

PNCWA Western Region Southwest Section
March 16, 2017

Nutrient Removal

Presented by: Robert and Thelma

Today's Presentation

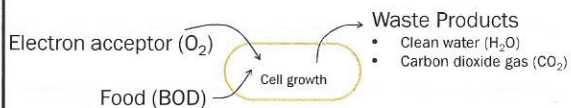
- Nutrient Removal Introduction
- Conventional Approaches
 - Biological Phosphorus Removal
 - Biological Nitrogen Removal
- New Approaches
 - Side stream treatment
 - Granular sludge treatment
 - Struvite Recovery

Nutrient Removal Introduction

Activated Sludge Bacteria

- Bacteria oxidize food
 - BOD, COD (carbon)
 - Ammonia (NH_4)
- In order to oxidize, they require an electron acceptor
 - Oxygen (O_2)
 - Nitrate (NO_3)
 - Nitrite (NO_2)

} Often referred to as "NOx"



Key Activated Sludge Bacteria

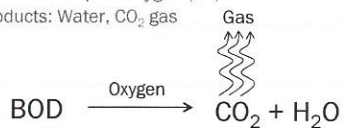
Three main classes

What do they remove?

- Heterotrophs**
 - BOD
- Nitrifying bacteria**
 - Ammonia oxidizing bacteria (AOBs)
 - Ammonia (NH_4)
 - Nitrite oxidizing bacteria (NOBs)
 - Nitrate (NO_3)
- Phosphorus accumulating organisms (PAOs)**
 - Phosphorus

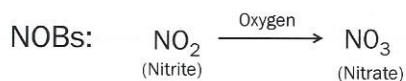
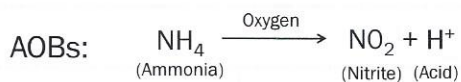
BOD Removal

- Heterotrophs**
 - Food source: BOD
 - Electron acceptor: oxygen (air)
 - Products: Water, CO_2 gas



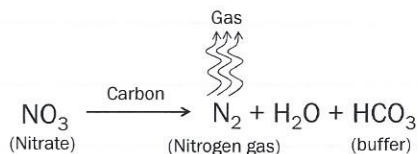
Nitrification

- Nitrifying bacteria- 2 types
 - Ammonia oxidizing bacteria (AOBs)
 - Nitrite oxidizing bacteria (NOBs)
- Food source: Ammonia
- Electron acceptor: oxygen (air)
- Produces: Nitrate, Acid



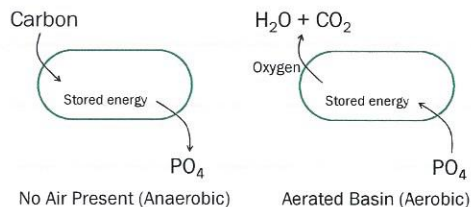
Nitrogen Removal (Denitrification)

- Heterotrophs
 - Food source: Carbon (readily biodegradable COD- rbCOD)
 - Electron acceptor: nitrate, nitrite
 - Produces: Nitrogen gas, water, carbonate (buffer)
 - Happens in the absence of oxygen



Phosphorus Removal

- Phosphorus accumulating organisms (PAOs)
 - Food sources: Carbon, Orthophosphate
 - Produces: Stored polyphosphate


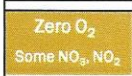
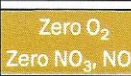


Summary

Goal: Remove BOD <ul style="list-style-type: none"> Bacteria: Heterotrophs Requirement: Oxygen Produces: Clean water 	Goal: Remove Ammonia <ul style="list-style-type: none"> Process: Nitrification Bacteria: AOBs, NOBs Requirement: Oxygen Produces: Nitrate, Acid
Goal: Remove Nitrogen <ul style="list-style-type: none"> Process: Denitrification Bacteria: Heterotrophs Requirements <ul style="list-style-type: none"> NO₃ from Nitrification Carbon Produces: Acid buffer 	Goal: Remove Phosphorus <ul style="list-style-type: none"> Bacteria: PAOs Requirements <ul style="list-style-type: none"> Carbon Anaerobic Conditions Produces: Stored P

Environment

- Different bacteria function in different environments within the aeration basins

 <p>High O₂</p>	 <p>Zero O₂ Some NO₃, NO₂</p>	 <p>Zero O₂ Zero NO₃, NO₂</p>
Aerated Cell (Oxic)	Un-aerated Cell (Anoxic)	Un-aerated Cell (Anaerobic)
Abundant electron acceptors O ₂ , NO ₃ , NO ₂	No Oxygen, but other electron acceptors present (nitrate, nitrite)	No electron acceptors present

What Nutrients Do We Care About?

- Nitrogen (N)
 - Organic Nitrogen
 - Ammonia (NH₃, NH₄⁺)
 - Nitrite (NO₂⁻)
 - Nitrate (NO₃⁻)
- } Total Kjeldahl Nitrogen (TKN)
- Phosphorus (P)
 - Total phosphorus (TP)
 - Orthophosphate, phosphate (PO₄³⁻)

Why Do We Care About Nutrients?

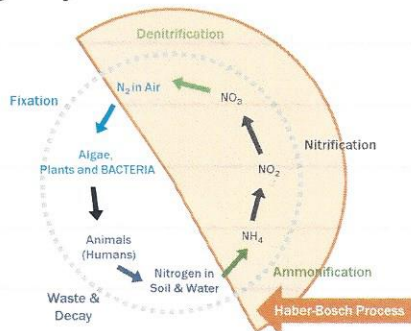
- N & P nutrients promote eutrophication
- Both exert O_2 demand – deplete DO in receiving waters
- Ammonia is toxic
- Nitrate & nitrite are toxic – “Blue Baby Syndrome”
- Limited by NPDES permits!



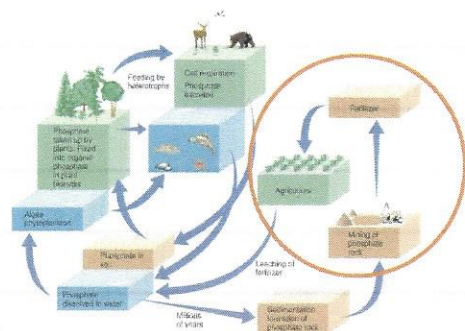
Images of eutrophication



Nitrogen Cycle



Phosphorus Cycle

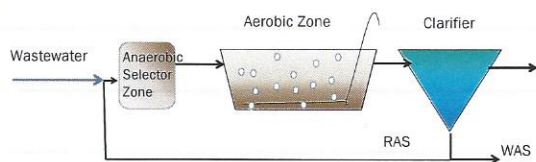


So, What Can We Do About It?

- **Biological Nutrient Removal**
 - Using bacteria to remove nitrogen and phosphorus
 - Activated sludge and attached growth
- **Physical/Chemical Nutrient Removal**
 - Physical or chemical separation of nutrient from wastewater
 - Chemical precipitation, ion exchange, adsorption

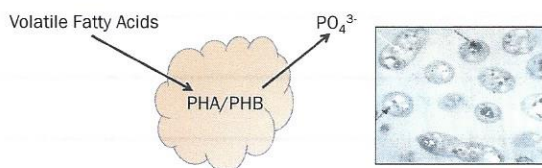
Biological P Removal

Biological Phosphorus Removal Process



BPR – Step 1, P Release

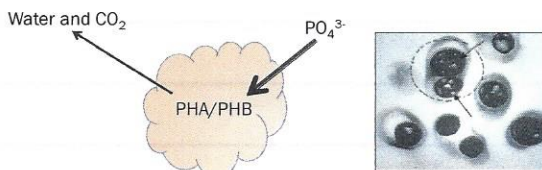
When there is no O_2 and no NO_3 or NO_2
(Anaerobic Conditions)...



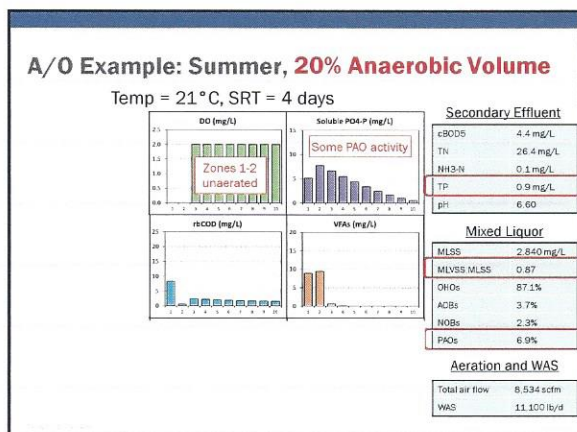
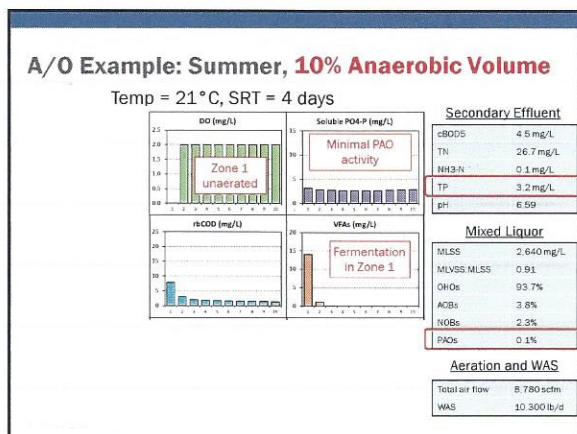
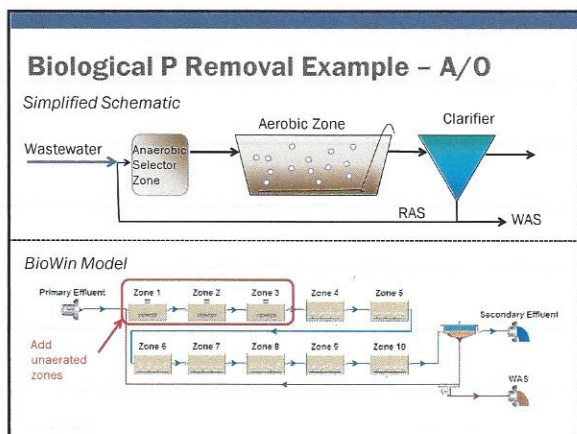
Phosphorus Accumulating Organisms (PAOs)
- Store PHB & release P in anaerobic zone

BPR – Step 2, P Uptake

But when there is O_2 ...

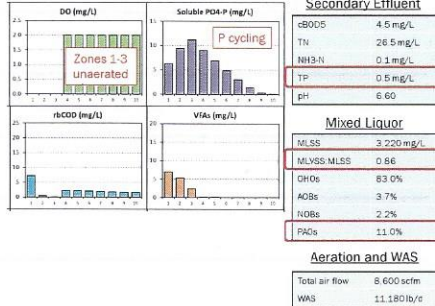


Phosphorus Accumulating Organisms
- Oxidize PHB, take up soluble P, store excess P in granules



A/O Example: Summer, 30% Anaerobic Volume

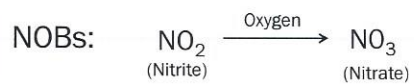
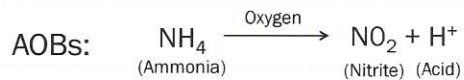
Temp = 21°C, SRT = 4.5 days

**Biological N Removal**

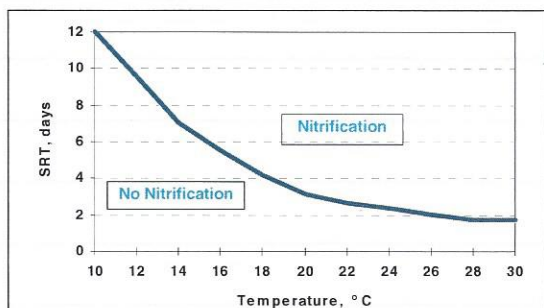
Brown & Caldwell

Nitrification

- Nitrifying bacteria- 2 types
 - * Ammonia oxidizing bacteria (AOBs)
 - * Nitrite oxidizing bacteria (NOBs)
- Food source: Ammonia
- Electron acceptor: oxygen (air)
- Produces: Nitrate, Acid

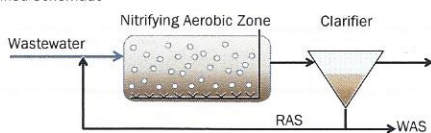


Nitrification Varies with SRT and Temperature

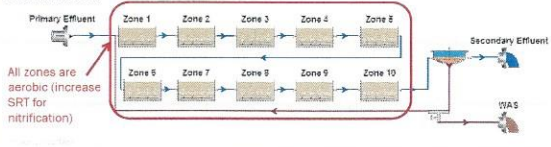


Nitrification Example

Simplified Schematic

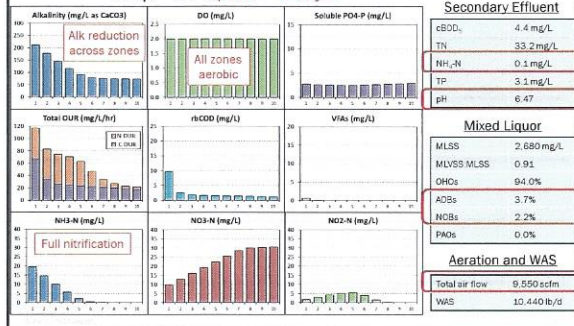


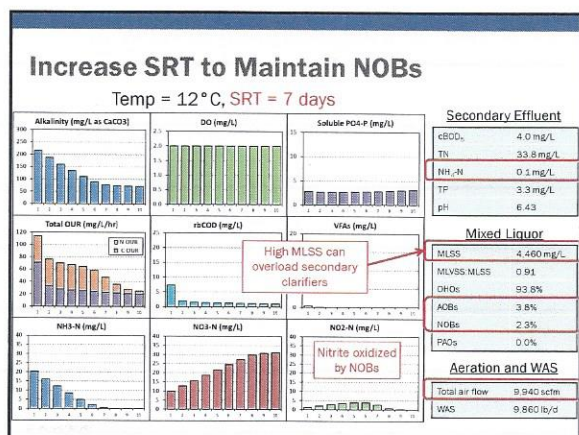
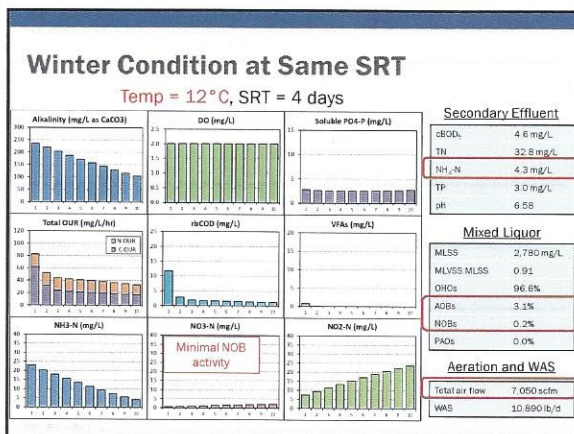
BioWin Model



Summer Condition

Temp = 21°C, SRT = 4 days





Nitrogen Removal (Denitrification)

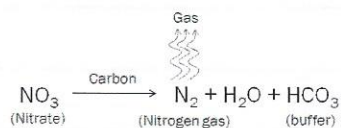
- **Heterotrophs**
 - Food source: Carbon (readily biodegradable COD- rbCOD)
 - Electron acceptor: nitrate, nitrite
 - Produces: Nitrogen gas, water, carbonate (buffer)
 - Happens in the absence of oxygen

$$\begin{array}{ccc}
 \text{NO}_3^- & \xrightarrow{\text{Carbon}} & \text{N}_2 + \text{H}_2\text{O} + \text{HCO}_3^- \\
 \text{(Nitrate)} & & \text{(Nitrogen gas)} \quad \text{(buffer)}
 \end{array}$$

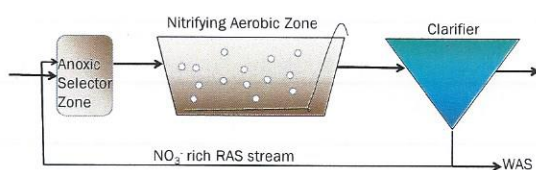
Gas

Carbon Deficiency

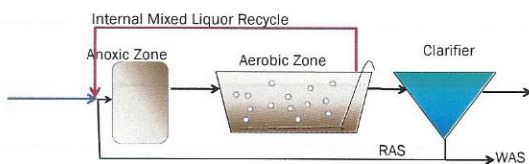
- Carbon supplementation
- **Readily degradable** carbon is required for N removal



Denitrification

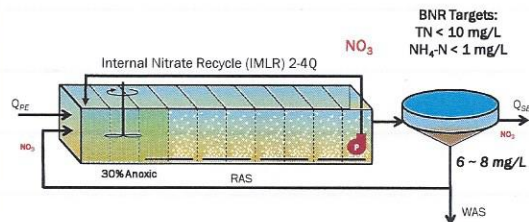


2-Stage Anoxic Selector Modified Ludzak-Ettinger (MLE) Process

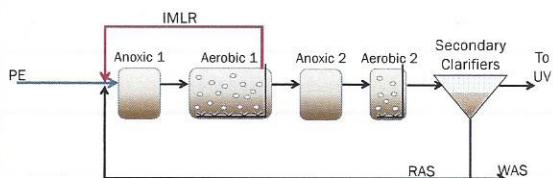


- Adds internal mixed liquor recycle (IMLR) to improve denitrification
- Can reliably remove TN <10 mg/L
- ...Can make more efficient by adding 2 stages (4-stage modified Bardenpho process...achieve TN <6 mg/L)

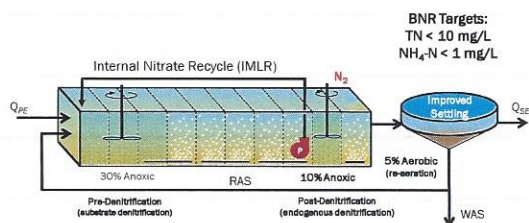
Building the BNR Facility – Modified Ludzack-Ettinger Process



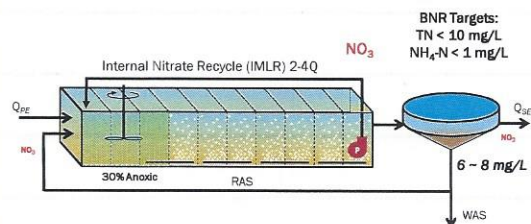
4-Stage Modified Bardenpho for N Removal



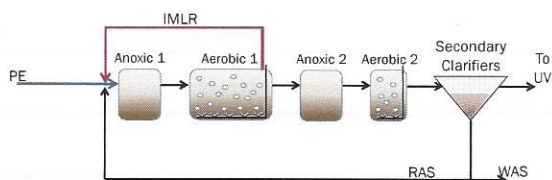
Building BNR – 4-Stage Bardenpho



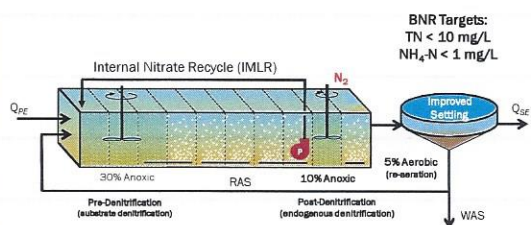
Building the BNR Facility – Modified Ludzack-Ettinger Process



4-Stage Modified Bardenpho for N Removal



Building BNR – 4-Stage Bardenpho



Side Stream Treatment

Brown & Caldwell

What is "Sidestream"?

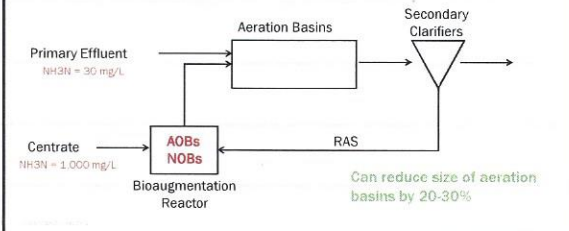
- Dewatering reject water
 - High nutrient content (ammonia, P)
 - Centrate
 - Filtrate
 - Pressate
- Solids thickening reject water?
 - Typically low nutrient content
 - Relative ineffective

Why do we want to treat a sidestream?

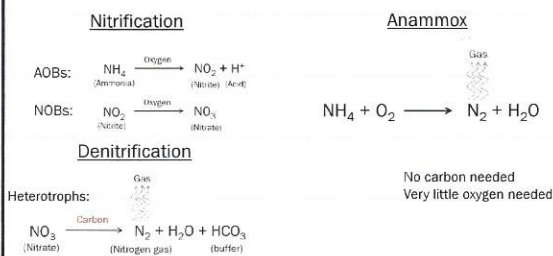
- Reduce nutrient load to main process
 - Sidestream may account for 20-30% of total ammonia load at some plants
- Recover nutrients

Conventional Processes

- Bioaugmentation
 - Create a "super-charged" community of nitrifying bacteria



Anammox Processes ("shortcut" N removal)



Commercial Anammox Processes

- Suspended Growth
 - Demon
 - Cleargreen
 - Terra-N-Hybrid

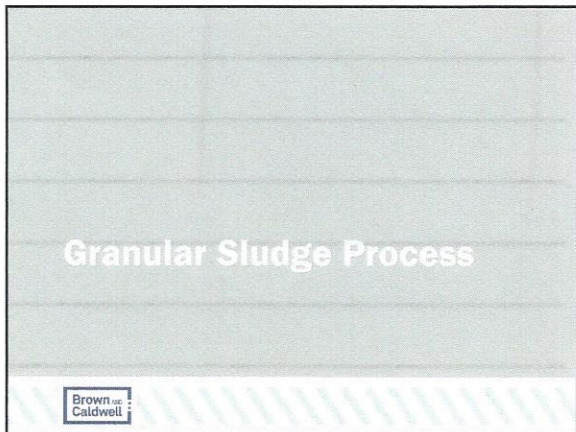


- Fixed Film
 - Anitamox




- Granular
 - Paques-Anammox



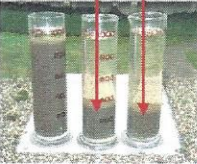


What is Granular Sludge?

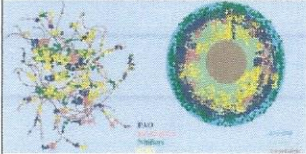
- Activated sludge which forms a dense granule
- Spherical biofilm without a carrier



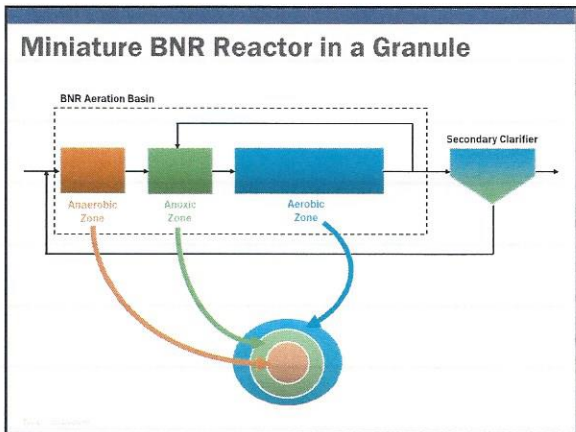
> 0.200 mm

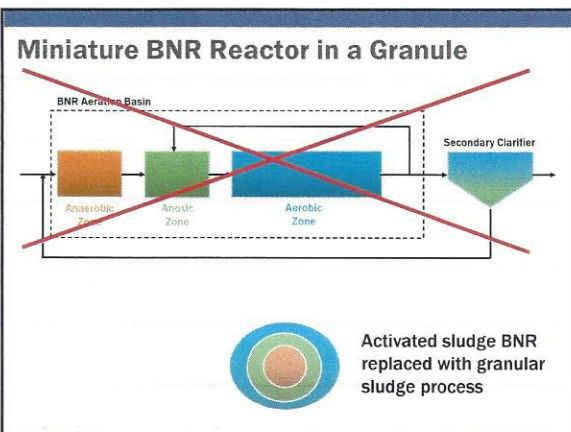


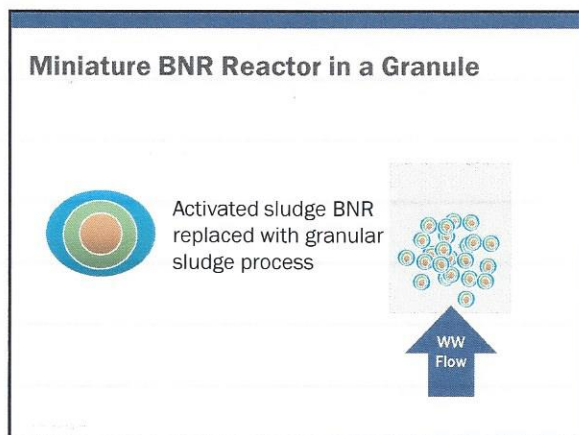
After 5 min settling
30 min settling



Courtesy Ronald Niermans, Haskoning DHV, Netherlands



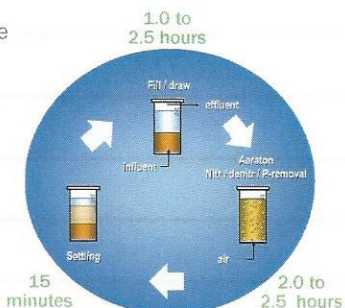






Nereda® Process

- All processes in one reactor
- Simple cycle
- Short settling phase
- Fill & draw combined
- For continuous feed: use multiple reactors or buffer tank



How Nereda Works: Simultaneous Fill-Draw

Plug flow from bottom to top

- Desired granules on bottom get food first & flocculent biomass gets what is left
- SWD > 16.5 feet
- 25-50% Volume displaced/cycle

Intermittent feed creates feast-famine conditions for slow-growing organisms

- PAO uptake RBCOD & convert to stored slowly biodegradable
- High conc. during feed leads to greater diffusion into granule



Fill is distributed uniformly at bottom through a piping network system

Courtesy Ronald Niermans, Haskoning DHV, Netherlands

Struvite Recovery

Brown & Caldwell

Struvite Recovery

Reaction



Equilibrium

$$[\text{Mg}^{2+}][\text{NH}_4^+][\text{PO}_4^{3-}] = K_{\text{sp}}$$

Struvite Crystallization Processes

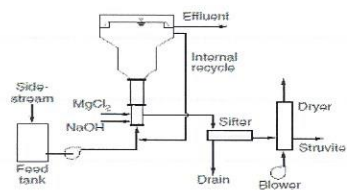
- Crystalactor®
- Ostara Pearl®:Crystalgreen
- PHOSPAQ™
- Multifarm Harvest
- NuReSys®
- Phosnix®
- AirPrex



© 2010, 2012

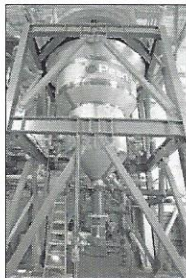
Example of Crystallizer System

- Typical process parameters:
 - * HRT ~ 1.0 hr
 - * MgCl_2 & NaOH added for pH control
 - * Hydrodynamics vary with reactor design
 - * 80-90% P, 15% N removal (but only 20-30% P recovery)

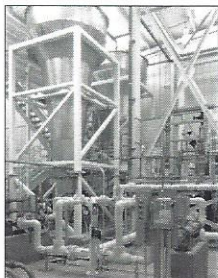


© 2010, 2012

Full-Scale Reactors



Ostara Pearl®, Tigard, Oregon
Durham WWTP



Multiform Harvest, Yakima, WA

Durham OR-- Ostara

- Ostara applied to dewatering centrate
- Non-biosolids fertilizer product (5-28-0) with 10% Mg
- Vendor options
 - Turnkey installation ("treatment fee")
 - **Outright purchase (\$2.5M)**
- Realize 25% reduction in biological P removal demand
- WASSTRIP innovation
 - Strip P from WAS prior to digestion
 - Increases P load to Ostara

Questions?

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