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June 22, 2015

OWEA PRECONFERENCE PRESENTATION

INTRODUCTION TO NUTRIENT CONTROL FOR SMALL COMMUNITIES

"NUTRIENTS 101"

Course Scope, Purpose & Objectives

- Emphasis is on small to medium sized communities
- Understand fundamentals of nutrient removal
- Understand how to begin to assess your system

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Why is Nutrient Removal Important?

- Nutrient removal is part of a nationwide trend
- For some impaired waters, Water Quality Standards cannot be met without addressing nutrients
- Greater linkages between drinking water source contamination and nutrients are documented
- Dead zone in the Gulf of Mexico from the Mississippi Basin raised the discussion to a national issue

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Status of Nutrient Rule

- The Ohio EPA Nutrient Technical Advisory Group (TAG) is concluding its work
- The TAG was an ad hoc steering committee and included active participation by the Ohio EPA
- The Ohio EPA intends to issue Draft Nutrient Rules in 2015 with a Final Rule in 2016

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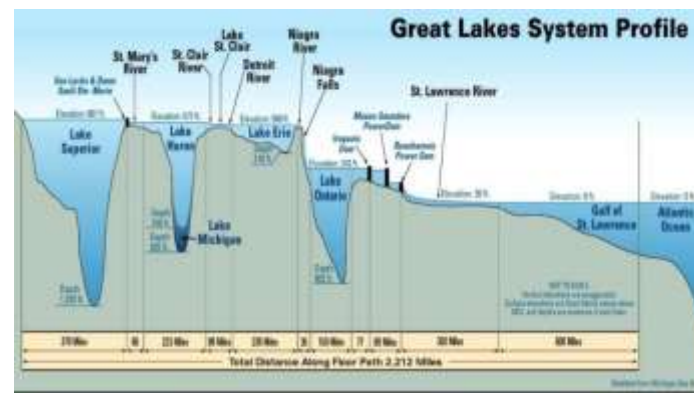
Ohio's Future Nutrient Limits (TP)

- Total Phosphorus (TP) is Ohio's first priority
- Expect mention of TP in the next permit cycle
- Initial TP limits may 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

Ohio's Future Nutrient Limits (Total Inorganic Nitrogen)

- Many Ohio POTWs have an Ammonia-N limit
- Few currently have a Total Inorganic Nitrogen (TIN) limit
- Total Inorganic Nitrogen (TIN or DIN) = Ammonia N + Nitrite N + Nitrate N
- In the future, expect to see limits TIN limits of 6 -10 mg/l based on findings from the Gulf of Mexico

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What is needed for Nitrogen Removal?

- The ability to remove Ammonia-N to low levels is required
- Suspended growth process is the easiest way to achieve low Ammonia-N removal, which is a foundation for TIN removal
- Biotower and natural systems can nitrify well, but it is typically harder to achieve complete nitrification in these systems unless special provisions are made

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Steps in TIN Removal

NITROGEN IN ITS VARIOUS FORMS IN MUNICIPAL WASTEWATER			
Name	Chem.	Oxidation State	**Notes**
Total Kjelhahl Nitrogen	TKN	0	**TKN is organic nitrogen and ammonia-N**
Ammonia-N	NH_3-N	-3	**Hydrolysis converts organic N to NH_3-N**
Nitrite-N	NO_2^-	+3	**Long SRT and Nitrosonomas. (Quick intermediate step to nitrate)**
Nitrate-N	NO_3^-	+5	**Long SRT, nitrite converted to nitrate with Nitrobactr.**
Nitrogen gas	**N_2 (g)**	**0**	**Nitrate is reduced to nitrogen gas under anoxic conditions**

Notes

TKN = Organic Nitrogen + Ammonia-Nitrogen

Organic – N hydrolyzes quickly to Ammonia - N

TKN > Ammonia –N

$NH_4 + + 2O_2$ + bacteria $= NO_3^- + 2H^+ + H_2O$

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Facts about Nitrification

- For activated sludge:
  - MCRT of > 10 days
  - DO > 3 mg/l and pH > 7.5
  - Full and sustained nitrification
  - Is temperature sensitive
- Nitrification consumes 7.1 mg/ alkalinity per mg of Ammonia-N
- Alkalinity concentrations > 100 mg/l recommended
- Denitrification restores 2.86 mg alkalinity per mg Nitrate-N converted

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Process Benefits of Nutrient

- General improved performance due to mixed cells in series reactor configuration
- Control of some filamentous organisms
- Alkalinity recovery in anoxic zones
- Bio P removal increases mass density of MLSS
- Keeps final clarifier blankets from “popping up” in low flows
- Useful for high flow management

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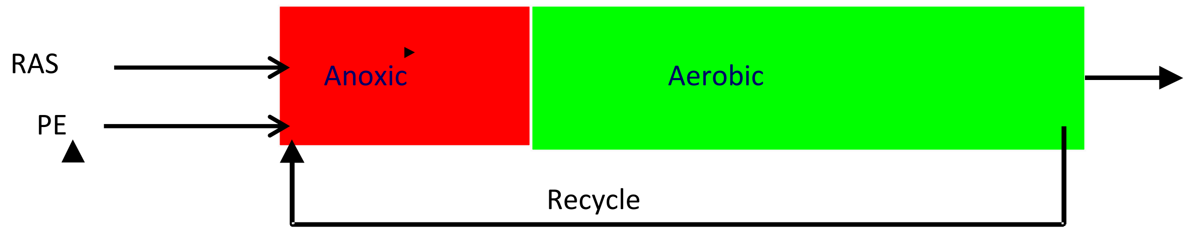
Idealized Reactor Configuration for Nitrogen Removal (Only)



- For limits of 6 - 10 mg/l TIN likely in Ohio, the MLE (Modified Ludzack Ettinger) process will be effective
- No additional recycle pumping loops are necessary
- The reactor must be compartmentalized

What is required for TIN Removal?

- Some assimilation of nitrogen occurs in biomass (12%) characterized as $C_5H_7O_2N$
- Must have anoxic zones operated at DO concentrations of 0.2 - 0.5 mg/l
- Removal of organic carbon (BOD), but no removal of Ammonia-N
- The reaction is temperature sensitive
- In retrofit applications, the addition of anoxic zones reduces oxic (aerated) capacity

Things to Know about Phosphorus

- Sewage is dominated by Orthophosphate
- The concentration of TP reaching a WWTP is 4-8 mg/l with an average of about 6 mg/l
- Effluent TP in MLSS is typically 50% soluble and 50% particulate
- Filtration is important for effluent concentrations < 0.5 mg/l)

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Approaches for Removal of Total Phosphorus

- Iron or aluminum salts chemically bind phosphorus
- Typical chemicals include Alum, Ferric/Ferrous Chloride or Sodium Aluminate
- Biological removal can achieve < 1 mg/l TP and generates no chemical sludge
- One popular approach to enhance reliability is to use biological P removal with chemical back up

Anoxic Versus Anaerobic

- ***Anoxic*** is different than ***anaerobic***
- Bacteria in anoxic zones use, in preferential order, oxygen, nitrate ion, sulfate ion to complete the respiration process
- Anaerobic bacteria function only in the complete absence of air
- ORP for Anoxic are – 50 mV to + 50 mV
- ORP for Anaerobic are < 100 mV

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Mechanism of Biological Phosphorus Removal

- Special bacteria called PAOs are created in anaerobic zones in presence of volatile fatty acids (VFAs).
- PAOs remove VFAs and release small amount of phosphorus in the anaerobic zone during initial uptake phase
- Under aerobic conditions, PAOs assimilate phosphorus at greatly enhanced rate, which is why it works!

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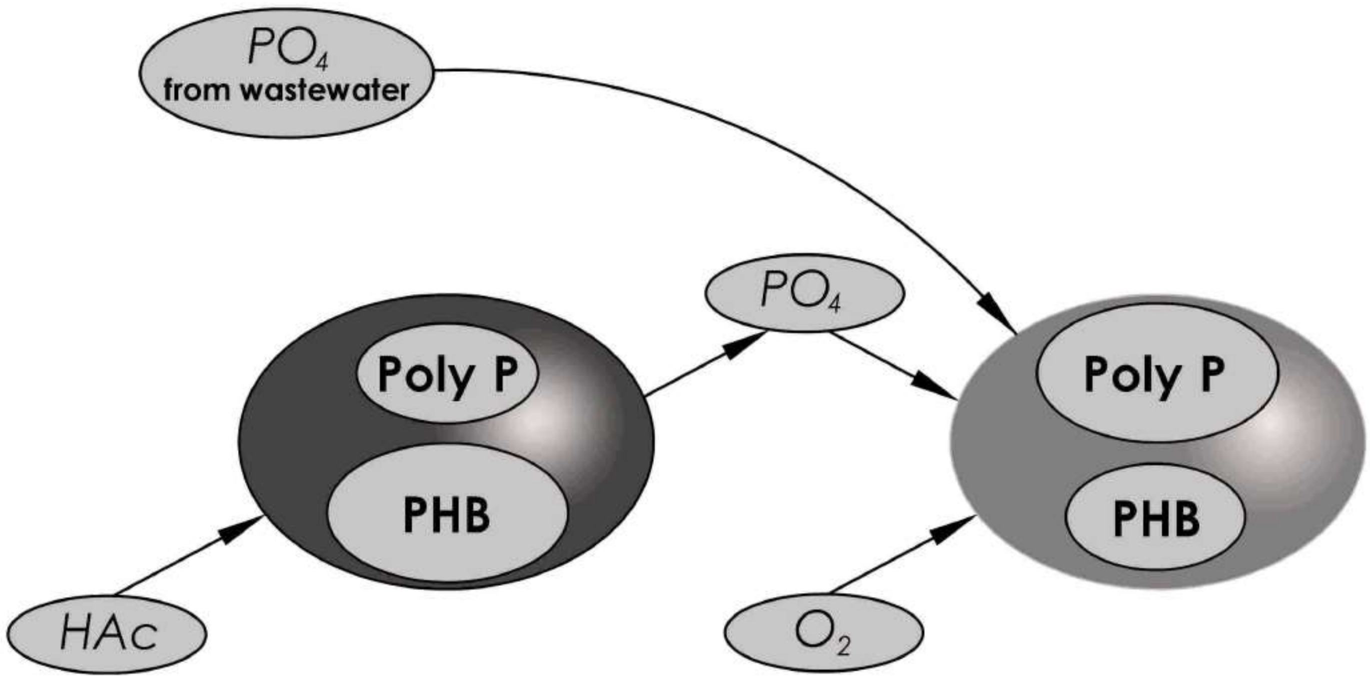
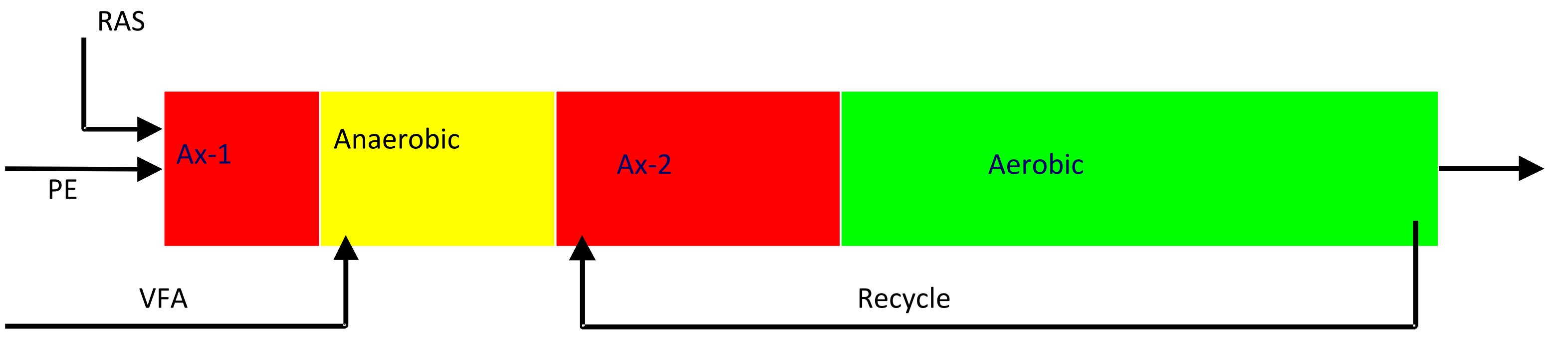
Biological Phosphorus Removal



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

Idealized Reactor Configuration for Nitrogen and Phosphorus Removal



Modified Johannesburg (MJB) Biological Nutrient Removal Process

- The 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

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Design Considerations for Biological Phosphorus Removal

- Process effectiveness depends on waste strength and concentration
- Soluble $CBOD_5$/TP <30
- VFA must be high to support the growth of PAOs
- Wet weather flows may impact waste strength
- To guarantee that $sCBOD_5/TP < 30$, some plants incorporate a fermentation process

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Alternatives for Control of TP

- Single or multi-point chemical feed using Alum, Ferric Chloride or Sodium Aluminate
- Tertiary filtration to meet limits $\leq$ 0.5 mg/l
- Optimization of final clarifiers, aeration system, enhanced baffling may help
- Side stream to reduce spike loadings
- Bio-P removal with or without fermentation

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Fermentation for Biological Phosphorus Removal

- Normally VFAs are produced when waste strength is high
- Fermentation may be necessary to provide sufficient VFAs deficiencies
- Typically a fraction of the primary sludge or WAS is diverted and retained into a covered and mixed tank until it hydrolyzes and forms VFAs
- Fermentation generates odor so special considerations are needed for odor control

Nutrient Study- Background and Scope

- A study is recommended to address both wet stream and solids handling issues
- One must consider near and long term needs and consult the Ohio EPA at the on set
- Integrate other needs into the study to help add value to the initiative.

Levels of Investment (TP Control)

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

*Investment is for general comparative purposes only and depends on existing conditions, size of facility, and other necessary investments in hydraulic modifications and pumping. It should be noted that the application of technologies is cumulative.

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Levels of Investment (TIN 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 . It should be noted that the application of technologies is cumulative.

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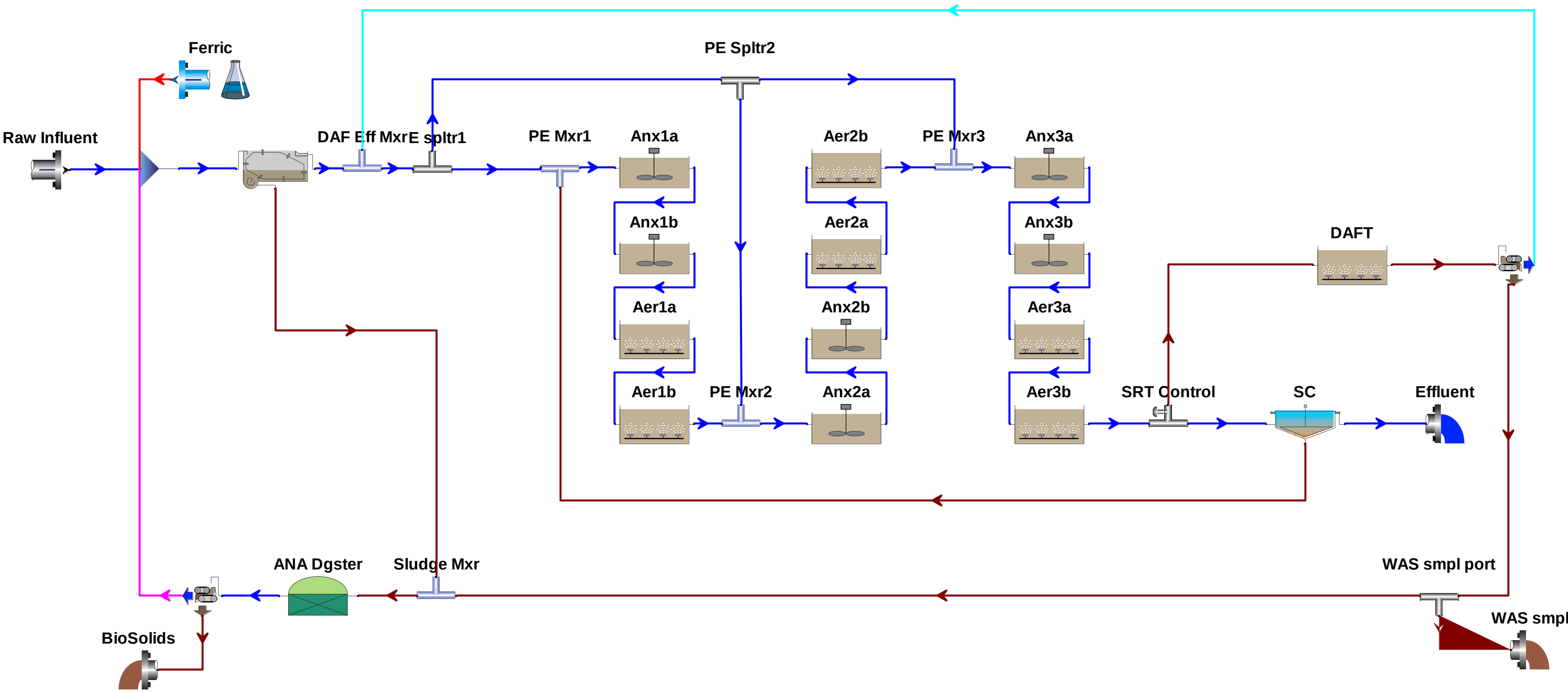
Nutrient Study- Sampling and Load Analysis

- Understand magnitude and variability of loads
- Benchmark current system performance
- Supplemental sampling to quantify recycle streams
- Develop appropriate model, which can be desktop or computerized

Example of Biowin Modeling Template



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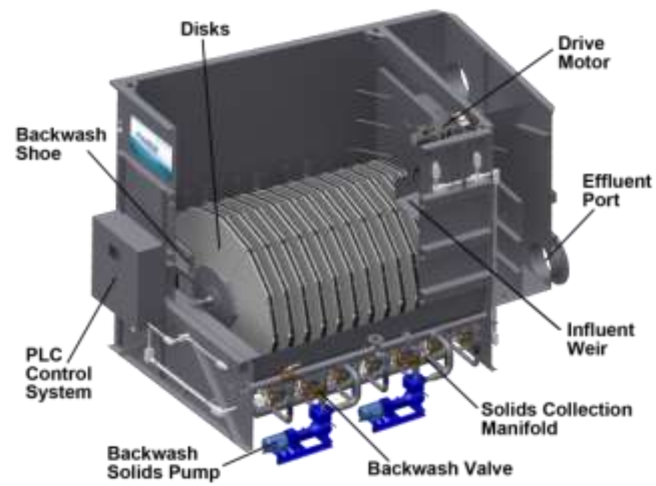
Nutrient Study- Alternatives Analysis

- Identify space and hydraulic grade line requirements
- Recycle stream leveling may reduce spike loadings
- Nitrification and aeration optimization may be required
- Final clarifier baffling to reduce effluent TSS



Disc Type Filter for TP Removal

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Nutrient Removal for Small Systems

- Define small systems as < 0.50 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

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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Pre-Manufactured System

Village of Richmondale

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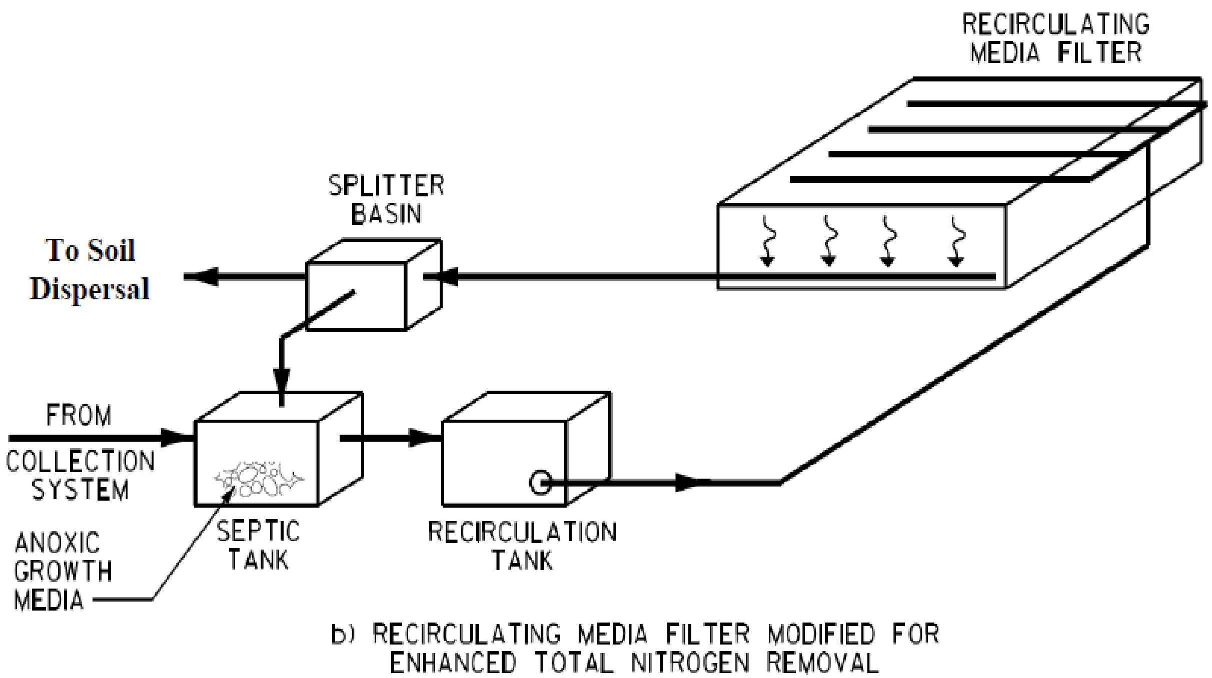
Schematic Diagram of Recirculating Sand Filter System

Compliments of USEPA Control Design Manual, EPA/600R-09/012, 2009



Recirculating Sand Filter System

Unspecified Location, ORENCO

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Decentralized Systems

- Small with discharges < 15,000 GPD
- Multiple facilities may exist in an area
- Rely on good pretreatment recirculating sand filters (RSFs) and incorporation of effluent into the soil in smaller systems
- Must be protective of ground water

Amesville WWTP, Non Discharging Decentralized System

Photo provided by Pejmaan Fallah, OEPA

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Example: Delaware County Scioto Reserve WWTP

- Effluent reuse on 18 hole golf course
- Capacity 424,000 GPD to BADCT treatment
- Effluent pumped to holding impoundment and applied to golf course
- Placed into service in 2000

Entrance to Scioto Reserve Community (Delaware County, Ohio)

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Scioto Reserve WWTP Operational Problems

- Located in Delaware County Ohio
- Pre-manufactured WWTP
- Plant sized on typical waste strength values
- Effluent Reuse System
- In service since 2000

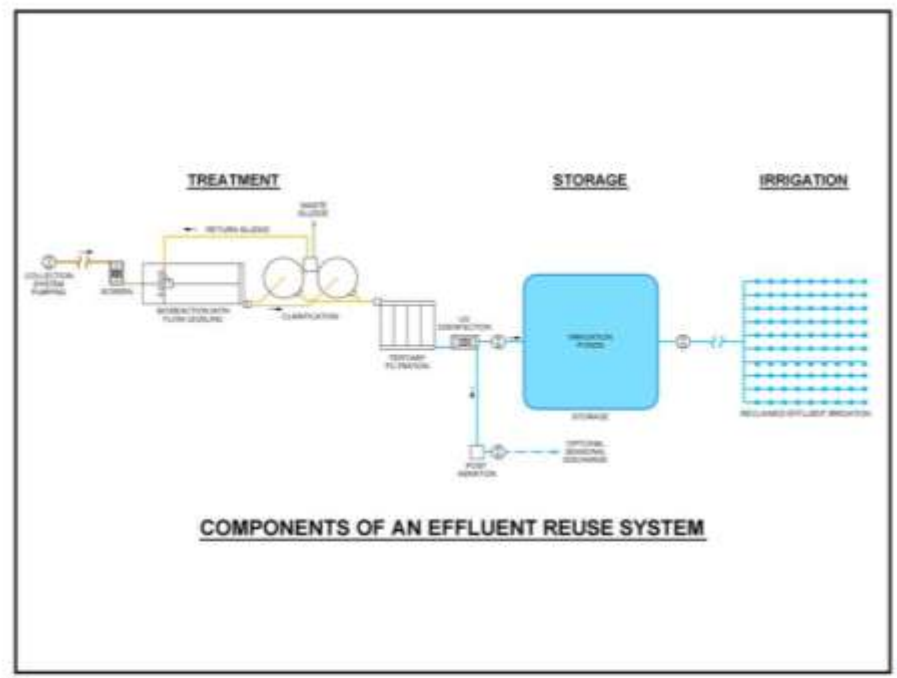

Figure 1: Components of a Typical Effluent Reuse System

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Scioto Reserve WWTP, Facts/Findings

- Study drivers included new NPDES permit with TIN limit
- Developer wanted to add more customers
- Plant was experiencing NPDES permit violations

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Scioto Reserve WWTP, Facts/Findings

- 2013 Plant study was done to define performance limiting factors and present possible solutions Stantec Consulting
- Anoxic zone for TIN removal (Led by Delaware County with Aqua Aerobics Mixer supplied by J. Dwight Thompson
- Instrumentation was provided by YSI to monitor DO (Rob Smith of YSI worked with Delaware County, and Ohio EPA Compliance Assistance Unit. Article published in May 2015 *Water &Wastes Digest,* page 26)

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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

Scioto Reserve WWTP, Before/After

Before

- Ammonia-N Violations
- Sludge Foaming due to *Microthrix Parvicella*
- Insufficient air to meet process needs
- Inability to meet NPDES TIN limit of 10 mg/l

After

- No Ammonia-N Violations
- TIN effluent of 6 mg/l
- Foaming issues subsided
- Anoxic zone offsets aeration demands
- 6 YSI monitors provide information

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Compartmentalizing a Bioreactor

- Marine plywood, redwood or fiberglass are good options
- Being water tight is not necessary
- Allow flow under and over to minimize headloss and scum accumulation

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Class Example

- Handout to be provided
- Calculate size of anoxic zone for TIN to meet effluent limit of 8 mg/l
- Chemical dose for TP removal to meet effluent limit of 1 mg/l

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In Conclusion

- A good plan is needed
- Plan must address the present and future needs
- Consider phased implementaiton
- Understand where loads originate
- TP removal will increase sludge generation


Questions &
Discussion