INTRODUCTION

First Designed in 1804
Paisley, Scotland

Records show that an experimental slow sand filter was first designed and built by John Gibb in 1804, for his textile bleachery in Paisley, Scotland.

Thames River in 1828
London, England

“Monster Soup Commonly Called Thames Water”

In 1828, the artist William Heath published a scathing caricature reflecting the public’s distaste for the water being supplied from the River Thames by London companies.

Thames River Filtered in 1829

In 1829, James Simpson (pictured) designed a slow sand filtration system for the Chelsea Water Company in London, England. This was the first use of slow sand filtration for the express use of producing drinking water and became a model for future designs.

The benefits of the slow sand filtration system prompted the passage of the Metropolis Water Act in 1852, requiring all water derived from the River Thames within 5 miles of St Paul’s Cathedral to be filtered.
LONDON CHOLERA REDUCTION

“The only other water company deriving a supply from the Thames, in a situation where it is much contaminated with the contents of sewers, was the Chelsea Company. But this company, which supplies some of the most fashionable parts of London, took great pains to filter the water before its distribution, and in so doing no doubt separated, amongst other matters, the great proportion of that which causes cholera.”

- Snow, John. Communication of Cholera, 1855, p. 64

TODAY - WORLD-WIDE USE

In use world-wide

WHO, 1974
IRC, 1987
UNICEF, 2009

According to the World Health Organization, “Under suitable circumstances, slow sand filtration may be not only the cheapest and simplest but also the most efficient method of water treatment.”

FIRST USED IN U.S. IN 1872
POUGHKEEPSIE, NY

Proven technology
First placed into use in the U.S. in Poughkeepsie, NY. Used from 1872 - 1962
Chlorine was added in 1909
Poughkeepsie pronounced “puh KIP see”

The first successful slow sand filtration plant in America was placed into service July 8, 1872. The success of this project was heralded as epidemics all but disappeared and Poughkeepsie could no longer be called a “sickly City.”

WASHINGTON D.C. - 1905


UNDER DRAINS - PITTSBURGH, PA

This photo shows the main collector and laterals before support gravel and filter sand were added. Photo by Bureau of Filtration, city of Pittsburgh, PA.

CLEANING - PHILADELPHIA, PA 1900

Between 1900 and 1913, Philadelphia, PA constructed 5 slow sand plants like the one shown above. This photo shows a filter scraping in progress.
TYPHOID FEVER DECLINES

Reductions in Typhoid Fever due to filtration (1909) and disinfection (1914).

Deaths per 100,000 people

100=>
50=>
10=>

Entire Supply Filtered 1909
Entire Supply Chlorinated 1914

Deaths per 100,000 people

100=>
50=>
10=>

MORE REDUCTIONS IN TYPHOID FEVER

Death rates from typhoid fever for the cities shown dropped an average of 73% once filtration was installed. The 3 cities that installed slow sand experienced an average drop in the death rate of 78%.


REVIVAL IN THE EARLY 1990’S

Proven technology in use in the U.S. Since 1872 (Poughkeepsie, NY)

2-log to 4-log removals of bacteria, viruses, and cysts for mature sand bed conditions (Hendricks, 1991)

1995 GUIDELINES BY USEPA

Chapter 3 Slow Sand Filtration (EPA, 1995)

Min # of Filters 3 (allows for 1 out of service)
Filtration Rate 0.1 – 0.2 m/hr (0.04 – 0.08 gpm/ft²)
Sand Effective Size (d10) 0.15 – 0.35 mm
Uniformity Coefficient (UC) < 3 (little added benefit for cost if < 1.5)
Scraping depth 10 – 15 mm (0.4 – 0.6 in)
Ripening Period 1 – 2 days
Min Bed Depth 12 inches (prior to re-sanding)

COST EFFECTIVE

Inexpensive Design & Construction

$16,000/MGD in 1913

2007 Infrastructure Needs Survey Project Cost Models (~ $16,000/MGD)

SIMPLE TO OPERATE

Simple to operate/maintain

Frequency Task (person-hour) Slow Sand Filter Maintenance Task
Daily 1 – 3
Check raw water intake
Check influent temperature
Check raw water level in clarifiers
Sample & check water quality (raw/finished NTU, raw temp)
Check pumps
Enter observations in logbook
Weekly 1 – 3
Check & grease any pumps & moving parts
Check/lubricate filters
Sample & check water quality (samples)
Enter observations in logbook
1 – 2 months
50 / 1,000 ft² / 12 inches of sand for re-sanding
Scrape filter beds
Wash scarpings & store retained sand
Check & record sand bed depth
Enter observations in logbook

Frequency and tasks are adapted from WHO, 1998. Fact Sheets on Environmental Sanitation, Fact Sheet 2.12: Slow Sand Filtration.

Letterman & Cullen, 1985

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Frequency and tasks are adapted from WHO, 1998. Fact Sheets on Environmental Sanitation, Fact Sheet 2.12: Slow Sand Filtration.
**REMOVAL MECHANISMS**

So what makes them effective at filtration?

More than just physical straining at work.

<table>
<thead>
<tr>
<th>Particulate</th>
<th>Diameter ((d_o))</th>
<th>Grain Diameter Needed for Straining/Adsorption ((d_g))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colloids</td>
<td>0.1 µm</td>
<td>0.0009 + D10 mm</td>
</tr>
<tr>
<td>Bacteria</td>
<td>0.3 µm</td>
<td>0.0045 + D10 mm</td>
</tr>
<tr>
<td>Giardia</td>
<td>10 µm</td>
<td>0.0145 + D10 mm</td>
</tr>
<tr>
<td>Crypto</td>
<td>5 µm</td>
<td>0.0193 + D10 mm</td>
</tr>
</tbody>
</table>

**Slow Sand Media Range**

- D10 0.15-0.35 mm
- D60 0.3 - 0.7 mm
- UC (D60/D10) 1.5 – 3.0
- Pore size ~ 60 µm

(\(d_o = 0.198 \times D10\))

**REMOVAL MECHANISMS – FLOW SPLITTING**

Flow splitting increases the chance that particles will collide with sand grains.

Flow splitting increases with smaller sand grain size.

**REMOVAL MECHANISMS – ATTACHMENT**

Whether particles attach to grains depends on:

1. Coating of the sand grains due to biofilm development; and
2. "Coagulation" of particles due to extracellular enzymes

With newly sanded filters, coliform removals are near zero (\(\alpha \approx 0\)). After the filter matures, removals range from 99 – 99.99% (\(\alpha = 1\)).

**REMOVAL MECHANISMS – BIOTA**

- Schmutzdecke – Top
- 1"-6" Bacteria, Protozoa, Rotifers
- 4" – 8" Copepods
- 8" – 12" Roundworms, Flatworms, & Oligochaetes (segmented worms)

**REMOVAL MECHANISMS**

Other removal mechanisms are at work.

Sand grains 0.5–2.0 mm in diameter can remove bacteria with sizes of 0.001 mm through physical processes (transport and attachment due to electrical and molecular forces).

**REMOVAL MECHANISMS – FLOW SPLITTING**

Particles are carried or transported by stream flows to sand grains and are either intercepted, settle out, or collide through diffusive forces.

- Interception
- Sedimentation
- Diffusion

Increases with lower flows

Increases with high temps & low flows

**REMOVAL MECHANISMS – BIOTA**

- Schmutzdecke – Top
- 1"-6" Bacteria, Protozoa, Rotifers
- 4" – 8" Copepods
- 8" – 12" Roundworms, Flatworms, & Oligochaetes (segmented worms)
Although sometimes seen as a nuisance, the presence of midge flies can improve performance by keeping head loss in check.

**REMOVAL MECHANISMS**

**Burrowing** reduces head loss. Silk dwelling tubes become covered with adsorbed detritus and dissolved organic matter.

**FACTORS AFFECTING REMOVAL**

Schmutzdecke biological removal mechanisms

Effectiveness relies on:

1. **Wet sand** (to keep microbes alive)
2. **Adequate food** (organic mater supplied by continuous inflow of raw water)
3. **High enough oxygen content** (above 3 mg/l in the filter effluent) in order for metabolism of biodegradable compounds and avoid anaerobic decomposition, which can release hydrogen sulfide, ammonia, and other taste and odor causing compounds.

Oxygen levels can be maintained by:

- Continuous raw water influent
- Aeration

**SLOW SAND PERFORMANCE**


**WHO Min – Max Removal**

- Viruses: 0.25 – 4 log
- Bacteria: 2 – 6 log
- Protozoa: 0.3 – 5+ log

**Critical Variables**

1. **Raw water characteristics** (temperature, particle characteristics, color, algae, nutrients, organic compounds, oxygen content).
2. **Sand size** ($d_{10}$) and uniformity coefficient (UC)
3. **Flow control and air binding**
4. **Head loss allowed**
5. **Sand bed depth**
6. **Filtration rate and variability**
7. **Maturity of the sand bed and biological organisms**
8. **Filter cleaning (frequency, length of time the filter is out of operation, ripening period)**
RAW WATER - IRON & MANGANESE

Iron and Manganese

Iron and Manganese both < 1 mg/l

1. Slow sand filters remove iron and manganese by precipitation at the sand surface. This can enhance organics removal, but too much iron and manganese precipitate can clog the filters.

2. Some slow sand filters have been specifically designed and installed to remove iron and manganese at levels higher than 1 mg/l, with removals as high as > 67%.

RAW WATER - ORGANICS

Organic Matter:

1. The removal of natural organic matter (NOM) is related to filter biomass in that NOM removal increases with increasing biomass concentrations in the filter.

2. For every 1 mg of carbon removed by the schmutzdecke, 0.04 mg of nitrogen and 6 micrograms of phosphorous are required (Skeat, 1961).

3. SSF also have the ability to remove up to 3 mg/L of ammonia from source water as it is used by algae as a source of nitrogen.

4. SSF can remove between 14 and 40% of Assimilable Organic Carbon (AOC) averaging 26% AOC removal (Lambert and Graham, 1995)

RAW WATER - BACTERIA

Bacteria:

The net accumulation of bacteria in porous media is controlled by:

1. DOC and phosphorous concentrations needed to promote growth.

2. Substrate utilization (bacteria need a substrate to cling too - a smaller effective sand size provides more attachment points). Organic carbon exudates produced by algae also produce a substrate for bacterial growth.

3. Deposition (bacteria coming into contact with the substrate)

4. Decay (end of life cycle)

5. Detachment (detachment increases at higher filtration rates or if scouring occurs at filter bed influent and other turbulent areas)

Bacteria, continued:

1. Bacterial growth is also influenced by assimilable organic carbon (AOC) exuded by algae (decomposition)

2. AOC of at least 10 µg of carbon/liter is needed to promote heterotrophic bacteria growth.
   - Rivers typically have AOC of 123 µg C/l.
   - Coliform bacteria need AOC of 50 µg C/l.
   - AOC is typically 10% of TOC (LeChevallier et al. 1991)

RAW WATER - PROTOZOA

Protozoa:

1. Graze on algae, bacteria, and sometimes smaller protozoa

2. Temperature increases grazing.

3. Most are obligate aerobes (DO is critical)

4. Algae provide assimilable nutrients
   - Higher assimilation from algae than detritus and bacteria
   - Lower assimilation from blue-green algae

RAW WATER - TEMPERATURE

Temperature:

1. Temperature impacts microbial growth in slow sand filters

2. Microbial growth occurs in the range of 10 – 45°C (outside of this range, growth ceases)
   - Minimum range is 10 – 15°C
   - Max range is 35 – 45°C
   - Optimum range is 24 – 40°C

3. When air temperature drops to below 2°C for any prolonged period, covering the filter may prevent excessive heat loss.

Seasonal Lake Turnover
**RAW WATER - TEMPERATURE, CONT.**

Temperature Continued:

Open filters should not be used where temperatures can drop below freezing.

---

**RAW WATER - DISSOLVED OXYGEN**

Dissolved Oxygen (DO):

1. DO above 3 mg/l in the filter effluent is a good indicator that aerobic conditions remain in the filter. Filter influent DO should be above 6 mg/l in order to ensure DO is present in the effluent.

2. Maintaining oxygen levels promotes metabolism of biodegradable compounds, prevents dissolution of metals, and avoids anaerobic decomposition, which can release hydrogen sulfide, ammonia, and other taste and odor causing compounds.

3. DO is critical for the survival of protozoa that graze on pathogens since most are obligate aerobes.

4. Oxygen levels can be maintained by:
   - Continuous raw water influent
   - Aeration

---

**RAW WATER - ALGAE**

Algae:

Algae in influent water may be a different species than that of algae in the headwater above the filter bed.

---

**RAW WATER - ALGAE, CONT.**

Algae, continued:

2. Primary benefit to water purification is build-up of cell material through photosynthesis and metabolism of carbon dioxide, nitrates, phosphates, and other nutrients. Photosynthesis reaction is as follows:

\[
6\text{CO}_2 + 6\text{H}_2\text{O} + \text{sunlight} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

The reverse reaction occurs when algal cells die and decompose (WHO, pp 34-35)

---

**RAW WATER - ALGAE, CONT.**

Algae, continued:

3. Algae increase oxygen content, keeping aerobic conditions in filter bed. If dissolved oxygen of the filtered water drops below 3 mg/l, this may signify anaerobic conditions in the filter bed, which could lead to the formation of hydrogen sulfide, ammonia, dissolved iron and manganese, and other taste and odor causing compounds (WHO, pp 32-33).

---

**RAW WATER CHARACTERISTICS**

Algae, continued:

4. Algae decrease carbon dioxide. If too much carbon dioxide is decreased (e.g. during algal blooms), this may cause bicarbonates to dissociate to insoluble carbonates and carbon dioxide. The lowering of the bicarbonate content will cause a decrease in the temporary hardness and will cause the insoluble carbonate to precipitate out, clogging the filter. Reaction is as follows:

\[
\text{Ca(HCO}_3\text{)}_2 \rightarrow \text{CaCO}_3 + \text{CO}_2 + \text{H}_2\text{O}
\]
RAW WATER CHARACTERISTICS

Algae, continued:

5. When filamentous algae predominate, a zoogaleal mat is formed that contains tightly woven filaments giving the mat high tensile strength (high enough that the Schmutzdecke mat can be rolled up in some cases). When sunlight is strong and able to reach the mat layer (dependent upon the clarity of headwater), oxygen bubbles can form within and under the mat, increasing its buoyancy, reducing the filter resistance and increasing the filtration rate.

6. When diatomaceous algae predominate, the filter resistance and clogging increases due to their hard inorganic shells. Diatoms generally increase in number in late winter, often with 2-3 additional blooms occurring during the spring.

RAW WATER – ALGAE, CONT.

Classification of Algal Species

<table>
<thead>
<tr>
<th>Filter Clogging</th>
<th>Filamentous</th>
<th>Floating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tabellaria</td>
<td>1. Hydrodictyon</td>
<td>1. Protococcales</td>
</tr>
<tr>
<td>2. Asterionella</td>
<td>2. Oscillatoria</td>
<td>2. Scenedesmus</td>
</tr>
<tr>
<td></td>
<td>5. Melosira</td>
<td>5. Euglena</td>
</tr>
</tbody>
</table>

Table adapted from Table 10.2 Water Treatment Plant Design, AWWA/ASCE/EWRI, 2012

Algae blooms can be extensive

In addition to meteorological conditions, other factors contribute to Lake Erie algae blooms. Chief among them is the widespread adoption, since the mid-1990s, of no-till farming and other agricultural practices that have increased the availability of a type of phosphorous, known as dissolved reactive phosphorous or DRP, that promotes algae growth.

HARMFUL ALGAE BLOOMS – CAN BE EXTENSIVE

Lake Erie – 2012 Bloom

Credit: MERIS/NASA; processed by NOAA/NOSS/NCCOS

Lake Erie – 2011 Bloom

Credit: MERIS/NASA; processed by NOAA/NOSS/NCCOS

HARMFUL ALGAE BLOOMS – CAN WORSEN

Lake Erie – 2011 Bloom
(1/6 the size of 2011)


Lake Erie – 2011 Bloom

Credit: MERIS/NASA; processed by NOAA/NOSS/NCCOS

The 2011 Lake Erie bloom was composed almost entirely of toxic blue-green Microcystis algae. Concentrations of microcystis, a liver toxin produced by the algae, peaked at about 24 times World Health Organization guideline of 1 µg/l.
### 2013 Harmful Algae Bloom Recreational Advisory Information

<table>
<thead>
<tr>
<th>Waterbody</th>
<th>County</th>
<th>Dominant Species/Toxin</th>
<th>Cell Count (cells/ml) / Level (ppb)</th>
<th>Start Date</th>
<th>End Date</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willow Creek Reservoir</td>
<td>Morrow</td>
<td>Anabaena flos-aquae</td>
<td>3,552,625</td>
<td>6/18/2013</td>
<td>8/13/2013</td>
<td>56</td>
</tr>
<tr>
<td>Lost Creek Lake</td>
<td>Jackson</td>
<td>Anabaena flos-aquae</td>
<td>4,125,513</td>
<td>6/20/2013</td>
<td>7/05/2013</td>
<td>15</td>
</tr>
<tr>
<td>Dexter Reservoir</td>
<td>Lane</td>
<td>Anabaena flos-aquae</td>
<td>2,218,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorena Reservoir</td>
<td>Lane</td>
<td>Anabaena flos-aquae</td>
<td>556,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Devils Lake</td>
<td>Lincoln</td>
<td>Microcystin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Lake</td>
<td>Multnomah</td>
<td>Visible Scum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fern Ridge Reservoir</td>
<td>Lane</td>
<td>Visible Scum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: [http://healthoregon.org/hab](http://healthoregon.org/hab)

### HARMFUL ALGAE - CYANOBACTERIA

Cyanobacteria (blue-green algae)

- A phylum of bacteria
- Obtain energy through photosynthesis
- “cyanobacteria” comes from the color of the bacteria (Greek: κυανός (kyanós) = blue).
- Produce oxygen as a byproduct of photosynthesis (converting reducing to oxidizing environment)

![Photomicrograph of cyanobacteria, Cylindrospermum](https://example.com/Photomicrograph)

Photo taken by Matthew Parker.

### HARMFUL ALGAE - COMMON GENERA

Cyanobacteria Common in Oregon

- **Cylindrospermopsis**
- **Microcystis**
- **Anabaena**

![Images of cyanobacteria](https://example.com/Images)

Source: [http://healthoregon.org/hab](http://healthoregon.org/hab)

### HARMFUL ALGAE - TOXINS

Cyanobacteria:

- Produce toxins that can be harmful
- Occur in warm, slow moving water
- Increasing in frequency and duration
  - happening more or better reporting?
  - more people, more nutrients, warmer water
- No known human deaths in United States; known dog deaths in Oregon

Guidelines and labs are available on our website: [healthoregon.org/hab](http://healthoregon.org/hab)
Then click link: “Algae and Drinking Water”

![DANGER - Lake Closed](https://example.com/DANGER)

Source: [healthoregon.org/hab](http://healthoregon.org/hab)
HARMFUL ALGAE - TOXINS

Algal Toxins

<table>
<thead>
<tr>
<th>Type of Algae</th>
<th>Toxin Produced</th>
<th>Type of Toxin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anabaena</td>
<td>Anatoxin, Saxitoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td>Planktothrix (Oscillatoria)</td>
<td>Anatoxin</td>
<td>Neurotoxin</td>
</tr>
<tr>
<td></td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td>Cylindrospermopsis</td>
<td>Cylindrospermopsin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td>Gloeotrichia</td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
<tr>
<td>Microcystis</td>
<td>Microcystin</td>
<td>Hepatotoxin</td>
</tr>
</tbody>
</table>

HARMFUL ALGAE BLOOMS - IDENTIFICATION

What does a harmful algae bloom look like?

Cyanobacterial accumulation at Binder Lake, IA, dominated by the blue green algae Microcystis

Total microcystin concentrations were 40 µg/L measured by enzyme-linked immunosorbent assay, Date 6-29-06. Credit: U.S. Geological Survey/USGS

Location: Lake Dora, FL, USA
Credit: U.S. Geological Survey/Department of the Interior/USGS

Although AFA blooms are not considered harmful, the microcystis that sometimes accompanies AFA later in the summer can produce toxins.

HARMFUL ALGAE BLOOMS - EXAMPLE 1

You may notice a green, red or brown film

Location: Mozingo Lake, MO, USA
Credit: U.S. Geological Survey

HARMFUL ALGAE BLOOMS - EXAMPLE 2

Location: Lake Dora, FL, USA
Credit: U.S. Geological Survey

HARMFUL ALGAE BLOOMS - EXAMPLE 3

Location: Upper Klamath Lake
Aphanizominon flos-aquae (AFA) bloom in 2008. Although AFA blooms are not considered harmful, the microcystis that sometimes accompanies AFA later in the summer can produce toxins.
**Harmful Algae Blooms**

**Example 4**

**Location:** Willamette River, Portland, OR

- Microcystis = 2.25 million cells/ml
- 16 day recreational advisory (9/16/14 – 10/2/14)

Lake water subsample containing colonies of Aphanizomenon flos-aquae (A), Microcystis (B), and Gloeotrichia (C). Although Aphanizomenon flos-aquae does not produce toxins, Microcystis and Gloeotrichia can both produce the hepatotoxin microcystin. Magnification = 3×. Photograph by Sara Eldridge, U.S. Geological Survey.


---

**Total Chlorophyll**

Total chlorophyll and blue-green algae concentrations from the Oswego Diversion Dam located in the Tualatin River at river mile 3.4. 5/13/10 to 9/22/10

The blue-green algae data at the Oswego Dam site is collected with a YSI model 6131 probe. Chlorophyll is monitored with a YSI model 6025. More info on YSI probes is on-line at: [http://www.ysi.com](http://www.ysi.com)

Source: [http://or.water.usgs.gov/cgi-bin/grapher/graph_setup.pl?basin_id=tualatin](http://or.water.usgs.gov/cgi-bin/grapher/graph_setup.pl?basin_id=tualatin)

---

**Harmful Algae – Minimizing Blooms**

**How do I minimize algae blooms?**

**Source Water Management (long-term & lasting)**

Control Factors Affecting Algae Growth

- Minimize phosphorus (P) through use reductions & source control from erosion. Target: <35-40 ppb Total Phosphorus
- Other Nutrients (Nitrogen)
- Temperature (shading riparian areas)
- Mixing/Stratification (e.g., SolarBee®)
- Sunlight (covers or floating materials or aquatic dyes)

SolarBee® on new water impoundment for City of Seaside.

---

**Harmful Algae – Phosphorus Control**

**Phosphorus Control**

**Target:** <35-40 ppb TP

The reduction of phosphorus loading is the most effective means of reducing phytoplankton biomass in eutrophic lakes, even if Nitrogen is initially limiting. (Lewis and Wurtsbaugh, 2008, Schindler et al, 2008).
HARMFUL ALGAE – MINIMIZING BLOOMS

Are there other ways to control algae blooms?
Non-chemical

1. Non-chemical options:
   • Barley straw (fungi decompose straw releasing chemicals that prevent algae growth)
   • Raking (physical removal of algae mats)
   • Triploid Grass Carp (a fish species native to Asia that must be certified disease free and sterile. Also called “white amur”, they live for 5-6 years)

HARMFUL ALGAE – OTHER CONTROLS

Minimizing algae blooms?
Other measures

• Algaecides (not during a bloom)
  • Copper-based (cupric)
  • Peroxides (e.g. GreenClean Pro)

• Follow manufacturer’s instructions
• Treatment (roughing filters, GAC, PAC, Ozone)
(Plan review & approval is needed for treatment)

HARMFUL ALGAE – SLOW SAND

Effectiveness of Slow Sand Filtration:

<table>
<thead>
<tr>
<th>Filtration Technology</th>
<th>Algal Cell Removal Efficiency</th>
<th>Algal Toxic Removal Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow Sand</td>
<td>~95% cell removal, low lysis of cells, reducing toxin release</td>
<td>Efficiency of dissolved microcystin is likely to depend on biofilm formation and filter run length, but is anticipated to be significant</td>
</tr>
<tr>
<td>Membrane</td>
<td>&gt;99% cell removal, low lysis</td>
<td>Depends upon size of membrane pores and toxin molecule</td>
</tr>
<tr>
<td>Conventional &amp; Direct Filtration</td>
<td>70-100% (CF, low lysis) &gt; 80% (OF, low lysis)</td>
<td>&lt; 10% of toxins</td>
</tr>
</tbody>
</table>

HARMFUL ALGAE BLOOMS – BEST PRACTICES

Best Management Practices (BMPs) for Harmful Algae Blooms for Drinking Water Providers is available on-line at:


IN THE EVENT OF AN ALGAE BLOOM

In the event of a bloom...

• Do not add algaecide (lysed cells can release 50-95% of the toxins)
• Do not use oxidants like chlorine prior to filtration (lyses cells)
• Use alternate source if possible
• Use PAC/GAC if available
• Monitor cells
• Monitor toxins

ALGAE CELL ID/COUNT TRIGGERS

Triggers for algae cell identification and enumeration:

Contact the State if a visible bloom develops, as evidenced by visible scum. (more on what that might look like will be presented later)
**TOXIN TESTING TRIGGERS**

Triggers for Toxin Testing:

<table>
<thead>
<tr>
<th>Cyanobacteria Cell Count Action Levels that trigger toxin sampling for Drinking Water (World Health Organization)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcystis spp.</td>
</tr>
<tr>
<td>Combination of all potentially toxic cyanobacteria species present</td>
</tr>
</tbody>
</table>

Contact the State if blooms indicate toxin testing should be done (financial assistance may be available)

**TOXIN TESTING**

Recommended Toxin Testing:

1. If there is an algae bloom in your source water, contact the Drinking Water Program for instructions on sampling raw water from the intake and finished water (after all treatment). Testing costs may be covered by the State.

2. If a bloom is present in the source water, a paired raw water intake and finished water sample should be taken at the same time:
   1. Have raw water tested for toxins.
   2. If raw water has toxins, also have finished water tested for toxins.
   3. Raw and finished water sampling should continue weekly until the bloom is gone.

**TOXIN LIMITS**

Acute Toxicity Limits in Finished Water:

Toxins should not exceed those levels listed in the table below. If they do, consult with the State.

<table>
<thead>
<tr>
<th>Oregon Health Authority Drinking Water Acute Toxicity Guidelines for Algal Toxins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toxin =&gt; Anatoxin-a</td>
</tr>
<tr>
<td>&lt;6 Years of Age</td>
</tr>
<tr>
<td>6 Years and Older</td>
</tr>
</tbody>
</table>

Utilities should be prepared to communicate the risks to customers should finished water toxin results exceed these levels.

**TOXIN LIMITS**

Why an age-specific guideline?

- Bottle-fed infants consume large amounts of drinking water compared to their body weight (when formula is prepared using tap water).
- Exposure to children < 12 months is 5x higher than for adults > 21 years of age, on a body-weight basis.
- At 6 years and older, exposure on a body weight basis is similar to that of an adult.

**WHEN TO ISSUE AN ADVISORY**

A “Do Not Drink” advisory should be issued for drinking water if the toxin limits are exceeded in the finished water. A recreational advisory may also be needed.
WHEN TO END TOXIN TESTING & ADVISORY

Monitoring and advisory status can return to pre-bloom conditions, once the bloom has subsided, as evidenced by the falling toxin levels and, if monitored, lower cell counts.

< Permanent sign flipped down for recreational health advisory.

Sign flipped up > when advisory is lifted

HAVE A BLOOM IN THE FILTER?

Apply the same steps if the bloom is occurring in your filter.

BE PREPARED

"HABS readiness kit"

A “HABS readiness kit” can help you respond:
1) Quickly,
2) Predictably, and
3) Consistently

HARMFUL ALGAE RESOURCES

Oregon Health Authority – Drinking Water Services

Oregon Health Authority – HABS Program
www.healthoregon.org/hab

Oregon DEQ
http://www.eyr.state.or.us/tyqa/AgaeAndBloom.htm

USEPA
http://www.epa.gov/nutrientpollution/harmful-algal-blooms

Washington Dept of Ecology – Algae Control Methods

APPLIED WATER CHARACTERISTICS

Recommended. Applied Water Quality (following any pre-treatment)

<table>
<thead>
<tr>
<th>Turbidity</th>
<th>Requirement</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10 NTU</td>
<td>(colloidal clays are absent)</td>
<td>Operation is more efficient with lower consistent turbidity in the 5-10 NTU range. Most slow sand plants successfully treat source water with a turbidity of less than 10 NTU (Slezak and Sims, 1984), which is recommended for an upper limit in designing new facilities. Colloidal clays may penetrate deeper into the filter bed causing long-term clogging and higher effluent turbidity. Effluent turbidity is typically &lt; 1.0 NTU. Roughing filters can provide up to 50 - 90% of turbidity removal.</td>
</tr>
</tbody>
</table>
**APPLIED WATER CHARACTERISTICS RECOMMENDED FOR SLOW SAND FILTRATION**

**Recommended Applied Water Quality (following any pre-treatment)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Color</td>
<td>&lt; 5 platinum color units</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>&gt; 6 mg/l (filtered water DO should be ≥ 3 mg/l)</td>
</tr>
<tr>
<td>Total Organic Carbon (TOC)</td>
<td>≤ 1.0 mg/l (low TOC to prevent DBP issues)</td>
</tr>
<tr>
<td>Iron &amp; Manganese</td>
<td>Each &lt; 1 mg/l</td>
</tr>
<tr>
<td>Algae</td>
<td>&lt; 200,000 cells/L (depends upon type)</td>
</tr>
<tr>
<td>Coliform Bacteria</td>
<td>&lt; 800 CFU or MPN/100 ml</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>&gt; 6 mg/l (filtered water DO should be ≥ 3 mg/l)</td>
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**QUESTIONS?**

USA Armco of Precision photo of Washington DC McMillan Water Filtration Plant, 1913. (mcmillan water filtration plant in use from 1905 – 1985)