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ACTIVATED SLUDGE AND OTHER BIOLOGICAL METHODS

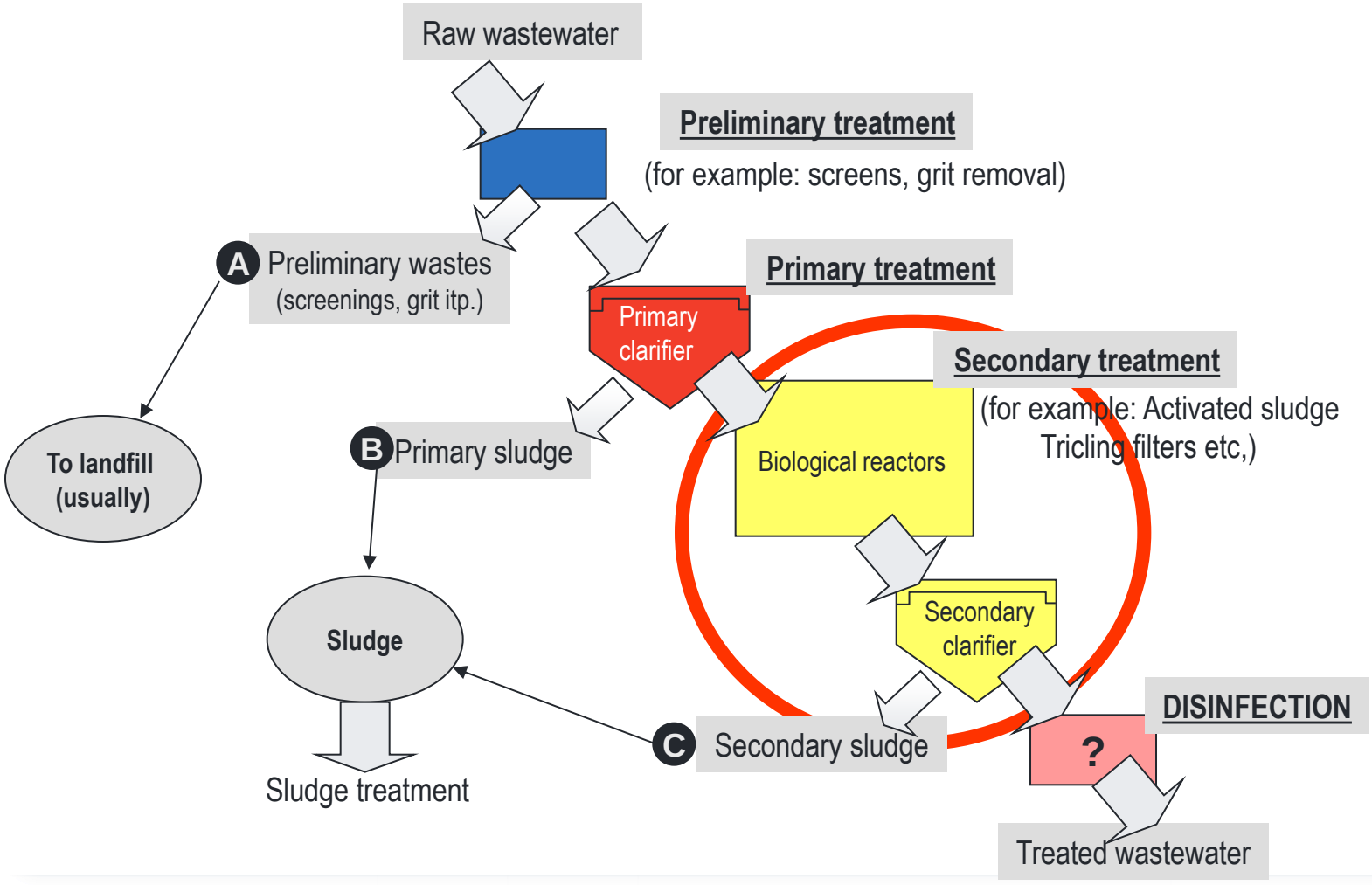
Wastewater Treatment Technology- course
Faculty of Environmental Engineering, Wroclaw University of Science and Technology

WROCŁAW, 2025

Presentation plan

1. Activated sludge
2. Trickling filters and wastewater ponds (lagoons)

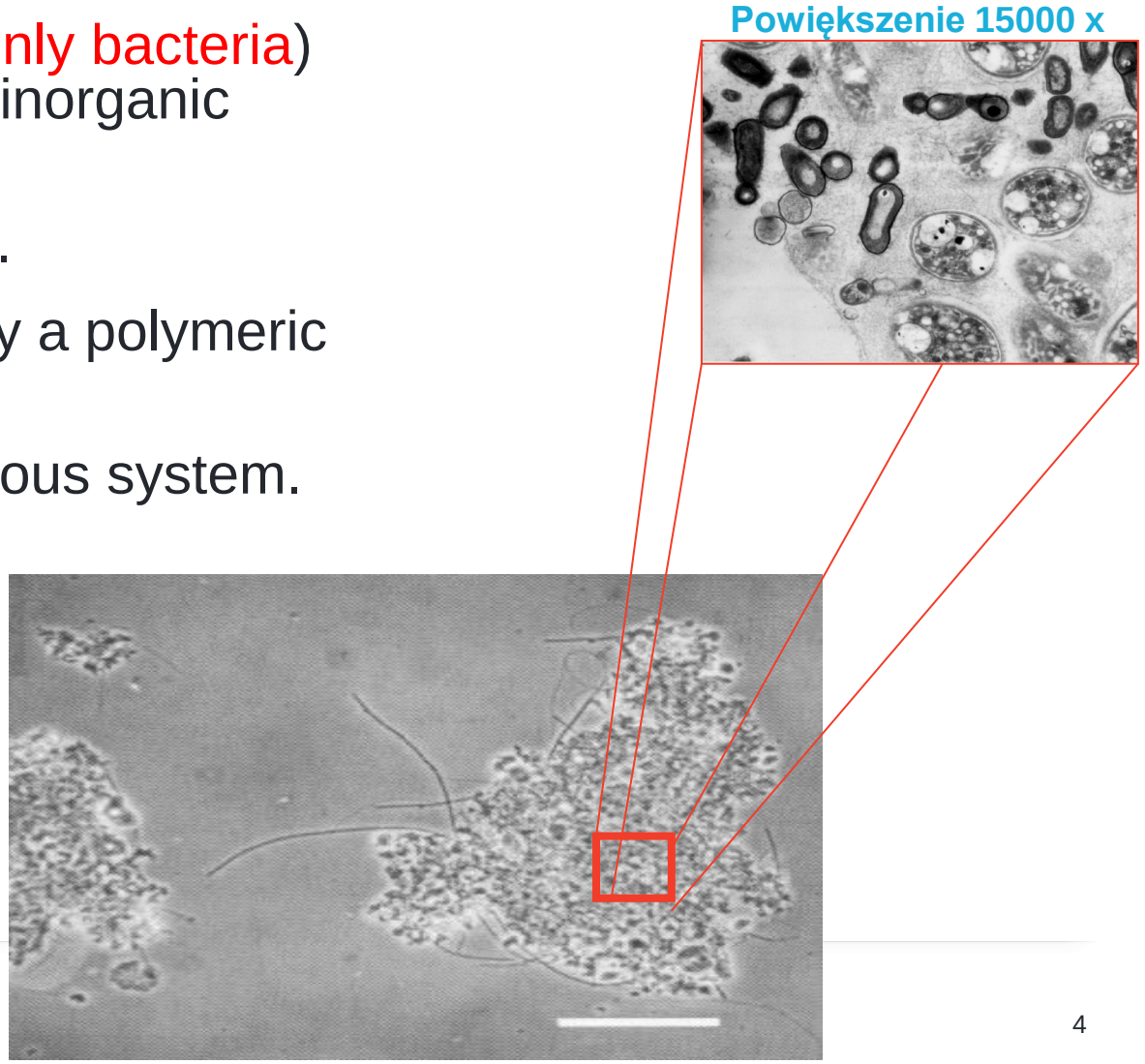
Where are we?


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

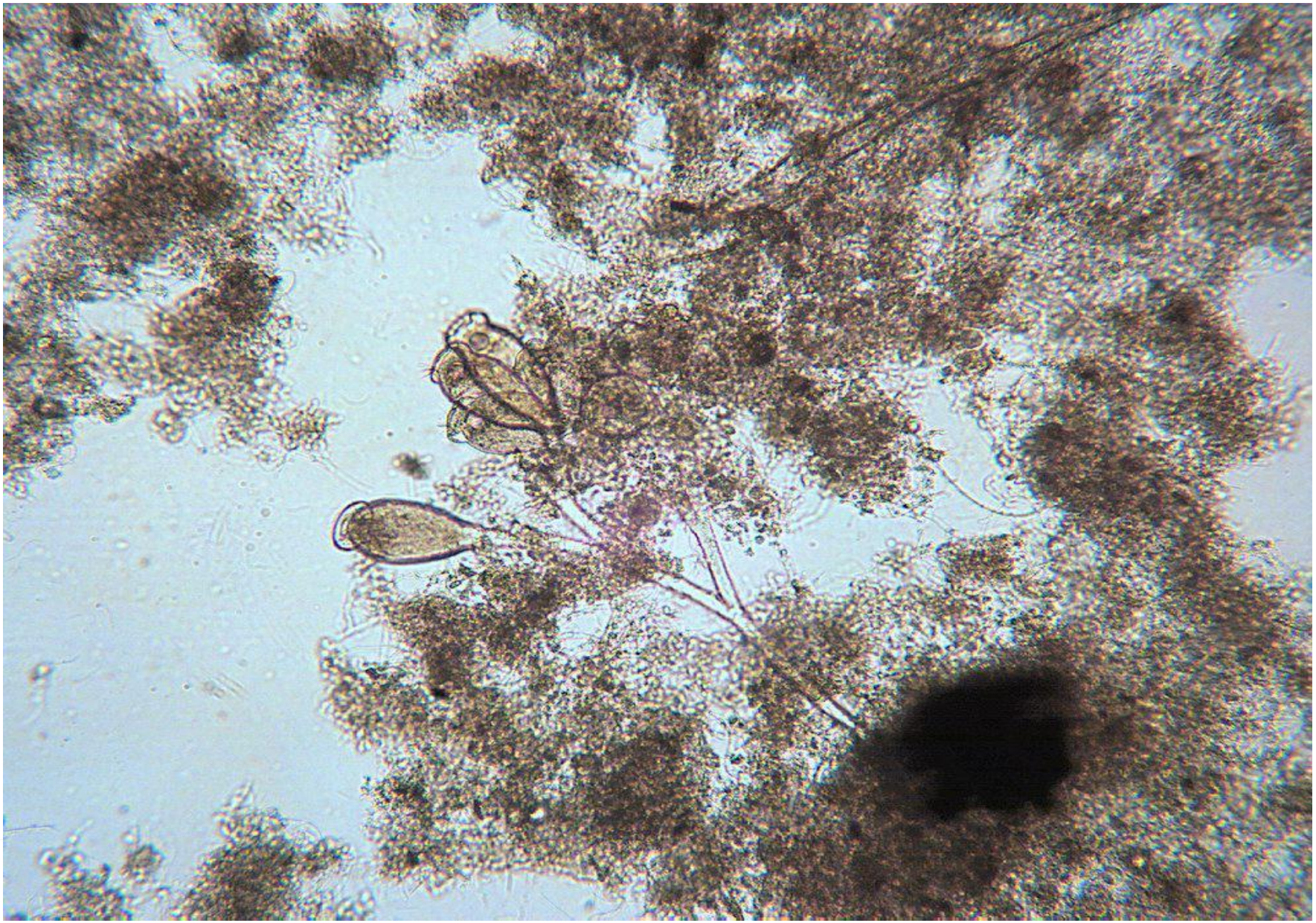
Activated sludge

What is activated sludge?

- **Flocculated mass of microorganisms** (mainly bacteria) and dead organic and inorganic matter.
- Floc size: ~10-300 μm.
- Bacteria surrounded by a polymeric substance.
- A complex heterogeneous system.



What is activated sludge?



What is activated sludge?

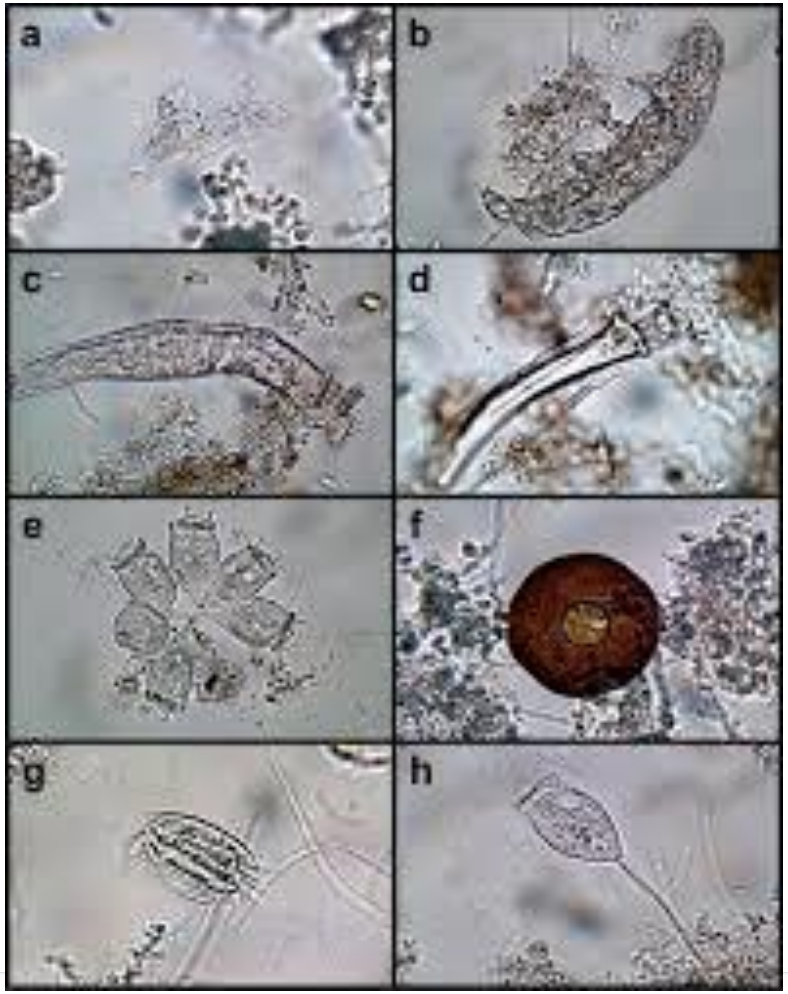
What is activated sludge?

Mechanism of activated sludge creation

Mechanism of activated sludge creation

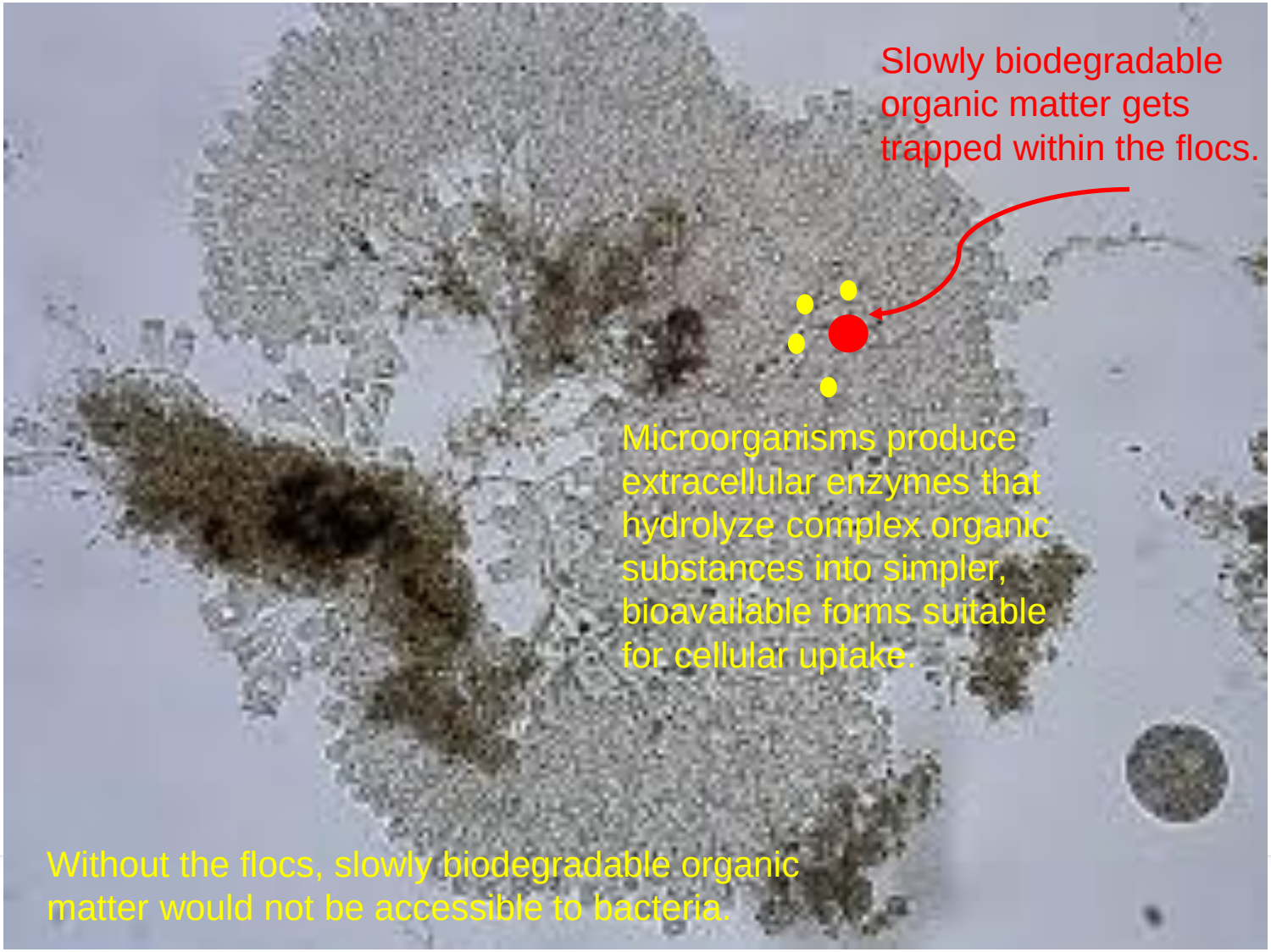
Protozoa

1. Predators of activated sludge
2. They have enormous filtration abilities.
3. Freely suspended bacteria are engulfed.



Mechanism of activated sludge creation

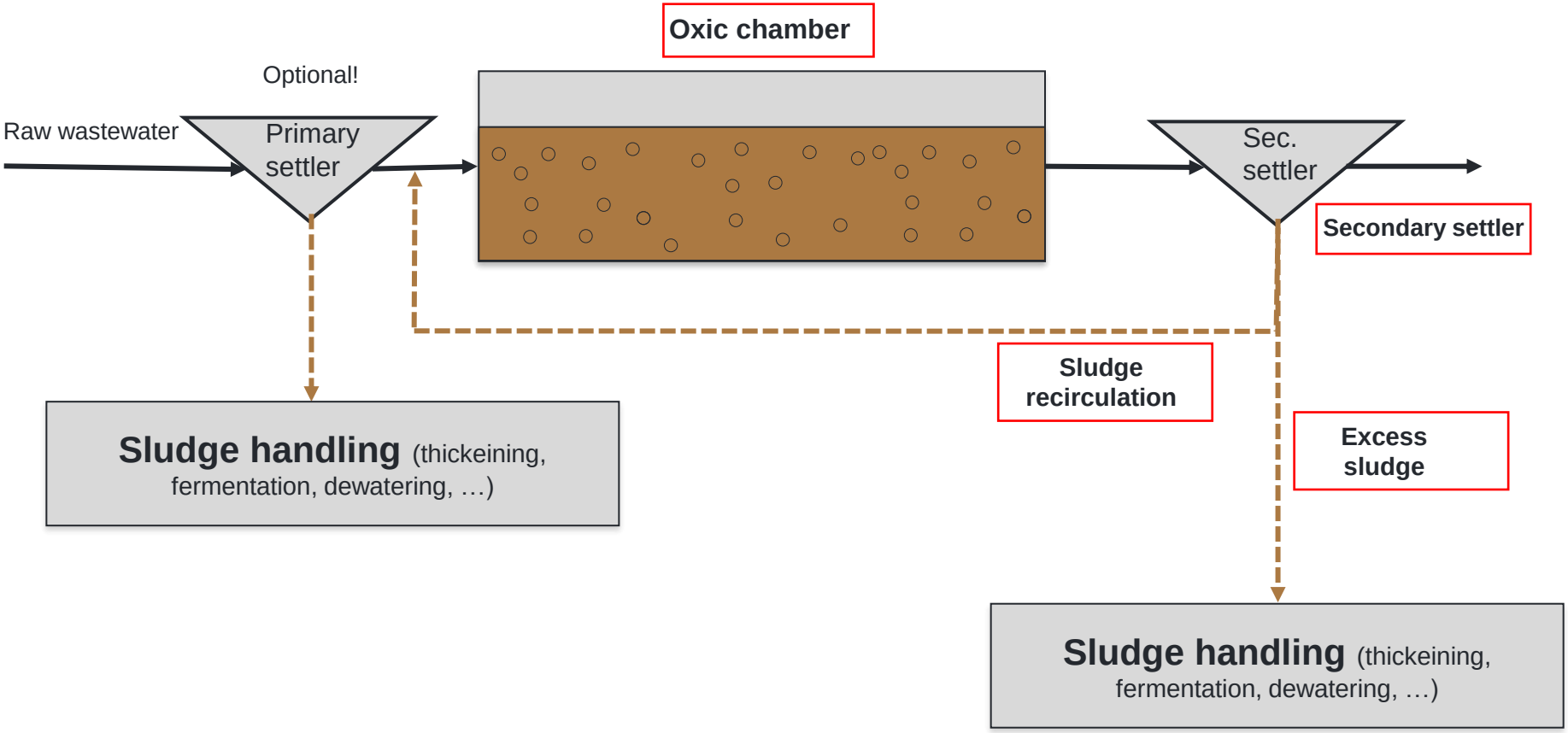
Access to slowly biodegradable matter



Basic activated sludge system

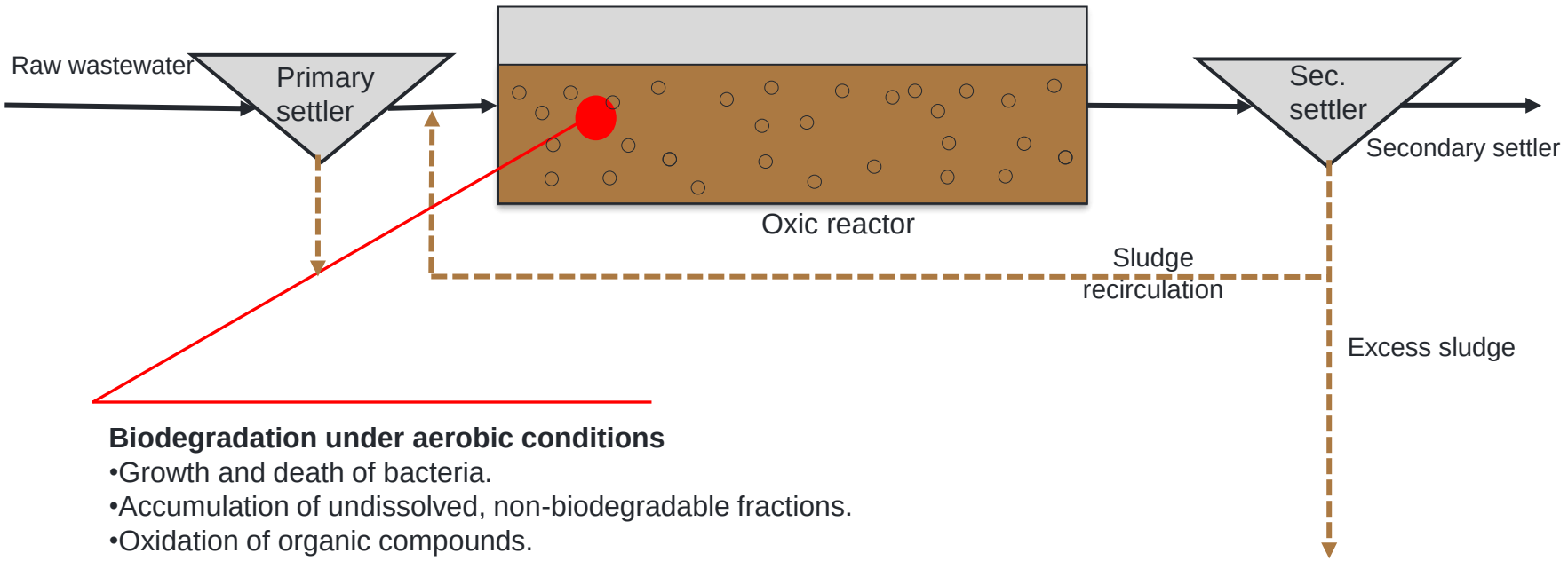
Basic activated sludge system

The Idea



Basic activated sludge system

Reactor

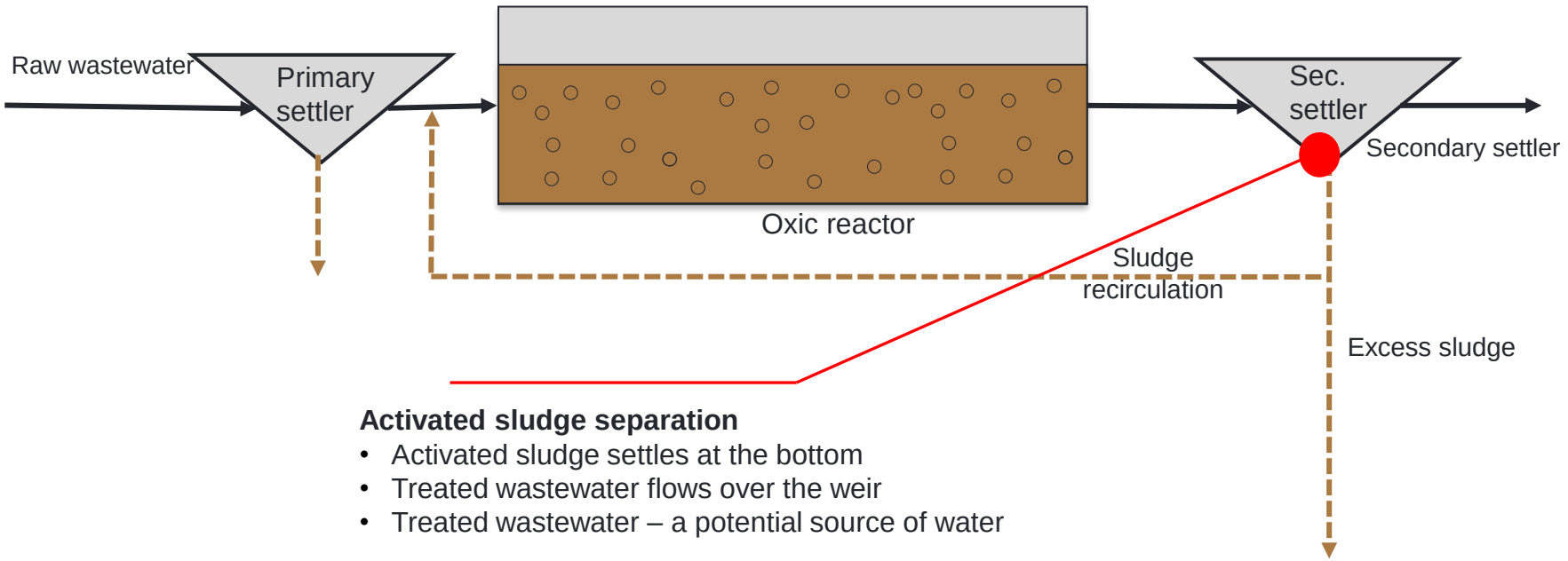


Biodegradation under aerobic conditions

- Growth and death of bacteria.
- Accumulation of undissolved, non-biodegradable fractions.
- Oxidation of organic compounds.
- Nitrification under appropriate conditions

Basic activated sludge system

Secondary settler

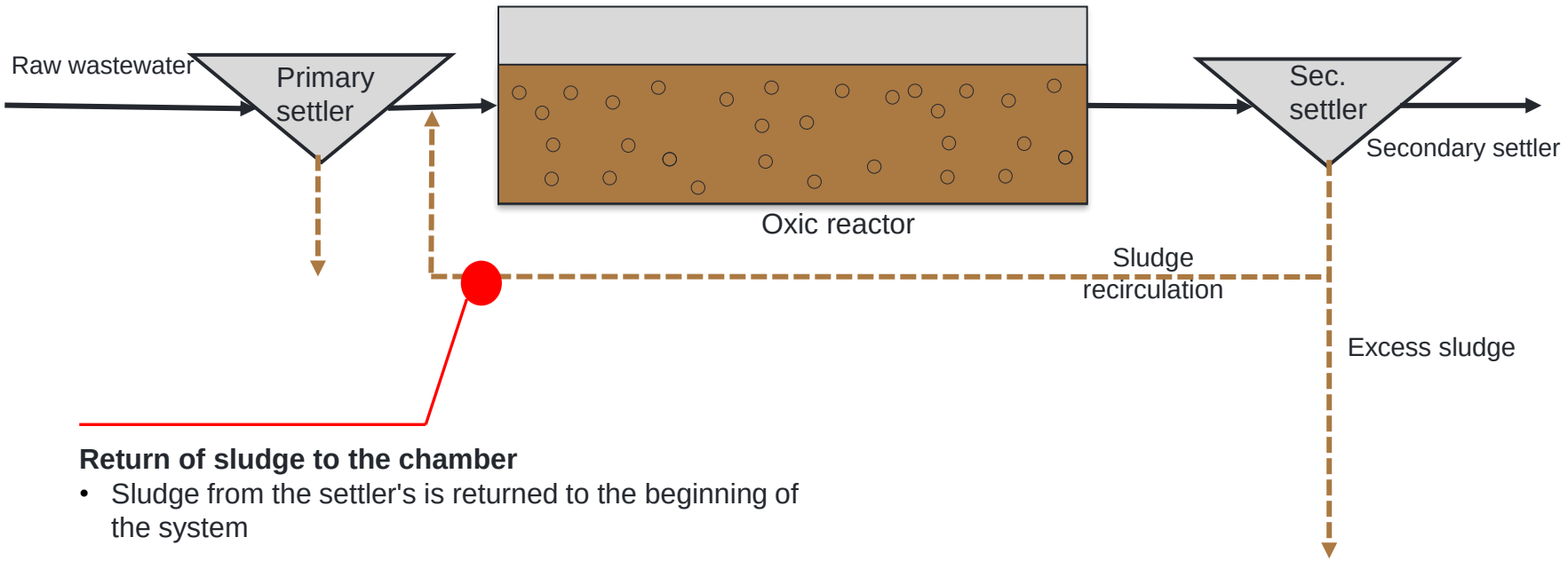


Activated sludge separation

- Activated sludge settles at the bottom
- Treated wastewater flows over the weir
- Treated wastewater – a potential source of water

Basic activated sludge system

Sludge recirculation

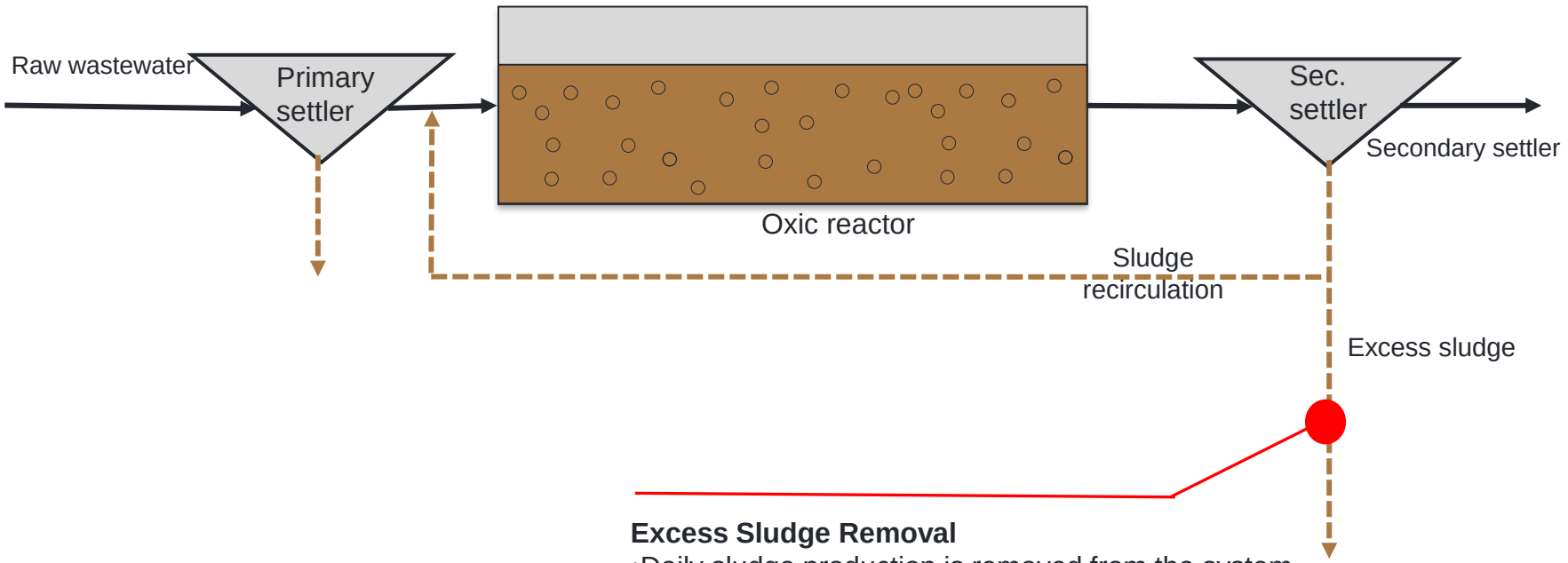


Return of sludge to the chamber

- Sludge from the settler's is returned to the beginning of the system

Basic activated sludge system

Sludge recirculation



Excess Sludge Removal

- Daily sludge production is removed from the system.
- Necessary for maintaining sludge mass stability in the reactor.

Basic activated sludge system

Summary

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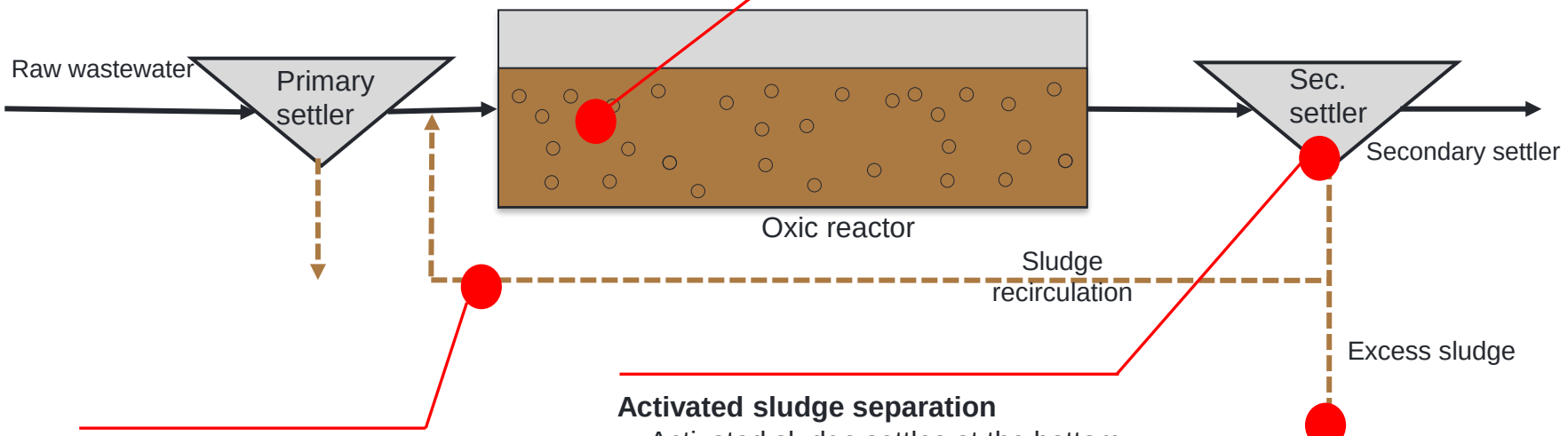

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How to cultivate activated sludge?

How to cultivate activated sludge?

Bacteria in raw wastewater

Parameter	Symbol	Unit	Wastewater characteristic			
			Conc.	Average	Diluted	Very diluted
- slowly biodegradable	X_S	g O_2/m^3	290	210	125	85
- heterotrophs	X_H	g O_2/m^3	120	90	55	35
- denitrifiers	$X_{H,D}$	g O_2/m^3	80	60	40	25
- autotrophs	X_A	g O_2/m^3	1	1	0.5	0.5

Raw wastewater contains bacteria that can be used as an inoculum

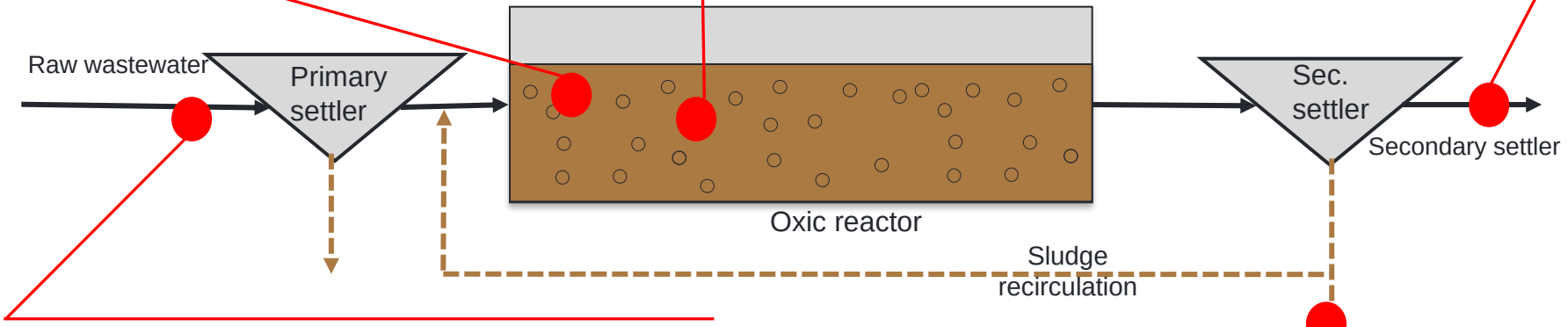
How to cultivate activated sludge?

Process start-up

Sludge from another treatment plant
- In practice, the startup process is often accelerated by introducing activated sludge from another wastewater treatment plant.

Aeration
- The reactor is continuously aerated.

Treated Wastewater Quality
- Initially poor,
- Improves over time.



We begin feeding the treatment plant with wastewater
- Wastewater contains organic compounds as well as all necessary macro- and micronutrients.
- It also introduces a variety of bacteria into the system.

Excess Sludge Removal
- No excess sludge is removed until a sufficient amount of activated sludge has been developed.

Control questions

1. Why does the ability to separate biomass have a critical impact on the size of a wastewater treatment plant?
2. What are the two main consequences of a secondary clarifier failure or shutdown? What will happen at the plant?
3. What is the role of sludge recirculation?
4. What happens if sludge recirculation is turned off?
5. What is excess sludge?
6. Why do we remove excess sludge?
7. What is the function of the biological treatment unit (biological block)?

Videos about activated sludge:

- https://www.youtube.com/watch?v=rJ6hf14MBYU
- https://www.youtube.com/watch?v=bVjefb6C5cA
- https://www.youtube.com/watch?v=3flM6rAUk10
- https://www.youtube.com/watch?v=oBMVXXXTne0
- https://www.youtube.com/watch?v=4abOOpbK2-M&ab_channel=TEN-TechnologyforENvironment
- https://www.youtube.com/watch?v=5uuQ77vAV_U&ab_channel=MITK12Videos

History of activated sludge:
http://www.iwa100as.org/history.php

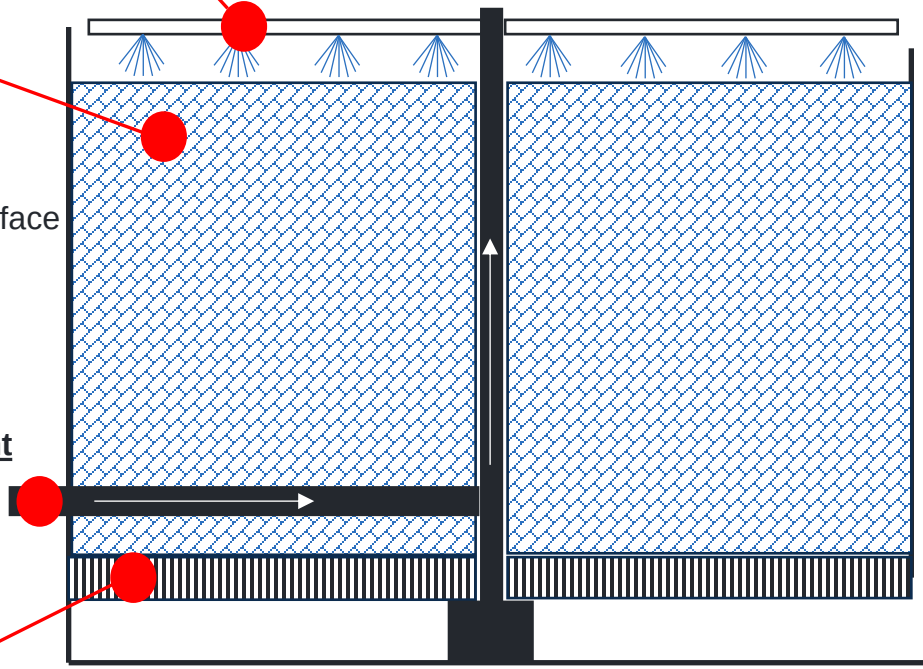
Trickling filters

Trickling filters

Idea

Sprinklers
- They evenly distribute wastewater over the filter bed

Media (Filling Material)
- Artificial or natural
- Large surface area
- Biofilm develops on its surface



Air Supply
- Provides aerobic conditions within the filter bed
- Can be natural or forced

Influent

Effluent to secondary settler

Support Grid (or Grate)
- Allows treated wastewater to pass through
- Prevents the media from escaping

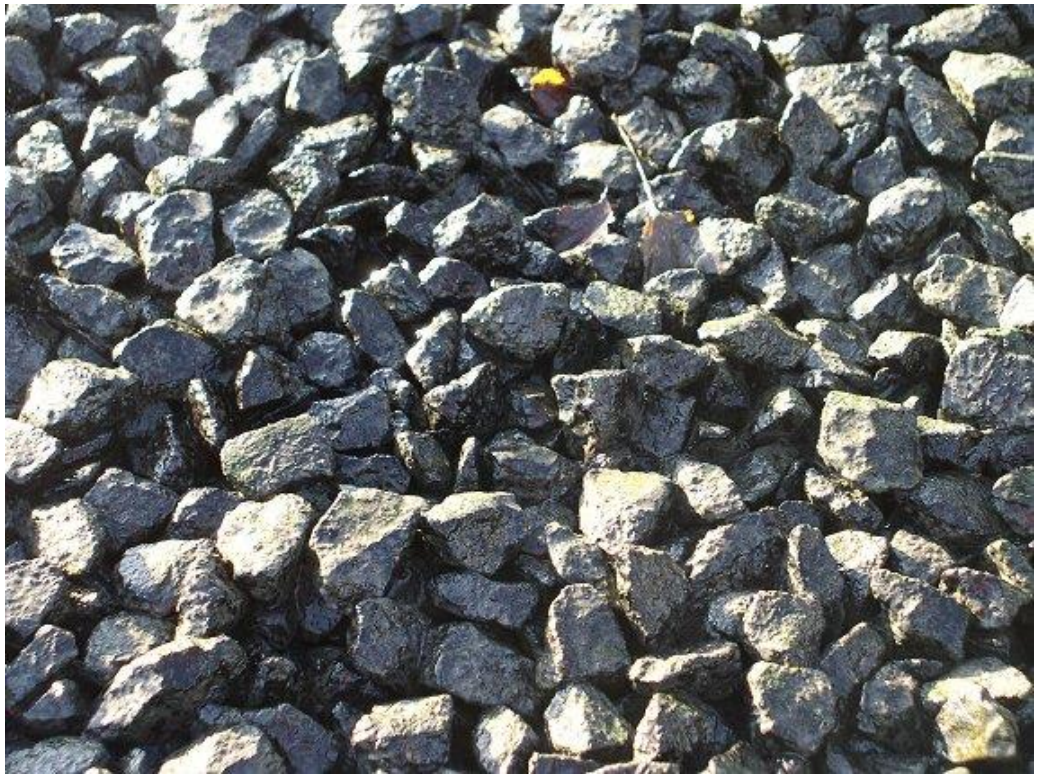
Recirculation

Trickling filters

Idea

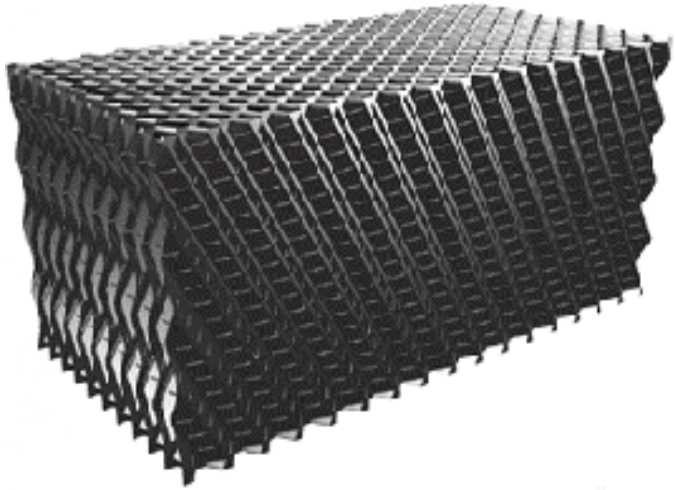
Trickling filters

Carrier Media - rock



Trickling filters

Carrier Media - plastic



Trickling filters

Carrier Media – Main Properties

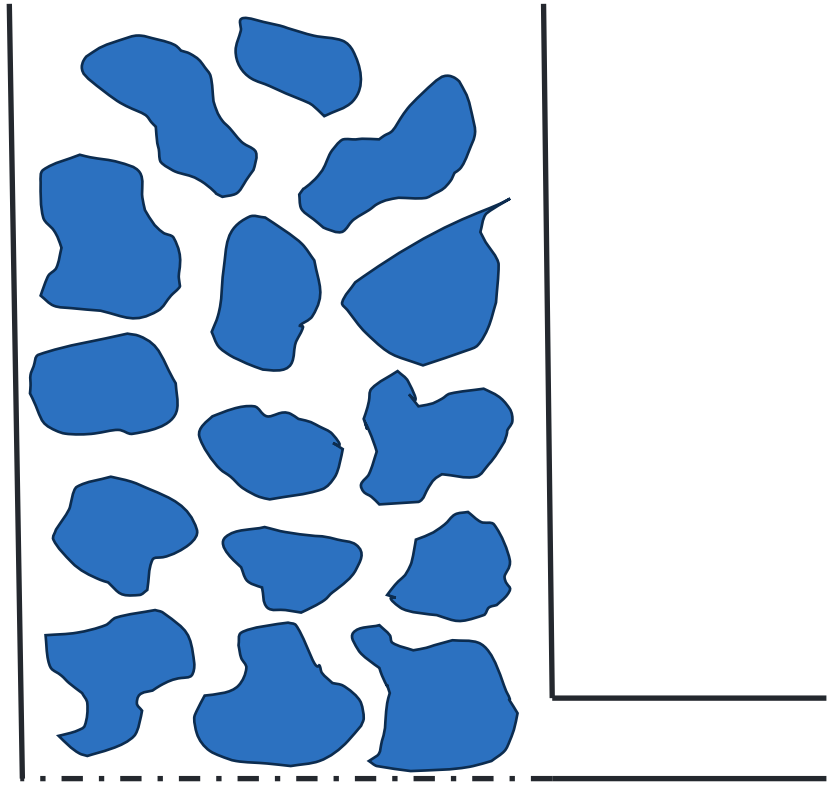
1. The primary function of the filter media is to provide optimal conditions for the growth of a large amount of biofilm.
2. The most important parameter is the specific surface area.
3. The specific surface area depends on the material and can exceed 100 m^2/m^3.
4. High porosity allows for the free flow of air.

Media type	Specific surface area, m^2/m^3	Porosity, %
Rock	50	55
Plastic	100 and more	95

Trickling filters

Principle of operation

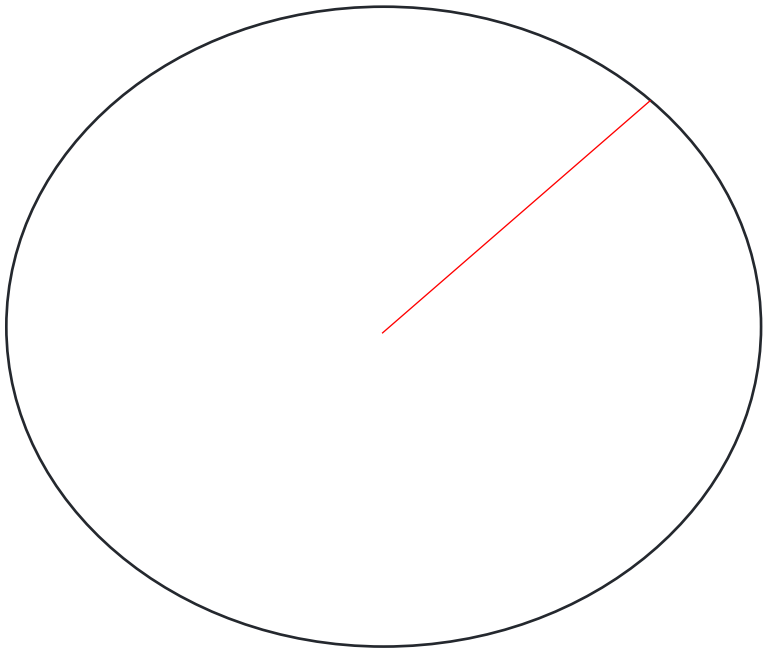
Place for student's notes



Trickling filters

Principle of operation- sprinklers

Place for student’s notes



Trickling filters

Design parameters

Parameter	Unit	BOD removal – low loading	BOD removal – high loading	BOD removal – high loading	BOD removal with nitrification
BOD removal efficiency	%	80-90	80-90	70-90	85-90
Type of media	-	Rock	Rock	Plastic	Plastic
Ventilation	-	Natural	Artificial	Artificial	Artificial
BOD load	kg BOD/m^3 d	0.08-0.3	0.6-1.6	0.6-2.4	0.08-0.4
Hydraulic loading	m^3/m^2 d	1-4	4-40	15-75	5-16
Recirculation	%Q	max. 100	100 to 200	100 to 200	100 to 200
Depth	m	1-2.5	1-2.5	3-12	3-12

Trickling filters

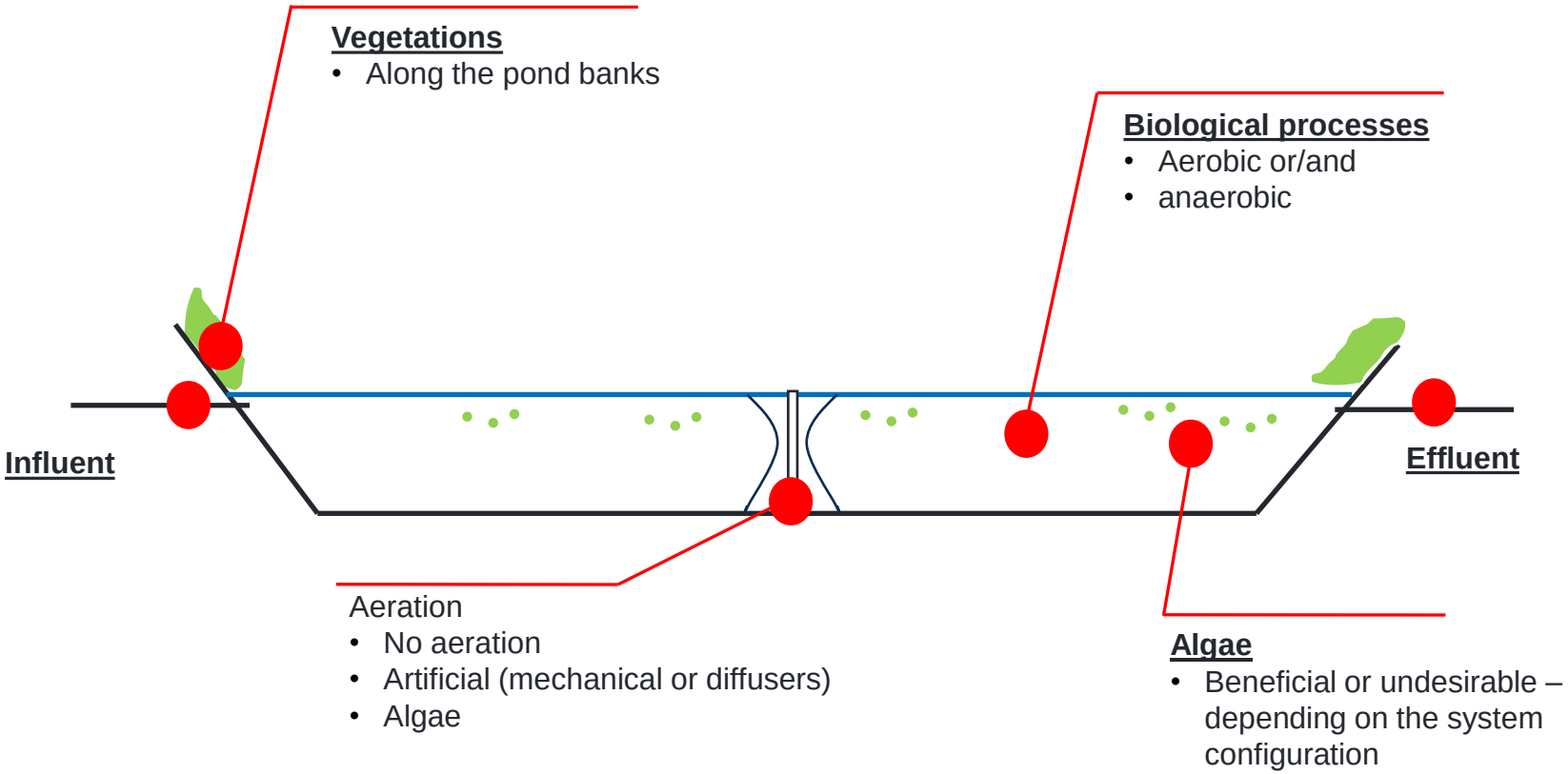
Other technologies

1. IFAS – Integrated Fixed-Film Activated Sludge. A hybrid system that combines activated sludge with fixed carriers submerged in the aeration tank.Description: Plastic media are suspended within the reactor, allowing biofilm growth and increasing biomass concentration.
2. MBBR – Moving Bed Biofilm Reactor. A biological reactor with freely moving carriers on which biofilm develops. Description: The carriers float and circulate throughout the reactor, enhancing treatment efficiency without the need for sludge recirculation.
3. Denitrifying Ponds (also known as denitrification lagoons or polishing ponds)Biological beds or lagoons used for post-treatment of wastewater, primarily for removing residual nitrates. Description: These systems facilitate denitrification under low-oxygen conditions and serve as a final treatment stage.

Lagoons

Lagoons

Idea



Lagoons

Idea

Lagoons

Anaerobic lagoons

Own drawning

Lagoons

Aerobic/anaerobic lagoons

Own drawning

Lagoons

Aerobic lagoons

Own drawning

Lagoons

Comparison

Process	Advantages	Drawbacks
Anaerobic lagoons	• Simple construction • Low investment and operating costs • Easy operation • Low sludge production • Potential for methane recovery • Effluent composition equalization • Dilution of inhibitors • Pathogen reduction • Relatively versatile	• Large volumes • Extensive surface area (+++) • Limited process control • High odor potential • Possibly low quality of treated effluent

Lagoons

Comparison

Process	Advantages	Drawbacks
Aerobic/anaerobic lagoons	• Simple construction • Low investment and operating costs • Easy operation • Low sludge production • Pathogen removal • Potential for nitrogen and phosphorus removal	• High hydraulic retention volumes • Extensive land requirement (++) • Limited controllability of biological processes • Risk of odor emissions

Lagoons

Comparison

Process	Advantages	Drawbacks
Aerobic lagoons	• Simple construction • Low investment costs • Good quality of treated wastewater • Easy operation • Low odor emissions	• Noticeable operating costs • Large surface area (+)

Control questions– trickling filters and lagoons

1. Describe the operating principle of a biological trickling filter.
2. What is the purpose of recirculation in a biological filter?
3. What is the aeration mechanism in a trickling filter?
4. Why does the presence of nitrifying bacteria in the filter depend on its organic loading rate?
5. What types of wastewater lagoons do you know?
6. Describe the operation of an anaerobic lagoon.
7. Describe the operation of a facultative (aerobic/anaerobic) lagoon.
8. Describe the operation of an aerobic lagoon.