INTRODUCTION TO NUTRIENT CONTROL FOR OHIO's MUNICIPAL WWTPs

Dale E. Kocarek, PE, BCEE
Stantec

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Objective of Presentation

- Understand why nutrient removal is a concern and why it is important at this juncture in time
- Gain an initial appreciation of what is involved

Why is Nutrient Removal Important?

- Ohio's In Stream Water Quality Standards cannot be met without addressing nutrients
- A strong link between blue green algae in Lake Erie and nutrients has been established.
- Dead zone in the Gulf of Mexico will continue to garner national attention and a "call to action."

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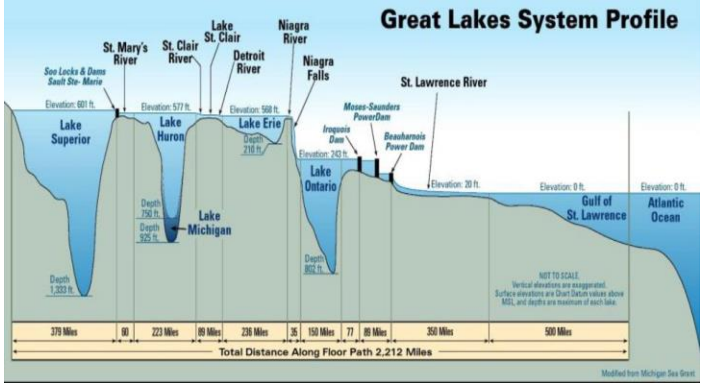
Ohio’s Future Nutrient Limits (TP)

- Total Phosphorus (TP) is priority in the next 5 years
- Expect mention of TP in the next permit cycle
- Initial TP limits for all entities will be set at 0.7-1.0 mg/l, but expect future lowering



The two photos on the right are from Jeffrey M. Reutter, Ph.D., Special Advisor, Ohio Sea Grant Program

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Important Terminology: Anoxic &Anaerobic

- ***Anoxic*** must not be confused for ***anaerobic***
- ***Anoxic*** *is a part of the respiration where the following ions are used (in order for the "terminal electron acceptor:*
  - *Oxygen*
  - *Nitrate*
  - *Sulfate*
- **Anaerobic** is a <u>completely</u> different pathway for organic stabilization and is done completely *without* air

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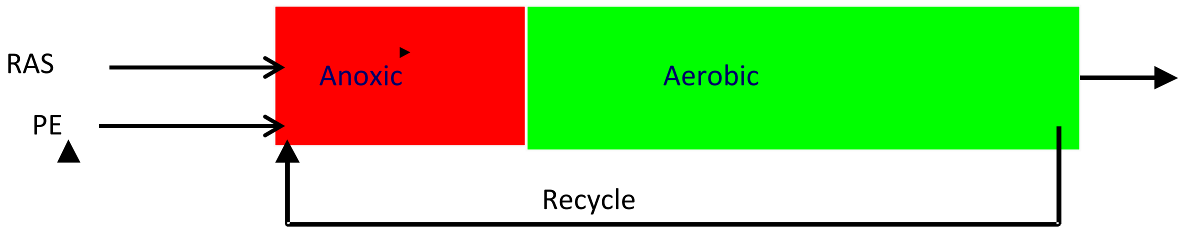
Important Terminology: Anoxic & Anaerobic

- ORP for different zones are:
- Oxic Zones > +100 mV
- Anoxic Zones – 50 mV to + 50 mV
- Anaerobic Zones < -150 mV
- Anoxic zones are relatively easy to create and normally require 4-6 hours of HDT
- Anaerobic zones must be entirely devoid of oxygen and normally require about 1-2 hours of HDT

Nitrification & De-Nitrification

- For activated sludge:
  - MCRT of > 10 days
  - DO > 3 mg/l
  - pH > 7.5 (Must have good Alkalinity)
  - Is temperature sensitive
- Nitrification consumes 7.1 mg/ alkalinity per mg of Ammonia-N and Denitrification restores 2.86 mg alkalinity per mg Nitrate-N converted

Idealized Reactor Configuration for Nitrogen Removal



- The MLE (Modified Ludzack Ettinger) is effective
- Reactor must be compartmentalized
- Anoxic zone removes Total Nitrogen
- No recycle pumping
- Easy to achieve < 10 mg/l in most facilities

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Important Aspects of Nitrogen Removal

- Some assimilation of nitrogen occurs (anyway) in biomass (12%) characterized as $C_5H_7O_2N$
- Must have anoxic zones operated at low DO (0.1-0.5 mg/)
- The reaction is temperature sensitive with Theta of about 1.06
- In retrofit applications, the addition of anoxic zones reduces oxic (aerated) capacity by < 20% (Be careful as this will de-rate a WWTP)

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Things to Know about Phosphorus

- Phosphorus is one of the most important elements in the world
- High quality Phosphorus is in short supply in the world
- In 1938 President Roosevelt spoke on the importance of high quality Phosphorus as critical to our national welfare
- Phosphorus is essential to life (ADP + P = ATP)
- The splitting apart of ATP is accompanied by a large release in energy
- Phosphorus is the easiest component to control for blue green algae

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Things to Know about Phosphorus

- TP includes may forms
- Approximately 85% of TP in raw sewage is Orthophosphate
- Average influent TP is 4-8 mg/l
- TP in raw sewage is lower now than it was in the early 1970s prior to the “phosphate ban”
- Effluent TP in MLSS is 50% soluble and 50% particulate (we will get back to this important point later)

Approaches for TP Removal

- Site and process specific
- Effluent requirements
- Typical approaches are biological and/or chemical
- Chemically removed using Iron or aluminum salts (traditional and relatively easy approach)
- Biological removal can achieve < 1 mg/l TP with no chemical sludge
- If Bio-P, there is usually chemical back up (high wet weather flows, etc.)

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Chemical Removal

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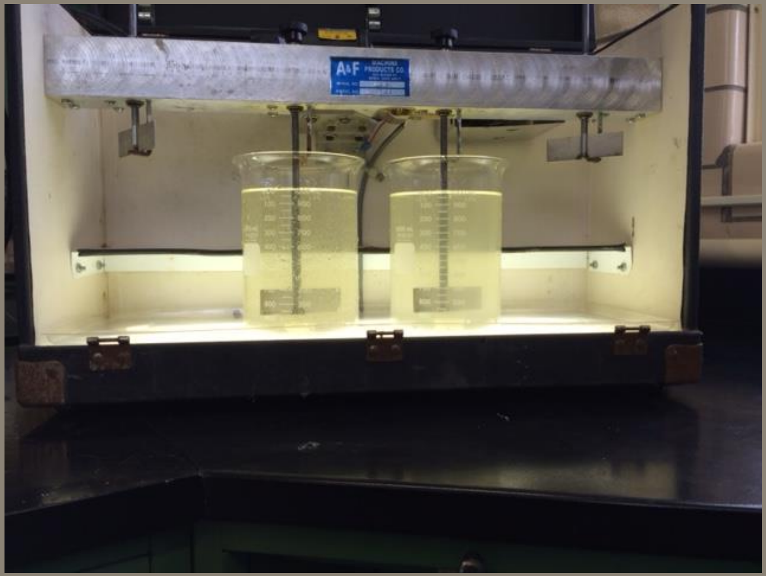
Chemical Removal

- Process can be optimized by the right chemical selection
- Options include ferrous and ferric chloride, Alum, Liquid Aluminum Sulfate (LSA), and other proprietary chemicals sold by vendors
- Removal is achieved by a combination of coagulation of colloidal solids: , conversion of soluble P to particulate P; enmeshment, and setting

Chemical Removal

- Invite vendors to perform jar testing
- Each wastewater is different
- Following jar testing, consider field trials for 30 days
- Observe under warm and cold weather
- % removals versus dose



Jar Test at the Napoleon WWTP

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Design/Operational Considerations

- Warm versus cold weather performance
- Other problems such as pH suppression
- Each wastewater is different
- Chemical delivery and handling
- Hose pumps and flow pacing

Alum Tank at the Napoleon WWTP

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Biological Phosphorus Removal

- Phosphorus Accumulating Organisms (PAOs) are created in anaerobic zones in presence of volatile fatty acids (VFAs)
- PAOs remove VFAs and release small amount of phosphorus during initial uptake phase
- Under aerobic conditions, PAOs assimilate phosphorus at enhanced rate of about 10 to 1

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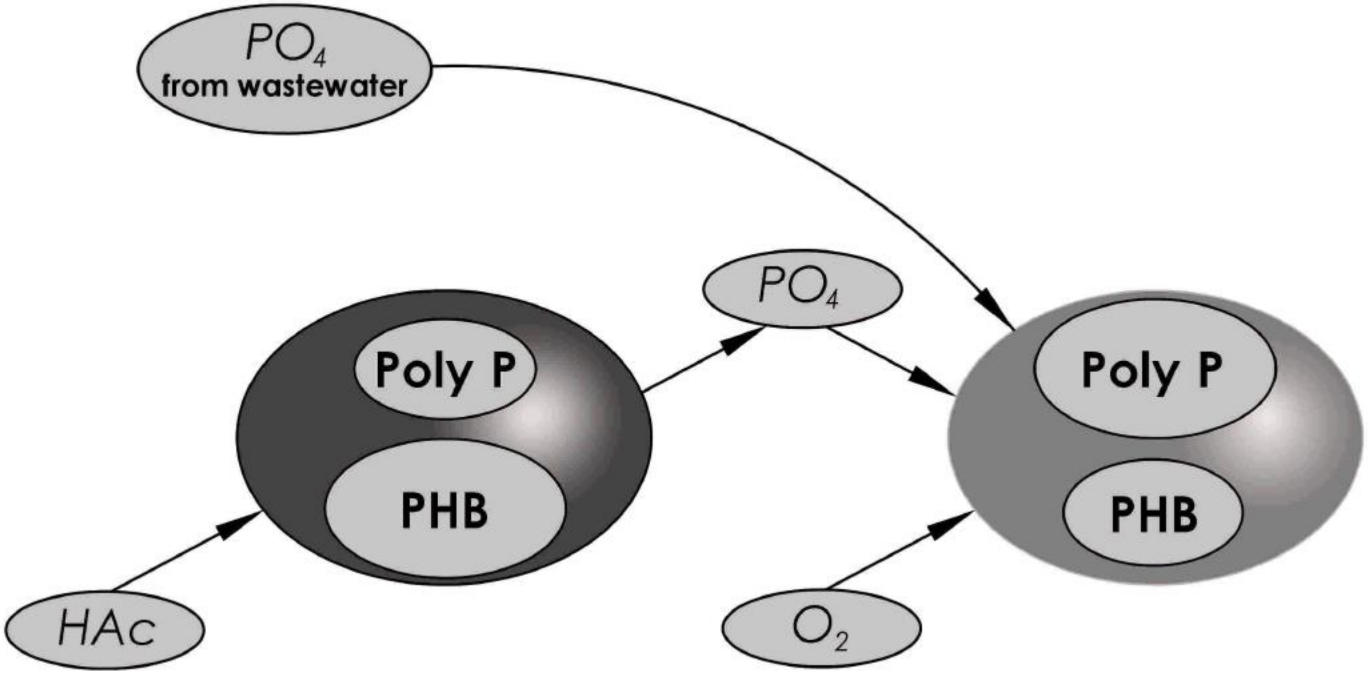
Biological Phosphorus Removal



Graphical Illustration of Bio-P Removal
Compliments of USEPA Control Design Manual, EPA/600R-09/012, 2009

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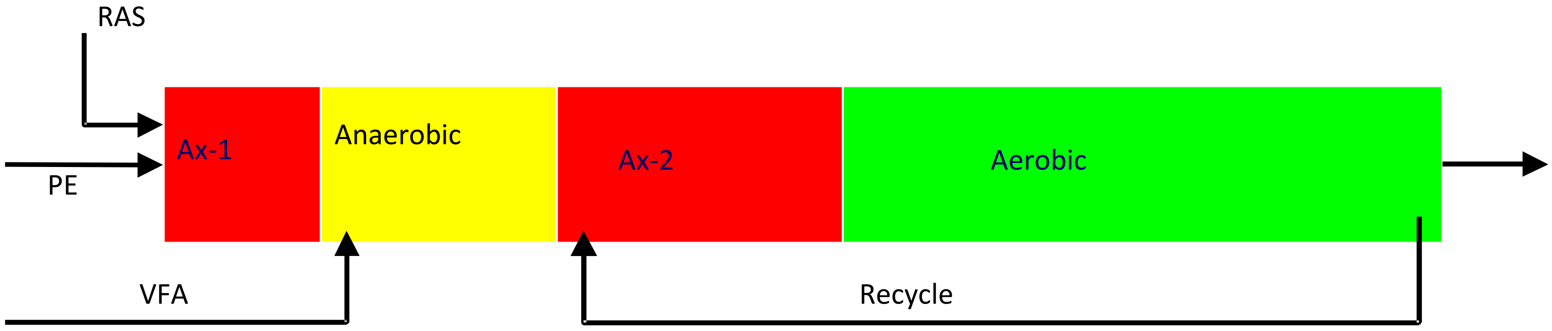
Idealized Reactor Configuration for Nitrogen and Phosphorus Removal



Modified Johannesburg (MJB) Process

- Modified Johannesburg (MJB) process is reliable for both TIN and TP
- Establishes dedicated anoxic and anaerobic zones
- The first anoxic cell removes nitrates from return activated sludge (RAS)
- The anaerobic cell is used for biological P removal
- Very effective process, but recycle flows must be carefully factored into the hydraulic design

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Design Considerations for Biological Phosphorus Removal

- Bio P depends on waste strength and concentration
- Soluble $CBOD_5$/TP <30 (VFA must be high to support the growth of PAOs
- To guarantee that $sCBOD_5$/TP < 30, some plants incorporate a fermentation process
- Fermentation tanks must be designed with robust odor control

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Nutrient Study- Background and Scope

- Planning study needed to address both wet stream, solids handling and space issues
- Must attempt to predict future effluent limits (where the puck is going to land versus where it is now)
- Chemical feed will add significantly to sludge handling
- Chemical removal will increase sludge mass by 5 times the mass of TP removed (not total sludge but that associated with TP)

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Levels of Investment (TP Control)

Technology	TP Conc.	Investment * (Magnitude)
Chem Feed	0.7-1.0 mg/l	Low
Bio P	0.5-1.0 mg/l	Low/Moderate
Effluent Filters	0.3-0.7 mg/l	Moderate
Post Step	< 0.3 mg/l	High

*Investment is for comparative purposes and depends on existing conditions, size of facility, and other necessary improvements

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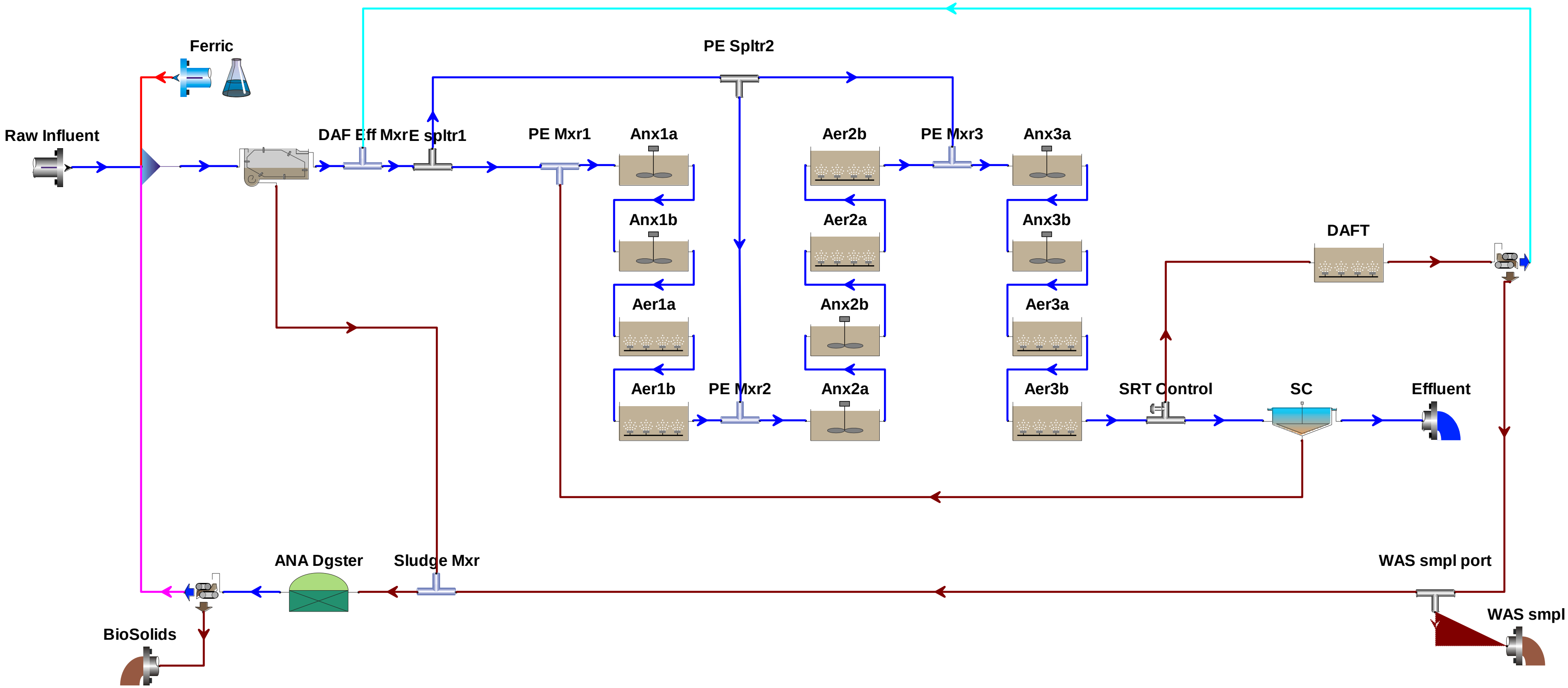
Levels of Investment (TN Control)

Technology	TIN Conc.	Investment * (Magnitude)
MLE	8-10 mg/l	Low
Step Feed	5-8 mg/l	Low/Moderate
Recycle Pumping	3-5 mg/l	Moderate
Post Step	< 3 mg/l	High

*Investment is for general comparative purposes only and depends on existing conditions, size of facility, reactor configuration and type .

Example of Biowin Modeling Template



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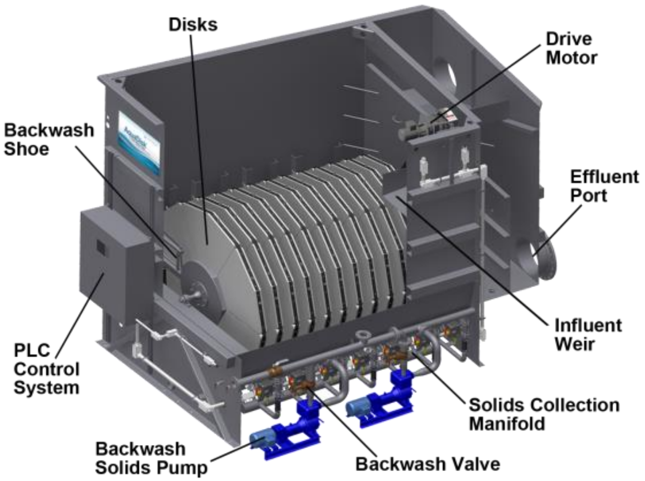
Nutrient Study- Alternatives Analysis

- Identify space and hydraulic grade line requirements
- Nitrification for most systems is a prerequisite
- Consider wet stream, solids handling, and space needs
- Filters are likely needed to achieve TP < 0.7 mg/l as target goals are usually 0.4 mg/l TP



Disc Type Filter for TP Removal

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Nutrient Removal for Small Systems

- Define small systems as < 0.25 MGD
- Small systems are intended to meet owner requirements of affordability and reliability
- Includes/emphasizes low tech/natural solutions
- Objective is to not add unnecessary complexity

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Nutrient Removal for Small Systems Based on Type

General Strategies for Nutrient Removal in Small Flow Systems				
Type	Technology	Ability to Achieve Nitrification	Ability for Nutrient Retrofit	Strategy
Pre-manufactured plants	Suspended Growth	Excellent	Relatively uncomplicated	Establish anoxic zones for TIN and chemical feed for TP
Oxidation Ditches	Suspended Growth	Excellent	May require hydraulic and external tanks for anoxic zones	Establish anoxic zones for TIN and chemical feed for TP
Recirculating Sand Filters	Attached Growth	Reasonable to > 3 mg/l	Requires hydraulic and external tank modifications and post step treatment.	Establish anoxic tank for TIN and chemical feed for TP.
Lagoons	Natural	Poor	Requires extensive modifications and post step treatment.	Post step treatment is required.
Wetlands	Constructed wetlands	Difficult to achieve < 5 mg/l	Precede wetland with aerobic system to reduce ammonia-N.	Wetlands must be sized for TIN and TP removal.
Non Discharging	Drip Irrigation or other	Must provide pretreatment	Removal through loading in soil matrix	Soil removal system

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Recirculating Sand Filter System

Unspecified Location, ORENCO

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Amesville WWTP, Non Discharging Decentralized System

Photo provided by Pejmaan Fallah, OEPA

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Example: Delaware County Scioto Reserve WWTP

Entrance to Scioto Reserve Community (Delaware County, Ohio)

- Capacity 424,000 GPD
- Residential golf course community
- Effluent pumped to holding impoundment and then to golf course
- Placed into service in 2000

Scioto Reserve WWTP Overview

- Delaware County Ohio
- Pre-manufactured WWTP
- Plant sized on typical waste strength values
- Effluent Reuse System

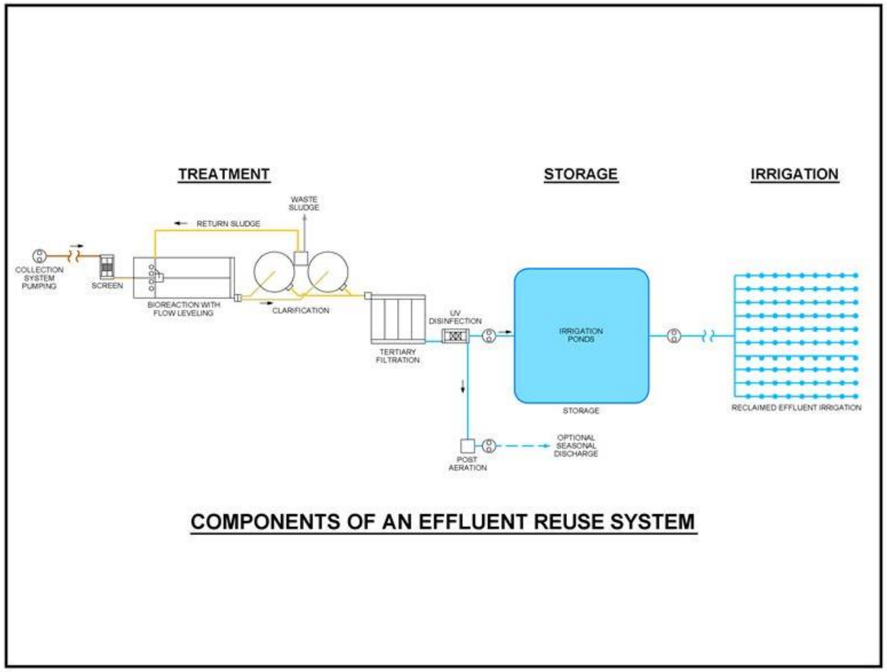

Figure 1: Components of a Typical Effluent Reuse System

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Scioto Reserve WWTP, Facts/Findings

- 2013 Plant study was done to define performance limiting factors and present after new NPDES permit was issued that required TN removal
- Anoxic zone for TIN removal (Aqua Aerobics Mixer supplied by J. Dwight Thompson
- Instrumentation was provided by YSI to monitor DO (YSI worked with County)

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Scioto Reserve WWTP, Baffle

Scioto Reserve WWTP Baffle Wall
Complements of the Delaware County Sanitary Engineering Department

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Scioto Reserve WWTP, Mixer

Floating Mixer
Complements of J. Dwight Thompson

Compartmentalizing a Bioreactor

- Marine plywood, redwood or fiberglass
- Not water tight
- Allow flow under and over – typically 20% over to minimize foam trap and 80% under to minimize hydraulic losses

In Conclusion

- A Master Plan is needed to consider all needs: future growth, wet weather, solids handling objectives, and space planning needs
- Plan must look at the future and determine the steps how the community will get there
- Understand where loads originate – solids handling from digestion/dewatering, pre-treatment, etc.
- Adaptive management in conjunction with Integrated planning may be one answer

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Future Opportunity

- The foundation of Ohio's Nutrient Rule will be a procedure called SNAP (Stream Nutrient Assessment Procedure)
- The SNAP is a "burden of proof" approach and not a "one size fits all" and includes:
  - Biological Community Indices
  - DO Swings
  - Chlorophyll A

Future Opportunity

- We believe that SNAP is an excellent tool if properly applied
- While this will not prevent the Ohio EPA from setting a TP limit of 1.0 mg/l, it may prevent it from going lower without a "burden of proof"
- SNAP requires adequate resources and data, which challenges the resources of the Ohio EPA

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