Filtration of Virus, Bacteria, and Protozoan Sized Particles in the Filtron

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Outline
- What is the Filtron and why do we need it?
- What were the goals of this research?
- How was the research conducted?
- What were the results?
- What do the results mean?

Availability of clean water
- Over 1 billion people w/o access to clean water
- 1.8 million people die every year from diarrhoeal diseases. (WHO)
- Problem is in big cities and small villages
- Women and children must walk miles to access clean water

The Filtron - what is it?
- Point-of-use device
- Porous ceramic pot
- Gravity filtration (no pumps)
- Easy to make
- Inexpensive ($10-$15)
- No technical expertise needed
- In use in over 14 countries

The Filtron - what do we know?
- Pores range in size from 0.6-3 microns
- Previous experiments have shown over 99% removal of pathogens (2-Log)
- Silver coating on filter inactivates pathogens
- As filter is used, sediments accumulate on the surface, causing a decrease in flow rate
- Breakthrough phenomenon

Objectives
1) Assess the Filtron’s ability to remove various sized particles, spanning virus through protozoan sizes
2) Determine whether recoating with silver effects removal efficiency
3) Make a quantitative description of the breakthrough phenomenon
Methods

- 6 filters: 1NS, 2NS, 1N, 2N, 1U, 2U

Microspheres

<table>
<thead>
<tr>
<th>Size (µm)</th>
<th>suspension</th>
<th>calculated microspheres/mL</th>
<th>excitation/emission</th>
<th>pathogen of similar size</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>2.00%</td>
<td>2.60E+15</td>
<td>535/575</td>
<td>Rhinovirus</td>
</tr>
<tr>
<td>2 Y/G</td>
<td>2.00%</td>
<td>3.64E+13</td>
<td>535/575</td>
<td>Influenza virus</td>
</tr>
<tr>
<td>5 Y/G</td>
<td>2.00%</td>
<td>2.93E+11</td>
<td>505/515</td>
<td>Aeromonas hydrophila</td>
</tr>
<tr>
<td>2 Y/G</td>
<td>2.00%</td>
<td>4.55E+09</td>
<td>505/515</td>
<td>Encephalitozoon spores</td>
</tr>
<tr>
<td>10 Y/G</td>
<td>2.90%</td>
<td>4.53E+08</td>
<td>441/486</td>
<td>Giardia lamblia</td>
</tr>
</tbody>
</table>

Methods

- Spike influent water with fluorescent microspheres

Methods

- Run water through filter. Measure depth and temperature at each sampling point

Methods

- Collect influent, effluent, and raw samples

Methods

- Analyze samples with fluorometer and determine sphere concentration
Series of Experiments

- All six filters were run concurrently
- Each filter has a complete data set
  - Batch = 3.5 hours runtime
  - 3 time points for each batch (1.5, 2.5, 3.5 hr.)
  - 3 batches of spiked water + 1 breakthrough batch for each sphere size
  - 5 sphere sizes (0.02 um, 0.1 um, 0.5 um, 2 um, 10 um)
  - 2 batches of unspiked water in between sphere sizes

Data for filter 1U, particle size 2um, all batches and all time points

Removal efficiency based on size

What do you get from all that sampling?

- For every microsphere size, there are 3 batches. Each batch has 3 or 4 time points. (1NS, 1um, second batch)

How much of the total data does this represent?

This table represents all the tests undertaken, with the previous data highlighted in green.

Removal efficiency of each filter

Particle Removal Based on Size

<table>
<thead>
<tr>
<th>Sphere Size (um)</th>
<th>0.02</th>
<th>0.1</th>
<th>0.5</th>
<th>2</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1NS</td>
<td>88</td>
<td>90</td>
<td>92</td>
<td>94</td>
<td>96</td>
</tr>
<tr>
<td>2NS</td>
<td>86</td>
<td>88</td>
<td>90</td>
<td>92</td>
<td>94</td>
</tr>
<tr>
<td>1N</td>
<td>84</td>
<td>86</td>
<td>88</td>
<td>90</td>
<td>92</td>
</tr>
<tr>
<td>2N</td>
<td>82</td>
<td>84</td>
<td>86</td>
<td>88</td>
<td>90</td>
</tr>
<tr>
<td>1U</td>
<td>80</td>
<td>82</td>
<td>84</td>
<td>86</td>
<td>88</td>
</tr>
<tr>
<td>2U</td>
<td>78</td>
<td>80</td>
<td>82</td>
<td>84</td>
<td>86</td>
</tr>
</tbody>
</table>
What do these data say about removal efficiency?

- Larger particles (10, 2 um) are removed better than smaller particles
- Smaller particles (0.5, 0.1, 0.02 um) can be effectively removed by the Filtron
- Removal of small particles varies greatly from filter to filter without pattern

Effect of Recoating Silver

- During the previous REU season, data was collected before recoating
- 1U
  - Recoated
  - 1NS
  - No silver

Paired t test

- Compared each filter in 2007 and 2008

<table>
<thead>
<tr>
<th>Comparison</th>
<th>1U</th>
<th>1NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02, 0.1 um</td>
<td>0.0152</td>
<td>0.0967</td>
</tr>
<tr>
<td>0.02, 0.2 um</td>
<td>0.0160</td>
<td>0.0550</td>
</tr>
<tr>
<td>0.05, 0.2 um</td>
<td>0.0271</td>
<td>0.0650</td>
</tr>
</tbody>
</table>

- High confidence for small sizes
- Low confidence for large sizes

Why does removal efficiency increase for both filters?

- Filter history between REU ’07 and REU ’08
- Several batches of water were run between these data
  - Bacteria and microspheres
  - Buildup of material in the filter (filter cake) could increase removal efficiency

Breakthrough Phenomenon

- Unspiked water was poured into the filter after the 3 spiked batches were run
- Sampled in same way as spiked batch
- Were there spheres in influent/effluent?
Dissociation of particles in the Filtron during the breakthrough batch

Breakthrough phenomenon
- Influent: larger spheres dissociate more readily into influent
- Effluent: sphere concentrations in breakthrough batch effluent are comparable to concentrations in spiked batch effluent

Conclusions
1) Virus sized particles can be removed, but not as efficiently as larger particles
2) Factors other than silver recoating are responsible for the difference between pre- and post-coating removal efficiencies.
3) Breakthrough can cause significant recontamination of previously unspiked water.

Further Work
- Extensive testing of various particle sizes
- Testing new silver coated filters against new uncoated filters
- Attempting to recreate breakthrough with live organisms (i.e. bacteria)
Acknowledgements

- Dr. Bielefeldt, for giving me this opportunity and providing constant support.
- Dr. Summers, for his constructive criticism and the awesome lunch at the place with the good clam chowder.
- Amanda Kohler, for her unending help and for always putting up with my shenanigans.
- The NSF, for making experiences like this possible.
- My fellow REU students, for making a community of friends, not just researchers.
- SCIENCE!!!