Future Directions In Wastewater Treatment
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Our Predicament

1. Choose to dilute and then concentrate
2. Choose 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
Conventional Activated Sludge

Air or Oxygen

Final Effluent

Returned Biomass

Waste 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

Air

A/S

Returned Biomass

C >>
N >
P =

Treatment

Heat treatment
Sonication
Mechanical abrasion
Chlorination
Ozonation

Final Effluent

Waste sludge
Reduce Sludge Production

A/S

Returned Biomass
90%

10%

Anaerobic Treatment

Anaerobic side stream reactor (ASSR), Cannibal™ process

(Waste sludge)

Final Effluent

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

Research with anaerobic side stream treatment and sludge wastage rates. Potential mechanisms may be energy uncoupling in A/S or altered metabolism of particulates; probably microbial consortium related.
Phosphorus Removal

In anaerobic zone, competition between PAOs and GAOs

C < C <<
N = N =
P > P <<

Anaerobic Aerobic

Returned Biomass

Final Effluent

Waste sludge
(P removal)
PAO organisms, Selected by VFAs, Store polyhydroxyalkanates, (PHAs)

Glycogen accumulating organisms, GAOs

PAOs are selected with shorter solid retention times
Phosphorus Removal Challenges

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

Research with proper anaerobic/aerobic timing and sludge wastage rates to optimize phosphorus storage
Modified EBPR

- Anaerobic side stream reactor (ASSR) and EBPR
- Returned Biomass: 90%
- Waste sludge (limited)
- Final Effluent

Chemical compositions:
- C >>
- N >
- P >>
- C <<
- N =
- P <<
Modified EBPR

C > C <<
N > N >
P > P <<

PC → Anaerobic → Aerobic → Final Effluent

A/D → Returned Biomass

Separation → VFA

Waste sludge
Nitrification/Denitrification

\[ C << \text{NH}_4 << \text{NO}_3 >> \]
\[ C \ ? \ \text{NH}_4 = \text{NO}_3 << \]

Carbon source

Aerobic

Anoxic

Returned Biomass

Final Effluent

Waste sludge
EPBR and Nitrification/denitrification Process
Bardenpho Process

Anaerobic

C <
NH4 =
NO3 =
P>

Aerobic

C <
NH4 =
NO3 <<
P=

Anoxic

C <<
NH4 <
NO3 >>
P<<

Anoxic

Returned Biomass

Waste sludge

Final Effluent
A2O Process for EBPR and Nitrification/Denitrification

- Anaerobic
- Anoxic
- Aerobic
- Final Effluent
- Returned Biomass
- Internal Recycle
- Waste sludge
AOA (ammonia oxidizing archaea) can convert ammonia to nitrite

Anammox can convert ammonia and nitrite to nitrogen gas

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

AOA probably cannot compete with ABO in this process.
<table>
<thead>
<tr>
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Omnivore System

5-10 day SRT

Air

Anammmox

Microscreen

Waste Sludge P removal

Membrane

PC

VFA

Anaerobic

Aerobic AOA

TSS<<

C =

NH4 =

NO2 0

P=

TSS<<

C =

NH4 =

NO2 0

P=

C <=

NH4 =

NO2 <

P>

C <=

NH4 <

NO2 >

P<>

C <=

NH4 <=

NO2 <<

P<<

TSS<<

C =

NH4 =

NO2 <=

P=?
Operating Characteristics

- 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