Industrial PWO Seminar

High Rate Compressible Media Filtration for Regulatory Discharge Compliance
Agenda

- Industrial Pollutants
- High Rate Compressible Media Filtration
- Mechanism of Filtration
- Phosphorus Application
Overview

- Wastewater discharges from industrial and commercial sources may contain pollutants at levels that could affect the quality of receiving waters or interfere with publicly owned treatment works (POTWs) that receive those discharges. The NPDES permitting program establishes discharge limits and conditions for industrial and commercial sources with specific limitations based on the type of facility/activity generating the discharge.

- Source: [https://www.epa.gov/npdes/industrial-wastewater](https://www.epa.gov/npdes/industrial-wastewater)
Discharge Limits

- BOD
- Copper
- Iron
- Zinc
- Lead
- Manganese
- TSS
- TDS
- Arsenic
- Zinc
- Copper
- Iron
- Zinc
- Copper
- Iron
- Zinc
Is there a Unit Process Silver Bullet?
Solutions Approach

Solutions Platform

Inquiry

TSS < 50 mg/L

Pretreatment

TSS > 50 mg/L

U/F

Dewatering

EQ

Post Treatment

Stop

Product Platform

Inquiry

TSS < 50 mg/L

Pretreatment

Stop
Systematic Solutions Approach
Test Parameters

Sample Characterization
- TDS, TSS, TS, Density (slurry/liquid), pH, temperature, Turbidity, T-hardness, iron, manganese, T-alkalinity, sulfate, chloride, nitrate, etc.

Chemical Screening
- Chemical type and dose
- Charge/Molecular Weight
- Mixing Time/Mix Intensity
- Polymer Dilution

Thickening/Clarification/Dissolved Air Flotation (4 hours)
- Effluent Clarity
- Settling Flux (solids dilution)
- Sizing criteria/underflow solids

Media Filtration
- Media compression ratio
- Filtrate quality
- Hydraulic/solids loading rates

Vacuum Filtration
- Filtrate quality
- Drum/Horizontal
- Sizing criteria/cake moisture

Pressure Filtration
- Filtrate quality
- Plate & Frame
- Sizing criteria/cake moisture
Fuzzy Filter
High Rate Compressible Media Filtration
Fuzzy Filter Evolution

Gen#1
30 gpm/ft²

Gen#2
45 gpm/ft²

Gen#3
>45 gpm/ft²
Fuzzy Filter
High Rate
Compressible Media Filter

Operational Cycles
Variable Porosity

Compression changes porosity in filter bed

More compression
= Smaller voids to capture
Small particles

Less compression
= Larger voids to capture
Large particles
High Rate Compressible Media

- Advance microfiber with a PPS backbone
- Interstitial void ratio 80 to 85%
- Variable compression (pore size)
- Adjustable solids removal characteristics with particles >4 microns
- 1.25” diameter synthetic fiber spherical balls
- Heat resistance at 200°C (392°F)
- Maintains strength over wide temperature ranges
Filtration Mechanism

Down Flow Filtration
Pass-By
<6 gpm/ft² Low HLR

Up Flow Filtration
Pass-Through

Up Fluid Flow Low HLR
10 gpm/ft²

Up Fluid Flow High HLR
10 gpm/ft²
# Influent Flow Vs. Fuzz Filter Size

<table>
<thead>
<tr>
<th>Filter Size</th>
<th>Design 30 gpm/ft²</th>
<th>Design 40 gpm/ft²</th>
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<td>1.5</td>
<td>68</td>
<td>90</td>
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<tr>
<td>2</td>
<td>120</td>
<td>160</td>
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<td>270</td>
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<td>4</td>
<td>480</td>
<td>640</td>
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<td>5</td>
<td>750</td>
<td>1,000</td>
</tr>
<tr>
<td>6</td>
<td>1,080</td>
<td>1,440</td>
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<td>1,960</td>
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<tr>
<td>8</td>
<td>1,920</td>
<td>2,560</td>
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</table>

[Design HLR Vs. Filter Size](chart.png)
Dairy Application
Phosphorus Reduction
Dairy Application

DAF/FOG Removal → SBR Bio Treatment → Fuzzy Filter → Chiller → UV

Raw Influent → Beltpress Dewater → Treated Discharge
## Sample Characteristic

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Phase I</th>
<th>Phase II</th>
</tr>
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<tbody>
<tr>
<td>Date of Characterization</td>
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<td>8/4</td>
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<tr>
<td>Turbidity, NTU</td>
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<tr>
<td>Raw water total phosphorus, mg/L</td>
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<td>Alkalinity, mg/L as CaCO3</td>
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<td>pH</td>
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<td>Temperature, °C</td>
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### Screening pH

<table>
<thead>
<tr>
<th>pH</th>
<th>Turbidity, NTU</th>
<th>Temperature, °C</th>
<th>Dosage, mg/L</th>
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</thead>
<tbody>
<tr>
<td>8.03</td>
<td>2.84</td>
<td>23.0</td>
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<tr>
<td>8.13</td>
<td>3.82</td>
<td>23.1</td>
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<tr>
<td>8.27</td>
<td>5.06</td>
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<td>8.38</td>
<td>7.01</td>
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<td>8</td>
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<tr>
<td>8.48</td>
<td>11.20</td>
<td>23.5</td>
<td>10</td>
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<tr>
<td>8.58</td>
<td>15.90</td>
<td>23.7</td>
<td>12</td>
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<td>8.68</td>
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<tr>
<td>8.91</td>
<td>29.30</td>
<td>24.3</td>
<td>20</td>
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**Titration Curve**

**pH Vs. NaOH Dosage**

- **pH Curve**
  - Equation: $y = -0.0008x^2 + 0.0887x + 7.8922$
  - $R^2 = 0.999$

- **Turbidity Curve**
  - Equation: $y = 0.0344x^2 + 0.8329x - 0.1035$
  - $R^2 = 0.988$
Screening Aeration

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<thead>
<tr>
<th>Time (Minutes)</th>
<th>Turbidity, NTU</th>
<th>pH</th>
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<td>40</td>
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# Phase I - Cursory Jar Test

## Results 7/18 – NaOH

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<tr>
<td>Raw water, pH</td>
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<td>7.73</td>
<td>7.73</td>
<td>7.73</td>
<td>7.73</td>
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<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
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<tr>
<td>Raw water total P, mg/L</td>
<td>21.8</td>
<td>21.8</td>
<td>21.8</td>
<td>21.8</td>
<td>21.8</td>
<td>21.8</td>
<td>21.8</td>
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<td>Solids recycle, Y/N</td>
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<td>No</td>
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<td>No</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>2</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>*2</td>
<td>*2</td>
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<tr>
<td>Mixing Intensity, ~rpm</td>
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<td>9.0</td>
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<td>10.8</td>
<td>30.8</td>
<td>30.8</td>
<td>46.5</td>
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<td>Flocculent Dose, mg/L</td>
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<td>0.96</td>
<td>0.36</td>
<td>0.36</td>
<td>0.12</td>
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<td>Bulk Settling, seconds</td>
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<td>Turbidity after flocculent, NTU</td>
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<td>N/A</td>
<td>5.5</td>
<td>N/A</td>
<td>1.1</td>
<td>N/A</td>
<td>&lt;2</td>
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<tr>
<td>Total Phosphorus, mg/L</td>
<td>0.030</td>
<td>14.9</td>
<td>0.017</td>
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<td>75</td>
<td>N/A</td>
<td>97.6</td>
<td>N/A</td>
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<td>Turbidity removal efficiency, %</td>
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<td>N/A</td>
<td>75</td>
<td>N/A</td>
<td>N/A</td>
<td>97.6</td>
<td>N/A</td>
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<td>TP removal efficiency, %</td>
<td>99.8</td>
<td>31.7</td>
<td>99.9</td>
<td>64.7</td>
<td>See note above</td>
<td>See note above</td>
<td>89.9</td>
<td>32.6</td>
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</table>
Phase I - Cursory Jar Test Results 7/18

Test #1 Settled Solids/Floc Structure
NaOH (pH 8.3) + Flocculant (0.96 mg/L)

Test #2 Settled Solids/Floc Structure
NaOH (pH 8.8) + Flocculant (0.36 mg/L)

Test #3 Settled Solids/Floc Structure
NaOH (pH 9.0) + Flocculant (0.12 mg/L)

Test #4 Settled Solids/Floc Structure
NaOH (pH 8.3 to 8.8) + Settled Solids Recycle Flocculant (0.08 mg/L)
## Phase II - Cursory Jar Test Results 8/4

<table>
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<tr>
<th>Test ID</th>
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<tr>
<td>Raw water, pH</td>
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<td>7.68</td>
<td>7.68</td>
<td>7.68</td>
<td>7.68</td>
<td>7.68</td>
<td>7.68</td>
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<tr>
<td>Raw water turbidity, NTU</td>
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<td>7.85</td>
<td>7.85</td>
<td>7.85</td>
<td>7.85</td>
<td>7.85</td>
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<td>Raw water total P, mg/L</td>
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<td>21.8</td>
<td>21.8</td>
<td>21.8</td>
<td>21.8</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
<td>Yes</td>
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<td>8.55</td>
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<td>NaOH dose, mg/L</td>
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<td>16</td>
<td>16</td>
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<td>Coagulant dose, mg/L</td>
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<td>--</td>
<td>0.89</td>
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<td>Mixing time, minutes</td>
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<tr>
<td>Bulk Settling, seconds</td>
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<td>--</td>
<td>--</td>
<td>300</td>
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<td>35</td>
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<tr>
<td>Turbidity after flocculent, NTU</td>
<td>1.58</td>
<td>--</td>
<td>0.35</td>
<td>2.5</td>
<td>39.2</td>
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<td>0.71</td>
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<tr>
<td>Total Phosphorus, mg/L</td>
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<td>Turbidity removal efficiency, %</td>
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<td>90.9</td>
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<td>TP removal efficiency, %</td>
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<td>64.7</td>
<td>82.5</td>
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<td>84.9</td>
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What the...
Phase II - Cursory Jar Test
Results 8/4

Test #1 Settled Solids/Floc Structure
NaOH (pH 8.4) 12 mg/L + Flocculant (0.1 mg/L)

Test #4 Settled Solids/Floc Structure
Aeration (40 minutes) pH 8.55 + Settled Solids Recycle + Coagulant 0.55 mg/L + Flocculant (1.2 mg/L) – Final pH 7.54
Dependent Variables

- Aeration time: 40 minutes
- Underflow solids recycle: ~ 5 to 10%
- NaOH as needed: 7 to 16 mg/L
- Mixing time: 1 minute
- Mixing speed: ~ 300 rpm
- Coagulant: 1 to 2 mg/L as PACl
  - Mixing time: 1 minute
  - Mixing speed: ~ 300 rpm
- Flocculant: 2 to 10 mg/L (lower side more than likely)
  - Mixing time: 3 minutes
  - Mixing speed: ~ 50 rpm (just enough to keep the solids suspended)
Conclusions

- **Aeration drives off the carbon dioxide, allowing a higher starting pH**
  - Benefits provided – reduced sodium hydroxide addition, lower chemical cost, minimization of TDS, facilitates insoluble solids for adsorption.

- **Solids recycle facilitates a higher starting pH and improved sweep floc formation (improved particle-particle collision)**
  - Benefits provided – dramatic improvement in settling flux, higher effluent quality (lower turbidity), reduced chemicals (sodium hydroxide, coagulation, aids in buffering pH decrease during coagulant addition, unused chemicals tied up in the preformed solids are allowed to be utilized, greater sweeping effect of the finely dispersed solids, greater surface adsorption and the potential for better dewatering characteristics.

- **Sodium hydroxide provided the catalyst for facilitating additional alkalinity for the coagulation process and aiding in the phosphorus precipitation process.**
  - Benefits provided – buffering capacity during the coagulant addition (coagulant reduces pH), less sludge formation (over lime),
Conclusions Continued

- Polyaluminum Chloride (PACl) was selected as the choice coagulant due to performance in reducing the total phosphorus (TP) level while minimizing the impact on the process water.
  - Benefits provided – PACl provided the lowest dosage while minimizing the impact on the process liquor (i.e., pH, TDS, etc.), more effective coagulant for TSS removal (than alum), generally does not depress pH, minimized the need for higher caustic used for pH adjustment (alkalinity consumption), minimized sludge formation.

- Anionic flocculant was selected due to efficient particle (colloids) agglomeration, improved settling flux, low dosage and effluent clarity.
  - Benefits provide – aid in bridging particles to achieve low level phosphorus removal, potential to optimize the flocculation to reduce coagulant consumption, facilitates settling flux and an optimum particle for solids retention on down stream equipment, like the Fuzzy Filter.

- Mixing time and mixing duration is significantly improved the particle collision efficiency and sweep floc formation.
  - Benefits provided – flash or vigorous mixing along with mixing time is necessary during the coagulation stage to facilitate the precipitation (coagulant dispersion) process, slower mix for particle agglomeration the flocculant stage,
Colloidal Precipitant
Next Steps

- Additional validation bench testing with collected samples to go to a certified lab for validation
- Review data, if validated by both the customer and the analysis from the certified lab, move to the next stage, Pilot Testing

Pilot Testing
- Mobilize pilot pretreatment Flotation/Clarification *(may not need)* followed by compressible post treatment
- Mobilize mixing tanks, chemical feeds, chemicals, samples collection jars, and outlined testing protocol
- Coordinate analysis with the customer’s lab and select the best condition for additional validation testing via certified lab.

- Generate report (i.e., process performance, equipment recommendations, CapEx, OpEx, etc.) and review with customer
Questions?

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Clean Bed Head loss
Compression Vs. Flow

![Graph showing Clean Bed Head loss vs. Filtration Rate for different compression levels.](image-url)
Solids Developed Head loss
Compression Vs. Flow

![Graph showing the relationship between filtration rate and average headloss development for different compression rates.]
Maximum Operating Head loss

Solids Accumulation
Typ. Headloss 36”

Operating Headloss 48”

Clean Media
Max. Headloss 12”

Wash Water

Effluent

Media Bed

Influent

Air