Biological Nutrient Removal Fundamentals

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Why Do You Think Nutrient Removal is Important?

- ?
- ?
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- ?
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- ?

Why is Nutrient Removal Important?

- Ammonia Toxicity to Aquatic Organisms
- Drinking Water Affects:
  - Nitrate - “Blue Baby Syndrome”
  - Ammonia
- Oxygen Consumption:
  - Nitrification
  - Eutrophication
  - Long Island Sound

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Oxygen Consumption Potential (OCP) Measures O_2 Demand

OCP =
1.2 x $cBOD_5$ +
4.6 x NH_3-N +
Greater of (100 x TP; 14 x TN)

Measures Environmental Impact on Dissolved Oxygen

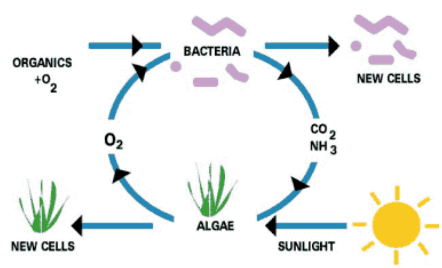

Figure 18: Symbiotic relationship between bacteria and algae in a wastewater

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OCP Assesses O_2 Demand of Wastewater/Effluent

Item	Conc (mg/L)	Factor	OCP (mg/L)
BOD_5	150	1.2	180
NH_3-N	20	4.6	92
TP	6	100	600
TN	30	14	~~420~~
TOTAL			872

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Secondary Treatment Reduces OCP

Item	Conc (mg/L)	Factor	OCP (mg/L)
BOD_5	20	1.2	24
NH_3-N	20	4.6	92
TP	4	100	400
TN	25	14	~~350~~
TOTAL			516

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Advanced Primary Treatment (CEPT) Also Reduces OCP

Item	Conc (mg/L)	Factor	OCP (mg/L)
BOD_5	60	1.2	72
NH_3-N	20	4.6	92
TP	1	100	~~100~~
TN	25	14	350
TOTAL			514

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Nutrient Removal Reduces OCP Further

Item	Conc (mg/L)	Factor	OCP (mg/L)
BOD_5	10	1.2	12
NH_3-N	1	4.6	5
TP	1	100	~~100~~
TN	8	14	112
TOTAL			129

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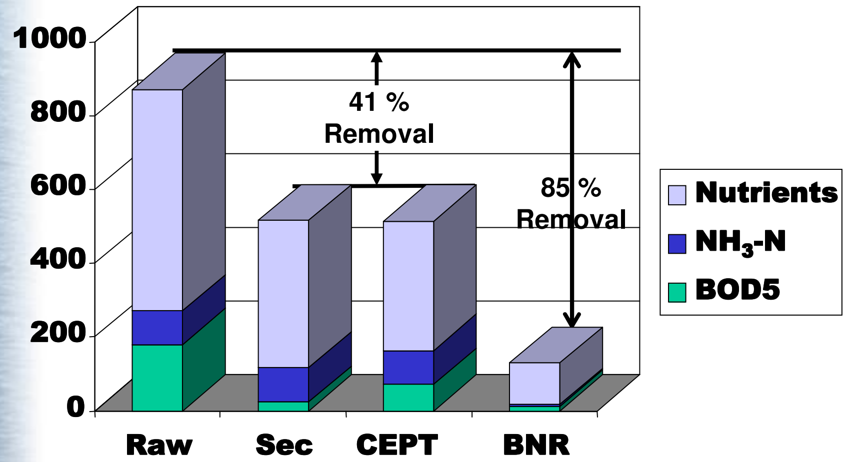
OCP Comparison Shows Why Nutrient Removal an Issue



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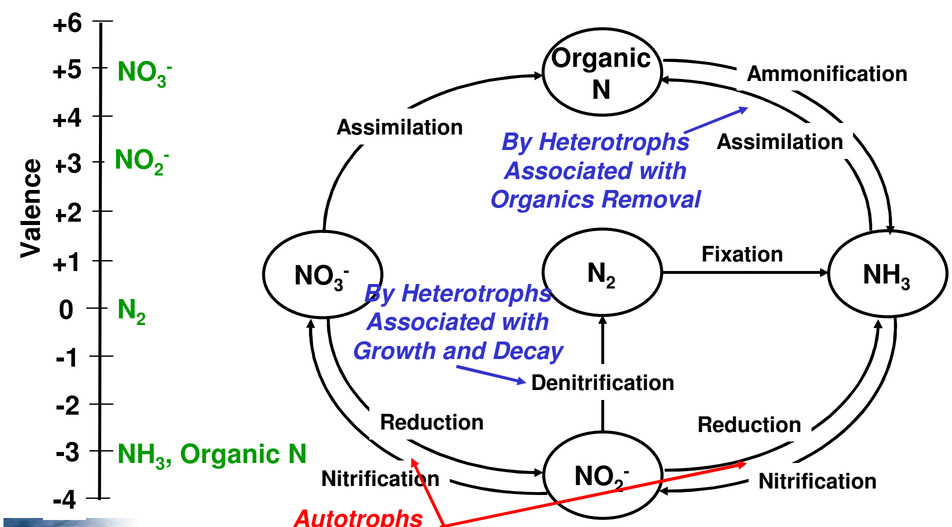
Biological Nitrogen Removal Is Driven by Nature's Nitrogen Cycle



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The Microbiological Cast of Characters in Nitrogen Removal

- Nitrification Accomplished by Autotrophs
  - Slow Growing
  - Low Yield
  - Consume Oxygen and Alkalinity
- Denitrification Accomplished by Heterotrophs:
  - Fast Growing
  - Require Carbon
  - Satisfy Oxygen Demand and Produce Alkalinity
- Numerous Process Configurations Available, Each with Own Characteristics

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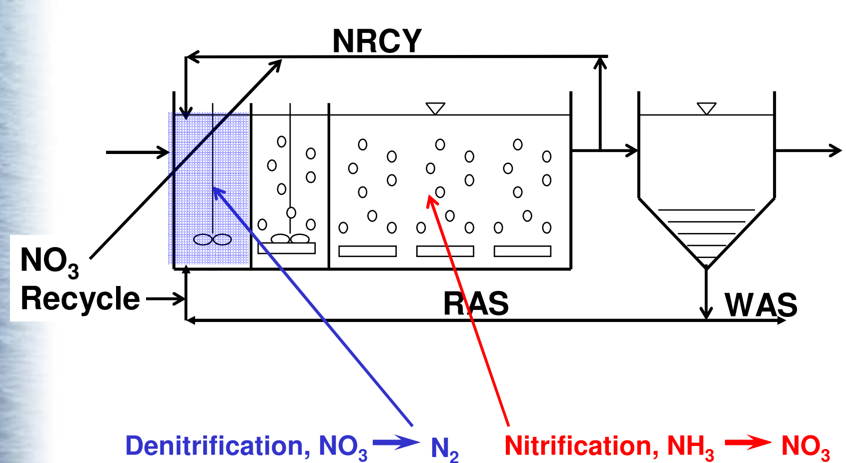
Nitrogen Removal Occurs by Anoxic & Aerobic Zones



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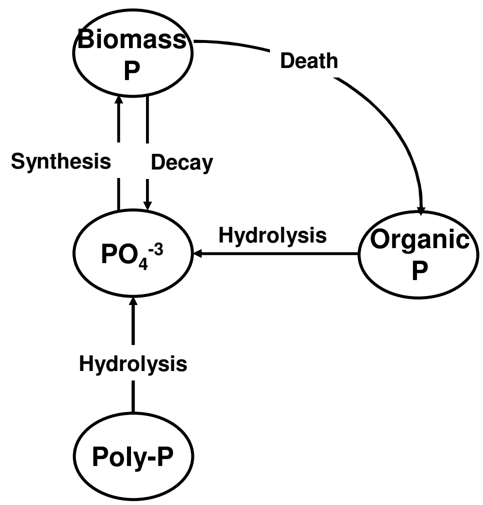
The Phosphorus Cycle: A Bit Simpler



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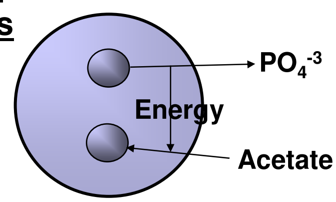
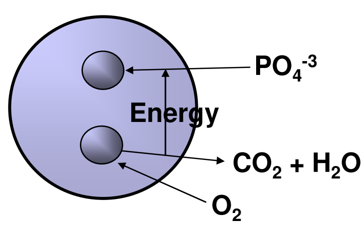
Phosphorus accumulating organisms (PAO's) Have Unique Anaerobic/ Aerobic Metabolism

<u>Anaerobic Conditions</u>



<u>Aerobic Conditions</u>



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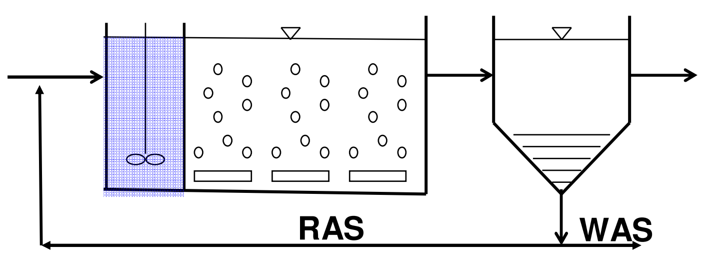
Manipulating Environmental Conditions are Key to Bio P Removal

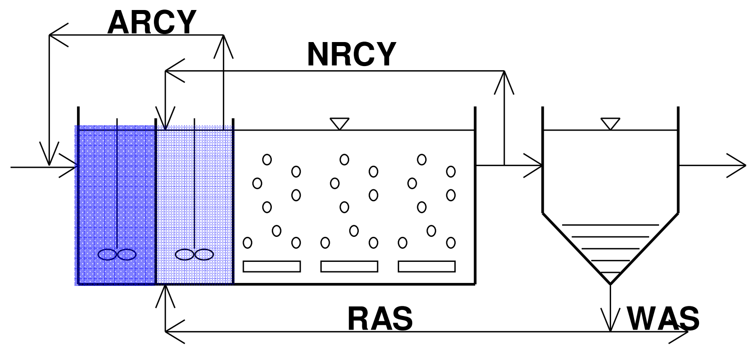
- Biological Phosphorus Removal Accomplished by Specialized Heterotrophs - PAOs
- Anaerobic/Aerobic Cycling with VFA's Present in Anaerobic Zone is Necessary
  - Sufficient VFA's Must be Available
- PAO's Grow Slower Than Most Heterotrophs But Faster Than Nitrifiers
- Nitrate Recycle to Anaerobic Zone Adversely Impacts Bio-P
- Several Process Options Exist

Bio-P Systems Provide Anaerobic/Aerobic Cycling



	Aerobic	Anaerobic
Oxygen	Yes	No
Nitrate	Maybe	No

N&P Removal Systems Include Anaerobic and Anoxic Zones



	Aerobic	Anoxic	Anaerobic
Oxygen	Yes	No	No
Nitrate	Maybe	Yes	No

BNR Fundamentals - Summary

- Succesful application of biological wastewater treatment processes depend on the understanding and application of nature's metabolic pathways
- Knowledge developed first from field observations, then harnessed by empirical applications, and eventually fully defined in the lab.
- Much is known, yet much more is still yet to be understood

TREATMENT PROCESS RECONFIGURATION OPTIONS FOR ADDRESSING KDHE'S NUTRIENT REDUCTION PLAN

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KDHE's Surface Water Nutrient Reduction Plan

Plan places Kansas in a Leadership Position in the Mississippi River Basin…

- Addresses State's eutrophication in surface waters, taste and odor in drinking supplies, and Gulf of Mexico hypoxia.
- Aims at 30% reduction of N&P from point and non-point sources
- Annual limits of 8 mg/l TN and 1.5 mg/l TP
- Facilities > 1 mgd; BNR preferred

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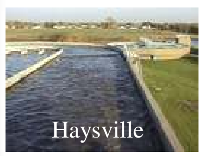
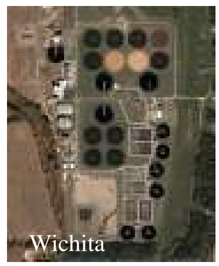
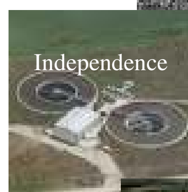
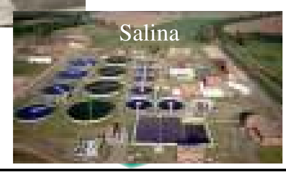
Wastewater Treatment in Kansas

- 85% of all wastewater comes from plants > 1 mgd.
- Many also incorporate NH_3-N treatment capabilities. A few N & P.
- Wide variety of process configurations.









Nitrogen Reduction

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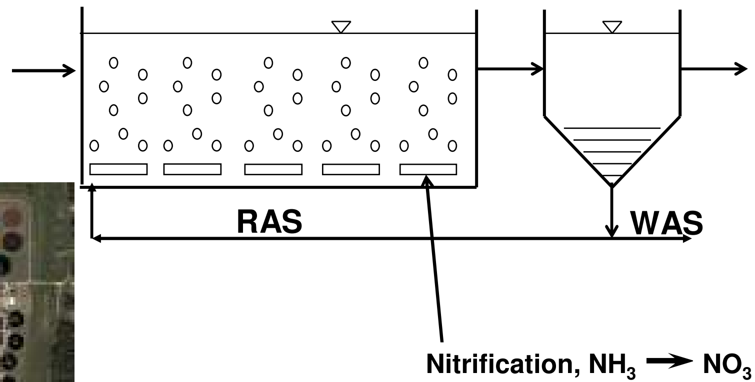
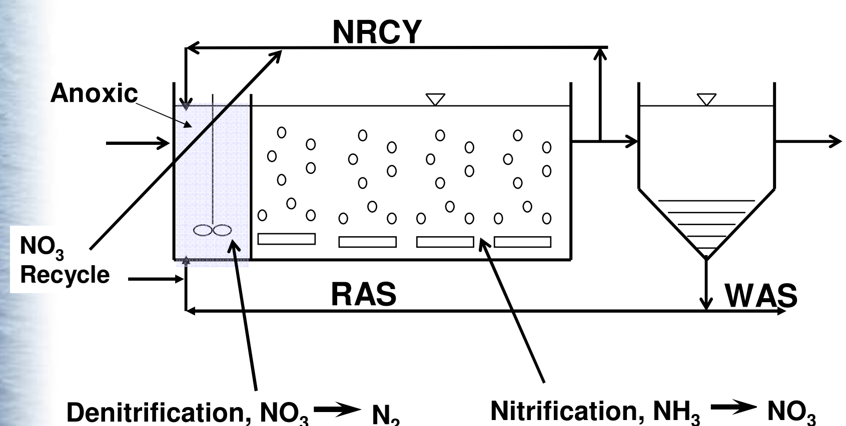
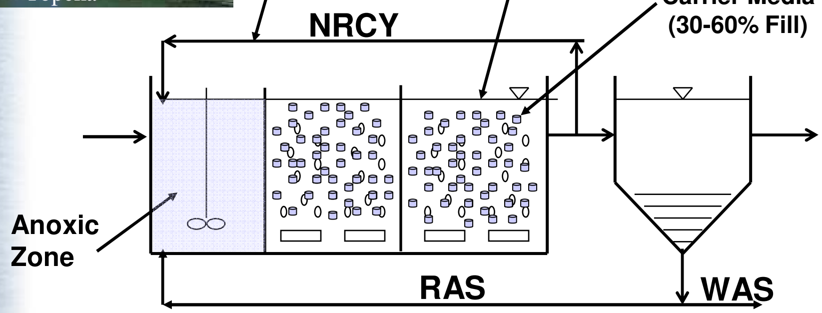
Modified Ludzak-Ettinger (MLE) is Basic N-deN Conversion Alternative



Modified Ludzak-Ettinger (MLE) is Basic N-deN Conversion Alternative



Integrated Fixed Film Activated Sludge (IFAS): Smaller Aeration Volumes for N Reduction



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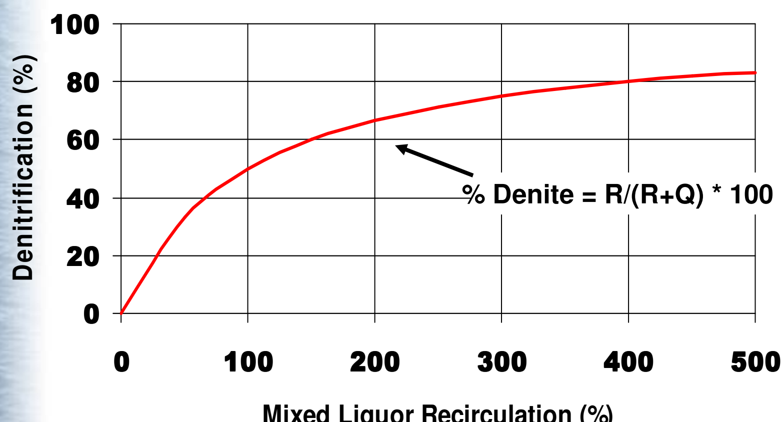
Denitrification is Controlled by Mixed Liquor Recirculation.



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Nitrification and Denitrification Affect Oxygen/Alkalinity

- Nitrification:
  - 4.6 mg O_2/mg NO_3-N Produced
  - 7.2 mg Alkalinity as $CaCO_3$/mg NO_3-N Produced
- Denitrification:
  - 2.86 mg O_2/mg NO_3-N Reduced
  - 3.6 mg Alkalinity as $CaCO_3$/mg NO_3-N Reduced

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Modified Ludzak-Ettinger (MLE) is Basic N-deN Process (Cont.)

- Benefits:
  - Good Nitrogen Removal
  - Moderate Reactor Volume
  - Alkalinity Recovery
  - Improved Sludge Settleability
  - Reduced Oxygen Requirements
  - Simple Control
- Drawbacks:
  - High Level of Nitrogen Removal Not Generally Possible

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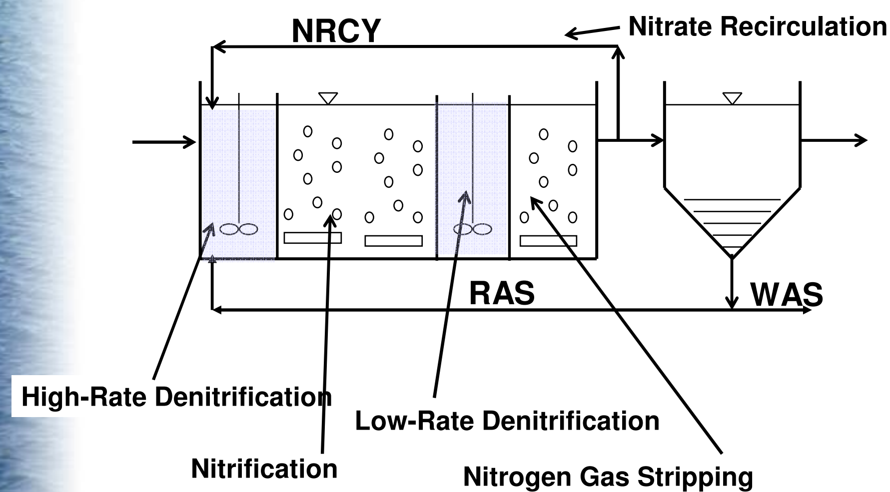
N-deN Systems Can Incorporate Several Anoxic Zones: 4 Stage Bardenpho



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Four-Stage Bardenpho Provides Further N-Removal (Cont.)

- Benefits:
  - Excellent Nitrogen Removal
  - Alkalinity Recovery
  - Good Solids Settleability
  - Reduced Oxygen Requirements
  - Simple Control
- Drawbacks:
  - Large Reactor Volume

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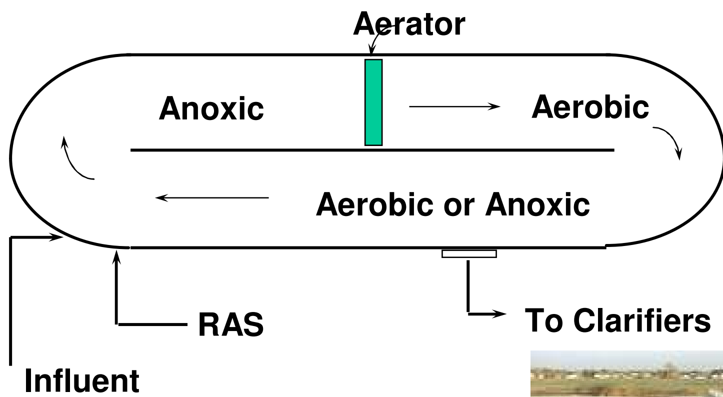
Oxidation Ditches Provide Effective Denitrification



Oxidation Ditches Provide Effective Denitrification (Cont.)

- Benefits:
  - Excellent Nitrogen Removal
  - Alkalinity Recovery
  - Reduced Oxygen Requirements
- Drawbacks:
  - Large Reactor Volume
  - Complex Control
  - Susceptible to Variable Loads
  - May Result in Poor Sludge Settleability

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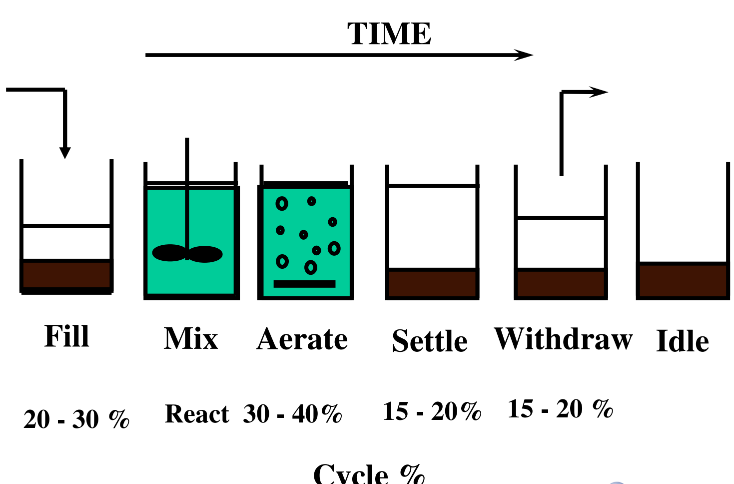
Phased Isolation Ditches

- Developed in Denmark
- Sequential aerated and unaerated conditions (similar to SBR although continuous flow)
- Separates aeration from mixing
- Operational flexibility by controlling duration of phases
- Can be used for N & P

Sequencing Batch Reactors can be Programmed to Achieve N Reduction



Sequencing Batch Reactors Achieve N-Reduction (Cont.)

- Benefits:
  - Good Nitrogen Removal
  - Alkalinity Recovery
  - Good Sludge Settleability
  - Reduced Oxygen Requirements
  - Operating Cycle Adjustable
- Drawbacks:
  - Discontinuous Discharge
  - Relatively Large Reactor Volumes

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Air Cycling Nitrogen Reduction

Alternating aeration creates aerobic/anoxic conditions

- Air on: BOD stabilization and nitrification
- Air off: BOD stabilization and denitrification
- Relatively simple operational change
- Mixers could be required
- Dynamic process simulation recommended

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Air Cycling Nitrogen Reduction

- Benefits
  - No facility modifications
  - No recirculation
  - Alkalinity Recovery
  - Good Sludge Settleability
  - Reduced Oxygen Requirements
- Drawbacks
  - Not for low N limits
  - Reduces nitrification capacity
  - Reduced operational options
  - Complex operation?
  - Best for long term (e.g. annual) requirements

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Phosphorus Reduction

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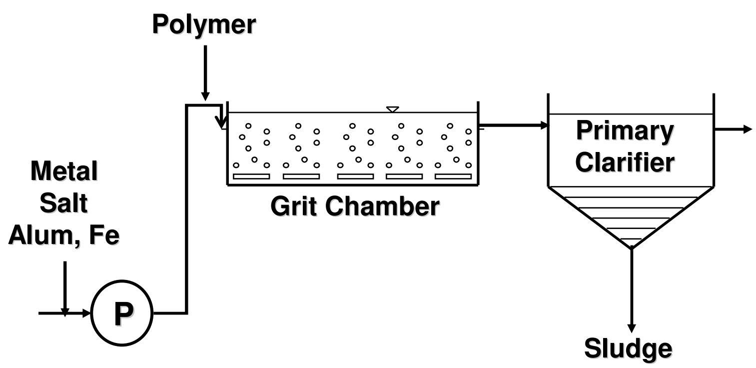
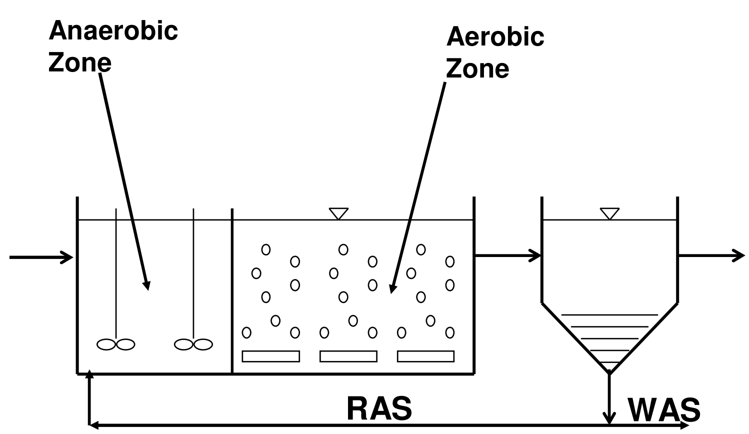
Chemical P Reduction can be Easily Incorporated into Primary Treatment Systems



A/O™ is Basic Bio-P Process



A/O™ is Basic Bio-P Process (Cont.)

- Benefits:
  - Minimum Reactor Volume
  - Good Phosphorus Removal
  - Good Solids Settleability
  - Simple Operation
- Drawbacks:
  - Phosphorus Removal Adversely Impacted by Nitrification
  - No Nitrogen Removal

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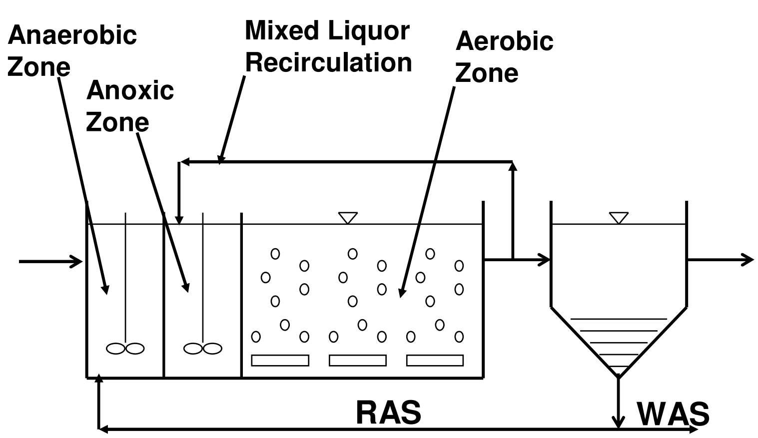
A²/O™ Provides N&P Reduction



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A^2/O^{TM} Provides N&P Reduction (Cont.)

- Benefits:
  - Good Nitrogen Removal
  - Moderate Reactor Volume
  - Alkalinity Removal
  - Good Solids Settleability
  - Reduced Oxygen Requirement
  - Simple Control
- Drawbacks:
  - High Level of Nitrogen Removal Not Generally Possible
  - Moderate Phosphorus Removal

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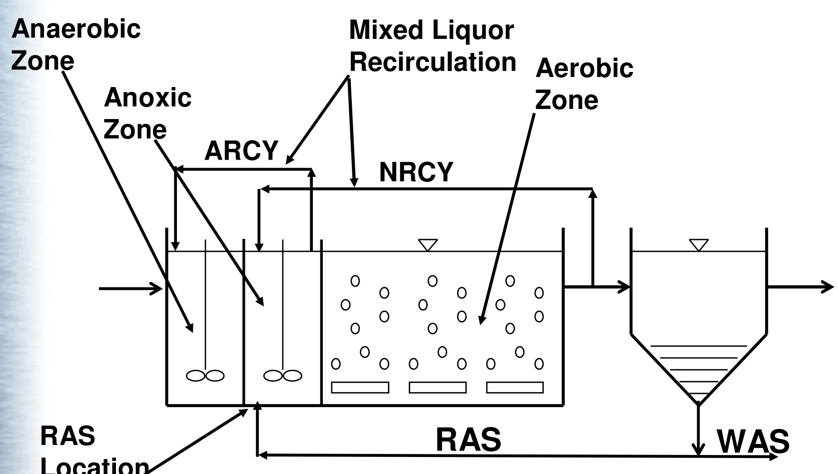
VIP/UCT Provides N and Enhanced P Reduction



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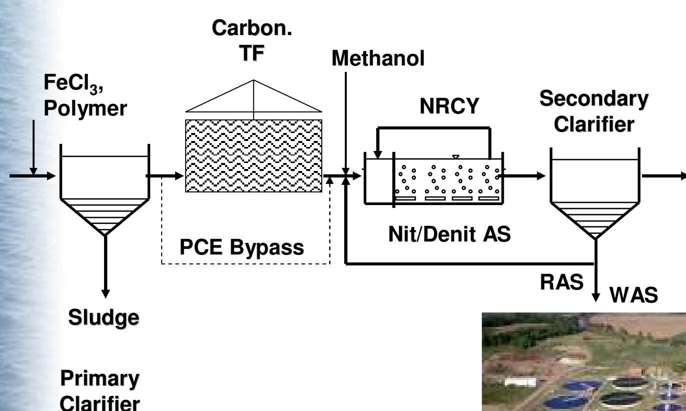
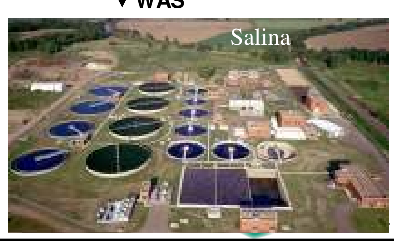
VIP/UCT Provides N and Enhanced P Reduction (Cont.)

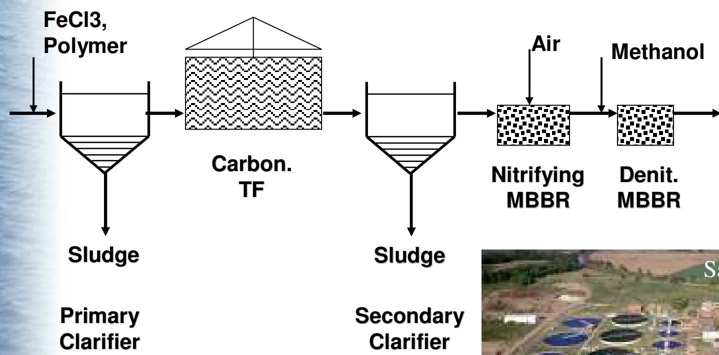
- Benefits:
  - Good Nitrogen Removal
  - Good Phosphorus Removal
  - Moderate Reactor Volume
  - Alkalinity Recovery
  - Good Solids Settleability
  - Reduced Oxygen Requirement
  - Simple Control
- Drawbacks:
  - High Level of Nitrogen Removal Not Generally Possible
  - Added MLR Step Required

Upgrading Trickling Filter Facilities By Adding Activated Sludge

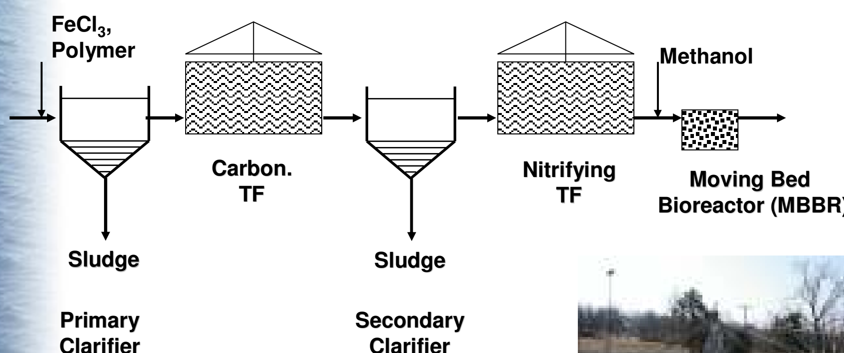




Upgrading Trickling Filter Facilities with Hybrid Processes

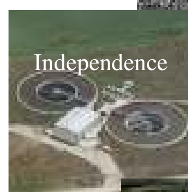


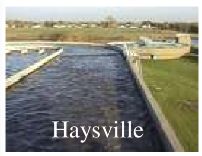
Upgrading Trickling Filter Facilities with Hybrid Processes

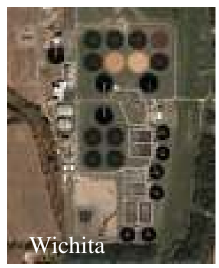


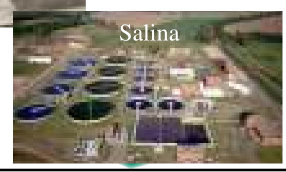
Reconfiguring for Nutrient Reduction

- You <u>will</u> have to provide for N & P reduction
- If you haven't started yet, you should….
- No silver bullet; many options
- Like a fine suit, yours need to be tailored to your needs.









TREATMENT PROCESS RECONFIGURATION OPTIONS FOR ADDRESSING KDHE'S NUTRIENT REDUCTION PLAN

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