**Critical Variables that Can Impact Performance**

<table>
<thead>
<tr>
<th>Critical Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Raw water characteristics (temperature, particle characteristics, color, algae, nutrients, organic compounds, oxygen content)</td>
</tr>
<tr>
<td>2. Sand size ($d_{10}$) and uniformity (U)</td>
</tr>
<tr>
<td>3. Flow control and air binding</td>
</tr>
<tr>
<td>4. Head loss allowed</td>
</tr>
<tr>
<td>5. Sand bed depth</td>
</tr>
<tr>
<td>6. Filtration rate and variability</td>
</tr>
<tr>
<td>7. Maturity of the sand bed and biological organisms</td>
</tr>
<tr>
<td>8. Filter cleaning (frequency, length of time the filter is out of operation, ripening period)</td>
</tr>
</tbody>
</table>

**Filtration Rate**

Filtration rate should be continuous
- Good for dissolved oxygen
- Good for nutrient supply
- Good for biological mechanisms
- Influent flow should not scour sand surface
- Cold temperatures may need lower filtration rates (e.g., 0.05 gpm/ft² when water temp < 5°C)
- Controls should be in place to prevent the tail water (effluent side) from dropping below the sand bed during operation (e.g., an effluent weir) – this helps prevent vacuum conditions and air entrainment.

**Flow Control – Inlet vs Outlet**

1. **Inlet Flow Control – Constant Rate**
   - Uses a throttling valve plus a flowmeter or V-notch weir prior to each filter. The operator uses the flow control valve to set the desired filtration rate. As the resistance of the filter bed increases, the water level rises. When it reaches the overflow pipe the bed should be cleaned.
     - Requires less operator involvement
     - Ensures a more constant rate of filtration
     - Allows operator to see headloss development as headwater rises
     - Low headwater at the beginning of filter runs may make filters more vulnerable to freezing in the winter if filters are not covered or insulated

2. **Inlet Flow Control – Declining Rate**
   - Uses a hydraulic control valve with a flowmeter and valve at the raw water line prior to each filter that regulates flow while maintaining a constant water surface elevation above the filter. Effluent flow decreases as the filter plugs.
     - Headwater level is not indicative of headloss development (piezometers or pressure gages are needed)
     - Decline in effluent rate or approach to terminal headloss indicates cleaning

3. **Outlet Flow Control (declining rate)**
   - Uses a control valve and flowmeter on the outlet pipe from each filter. As the filter plugs, the filtration rate will decrease, even if the headwater level is increased. The level of water on top of the filter can be controlled by using float switches to turn on and off raw water pumps or control inlet control valves.
     - Most common
     - Fairly simple control method although operator involvement is higher if no automation is used
     - Higher rates may be implemented faster for emergency situations, since you don’t have to wait for headwater to rise as with constant rate influent control.
     - Ability to maintain higher headwater level provides better protection from freezing.
     - Higher headwater level provides raw water storage should influent flows be interrupted due to power failure or intake shutdown due to damage or to avoid high turbidity events.
     - Headwater level is not indicative of headloss development (piezometers or pressure gages are needed)

---

**Diagram:**

**Constant Rate Inlet Control**

- Starts off with a lower headwater level
- Influent valve is set to the desired rate (e.g., 0.1 gpm/ft²)
- Outlet valve is fully open
- The filter will need to be cleaned when the headwater approaches the overflow

**Overflow**
Filter Inlet
Filter Drain
To waste or return to inlet

Excess water produced is re-circulated (pumped) to influent or sent to waste (gravity)
DECLINING RATE OUTLET CONTROL

- Starts off with a higher headwater level
- Influent valve is adjusted to keep filter from overflowing
- Outlet valve is partially closed at first and then is gradually opened as the yield drops due to filter plugging
- The filter will need to be cleaned when the yield cannot keep up with demands

WHAT GOES INTO THE FILTER WILL GO OUT OF THE FILTER (EXCESS CAN BE OVERFLOWED IF NEEDED)

HEADLOSS BUILDS UP TOWARDS THE END OF THE FILTER RUN AS IT PLUGS UP CAUSING HEADWATER TO RISE

CLEANING UNPLUGS FILTER ALLOWING HEADWATER TO DROP AND YIELD TO RECOVER

INFLENT WATER IS BALANCED WITH EFFLUENT OR EXCESS CAN BE OVERFLOWED FROM HEADWATER

FLOW MEASUREMENTS

Flow can be measured using weirs (square, v-notch), orifice plates, or flow meters.

Flow calculation for V-notch weir with a 60 degree angle:

\[ Q = 1.44 \frac{H^{2/3}}{g^{1/2}} \]

Where:

- \( Q \) = ft³/second
- \( H \) = height of water level above weir crest (ft)
- \( g \) = 32.2 ft/s² (gravity)

FLOW MEASUREMENTS

Flow calculation for rectangular weir:

\[ Q = C_w \times (2g)^{1/2} \times b \times H^{3/2} \]

Where:

- \( Q \) = ft³/second
- \( H \) = height of water level above weir crest (ft)
- \( g \) = 32.2 ft/s² (gravity)
- \( b \) = length of weir crest (ft)
- \( C_w \) = weir coefficient where \( C_w = 0.40 + (0.05 \times \frac{H}{P}) \) where \( P \) = distance in feet from floor of channel to weir crest

FLOW MEASUREMENTS

Rectangular weir flow determinations:

Yellow cells indicate acceptable range of filtration rates from 0.03 - 0.1 gpm/ft² (with unit conversions for \( H \) & \( P \) in inches and \( Q \) in gpm, MGD, or gpm/ft²).

<table>
<thead>
<tr>
<th>( H ) (inches)</th>
<th>( Q ) (gpm)</th>
<th>( Q ) (MGD)</th>
<th>( Q ) (gpm/ft²) w/ 1,000 ft²</th>
<th>Filter Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>72</td>
<td>0.00402</td>
<td>0.00402</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.7</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>72</td>
<td>0.00403</td>
<td>0.019</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>21.3</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>0.75</td>
<td>72</td>
<td>0.00405</td>
<td>0.053</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>41.5</td>
<td>0.092</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>72</td>
<td>0.00407</td>
<td>0.100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>69.4</td>
<td>0.150</td>
<td></td>
</tr>
<tr>
<td>1.25</td>
<td>72</td>
<td>0.00409</td>
<td>0.149</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>86.5</td>
<td>0.234</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>72</td>
<td>0.00414</td>
<td>0.234</td>
<td>0.098</td>
</tr>
<tr>
<td></td>
<td></td>
<td>96.4</td>
<td>0.426</td>
<td>0.197</td>
</tr>
<tr>
<td>1.75</td>
<td>72</td>
<td>0.00416</td>
<td>0.295</td>
<td></td>
</tr>
</tbody>
</table>

WHEN TO CLEAN

Cleaning is needed when either terminal head loss is reached (i.e., headwater reaches the overflow level) or when filter effluent is unable to keep up with system demands.

This graph shows head loss increase, while permeability decreases towards the end of each filter run.

FACTORS THAT IMPACT FILTER CLEANING:

1. Cleaning method (scraping or harrowing)
2. Cleaning mechanisms (hand shovel or larger equipment)
3. Presence of 2 or more filter beds (the more filters, the smaller the area to be cleaned at any one time)
4. Room to stage equipment, stockpile sand, etc.
5. Other provisions to minimize down time during cleaning
6. Monitoring capability (individual and combined filter effluent turbidity, taps to sample for individual filter effluent coliform bacteria, turbidity, and other parameters, and filter-to-waste effluent taps for monitoring coliform and turbidity during the ripening period)
7. Ability to measure sand bed depth (keyway, staff gage (shown), etc.)
**PREDICTING WHEN TO CLEAN**

Daily measurement of headwater (influent or supernatant water) and tailwater (effluent or permeate water) levels can be used to develop plots of headloss versus time (like the one shown below), which can then be used to predict when the filter will need to be cleaned.

Note: The clean bed headloss through 4 ft of media is only about 10 inches, depending on effective size and filtration rate, which only amounts to a decrease in filter run of 2-3 days as compared with a 3-ft deep bed (HL ~ 8 inches)

\[
\text{Headloss} = \text{headwater elevation} - \text{tailwater elevation}
\]

For the graph shown, if the terminal headloss is 5 ft, then cleaning is predicted to be needed in 50 days = 5 ft / (0.1 ft/day)

**CLEANING METHOD**

Cleaning can be accomplished by either:
1. Scraping or
2. Harrowing

**SCRAPING PROCESS**

Scraping Process (also called dry skimming)

1) Water is lowered to approximately 2-12" below the sand level (to be able to safely walk and maneuver machinery around);
2) Schmutzdecke and plugged sand (1-2 cm) is scraped with either flat shovels or specially designed machinery;
3) The debris is then conveyed out of the filter bed using a wheel borrow or dump truck;
4) The beds are leveled;
5) Slowly re-filled from the bottom with filtered unchlorinated water to about 12" above the sand (this prevents sand scour that may occur from top filling);
6) Slowly filled from the top the remaining amount; and
7) Filtered to waste until fully ripened.

**SCRAPING PHASE 1**

Shut off raw water inlet and let filter drain down (overnight for larger filters) Or use supernatant drain for smaller filters

**SCRAPING PHASE 2**

- Shut off the effluent valve to the clear well;
- Open the supernatant drain to drain off any remaining water; and
- Drop the weir to lower the water level 2-24" below the sand.
• Scrape the schmutzdecke and roughly ¼ - ½ inch (0.635 – 1.27 cm) of sand from the filter.
• Close the supernatant drain, raise the weir and then begin re-filling from the bottom with filtered water at a rate below that which would fluidize the sand (around 0.3-0.6 ft/hr (0.1 – 0.18 m/hr or 0.0374 – 0.0748 gpm/ft²)). This purges air from the sand bed.
• Continue filling until the supernatant water is 12 inches above the sand bed – this prevents scouring when raw water is introduced from the top.

**Filter to be Scraped**

Overflow
Raw Water Inlet
Supernatant Drain
Filter to be Scraped

Overflow
Raw Water Inlet
Supernatant Drain
Filter to be Scraped

**SCRAPING[method]**

Scraping Method
1. Hand shovel
2. Larger equipment

Photo courtesy of Stephen Baker, WA DOH

**SCRAPING BY HAND**

Hand Scraping Tools
1. Asphalt lute (top)
2. Snow shovel (lower right)
3. Flat blade, square point transfer shovels (lower left)
4. Wheelbarrow or 5-gal buckets (for removal from filter bed)

Hand scraping at Empire, Colorado, filter:
1. Scrape schmutzdecke and top 0.5 cm of sand bed into windrows using asphalt lute
2. Shovel scraped material from windrows into 5-gallon buckets (or could use wheelbarrow) for removal
3. Cleaning Rate = 205 ft² / person / hr

Note:
• Avoid treading directly on schmutzdecke
• Use plywood and planks to keep from treading on or running wheelbarrows on sand bed
**SCRAPING BY HAND**

Hand scraping filter:

![Image of hand scraping](image)

**SCRAPING BY HAND**

Scraping
1. hand shovel

![Image of water eductor](image)

**WASHING SAND**

Washing Sand
hand shovel => eductor =>
Washer =>
Sand filter or stockpile

![Image of washing sand](image)

**SAND WASHING PROCESS**

This diagram illustrates the sand washing and grading process

![Diagram of sand washing process](image)

**SCRAPING MACHINES**

Scraping
1. larger equipment

![Image of scraping machines](image)
Scraping machines

Scraping blade

The blade height can be set for precise filter media skimming thickness tolerances.

USG Puma 2400 "Sand Skimmer"

Scraping USG Puma 2400

www.youtube.com/embed/AtX65tbf1q8

www.youtube.com/embed/G259QNQRbDY

USG Puma 3000

www.youtube.com/embed/AtX65tbf1q8

Scraping USG Puma 3000

www.youtube.com/embed/G259QNQRbDY

USG Puma 3000

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Scraping USG Puma 3000

www.youtube.com/embed/G259QNQRbDY
Scraping USG Puma 2400

Scraping USG Puma 2400

Scraping USG Puma 2400

Scraping USG Puma 2400

Scraping USG Puma 3000

Scraping USG Puma 3000

Scraping USG Puma 3000

Scraping USG Puma 3000

HARROWING PROCESS

Harrowing Process (also called wet harrowing)
1. Water is lowered to approximately 6” above the sand level;
2. Water is introduced to provide a cross flow at a rate of about 20 gpm/ft$^2$ of cross-sectional area (e.g., 1,000 gpm for 6” water depth in a 100-ft long filter);
3. Filtered, unchlorinated water is introduced from the bottom to provide a “backflow”, which keeps debris from sinking into the filter bed;
4. Stiff tined rake or harrow equipment is run over the top of the sand;
5. The debris (not sand) is then conveyed out of the filter bed from a harrow drain located just above the sand bed;
6. The beds are leveled;
7. Slowly re-filled from the bottom to about 12” above the sand (this prevents sand scour that may occur from top filling);
8. Slowly filled from the top the remaining amount; and
9. Filtered to waste until fully ripened, which is typically shorter than scraping.

HARROWING EQUIPMENT

Harrowing Equipment
Wet harrowing can be done with a chain harrow, comb-toothed harrow, or a stiff tined rake.

HARROWING SMALL FILTERS

Wet harrowing is a common method of cleaning small filters.

Basic process:
1. Lower water level to ~6” above the top of the sand.
2. Use a rake or rake-like Mechanism
3. Agitate top 2”-3” of sand while slowly backflushing with filtered, but unchlorinated water.
HARROWING SMALL FILTERS

Harrowing small 3-gpm filters using a stiff-tined garden rake.

HARROWING PIPING

Blue Future Filters rely on a wet harrowing process.

HARROWING VALVE

Harrowing Valve

HARROWING VALVE WASTE LINE

Inlet float control valve

ENSURE ADEQUATE ACCESS

Access to Filters

As seen before, the schmutzdecke is different in covered filters.
SCRAPED VS HARROWING

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scraped</th>
<th>Harrowed (wet harrowed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass Development</td>
<td>Biomass and schmutzdecke take longer to develop due to the removal of biomass</td>
<td>Biomass and schmutzdecke restore at a faster rate, however, the sudden release of nutrients can cause dissolved oxygen to dip as microbial grazing intensifies. Keeping influent water flowing and filtering to waste at a higher initial rate can help to replenish depleted oxygen levels.</td>
</tr>
<tr>
<td>Removal Efficiency</td>
<td>Equivalent once filter is properly ripened</td>
<td>Equivalent once a filter is properly ripened – usually takes less time to accomplish this.</td>
</tr>
<tr>
<td>Filter life</td>
<td>Impacted by removal of top ~1 cm of plugged sand layer</td>
<td>Little media loss leads to longer filter life. Media is more susceptible to deep bed clogging if not done properly.</td>
</tr>
</tbody>
</table>

FILTER RIPENING

1. Turbidity
2. Coliform Counts (CFU/100 ml)

FILTER RE-SANDING

Two methods
1. Trenching or "throw-over" method
2. Full replacement

FILTER RE-SANDING

Trenching or "throw-over" method:
1. Sand bed is cleaned (scraped or harrowed)
2. Most of the sand is removed and set aside for later reuse from a strip along one wall, forming a trench (underlying gravel is left undisturbed by leaving 4-6 inches (10-15 cm) of sand).
3. Fresh sand (either new or washed) is placed in the trench to a thickness, with the residual sand, equal to the depth of the sand in the filter prior to re-sanding.
4. Residual sand from the next strip is "thrown over" on top of the freshly placed sand in the first strip.
5. This process is repeated until the last row. New sand is placed in the last row and the sand excavated from the first row is then placed on top of the new sand in the last row.

RIPENING OF RE-SANDED CELL

Ripening of newly sanded filters can take 3 or more weeks as evidenced by total coliform counts. Oftentimes it takes more than a month to wash out fines and ripen the filter.

Note: Burying old sand under new sand can cause taste and odor issues as the biological material dies off and decays.
RIPENING OF RE-SANDED CELL
HISTORICAL PERFORMANCE
JANUARY 2010 – NOVEMBER 2010

City of Astoria (00055) Cell 1 Turbidity (NTU)

Filtering to waste
NTU Goal
Raw Water NTU
Filtered Water NTU

NTU
8/29/2010
0
2
4
6
8
10
12
14
16
18

RIPENING RE-SANDED CELL
PERFORMANCE AFTER RE-SANDBING
AUGUST 2010 – OCTOBER 2010

City of Astoria (00055) Cell 1 Turbidity (NTU)

Filtering to waste
NTU Goal
Raw Water NTU
Filtered Water NTU

NTU
8/29/2010
0
2
4
6
8
10
12
14
16
18

NEED FOR OPTIMIZATION
GOALS & PRACTICES

1. Misunderstood removal mechanisms
2. Used in small communities (limited resources/expertise)
3. Turbidity is not a good indicator of filter performance
4. Good operating practices are the key to optimal performance
5. Goals were developed through literature review and comments received from experts in the field.

KEY PUBLICATIONS - 1974
http://www.who.int/water_sanitation_health/publications/sf9241540370.pdf

KEY PUBLICATIONS - 1987
http://www.irc.nl/docsearch/title/s8790

KEY PUBLICATIONS - 1991
KEY PUBLICATIONS - 2009


KEY PUBLICATIONS - 2012


INPUT FROM EXPERTS

Gary S. Logsdon, P.E.

<= Dr. Robin Collins

OPERATIONAL GUIDELINES

Operational Guidelines for Normal Operation

Operate slow sand filters continuously without filter effluent flow rate changes. If filter effluent flow changes are needed, ensure that the flow changes are made gradually to minimize detachment of particles from the sand with no more than a 50% variation in flow in a 24-hr period. Use filter effluent flow controls to accommodate changes in system demands (e.g., setting the filtration rate high enough to meet anticipated peak day demands and divert excess water to waste or filter headwater influent during low demand periods). Intermittent operation of slow sand filters should not be used as a means of rate control.

Influent water should be introduced into the headwater at least 1-ft of clearance above the sand bed and filter walls.

Ensure filter effluent rates (Hydraulic Loading Rates, or HLR) of between 0.03 - 0.10 gpm/ft² (0.07 – 0.24 m/hr). Filtration rates may need to be lowered should raw water quality deteriorate with lower temperatures. A flow rate of 0.05 gpm/ft² may be used with water temperatures less than 5°C.

In order to prevent air binding within the filter, the tail water elevation must always be maintained at or above the level of the sand bed. Filtration rates and effluent weir levels should be routinely checked and adjusted only if needed.
WATER QUALITY GOALS

Optimization Goals for Normal Operating Conditions

- IFE & CFE Turbidity ≤ 1.0 NTU in 95% of the highest daily readings, measured at least once daily.
- IFE & CFE Turbidity ≤ 5.0 NTU, measured at least once daily.
- IFE Total Coliform < 10 MPN/100 ml, measured at least weekly.
- Water entering the distribution system is absent of total coliform bacteria (measure weekly when IFE or CFE turbidity > 1 NTU)

IFE = Individual Filter Effluent
CFE = Combined Filter Effluent
NTU = Nephelometric Turbidity Units
TC = Total Coliform, Most Probable Number (MPN) or Colony Forming Units (CFU) per Standard Methods.

FILTER SCRAPING GUIDELINES

Operational Guidelines for Cleaning - Scraping

- Headwater depth reaches the headwater overflow level;
- The achievable filter production rate decreases to 0.03 gpm/ft² (0.073 m/hr); or
- Daily demands are anticipated to not be met.

When removing a filter from service for cleaning, schedule the event to avoid overloading the remaining filters.

Minimize the time a de-watered filter is off-line.

Do not de-water the filter more than necessary in order to safely clean the filter (e.g. 2-12 inches below the sand surface).

FILTER SCRAPING GUIDELINES CONTINUED

Operational Guidelines for Cleaning - Scraping

- Remove the schmutzdecke and no more than ¼ - ½ inch (0.635 – 1.27 cm) of sand with each cleaning. Depending upon the effective size (d₁₀) and applied water quality, more sand may need to be scraped (1/2 – 1”) in order to remove the plugged portion of the filter, allowing clean bed headloss to recover. Operators should monitor headloss before and after each scraping in order to determine how much sand is needed to be removed to maximize filter recovery while avoiding excessive sand removal. Monitoring headloss development by plotting daily headloss readings for each filter should be used to schedule filter cleanings during times of low demands and higher applied water temperatures (above ⁵°C). Scheduling cleanings during low system demands will help ensure that demands are able to be met without overloading adjacent filters. Scheduling cleanings during times of warmer water temperature will help minimize the adverse effects of cold temperatures on the filter biota. The minimum permissible sand bed depth should be no less than 20-24 inches.

Avoid walking or driving directly on the schmutzdecke during cleaning.

After the filter has been cleaned, slowly refill the filter from the bottom at a rate of 0.3-0.6 ft of bed depth per hour (0.1 – 0.18 m/hr or 0.0374 – 0.0748 gpm/ft²) in order to purge entrained air. Refill with non-chlorinated filtered water from one of the other filters until the headwater is 1-ft above the sand to minimize scouring of the sand bed when filling from the top begins. Then fill from the top at a rate that minimizes disturbing the sand bed.

Note: To convert ft/hr to gpm/ft², multiply (ft/hr) by (1 ft³/160 min) and then multiply by (7.48 gal/ft³). Example: 0.3 ft/hr x (1 ft³/160 min) x (7.48 gal/ft³) = 0.0347 gpm/ft².
FILTER SCRAPING GUIDELINES CONTINUED

Operational Guidelines for Cleaning - Scraping

Begin filtering to waste at the same rate as was used prior to cleaning, or at the anticipated rate needed when the filter is brought back on-line. Do not exceed the design flow rate and keep the rate < 0.1 gpm/ft².

Filter to waste one hour for each hour that the filter is off-line, but for no less than 24 hours. Filter to waste until the optimization goals following filter cleaning have been met.

FILTER SCRAPING GUIDELINES

MINIMUM SAND DEPTH GUIDELINE

20 – 24 INCHES

FILTER HARROWING GUIDELINES

Operational Guidelines for Cleaning - Harrowing

Lower water level to the level of the harrowing waste valve (e.g., about 6" (15 cm) above the sand bed). This is done to keep the head pressure low in order to minimize migration of debris down into the filter during the raking process.

Open the harrowing waste valve and begin introducing filtered unchlorinated water from the bottom of the filter at a rate of 0.16 ft/hr (0.02 gpm/ft²) and low enough to prevent the sand from being fluidized. This serves to suspend debris, and keeps it from settling back into the filter bed during raking.

Introduce water into the top of the filter at a rate low enough to prevent sand migration, but high enough to flush the debris to waste during raking. For rectangular filters, a typical flow rate of about 20 gpm times the depth of water above the sand during harrowing times the length of the filter that is perpendicular to the incoming flow will work. For example, 1,000 gpm will work with 6 inches of water depth in a 100-ft wide filter provided the flow path is directed across the width of the filter. For other filters, influent flow should be adjusted to maintain a steady water level above the sand during raking. In either case, it is important to maintain a constant water level above the sand throughout the harrowing process by balancing flows into and out of the filter.

Using a stiff tined rake or harrowing equipment, gently agitate the top 2 – 3" (5 – 8 cm) of sand until the headwater begins to clarify, as indicated by the ability to see the sand bed when the raking is stopped.

FILTER HARROWING GUIDELINES

Operational Guidelines for Cleaning - Harrowing

After it has been cleaned, slowly refill the filter from the bottom at a rate of 0.3-0.6 ft of rise per hour (0.1 – 0.18 m/hr or 0.0374 – 0.0748 gpm/ft²) in order to purge entrained air. Refill with non-chlorinated filtered water from one of the other filters until the headwater is 1-ft above the sand to minimize scouring of the sand bed when filling from the top begins. Then fill from the top at a rate that minimizes disturbing the sand bed.

Note: To convert ft/hr to gpm/ft², multiply (ft/hr) by (1 hr/60 min) and then multiply by (7.48 gpm/ft³). Example: 0.3 ft/hr x (1 hr/60 min) x (7.48 gpm/ft³) = 0.0347 gpm/ft².

Begin filtering to waste at the same rate as was used prior to cleaning, or at the anticipated rate needed when the filter is brought back on-line. Do not exceed the design flow rate and keep the rate < 0.1 gpm/ft².

Filter to waste one hour for each hour that the filter is off-line, but for no less than 24 hours. Filter to waste until the optimization goals following filter cleaning have been met.

FILTER RIPENING GUIDELINES

Optimization Goals Following Filter Cleaning (scraping or harrowing)

Filter to waste for each hour that the filter is off-line, but no less than 24 hours, until sampling demonstrates that the goals below have been met

Filter not to be brought on-line until:

- IFE TC ≤ 5/100 ml (MPN or CFU) (sample no earlier than 24 hours after the start of filtering to waste)
- IFE NTU ≤ 1.0 NTU

IFE = Individual Filter Effluent
CFE = Combined Filter Effluent
NTU = Nephelometric Turbidity Units

"Scraping invariably reduces a filter's ability to remove E. coli." (Unger & Collins, 2008)

"Total coliform was the most suitable surrogate...borne out by data in which there was the closest correspondence between removals of total coliform and Giardia cysts and serves as an index that the filter is biologically mature." (Hendricks, 1984)

"Total coliform was the most suitable surrogate...borne out by data in which there was the closest correspondence between removals of total coliform and Giardia cysts and serves as an index that the filter is biologically mature." (Hendricks, 1984)
RECOMMENDED MEDIA SPECS FOR RE-SANDING

<table>
<thead>
<tr>
<th>Specification</th>
<th>Recommended Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective Diameter (d10)</td>
<td>0.2 – 0.35 mm</td>
</tr>
<tr>
<td>Uniformity Coefficient (U)</td>
<td>1.5 – 3.0</td>
</tr>
<tr>
<td>% fines passing #200 sieve</td>
<td>&lt; 0.3% by Wt.</td>
</tr>
<tr>
<td>Acid Solubility</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>Apparent Specific Gravity</td>
<td>≥ 2.55</td>
</tr>
<tr>
<td>Minimum Depth</td>
<td>20-24 inches</td>
</tr>
<tr>
<td>Delivery/Installation</td>
<td>Sand should be washed prior to installation</td>
</tr>
<tr>
<td>NSF-61</td>
<td>Certified or equivalent</td>
</tr>
</tbody>
</table>

OPERATION & MAINTENANCE MANUAL

An O&M Manual should include procedures for...

1. Determining filtration rate
2. Changing filtration rate
3. Determining when to clean filters
4. Draining and refilling filters
5. Cleaning (scraping/harrowing)
6. Assuring adequate filter ripening
7. Dealing with seasonal changes (e.g., cold winters, high NTU, algae blooms, etc.)
8. Determining sand bed depth and when to re-sand
9. Re-sanding (including media specifications and handling)
10. Maintaining/operating disinfection system

O&M MANUALS

Other procedures include:
- Instrument calibration methods and frequency
- Data handling/reporting (Monitoring for regulatory requirements and process control)
- Chemical dosage determinations
- CT determinations
- Responding to abnormal conditions (emergency response plan)

MAINTENANCE TASKS

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Labor (person hours)</th>
<th>Task Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>1 - 3</td>
<td>Check raw water intake, check/adjust filtration rate, check water level in filter, sample &amp; check water quality (raw/finished NTU, raw temp), check pumps, enter observations in logbook</td>
</tr>
<tr>
<td>Weekly</td>
<td>1 - 3</td>
<td>Check &amp; grease any pumps &amp; moving parts, check/re-stock fuel, sample &amp; check water quality (coliform), enter observations in logbook</td>
</tr>
<tr>
<td>1 – 2 months</td>
<td>5 / 1,000 ft², 50 / 1,000 ft² / 12 inches of sand for re-sanding (Letterman &amp; Colli, 1985)</td>
<td>Scrape filter beds, wash scrapings &amp; store retained sand, check &amp; record sand bed depth, enter observations in logbook</td>
</tr>
</tbody>
</table>

MONITORING

The recommended minimum location points for recording and monitoring include:

Source water for:
- Turbidity
- Flow
- Temperature
- pH
- Grab sampling of coliform, TOC, or other water quality parameters

Supernatant for:
- Level (for filter headloss)
- Grab sampling of coliform, TOC, or other water quality parameters

Individual filter effluent for:
- Flow rate and quantity
- Turbidity
- Grab sampling of coliform, TOC, or other water quality parameters

Combined filter effluent for:
- Flow rate and quantity
- Turbidity
- Grab sampling of coliform, TOC, or other water quality parameters

Finished water (post disinfection and storage used for disinfection contact time) for:
- Flow rate and quantity
- pH
- Temperature
- Chlorine residual
- Grab sampling of coliform, TOC, or other water quality parameters

Finished water storage for:
- Effluent flows
- Level
**COLIFORM COUNTS**

1. Membrane Filtration (CFU/100 ml) – SM 9221A,B – exact count
2. Multiple-Tube Fermentation (MPN/100 ml) – SM 9222A,B,C – statistical estimate
3. ONPG-MUG Test or “Autoanalysis Colilert” (MPN/100 ml) – SM 9223 – estimate

**Most Probable Number (MPN/100 ml)**

Both examples below use statistical MPN Multiple-tube fermentation (MTF)

- Test tubes (20 x 150 mm)
- Culture media (e.g., R2A agar)
- Scale to measure media
- Autoclave to sterilize media
- Incubator

Formation of gas first indicates presumptive positive results, which are then confirmed

**IDEXX Quanti-Tray and Quanti-Tray/2000**

- Quanti-Tray Sealer & Incubator (35°C)
- IDEXX Quanti-Tray Range: 1-200 CFU/100 ml (95% confidence)
- IDEXX Quanti-Tray/2000 Range: 1 – 2,419 CFU/100 ml (95% confidence)
- Ortho-nitrophenyl-β-galactopyranoside (ONPG) reagent
- 4-methylumbelliferyl-β-D-glucuronide (MUG) - only E.coli produce an enzyme that reacts with MUG

**MONITORING HEAD LOSS**

Head loss Measurement

On smaller facilities, routine visual observation of the supernatant depth and recording of the flow rate may be sufficient to monitor filter head loss development.

On larger facilities, screened probes at the top and bottom of the filter sand can allow easy measurement of head loss with simple piezometers mounted outside the filter, or through the use of a differential pressure transducer connected to the facility’s SCADA system.

Tracking this data will allow the operator to predict and plan filter cleanings.

**QUESTIONS ABOUT OPERATIONS?**

Wickiup Water District, Oregon