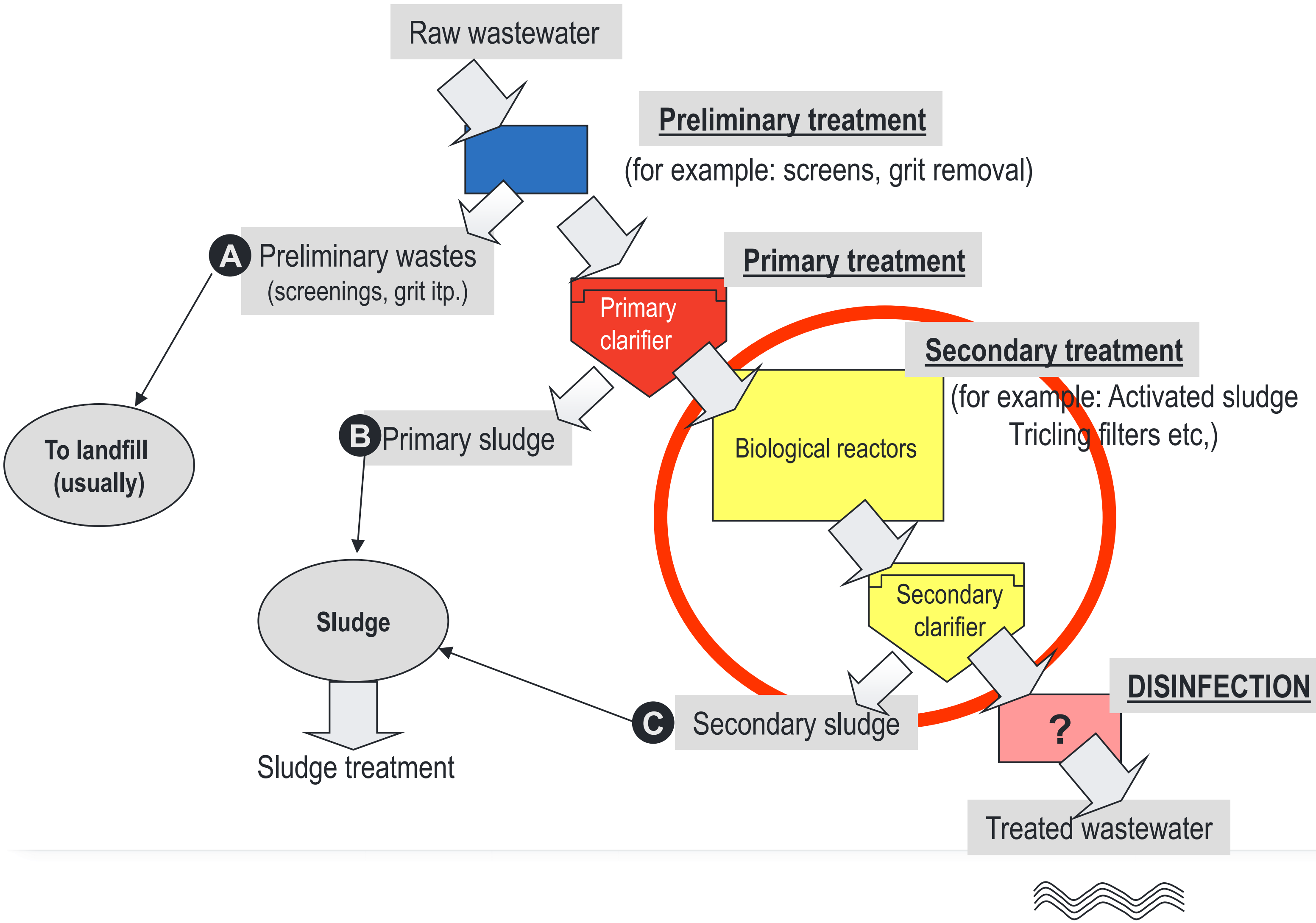
WROCŁAW, 2025

Where are we?


Raw wastewater
Preliminary treatment
(for example: screens, grit removal)
A
Preliminary wastes
(screenings, grit itp.)
Primary treatment
Primary clarifier
Secondary treatment
(for example: Activated sludge
Tricling filters etc,)
To landfill (usually)
B
Primary sludge
Biological reactors
Secondary clarifier
Sludge
DISINFECTION
?
C
Secondary sludge
Sludge treatment
Treated wastewater

Denitrification

Reaction

Low amount in comparison to NO_3

$$\text{Organic compounds} + NO_3^- + NH_4^+ \longrightarrow CO_2 + H_2O + N_2 + \text{bacteria} + OH^- + H^+$$

Associated with NH_4 assimilation

Oxygen is the process inhibitor

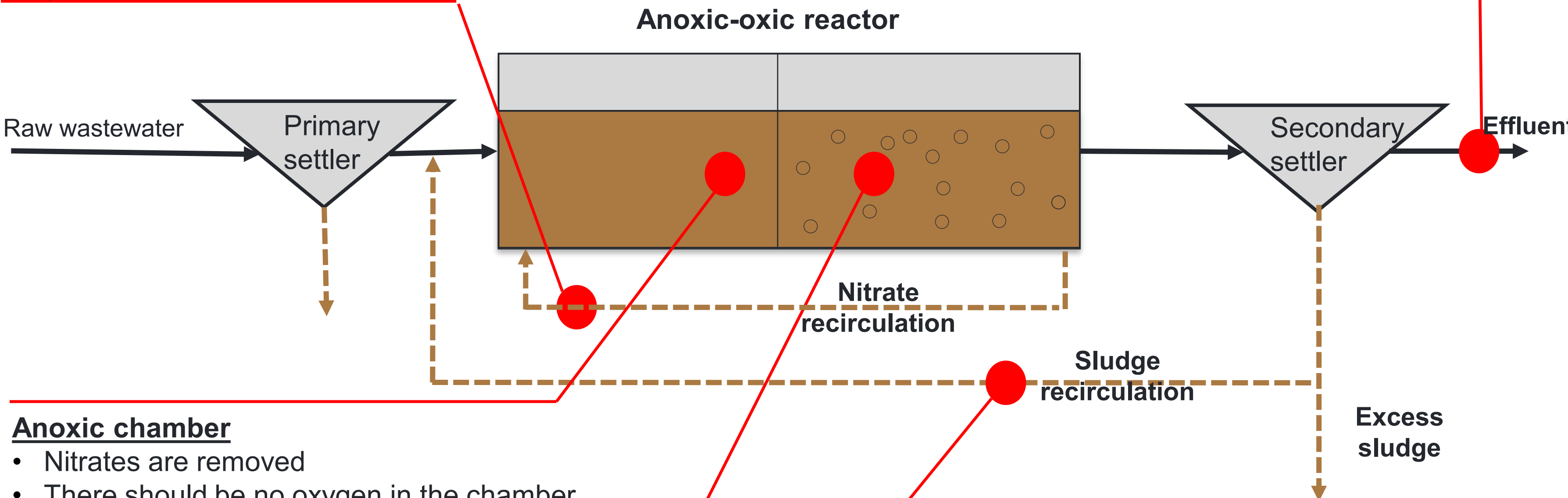
Numerical values are omitted on purpose

Denitrification

Simplest process

Nitrate recirculation
- The nitrates produced during nitrification are returned to the anoxic chamber.
- The recirculation rate usually amounts to several hundred percent of the influent flow rate

Treated wastewater
- Significantly fewer nitrates compared to a system with only an aerobic chamber



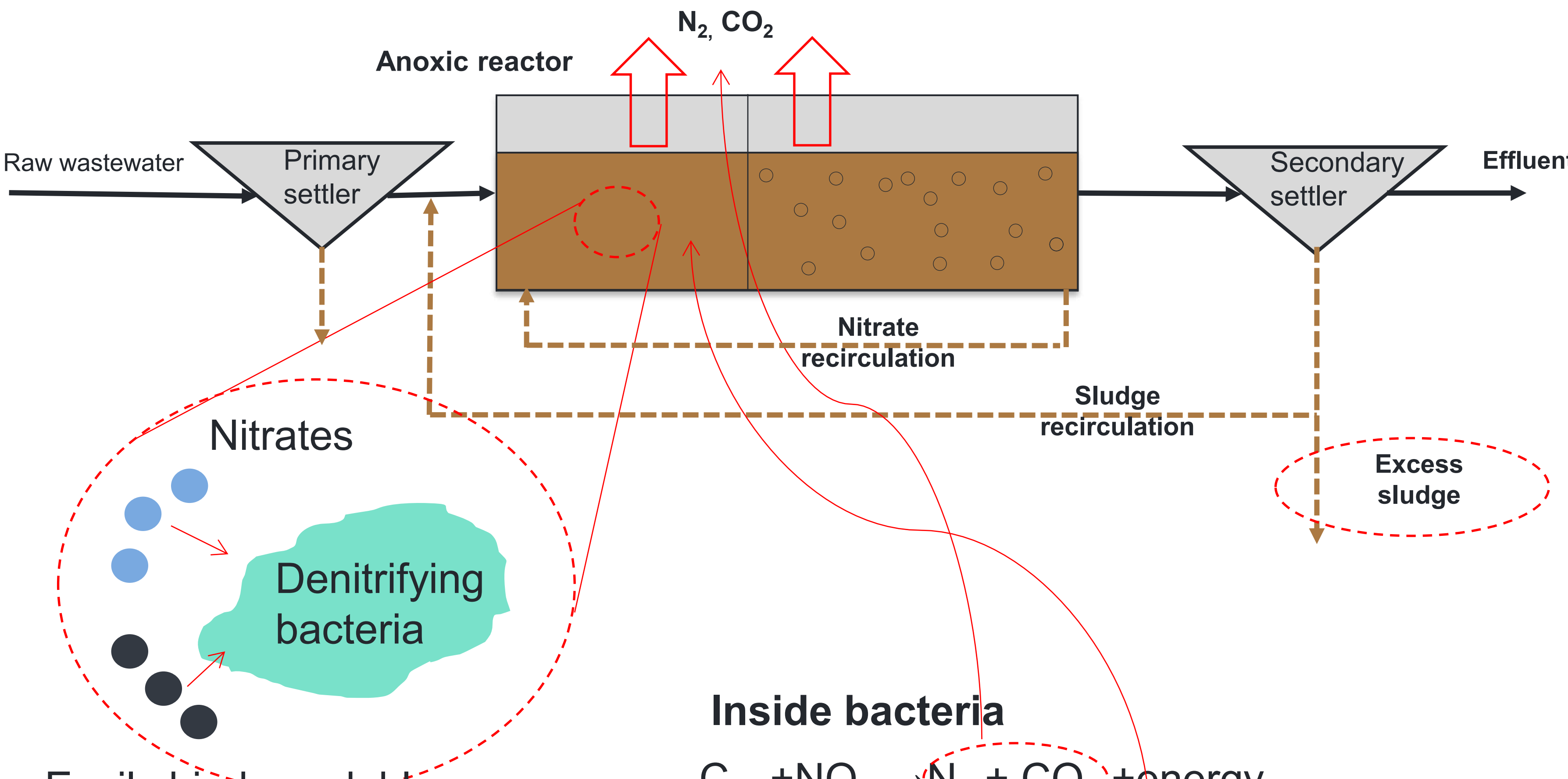
Anoxic chamber
- Nitrates are removed
- There should be no oxygen in the chamber

Aerobic chamber
- Nitrate production through the nitrification process

Sludge recirculation
- In addition to sludge, certain amounts of nitrates are also returned

Denitrification

Process – anoxic chamber



Inside bacteria

$C_{org} + NO_3 \rightarrow N_2 + CO_2 + \text{energy}$

$C_{org} + NH_4 + \text{energy} \rightarrow \text{new bacteria}$

energy → maintenance of life processes

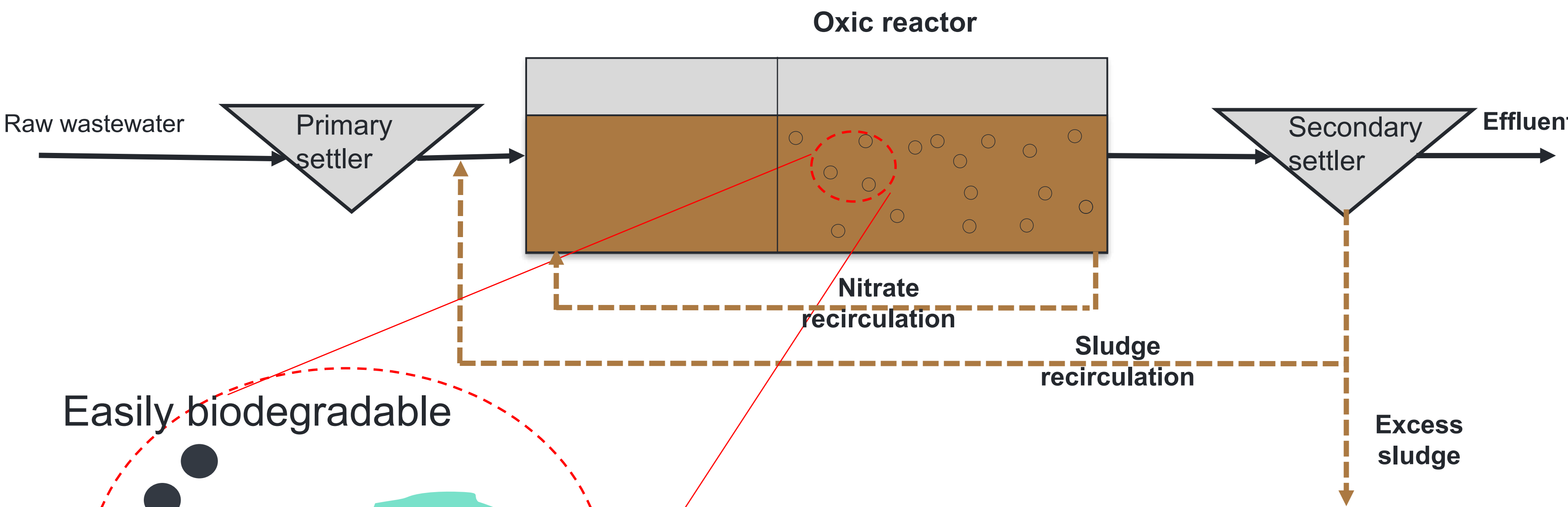
Denitrification

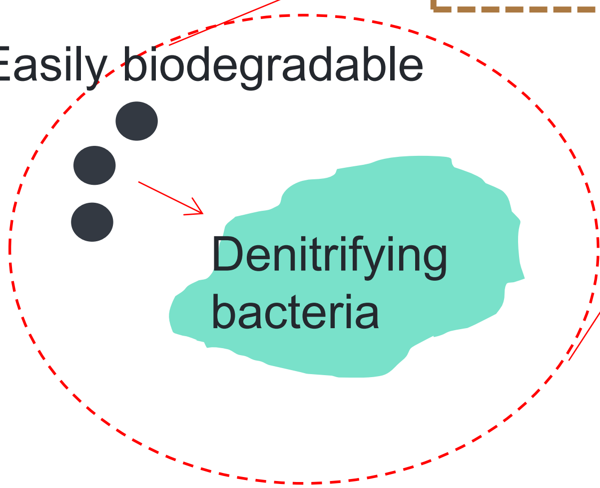
Process – anoxic chamber

1. Easily biodegradable compounds and nitrates are assimilated by heterotrophic bacteria.
2. Inside the bacterial cell, organic compounds are oxidized using nitrates.
3. The energy obtained from this oxidation is used for biomass growth (along with non-oxidized organic compounds) and other life processes.
4. The growth of nitrifying bacteria is slow and highly dependent on temperature.

Denitrification

Process – aerobic chamber – under typical conditions





Denitrifying bacteria usually have the ability to also carry out aerobic processes. They are common heterotrophs.

Inside bacteria

$C_{org} + O_2 \rightarrow CO_2$ + energy

$C_{org} + NH_4$ + energy $\rightarrow$ new bacteria

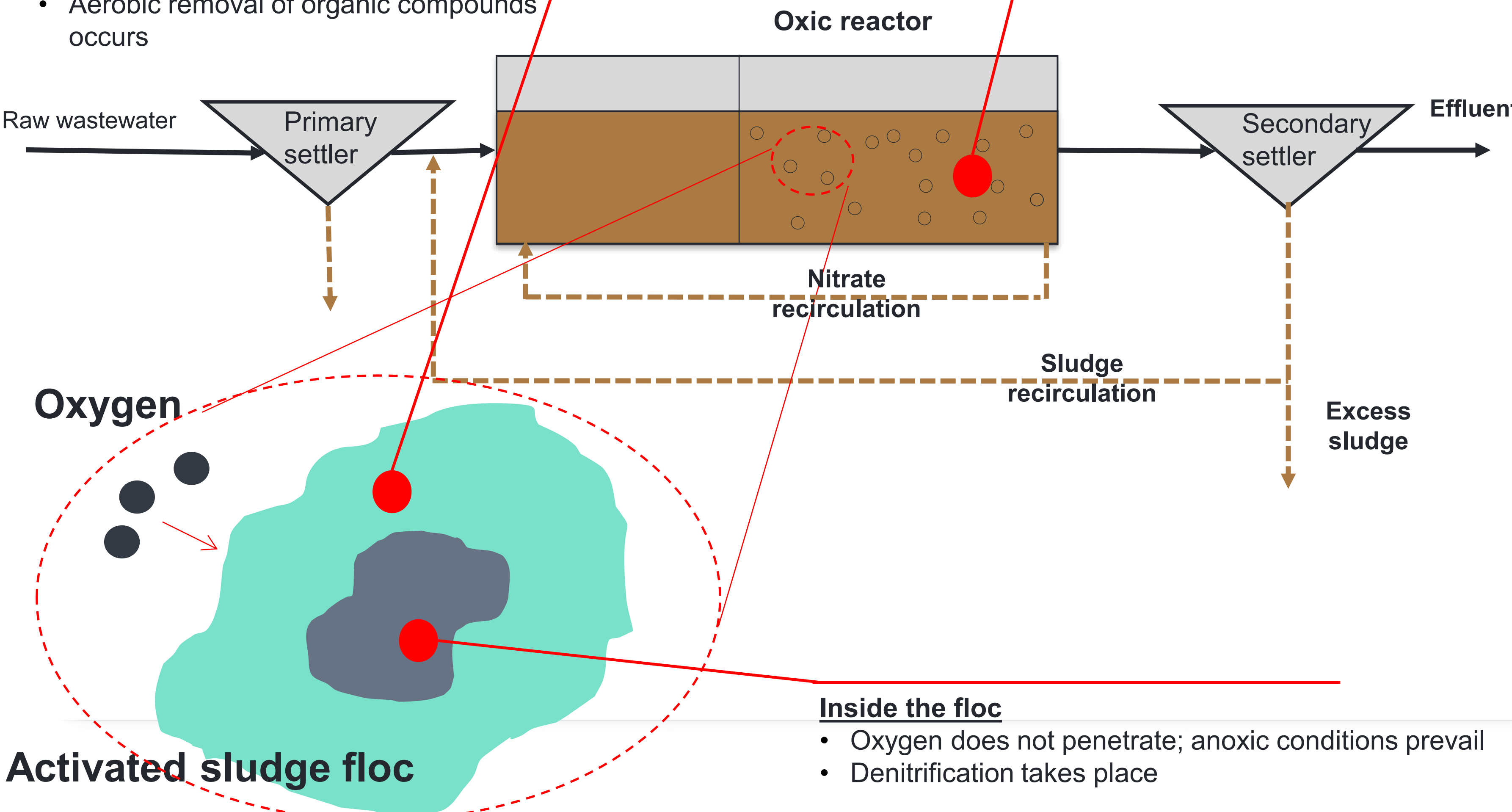
energy → maintenance of life processes

Denitrification

Process – aerobic chamber – under appropriate conditions

Outside the floc
- Aerobic conditions prevail
- Nitrification takes place
- Aerobic removal of organic compounds occurs

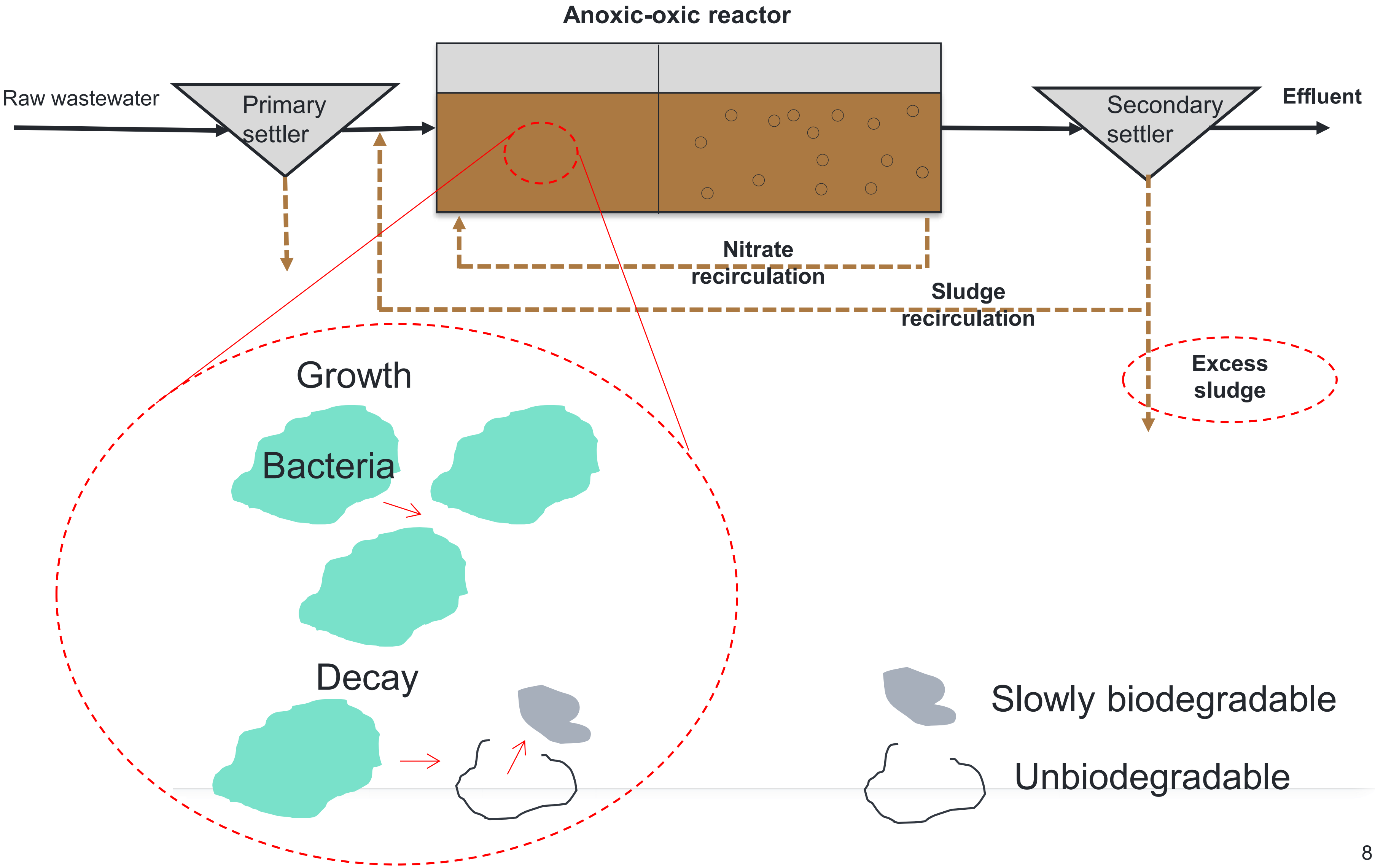
Oxic conditions
- Low O_2, usually 1.0 - 0.5 gO_2/m^3



Inside the floc
- Oxygen does not penetrate; anoxic conditions prevail
- Denitrification takes place

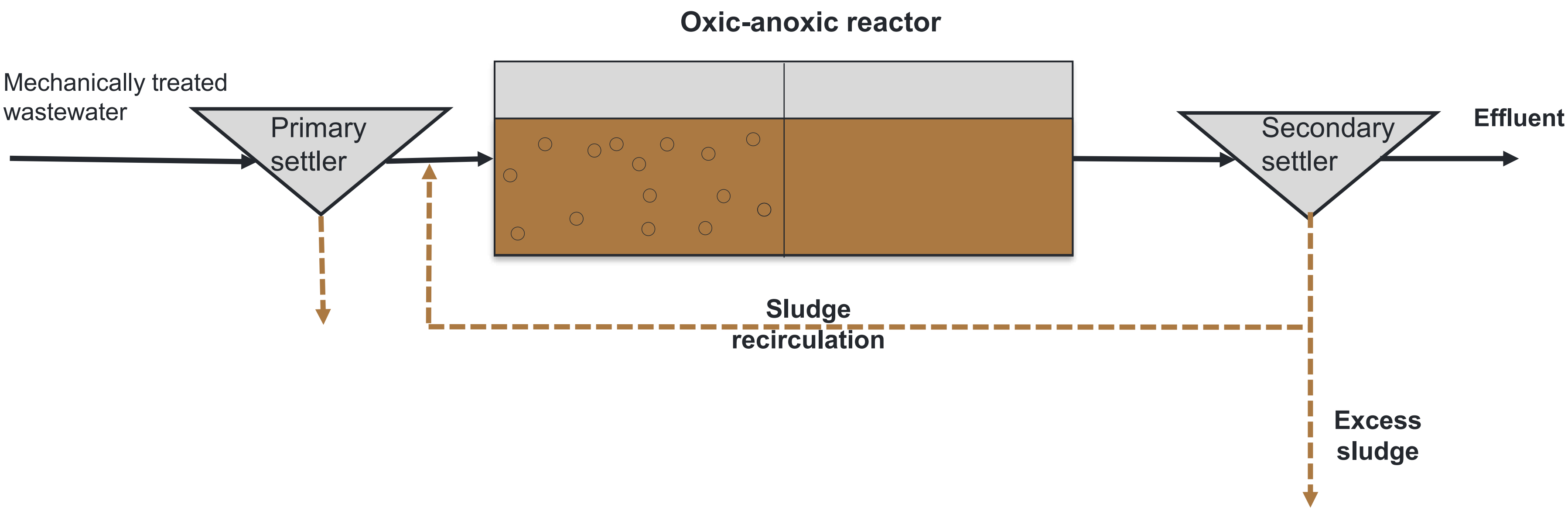
Denitrification

Bacteria



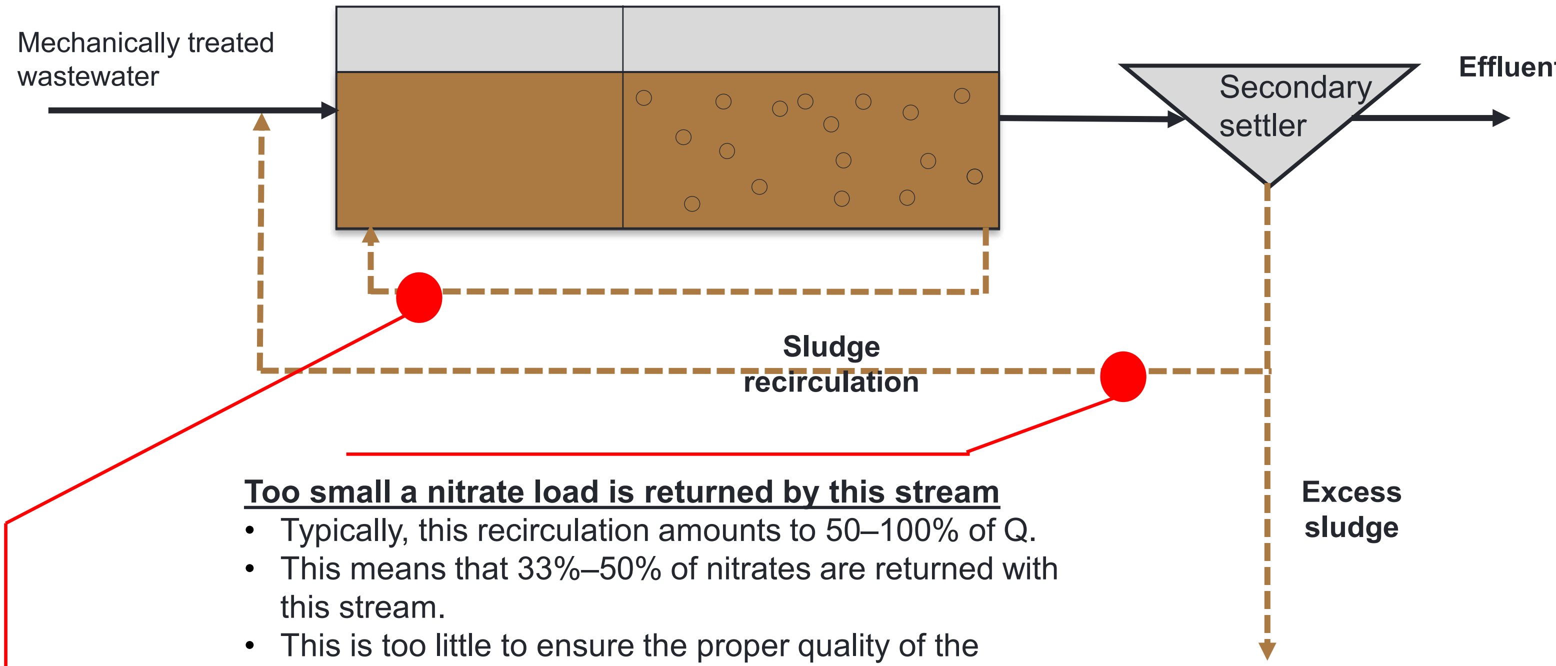
Denitrification

Why not that scheme?



Denitrification

The role of nitrate recirculation

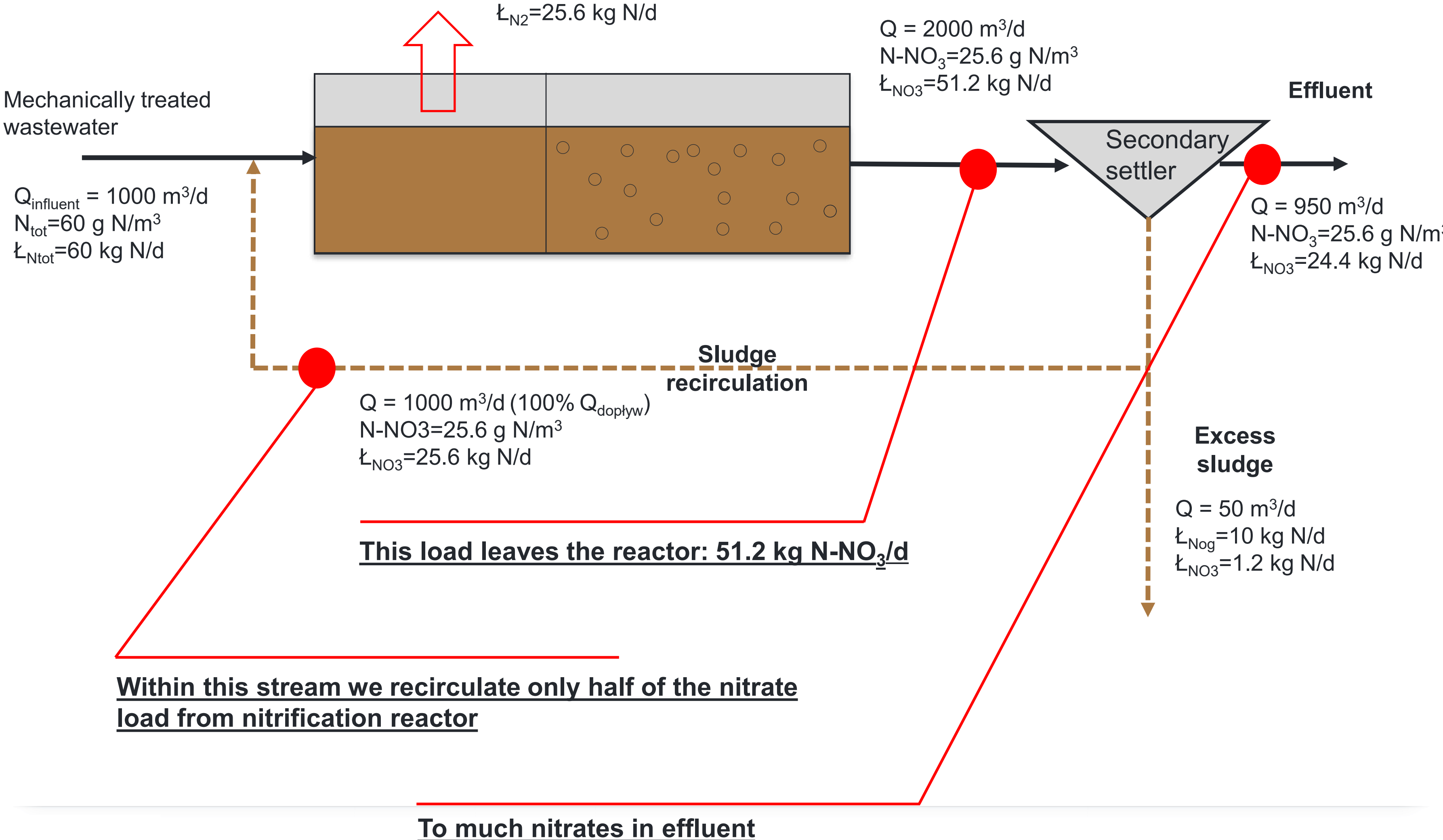


<u>Too small a nitrate load is returned by this stream</u>
- Typically, this recirculation amounts to 50–100% of Q.
- This means that 33%–50% of nitrates are returned with this stream.
- This is too little to ensure the proper quality of the treated wastewater.

<u>This recirculation serves to return an additional nitrate load</u>
- Typically, this recirculation amounts to several hundred percent of Q.
- The majority of the produced nitrates are returned via this stream.
- Thanks to this, it is possible to remove most of the nitrates in the denitrification chamber and meet the quality standards.

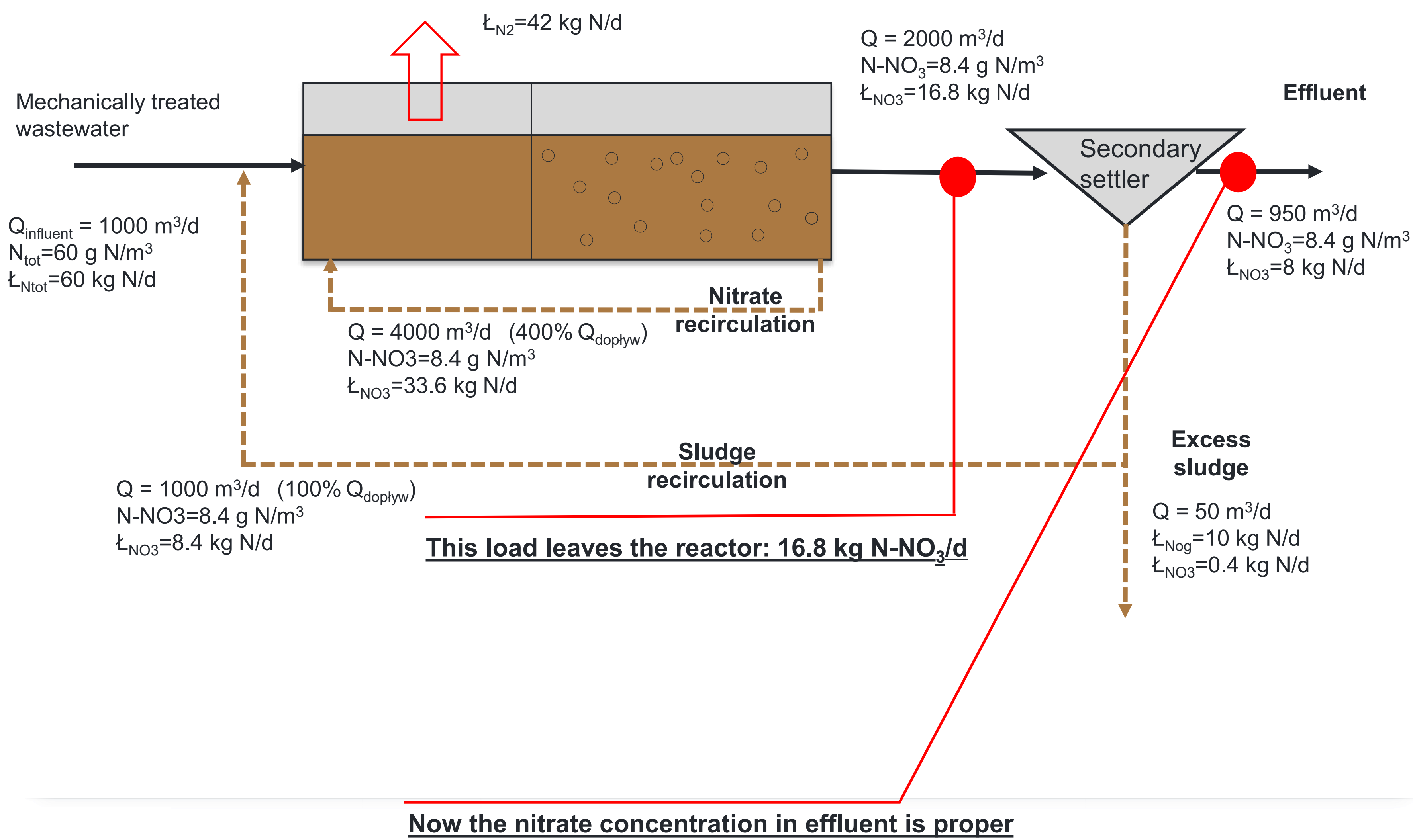
Denitrification

The role of nitrate recirculation



Denitrification

The role of nitrate recirculation



Denitrification

Technological parameters

Sludge retention time > 10 d (AX/OX scheme)
pH – 6.0 – 8.0
T >8°C
O_2 in anoxic reaktor < 0.5 gO_2/m^3

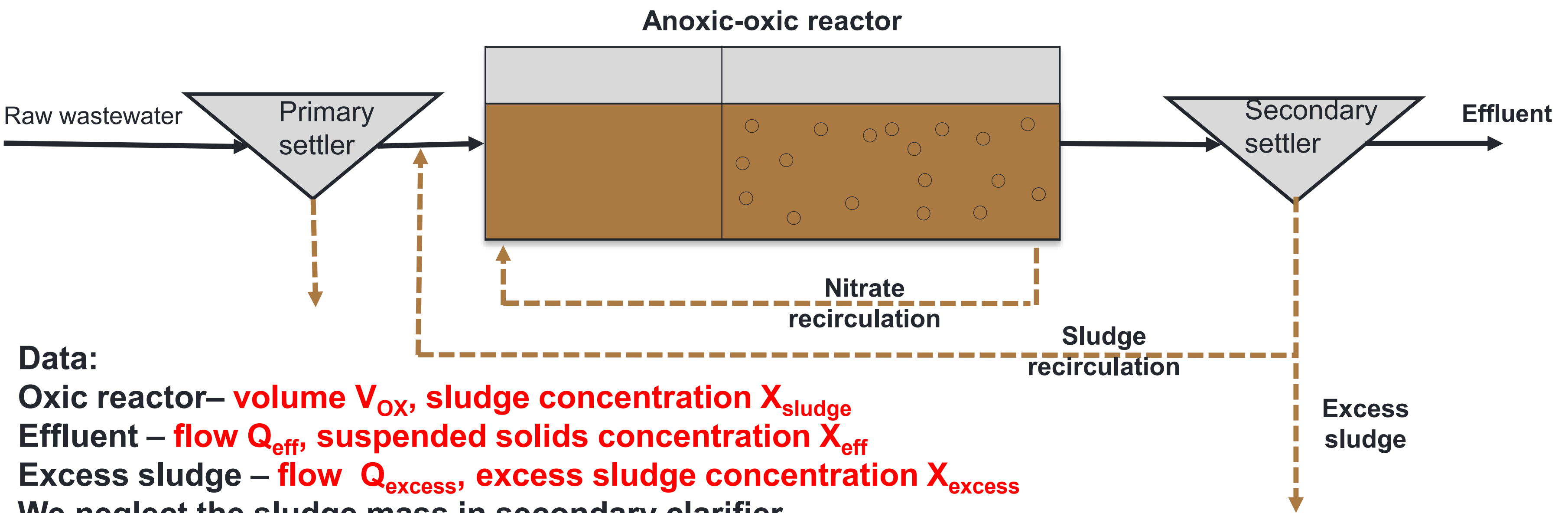
Denitrification

Treatment efficiency

In appropriate conditions:
>95% NH_4
>90% NO_3
ca. 90 % N_{tot}

Oxic sludge retention time

Definition



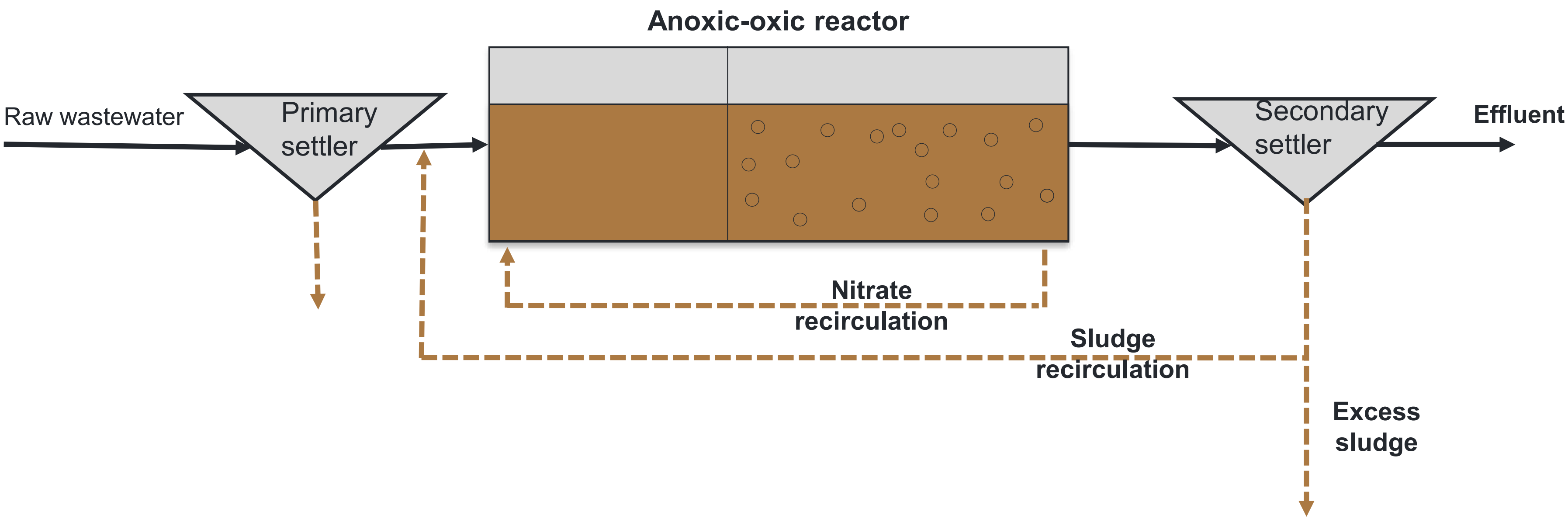
Data:
Oxic reactor– volume V_{OX}, sludge concentration X_{sludge}
Effluent – flow Q_{eff}, suspended solids concentration X_{eff}
Excess sludge – flow Q_{excess}, excess sludge concentration X_{excess}
We neglect the sludge mass in secondary clarifier

Sludge mass in oxic reactor, kg sm

$$SRT_{OX} = \frac{V_{OX} \cdot X_{sludge}}{Q_{excess} \cdot X_{excess} + Q_{eff} \cdot X_{eff}}, \text{ d}$$

Oxic sludge retention time

Definition



$$\frac{SRT_{OX}}{SRT} = \frac{= \dfrac{V_{OX} \cdot X_{sludge}}{Q_{excess} \cdot X_{excess} + Q_{eff} \cdot X_{eff}}}{\dfrac{V \cdot X_{sludge}}{Q_{excess} \cdot X_{excess} + Q_{eff} \cdot X_{eff}}} = \frac{V_{OX}}{V}$$

Oxic sludge retention time

Example

Data:
Oxic reactor
volume V_{OX}=500 m^3
sludge concentration X_{sludge}=4 kg SS/m^3
Effluent –
flow Q_{eff} =–1000 m^3/d
suspended solids concentration X_{eff} =10 g SS/m^3
Excess sludge –
flow Q_{excess}=50 m^3
excess sludge concentration X_{excess}=8 kg SS/m^3
We neglect the sludge mass in secondary clarifier

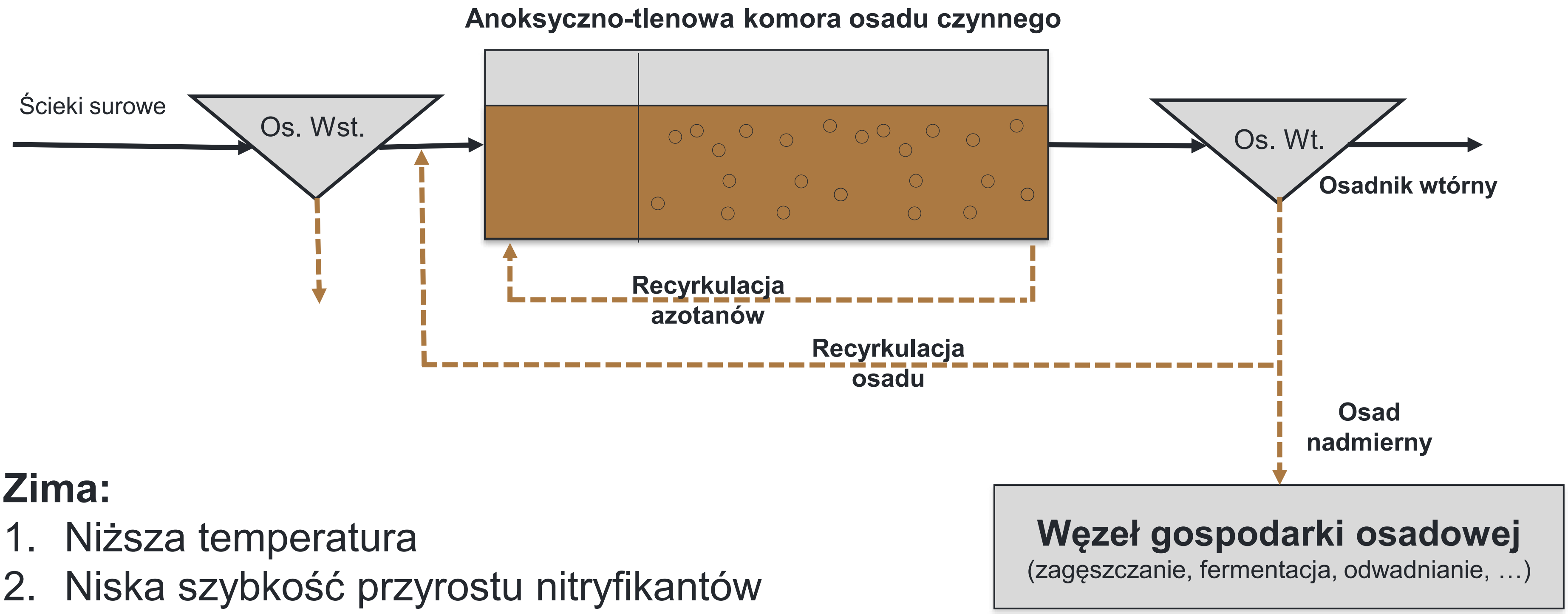
$$SRT_{OX} = \frac{V_{OX} \cdot X_{OX}}{Q_{excess} \cdot X_{excess} + Q_{eff} \cdot X_{eff}} = \frac{500 \cdot 4}{50 \cdot 8 + 1000 \cdot 0.01} =$$

$$\frac{2000}{400 + 10} = 4.87\ d$$

Usually can be omitted

Denitryfikacja

Eksploatacja w zimie

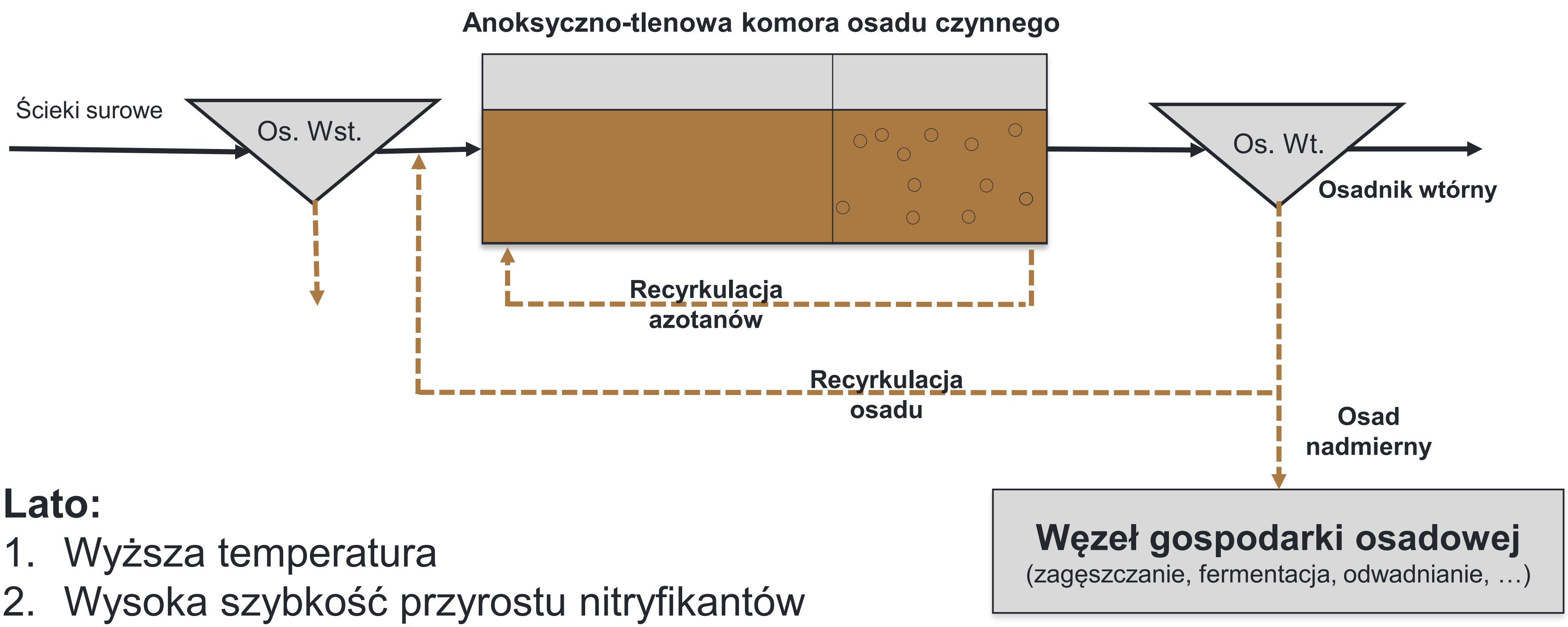


Zima:

1. Niższa temperatura
2. Niska szybkość przyrostu nitryfikantów
3. Tlenowy wiek osadu musi być wyższy
4. Musimy więc zwiększyć objętość strefy tlenowej
5. Walczymy o utrzymanie nitryfikacji

Denitryfikacja

Eksploatacja w lecie



Lato:

1. Wyższa temperatura
2. Wysoka szybkość przyrostu nitryfikantów
3. Tlenowy wiek osadu może być niższy
4. Możemy więc zmniejszyć objętość strefy tlenowej
5. Poprawiamy usuwanie azotu

Control questions

1. Describe the course of the denitrification process
2. Under what conditions is denitrification possible in the aerobic chamber?
3. What are the substrates of the denitrification process?
4. What role does nitrate recirculation play?
5. What does nitrate removal look like when there is no nitrate recirculation?
6. What is the aerobic sludge age?