The early filtration units developed in Great Britain used a process in which the hydraulic loading rate is relatively low. Typical slow sand filtration velocities are only about 0.4 m/hr. At these low rates, the filtered contaminants do not penetrate to an appreciable depth within the filtration medium.

The filter builds up a layer of filtered contaminants on the surface, which becomes the active filtering medium. Slow sand filters are cleaned by taking them off line and draining them. The organic or contaminant layer is then scraped off. The filter can then be restarted. After water quality reaches an acceptable level, the filter can then be put back on line.

In rapid sand filtration much higher application velocities are used. Filtration occurs through the depth of the filter. A comparison of rapid and slow sand filtration is shown in the table below.

<table>
<thead>
<tr>
<th>Filtration Type</th>
<th>Application Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow Sand</td>
<td>0.04 to 0.4</td>
</tr>
<tr>
<td></td>
<td>340 to 3,400</td>
</tr>
<tr>
<td>Rapid Sand</td>
<td>0.4 to 3.1</td>
</tr>
<tr>
<td></td>
<td>3,400 to 26,000</td>
</tr>
</tbody>
</table>

In the United States, filter application rates are often expressed as volumetric flowrate per area, or gal/min-ft², which is actually a velocity with atypical units.
Hydraulic Loading Rate

Let's compute the hydraulic loading rate on our filters in lab:

Flowrate: 1,000 ml/min

Area of filter: 3.5 in. diameter filter

\[
\text{Loading Rate} = \frac{\text{Flowrate}}{\text{Area}} = \frac{1,000 \text{ ml/min}}{\pi \times \left(\frac{3.5\text{ in.}}{2}\right)^2} = 3.954 \text{ gpm/ft}^2
\]

Hydraulic Loading Rate

Let's compute the hydraulic loading rate on our filters in lab:

Flowrate: The one you used in lab last week.

Area of filter: 3.5 in. diameter filter

\[
\text{Loading Rate} = \frac{\text{Flowrate}}{\text{Area}} = \frac{\text{Flowrate} \text{ ml/min}}{\pi \times \left(\frac{3.5\text{ in.}}{2}\right)^2} = \text{gpm/ft}^2
\]

Hydraulic Loading Rate

Let's compute the hydraulic loading rate on our filters in lab:

Flowrate (ml/min) Loading Rate (gpm/ft²)

<table>
<thead>
<tr>
<th>Flowrate (ml/min)</th>
<th>Loading Rate (gpm/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>3.163</td>
</tr>
<tr>
<td>1,000</td>
<td>3.954</td>
</tr>
<tr>
<td>1,200</td>
<td>4.745</td>
</tr>
</tbody>
</table>

Hydraulic Loading Rate

A hydraulic loading rate of 3.954 gpm/ft² could be classified as:

1. A high-end direct filtration (1-6 gpm/ft²)
2. A mid-range rapid filter (range of 2-10 gpm/ft² with 5 gpm/ft² normally the maximum design rate)

Hydraulic Loading Rate

To convert the hydraulic loading rate to the U.S. standard of gpd/ft², convert minutes to days

\[
\text{Loading Rate} = \frac{\text{Flowrate}}{\text{Area}} = \frac{3.954 \text{ gpm/ft}^2 \times 60 \text{ min/hr} \times 24 \text{ hr/day}}{3.785 \text{ ml/gal} \times \frac{1 \text{ gallon}}{144 \text{ in.}^2}} = 5,694 \text{ gpd/ft}^2
\]

A hydraulic loading rate of 5,694 gpd/ft² could be classified as a rapid sand filter

<table>
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</tr>
</tbody>
</table>
Hydraulic Loading Rate

Let's compute the hydraulic loading rate for flowrates in class:

Flowrate: 800 and 1,200 ml/min

Area of filter: 3.5 in. diameter filter

\[
\text{Flowrate Loading Rate} = \frac{\text{Flowrate (ml/min)}}{\text{Area (ft.²)}} = \frac{\text{Flowrate (ml/min)}}{\frac{\pi \times (\text{diameter}/2)^2}{4} \times \frac{1\text{ gallon}}{3,785\text{ ml}} \times \frac{144\text{ in.}^2}{\text{ft.}^2}}
\]

Hydraulic Loading Rate

Let's compute the hydraulic loading rate for flowrates in class:

Flowrate: 800 and 1,200 ml/min

Area of filter: 3.5 in. diameter filter

Flowrate of 800 ml/min \( \rightarrow \) 3.164 gpm/ft.²

Flowrate of 1,200 ml/min \( \rightarrow \) 4.746 gpm/ft.²

Hydraulic Loading Rate

To convert the hydraulic loading rate to the U.S. standard of gpd/ft.², convert minutes to days

\[
\text{Loading Rate} = \frac{\text{Flowrate (gpm)}}{\text{Area (ft.²)}} = \frac{4.746 \text{ gpm/ft.²} \times \frac{60\text{ min}}{\text{hr}} \times \frac{24\text{ hr}}{\text{day}}}{\text{Area (ft.²)}} = 6,834 \text{ gpd/ft.²}
\]

Rapid Sand Filtration

- The water above the filter provides the hydraulic pressure (head) for the process.
- The filter medium is above a larger gravel, rock, or other media for support.
- Below the rock is usually an underdrain support of some type.
- The water flows through the filter and support media, exiting from a pipe below.
Rapid Sand Filtration

Most modern filters employ two separate filter media in layers:
- The lower layer is composed of a dense, fine media, often sand
- The upper layer is composed of a less dense, coarse media, often anthracite coal
- The coarse upper layer removes larger particles before they reach the fine layer, allowing the filter to operate for a longer period before clogging.

As the filter begins to clog from accumulated solids, less water will pass through it. At some point cleaning is required.
- Usual filter operation before cleaning is from a few hours to 2 days.
- Cleaning is accomplished by reversing the flow of water to the filter, or backwashing.

The backwash velocity is sufficient to fluidize the bed - that is, to suspend the bed with the reverse flow.
- After backwashing, the filter is again placed in operation.
End of Part 3
Any Questions?