Opportunities for improved nutrient removal and recovery from municipal wastewater

Nutrient removal practice and developing trends

Damian J. Kruk, Tanner R. Devlin, Jan A. Oleszkiewicz

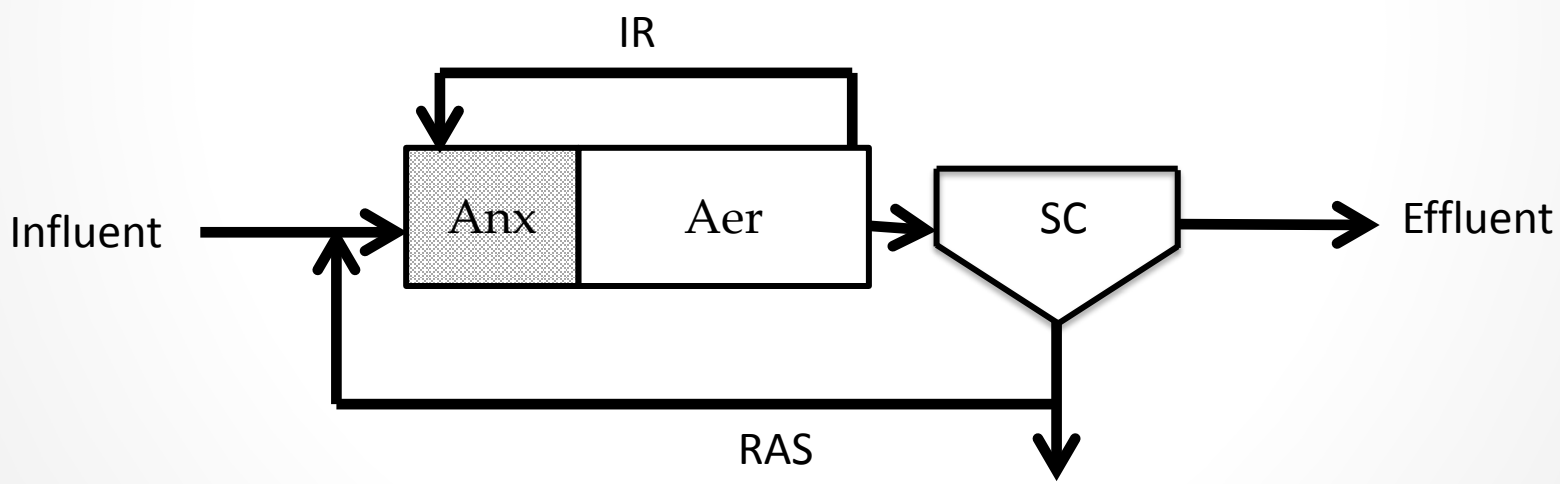
Webinar, October 22nd; 2015

Canadian Water Network

University of Manitoba

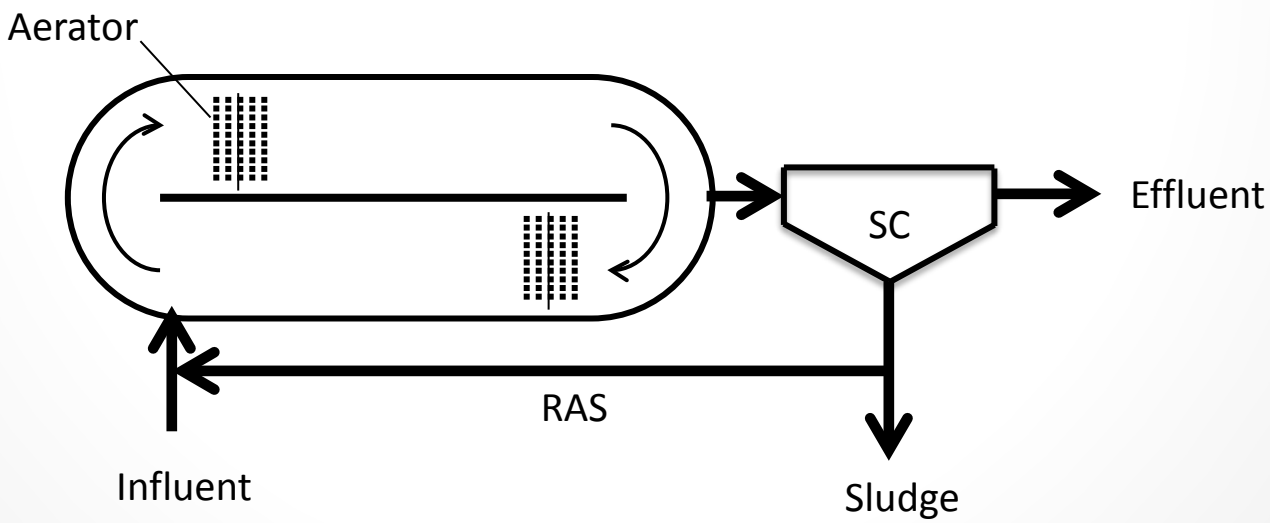
Biological N removal

1. Modified Ludzcak-Ettinger (MLE)
   - TN removal
   - Defined Aerobic and Anoxic zones



Biological N removal

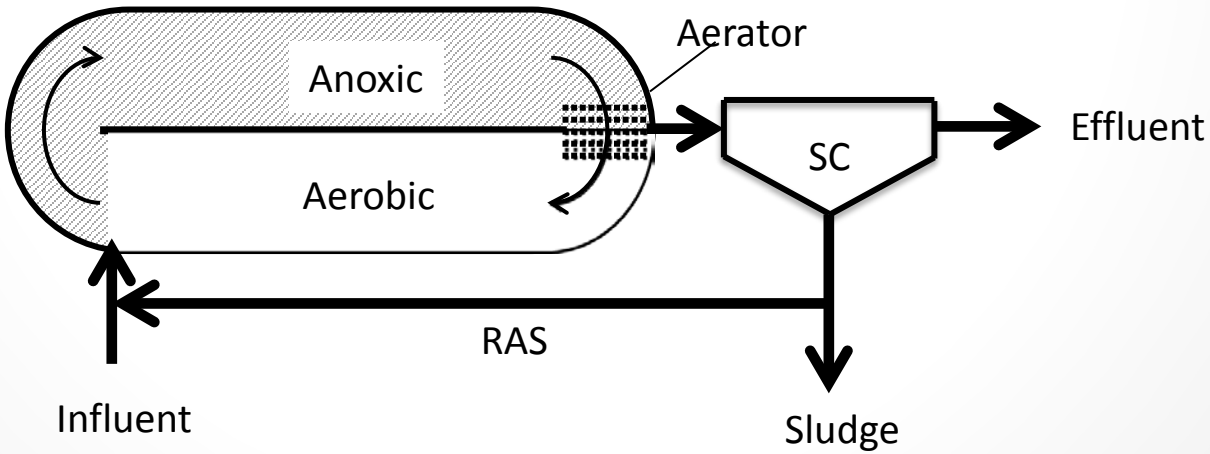
2. CAS Extended aeration
   - E.g. oxidation ditch
   - Only nitrification
   - SRT > 10d



Biological N removal

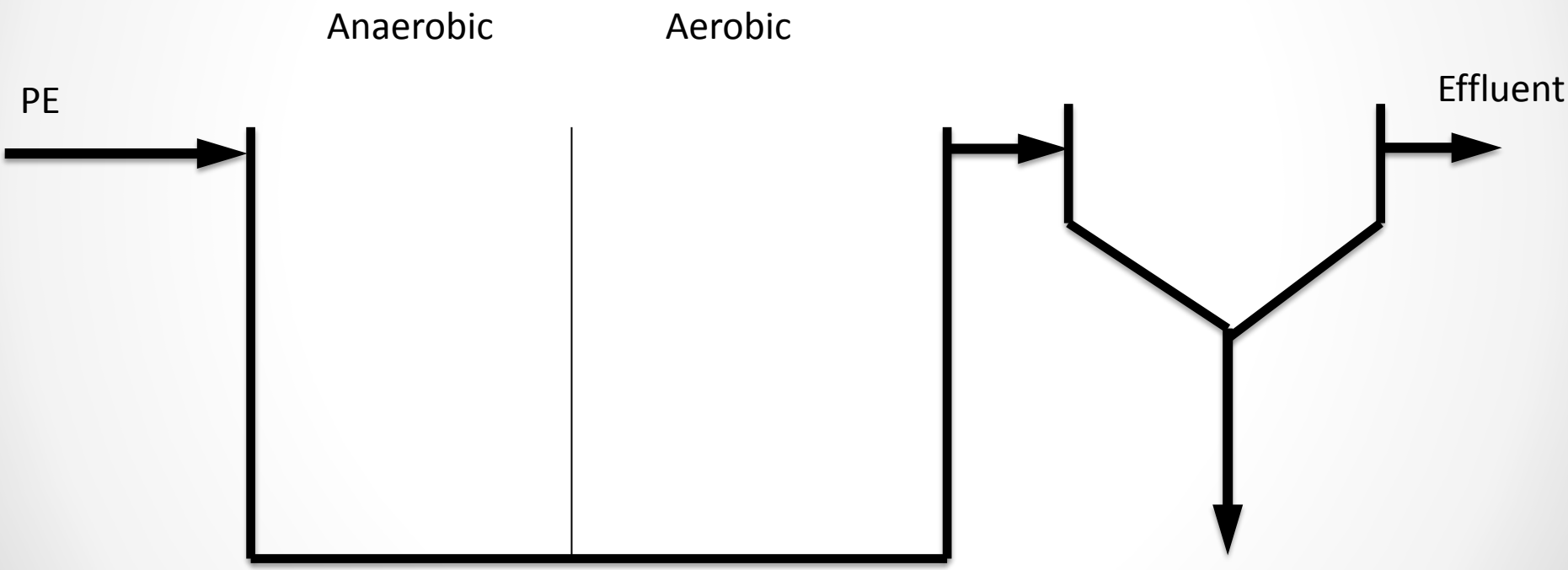
3. Carousel oxidation ditch

- Both processes occur in the same tank
  Simultaneous Nite/Denite
- Extended SRT required



Biological P removal

EBPR: PAO metabolism



Biological P removal

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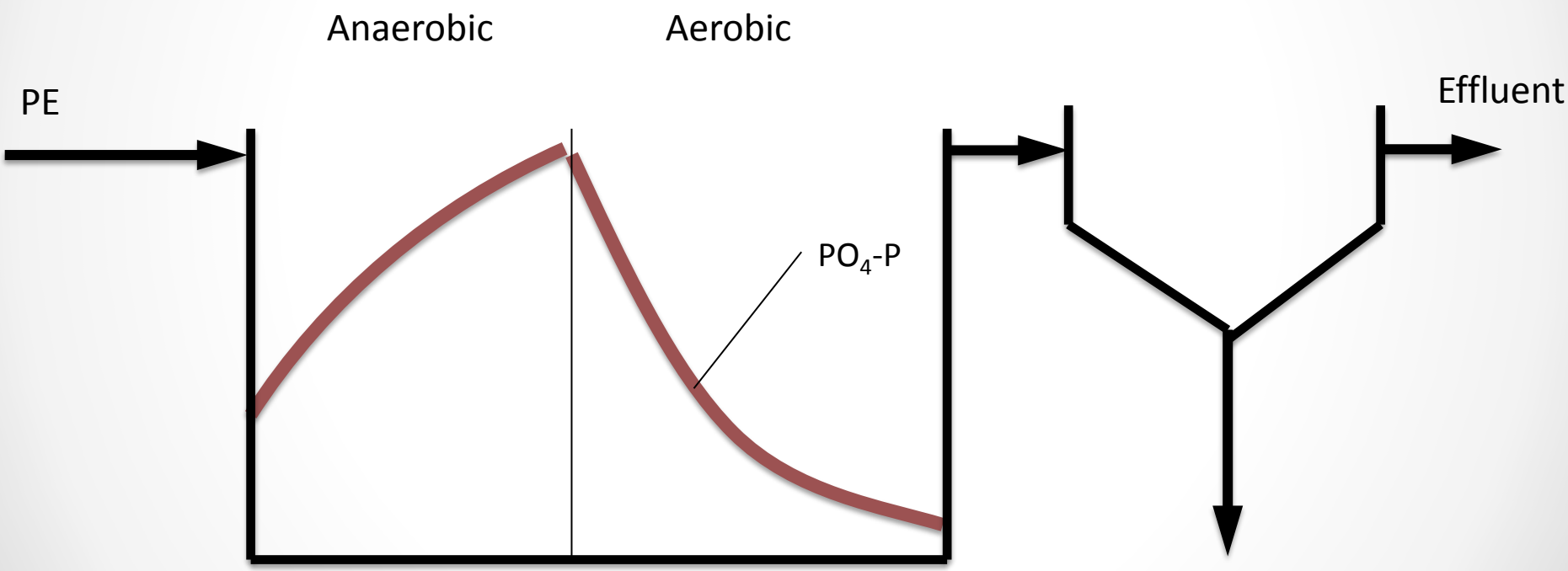

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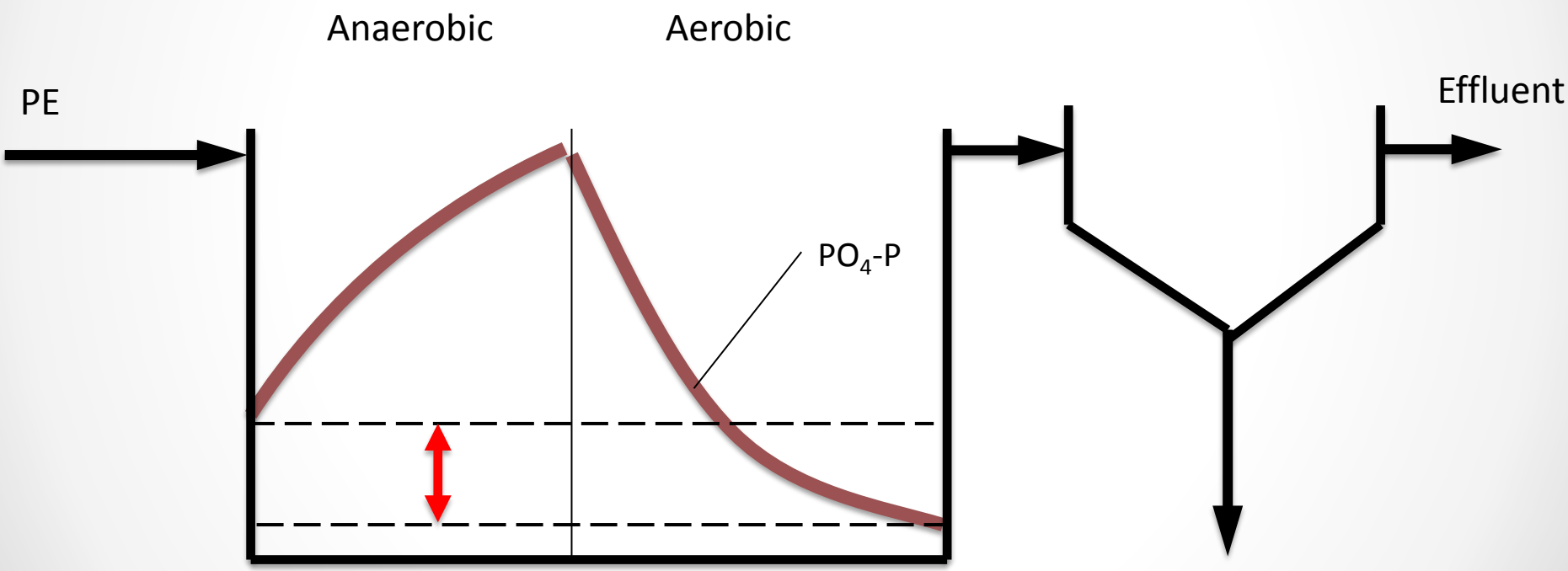
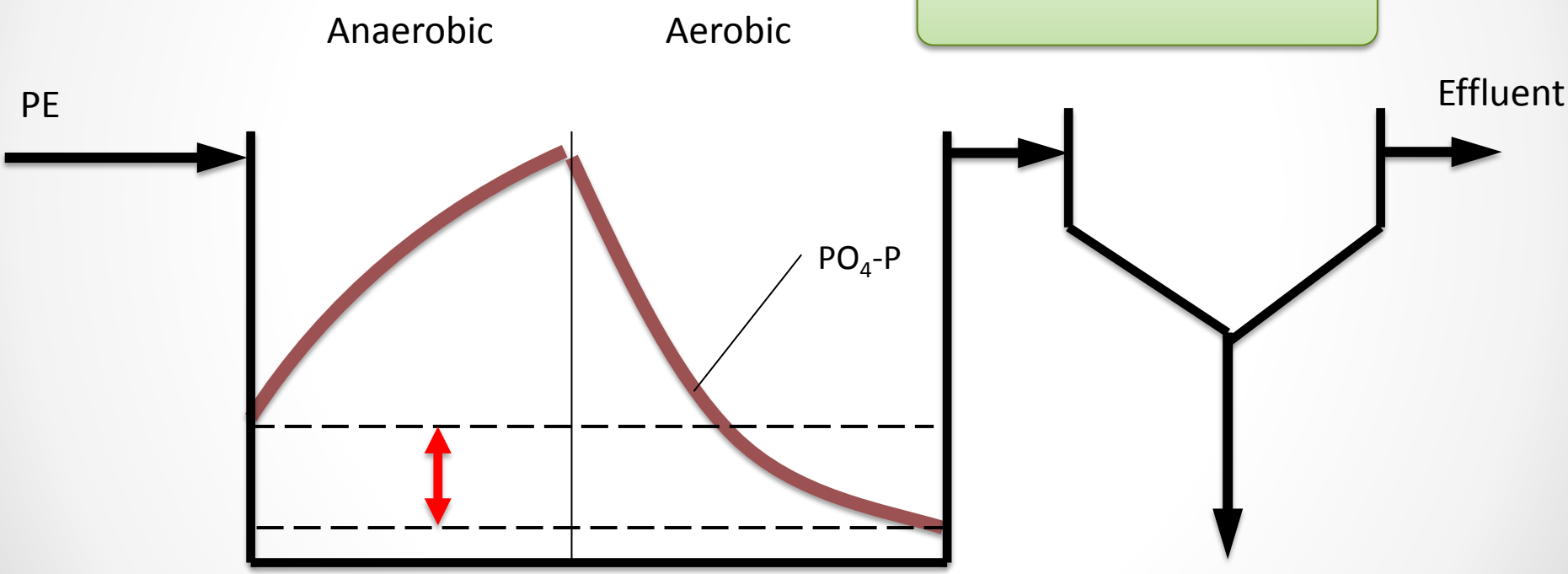


P removed in WAS

Biological P removal

EBPR: PAO metabolism

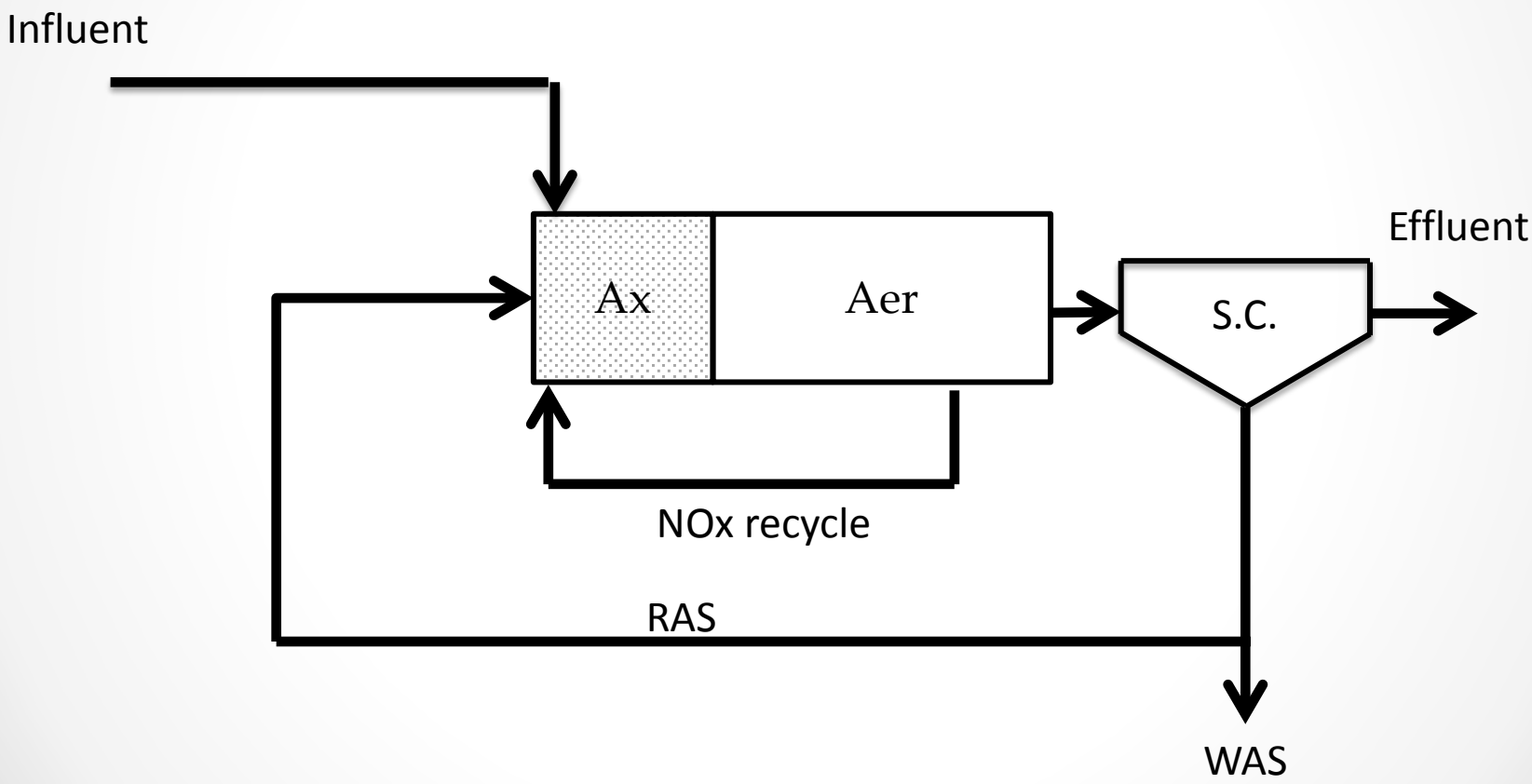
EBPR needs VFA!



P removed in WAS

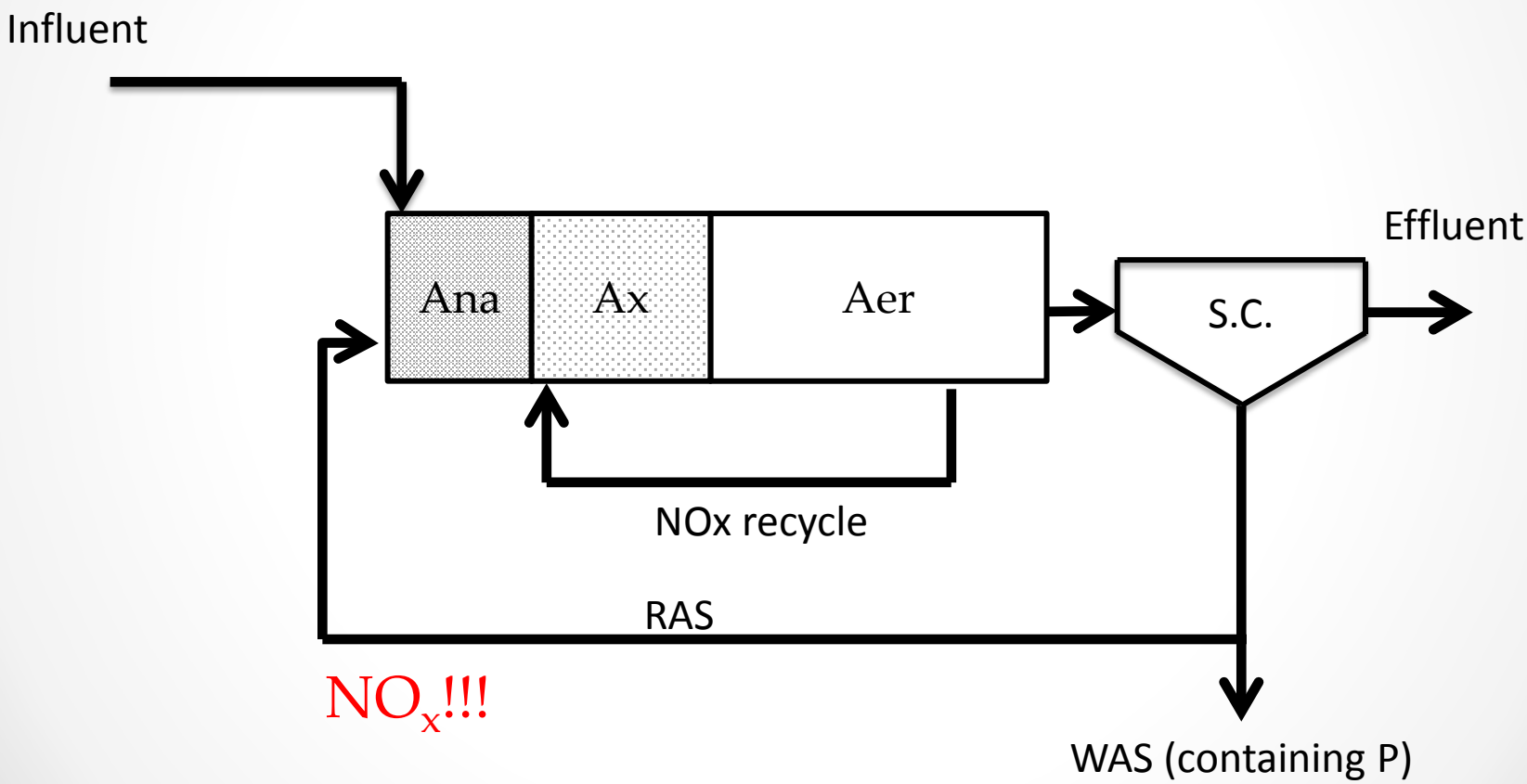
BNR with EBPR

Simultaneous N and P removal



BNR with EBPR

- Reduce ORP in Anaerobic zone



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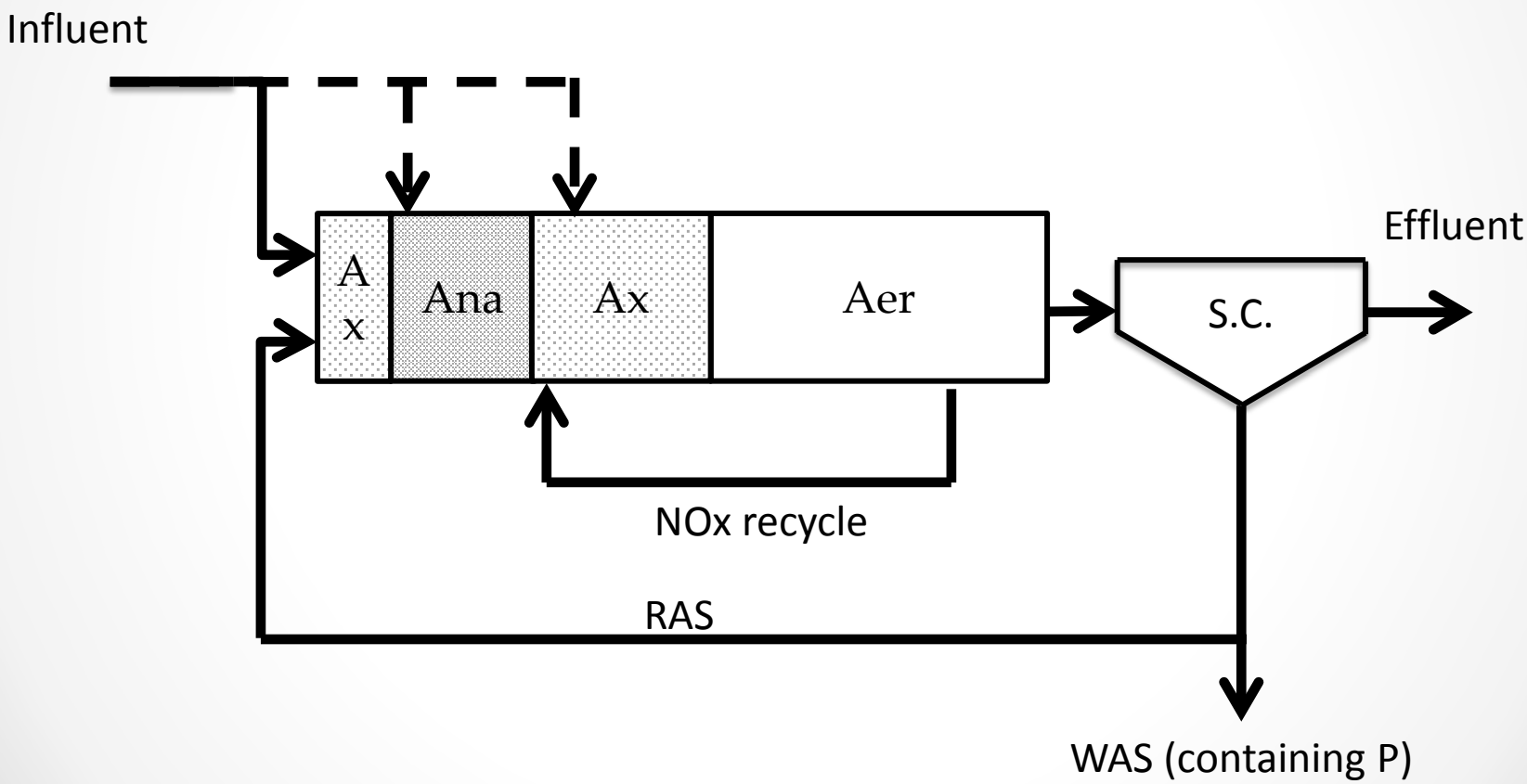
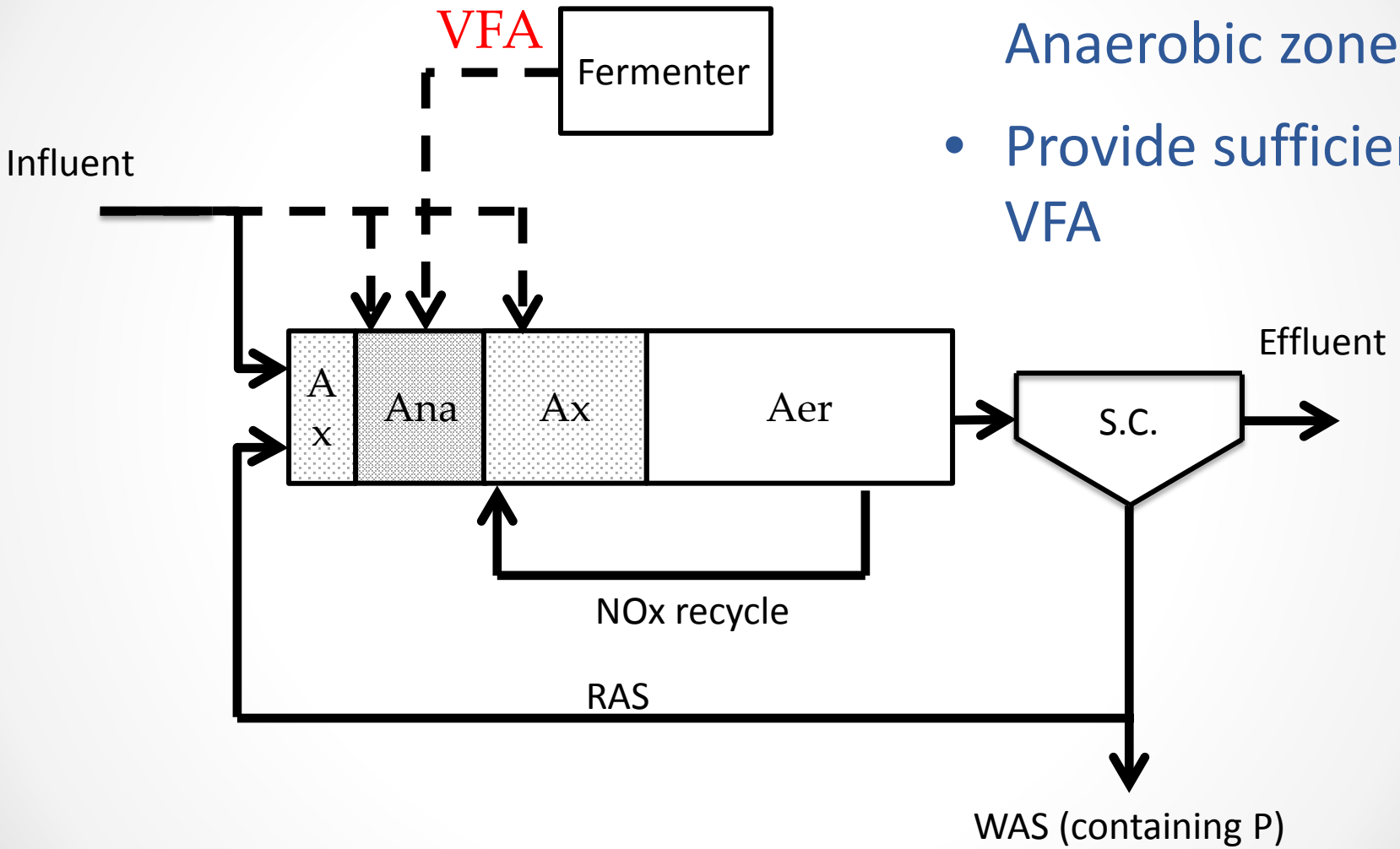


BNR with EBPR

- Reduce ORP in Anaerobic zone
- Provide sufficient VFA



Chem. P removal: Coagulation

- Al and Fe salts: Al^{3+} ; Fe^{3+}
- Small footprint
- Easy to retrofit

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- Small footprint
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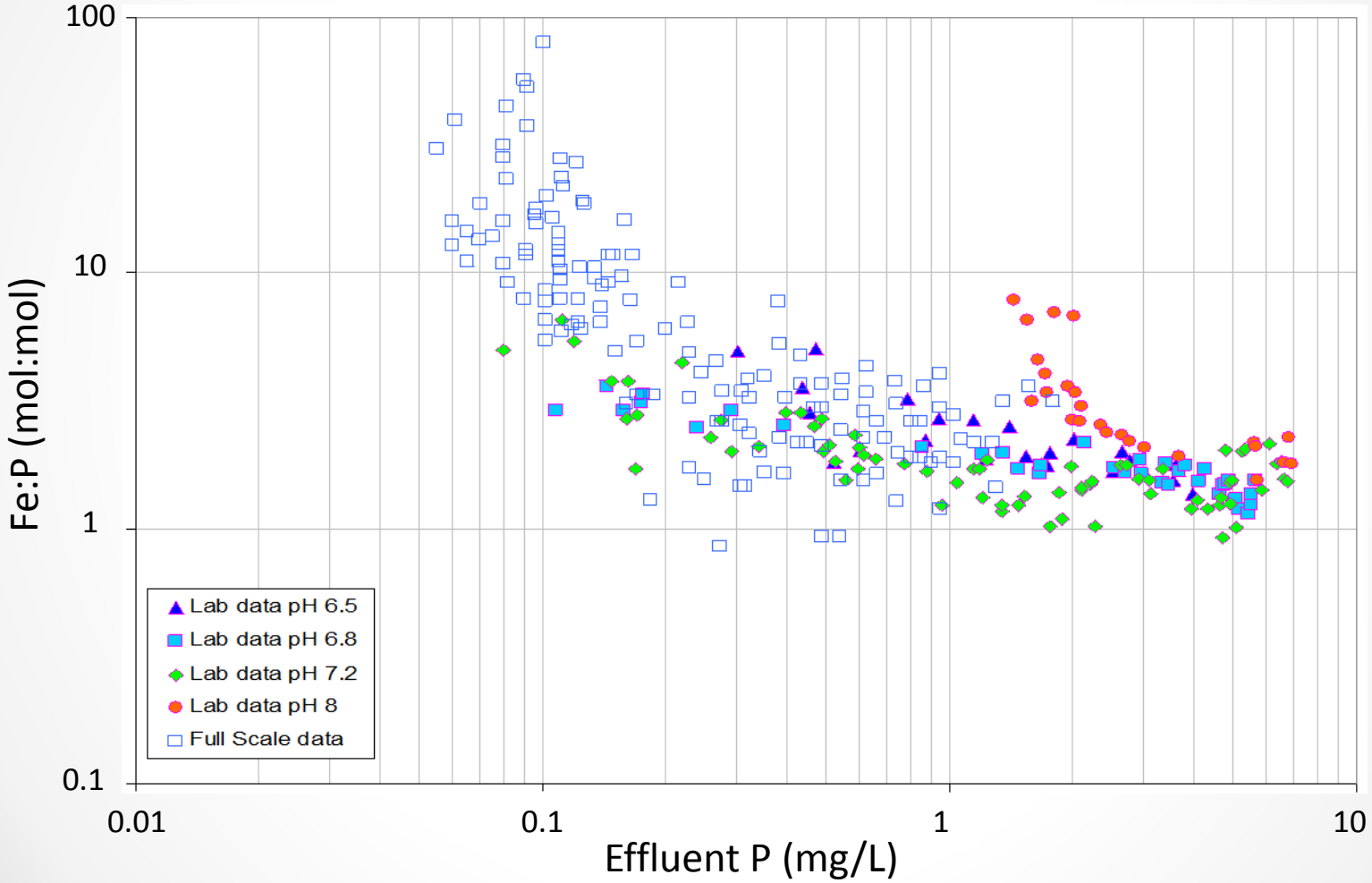
… but:

- Higher sludge production
- High chemical costs
- Prevents recovery from liquid phase

Ferric dose for P precipitation

Data Dr S Hermanowicz, UC Berkeley



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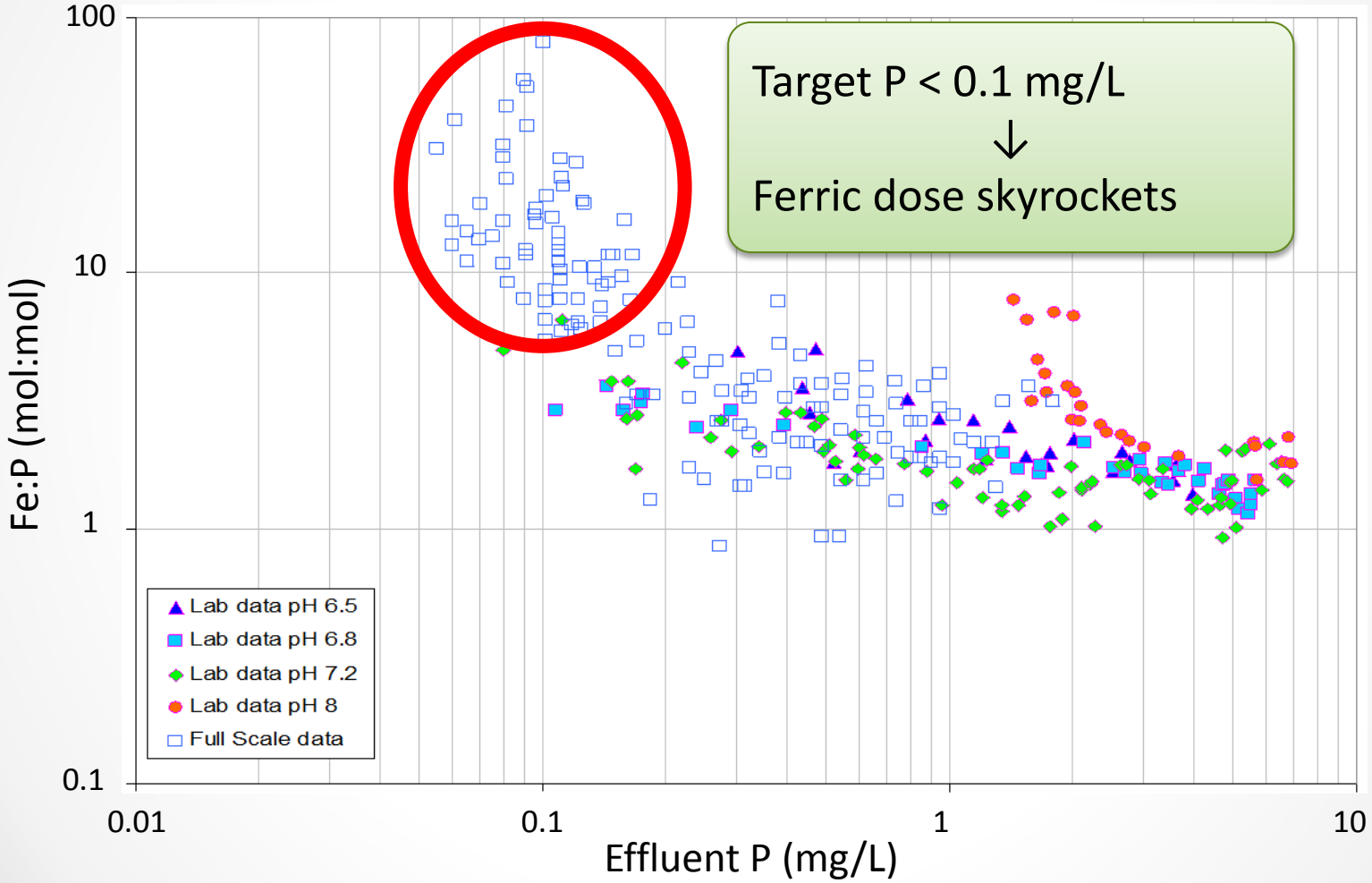

EBPR ~~vs~~ + Chem. P

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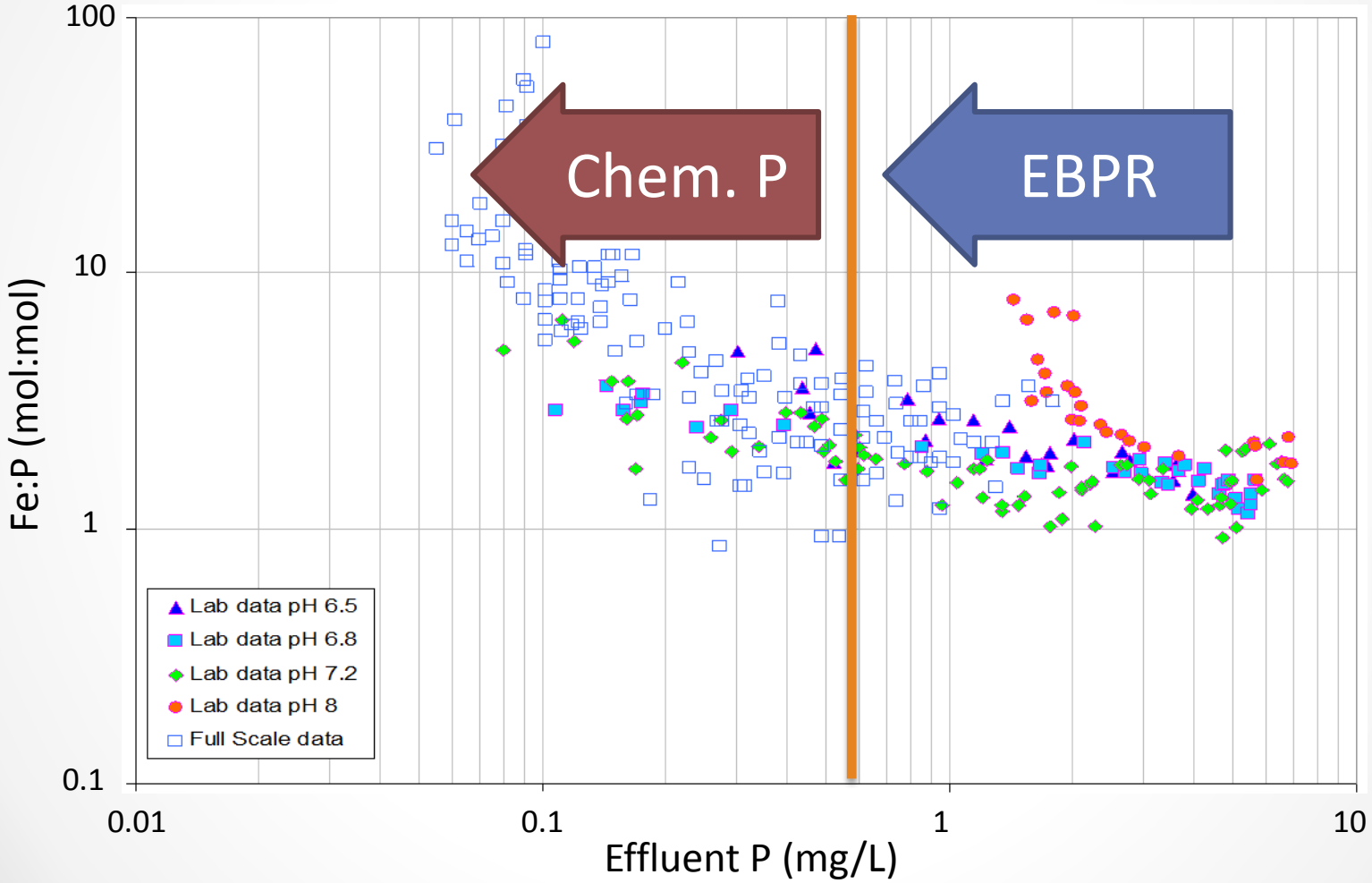

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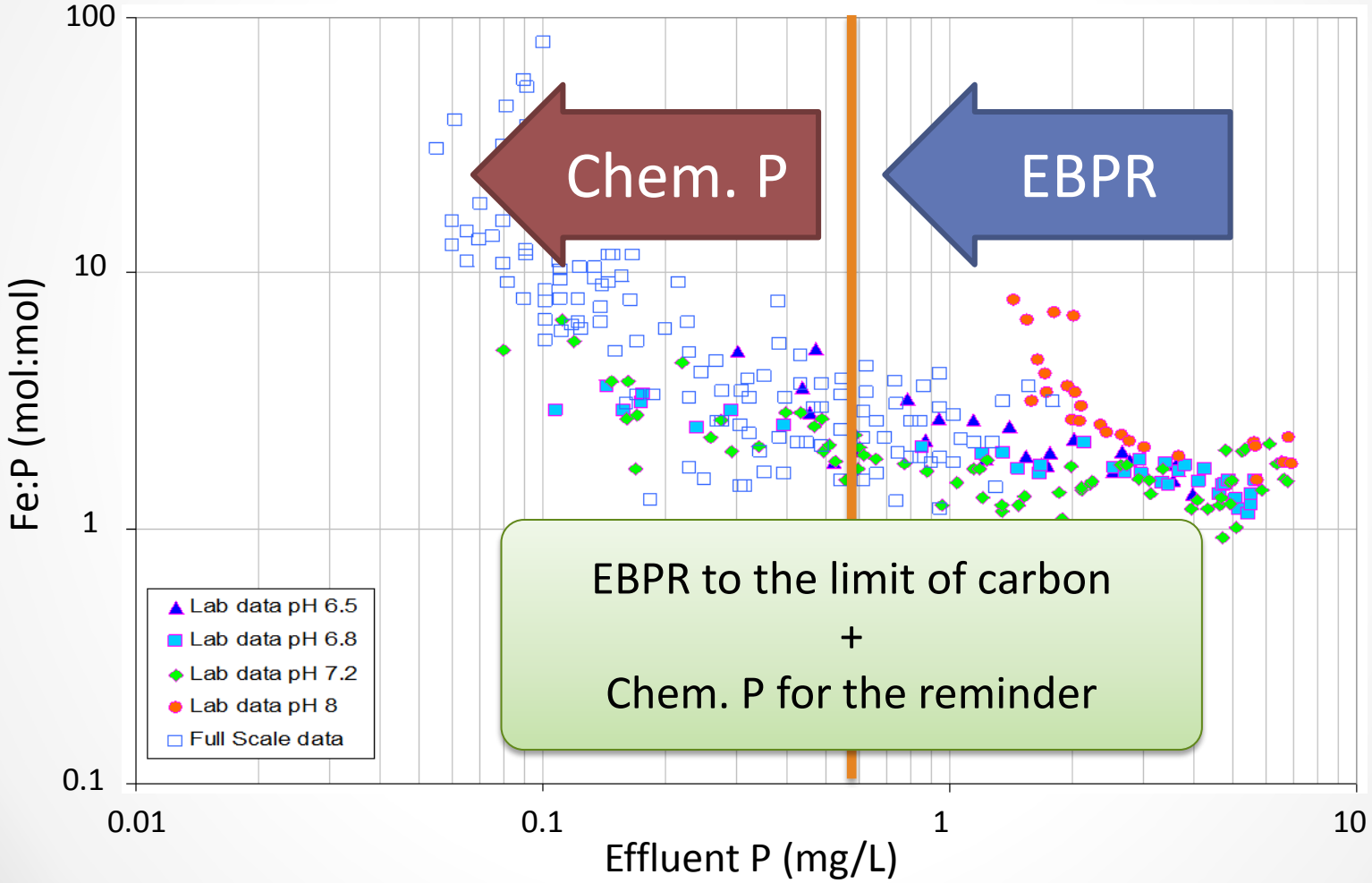

Key issues of nutrient removal

1. Oxygen demand

- DN is advantageous
  - Reduction of oxygen demand

    1 kg NO_3-N removed = 2.9 kg O_2 saved
  - Recovers Alkalinity

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- Sidestream PN/Anammox

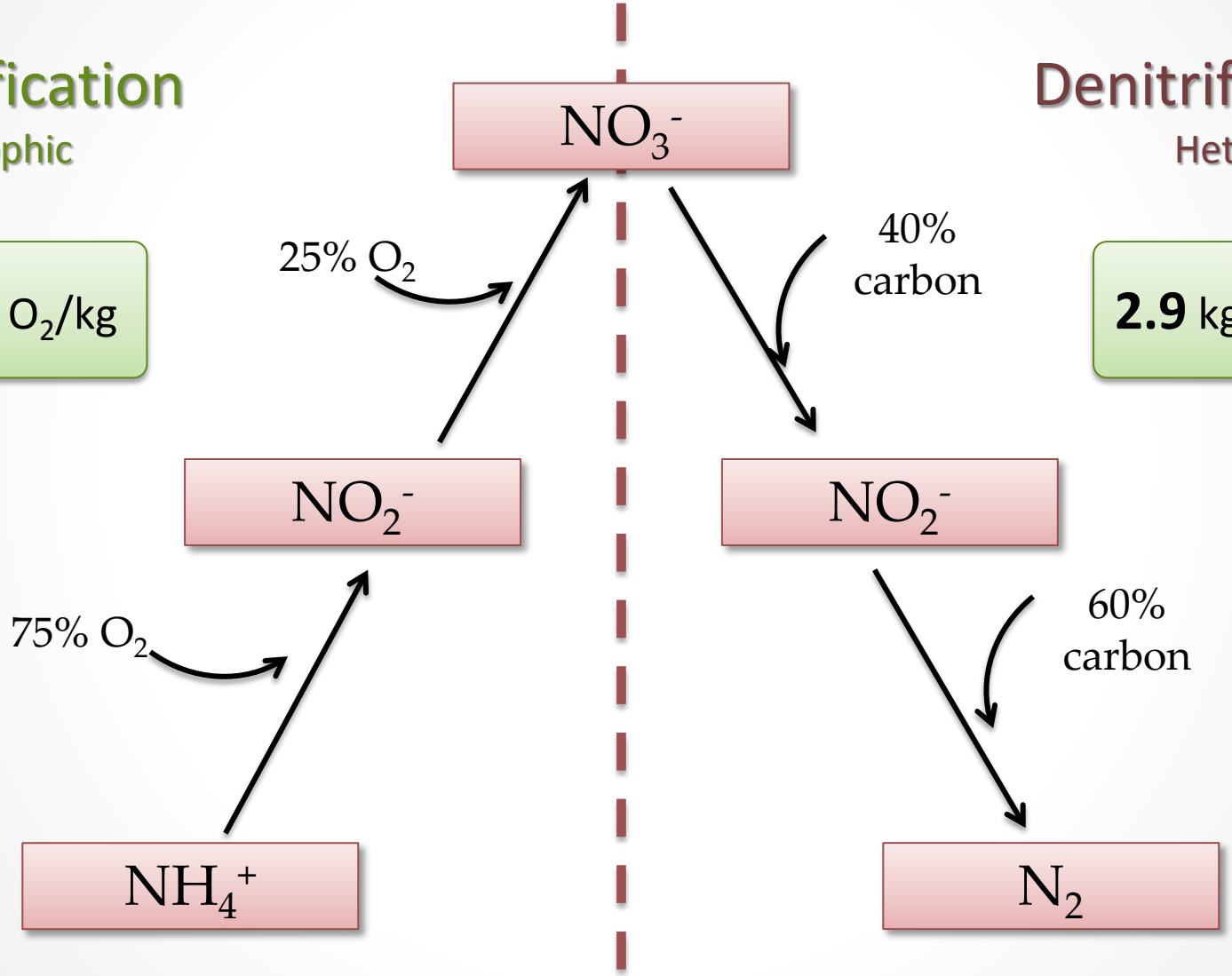
Biological N removal

Nitrification
Autotrophic

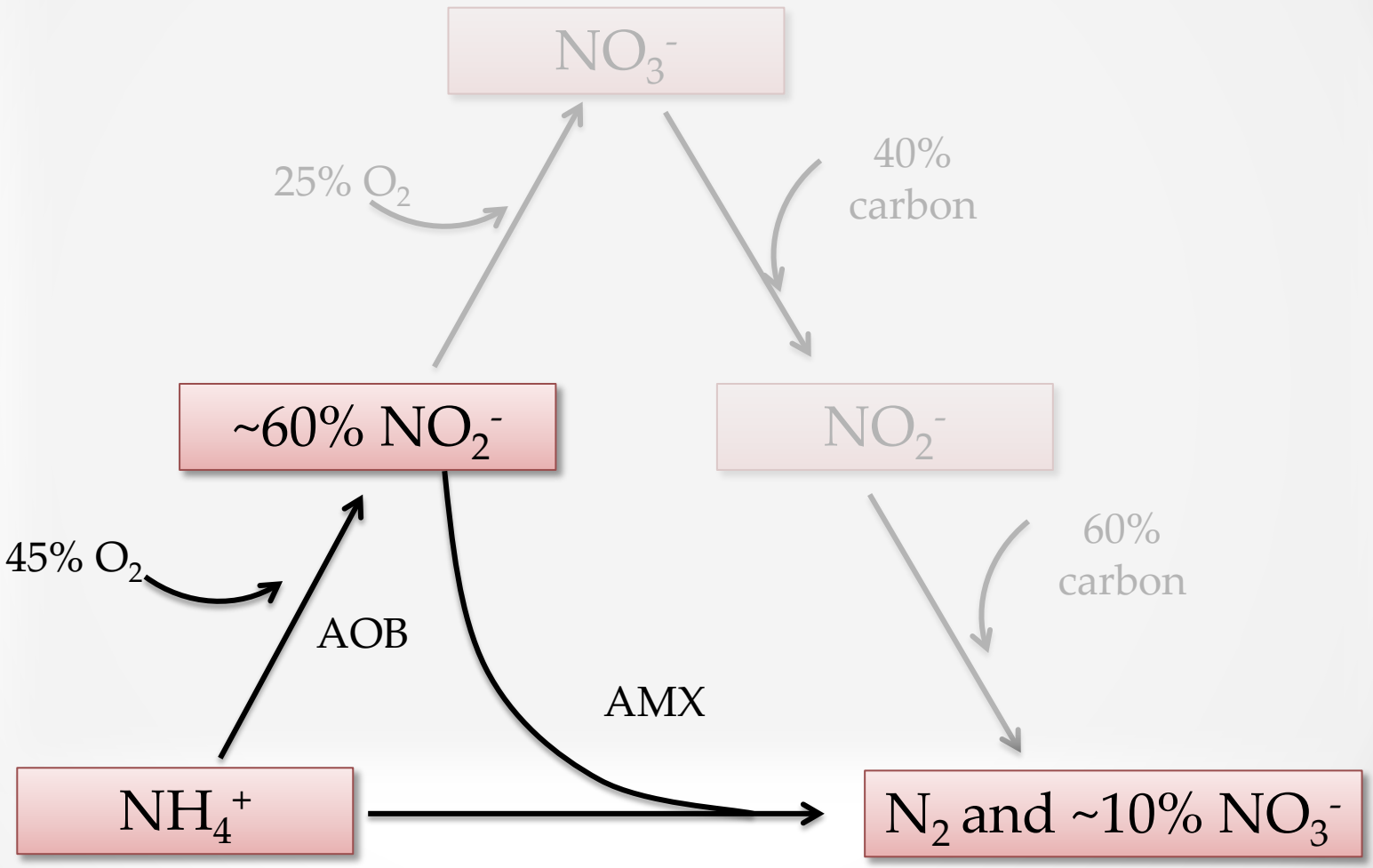
4.5 kg O_2/kg

Denitrification
Heterotrophic

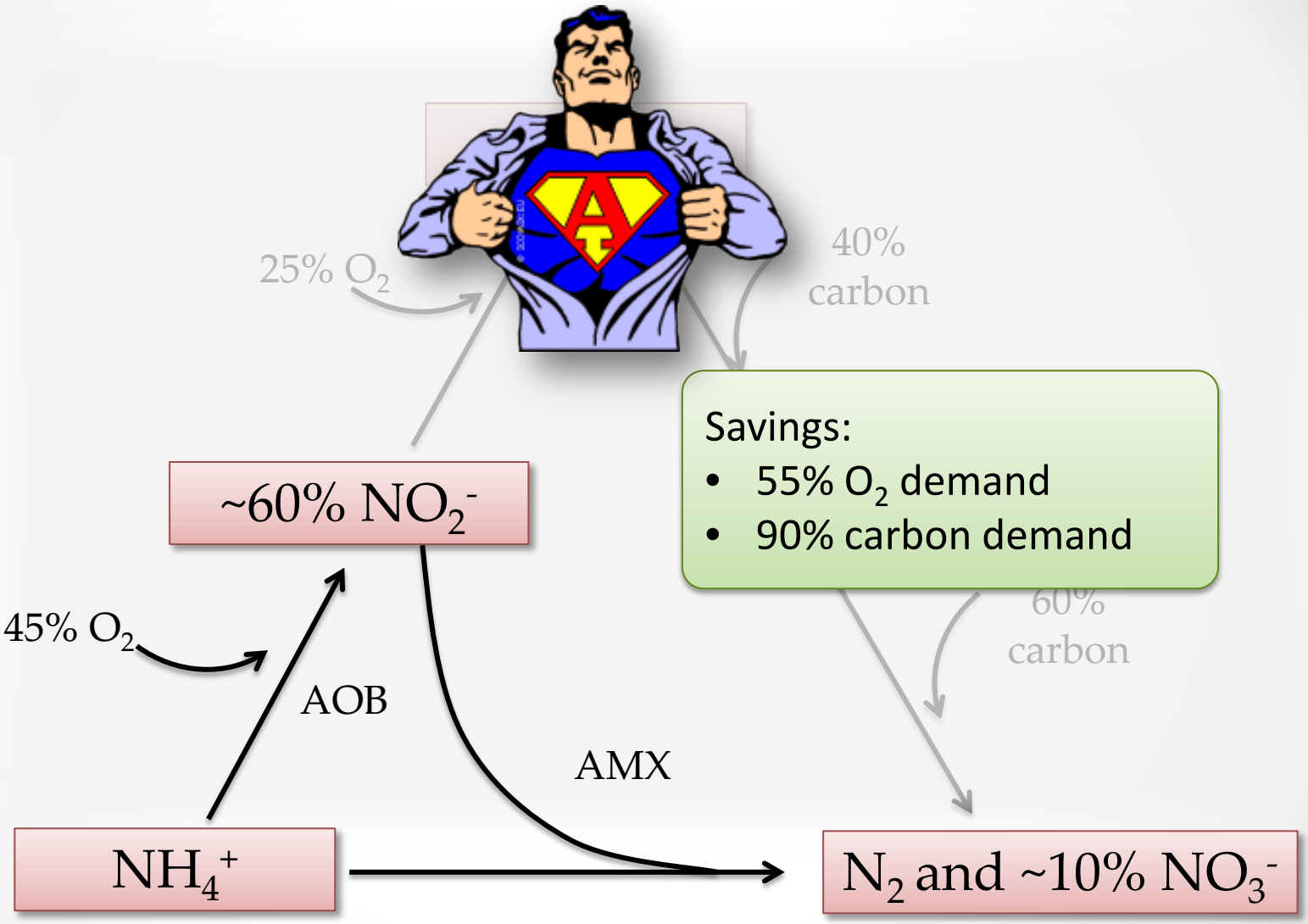
2.9 kg COD/kg



PN/Anammox


NO_3^-
25% O_2
40% carbon
~60% NO_2^-
NO_2^-
45% O_2
AOB
60% carbon
AMX
NH_4^+
N_2 and ~10% NO_3^-

PN/Anammox


25% O_2
40% carbon
Savings:
• 55% O_2 demand
• 90% carbon demand
~60% NO_2^-
45% O_2
AOB
AMX
60% carbon
NH_4^+
N_2 and ~10% NO_3^-

Key issues of nutrient removal

2. Carbon demand

- Approx. requirements
  - **6 g** bCOD/g **N**
  - **20 g** bCOD/g **P**

Missing:
33 mg bCOD/L

In	Out	
35	5	mg **N**/L
5.5	0.5	mg **P**/L

Need:
280 mg bCOD/L

Have:
380*0.65 = 247 mg bCOD/L

Key issues of nutrient removal

2. Carbon demand

Possible improvements:

- Fermentation of PS + 34 mg bCOD/L (VFA)
- Sidestream PN/Anammox + 47 mg bCOD/L
- Sidestreeam P recovery + 80 mg bCOD/L
- Simultaneous Nite/Dinite
- Supplemental COD
- Chem. P removal

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In many cases fermentation is enough

Key issues of nutrient removal

3. Limit of technology

Process	TP mg P/L	TAN mg N/L	TN mg N/L
CAS EA	5	<3	25
CAS EA with SND + Chem. P	<0.3	<1	<7
BNR with adequate VFA	<0.3	<1	<7
BNR with adequate VFA + Filtration	<0.1	<1	<7
CAS EA with SND+ ballasted flocculation	<0.1	<1	<7
BNR + post DN + post-precipitation + UF	0.01	<1	<3

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rDON is the absolute TN limit (1 to 2 mg/L)

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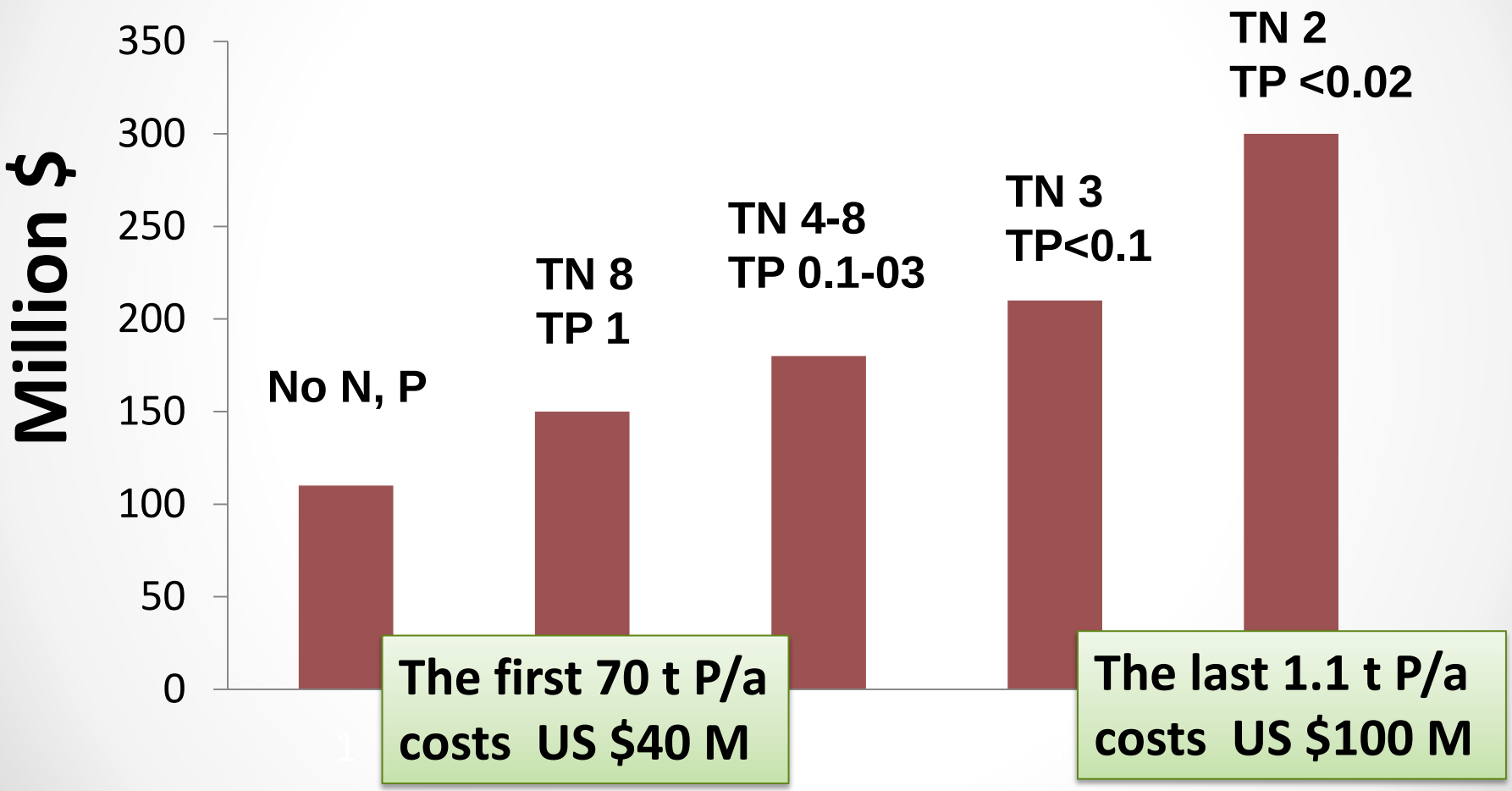
High costs of low limits

Total present worth for a 38 MLD WWTP



from JB Neethling, HDR, 16 May, 2012, WERF CBP STAC Workshop

Opportunities for improved nutrient removal and recovery from municipal wastewater

Thank you

Canadian Water Network

University of Manitoba

Opportunities for improved nutrient removal and recovery from municipal wastewater

Nutrient Recovery and Reuse: Practice and Developing Trends

Tanner R. Devlin, Damian J. Kruk, Jan A. Oleszkiewicz

Webinar, October 22nd, 2015

Canadian Water Network

University of Manitoba

Recovery and reuse practice

Should we recover or reuse nutrients?

If

1. Recognized ROI**; or**
2. Mandated

<u>Then yes!</u>

Fluctuating market:

- Phosphorus = $0.75/kg P
- Ammonium = $0.20/kg N
- Dried biosolids = $0.15/kg DS

Recovery and reuse practice

Cases

Saskatoon BNR facility (85 MLD)

- Crystallizer + P stripping from WAS
- 7 to 10 year payback

Miami-Dade HPO facility (541 + 426 MLD)

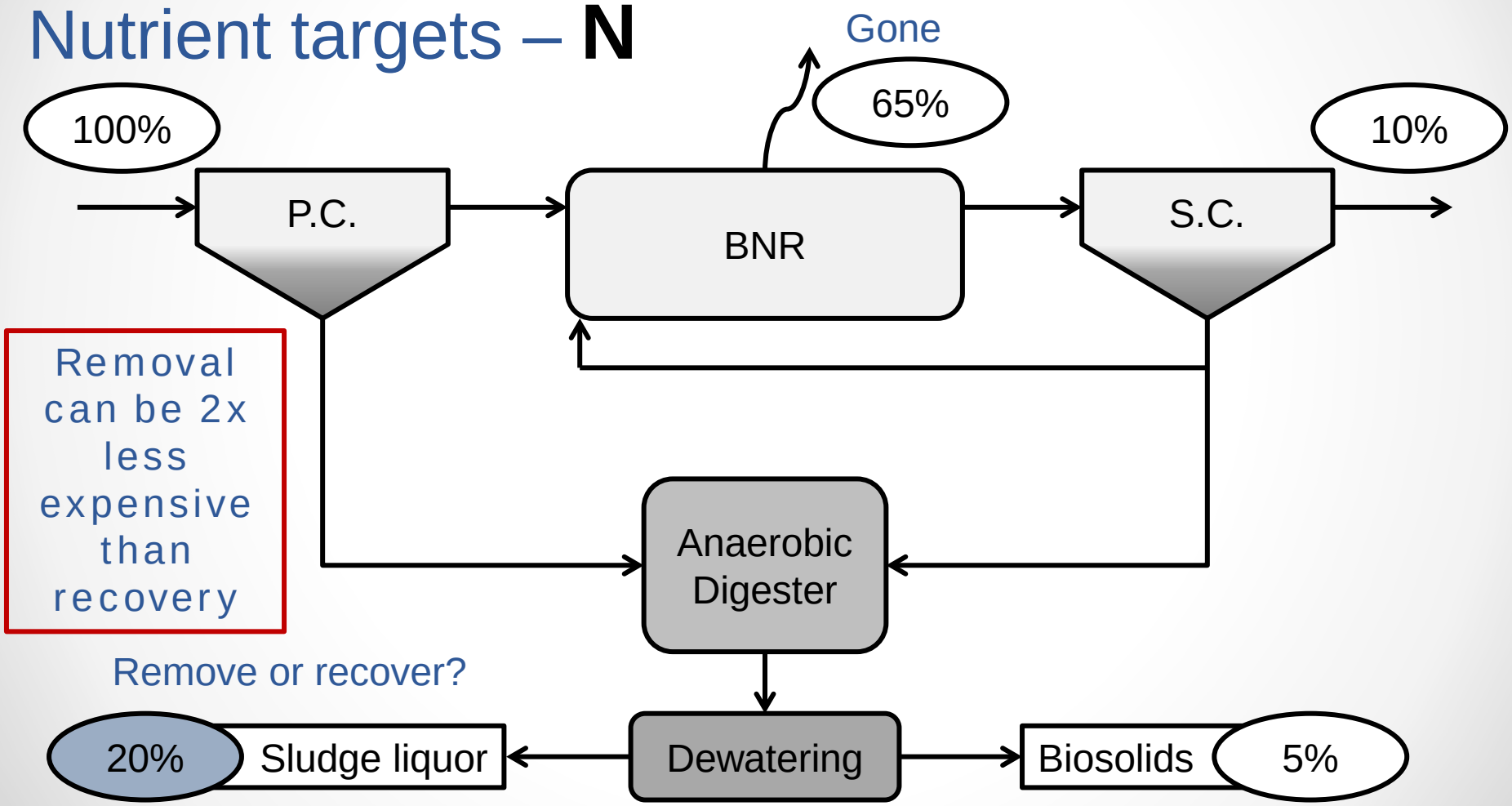
- Crystallizer on centrate (planned)
- $NPV_{(20y)}$ < 2x existing operations and ferric dosing!

New York 26th Ward Centrate facility (4.5 MLD)

- Ion-exchange based ammonium capture and extraction
- Promising, but lost bid in 2014 to anammox removal

Recovery and reuse practice

Nutrient targets – **N**



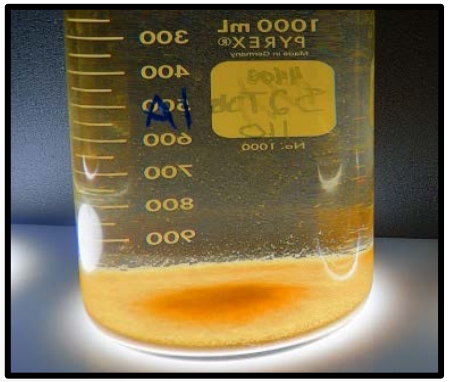
Recovery and reuse practice

Nutrient targets – **P**

Yields large P cache when EBPR

Biological sludge

Solids processing

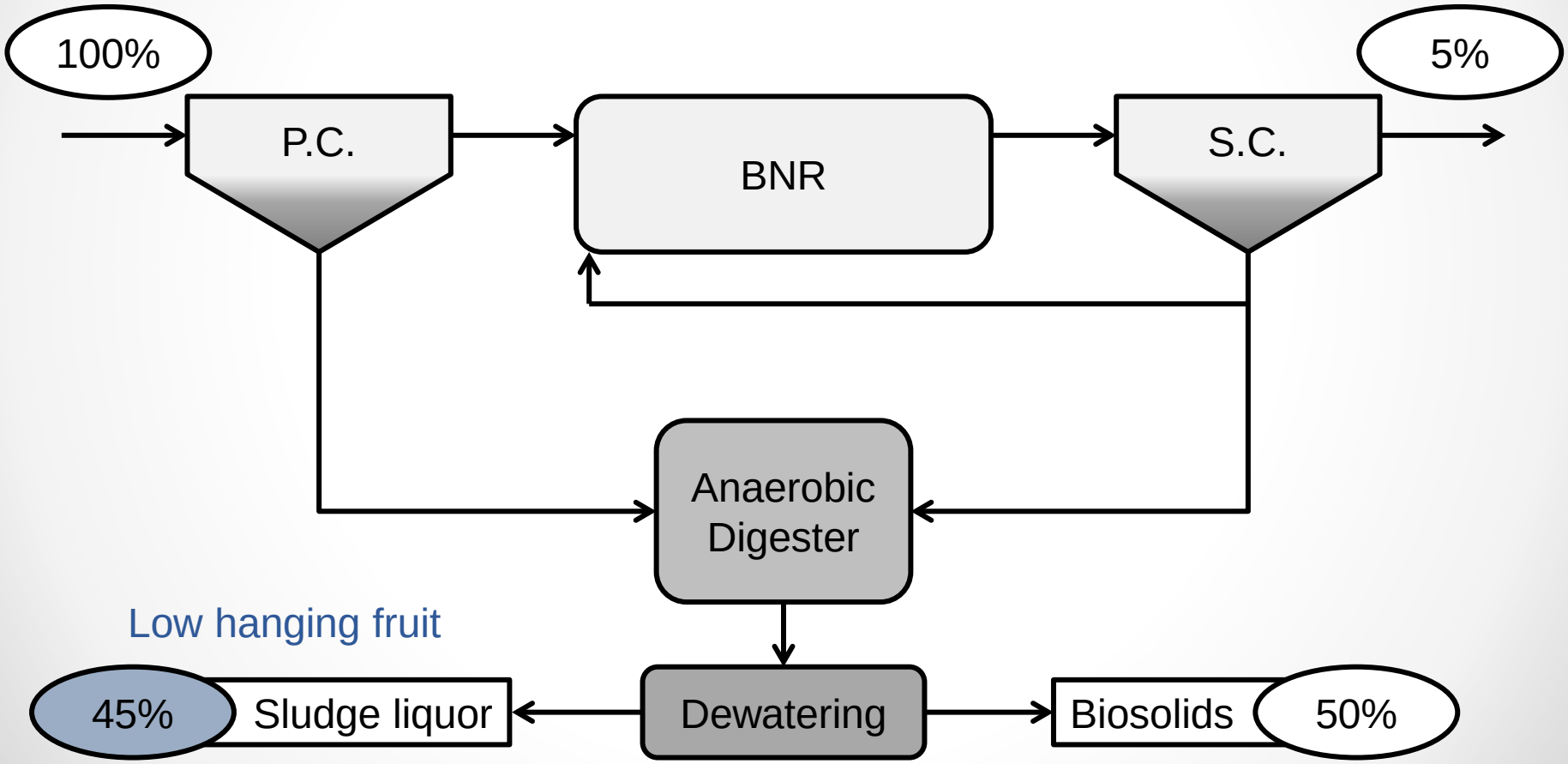


Chemical sludge

P locked and unavailable?

Recovery and reuse practice

Nutrient targets – **P**

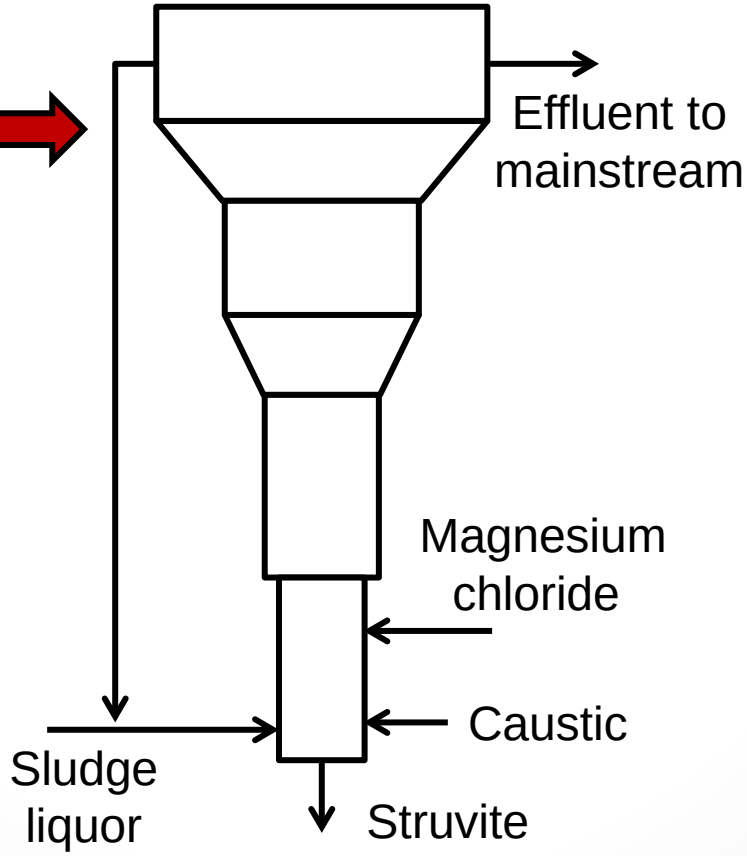


Recovery and reuse practice

Nutrient targets – **P in sludge liquor**

Many processes:

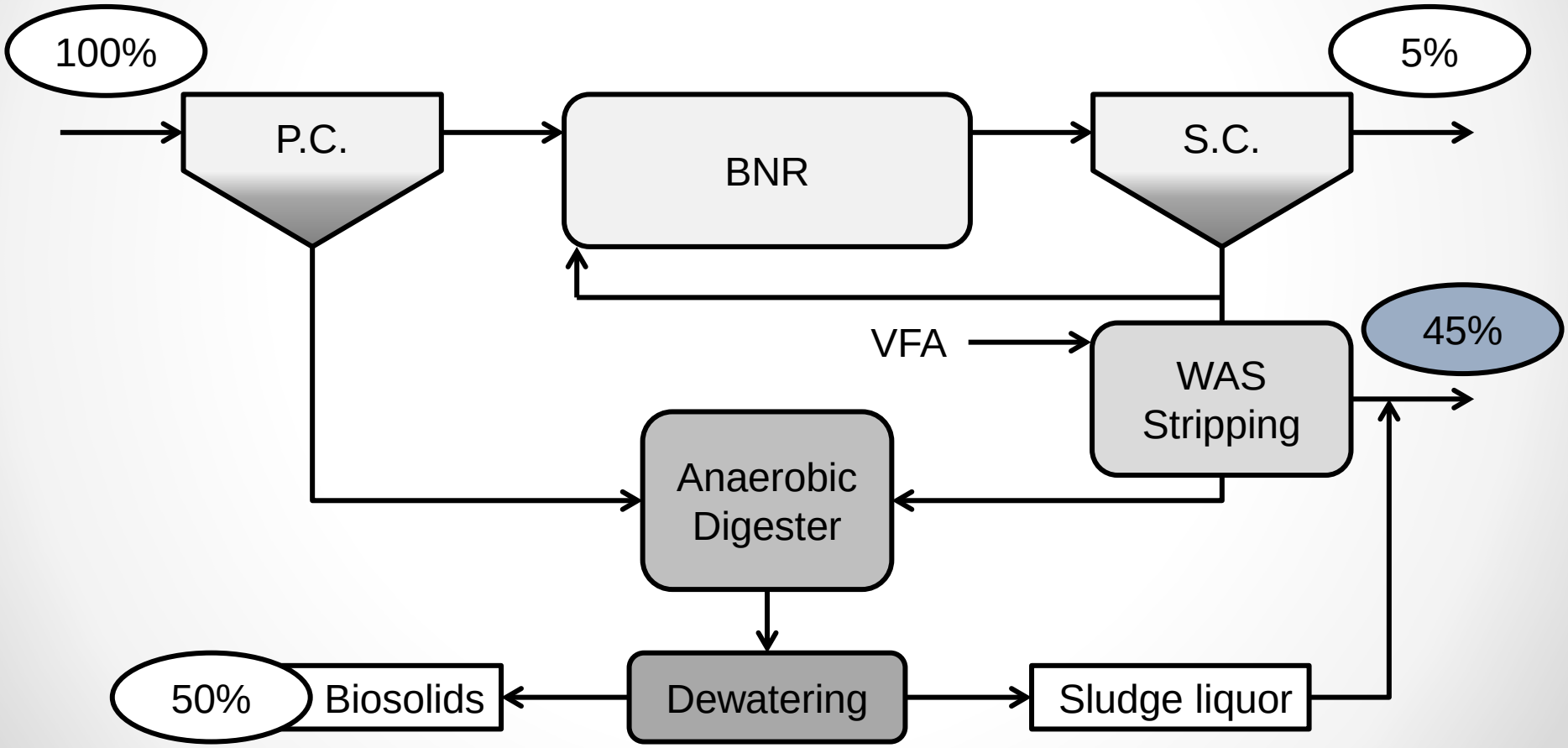
- Ostara Pearl
- Multiform harvest
- PHOSNIX
- P-RoC
- Phospaq
- Crystalactor



Struvite from Pearl

Recovery and reuse practice

Nutrient targets – **P stripping sidestream**



Recovery and reuse practice

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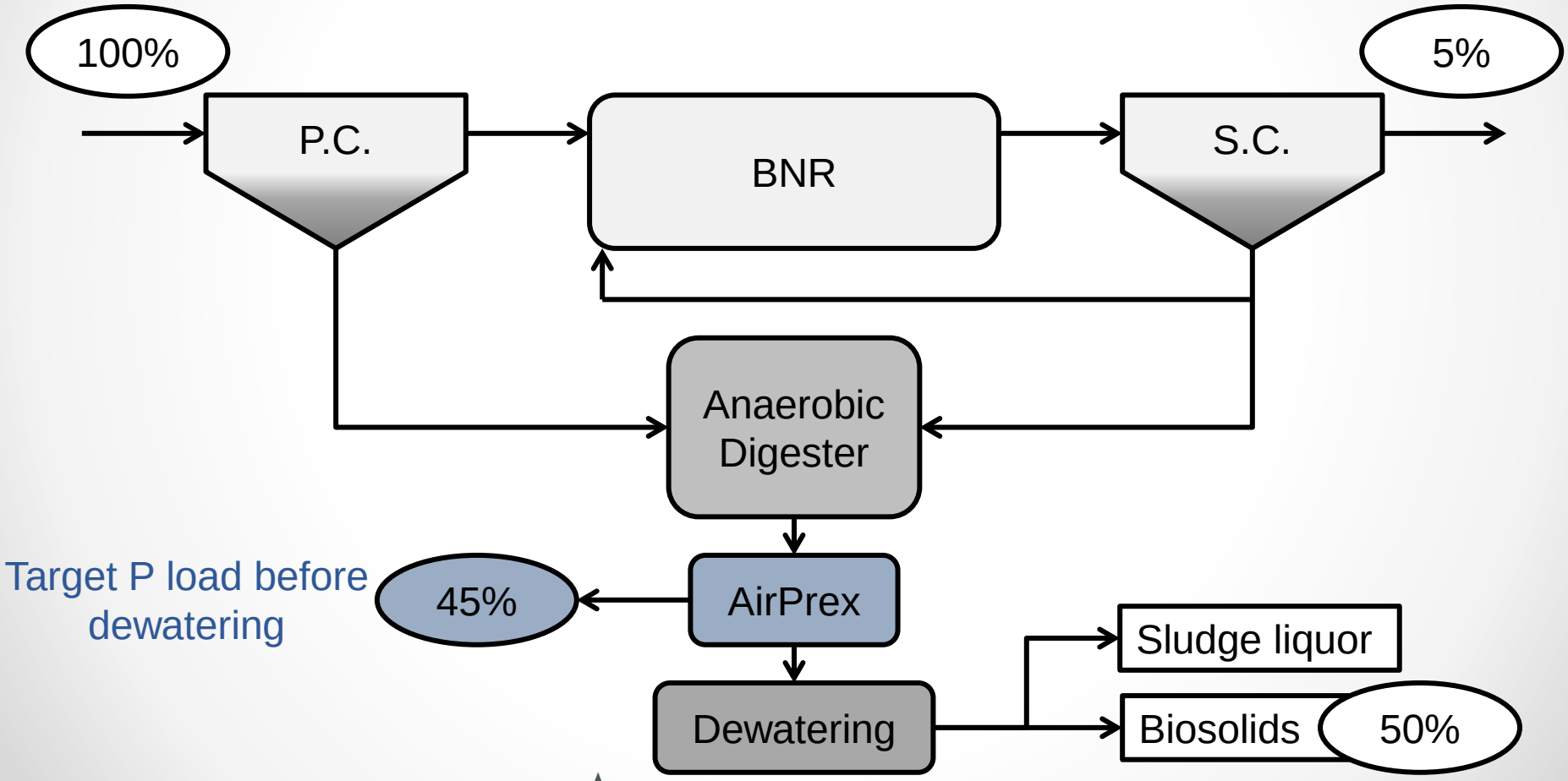
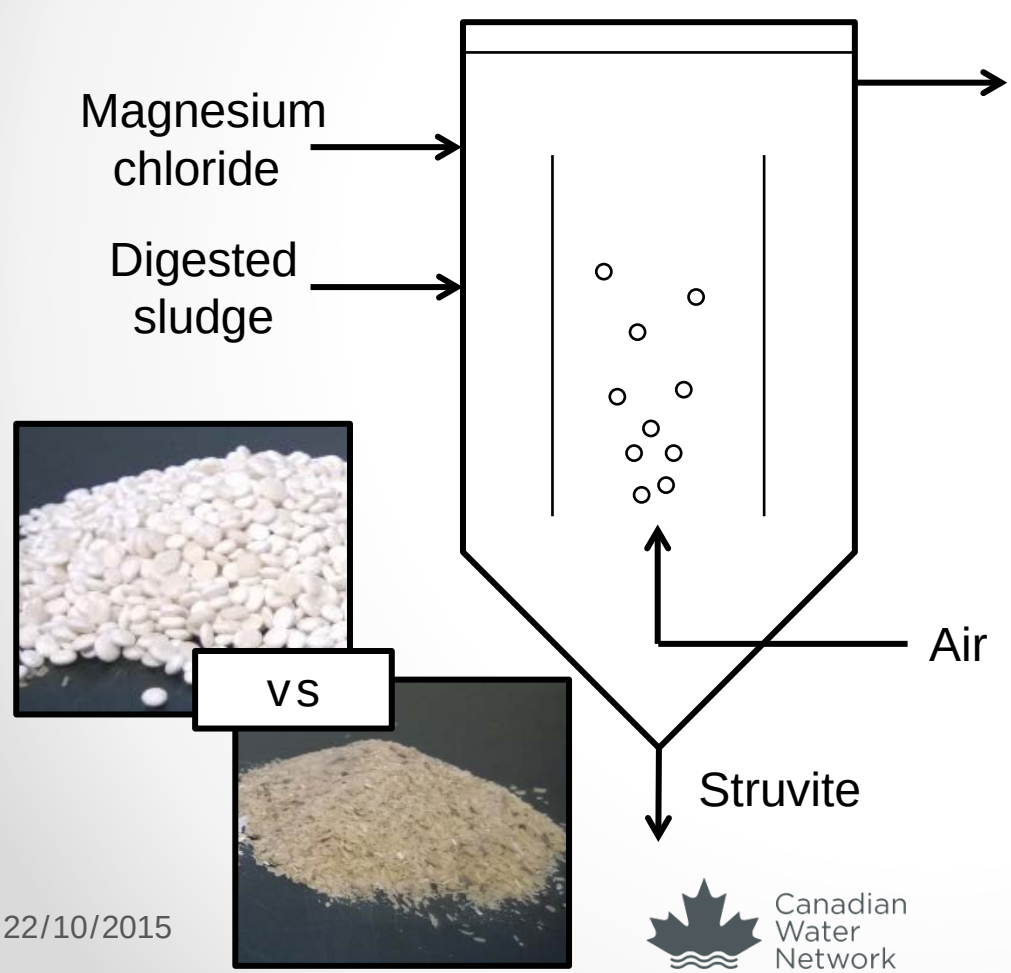


Recovery and reuse practice

Nutrient targets – **P in digested sludge**



AirPrex

Benefits:

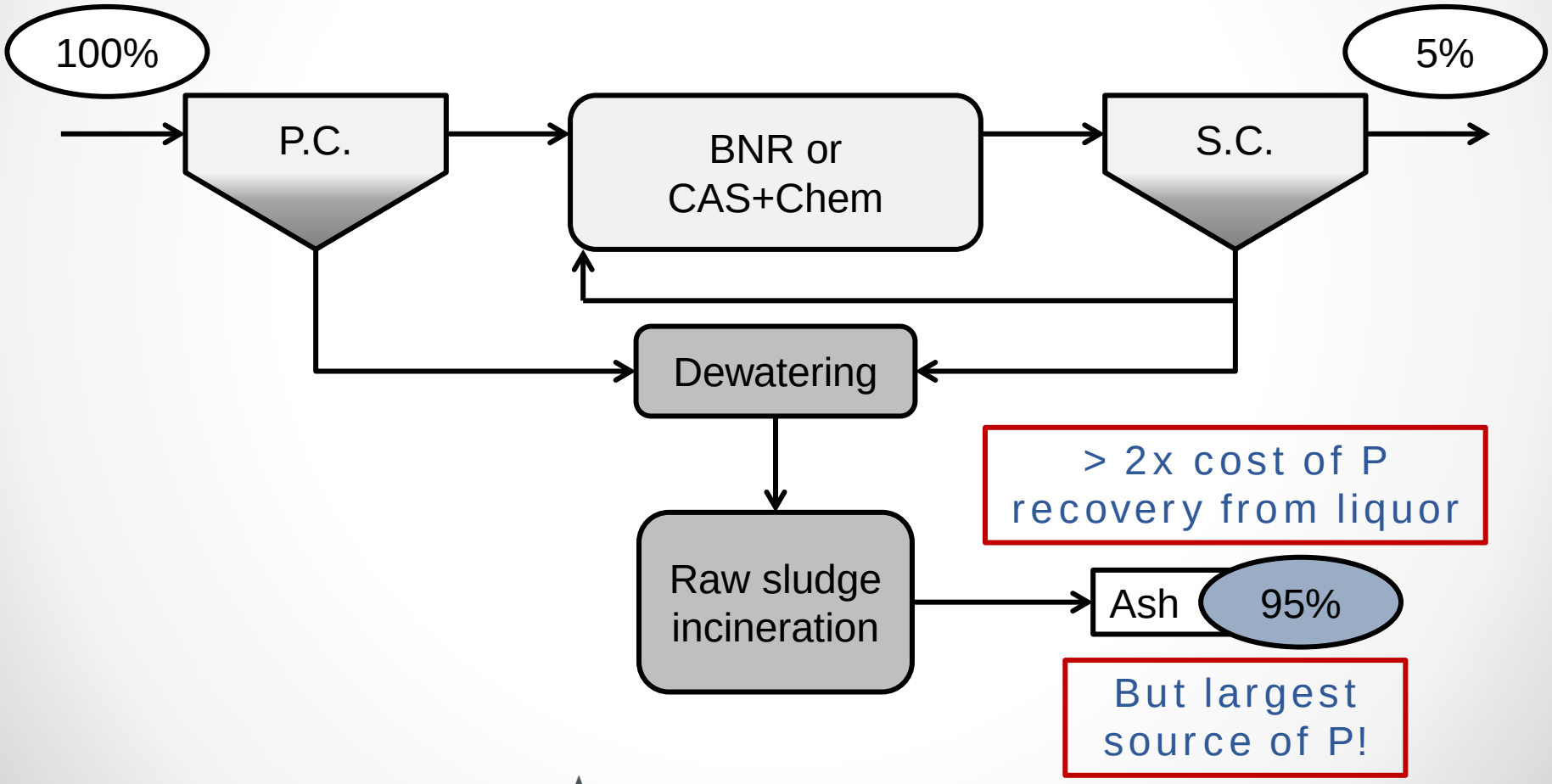
1. Better solids dewaterability (> 4% improvement)
2. Reduced maintenance costs (up to 50%)
3. Reduced P recycle (up to 90%)

and then…

4. Increased revenue from fertilizer (up to 10%)

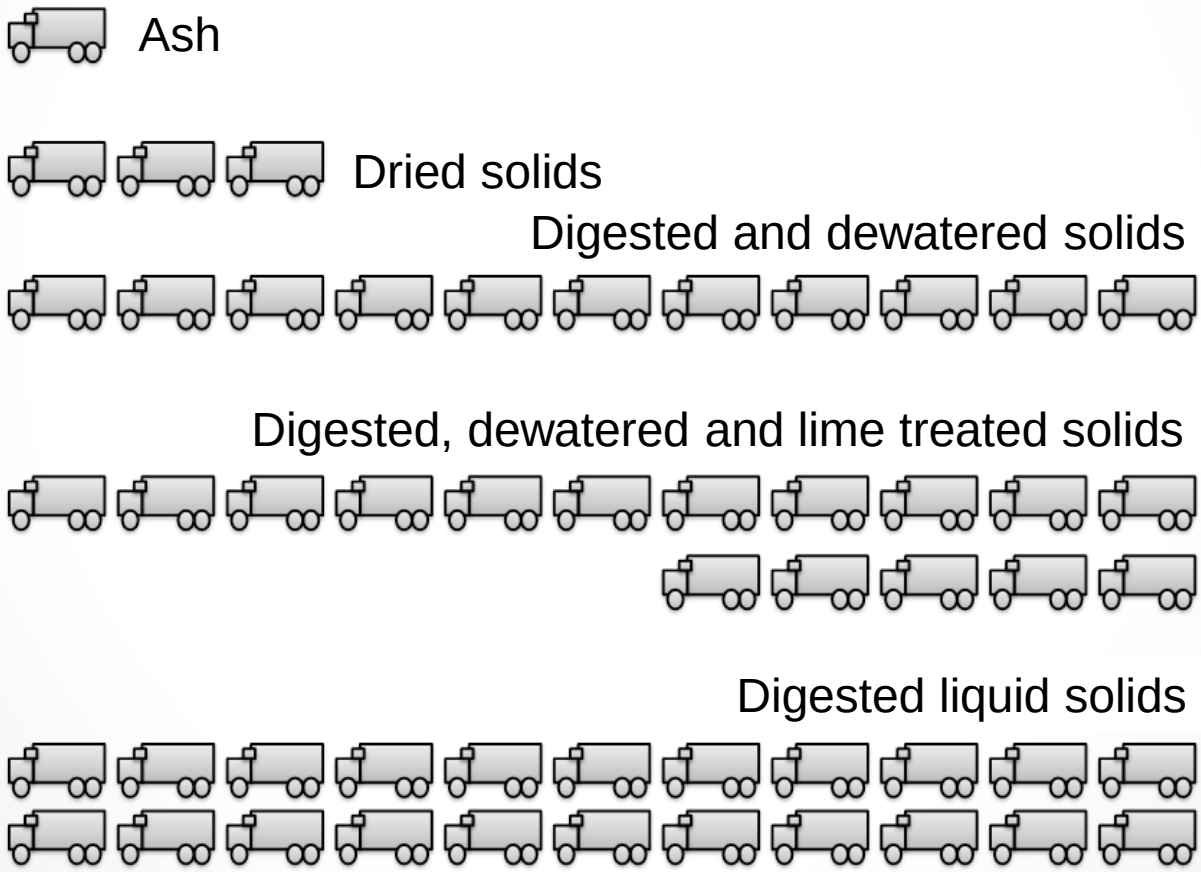
Recovery and reuse practice

Nutrient targets – **P**



Recovery and reuse practice

Nutrient targets – **P in ash**



Recovery and reuse practice

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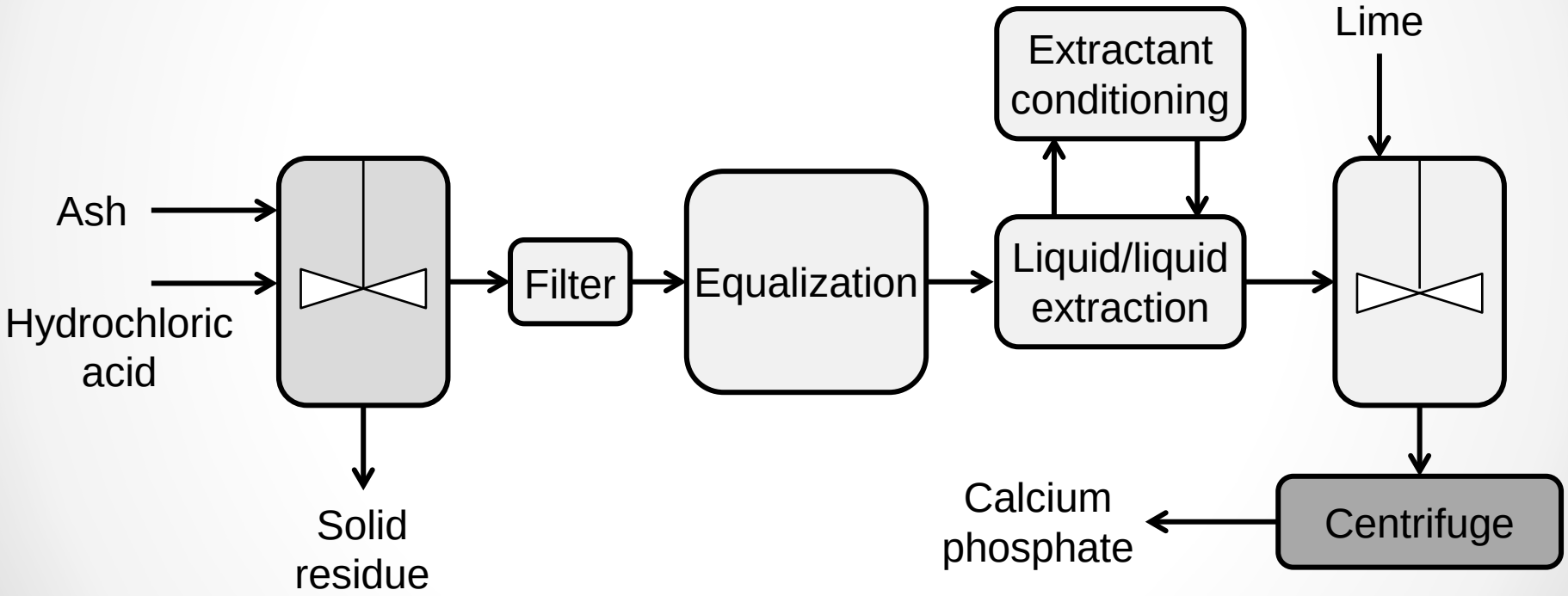
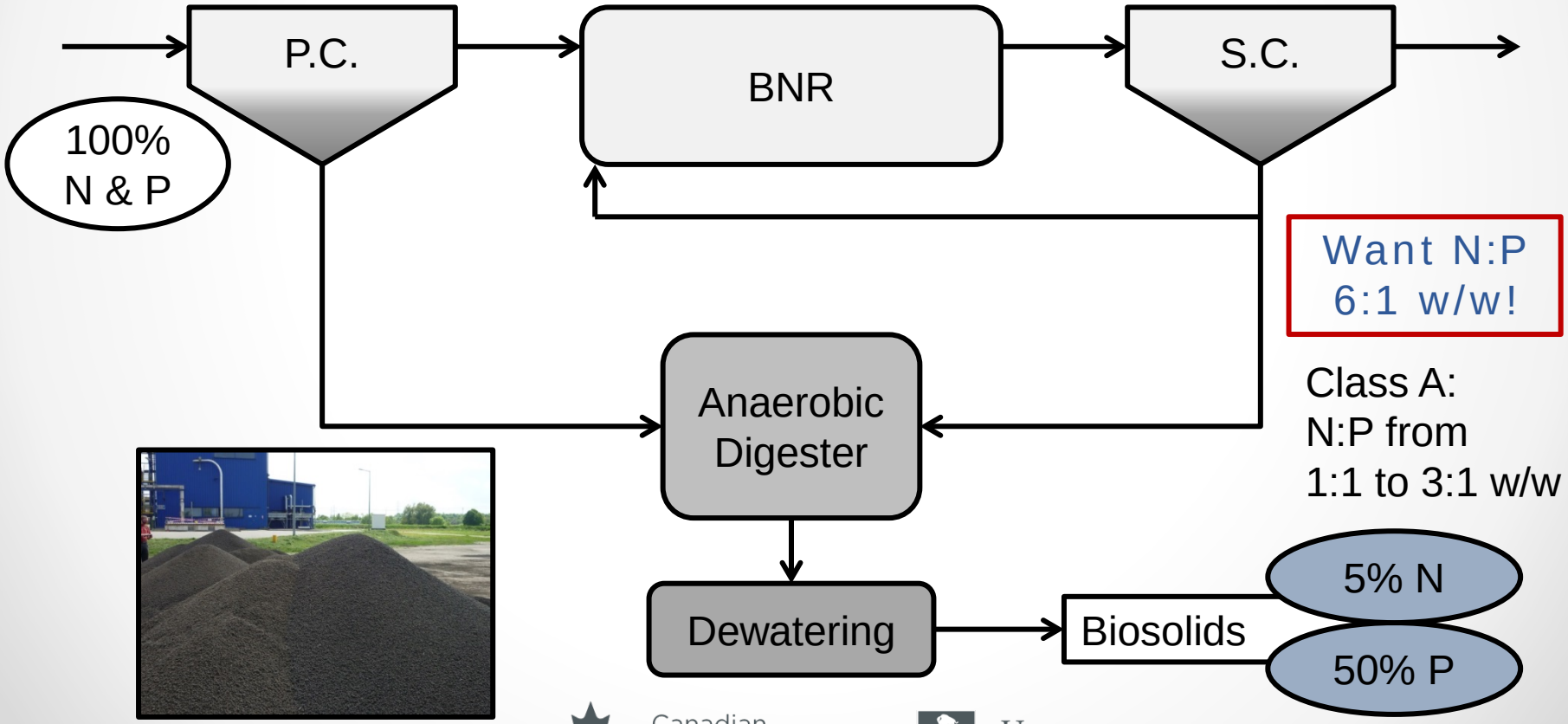


PASH

Recovery and reuse practice

Nutrient targets – **N & P in biosolids**



Recovery and reuse practice

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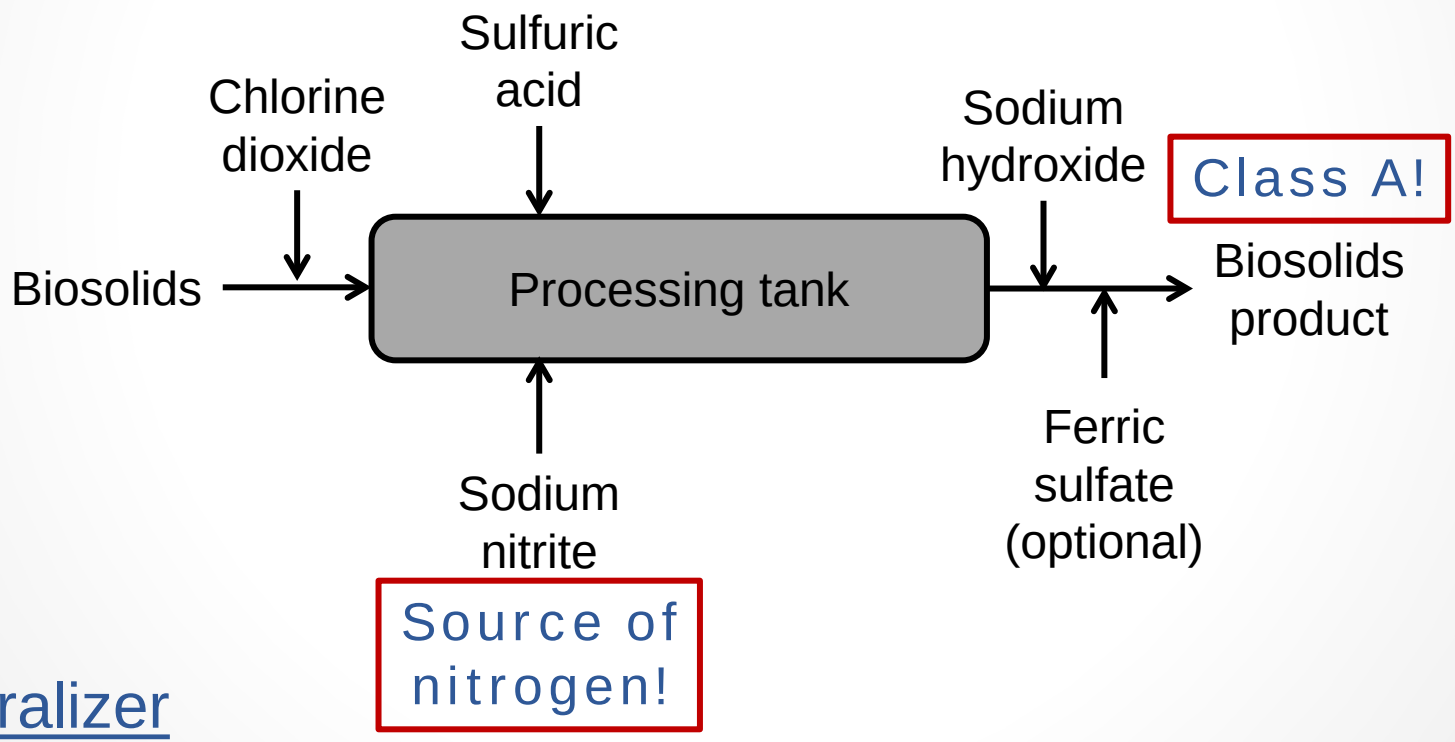


Neutralizer

Recovery and reuse practice

Summary:

- N recovery is usually not economical
  - o Cheaper to remove and produce N
- Many P recovery technologies, but…
  - o Need recognized ROI
  - o Recovery from liquor dominates
  - o Recovery from ash pros and cons?
- Decision = f(ROI & Regulations)

Opportunities for improved nutrient removal and recovery from municipal wastewater

Thank you!

Canadian Water Network

University of Manitoba

Nutrient Removal and Recovery Webinar

Emerging issues and research needs. Improvement of current performance

Jan Oleszkiewicz, Damian Kruk, Tanner Devlin

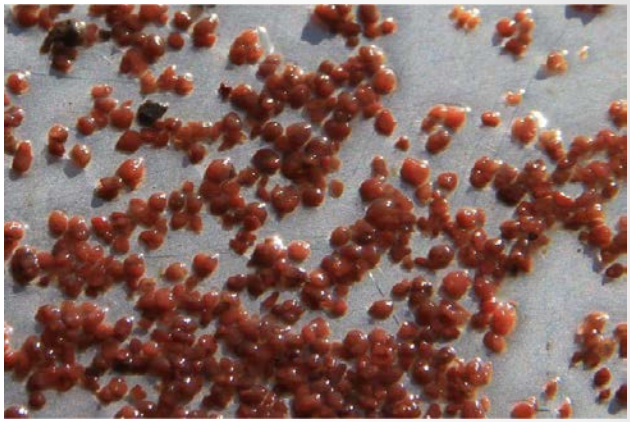
Canadian Water Network

University of Manitoba

Lowering ammonia load by sludge liquor treatment with decreased energy demand

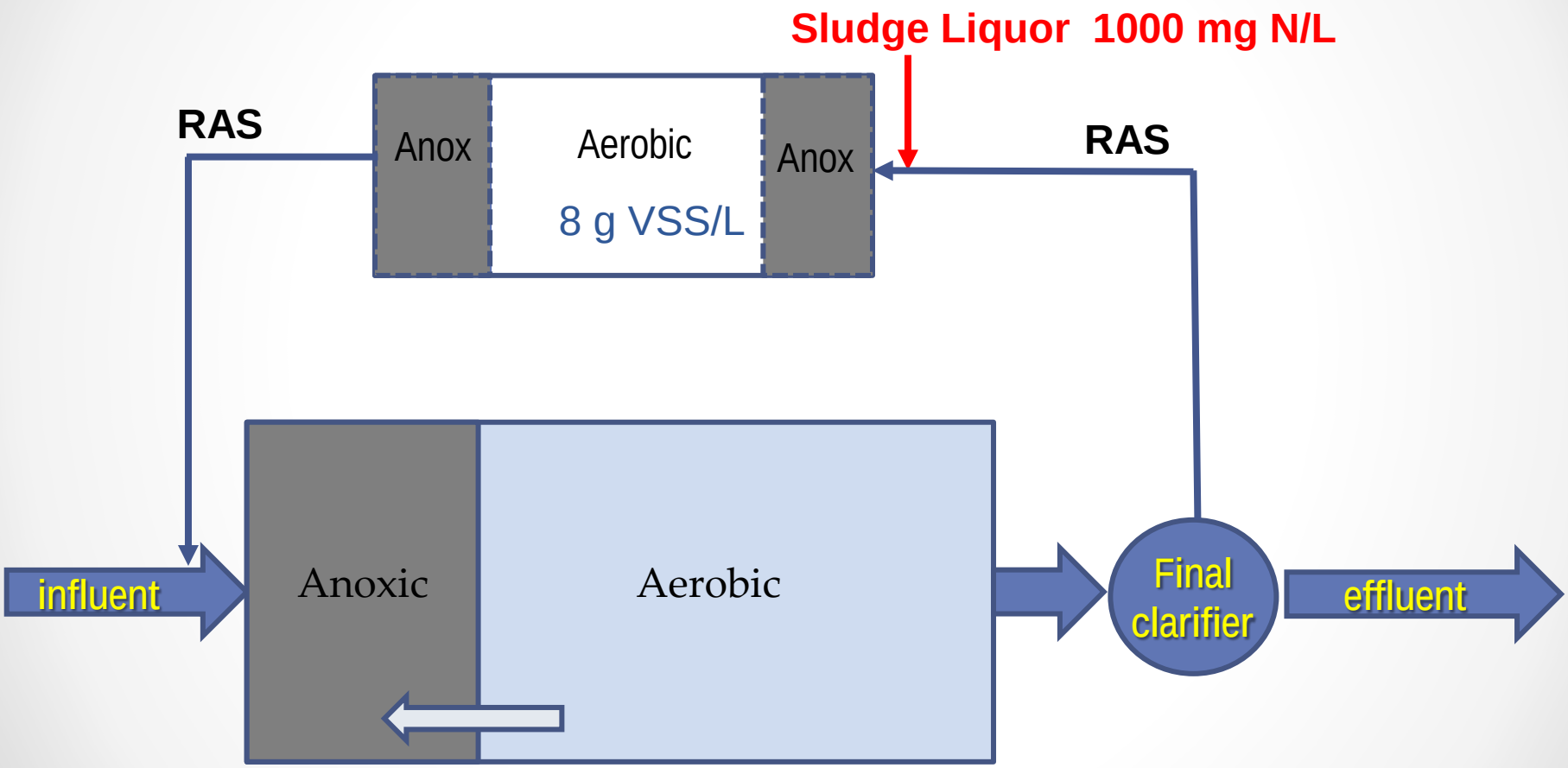
- Full scale application of one-stage anammox processes in high-ammonia side-stream treatment (100 installations, none in Canada)
- $NH_3 \rightarrow NO_2$ nitrifiers
- $NO_2 + NH_3 \rightarrow N_2$ anammox

- Bioaugmentation and retention of granules or media in tank



World Water Works Inc

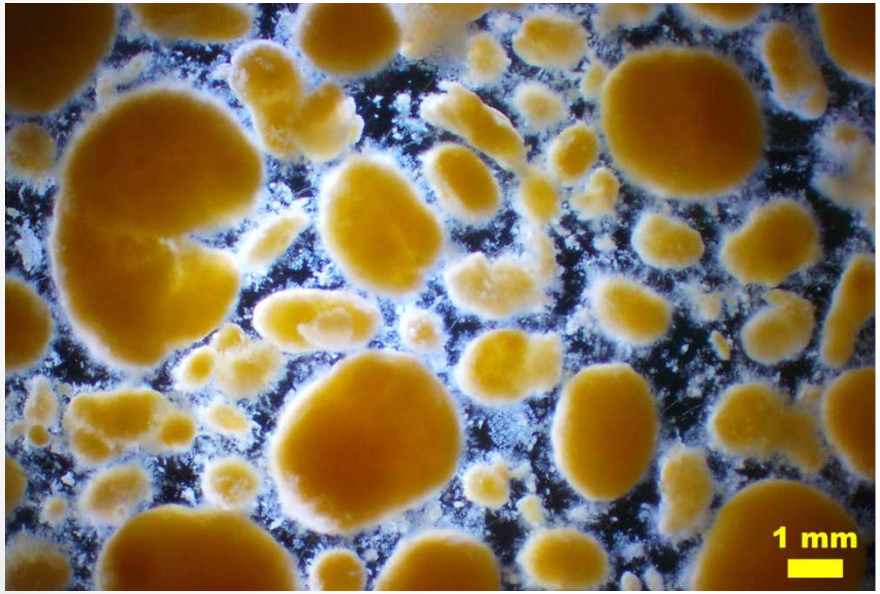
Lowering ammonia load by sludge liquor treatment: bioaugmentation and RAS reaeration

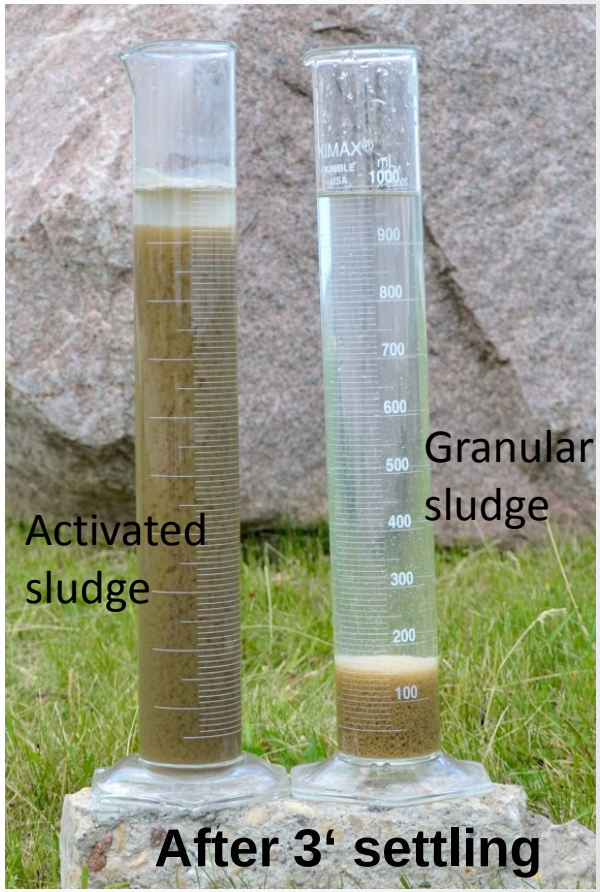


Oleszkiewicz CIVL7930, University of Manitoba

Retrofit nutrient removal (NR) into existing systems

- Fit aerobic granular sludge (AGS) for removal of N, P into existing bioreactors
- Apply AGS to continuous flow

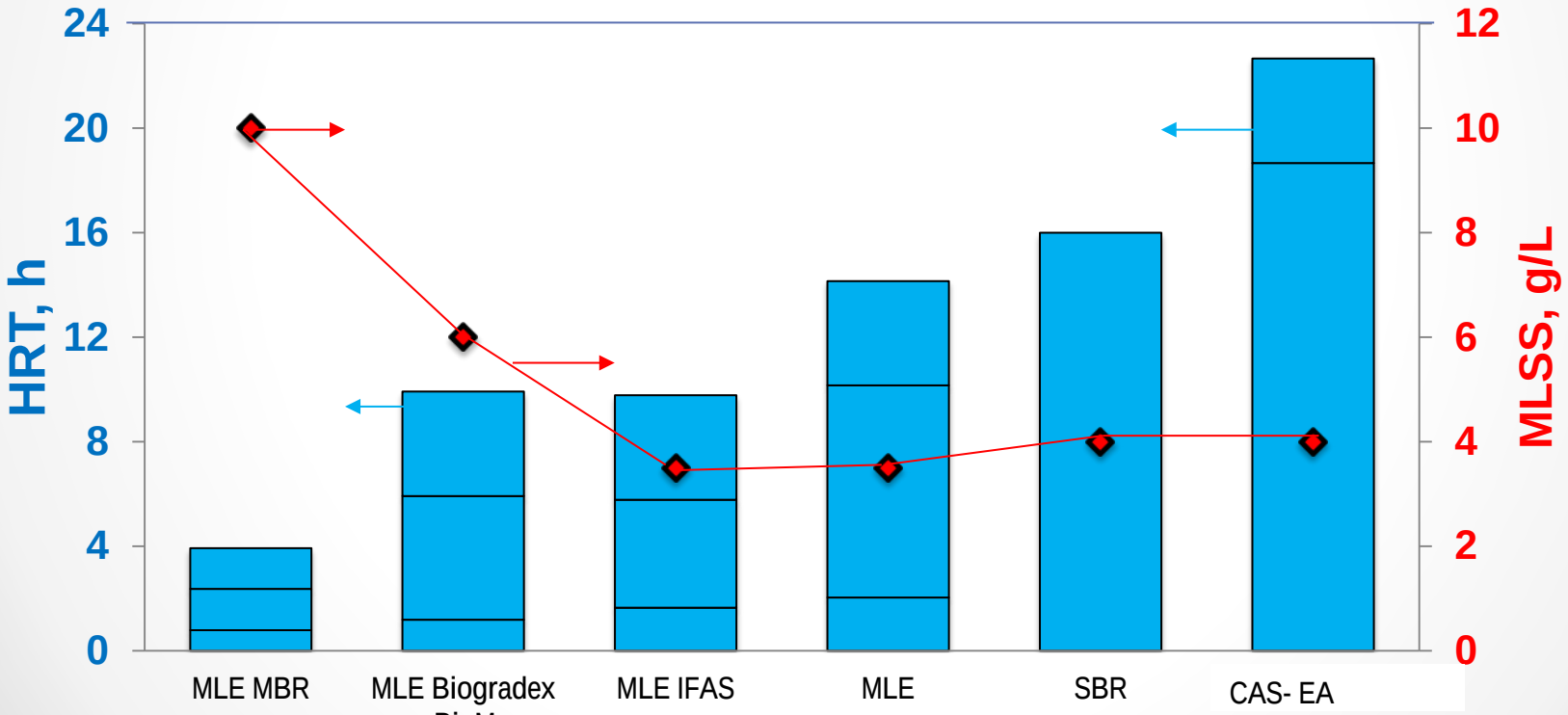




T Devlin, University of Manitoba 2015

Retrofit NR into an existing system

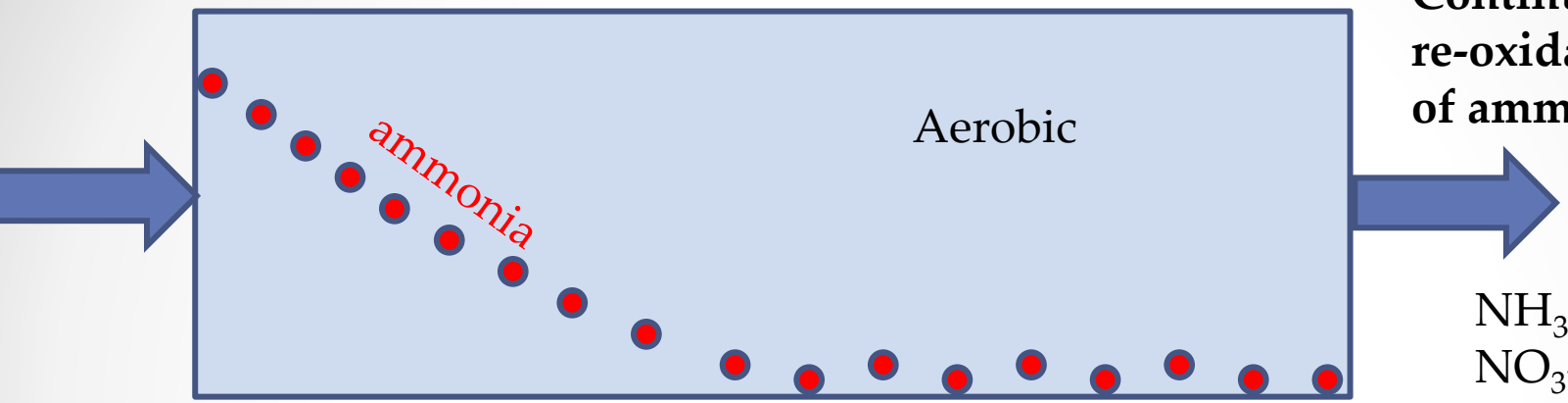
- Biomass retention and concentration is the key
- Possible immediate CAS EA process upgrades to a BNR enabling P recovery



Kruk & Oleszkiewicz, 2015

Retrofit NR into existing systems

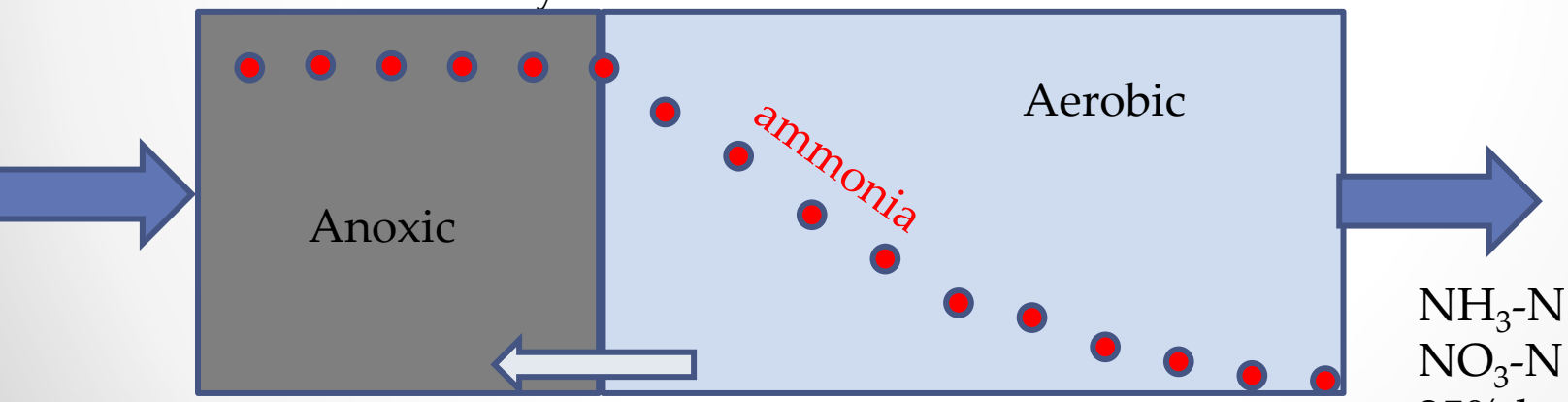
Extended aeration 8 h HRT 12°C



Continuous re-oxidation of ammonia

NH_3-N = 2
NO_3-N = 30

MLE system 8 h HRT 12°C

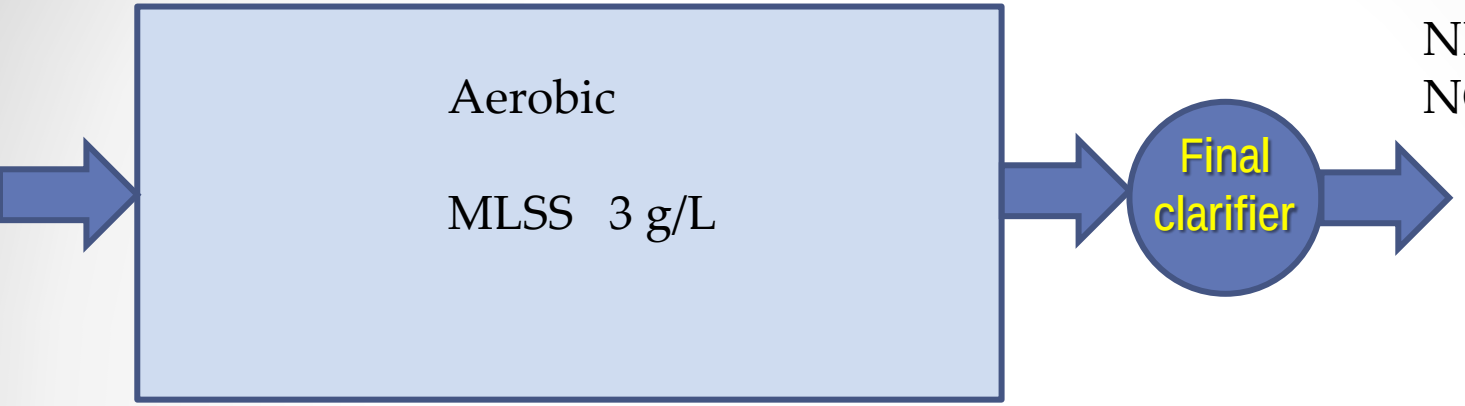


NH_3-N = 2
NO_3-N = 12
25% less energy

Oleszkiewicz CIVL7930, University of Manitoba

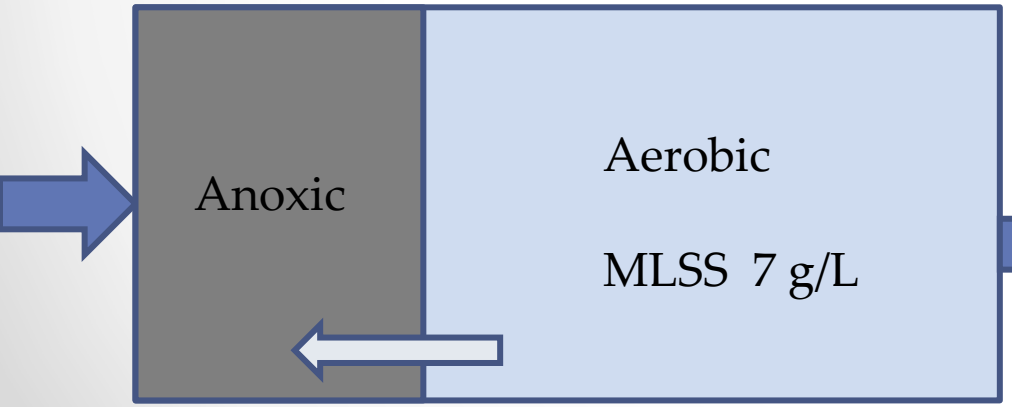
Retrofit NR into existing systems

Conventional Activated Sludge; 6 h HRT



NH_3-N = 10
NO_3-N = 23

MLE 6 h HRT

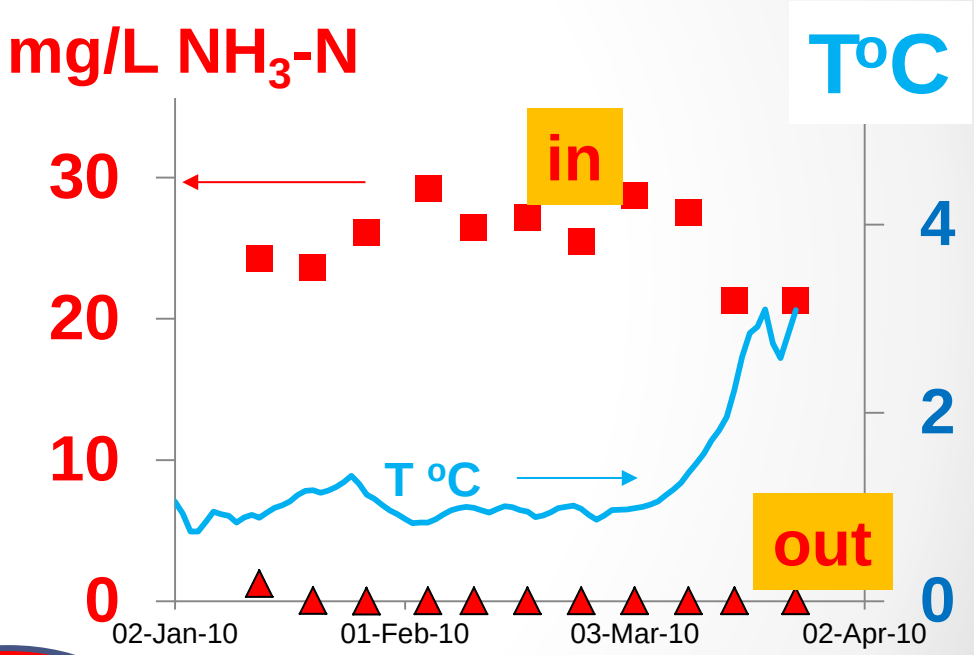


Vacuum degasification

NH_3-N = 8
NO_3-N = 12
15% less energy

Retrofit NR into existing systems: lagoon's effluent

- Commercially available technologies to remove TN and TP at 1°C



Nelson Environmental

SAGR

Research: Chemical versus biological P removal

- There is too much P in biosolids but not enough N
- Unsure fate of P from Chem. P biosolids
  - o Full scale field research needed
- Triple bottom line analysis of [CAS EA + Chem P] versus [BNR + Chem P] both achieving limit of treatment level. Factor-in potential of P recovery

Principled nutrient management

- Demonstrate cost-effectiveness of nutrient recovery and nutrient trading in watershed partnerships where agricultural stakeholders would be recipients of the recovered nutrients

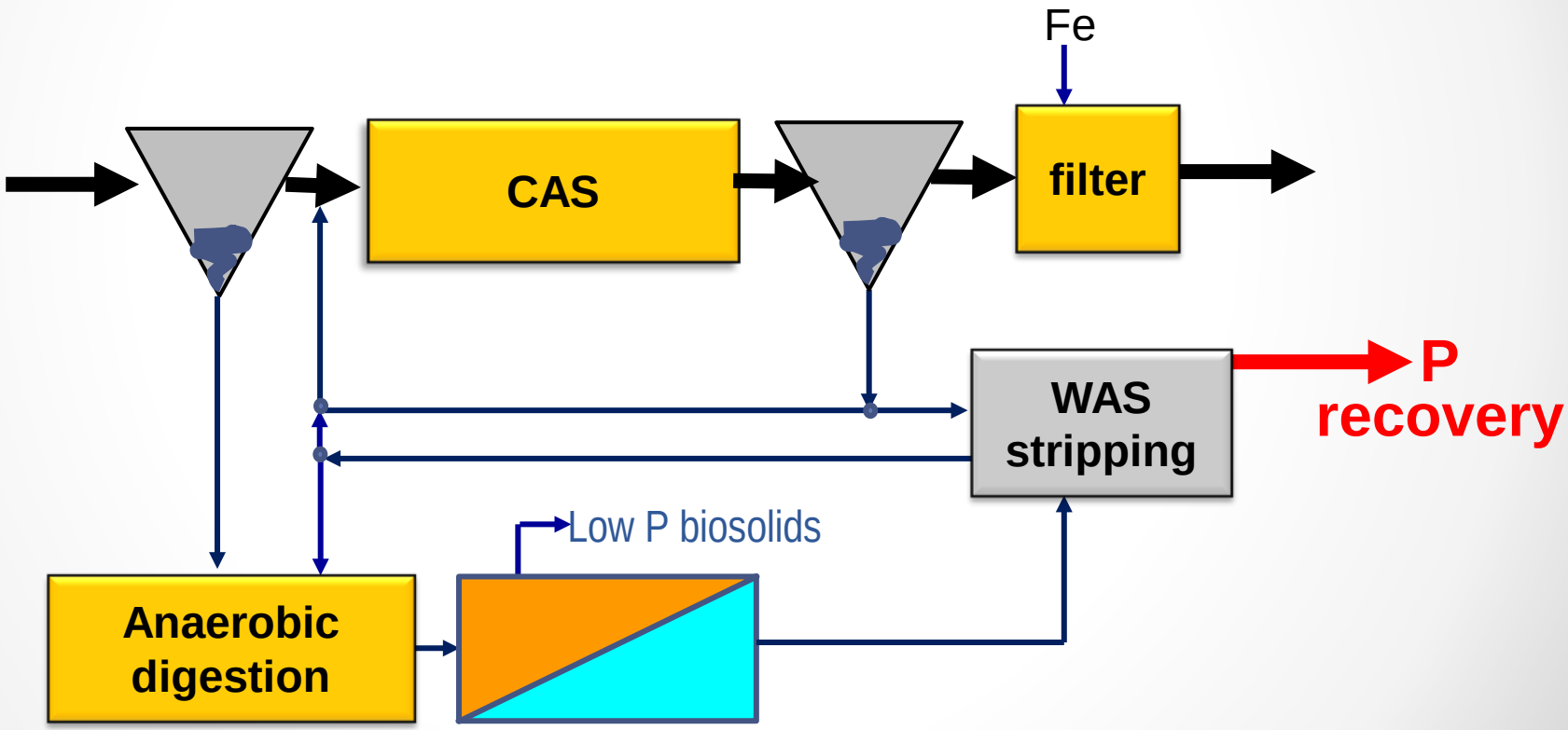
- Example: Great Miami River Watershed Water Quality Trading Program (2015 NACWA)
  - WWTP point sources: remove $11/kg P through BNR
  - Nonpoint source: $0.5/kg P removed through agricultural management e.g. change of farmer's practices: conservation tillage, grassed waterways, cover crops

Research: pre-commercialization technologies

- Affordable P recovery from ash
- Reliable P removal to 0.01 mg TP/L
- Retrofit technologies for internal generation of carbon for biological P removal and denitrification.
- Improved removal of emerging substances of concern in biological nutrient removal processes

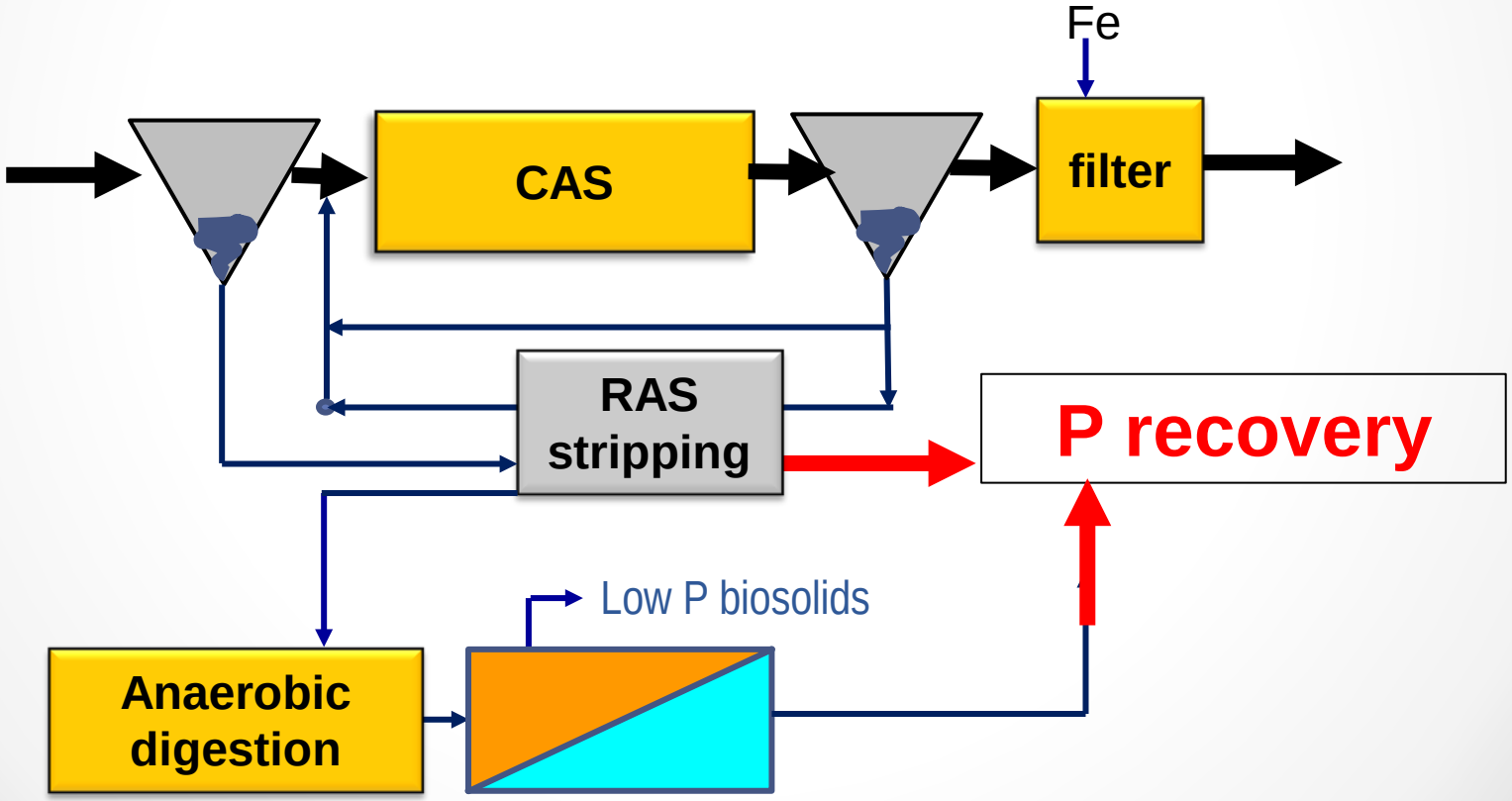
Research on pre-commercialization technology : P removal/recovery in conventional activated sludge (CAS)

- Process upgrades to promote release of **P** from WAS biomass stream, ahead of sludge processing.



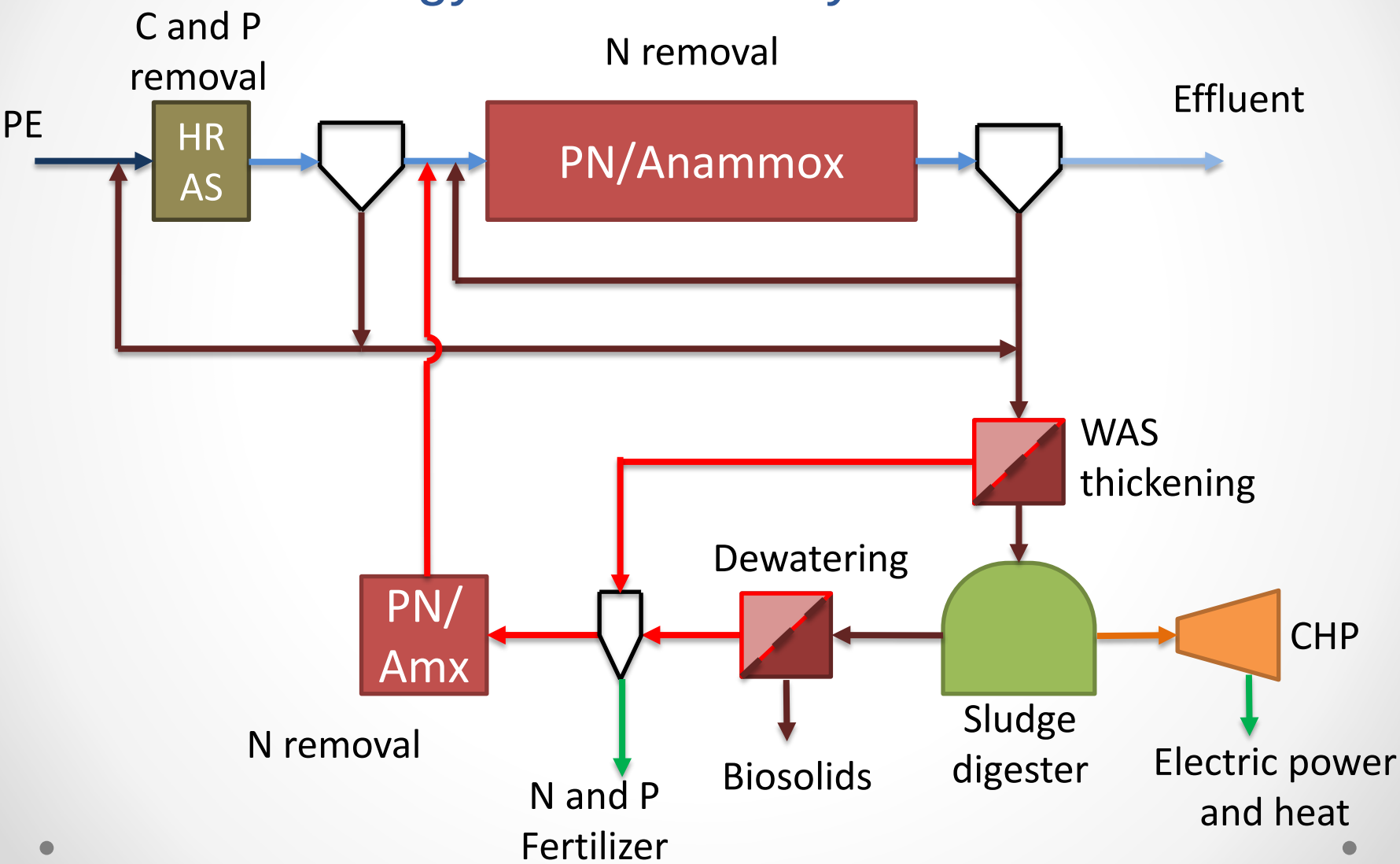
Research: Phosphorus removal/recovery in CAS

- Application of a PhoStrip process on RAS ahead of solids treatment



Research: Pre-commercialization technology

Energy neutral facility



Nutrient Removal and Recovery Workshop:
Improving Canadian Wastewater Management

Thank you

Canadian Water Network

University of Manitoba