Modernizing Fixed Film Media for Nutrient Removal

John Harrison
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What we will Discuss

1. Parent Processes
2. Combined Processes
3. Case Histories – The End
4. Troubleshooting
1. Parent Processes

- Trickling Filter
- Activated Sludge
- Dual or Combined Processes

What is Fixed Film?
High Rate Media - Filter Tower
Trickling Filter - Section
Differences in TF Media

<table>
<thead>
<tr>
<th>MEDIA</th>
<th>Surface Area</th>
<th>Void Ratio</th>
<th>Dry Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>HORIZONTAL</td>
<td>14</td>
<td>94</td>
<td>10</td>
</tr>
<tr>
<td>VERTICAL</td>
<td>27</td>
<td>97</td>
<td>2</td>
</tr>
<tr>
<td>60 XFLOW</td>
<td>30</td>
<td>95</td>
<td>2</td>
</tr>
<tr>
<td>RANDOM</td>
<td>32</td>
<td>92</td>
<td>3</td>
</tr>
<tr>
<td>ROCK</td>
<td>15</td>
<td>35</td>
<td>80</td>
</tr>
</tbody>
</table>

Moving Bed Media =150 to 180 sq ft per cu ft
### RELATIVE DIFFERENCE IN TRICKLING FILTER MEDIA

<table>
<thead>
<tr>
<th>Media Type</th>
<th>Low Load</th>
<th>High Load</th>
<th>General Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td><img src="image1" alt="Illustration of Horizontal Media" /></td>
<td><img src="image2" alt="Illustration of Horizontal Media" /></td>
<td>Surface area low, not recommended for trickling filter use. Sludge recycle may be required to optimize media.</td>
</tr>
<tr>
<td>Vertical</td>
<td><img src="image3" alt="Illustration of Vertical Media" /></td>
<td><img src="image4" alt="Illustration of Vertical Media" /></td>
<td>Optimum use is at high loading, but the filter especially where plugging might be a problem with other media.</td>
</tr>
<tr>
<td>60° Crossflow</td>
<td><img src="image5" alt="Illustration of 60° Crossflow Media" /></td>
<td><img src="image6" alt="Illustration of 60° Crossflow Media" /></td>
<td>Best available media for use with filters at low to moderate loading or where nitrification is required.</td>
</tr>
<tr>
<td>45° Crossflow</td>
<td><img src="image7" alt="Illustration of 45° Crossflow Media" /></td>
<td><img src="image8" alt="Illustration of 45° Crossflow Media" /></td>
<td>Not recommended in lieu of available 60° crossflow media.</td>
</tr>
<tr>
<td>Random</td>
<td><img src="image9" alt="Illustration of Random Media" /></td>
<td><img src="image10" alt="Illustration of Random Media" /></td>
<td>Best used at low loading, wetting characteristics are poor.</td>
</tr>
<tr>
<td>Rock</td>
<td><img src="image11" alt="Illustration of Rock Media" /></td>
<td><img src="image12" alt="Illustration of Rock Media" /></td>
<td>Best used at low to moderate loadings and where oxygen transfer is not a limitation.</td>
</tr>
</tbody>
</table>

### NOTES:

- **A** BEST
- **B** GOOD
- **C** AVERAGE
- **D** POOR
- **E** WORST

"ALL OPERATED IN THE TRICKLING FILTRATION PROCESS WITH 20 FOOT MEDIA DEPTH EXCEPT ROCK AT 8 FEET."

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### Graph

**Graph Legend:***
- **CrossflowMedia**
- **VerticalMedia**

![Graph Showing Effluent TSS vs Organic Load to Filter (lb BOD/d*1000 cu ft)](image13)
<table>
<thead>
<tr>
<th>Item</th>
<th>Units</th>
<th>Vertical</th>
<th>Crossflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flushing</td>
<td>Observation</td>
<td>++</td>
<td>--</td>
</tr>
<tr>
<td>Cyclic Weight Change</td>
<td>Max: Avg</td>
<td>3.2:1</td>
<td>&gt;10:1</td>
</tr>
<tr>
<td>Biomass Weight</td>
<td>lb/cu ft</td>
<td>8.6</td>
<td>6.3</td>
</tr>
<tr>
<td>Nitrification</td>
<td>Ammonia, mg/L</td>
<td>6.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

**MBBR – Moving Bed Media**

Primary Effluent → MBBR → ML to Clarifier
Organic Loading

- **Low**
  - < 25 lb BOD/d-1000 cu ft
- **Intermediate**
  - 25 to 60 lb BOD/d-1000 cu ft
- **High**
  - 60 to 100 lb BOD/d-1000 cu ft
- **Roughing**
  - 100 to 300 lb BOD/d-1000 cu ft

Selector Activated Sludge
MCRT vs. OLR

<table>
<thead>
<tr>
<th>Item</th>
<th>MCRT (days)</th>
<th>OLR (lb BOD/d/1000 cu ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD Only</td>
<td>3.5</td>
<td>64</td>
</tr>
<tr>
<td>Seasonal NR</td>
<td>7.5</td>
<td>30</td>
</tr>
<tr>
<td>Yearly NR</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Stringent BNR</td>
<td>22</td>
<td>10</td>
</tr>
</tbody>
</table>

Selector Options

- Ox
- RAS
- PE
- CAS
- SAS
- ESAS

Optional Mixe'd Liquor Recycle (MLR)
Optional Selector RAS
Primary Sludge Fermentation

Raw Wastewater → Primary Clarifiers → Primary Effluent

GT @ 2.5 d SRT → Volatile Fatty Acids

Denitrification with TF

TF → Ox → 2nd → TF

MLR → Ax → Ox → 2nd → TF

TF → Ox1 → Ax → 2nd → TF

MLR → Ax → Ox → 2nd → TF

TF → Ax → Ox → 2nd → TF
Anoxic FFR Activated Sludge (AxFFR/AS)

2. Combined Processes
Activated Biofilter

Trickling Filter Activated Sludge
**FF/AS BNR**

Raw Wastewater

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**Integrated Fixed Film & AS**

Influent

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**MLR = 3xQ**
Why Integrated FF & AS

Oxic MCRT
7.5 days (+50%)

IFAS – Integrated FF Activated Sludge

MBBR – Moving Bed Bioreactors
### 3. Case Histories

1. Salmon Arm  
2. Corvallis  
3. Yakima  
4. Coeur d’Alene  
5. Duck Creek  
6. Littleton Englewood

### da Terms

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF_L</td>
<td>Fixed Film _ Load</td>
</tr>
<tr>
<td>SYS_L</td>
<td>System _Load</td>
</tr>
<tr>
<td>SG_MCRT</td>
<td>Suspended Growth _MCRT</td>
</tr>
<tr>
<td>EFF_NH4</td>
<td>Effluent Ammonia</td>
</tr>
<tr>
<td>Solids (Y)</td>
<td>Sludge Yield</td>
</tr>
<tr>
<td>Power (EP)</td>
<td>Energy for 2(^{nd}) Treatment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BOD/d-1000 ft(^3)</td>
</tr>
<tr>
<td></td>
<td>BOD/d-1000 ft(^3)</td>
</tr>
<tr>
<td></td>
<td>days</td>
</tr>
<tr>
<td></td>
<td>mg / L</td>
</tr>
<tr>
<td></td>
<td>TSS/BOD</td>
</tr>
<tr>
<td></td>
<td>hp/1000 lb BOD</td>
</tr>
</tbody>
</table>
### Selector Activated Sludge

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF_L</td>
<td>-0-</td>
</tr>
<tr>
<td>SYS_L</td>
<td>17</td>
</tr>
<tr>
<td>SG_MCRT</td>
<td>12</td>
</tr>
<tr>
<td>EFF_NH4</td>
<td>3</td>
</tr>
<tr>
<td>Solids</td>
<td>0.8</td>
</tr>
<tr>
<td>Power</td>
<td>50</td>
</tr>
</tbody>
</table>

### 1 - Salmon Arm, BC

- **Raw Wastewater**
- **Pri Clarifiers**
- **Air Cell**
- **Ax Cell**
- **Biofilters**
- **Biofilters**
- **Solids Contact Basin**
- **2nd Clarifiers**
- **Thickening**
- **ATAD Aerobic Digestion**
- **Sludge Dewatering**
- **Effluent Filtration UV Dis**
Salmon Arm, BC

Item | Value
--- | ---
FF_L | 28
SYS_L | 17
SG_MCRT | 6 / 2
EFF_NH4 | 6.8
Solids | 1.0
Power | 127

EFF_P = 0.4 mg/L

Raw Wastewater

4500 mg/L

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Salmon Arm, BC
Corvallis, OH

![Diagram of wastewater treatment process]

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item Value</td>
<td></td>
</tr>
<tr>
<td>SYS_L</td>
<td>11</td>
</tr>
<tr>
<td>SG_MCRT</td>
<td>9.7 / 4.3</td>
</tr>
<tr>
<td>EFF_NH4</td>
<td>3</td>
</tr>
<tr>
<td>Solids</td>
<td>0.3</td>
</tr>
<tr>
<td>Power</td>
<td>29</td>
</tr>
</tbody>
</table>
### Yakima

- **Item**: FF_L
  - **Value**: 44

- **Item**: SYS_L
  - **Value**: 18

- **Item**: SG_MCRT
  - **Value**: 12.6 / 12.6

- **Item**: EFF_NH4
  - **Value**: 0.2

- **Item**: Solids
  - **Value**: 0.3

- **Item**: Power
  - **Value**: 40

### 4 – Coeur d’Alene, ID

- **Item**: 2095 mg/L

- **Item**: Raw Wastewater
  - **Value**: Yakima - Coeur d’Alene, ID
5 – Duck Creek, Garland, TX

Duck Creek, Garland, TX
**Duck Creek, Garland, TX**

- Item: FF_L, Value: 35
- Item: SYS_L, Value: 30
- Item: SG_MCRT, Value: 3.4 / 2.1
- Item: EFF_NH4, Value: 0.4
- Item: Solids, Value: 0.6
- Item: Power, Value: 24

**6 – Littleton-Englewood, CO**
### Littleton-Englewood, CO

#### Process Flow Diagram

- **Raw Wastewater**
- **Primary Clarifiers**
- **DAP Thickeners**
- **Sludge Digestion**
- **Sludge Denitrification**
- **Settlers**
- **Solids Contact Basins**
- **QAD Clarifiers**
- **Final Denitrification**

#### Table

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF_L</td>
<td>30</td>
</tr>
<tr>
<td>SYS_L</td>
<td>22</td>
</tr>
<tr>
<td>SG_MCRT</td>
<td>1.2/1.2</td>
</tr>
<tr>
<td>EFF_NH4</td>
<td>2.1</td>
</tr>
<tr>
<td>Solids</td>
<td>1.0</td>
</tr>
<tr>
<td>Power</td>
<td>94</td>
</tr>
</tbody>
</table>

1723 mg/L
Are Fixed Film Reactors Outdate for BNR?

It Depends!
Yes – to Fixed Film!

- Energy
- Space
- Solids
- Ease of Operation
- Existing Unit

No – to Fixed Film!

- Blue-Ribbon Stream
- N / dN
- No Primary Clarifiers
- Odor
- Perception
- Pumping
4. Troubleshooting

1. Media Type or Spec.
2. Organic Overloading
3. Poor Solids Handling
4. Unrealistic Expectations
5. Wrong Neighborhood
6. Effluent Limitations

Questions?