Future Directions In Wastewater Treatment

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Clean Water Services

Our Predicament

1. Chose to dilute and then concentrate
2. Chose processes requiring large inputs
3. Avoided “cradle-to-cradle” paradigm

All for good reasons:

Extension of earlier approaches

-European streets

Easier

-Connected to existing storm sewers

-No pumping

-Aerobic vs anaerobic treatment

Cheaper

-No recycling of nitrogen and phosphorus

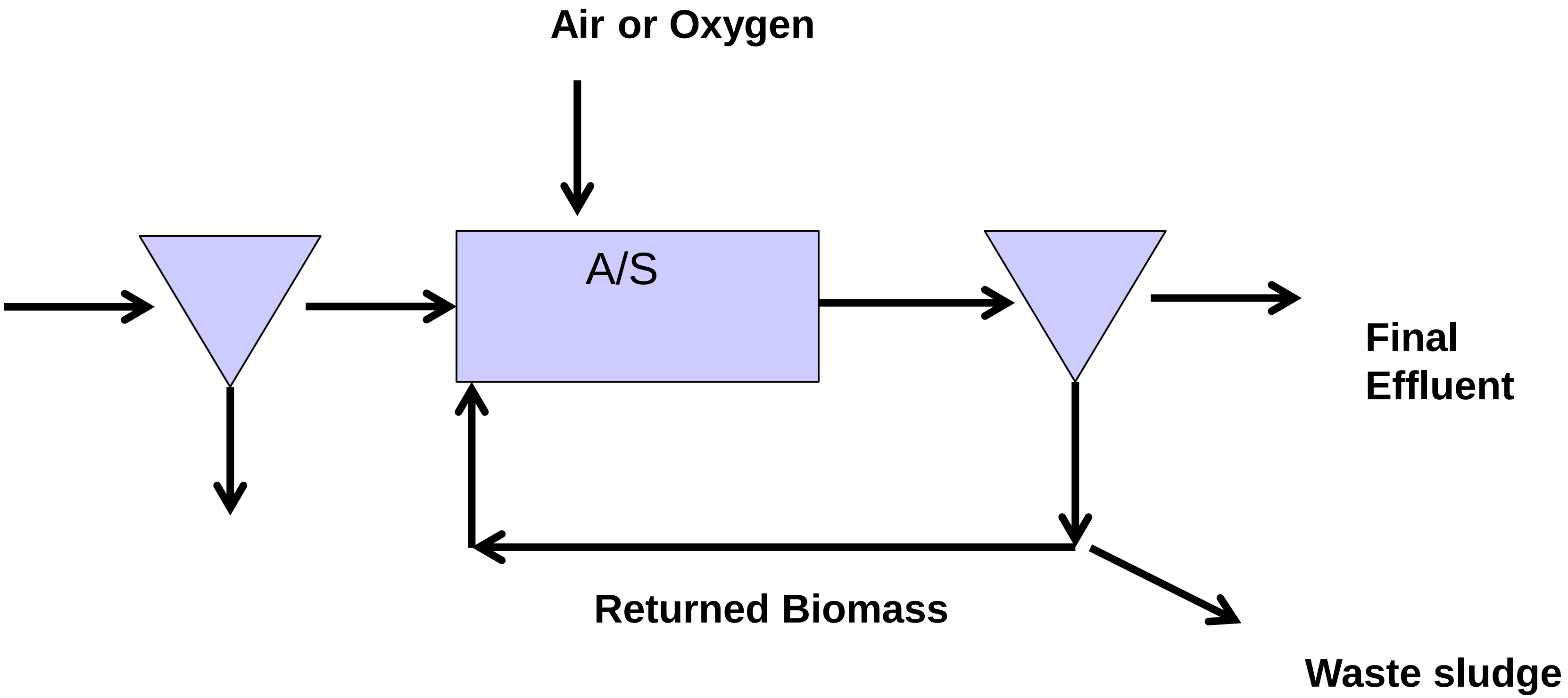
-Stream discharge of “trace” contaminants

Sisyphys (1548-1549) by Titian, Prado Museum, Madrid, Spain

Drivers

- Development patterns
  - Urbanization
  - Coastal development
- Climate change
  - Sea level rise
  - More intense storms
- Aging infrastructure, decreasing flows
- Treat wastewater “cradle to cradle”
- Impacts of effluent contaminants

Conventional Activated Sludge



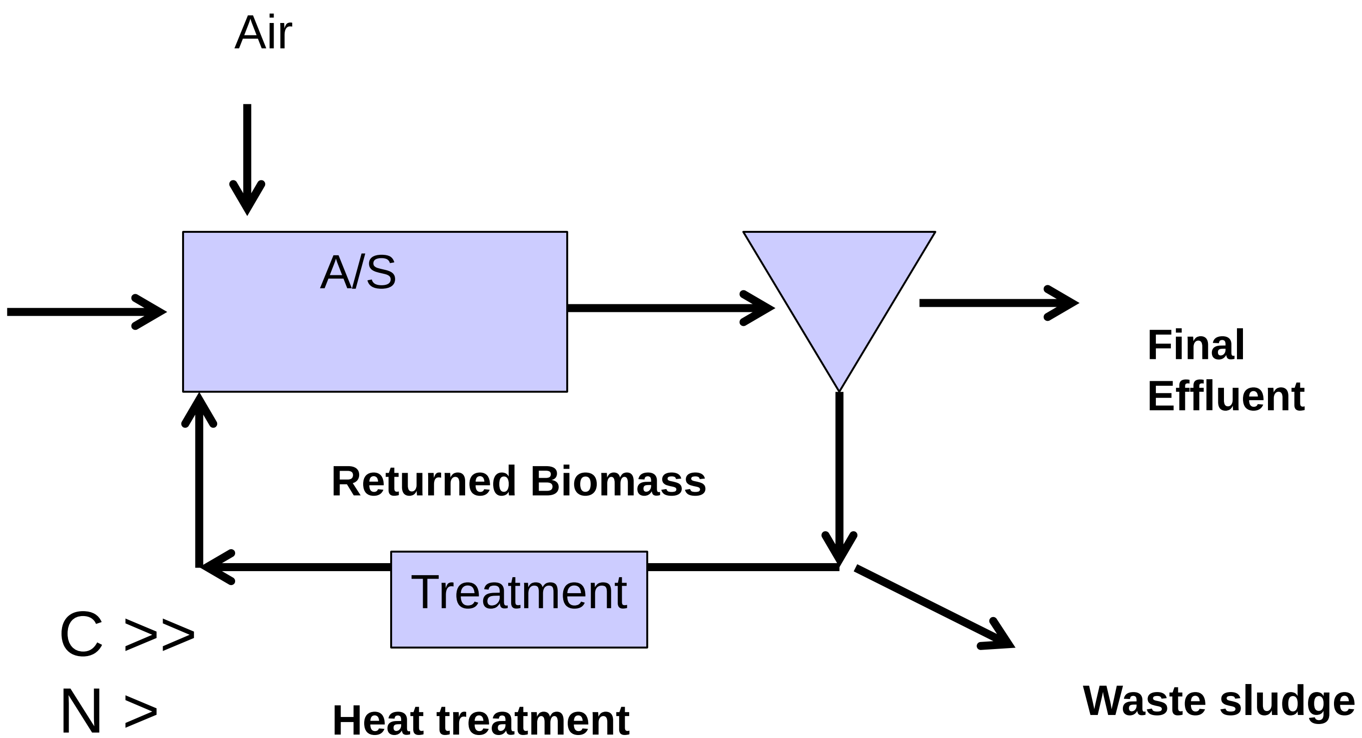
C <<
N =
P =

Control SRT,
Control settling

Stable Solids Retention Times

Heterotrophic carbon removal	2-5 days
Nitrification	5-15 days
Denitrification	2-4 days
Anaerobic fermentation	2 days
Methane fermentation	5-20 days
PAOs	5-10 days
Anammox	20 days
Nitritication	10-15 days

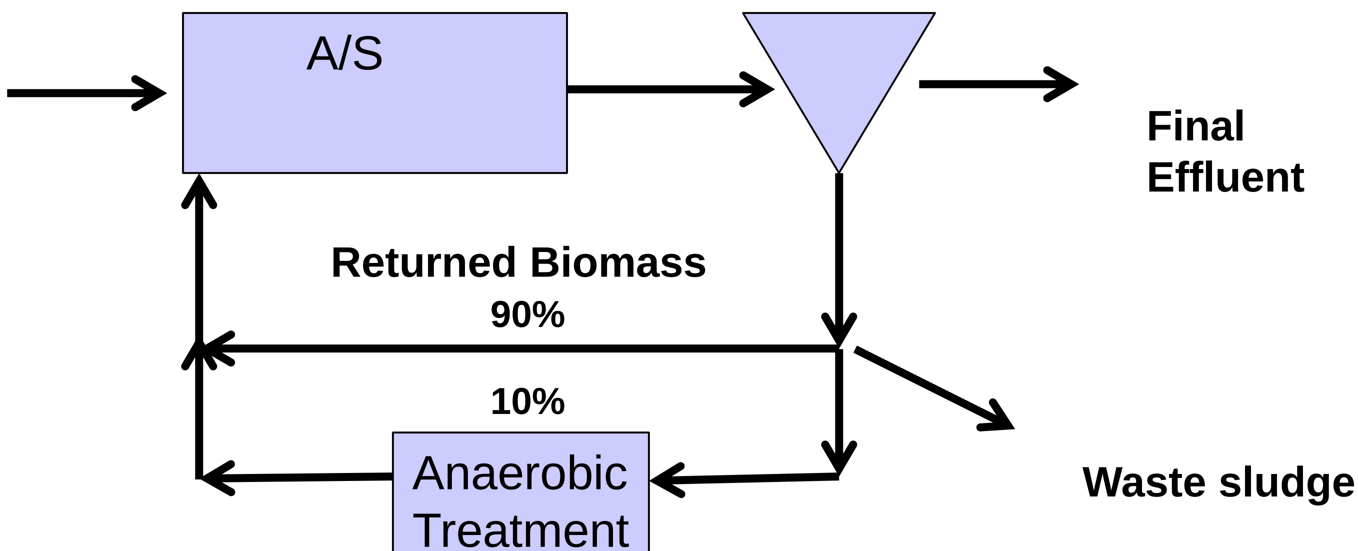
Reduce Sludge Production



C >>
N >
P =

Heat treatment
Sonication
Mechanical abrasion
Chlorination
Ozonation

Reduce Sludge Production



(Goel and Noguera, 2006;
Novak, et al., 2007;
Datta, et al., 2009)

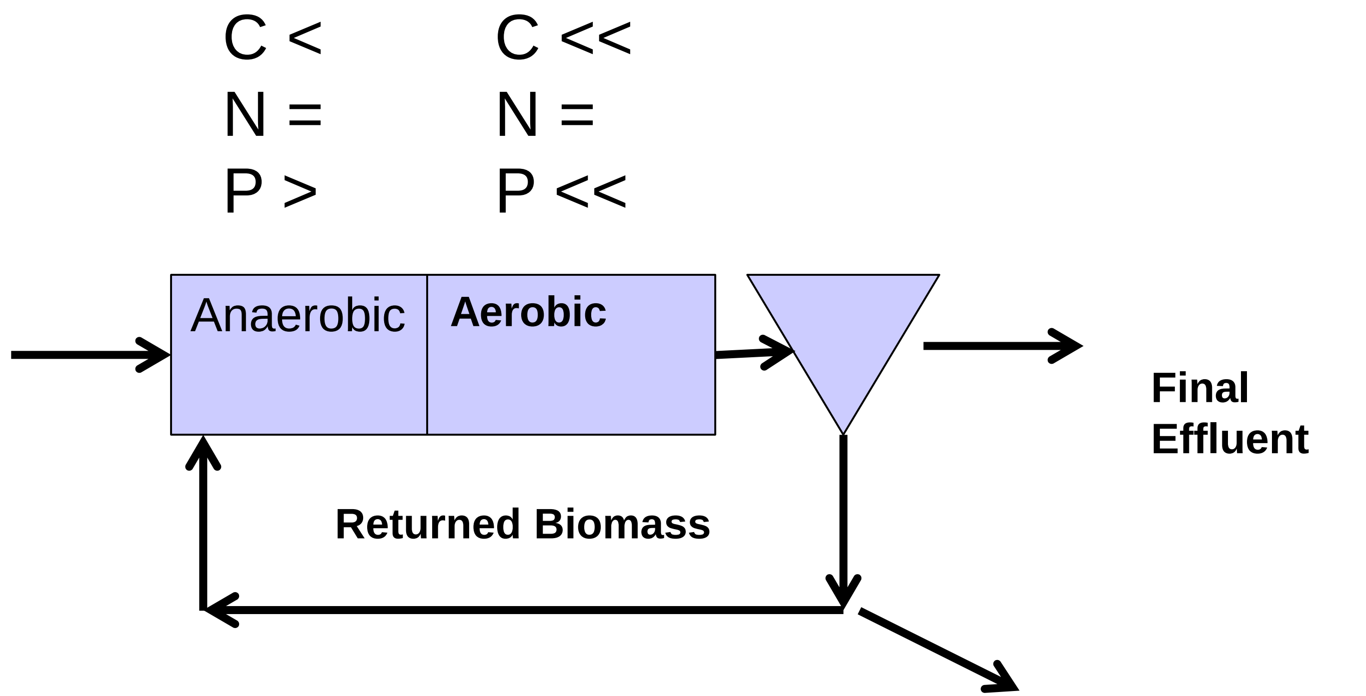
Anaerobic side stream reactor (ASSR), Cannibal™ process

ASSR Challenges

- No known mechanism
- Difficult to match with enhanced biological phosphate removal (EBPR) and nitrification/denitrification because solids retention time is unknown or uncontrollable

Potential mechanisms may be energy uncoupling in A/S or altered metabolism of particulates; probably related to microbial consortium.

Phosphorus Removal



In anaerobic zone, phosphate accumulating PAOs take up VFAs and release phosphorus

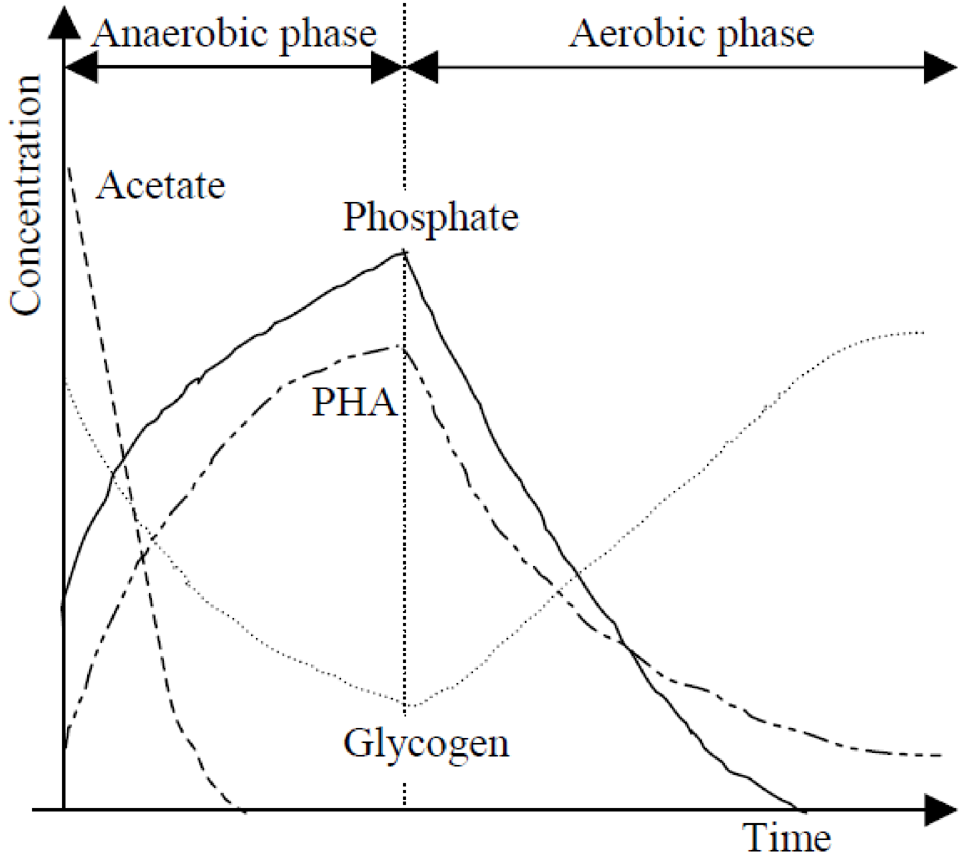


Figure 7 Schematic representation of concentration profiles for EBPR under anaerobic-aerobic conditions

PAO organisms, Selected by VFAs, Store polyhydroxyalkanates, (PHAs)

Glycogen accumulating organisms, GAOs, compete with PAOs

PAOs are selected with shorter solid retention times

Phosphorus RemovalChallenges

- Need to select for PAOs over GAOs
- Need tight control of SRT, 5-10 days
- Need production of VFA, glycogen, polyhydoxyalkanates, other carbon sources

Process is presently difficult to control related to anaerobic/aerobic timing and sludge wastage rates to optimize phosphorus storage

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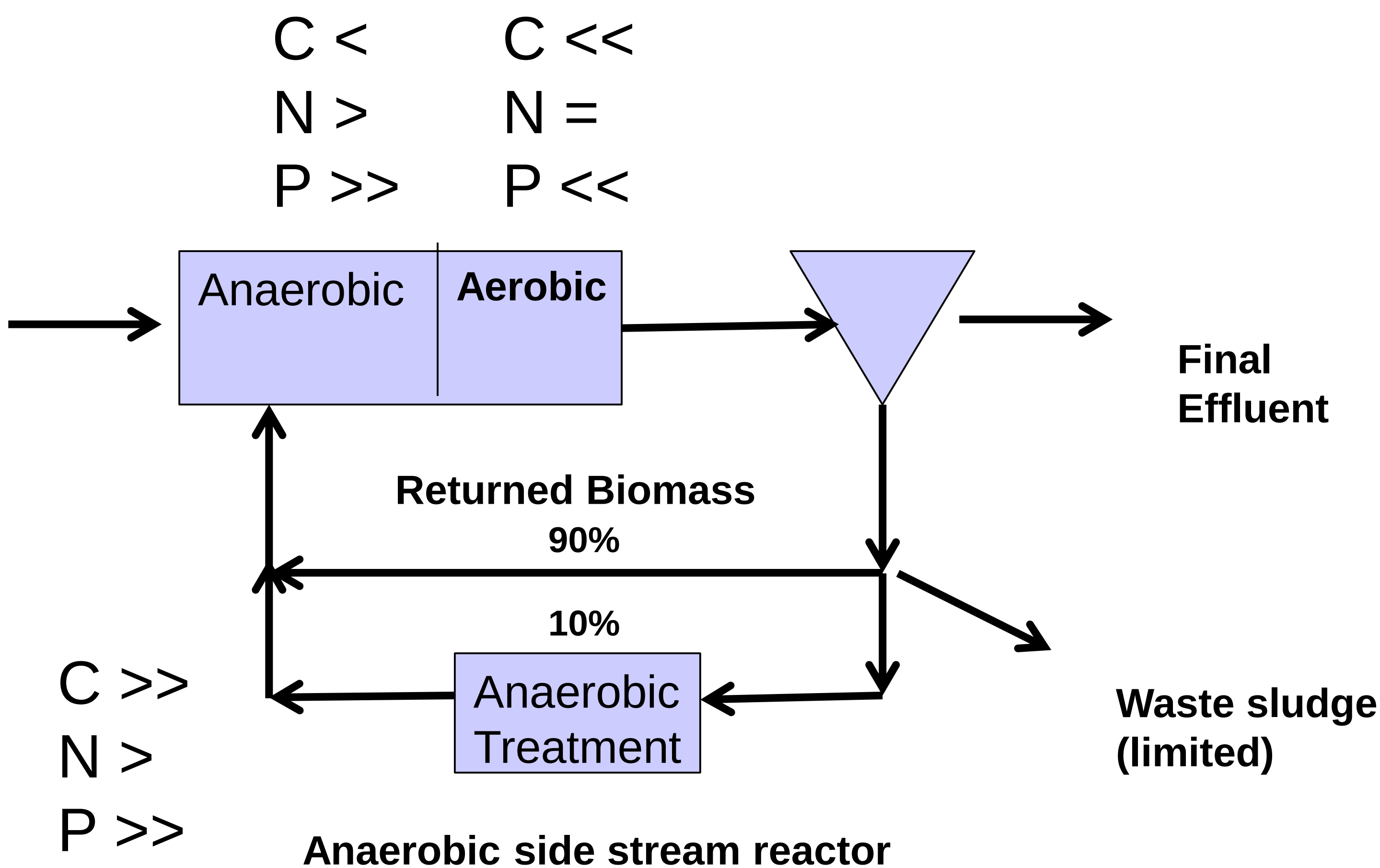
Modified EBPR

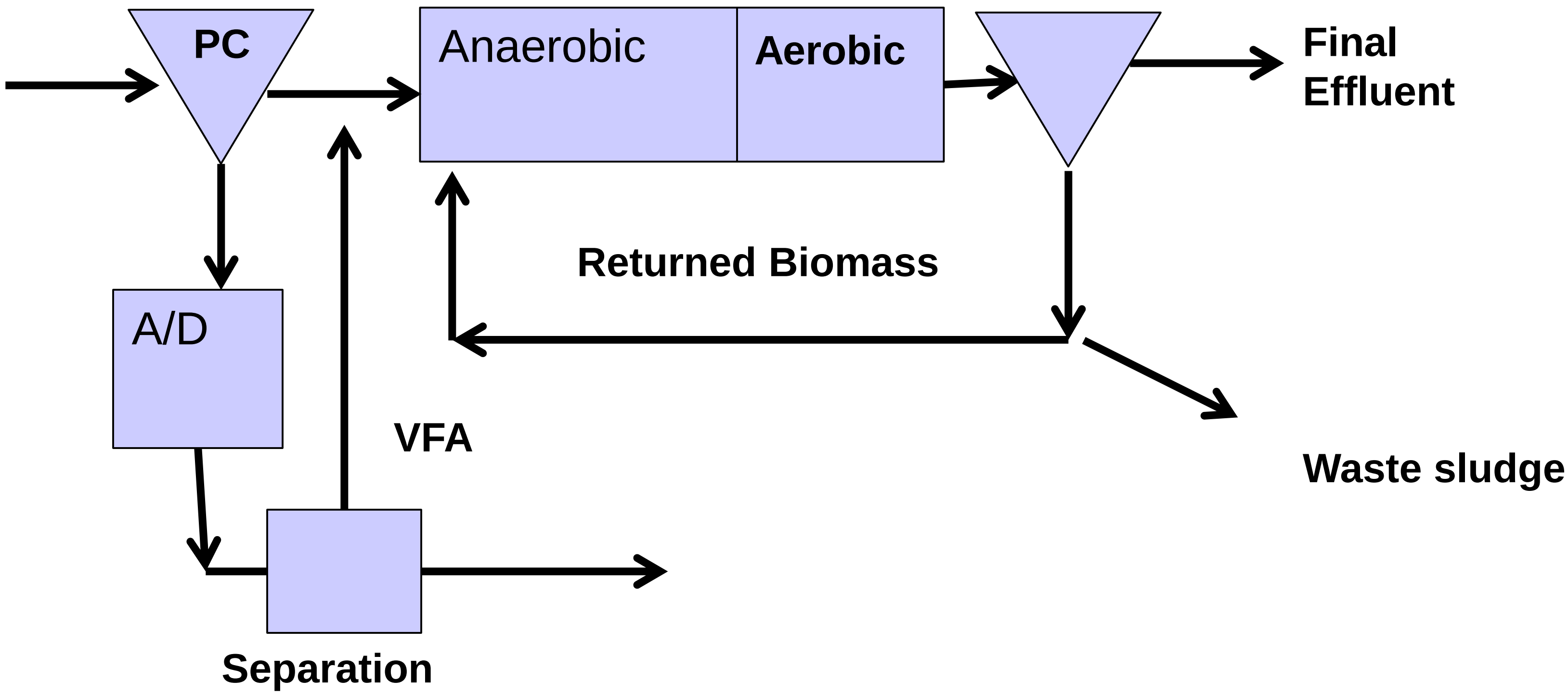


Anaerobic side stream reactor (ASSR) and EBPR

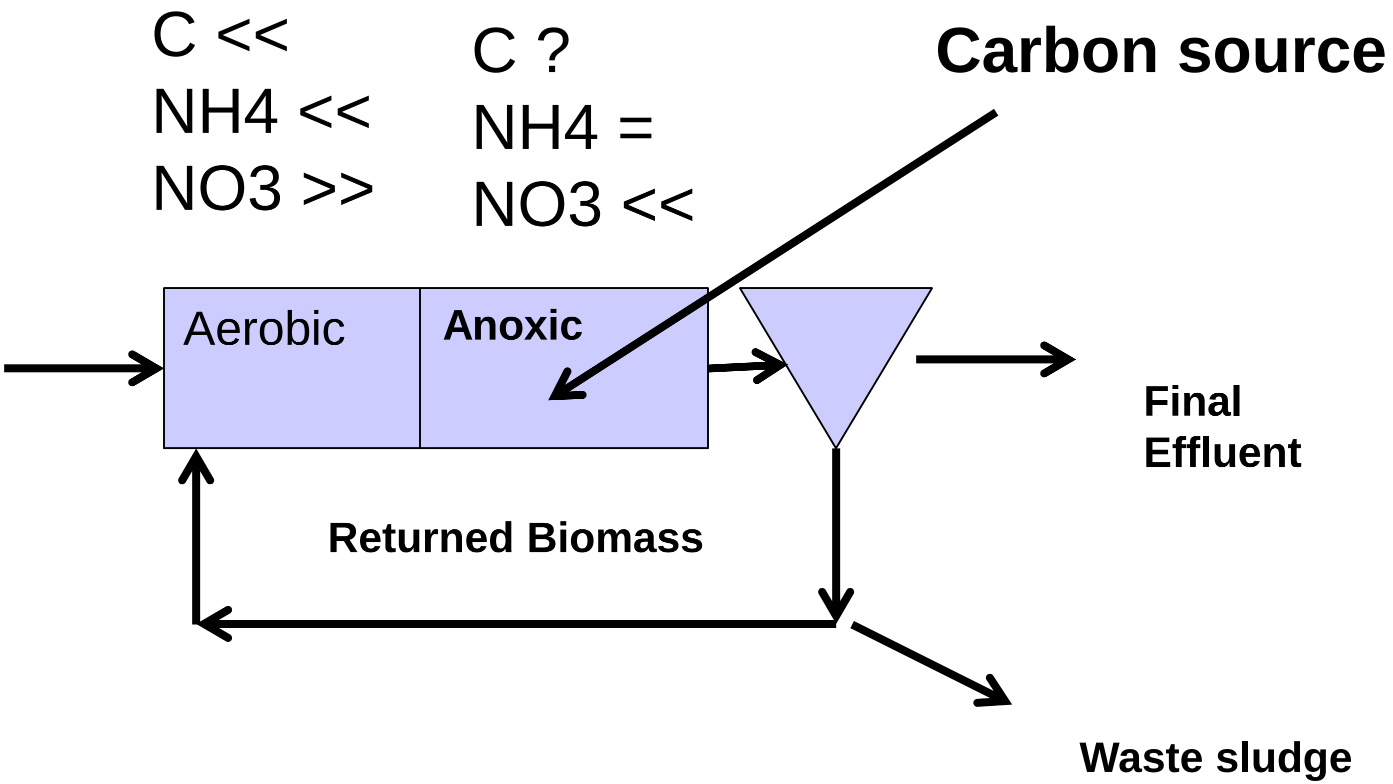
Modified EBPR

C <
N >
P >

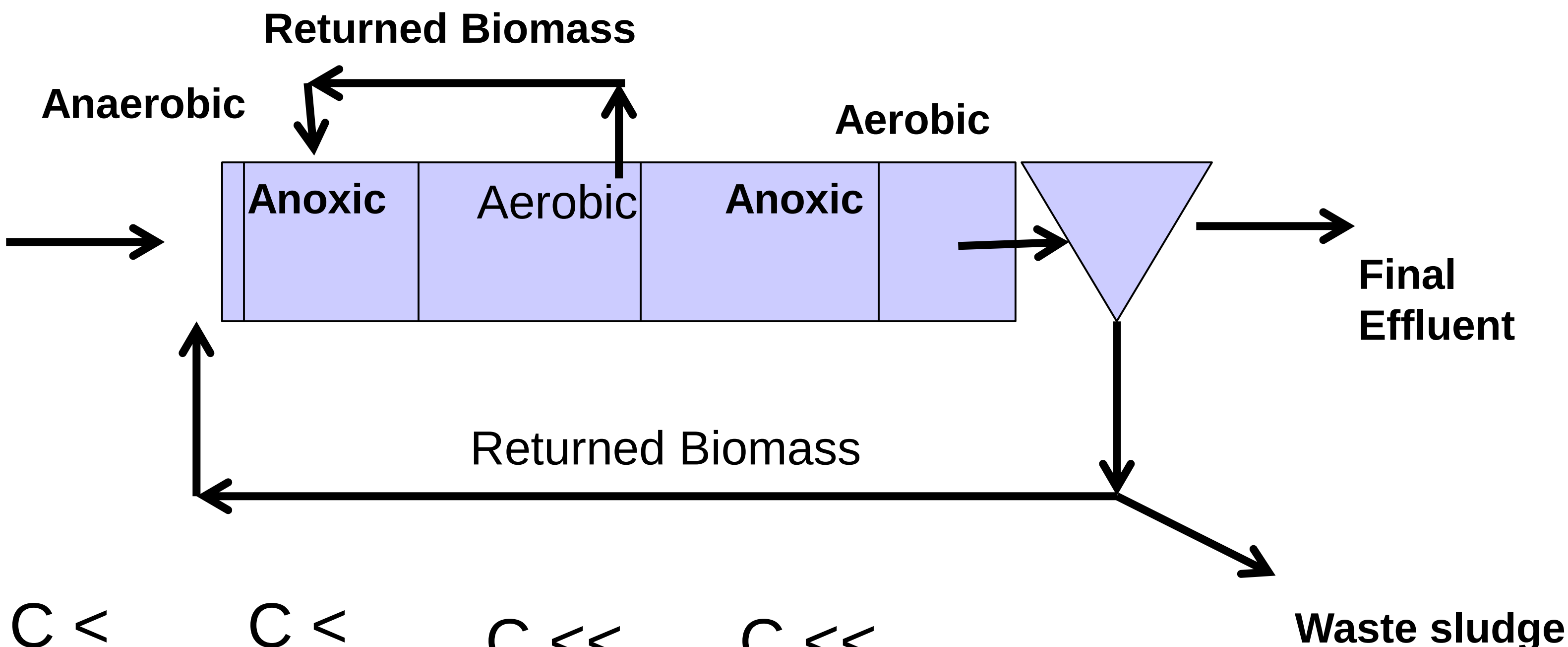
C <<
N >
P <<



Nitrification/Denitrification

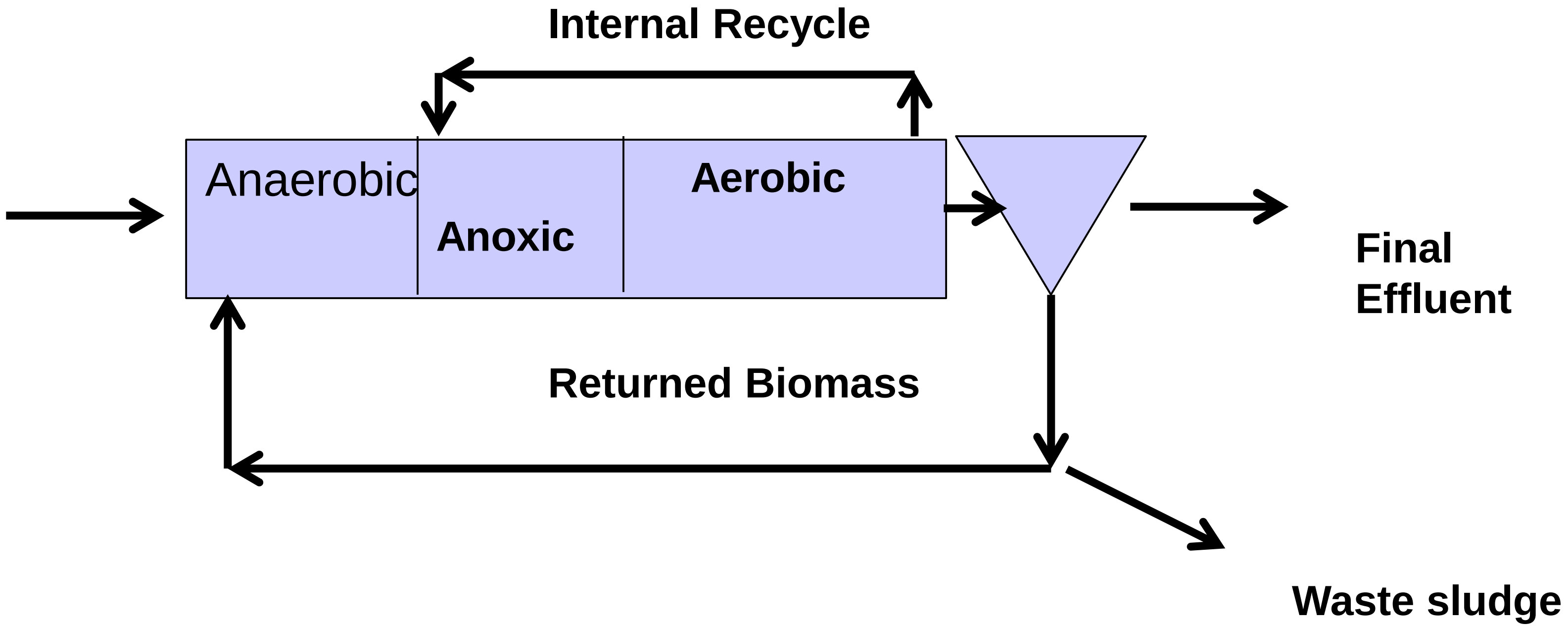


EPBR and Nitrification/denitrification Process
Bardenpho Process

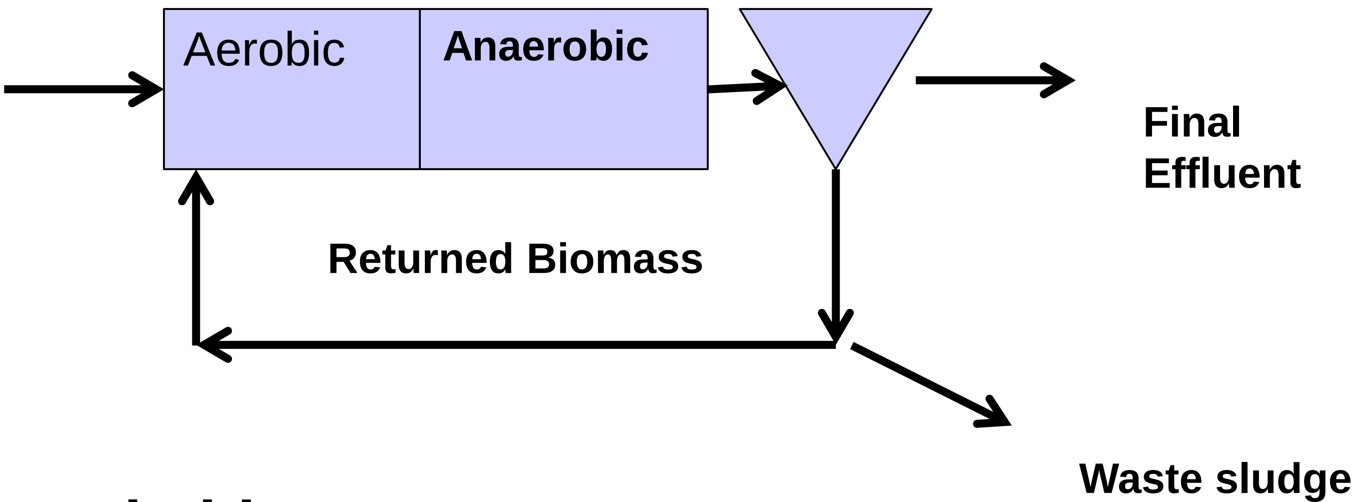


C <	C <	C <<	C <<
NH4 =	NH4 =	NH4 <<	NH4 =
NO3 =	NO3 <<	NO3 >>	NO3 <<
P>	P=	P<<	P<<

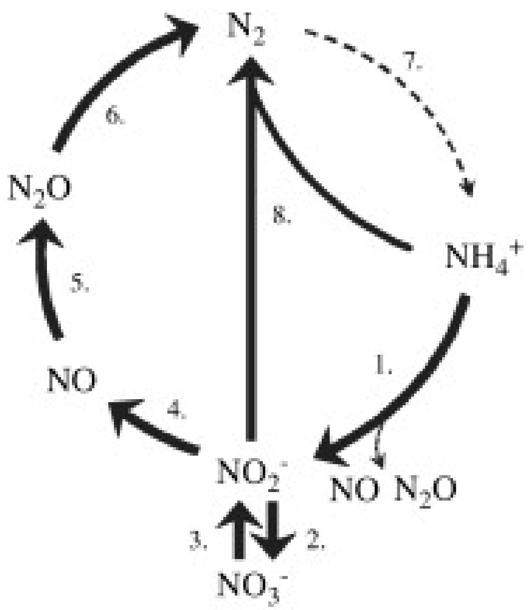
A2O Process for EBPR and Nitrification/Denitrification



Nitrification/Denitrification with Nitrifying Archaea (AOA) and Nitrifying Bacteria (ABO)



AOA probably cannot compete with ABO in this process



Nitritration: $NH4^+ + O2$ to $NH4^+ + NO2^-$

Anammox: $NH4^+ + NO2^-$ to N2

Fig. 1. Biological nitrogen conversions. (1) Aerobic ammonia oxidation (autotrophic and heterotrophic AOB and AOA), (2) aerobic nitrite oxidation (NOB), (3) nitrate reduction to nitrite (DEN), (4) nitrite reduction to nitric oxide (AOB and DEN), (5) nitric oxide reduction to nitrous oxide (AOB and DEN), (6) nitrous oxide reduction to dinitrogen gas (DEN), (7) nitrogen fixation (not relevant in most WWTPs), (8) ammonium oxidation with nitrite to dinitrogen gas (Anammox). Complete nitrification comprises step 1 and 2, complete denitrification step 3–6.

Kampschruer, et al. 2009

Stable Solids Retention Times

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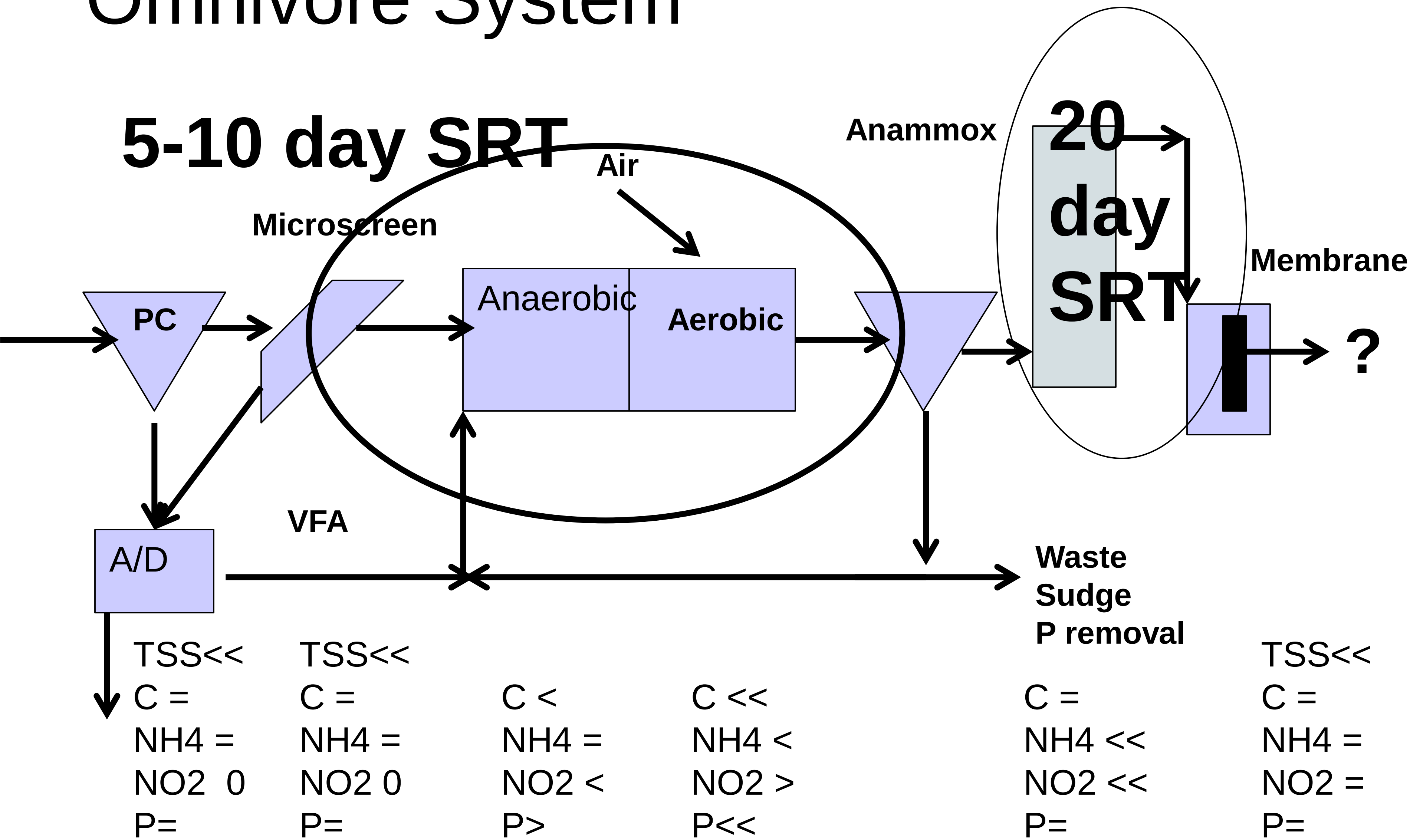
Anammox	20 days
Nitritication	10 days

Omnivore System



What do we achieve???

- Effluent BOD<1 mg/L, NH4<0.1 mg/l, P<0.02 mg/L
- Less energy required
- High quality water for reuse, further treatment
- Lower sludge production because of increase anaerobic treatment, reduced aerobic treatment
- We don’t have to push the rock up the hill again