Treatment Approaches for High Levels of Manganese

NHWWA and NHDES Manganese Workshop – June 1, 2016
Manganese Removal Processes

• Softening/Ion Exchange

• Adsorption: GreensandPlus™, LayneOX™
• Adsorption: Coated Sand and Anthracite
• Adsorption: Manganese Contactors

• Media Filtration
• Membrane Filtration

• Biological Manganese Removal
Ion Exchange/Softening

- Dissolved Fe and Mn is held directly on media surface
- Fe/Mn replaces sodium, which is released into water
- When media is saturated, brine (NaCl) is added to media bed to remove Fe and Mn
- Disposal of waste brine can be difficult

Typically used for private homes and small systems

Sommerfeld, 1999
Adsorption: GreensandPlus™ and LayneOX™

Very commonly used for Municipal Drinking Water Applications

- Sorption of dissolved Mn(II) directly onto Mn-oxide coated surface.
- GreensandPlus™ is a silica sand coated with MnOx
- LayneOX™ is a solid MnOx particle mined and sized for filter applications
- Sorption sites require regeneration using an oxidant
- Continuous Regeneration VS Intermittent Regeneration
- Performance and Capacity are a function of media coating, oxidation state of media, hydraulic loading rate
GreensandPlus™ Filters

Hanover MA
Horizontal Pressure Filters with GreensandPlus™
Performance of MnOx Process

Figure 3.03: COPAF Trial 2A at 2 gpm/sf
Putnam CT, Well SG2 - May 28 to May 30, 2014

Effluent Fe (mg/L), Mn (mg/L), Turbidity (NTU)
Pressure Transducer Differential (psi)
FSLR (gpm/sf)

Trial Started 5/28/2014 @ 11:48
Pretreatment: NaOCl + KMnO₄

\[ y = 0.1711x + 0.7142 \]
\[ R^2 = 0.9812 \]
Figure 3.10: COPAF Trial 3B at 2 gpm/sf
Putnam CT, Well SG2 - May 30 to June 02, 2014

Effluent Fe (mg/L), Mn (mg/L), Turbidity (NTU)

Pressure Loss (psi)

Effluent Fe (mg/L)
Effluent Mn (mg/L)
Pressure Transducer Differential (psi)
FSLR (gpm/sf)

Trial Started 5/30/2014 @ 12:26
Pretreatment: NaOCl

\[ y = 0.0162x + 2.0834 \]
\[ R^2 = 0.6999 \]
Putnam CT, Well SG2- May 27 to June 13, 2014

- Effluent Mn (mg/L)
- Pressure Transducer Differential (psi)
**Performance Media for Water Filtration**

**GREENSANDplus**

**Pressures Sandplus Pressure Drop (Clean Bed)**

GREENSANDPLUS PRESSURE DROP (CLEAN BED)

FLOW RATE (GPM/Ft²)

BED EXPANSION DURING BACKWASHING

**GREENSANDplus Technical Data**

**Suggested Operating Conditions**

**Bed Type**
- Dual media, anthracite 15-18 in. (381 mm - 457 mm) and GreensandPlus 15-24 in. (381 mm - 610 mm)

**Capacity**
- 700-1200 grains of oxidized iron and manganese/ sq. ft. of bed area based on oxidant demand and operation to iron break through or dp limitations.

**Backwash**
- Sufficient rate using treated water to produce 40% bed expansion until waste water is clear, for 10 minutes, whichever occurs first.

**Air/Water Scour**
- Optional using 0.8-2.0 cfm/sq. ft. (15 m³/hr - 7 m³/hr) with a simultaneous treated water backwash at 4-6.5 gpm/sq. ft. (5.8 m³/hr - 11.03 m³/hr)

**Raw Water Rinse**
- At normal service flow rate for 3 minutes or until effluent is acceptable.

**Flow Rate**
- Recommended flow rates with CO operation are 2-12 gpm/sq. ft. (4.9 m³/hr - 29.4 m³/hr).

**Contaminant Loading**
- Fe: 1.0 gpm/sq. ft. (2.2 m³/hr)

**Raw Water Quality**
- pH: 6.2-8.2

**General Notes**

**pH**
- Raw waters having natural pH of 6.2 or above can be filtered through GreensandPlus without pH correction. Raw waters with a pH lower than 6.2 should be pH-corrected to 6.5-8.0 before filtration. Additional alkali should be added following the filters if a pH higher than 6.5-6.8 is desired in the treated water. This prevents the possible adverse reaction and formation of a colloidal precipitate that sometimes occurs with iron and alkali at a pH above 6.8.

**Initial Conditioning of GreensandPlus**
- GreensandPlus media must be backwashed prior to adding the anthracite cap. The GreensandPlus backwash rate must be a minimum of 12 gpm/sq. ft. @ 55°F.

**The Intermittent regeneration (IR) operation is available for certain applications. Contact your Inversand representative for additional information.**
MnOx Coated Media Capacity to Contaminant Breakthrough

Filter Loading Rate (gpm/sf)

Media Capacity to Breakthrough (grams/cf)

Inversand Model (700 to 1200 grains)
MnOx Coated Media Capacity to Contaminant Breakthrough

Filter Loading Rate (gpm/sf)

- Inversand Model (700 to 1200 grains)
- Georgetown MA
- Hopedale MA
- Merrimack NH
- Woolwich NJ
MnOx Coated Media Capacity to Contaminant Breakthrough

- Inversand Model (700 to 1200 grains)
- Georgetown MA
- Hopedale MA
- Merrimack NH
- Woolwich NJ
- Milford PA
- Manchaug MA

Filter Loading Rate (gpm/sf)

Media Capacity to Breakthrough (grams/cf)
MnOx Coated Media Capacity to Contaminant Breakthrough

Filter Loading Rate (gpm/sf)

- Inversand Model (700 to 1200 grains)
- Georgetown MA
- Hopedale MA
- Merrimack NH
- Woolwich NJ
- Milford PA
- Manchaug MA
- East Chelmsford MA
MnOx Coated Media Capacity to Contaminant Breakthrough

Filter Loading Rate (gpm/sf) vs. Media Capacity to Breakthrough (grams/cf)

- Inversand Model (700 to 1200 grains)
- Blueleaf Model
- Georgetown MA
- Hopedale MA
- Merrimack NH
- Woolwich NJ
- Milford PA
- Manchaug MA
- East Chelmsford MA
Methods for coating sand, anthracite, ceramic media are available

Technically appropriate but Engineer/Owner may want Experienced Vendor involved

Manganese contactors /Second Stage Contactors may be a useful alternative for surface water, high Fe sites

Currently in use at Lantern Hill, Mystic CT
Membrane Filtration

Often used at sites with other contaminants, or concerns with GWUI

- Completed membrane pilot studies for Fe and Mn at:
  - Orleans MA (concerns with future GWUI)
  - Acton MA (high color and organics), two sites
  - Stow MA (high color and organics)
  - Kent County RI (high color and organics)
  - Chelmsford MA (high color and organics)
  - Rowley MA (concerns with future GWUI)
  - Framingham MA (high concentrations of Fe and Mn)
Membrane Filters
Biological Filtration

Process used in Europe for 40 years. 160 Worldwide, 35 in North America

- Pre-existing Organisms
- Iron Oxidizing Organism
  - Gallionella ferruginea
- Manganese Oxidizing Organism
  - Leptothrix ochracea
## Biological Filtration

### Advantages
- Higher iron and manganese retention capacity
  - Less filter area
- Chemical pretreatment is less costly
  - Air and pH adjustment
- Less backwash water needed
  - 58 ga/sf (biological) VS
  - 125 ga/sf (greensandPlus)

### Disadvantages
- Discomfort with biological treatment
- Long acclimation times
  - 2-3 days Fe
  - 20-40 days Mn
  - Not suitable for seasonal/intermittent use
- Separate Vessels needed for Fe and Mn
Performance of MnOx Process

Figure 3.03: COPAF Trial 2A at 2 gpm/sf
Putnam CT, Well SG2- May 28 to May 30, 2014

Effluent Fe (mg/L), Mn (mg/L), Turbidity (NTU)

Runtime (hours)

Trial Started 5/28/2014 @ 11:48
Pretreatment: NaOCl + KMnO$_4$

$y = 0.1711x + 0.7142$
$R^2 = 0.9812$
Performance of Biological Mn Removal

Figure B18: Mangazur Filter #2, Trial 6 @ 5 gpm/sf
July 16 to July 22 2014

Manganese Concentration (mg/L) vs. Run Time (hours)

- MZ2 Effluent Mn Concentration (mg/L)
- DO into filters (ppm)
- pH into Filters (s.u.)
- Headloss (psi)

Trial Started 7/22/2014 @09:44
Pretreatment: Aeration, KOH

Mn SMCL < 0.0500 mg/L

Run Time (hours)

Manganese Concentration (mg/L)

DO (ppm), pH (s.u.), Headloss (psi)

y = 0.663e^{0.0257x}
R² = 0.9566
Evaluation completed for Shrewsbury MA (7 MGD Biological Manganese Removal)

<table>
<thead>
<tr>
<th>Biological</th>
<th>GreensandPlus</th>
</tr>
</thead>
</table>
| Step 1: 3.5 scfm/sf air for 1 min   | Air Scour: 12-15 gpm/sf for 10 min=
| Step 2: 6 gpm/sf water for 3 min   | 120-150 gal/sf                    |
| with air scour continued            | Without: 25 gpm/sf for 5 minutes  |
| Step 3: 8 gpm/sf for 5 minutes      | = 125 gal/sf                      |
| = 58 gal/sf                         |                                   |
| Filter Loading Rate: 10 gpm/sf      | Filter Loading Rate: 5 gpm/sf     |
| Runtime: 100 hours                  | Runtime: 24 hours                 |
| For 6 MGD plant, need 416 sf        | For 6 MGD plant, need 833 sf      |
| 4 days: 24,128 gallons BW water     | 4 days: 416,500 gallons BW water  |
## Blueleaf Pilot Studies

### Biological Fe and Mn Removal

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Fe</th>
<th>Mn</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavendish VT</td>
<td>2004</td>
<td>2.8</td>
<td>2.25</td>
<td>Full Scale – Fe now 5 to 6</td>
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<tr>
<td>Middleborough MA</td>
<td>2005</td>
<td>1.2</td>
<td>0.055</td>
<td>MaDEP NTA, In design</td>
</tr>
<tr>
<td>Sharon MA</td>
<td>2005</td>
<td>0.1</td>
<td>1.1</td>
<td>Greensand</td>
</tr>
<tr>
<td>Milford MA</td>
<td>2006</td>
<td>7</td>
<td>0.45</td>
<td>DAF</td>
</tr>
<tr>
<td>Auburn MA</td>
<td>2008</td>
<td>1.5</td>
<td>1.2</td>
<td>None</td>
</tr>
<tr>
<td>Rye NH</td>
<td>2009</td>
<td>0.2</td>
<td>0.6</td>
<td>Recalcitrant Fe, In Design</td>
</tr>
<tr>
<td>Whitinsville MA</td>
<td>2011</td>
<td>0.7-1.0</td>
<td>0.33</td>
<td>Greensand</td>
</tr>
<tr>
<td>Annapolis MD</td>
<td>2013</td>
<td>6-12</td>
<td>0.1-0.3</td>
<td>Gravity Settling</td>
</tr>
<tr>
<td>Middleborough MA</td>
<td>2014</td>
<td>1.2</td>
<td>0.055</td>
<td>See above</td>
</tr>
<tr>
<td>Putnam CT</td>
<td>2014</td>
<td>0.1</td>
<td>1.4</td>
<td>In Design</td>
</tr>
<tr>
<td>Shrewsbury MA</td>
<td>2015</td>
<td>0.1</td>
<td>1.0</td>
<td>In Design</td>
</tr>
</tbody>
</table>
Raw waters with Fe<0.3 require only Mangazur filter and are highly-competitive against greensand filters

Biological has clear advantage over greensand filters. Starting to enter area where other clarification processes are considered

Biological has slight advantage

Require both Ferazur AND Mangazur filters. Not competitive against greensand filters

Raw waters with Mn<0.05 require only Ferazur filter and are highly competitive against greensand filters

Biological has clear advantage over greensand filters.
Manganese Removal Processes

• Softening/Ion Exchange
  Small systems, salt

• Adsorption: GreensandPlus™, LayneOX™
  Widely used

• Adsorption: Coated Sand and Anthracite
  Technically OK, no vendor

• Adsorption: Manganese Contactors
  Post treatment

• Media Filtration
  part of Greensand process

• Membrane Filtration
  good if other concerns

• Biological Manganese Removal
  Competitive for high-Mn
  Continuous operation