Treatment Facility Technologies and Costs for Phosphorus Removal

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TOPICS COVERED

Technologies
- Disc Filtration
- Ballasted Setting
- Continuous BackWash Filter
- Membrane Bioreactors (MBR’s)

Levels of Treatment

Costs

Sizing
PRESENTATION WILL NOT COVER

- Regulations
- Nutrient Trading
- Adaptive Management
DISC FILTER APPLICATIONS

- Effluent Filtration
- Water Re-use

- Phosphorus Reduction
- CSO/SSO
DISC FILTER OPERATION

- Gravity Flow
- Partially Submerged
- Stationary Filter Discs
- Automatic Operation
- Continuous Operation
DISC FILTER INSTALLATION
(Concrete)
DISC FILTER PERFORMANCE (Turbidity)

Influent Turbidity, NTU vs. Effluent Turbidity, NTU

- Upflow
- Dual-medium
- Deep-Bed
- Mono-medium traveling bridge
- Dual-medium traveling bridge
- AAS CMDF
- Disc Filter
OCONOMOWOC, WI
TERTIARY POLISHING
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TERTIARY POLISHING
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TERTIARY POLISHING
<table>
<thead>
<tr>
<th>Phosphorus Levels</th>
<th>Technology</th>
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<tbody>
<tr>
<td>1.0 mg/l</td>
<td>Coagulant</td>
</tr>
<tr>
<td>0.50 - 0.30 mg/l</td>
<td>Multipoint coagulant addition, Assisted with biological</td>
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<tr>
<td>0.30 - 0.20 mg/l</td>
<td>Coagulant, Biological, Coagulant and Polymer, Disc Filter</td>
</tr>
<tr>
<td>&lt; 0.20 mg/l</td>
<td>Coagulant, Biological, Coagulant and Polymer, Disc Filter</td>
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COAGULATION/FLOCCULATION PRIOR TO FILTRATION

- **Secondary Clarifier Effluent**
- **Coagulant**
- **Coagulation (3 - 5 min HRT)**
- **Static Mixer**
- **Polymers**
- **Flocculation (3 - 6 min HRT)**
- **Disc filter**
- **Filtered Effluent**
PILOT STUDY - CLINTON, MA (MARCH/APRIL 2011)

- Disc Filtration used for total Phosphorus removal - <0.10 mg/L

- Normal and Stressed Conditions

- Ferric Chloride and Aluminum Sulfate Used
CLINTON, MA

Clinton, MA Kruger Disc filter Pilot Study
Week Four - April 18 to April 22

Total Phosphorus (mg/l)

Sample Date / Composite Duration

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

Influent TP
Effluent TP
Polymer molecules bridge between suspended particles, “glue” them together as “flocs”, and concentrate the solids.
BALLASTED SETTLING - FLOC PARTICLE

Particles acquire 2.65 S.G. For Enhanced Settling

~ 150 µm
BALLASTED SETTLING - COAGULATION/FLOCCULATION

Secondary Clarifier Effluent → Static Mixer → Coagulation (3 - 5 min HRT) → VFD → Flocculation (3 - 6 min HRT) → VFD → Polymer → Coagulant
BALLASTED SETTLING - PROCESS SCHEMATIC

- High Rate Clarifier, 30-50 gpm/ft²
BALLASTED SETTLING - HYDRO CYCLONE SLUDGE SEPARATION

SLURRY
FEED
OVERFLOW
(SLUDGE)

SLURRY
FEED

AIR CORE

INNER
VORTEX

APEX

UNDERFLOW
(SAND)

OUTER
VORTEX

APEX
BALLASTED SETTLING - CALDWELL, ID PILOT STUDY RESULTS
EXTENDED RUN WITH FERRIC CHLORIDE

- Bio-P Selector Bypassed
- Influent Total Phosphorus Increased from 0.3 mg/l to 3 mg/l
- Achieve 70 ppb Effluent Total Phosphorus
CONTINUOUS BACKWASH FILTER

- Regenerative Adsorptive Column
- Coagulant Ferric Sulfate or Ferric Chloride
CONTINUOUS BACKWASH FILTER

Headworks

Biological System

Secondary Clarifier

Back Wash Filter

RAS

Digest

WAS

Solids

Dewatering

Reject Recycle

Optional 2nd Pass

Optional 2nd Pass

Ruekert Mielke

engineering solutions for a working world
CONTINUOUS BACKWASH FILTER

Secondary Effluent → Rapid Conditioning Zone

Water

Particles

HFO Sand Grain

Fe PO₄

Fe O Fe O Fe O
CONTINUOUS BACKWASH FILTER

- Hydrous Ferric Oxide-Coated Sand
  - Images from scanning electron microscopy
- X-ray Flourescence
CONTINUOUS BACKWASH FILTER

Total Phosphorus (mg/L)

Date (month/day)

1st Pass
2nd Pass
MBR PROCESS

- Screening & Grit Removal, ≤ 2mm
- Biological Reactors
  - N-DN
  - Bio-P
- Membrane Tanks
  - Mixed Liquor Pumps (WAS)
  - Permeate Pumps
MBR - MEMBRANES

Number of pore ($10^{12} / m^2$) vs. Pore diameter (micron)

- PVDF Membrane
- Type B
- Choice “A”

Membrane: 3.0 micrometer

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engineering solutions for a working world
MBR FLUX & PRESSURE
Comparison of Immersed Membrane Modules

MLSS: 10,000 mg/l

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FLAT SHEET MEMBRANE

- 0.08 μm nominal pore size
- ~15 ft² (~1.4m²) per element
- 5.3’ High x 1.7’ Wide x 0.04’ Thick
PHASED MBR - N-DN PROCESS

DENITRIFICATION

NITRIFICATION

4-5Q Sludge Recycle
PHASED MBR - WITH BIO P REMOVAL

Selector

DENITRIFICATION

NITRIFICATION

4-5Q Sludge Recycle

MBR

MBR

MBR

MBR
MBR OPERATING MODES: FILTRATION AND RELAXATION MODE

Relaxation (Intermittent Filtration)
10 minute cycle: 9 minutes filtration followed by 1 minute relaxation and suspension of permeate (aeration is continuous)
MBR - MEMBRANE TANKS
MBR - BERMUDA

- Operating since Oct 2009
- 0.25 MGD
- Gravity Flow Permeate
- Membrane Thickening
MBR - MEMBRANE TANKS

- Two tanks - Five modules each
- Membrane thickening: One tank, one module
LEVELS OF TREATMENT

Approximate

- Disc Filtration > 0.15 mg/L TP
- Ballasted Settling > 0.06 mg/L TP
- Continuous Back Wash Filter < 0.06 mg/L TP
- MBR < 0.06 mg/L TP
WHICH TECHNOLOGY?
EQUIPMENT COSTS FOR PHOSPHORUS REMOVAL

- Disc Filters >=0.15 mg/L TP
- Ballasted Settling >=0.06 mg/L TP
- Membranes <0.06 mg/L TP
- Continuous Backwash Filter <0.06 mg/L TP

Capital Cost vs. Capacity, MGD
WWTF FACILITY UPGRADE COSTS FOR PHOSPHORUS REMOVAL

Capital Cost

Disc Filters >= 0.15 mg/L TP
Ballasted Settling >= 0.06 mg/L TP
Membranes < 0.06 mg/L TP
Continuous Backwash Filter < 0.06 mg/L TP

Capacity, MGD
EQUIPMENT SIZING

- Not always peak hour flow
- 365 Day Average, Total P Limit
- Blending Potential
DISC FILTRATION - TAKE AWAYS

- Tertiary Polishing ⇔ Phosphorus Treatment
- Phosphorus Reduction - Need Coagulation or Flocculation
  - In-pipe dosing not sufficient
  - Mixing, energy critical
- Floc needs structural integrity
- Use existing tankage (if possible)
BALLASTED SETTLING - TAKEAWAYS

- Enhanced Floc Formation
- Shorter HRT → Higher Loading Rate
- Mixing energy critical
- Use existing tankage (if possible)

Particles acquire 2.65 S.G. For Enhanced Settling
CONTINUOUS BACKWASH FILTERS - TAKEAWAYS

- Regenerative Adsorption Process
- Hydrous Ferric Oxide-Coated Sand
- Multiple Passes for Additional Treatment
- Lower Coagulant Dose
- Reject Stream
  - Possible Re-use
MBR - TAKEAWAYS

- High level of treatment
  - P
  - Water reuse
  - Micropollutants

- Energy intensive

- High Capital Cost

- Compact footprint

- Membrane fouling critical
  - Aeration
  - Intermittent relaxation
  - Backwashing
  - Citric Acid
QUESTIONS?