Development of a procedure and apparatus to quantify pathogen reduction throughout an intermittent biosand filter

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Duchity, Haiti
Duchity, Haiti – Water Quality
Intermittent biosand filter

- Adaptation of a traditional slow sand filter
- Designed by Dr. David Manz (1991)
- Implemented in more than 70 countries
- Appropriate technology
  - Low cost
  - Materials availability
  - Operational simplicity

Diagram details:
1. Reservoir Zone
2. Standing water Zone
3. Biological Zone
4. Non-Biological Zone
5. Gravel Zone

Dimensions:
- 304 mm x 108 mm
- 158 mm
- 940 mm
- 543 mm
- 50 mm
- 66 mm

Source: CAWST Manual 2009
Biosand filter operation

- Biosand filter mechanisms
  - Mechanical trapping
  - Adsorption
  - Biological Activity
  - Lack of oxygen and nutrients

(1) CAWST Manual 2009
Technology comparison

- **Intermittent biosand filter**
  - Intermittent flow
  - No maintenance cost
  - Household level
  - Simple operation

- **Traditional slow sand filter**
  - Continuous flow
  - Municipal level
  - Volume of treated water
Objectives

- Evaluate the impact and contribution of microbial activity and dissolved oxygen concentration in pathogen reduction as functions of medium depth and time.
  - Understand the filter mechanisms interaction
  - Improve filter design
  - Optimize materials use
### Table 1. Bench scale dimensions

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter [m]</td>
<td>0.10</td>
</tr>
<tr>
<td>Total height [m]</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Outlet tube</strong></td>
<td></td>
</tr>
<tr>
<td>Inside diameter [mm]</td>
<td>9.53</td>
</tr>
<tr>
<td>Outside diameter [mm]</td>
<td>6.35</td>
</tr>
<tr>
<td>Tube height [mm]</td>
<td>695</td>
</tr>
<tr>
<td>Effective volume [mL]</td>
<td>2,280</td>
</tr>
</tbody>
</table>

### Table 2. Haiti local sand

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size [mm]</td>
<td>0.7 - 0.1</td>
</tr>
<tr>
<td>Effective size [mm]</td>
<td>0.13</td>
</tr>
<tr>
<td>Uniformity Coefficient</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Minerals</strong></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>SiO&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Calcite</td>
<td>CaCO&lt;sub&gt;3&lt;/sub&gt;</td>
</tr>
</tbody>
</table>
### Table 3. Sampling ports dimensions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring diameter [mm]</td>
<td>50</td>
</tr>
<tr>
<td>Wall distance [mm]</td>
<td>25.4</td>
</tr>
<tr>
<td>Tube</td>
<td></td>
</tr>
<tr>
<td>Outside diameter [mm]</td>
<td>9.53</td>
</tr>
<tr>
<td>Inside diameter [mm]</td>
<td>6.35</td>
</tr>
<tr>
<td>Perforations quantity</td>
<td>5</td>
</tr>
<tr>
<td>Mesh</td>
<td></td>
</tr>
<tr>
<td>Opening size [μm]</td>
<td>105</td>
</tr>
</tbody>
</table>
Methodology

2.3 L Solution
796 mg/L NaCl

Solution addition

Sampling Port 1

Sampling Port 2

Sampling Port 3

Sampling Outlet

Multi-parameter PCSTestr 35 Oakton

Conductivity measurements

New batch addition
Results: Tracer test
Results: Tracer Test

Morrill Dispersion Index

\[ MDI = \frac{T_{90}}{T_{10}} \]

Mixture

Plug Flow
Volumetric flow rate and hydraulic head

Volumetric flow rate as function of time in a biosand filter

\[ y = 101.71e^{-0.052x} \]

Hydraulic head as function of time in a biosand filter

\[ y = 33.143e^{-0.073x} \]
Volumetric flow rate and hydraulic head

Volumetric flow rate as function of the hydraulic head in a biosand filter

\[ y = 4.2028x + 2.7766 \]

\[ R^2 = 0.9968 \]
Future Work

- Develop concentration profiles as a function of depth and time
  - Total coliform
  - *Enterococcus spp.*
  - Dissolved oxygen

- Evaluate the impact in the bacteriological quality of the biosand filter effluent with a modified zeolite treatment.

- Conduct a person-to-person survey in Duchity, Haiti.

### Table 4. Preliminary Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Treatment time</th>
<th><em>E. coli</em> CFU/100 mL</th>
<th>Total coliform CFU/100 mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>0 hr</td>
<td>3,100</td>
<td>66,900</td>
</tr>
<tr>
<td>Control</td>
<td>1 hr</td>
<td>3,600</td>
<td>56,500</td>
</tr>
<tr>
<td></td>
<td>2 hr</td>
<td>3,400</td>
<td>53,700</td>
</tr>
<tr>
<td>Non-modified zeolite</td>
<td>1 hr</td>
<td>400</td>
<td>13,000</td>
</tr>
<tr>
<td></td>
<td>2 hr</td>
<td>100</td>
<td>9,700</td>
</tr>
<tr>
<td>Modified zeolite</td>
<td>1 hr</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2 hr</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Acknowledgements
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http://greatidea.uprm.edu