



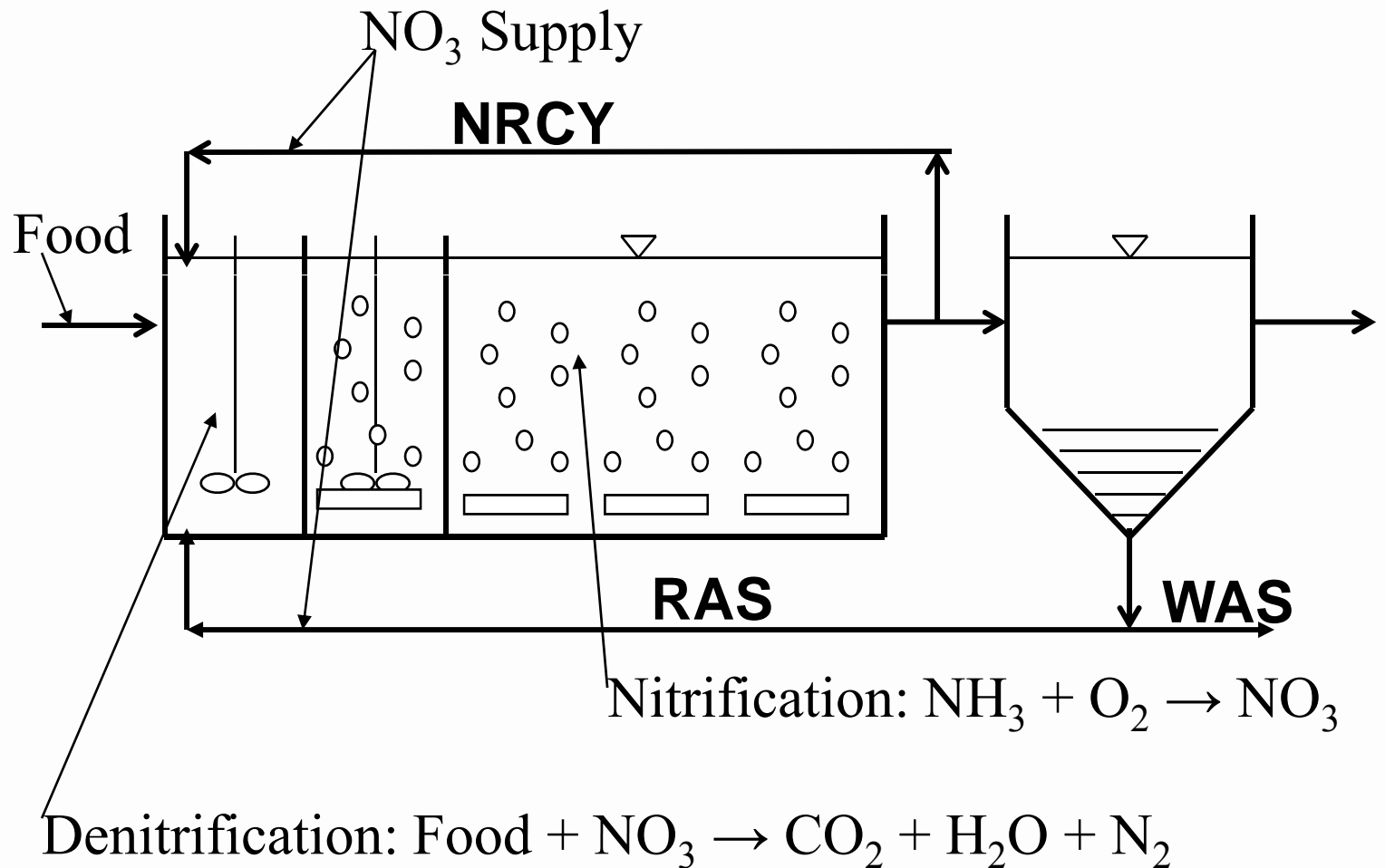
Biological Nutrient Removal 101

Glen T. Daigger, Ph.D., P.E., BCEE, NAE
Senior Vice President and
Chief Technology Officer





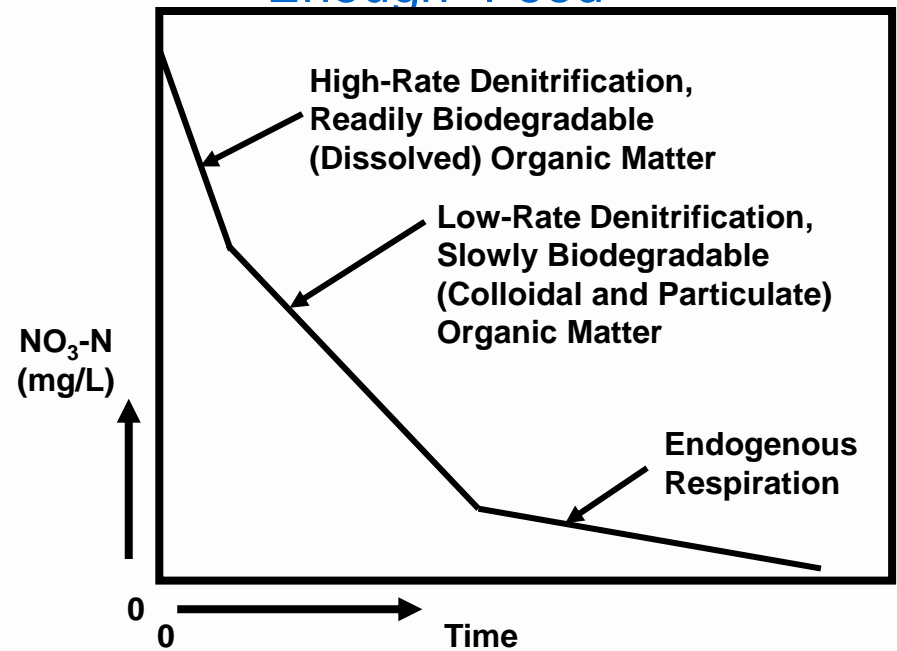
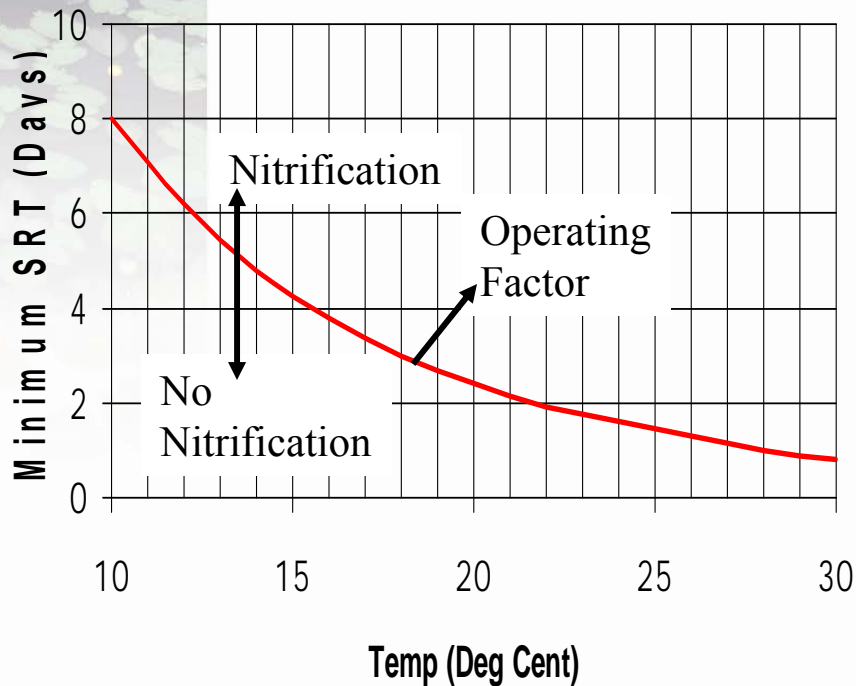
BN(itrogen)R Removal Occurs by Nitrification and Denitrification





Here's What's Needed to Do This:

- **Nitrification:**
 - Adequate Aerobic SRT
 - Adequate Oxygen Supply
 - Adequate Buffering (Alkalinity)
- **Denitrification:**
 - Adequate Anoxic SRT
 - Recycle of Nitrate to Anoxic Zone
 - Exclude DO
 - Enough "Food"



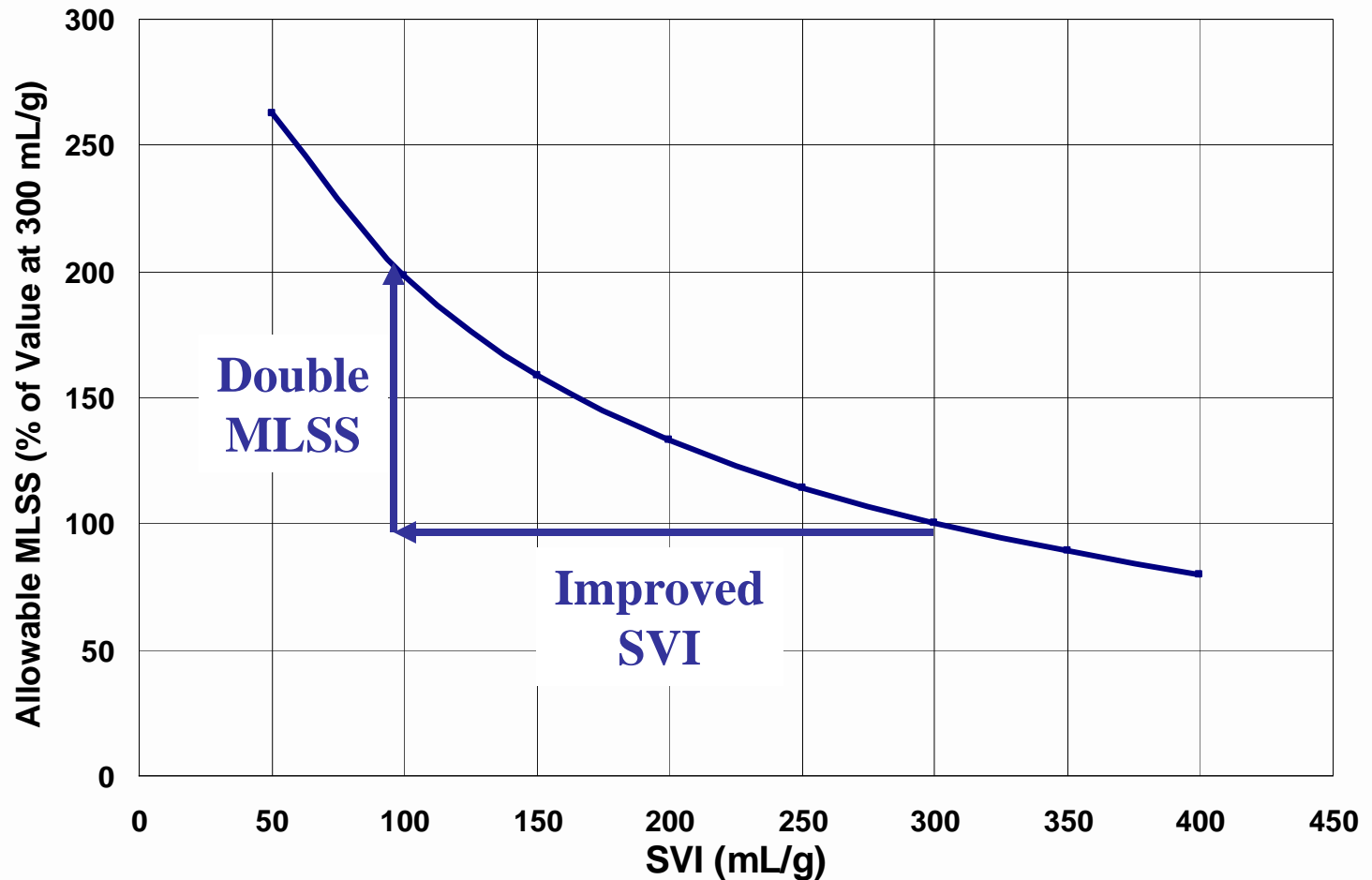


Six Key Biological Nitrogen Removal Principals Include:

- Use Influent Carbon First
- Design for Good Sludge Settleability
- Use Physical Foam Control
- Not All Supplemental Carbon is Created Equal
- SNdeN Becomes Predictable
- How Much GHG's are We Creating?

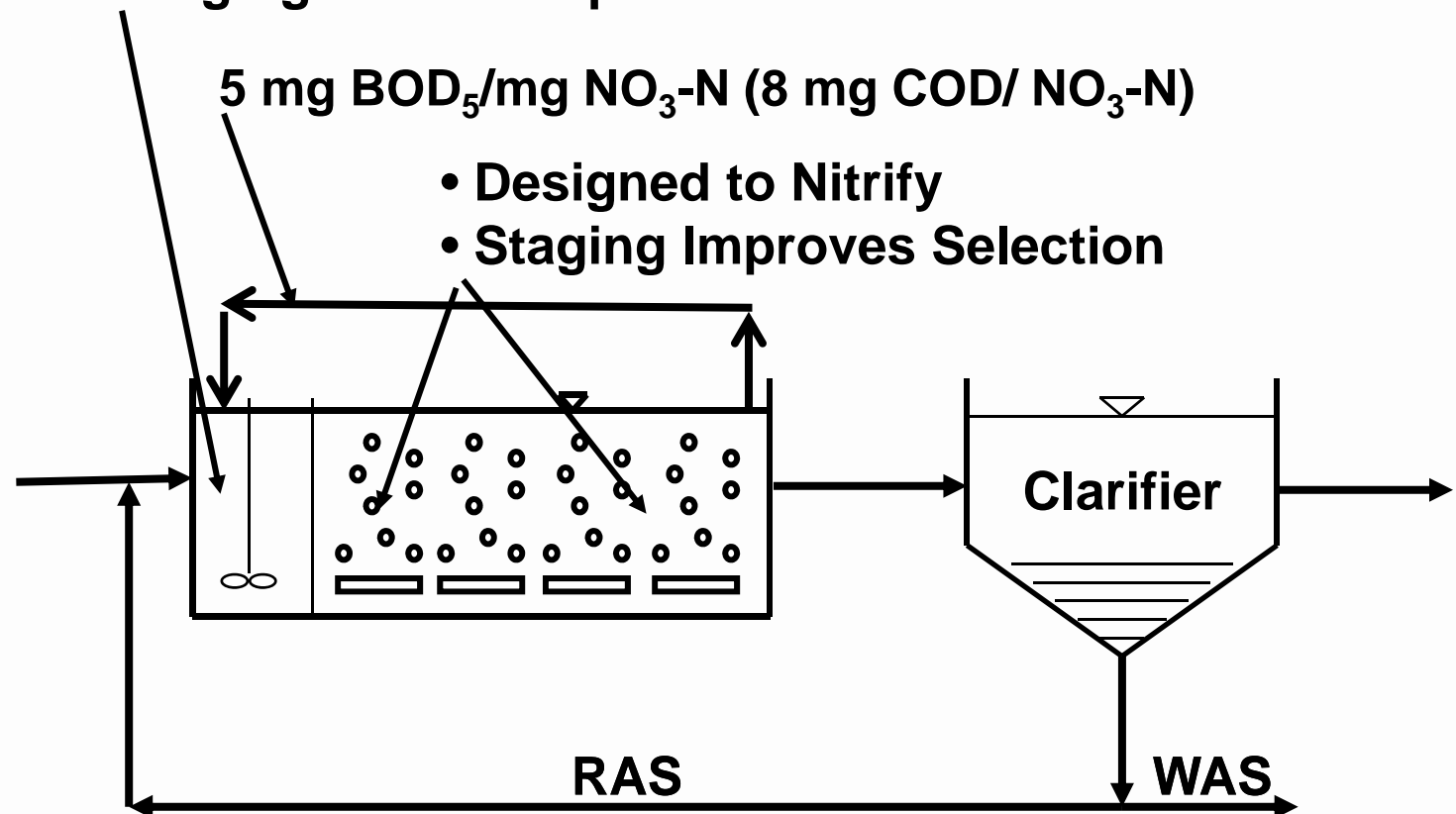


Sludge Settleability Dramatically Affects Bioreactor Inventory



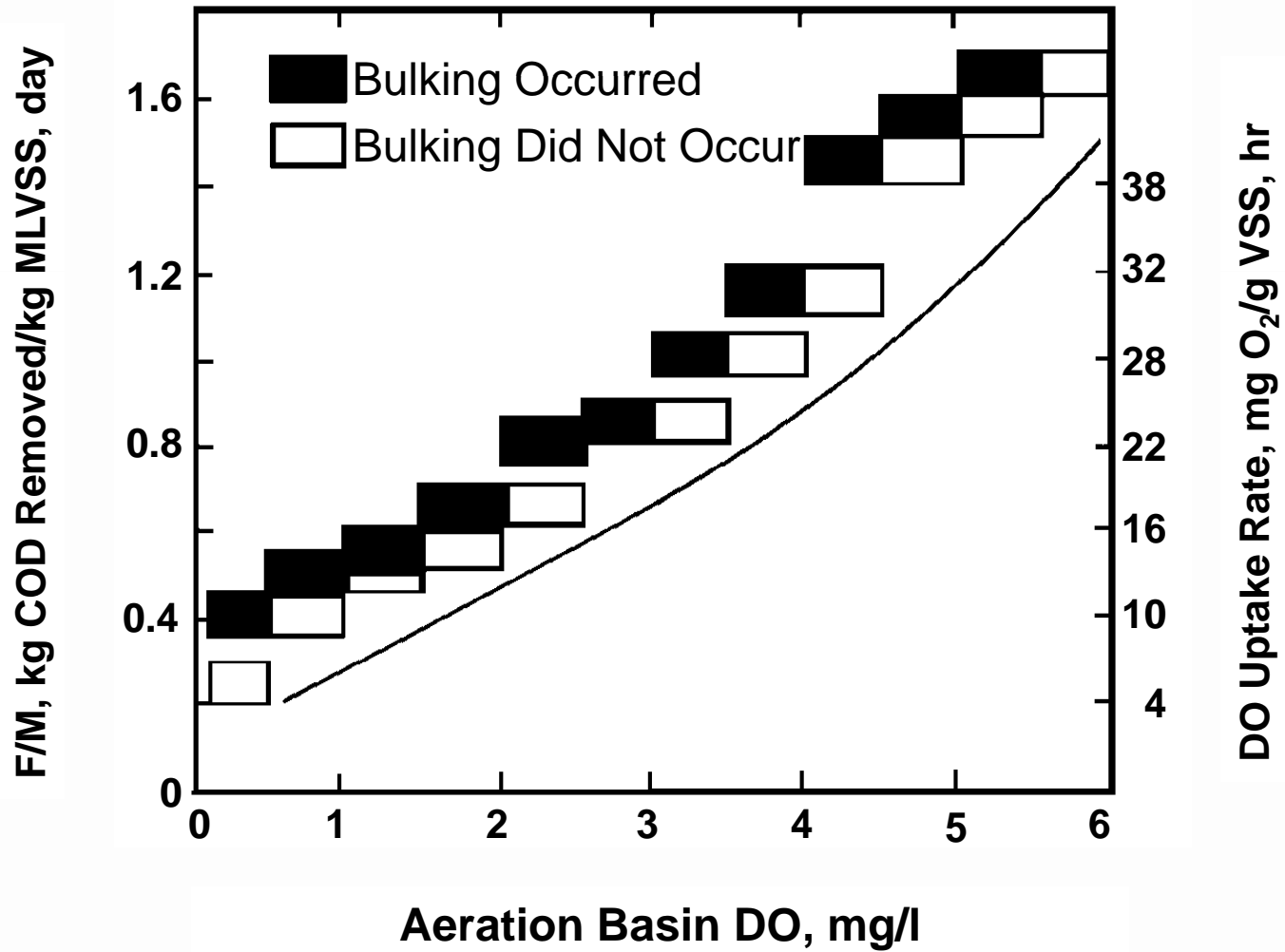
Anoxic Selector Sized Based on Anoxic SRT

- SRT = 2-3 Days, Depending on Temperature
- Staging Further Improves Selection





Required Aerobic Zone DO Correlates with Respiration Rate





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Two Professionals Study Foam Problem!



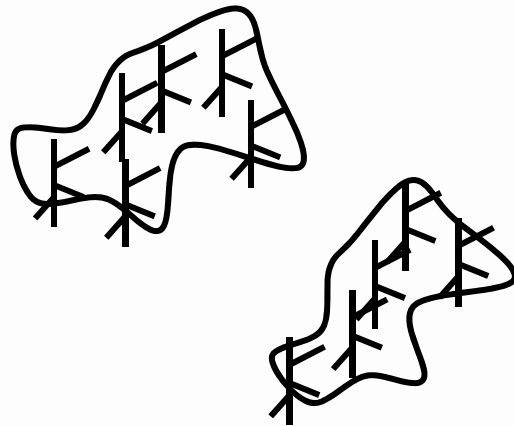
Nocardia
Can Be Fun!



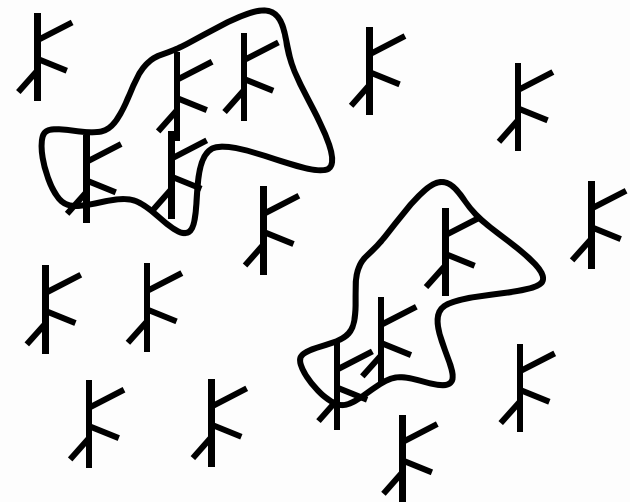
Principal Cause of *Nocardiform* Foaming is Trapping

- Demonstrated at Laboratory and Full-Scale
- Growth Form Varies with Trapping:

No Trapping System

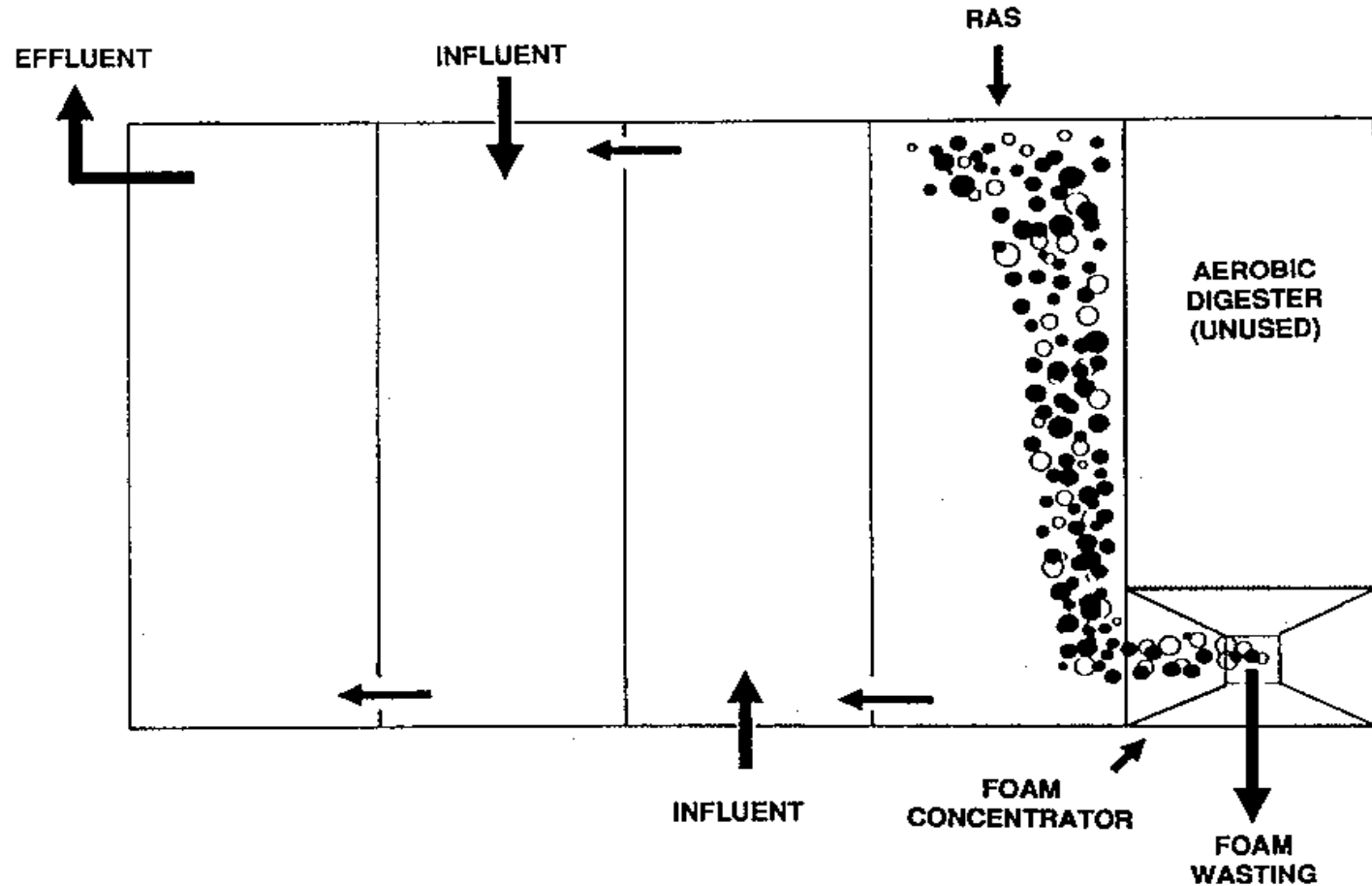


Trapping System





Selective Foam Wasting is a Proven Technique

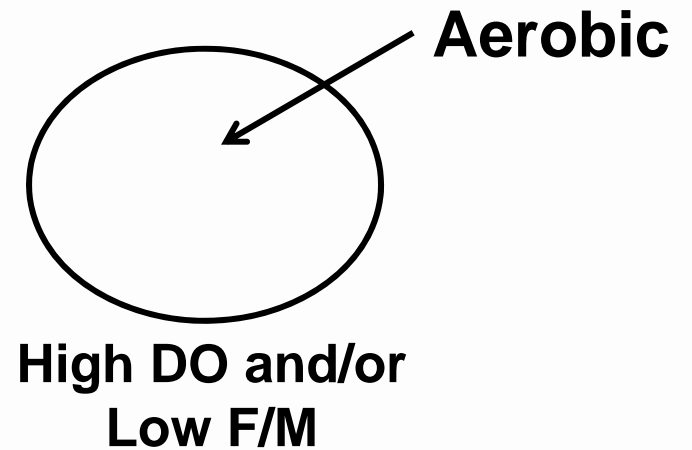
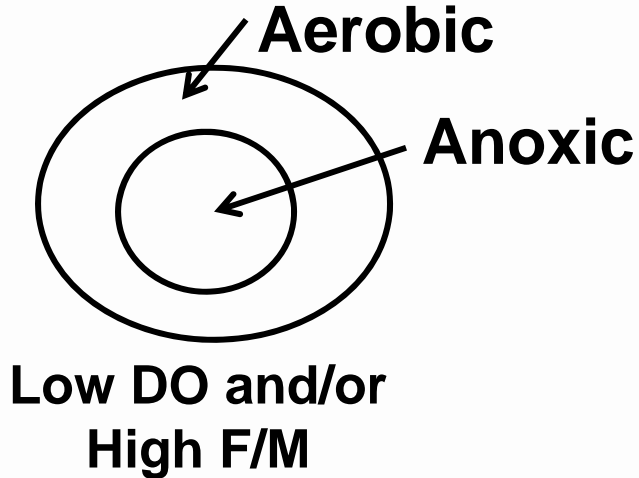




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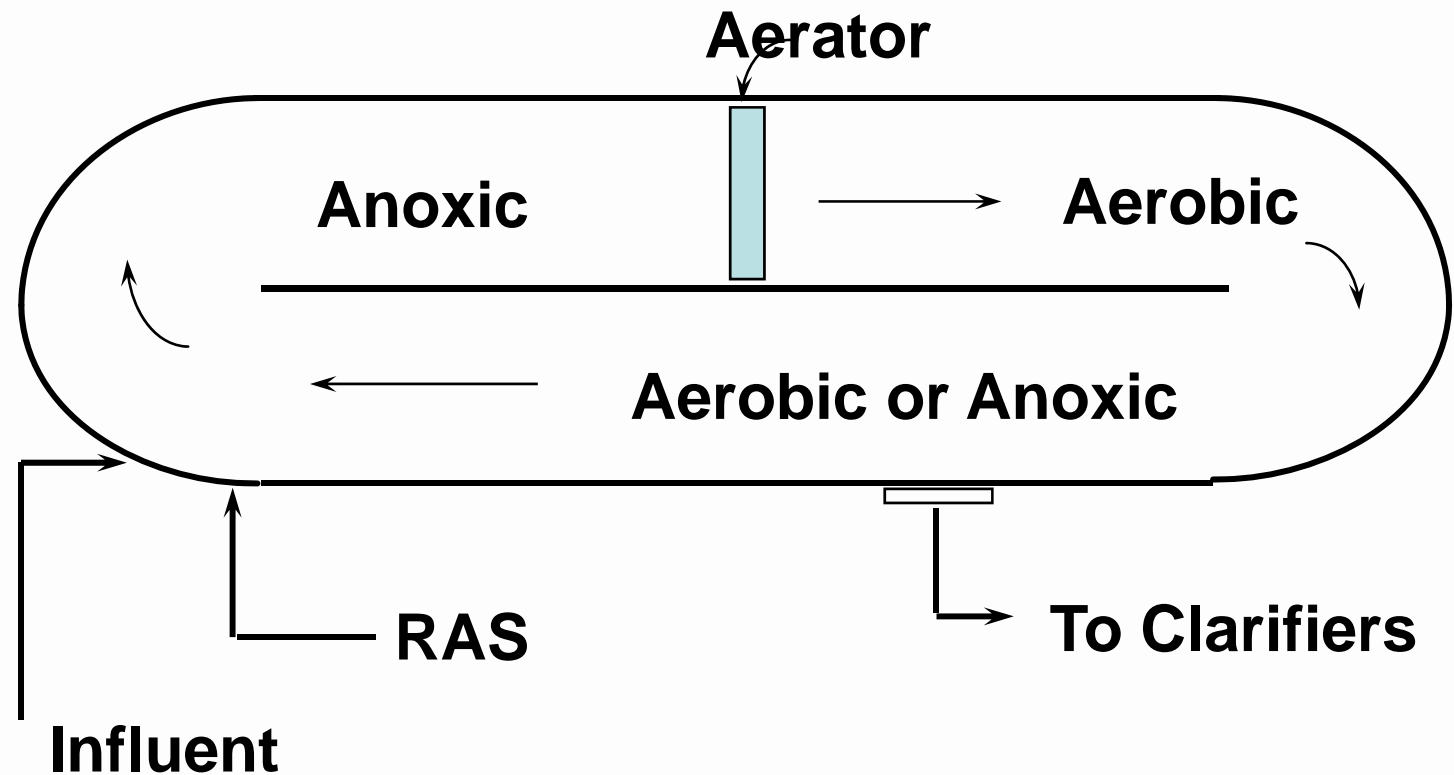
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Denitrification Can Occur Inside Activated Sludge Flocs



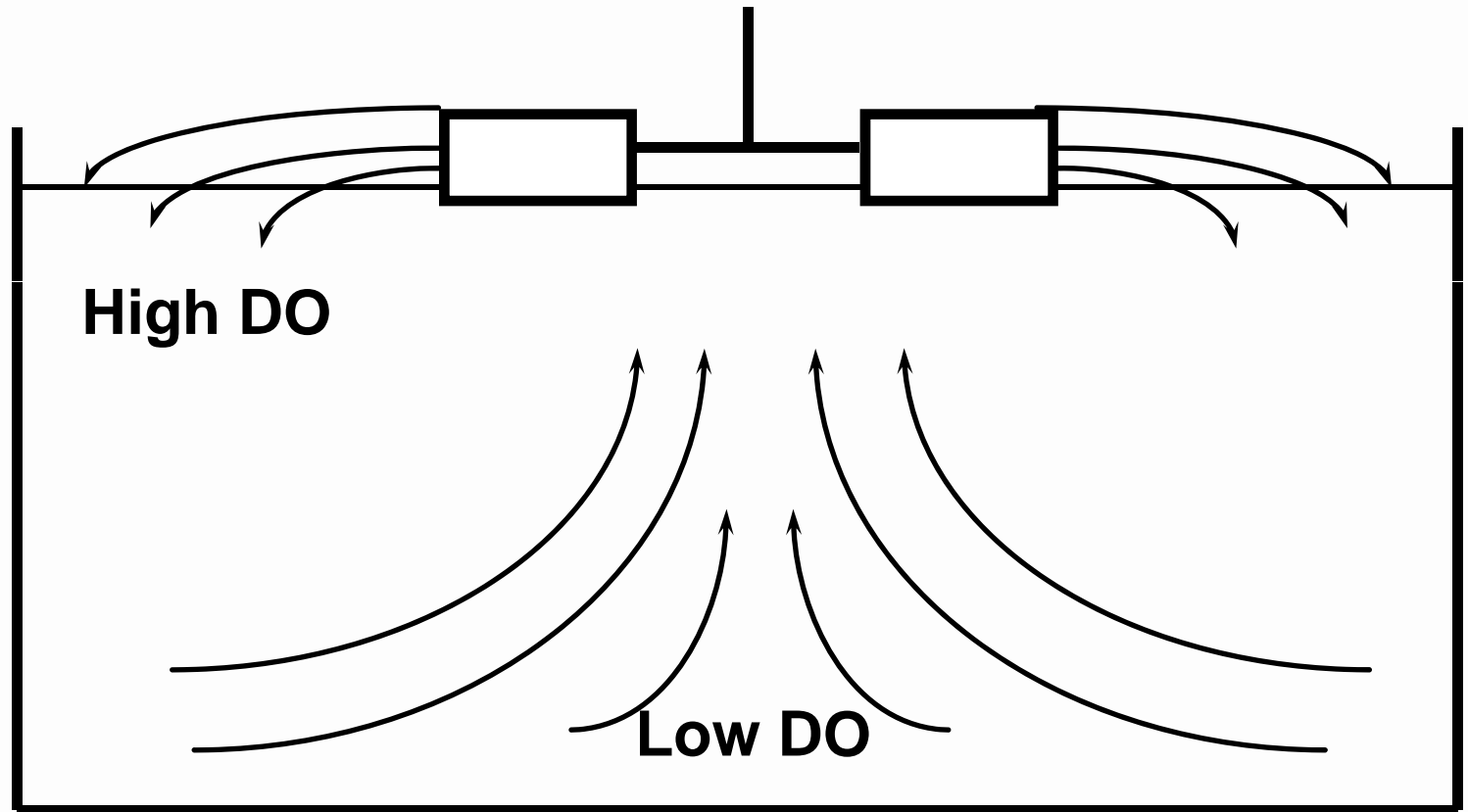


Denitrification Can Also Occur Due to Bioreactor Mixing Pattern





Denitrification Can Also Occur Due to Bioreactor Mixing Pattern

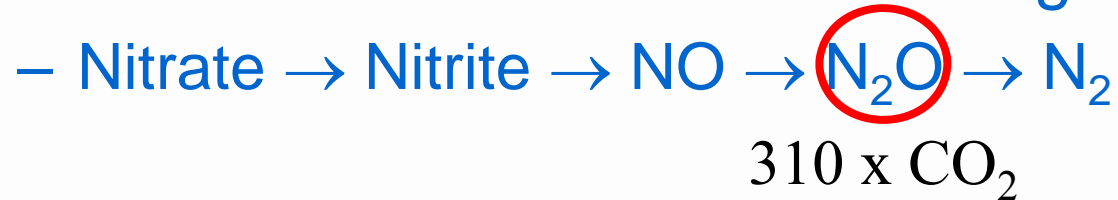


Controlling Oxygen Input Key to Reliable Performance!

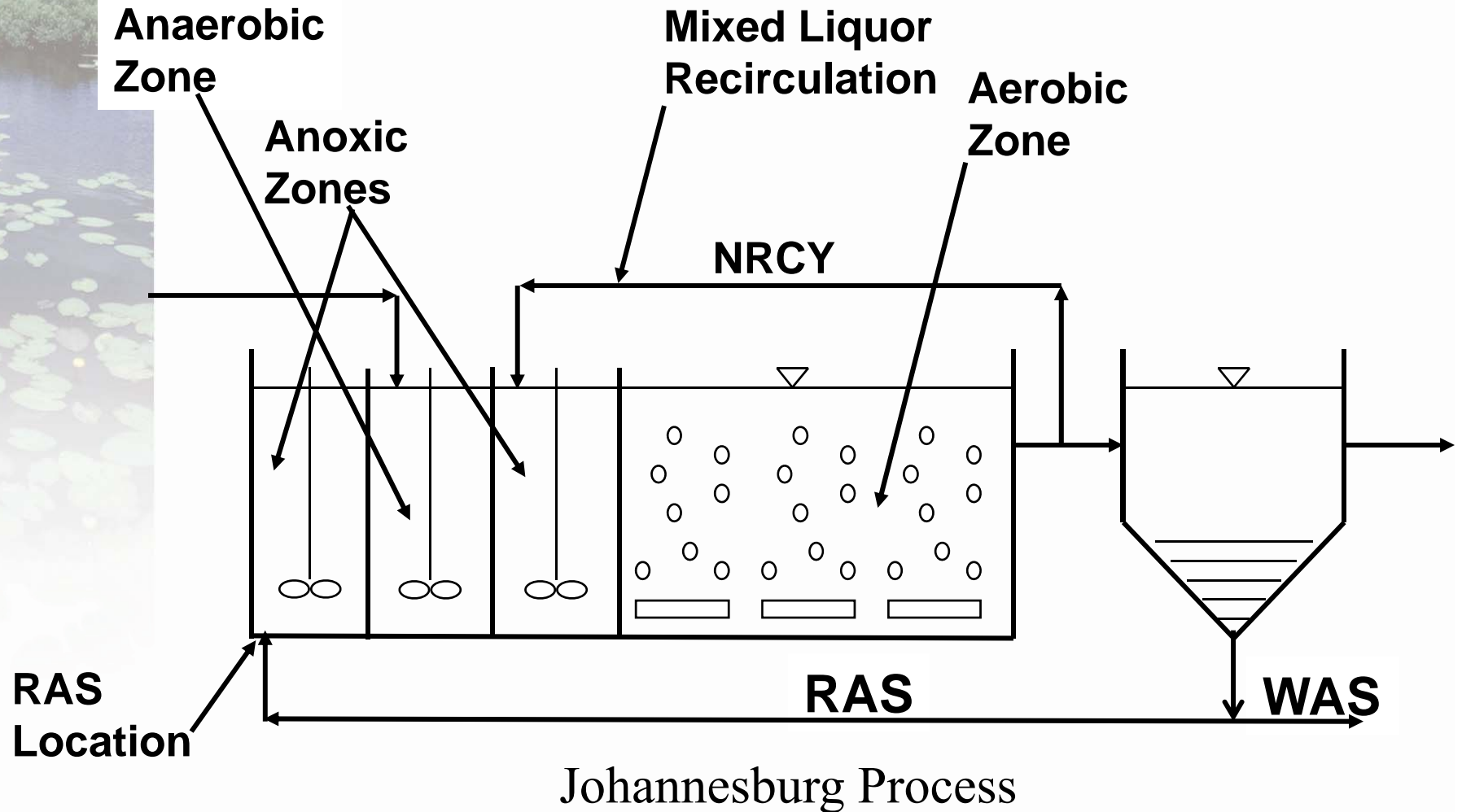


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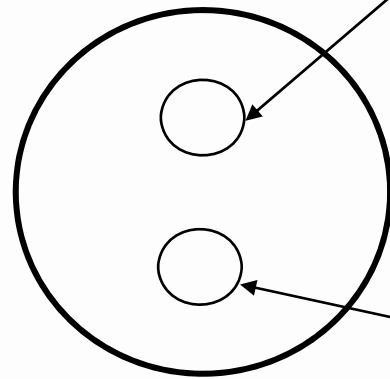
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BP(hosphorus)R Requires Anaerobic Zone



Phosphorus Accumulating Organisms (PAO's) Include:



Polyphosphate Granules:

- $\text{PO}_4 \equiv \text{PO}_4 \equiv \text{PO}_4 \equiv \text{PO}_4 \equiv \text{PO}_4$
- Phosphate Storage
- Energy Storage

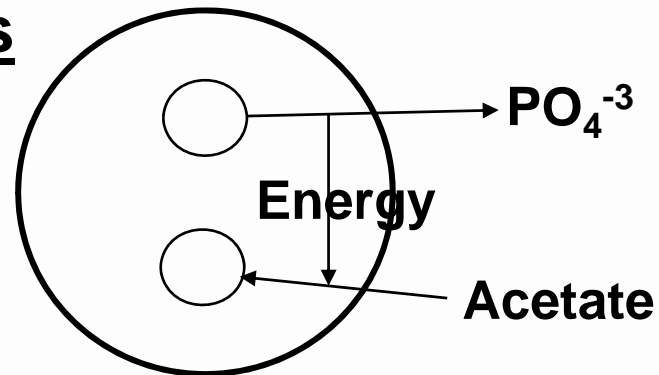
Poly- β -hydroxy butyrate:

- Lipid
- Carbon Storage

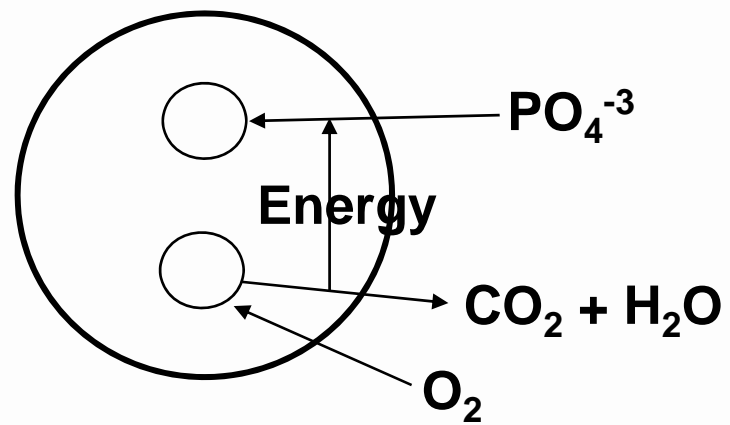


PAO's Have Unique Anaerobic/ Aerobic Metabolism

Anaerobic Conditions



Aerobic Conditions





Four Key Biological Phosphorus Removal Principals Include:

- Exclude Nitrate From Anaerobic Zone
- It's Not the Process, It's the Wastewater
- If VFA's Insufficient, Make Your Own
- A Fat Bug is a Happy Bug

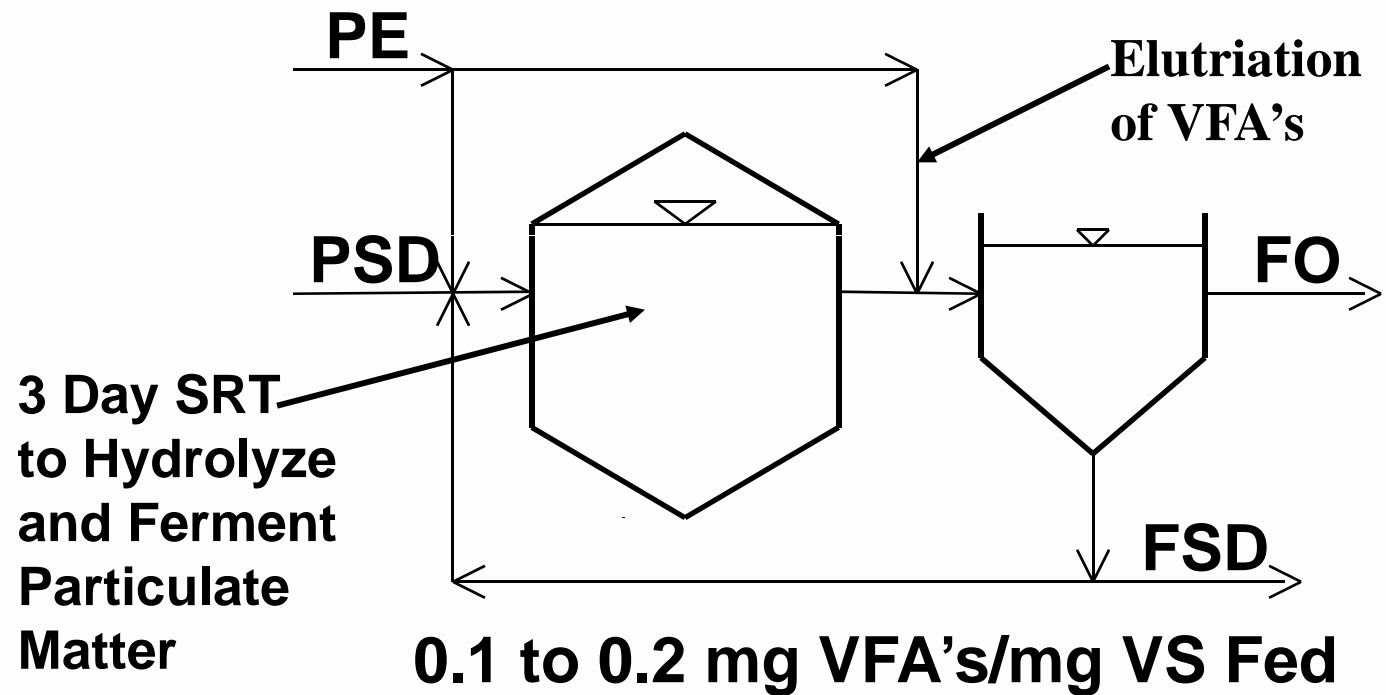


Stoichiometry Controls Phosphorus Removal

- Efficiency Depends on Organic Matter:
 - Expressed as BOD_5/TPO_4 Ratio; Typically Requires 15 to 25 mg BOD_5 /mg TPO_4 , Depending on Process.
- Specifically Requires VFAs:
 - Acetic and Propionic Acid; 7 to 10 mg VFA/mg P Removed by Bio-P
- Sufficient VFAs
 - Influent Wastewater (Produced in Collection System)
 - Produce in Anaerobic Zone
 - Produce From Influent Organics
 - Purchase and Add



Sludge Fermentation Increases VFA Feed to BNR Systems



Many Other Configurations are Possible

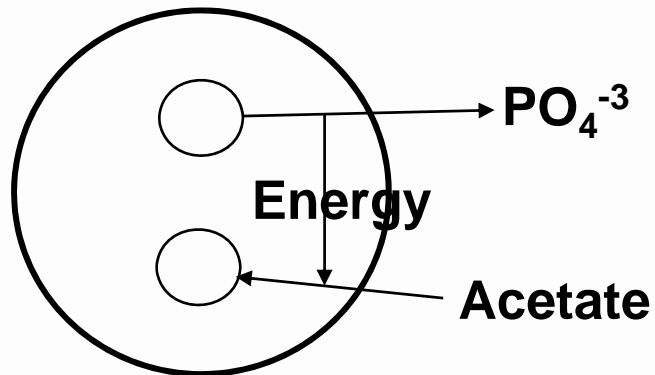


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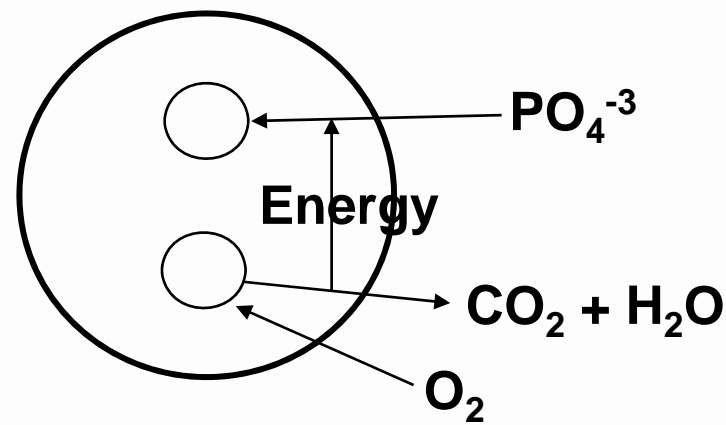
Several Reactions Occur in Bio-P Systems

Anaerobic Conditions



- VFA Uptake and PHA Formation (Phosphorus Release)
- Fermentation of Readily Biodegradable Organic Matter
- Denitrification (Undesirable)

Aerobic Conditions



- PHA Oxidation
- Poly-P Formation
- Poly-P Lysis
- PAO Growth
- Heterotroph Growth
- Decay
- Nitrification



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