

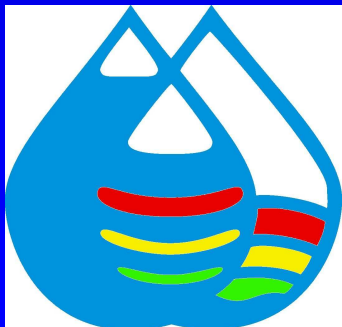
Biological Wastewater Treatment by Activated Sludge Process

Jiri Wanner

Prague Institute of Chemical Technology

ACE CR – Association of Wastewater

Treatment Experts
of the Czech Republic



Bacterial kinetics and selection



BASIC TERMS

- SUBSTRATE: defined as the source of energy for living cells.
- CARBON SOURCE: synthesis of new biomass
 - inorganic x organic; external x internal
- NUTRIENTS: macro x micro
- ELECTRON ACCEPTORS: cultivation conditions *anaerobic, anoxic, oxic*

Bacterial kinetics and selection



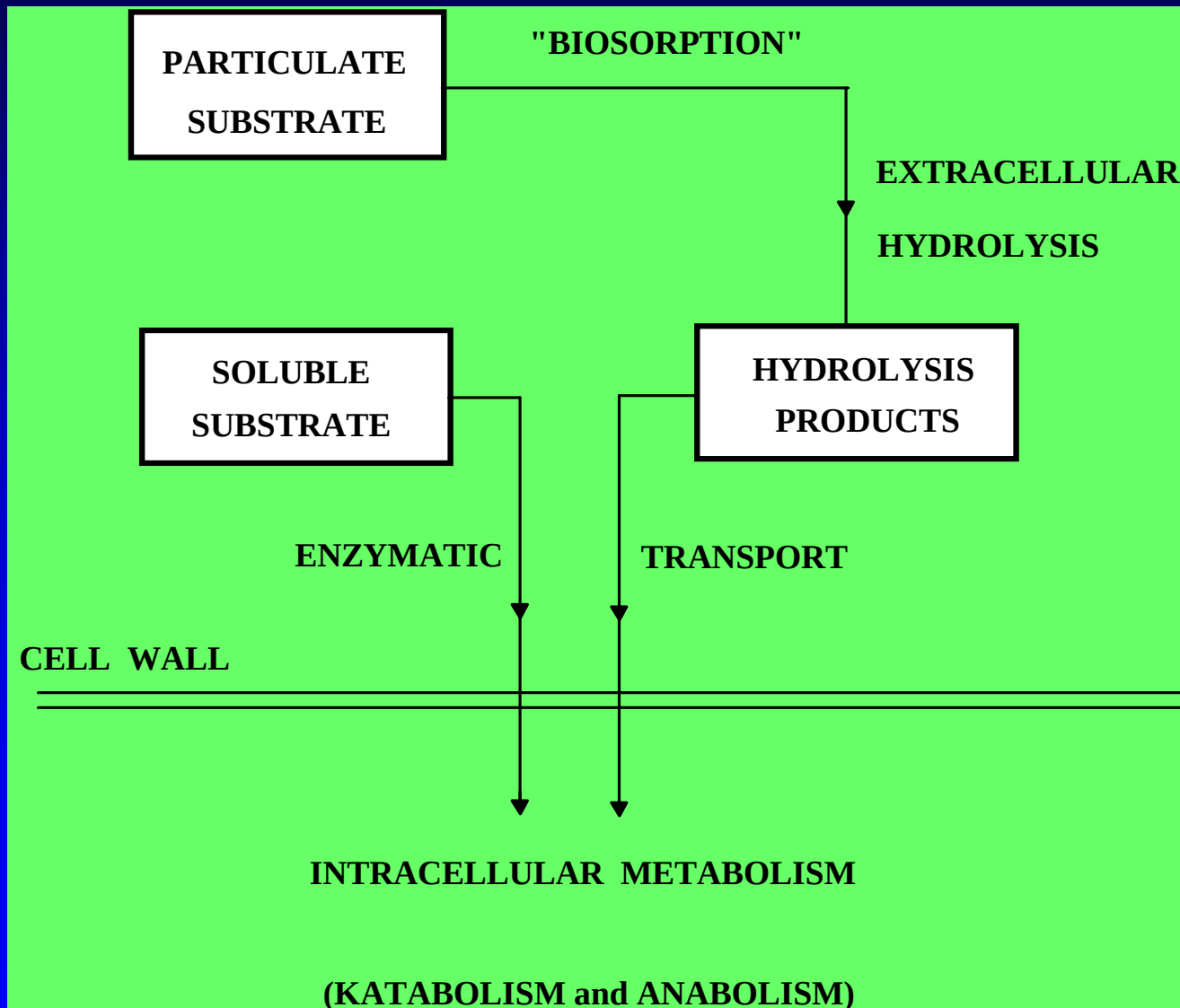
ORGANIC CARBON REMOVAL

- TRANSPORT AND „BIOSORPTION“
- ACCUMULATION AND STORAGE
- METABOLISM:
 - KATABOLISM - production of energy
 - ANABOLISM - synthesis of new biomass
- FERMENTATION under anaerobic cond.
- org. C REMOVAL AND *EBPR*

Bacterial kinetics and selection



REMOVAL OF ORGANIC POLLUTION



Bacterial kinetics and selection



KINETIC SELECTION

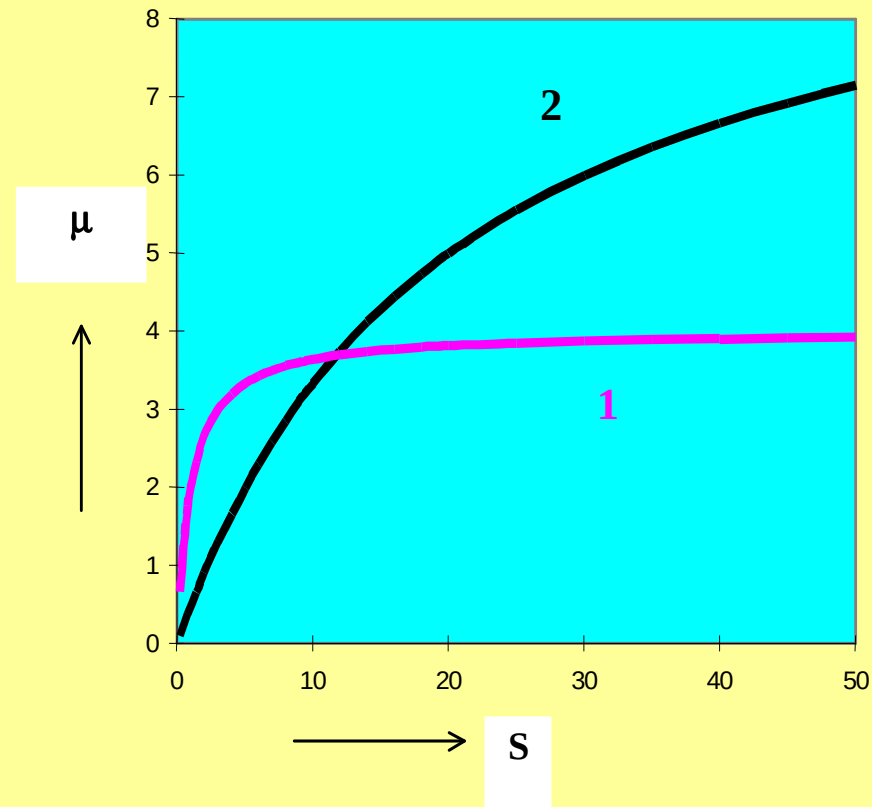
1) “BALANCED GROWTH”

— μ_{MAX} and K_S strategy

$$\mu = \mu_{MAX} \frac{S}{S + K_S}$$

1) K_S STRATEGY

2) μ_{MAX} STRATEGY



Bacterial kinetics and selection

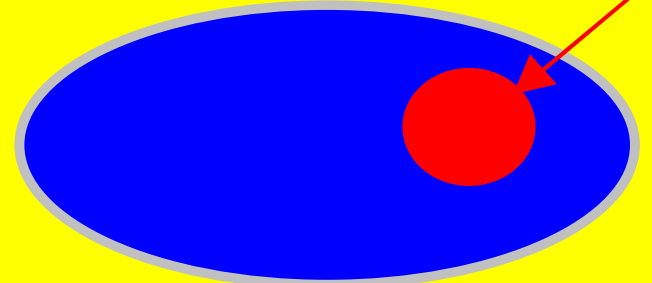


KINETIC SELECTION

2) “UNBALANCED GROWTH”

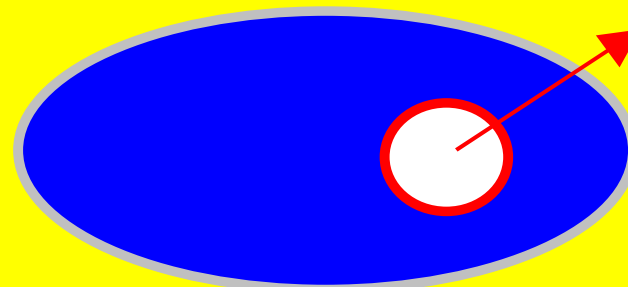
A.S. SYSTEM WITH
SUBSTRATE
CONCENTRATION
GRADIENT

CONTACT (EXO - SUBSTRATE)



COD

REGENERATION (ENDO-METAB.)

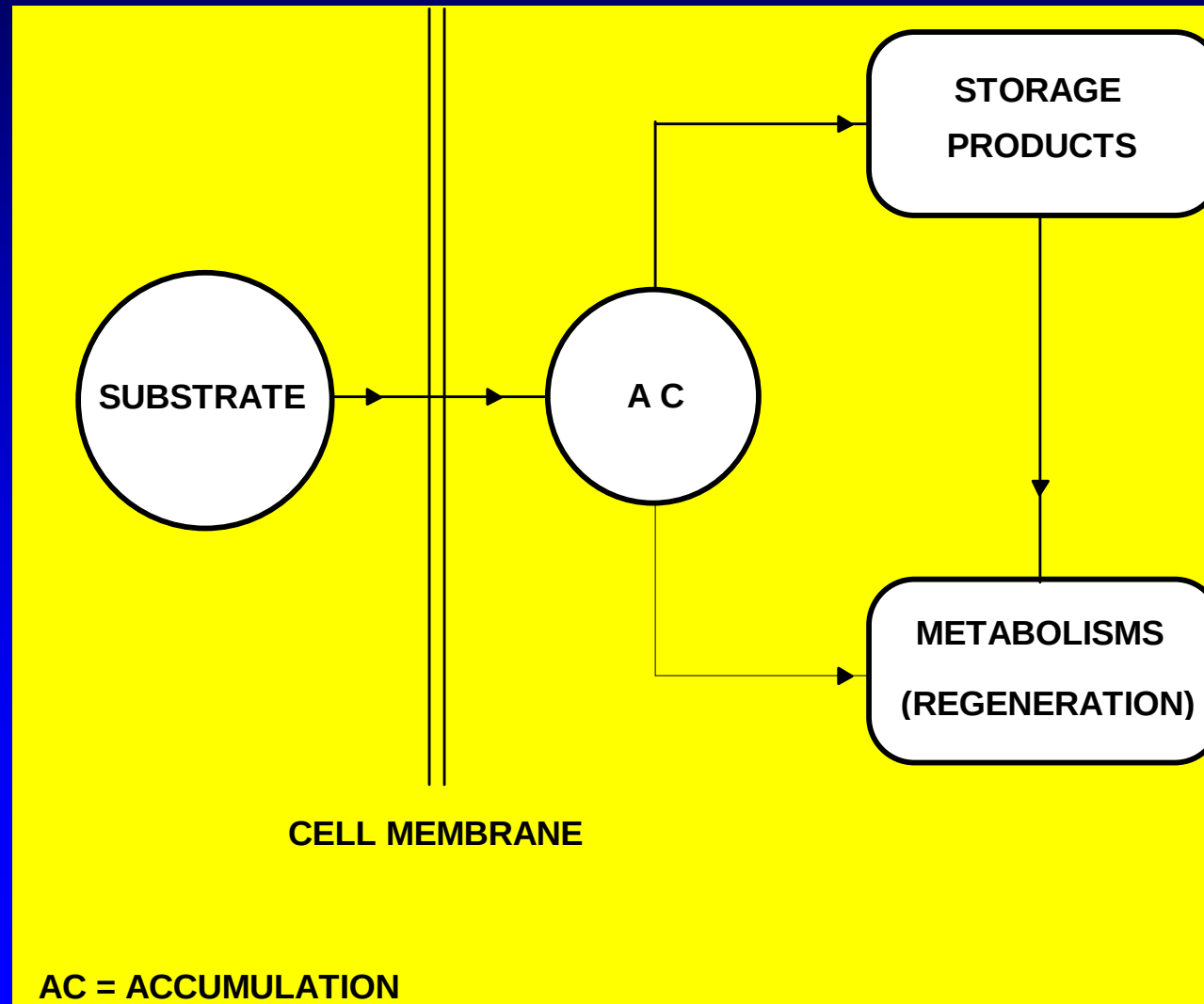


CO₂ + H₂O

Bacterial kinetics and selection



KINETIC SELECTION - UNBALANCED GROWTH



Bacterial kinetics and selection

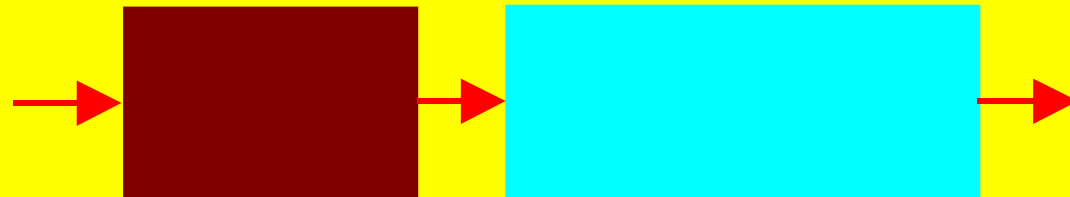


METABOLIC SELECTION

UTILIZATION OF ORG. C

ACCUM/
STORAGE

METABOLISM
(KATA- ANA-)



CONDITIONS:

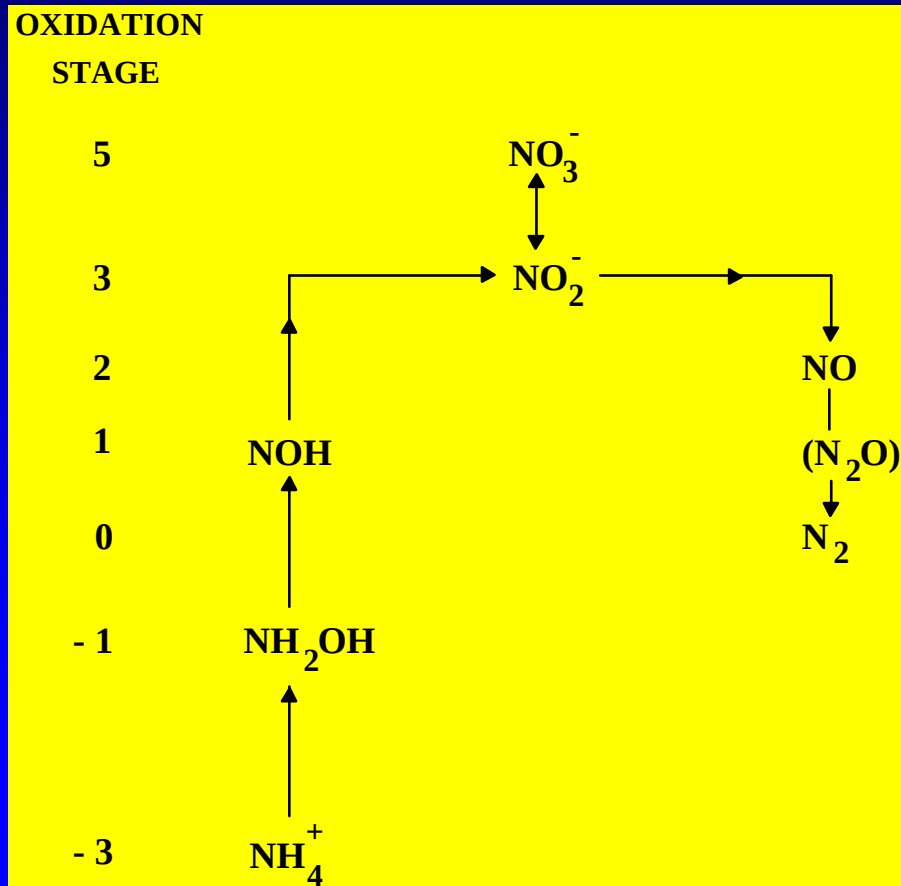
NON-AERATED

OXIC

Bacterial kinetics and selection



OXIC / ANOXIC CONDITIONS



NITRIFICATION:

N donor of 8 electrons

DENITRIFICATION:

N acceptor of 5 electrons

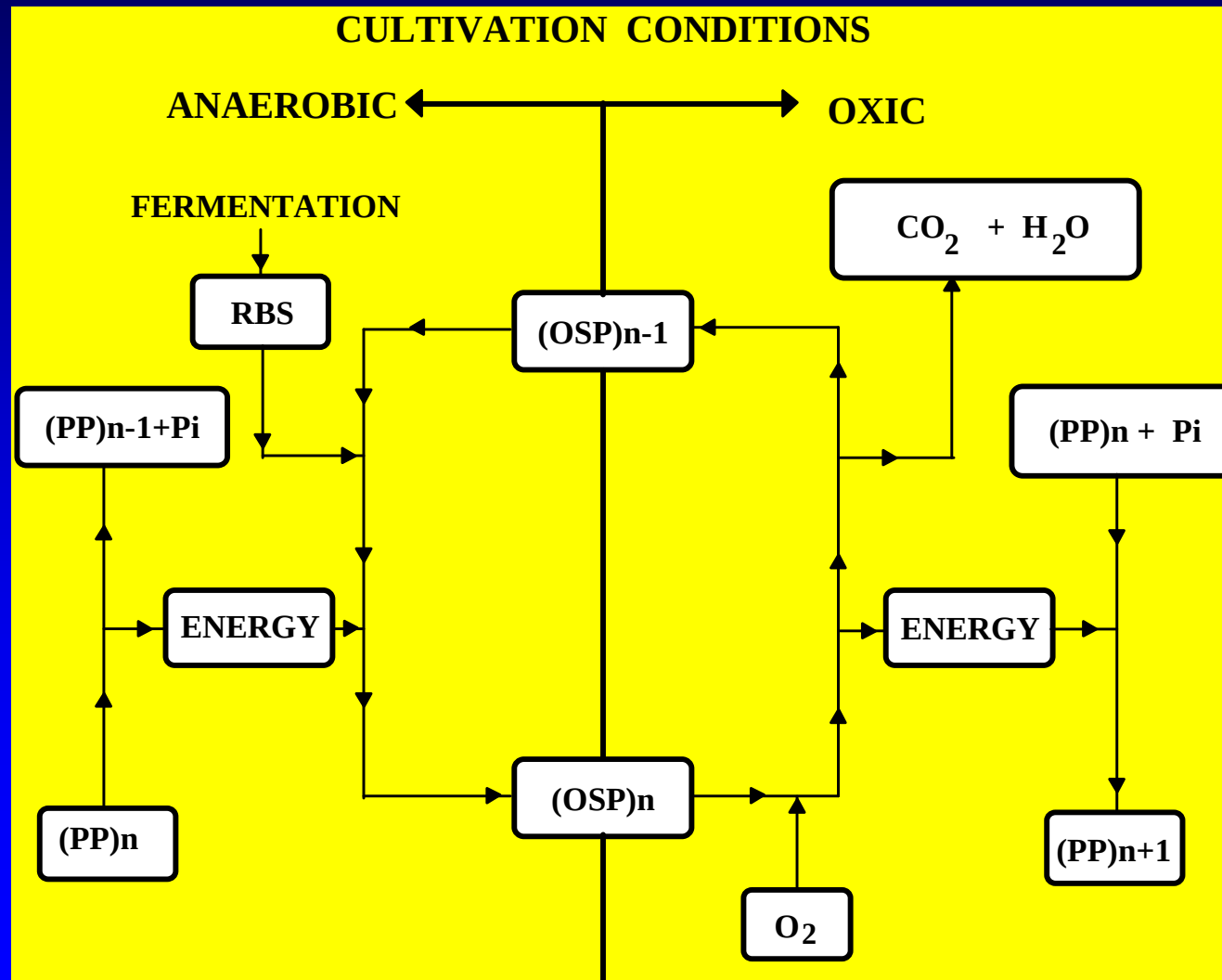
(1 N = 5/4 O₂)

(1 g N = 2.86 g O₂)

Bacterial kinetics and selection



OXIC / ANAEROBIC CONDITIONS



Bacterial kinetics and selection



KINETIC SELECTION

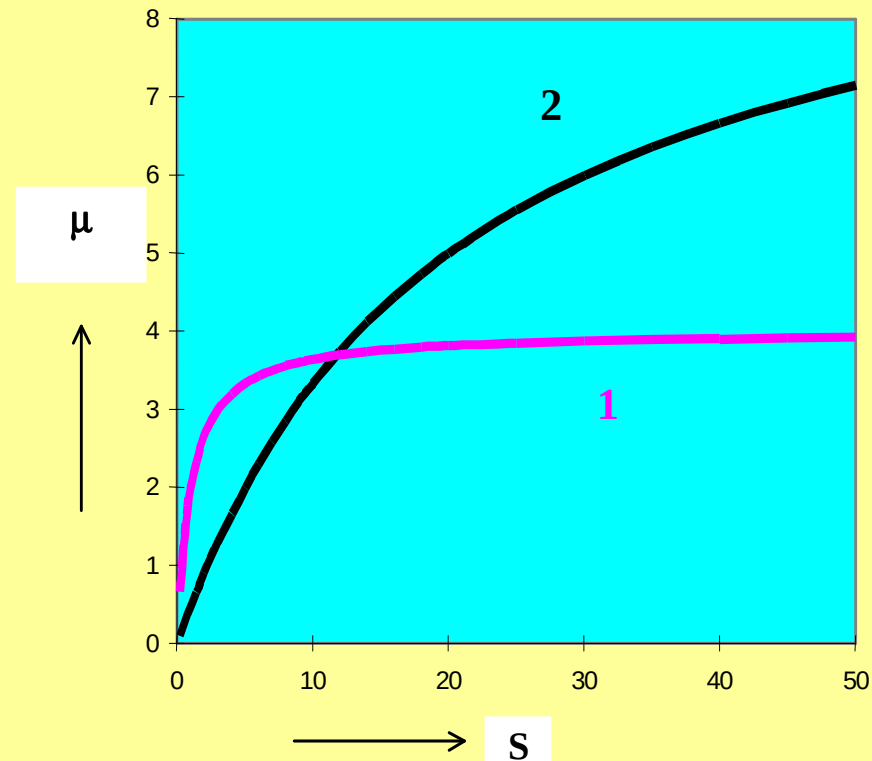
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Bacterial kinetics and selection

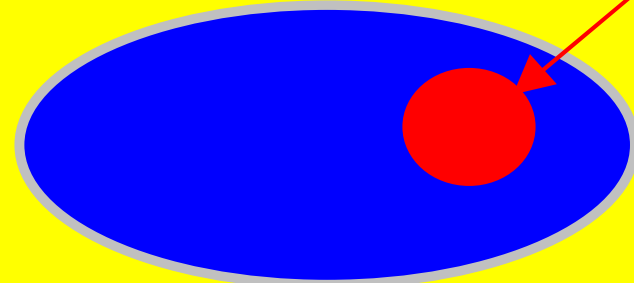


KINETIC SELECTION

2) “UNBALANCED GROWTH”

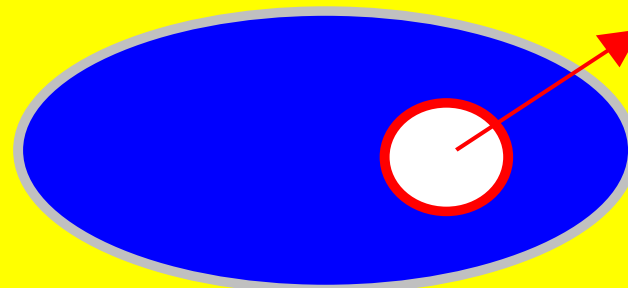
A.S. SYSTEM WITH
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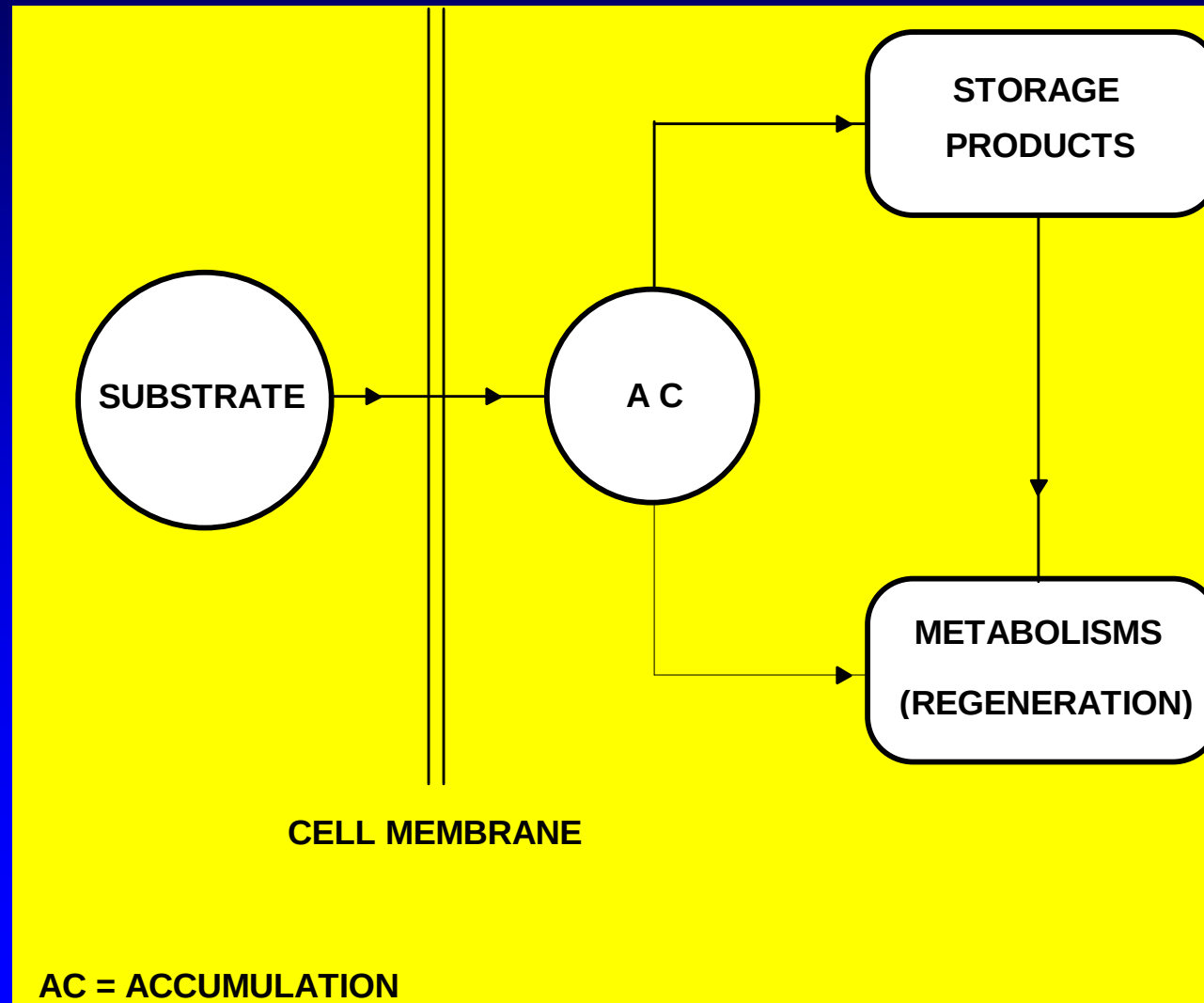


CO₂ + H₂O

Bacterial kinetics and selection



KINETIC SELECTION - UNBALANCED GROWTH



Bacterial kinetics and selection

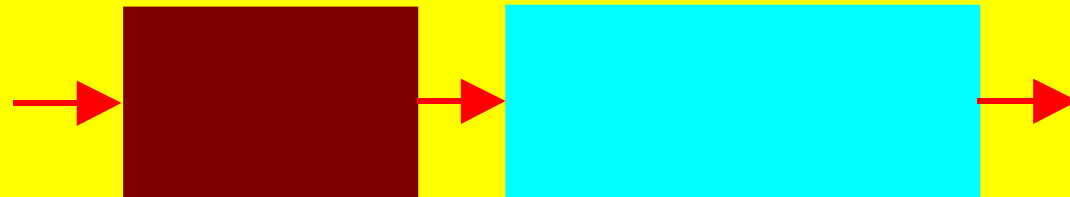


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ACCUM/
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METABOLISM
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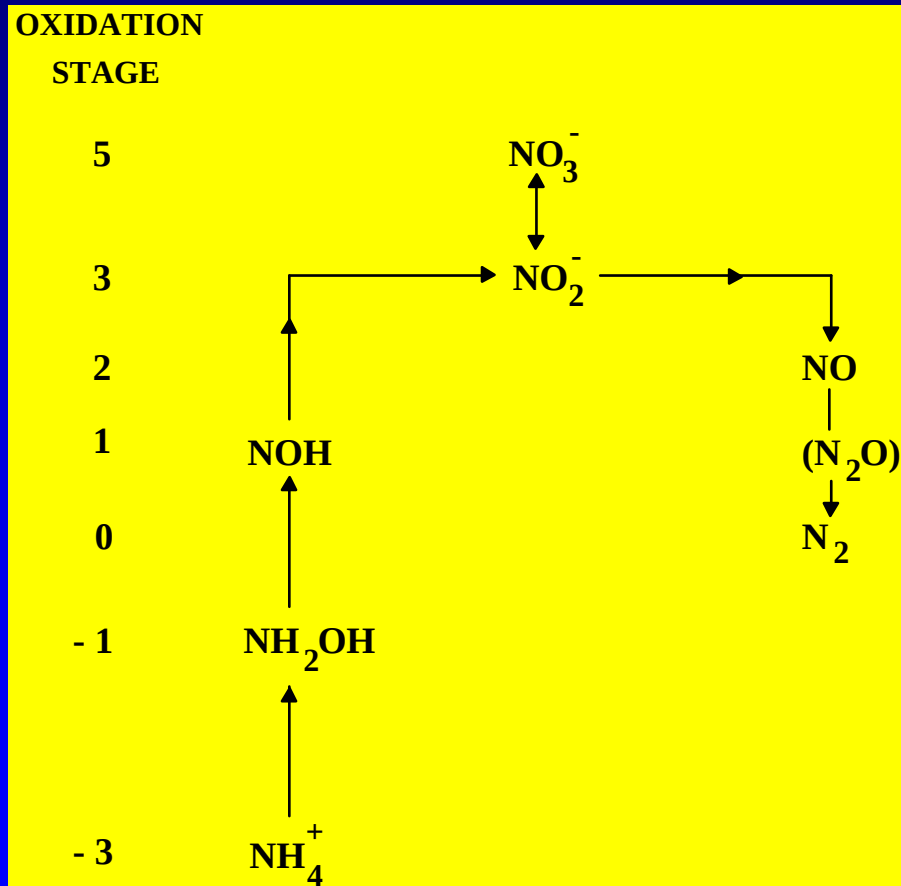
NON-AERATED

OXIC

Bacterial kinetics and selection



OXIC / ANOXIC CONDITIONS



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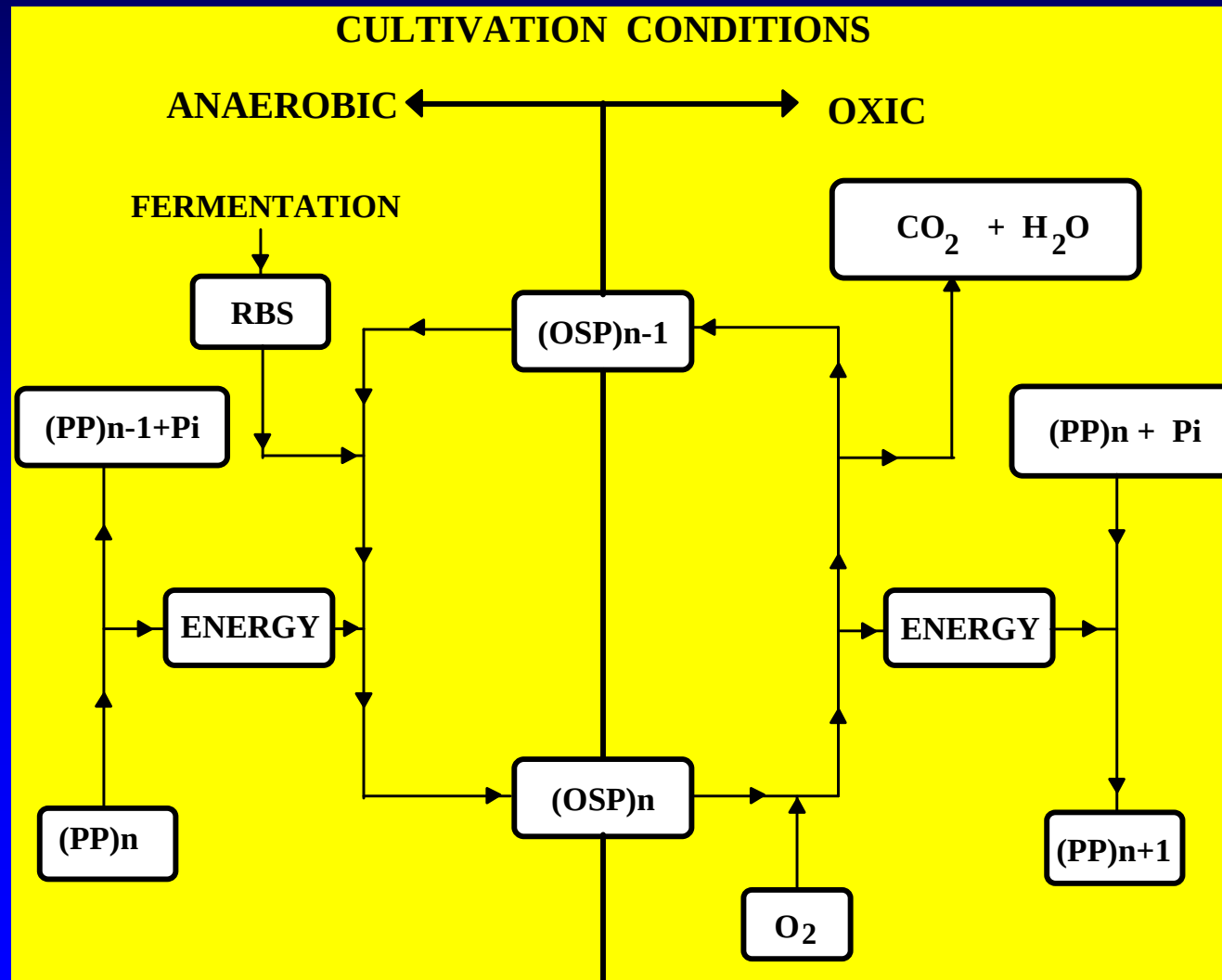
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Bacterial kinetics and selection



OXIC / ANAEROBIC CONDITIONS



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS BULKING
PRINCIPLES - EXAMPLES

WELL SETTLING ACTIVATED SLUDGE

- **primary condition for the separation of activated sludge from treated wastewater**
- **separation based on gravity sedimentation**
- **so far the only economically feasible option**
- **membrane filtration: the solution for future?**

CONTROL OF ACTIVATED SLUDGE FILAMENTOUS BULKING

PRINCIPLES - EXAMPLES

WELL SETTLING ACTIVATED SLUDGE

- settles fast, with zone settling velocities 3 m/h and more
- does not occupy an excessive volume after settling and thickening in secondary clarifier
- after sedimentation leaves a clear supernatant ($X = 15 \text{ mg/l}$ and less)
- does not rise within at least 2-3 h period after sedimentation

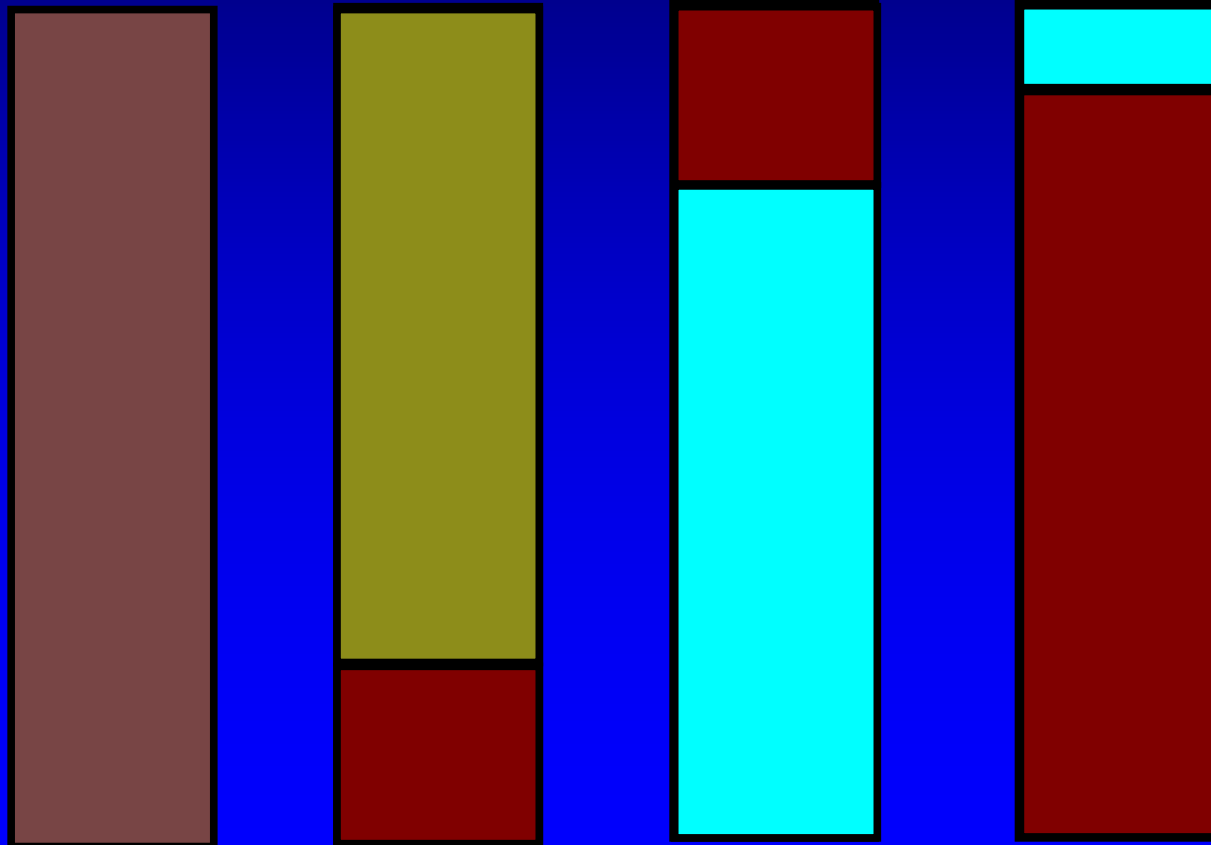
CONTROL OF ACTIVATED SLUDGE FILAMENTOUS BULKING
PRINCIPLES - EXAMPLES

ACTIVATED SLUDGE SEPARATION PROBLEMS

- **DISPERSED GROWTH**
- **UNSETTLEABLE MICROFLOCS**
(PINPOINT FLOCS)
- **RISING SLUDGE**
- **VISCOUS BULKING**
- **FILAMENTOUS BULKING**
- **FOAMING CAUSED BY FILAMENTS**

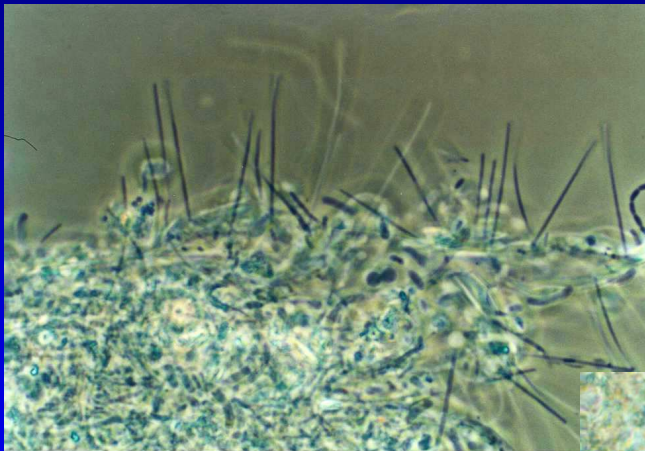
CONTROL OF ACTIVATED SLUDGE FILAMENTOUS BULKING
PRINCIPLES - EXAMPLES

SEPARATION PROBLEMS



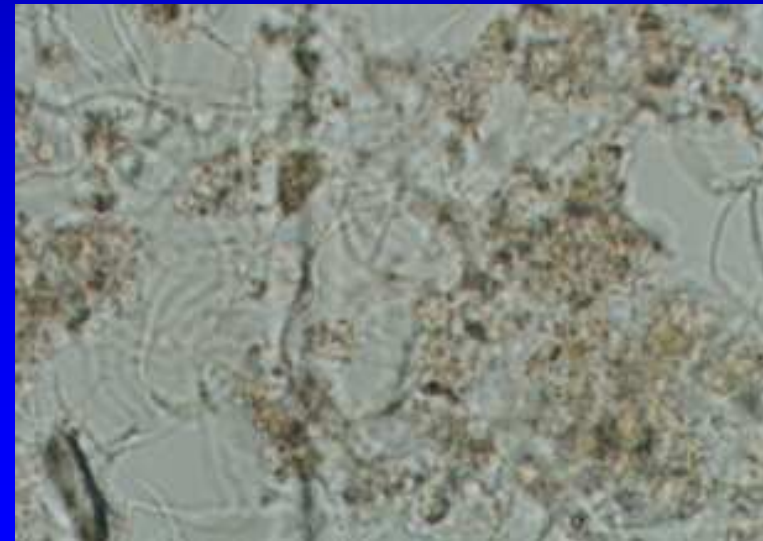
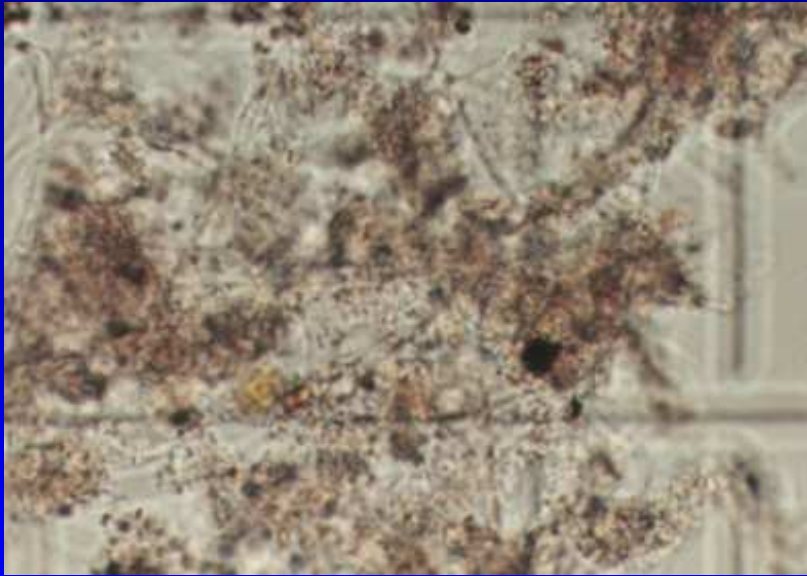
CONTROL OF ACTIVATED SLUDGE FILAMENTOUS BULKING
PRINCIPLES - EXAMPLES

**INTERFERENCE OF FILAMENTS WITH
SETTLING PROPERTIES - BRIDGING**



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS BULKING
PRINCIPLES - EXAMPLES

**INTERFERENCE OF FILAMENTS WITH
SETTLING PROPERTIES - OPEN STRUCTURE**



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS FOAMING

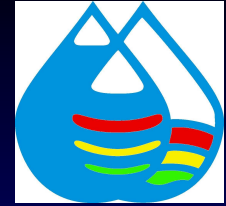
PRINCIPLES - EXAMPLES

Water sprays



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS FOAMING

PRINCIPLES - EXAMPLES



Mechanical skimming

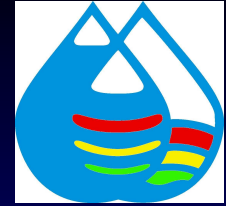
a) In connecting channels

$$D > \mu - b$$



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS FOAMING

PRINCIPLES - EXAMPLES



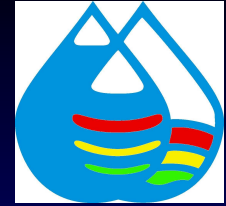
Mechanical skimming

b) In secondary clarifiers



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS FOAMING

PRINCIPLES - EXAMPLES

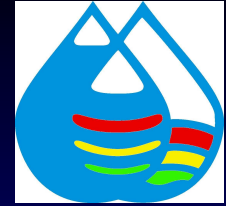


Sometimes very difficult



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS FOAMING

PRINCIPLES - EXAMPLES

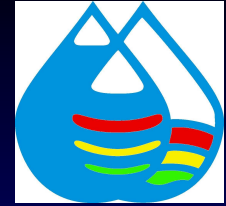


“Travelling” scum box



CONTROL OF ACTIVATED SLUDGE FILAMENTOUS FOAMING

PRINCIPLES - EXAMPLES



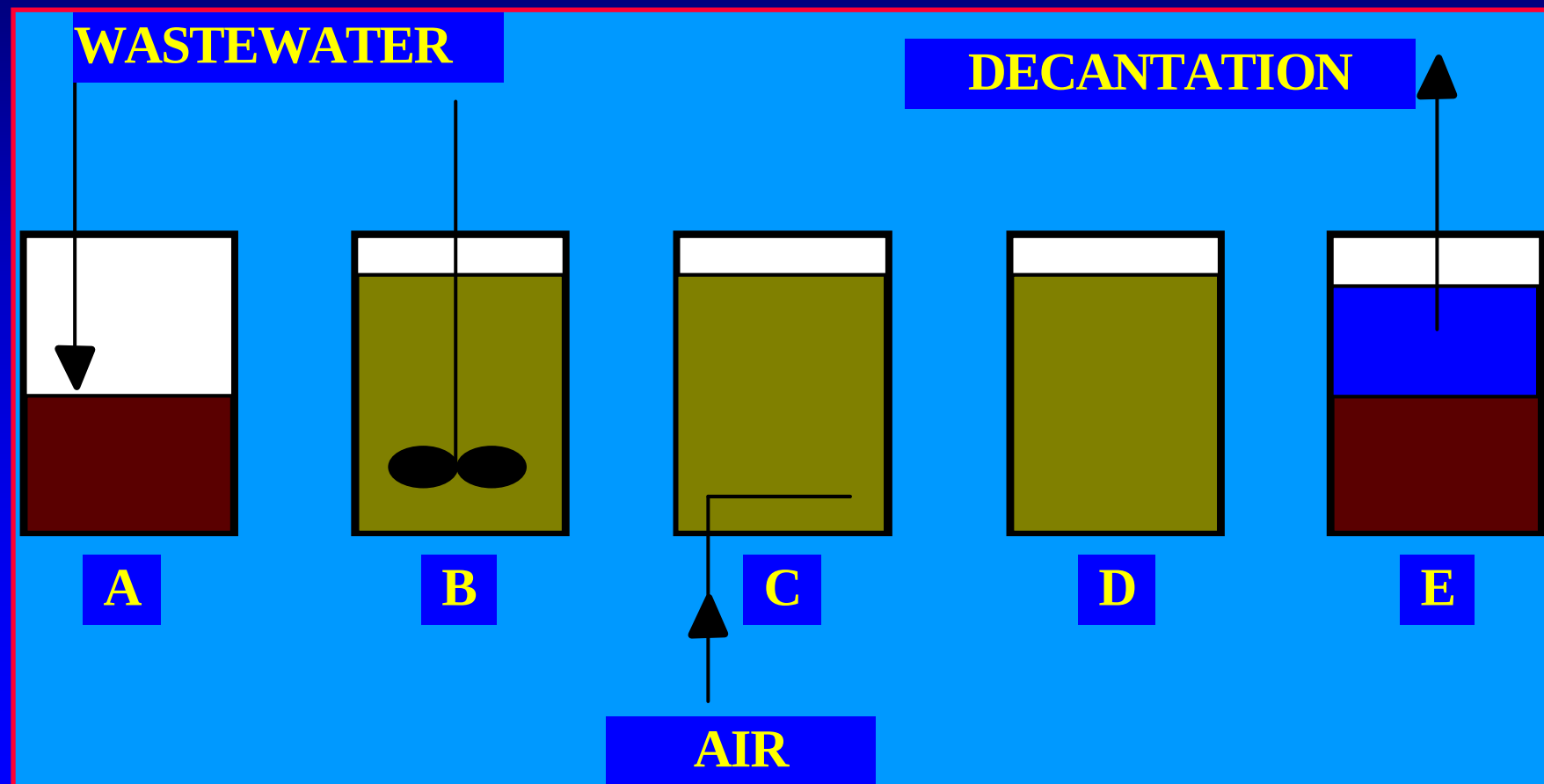
Foaming in digesters



Bacterial kinetics and selection



SBR: CONFIGURATION FOR BULKING CONTROL



Bacterial kinetics and selection



SBR – CAST system: **contact zone**



Bacterial kinetics and selection



SBR – CAST system: aeration/anoxic zone

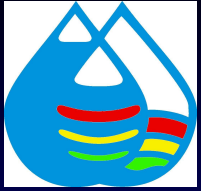


Bacterial kinetics and selection



SBR – CAST system: decantation



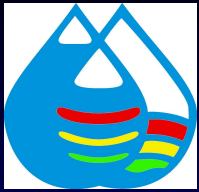


Wastewater treatment in CZ



Typical wastewater treatment processes in new or upgraded WWTPs

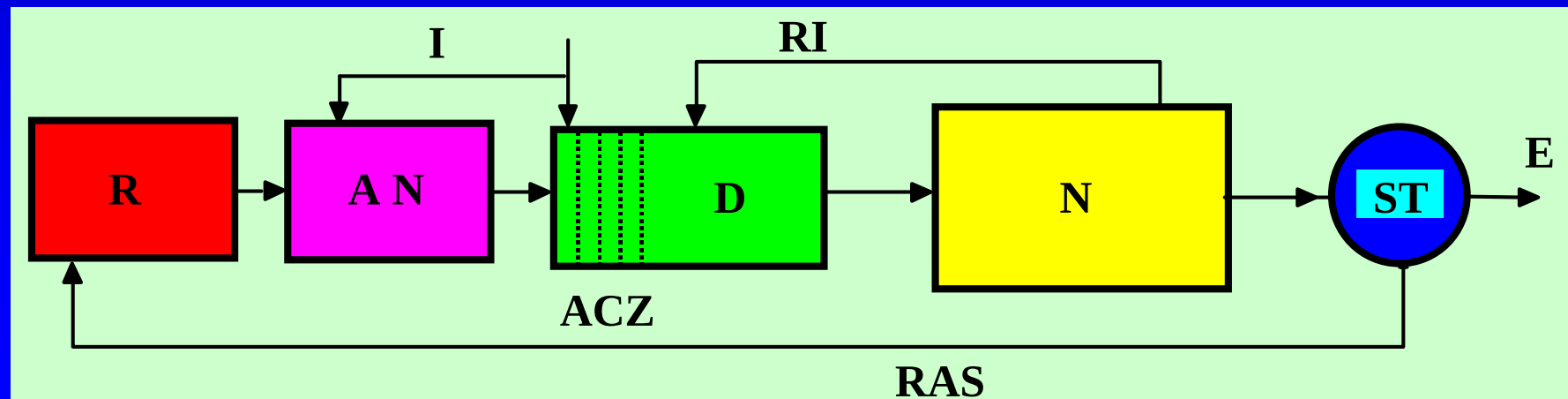
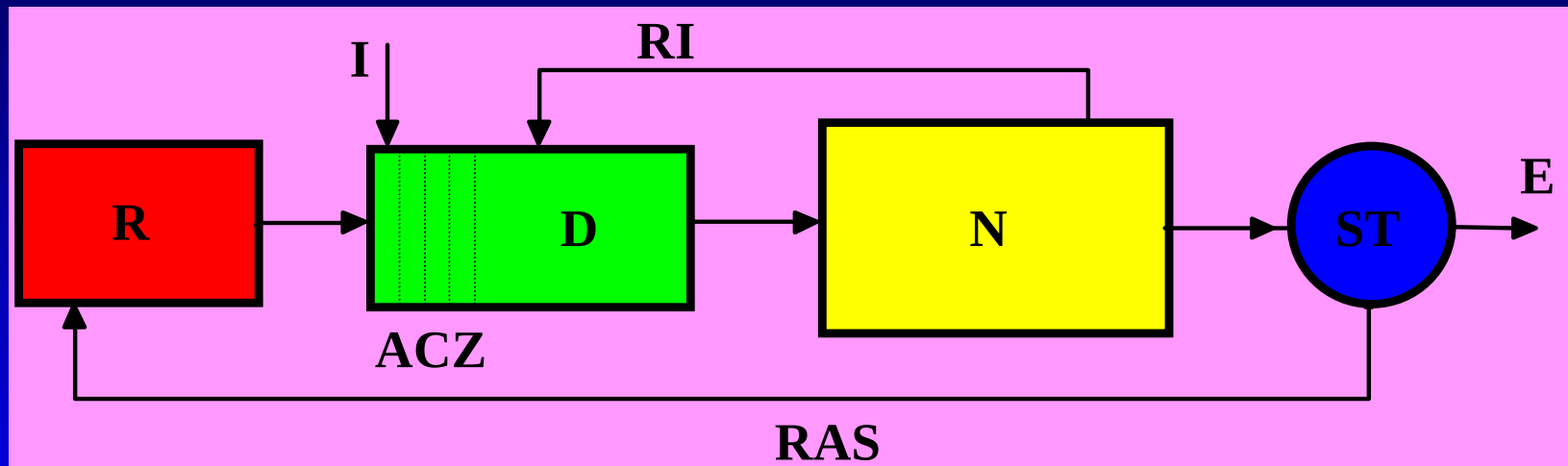
- R-D-N or R-AN-D-N Process for medium-size and large WWTPs
- Carousel-type D-N aeration systems with intermittent aeration and anaerobic contact zones

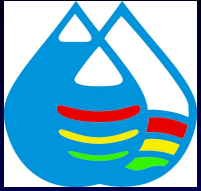


Wastewater treatment in CZ



Regeneration zone





Wastewater treatment in CZ

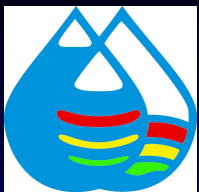


The Prague WWTP after upgrade:

R - ZONE

**4 NEW
CLARIFIERS**





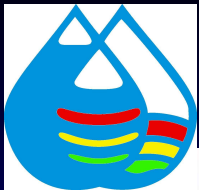
Wastewater treatment in CZ



Examples



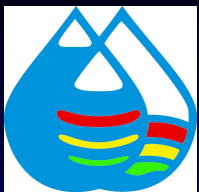
Pilsen WWTP under construction



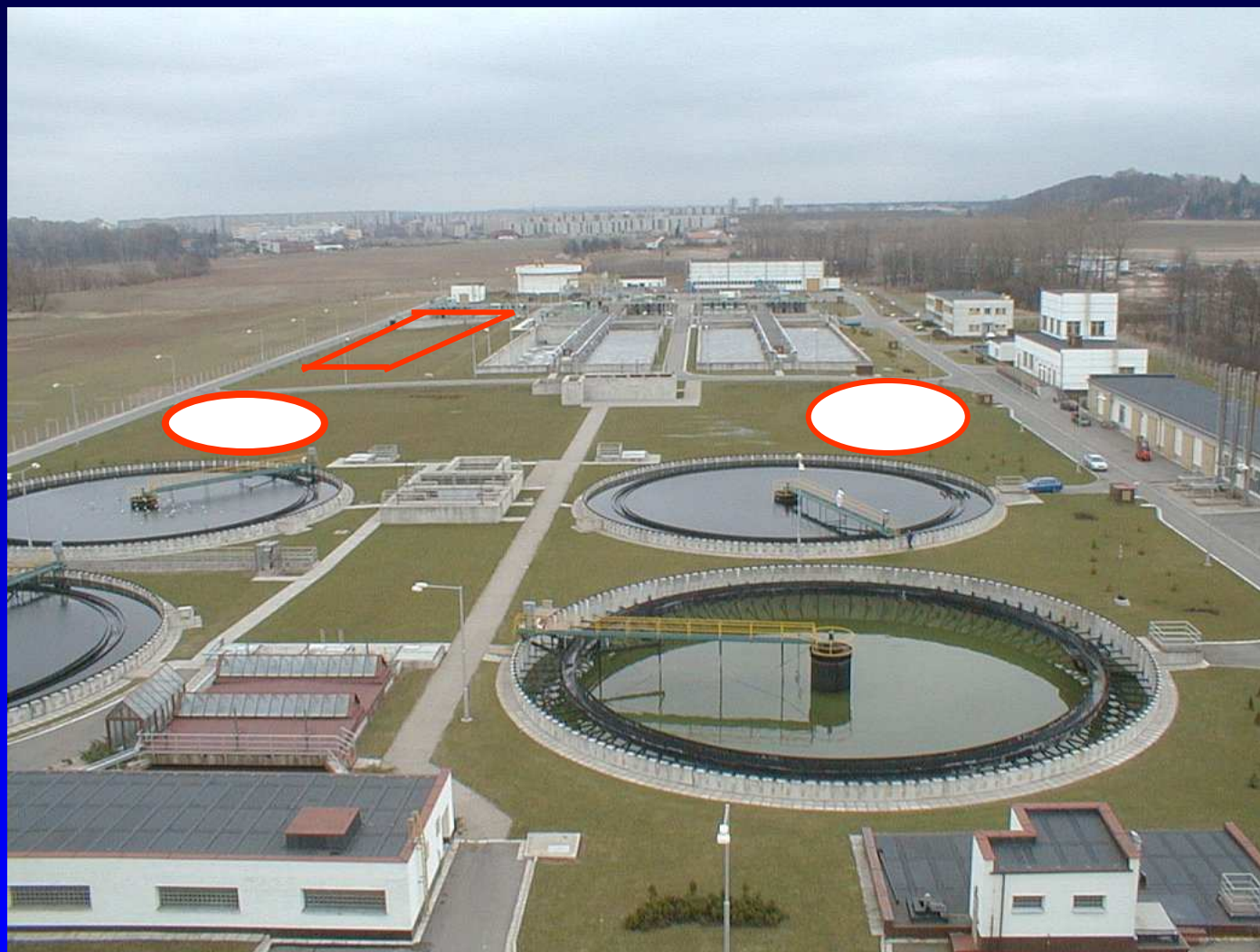
Wastewater treatment in CZ



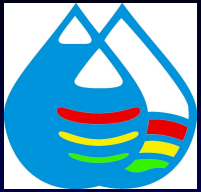
Pilsen WWTP in operation, 430 000 PE



Wastewater treatment in CZ



Hradec Kralove WWTP in operation, 180 000 PE, R-D-N Process

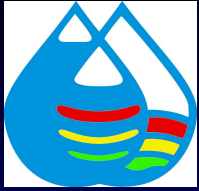


Wastewater treatment in CZ



Usti nad Labem, 180 000 PE, R-AN-D-N Process



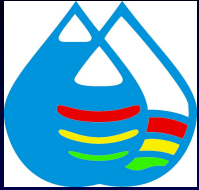


Wastewater treatment in CZ



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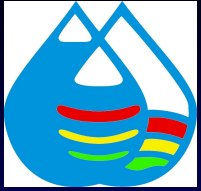




Wastewater treatment in CZ

Nymburk, 35 000 PE, Carrousel plant with simultaneous N – D and bio-P removal





Wastewater treatment in CZ



Melnik, 12 000 PE, Carrousel plant with intermittent aeration and bio-P removal

