Optimizing the Operation of Activated Sludge Wastewater Treatment Facilities to Remove Nitrogen & Phosphorus

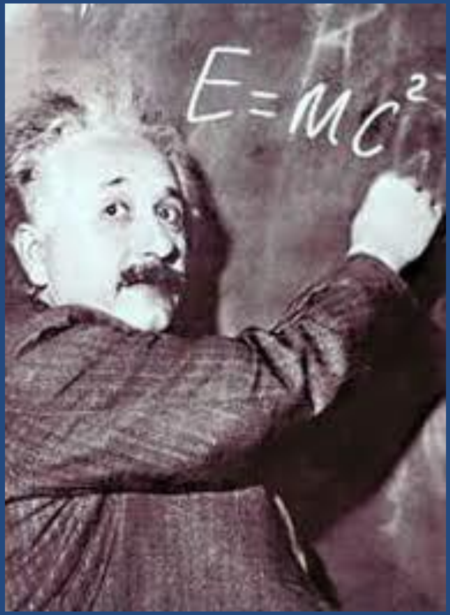
Grant Weaver, PE & wastewater operator

Webinar
March 18, 2014

The Water Planet Company

www.cleanwaterops.com

Optimizing Activated Sludge Operations for N&P Removal



<u>Upcoming Webinars</u>

Sequenced Aeration: Montague, MA – April 15, 2014

Modifying Operations at Amherst, MA to avoid a $61 million facility upgrade – May '14

<u>Today's Webinar</u>

Nitrogen & Phosphorus Removal Fundamentals

Habitat protection

Optimizing conditions

Comments, Questions & Answers

www.cleanwaterops.com

7

N

Nitrogen

Biological Nitrogen Removal:
Soluble organic-N is converted to ***Nitrogen Gas***

Oxygen Rich Habitat

Ammonia-Nitrogen (NH_4) converts to Nitrate-Nitrogen (NO_3)

NH_4 + oxygen → NO_2

NO_2 + oxygen → NO_3

Oxygen Poor Habitat

Nitrate-Nitrogen (NO_3) converts to Nitrogen Gas (N_2)

NO_3 – oxygen → N_2

Habitats: Biological Nitrogen Removal
Aerobic - Ammonia (NH_4) conversion to Nitrate (NO_3)

Oxygen Rich Habitat

F:M of 0.12 or less; MLSS* of 2500+ mg/L (High Sludge Age, low F:M)
ORP* of +100 to +150 mV (High DO)
Time* (high HRT … 24 hr, 12 hr, 6 hr, 4 hr)
Low BOD

Consumes Oxygen
Adds acid - Consumes 7 mg/L alkalinity per mg/L of $NH_4 \rightarrow NO_3$

*All numbers are approximate, each facility is different.

Habitats: Biological Nitrogen Removal
Anoxic - Nitrate (NO_3) conversion to Nitrogen Gas (N_2)

<u>Oxygen Poor Habitat</u>

ORP* of -100 mV or less (DO < 0.3 mg/L)

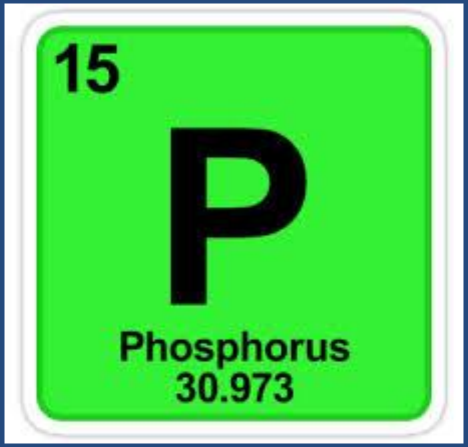
Surplus BOD* (100-250 mg/L: 5-10 times as much as NO_3)

Retention Time* of 45-90 minutes

Gives back Oxygen

Gives back Alkalinity (3.5 mg/L per mg/L of $NO_3 \rightarrow N_2$)

*All numbers are approximate,
each facility is different.


15
P
Phosphorus
30.973

Biological Phosphorus Removal:
Converting liquid phosphorus to solid phosphorus

Zero Oxygen Habitat (Fermentation)

Bacteria break down BOD to create volatile fatty acids (VFAs)

Other bacteria (PAOs) take in the VFAs as an energy source and temporarily release more ortho-P into solution

Oxygen Rich Habitat (Aeration Tank)

PAO bacteria use the stored energy to “bulk up” on ortho-P

Phosphorus Removal: What an Operator needs to know

ONE. Convert soluble phosphorus to TSS …

- Biologically
- Chemically

TWO. Remove TSS

Rules of Thumb:

0.05 mg/L of soluble phosphorus (ortho-P) remains after treatment

Each 1 mg/L TSS contains up to 0.05 mg/L total-P (5%)

TSS Removal Requirements

Since all but 0.05 mg/L of the soluble Phosphorus can be converted to TSS Phosphorus (Biologically and/or Chemically)

And, because approximately 5% of Effluent TSS is Phosphorus

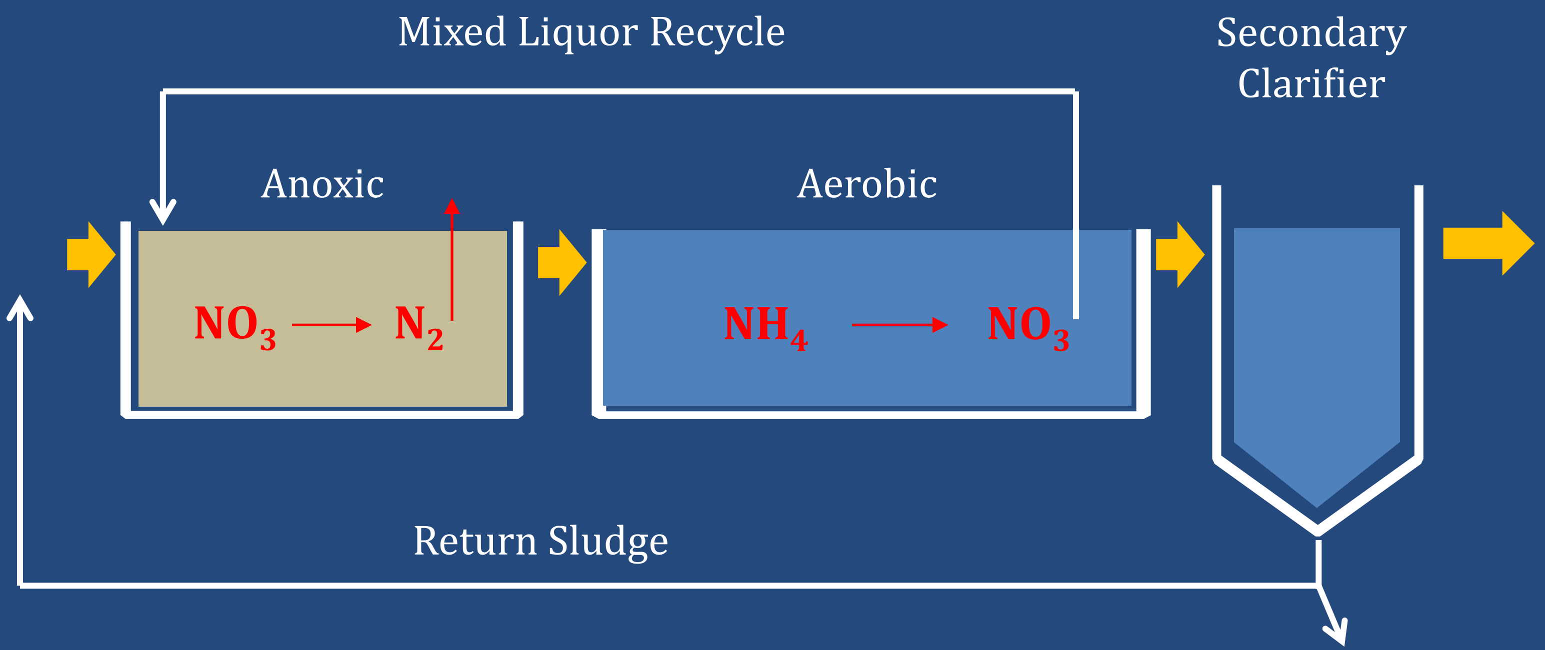
… To meet a total-P limit, the effluent TSS needs to be kept to the max TSS number shown in the table.

P Limit	max TSS
0.1	1
0.2	3
0.3	5
0.4	7
0.5	**9**
0.6	11
0.7	13
0.8	15
0.9	17
1.0	**19**
1.1	21
1.2	23
1.3	25
1.4	27
1.5	29

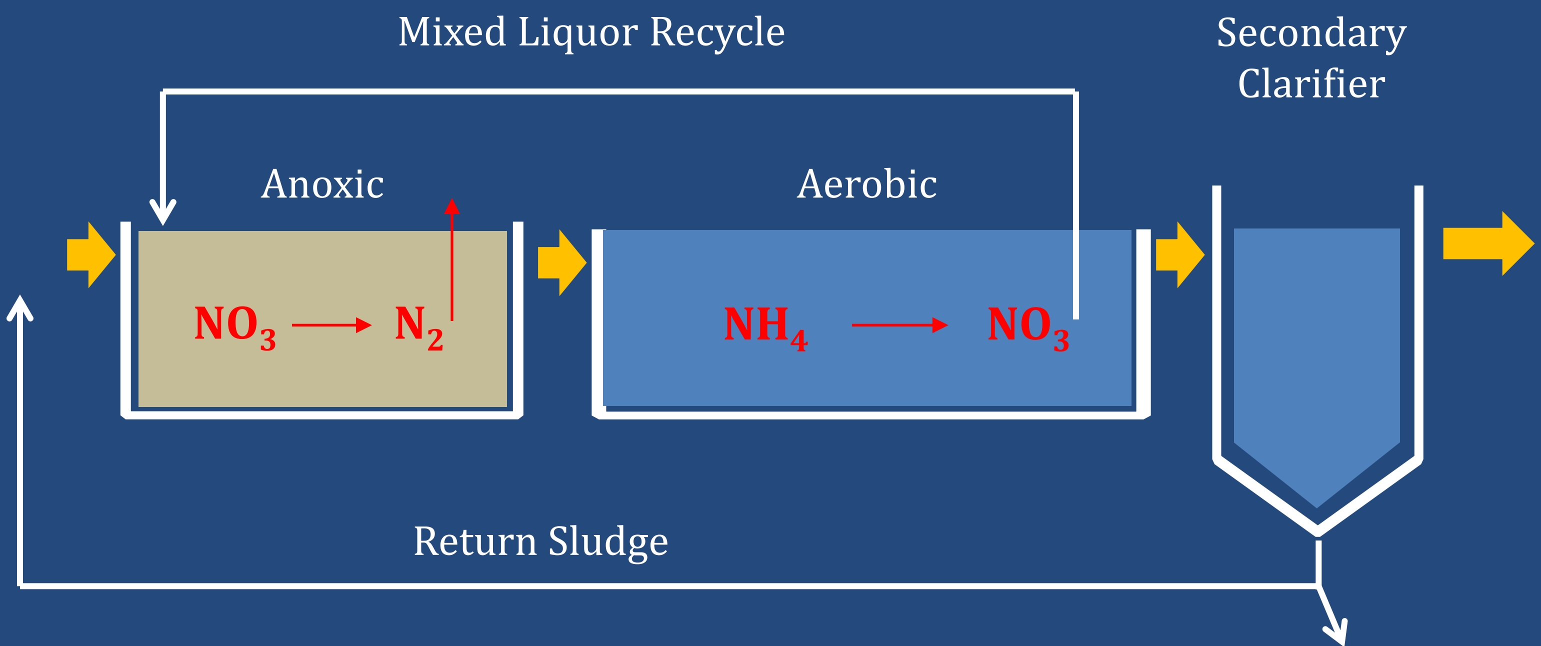
Creating Optimal Habitats

Dialing In Biological N&P Removal

Denitrifiers outcompete PAOs for volatile fatty acids (VFAs)

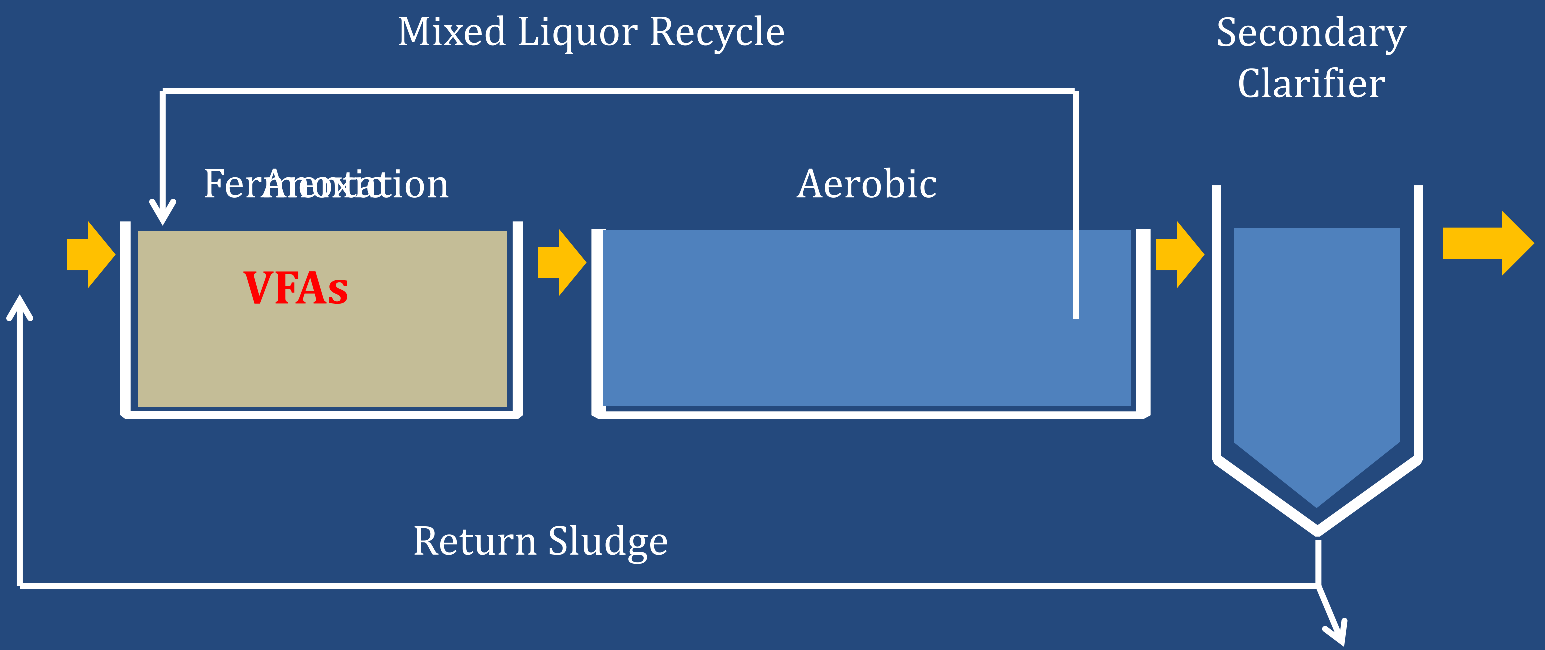

Mixed Liquor Recycle
Secondary Clarifier
Anoxic
Aerobic
NO_3 → N_2
NH_4 → NO_3
Return Sludge

MLE Process

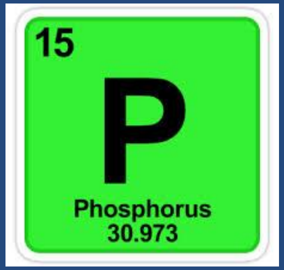

Mixed Liquor Recycle
Secondary Clarifier
Anoxic
Aerobic
NO_3 → N_2
NH_4 → NO_3
Return Sludge

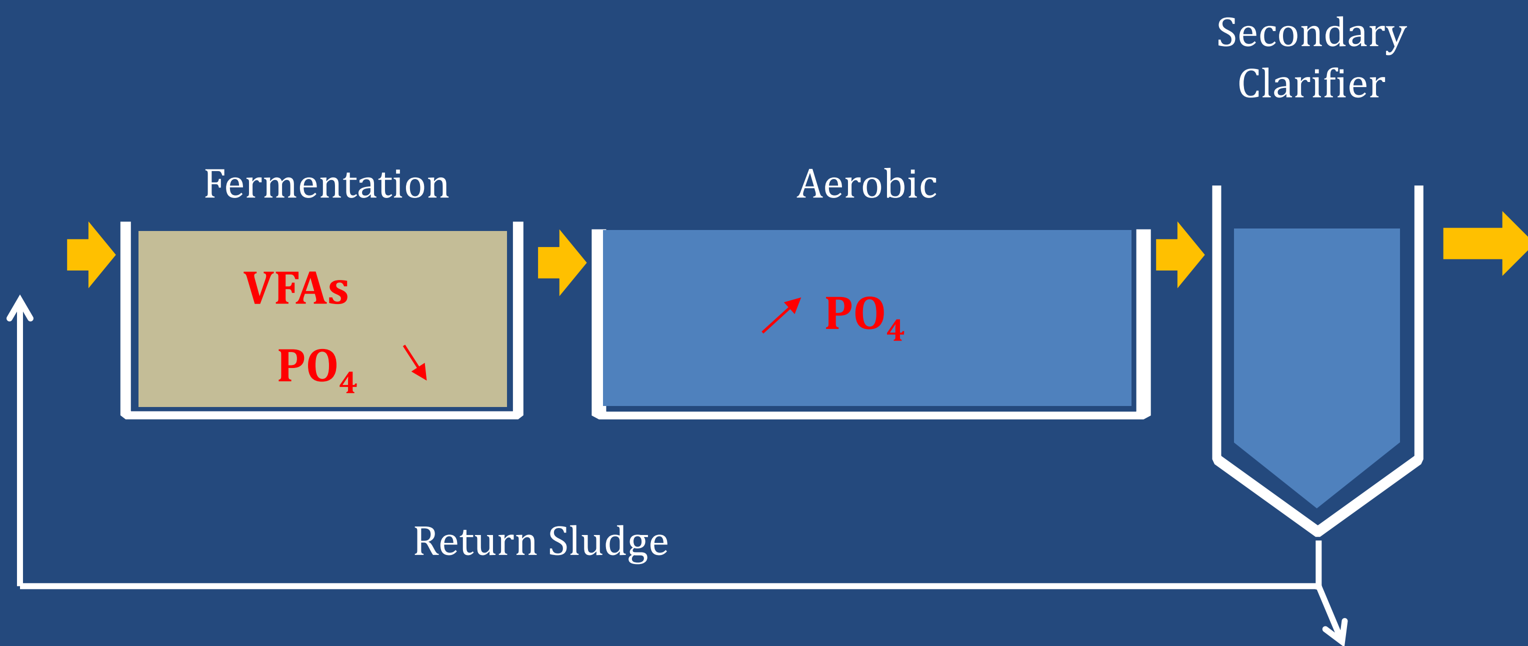
MLE Process


7
N
Nitrogen

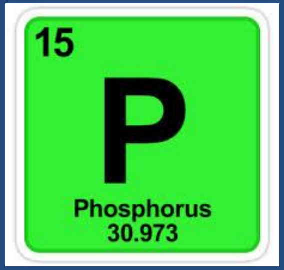

Mixed Liquor Recycle
Secondary
Clarifier
Fermentation
Anoxic
Aerobic
VFAs
Return Sludge

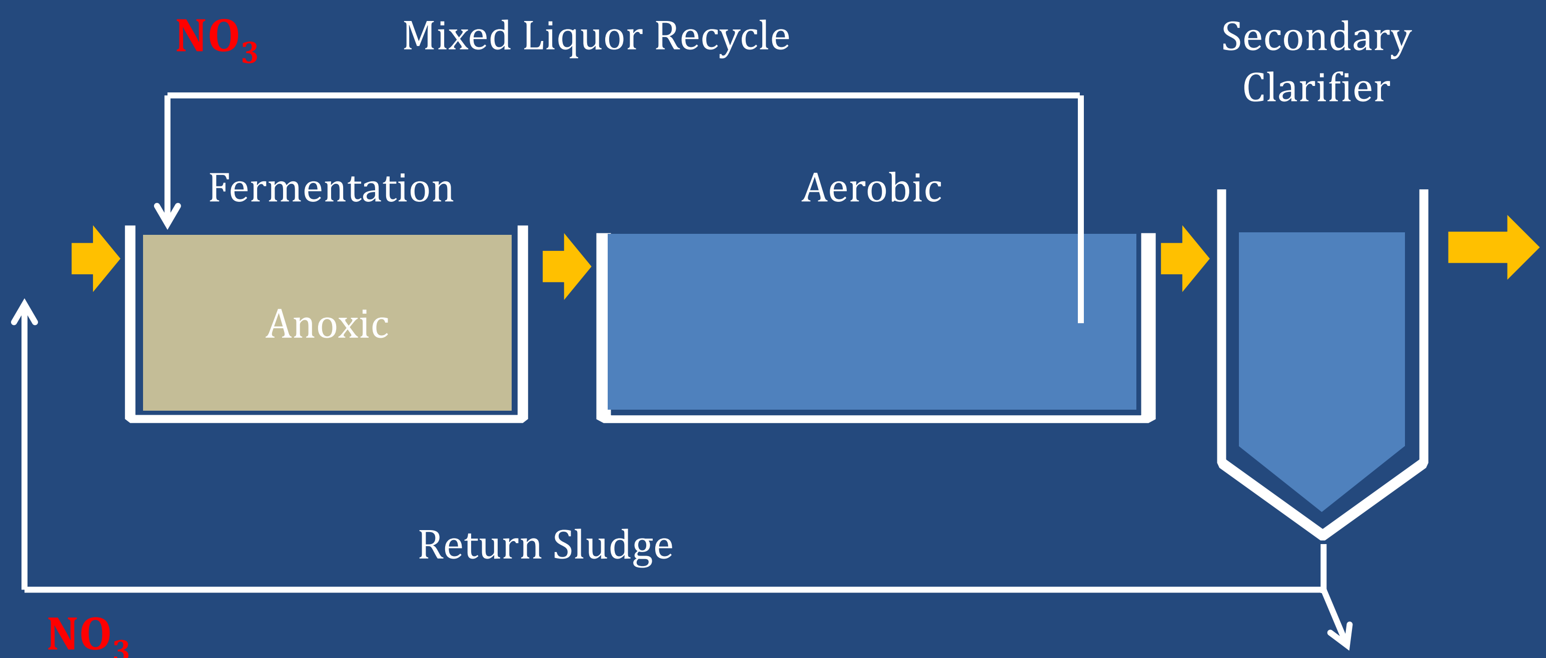
A/O Process


15
P
Phosphorus
30.973

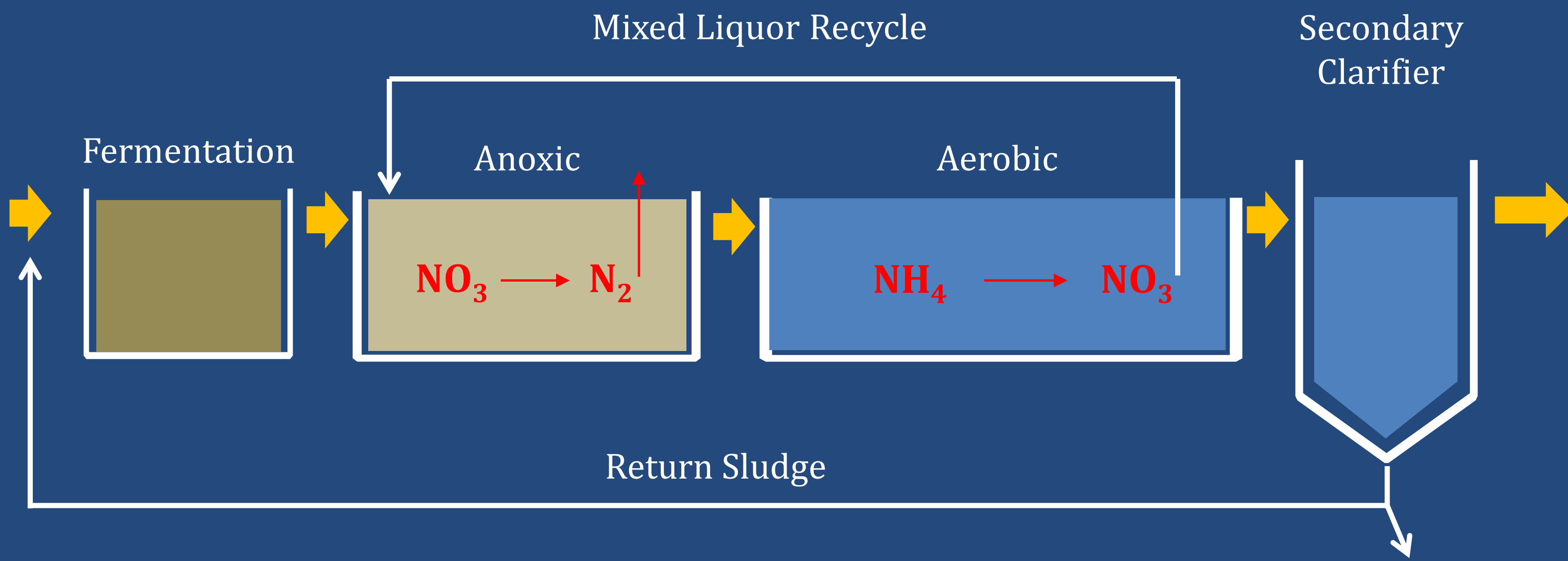

Secondary
Clarifier
Fermentation
Aerobic
VFAs
PO4
PO4
Return Sludge

A/O Process

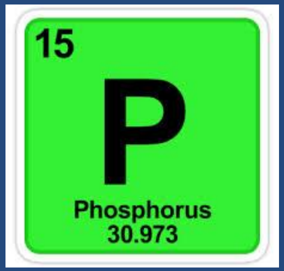

15
P
Phosphorus
30.973

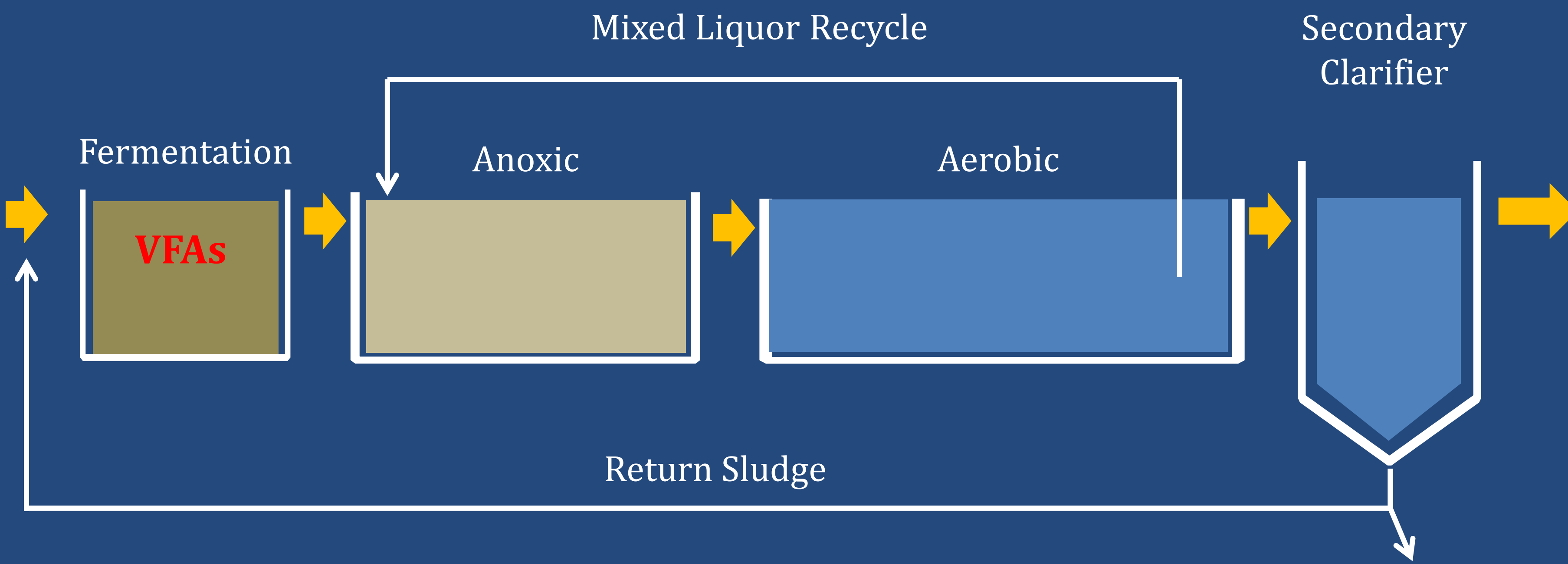


Why not both N&P Removal?

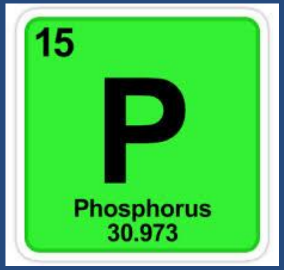


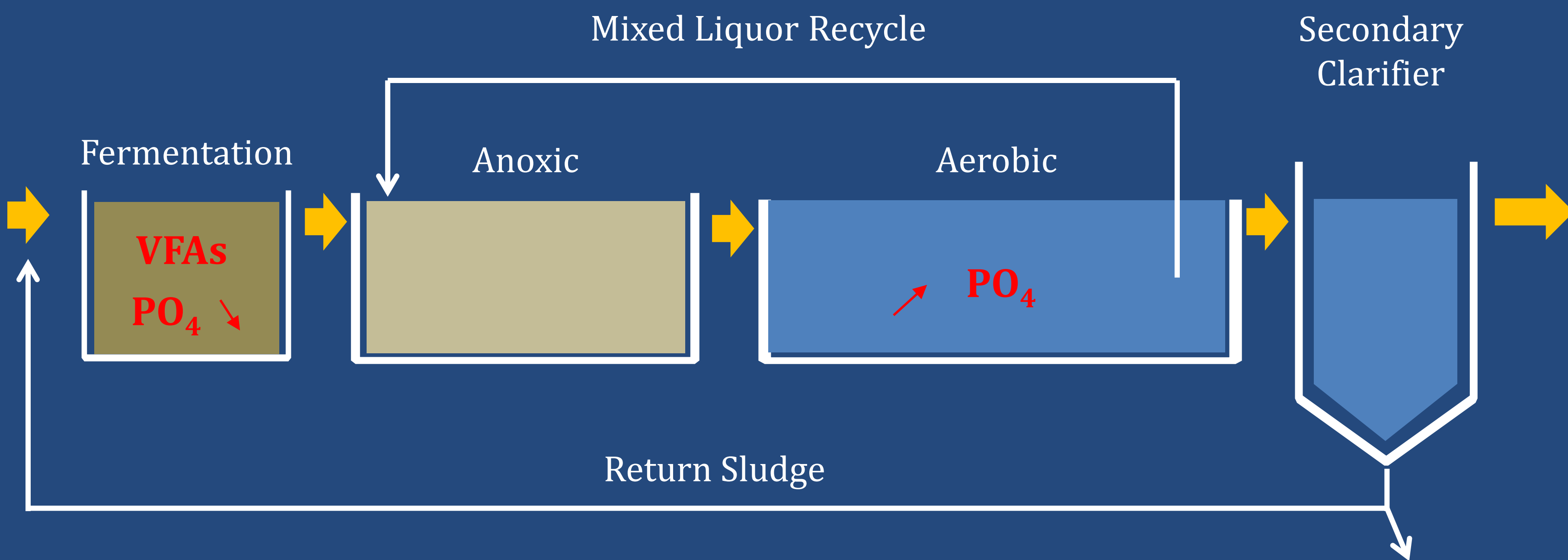
Biological N&P Removal



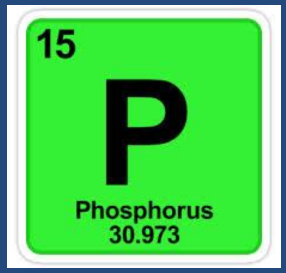


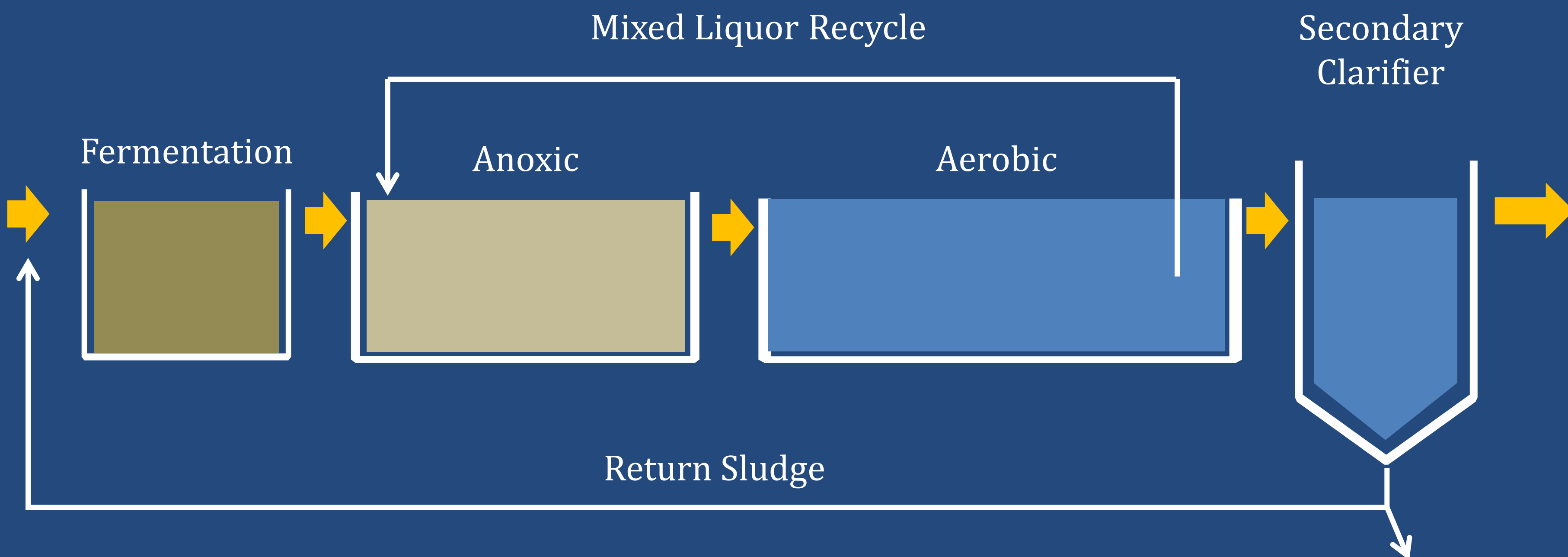
Biological N&P Removal



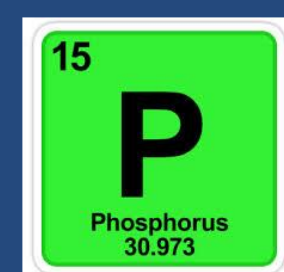


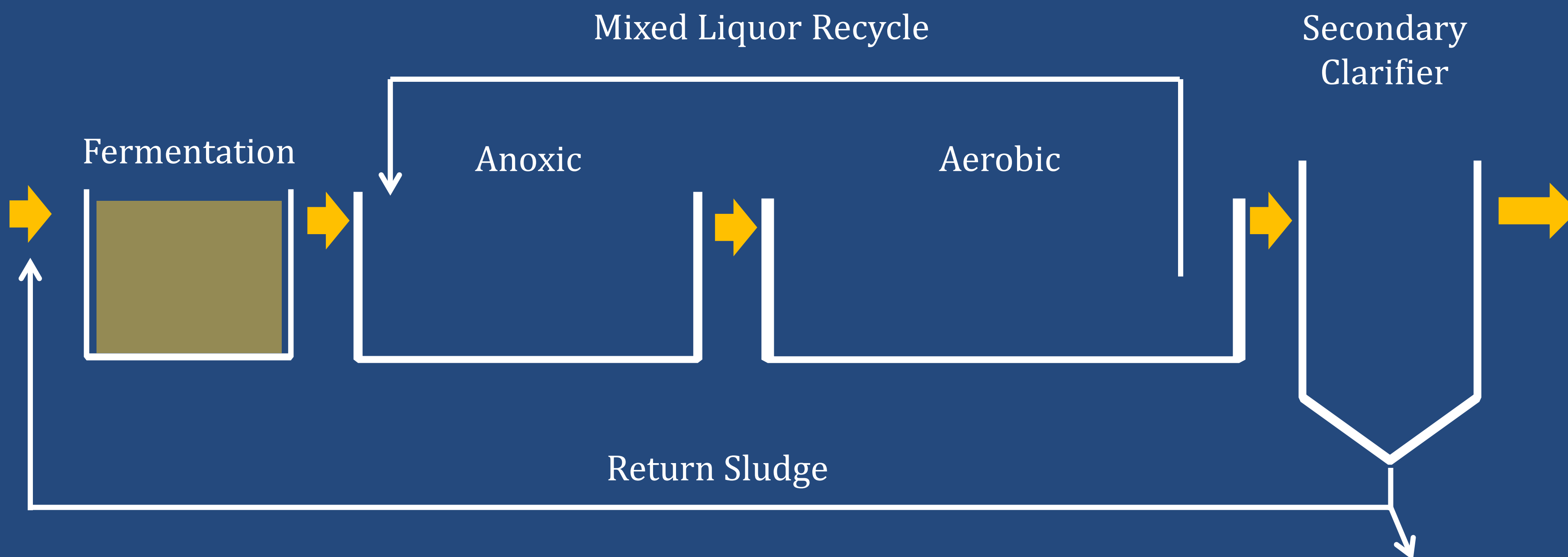
Biological N&P Removal





Biological N&P Removal





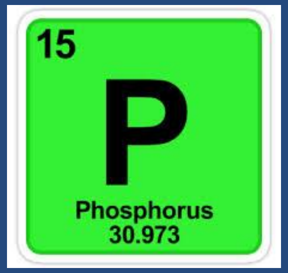
Fermentation Tank

Nitrogen Removal:

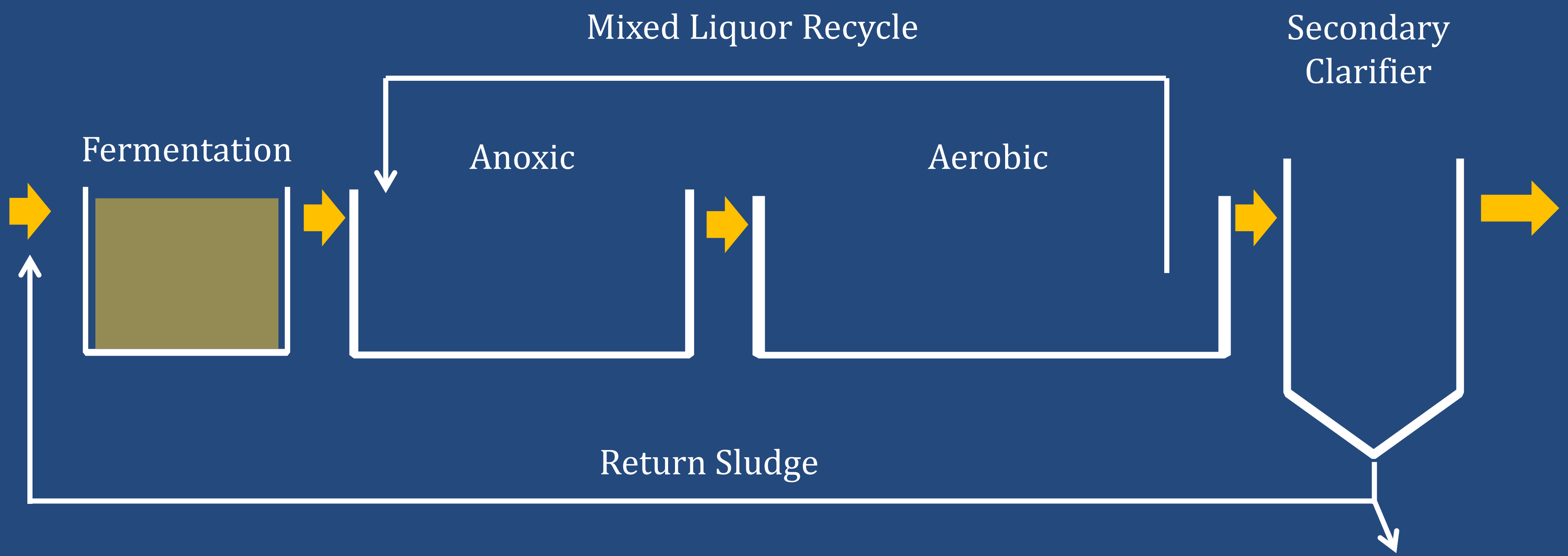
- Minimal NO_3 Removal

Phosphorus Removal:

- VFA production
- PAO take up VFAs and release PO_4
- Minimal competition from Denitrifying bacteria



Optimal Process Settings



Fermentation Tank

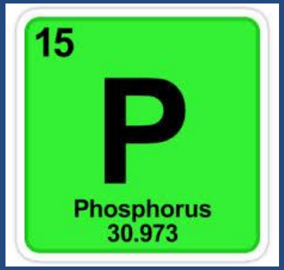
~1 hour HRT

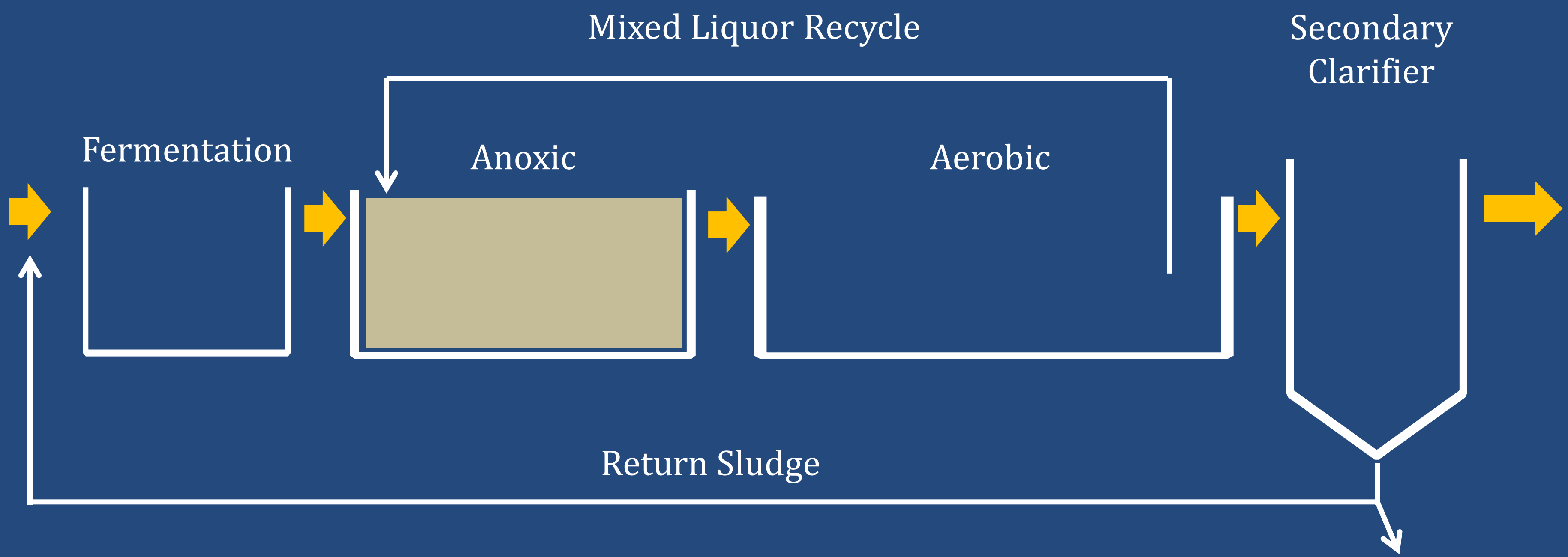
-200 mV ORP

20+ mg/L ortho-P (as P) exiting tank

… 25 times as much BOD as influent ortho-P to create VFAs

… return as little NO_3 as practical





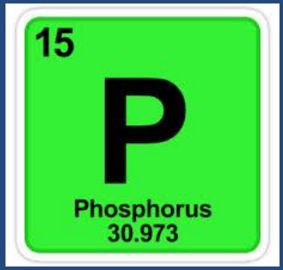
Anoxic Tank

Nitrogen Removal:

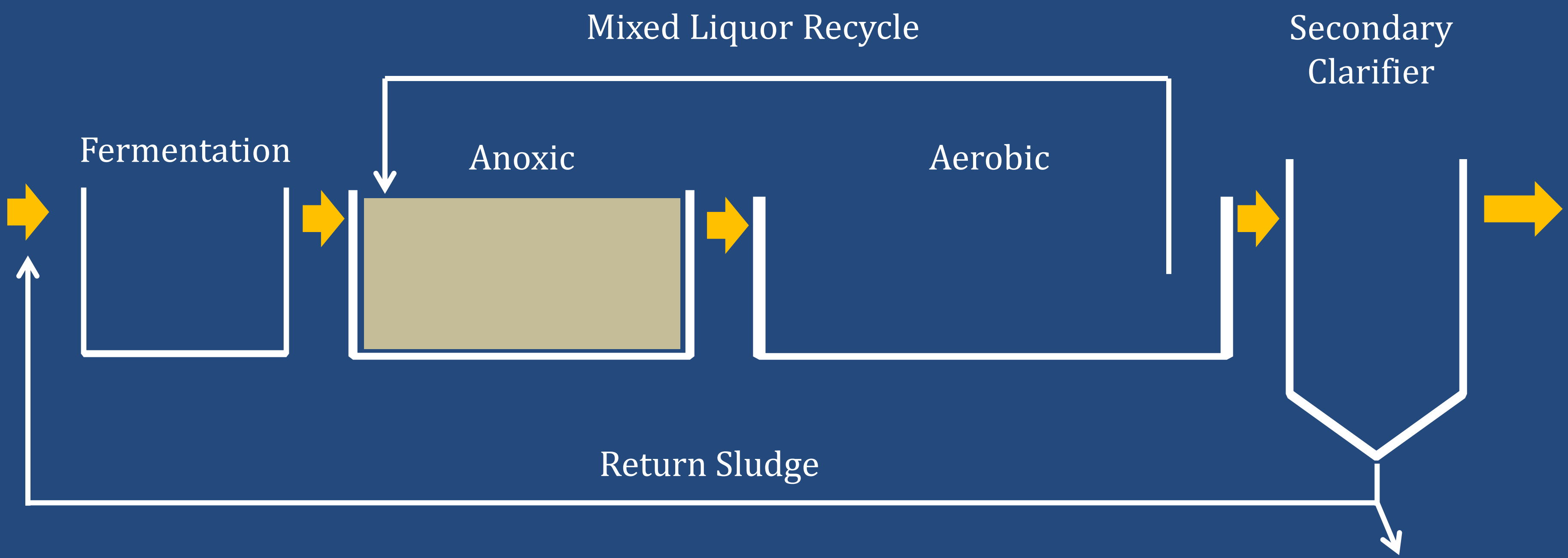
NO_3 conversion to N_2

Phosphorus Removal:

NONE



Optimal Process Settings



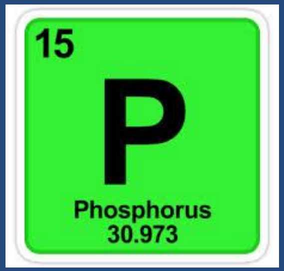
Anoxic Tank

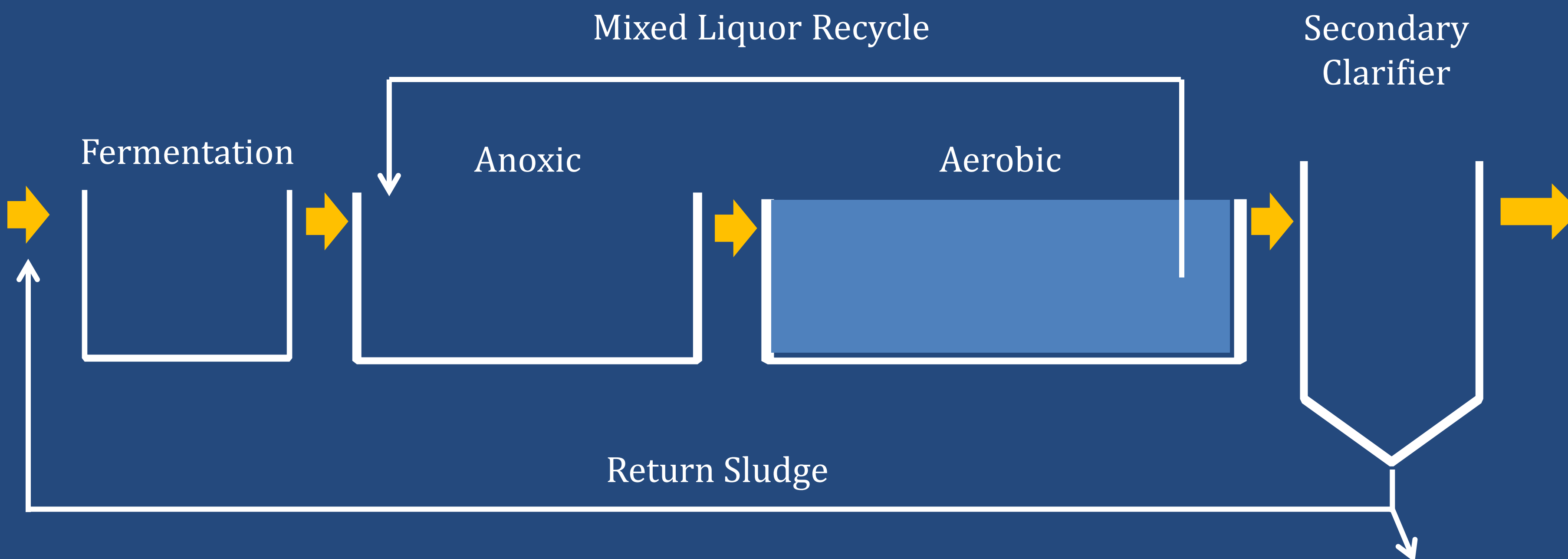
~2 hr HRT

-100 mV ORP

~2 mg/L NO_3 exiting tank

… 5-10 times as much BOD as NO_3





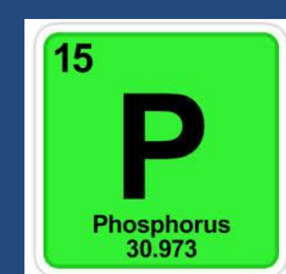
Aeration Tank

Nitrogen Removal:

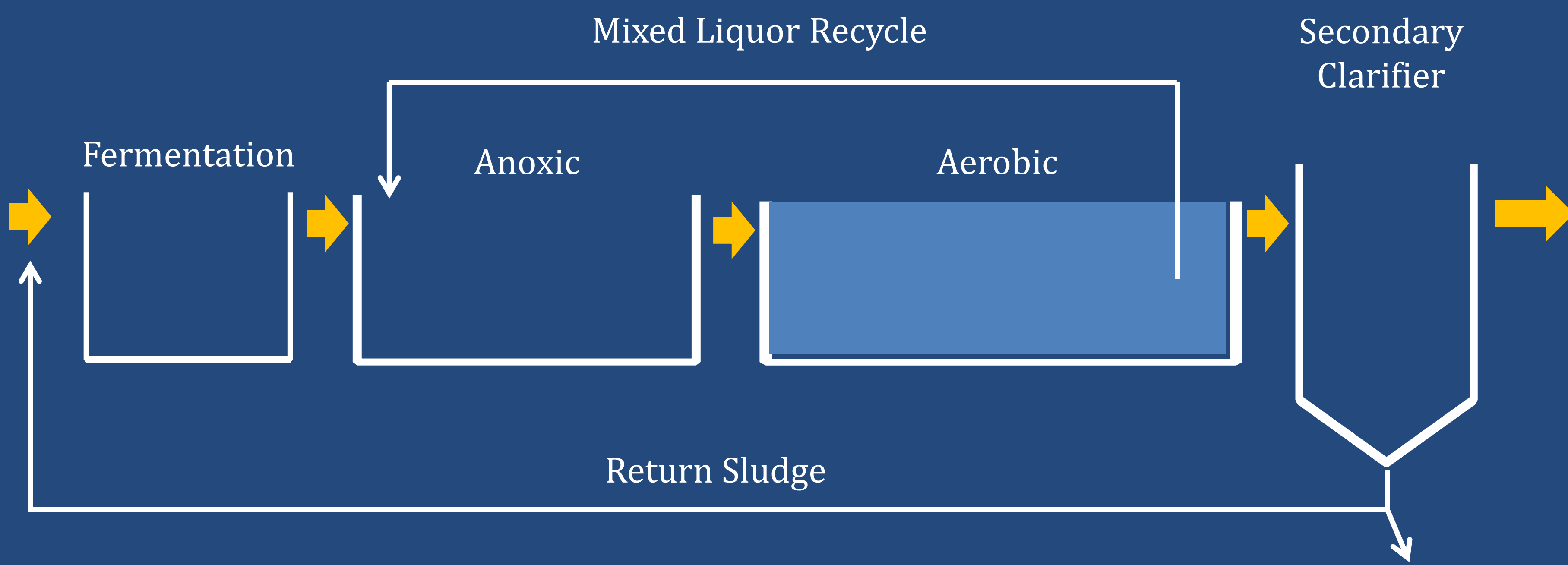
NH_4 conversion to NO_3

Phosphorus Removal:

PAOs take in PO_4



Optimal Process Settings



Aeration Tank

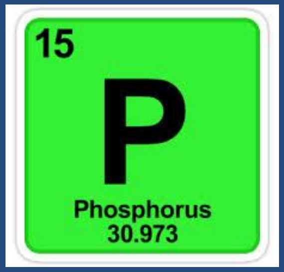
+100 mV ORP, ~2 mg/L DO

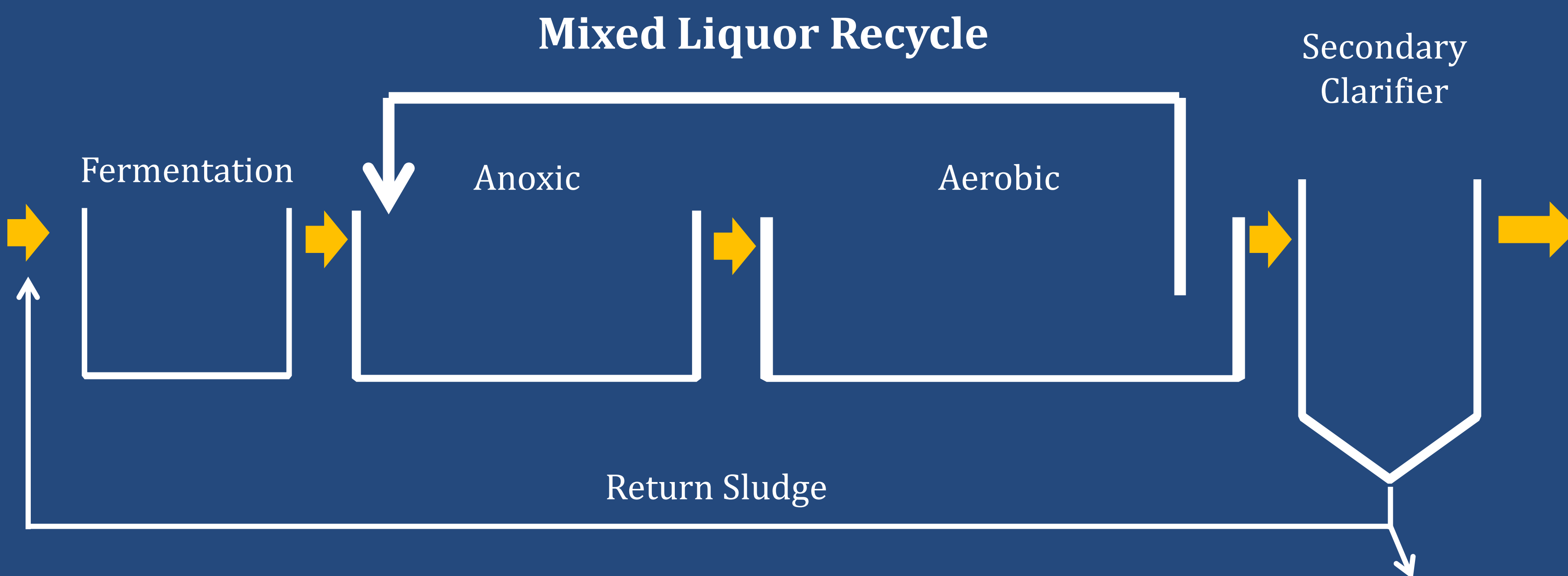
>6.8 pH, >60 mg/L alkalinity

<0.12 F:M (2500+ mg/L MLSS)

<0.5 mg/L NH_4

<0.1 mg/L ortho-P





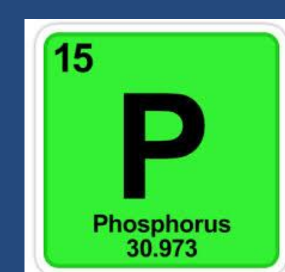
Mixed Liquor Recycle (Internal Recycle / Nitrate Recycle)

Nitrogen Removal:

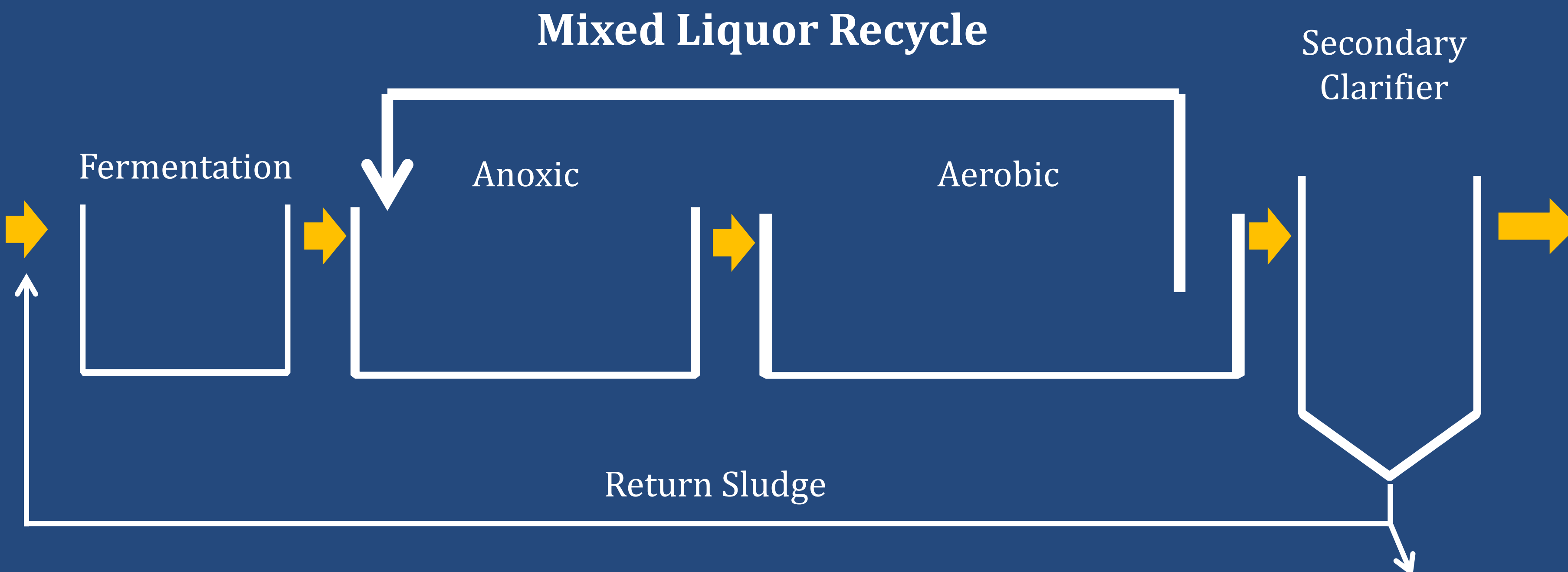
- NO_3 return to Anoxic Tank
- DO damage Anoxic Tank habitat
- Too much flow shortens time in Anoxic and Aerobic

Phosphorus Removal:

- NONE



Optimal Process Settings



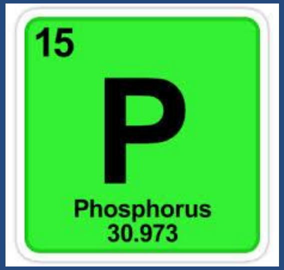
Mixed Liquor Recycle (Internal Recycle / Nitrate Recycle)

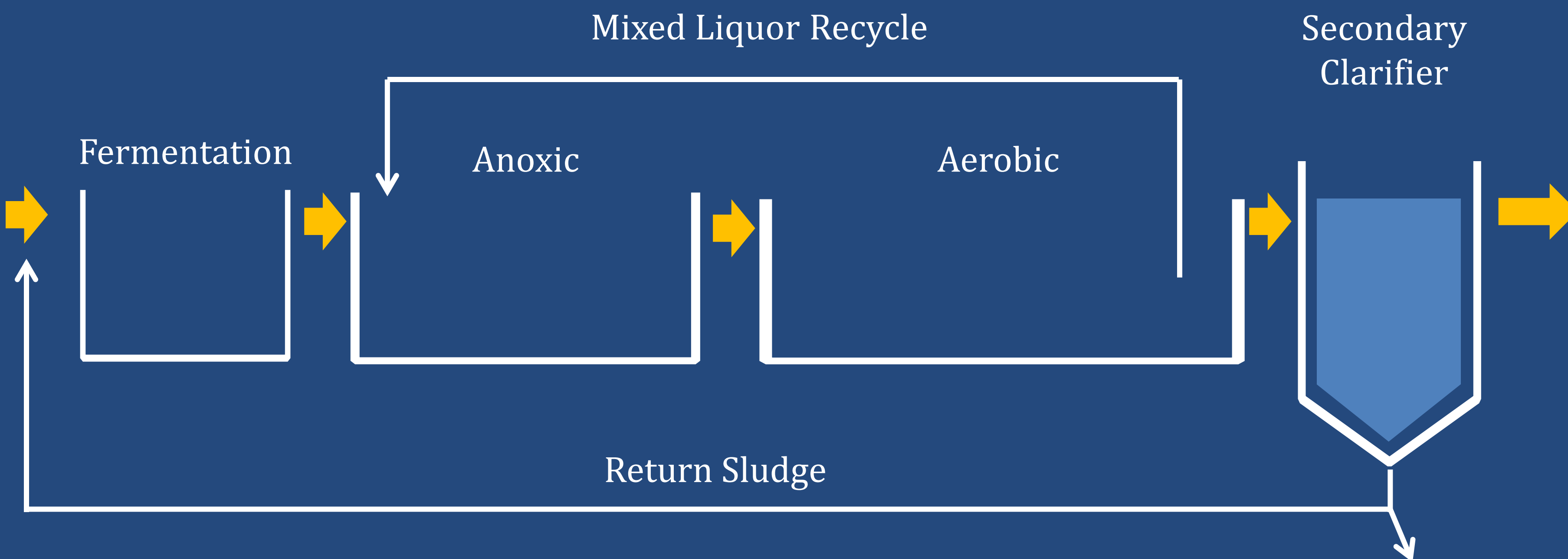
The greater the flow, the more NO_3 returned for denitrification

The lower the flow:

the less damage to the Anoxic and Aerobic habitats &

the longer the consecutive minutes in the Anoxic and Aerobic habitats





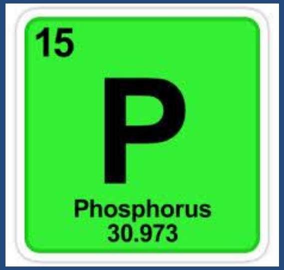
Secondary Clarifier

Nitrogen Removal:

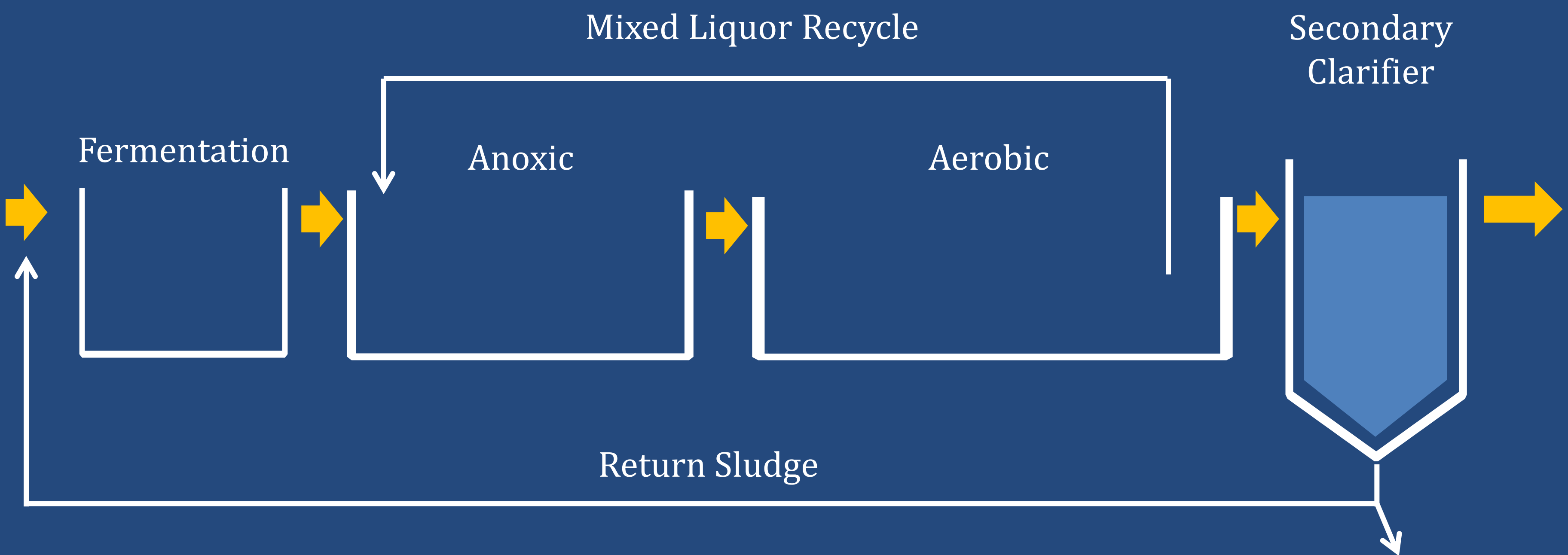
Possible NH_4 release (not likely)

Phosphorus Removal:

Possible PO_4 release (not likely)



Optimal Process Settings

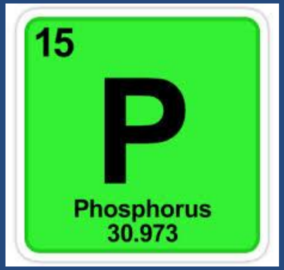


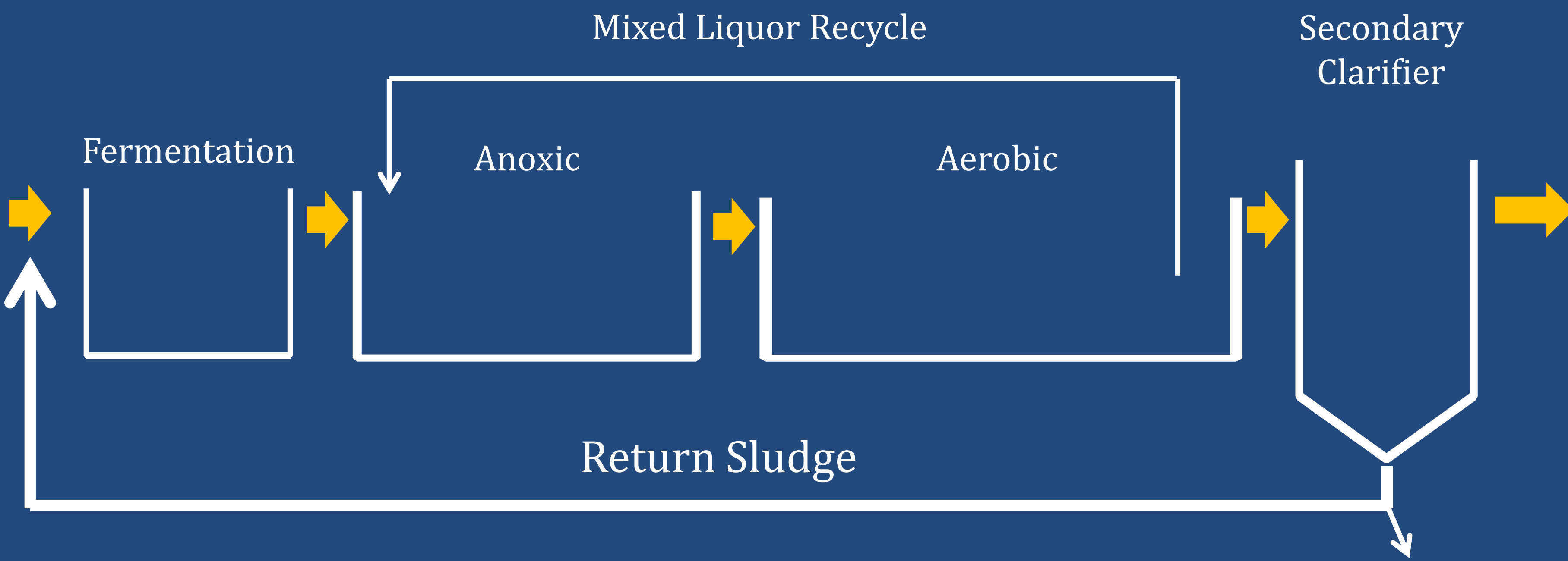
<u>Secondary Clarifier</u>

Minimal sludge blankets

Optimal levels of NH_4, NO_3 & NO_2 exiting tank

Optimal levels of ortho-P and TSS exiting tank





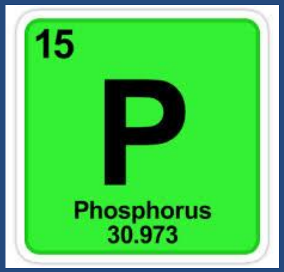
Return Sludge (RAS)

Nitrogen Removal:

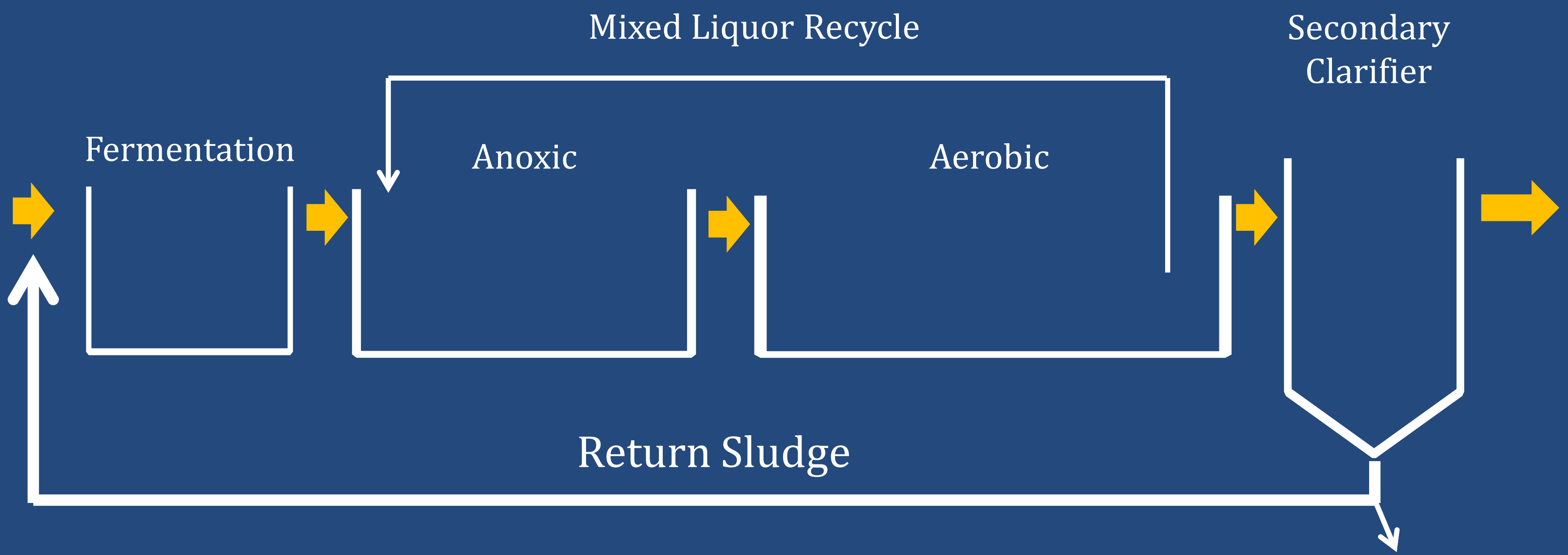
Some NO_3 return to Fermentation Tank

Phosphorus Removal:

High DO may damage Fermentation habitat



Optimal Process Settings



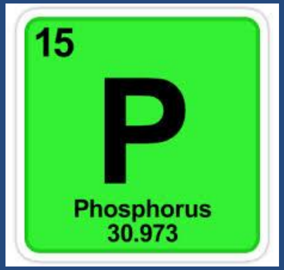
Return Sludge (RAS)

Nitrogen Removal:

Some NO_3 return to Fermentation Tank

Phosphorus Removal:

High DO may damage Fermentation habitat



Summary

Biological phosphorus removal requires Volatile Fatty Acids as a fuel for PAOs – phosphate accumulating organisms.

Nitrate (NO_3) removing bacteria (denitrifiers) will outcompete PAOs for VFAs.

Understanding each habitat, monitoring, and controlling conditions allow for optimal N&P removal in plants design for N&P removal and in plants not designed for N&P removal.

Advantages to BNR are many:

- Filament control (selectors)
- Less sludge production (higher MLSS / lower F:M)
- Less electricity because of "free" BOD removal in Anoxic Tank
- Fewer chemicals

Experimentation can provide multi-million capital savings.

THE WATER PLANET COMPANY

Making clean water affordable

www.cleanwaterops.com

Optimizing the Operation of Activated Sludge Wastewater Treatment Plants to Remove Nitrogen & Phosphorus

Grant Weaver, Your Presenter

g.weaver@cleanwaterops.com

President
The Water Planet Company

<u>Licensing</u>

Professional Engineer

Wastewater Operator

<u>Education</u>

Massachusetts Institute of Technology (MIT):
Post-Graduate Studies in Environmental Toxicology

Oklahoma State University (OSU):
MS Bio-Environmental Engineering

Kansas State University (KSU):
BS Biology

Thank You!

g.weaver@cleanwaterops.com

<u>Upcoming Webinars</u>

11 AM EST April 15th: Sequenced Aeration in Montague, Massachusetts

Modifying Operations at Amherst, MA to avoid a $61 million facility upgrade – May ‘14