Impact of UV radiation dose, suspended solids and organic matter on its efficiency to remove pathogens from greywater

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Greywater reuse

- Greywater (GW) is domestic wastewater excluding the toilet stream

- Using GW may reduce domestic water use by up to 50% and typically used for gardening and toilet flushing

- Many GW reuse standards require to lower indicator bacteria concentrations ➔ Disinfection is needed
UV radiation damages bacterial/viruses nucleic acids (DNA/RNA), thereby preventing them from replicating.
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Pros and cones using UV

**Advantages:**
- Does not require addition of chemicals
- Effective on a wide range of pathogens
- Fairly simple and low cost operation and maintenance
- Safe for operators in general and in comparison to chlorination
- No by-products

**Disadvantages:**
- Disinfection is limited as a result of repair mechanisms
- No residual effect
- Fouling of the quartz sleeve decreases the efficacy of disinfection
- Insufficient water quality might reduce UV efficiency.

Specifically, total suspended solids (TSS) and organic substances
Effect of TSS on UV disinfection efficiency

Impact of particle “shielding” by absorption, scattering, refraction and reflection

Impact of particles enmeshed/associated with microorganisms
Investigate the **efficiency** of low-pressure UV disinfection of GW under a range of: **UV doses**, **TSS** and dissolved **BOD$_5$** concentrations

Develop a **statistical model** for the prediction of the impact of TSS and BOD$_5$ on disinfection efficiency

Correlate between a **collimated beam results** that is mostly used in the laboratory to **flow-through reactors** which are mostly used in the field
Laboratory setup:
Range of TSS and BOD were tested

Treated GW
Changing concentration of TSS and BOD
Each sample, 3 replicates

Recirculating vertical flow constructed wetland

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>FC (CFU/100ml)</td>
<td>$10^4 - 10^5$</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>1-130</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>3-100</td>
</tr>
</tbody>
</table>

432 combinations

Collimated beam

UV irradiation doses: 7.5, 15 and 30 mJ/cm²
Field experimental setup:
Range of TSS and BOD were tested

Household GW source
(bathroom and laundry)

Storage of Raw GW

GW Biological Treatment

UV Disinfected GW
dose: 44 mJ/cm²

<table>
<thead>
<tr>
<th>Quality of pre-disinfected treated GW from 11 onsite treatment systems</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS (mg/L)</td>
<td>3.9-233</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>0-107</td>
</tr>
<tr>
<td>% Transmission$_{254 \text{ nm}}$</td>
<td>39-85</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>1.47-512</td>
</tr>
<tr>
<td>FC (CFU/100ml)</td>
<td>0-10⁶</td>
</tr>
</tbody>
</table>
As expected, disinfection efficiency increased with increasing UV dose and was negatively affected by the presence of TSS and BOD.
Results: Multiple linear regression (MLR) model

\[
\text{log FC removal} = \beta_1 \cdot [\text{BOD}] + \beta_2 \cdot [\text{TSS}] + \beta_3 \cdot [\text{log FC}_{\text{Gw}}] + \beta_4 \cdot [\text{UV dose}]
\]

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Estimate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\beta_1)</td>
<td>0.001</td>
<td>0.2211*</td>
</tr>
<tr>
<td>(\beta_2)</td>
<td>-0.012</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(\beta_3)</td>
<td>0.495</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(\beta_4)</td>
<td>0.059</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
TSS reduced the UV disinfection efficiency more than BOD$_5$
Results: Multiple linear regression (MLR) model

\[ R^2 = 0.84 \]
\[ p < 0.0001 \]
Results:
Correction Factor (CF)

For the same log removal dividing the measured UV dose in the flow-through reactor by the model-predicted UV dose (based on collimated beam results), resulted in a correction factor (CF) of 7.47

Reactors UV dose = 7.47 \cdot \text{UV collimated beam}
Conclusions:

- UV disinfection efficiency decreases as a result of increasing TSS concentration beyond a threshold value of 50 mg/L.

- As UV dose the influence of TSS (30 mJ/cm CB).

- The effect of dissolved organic substances on UV disinfection efficiency is significantly smaller than of TSS.

- It is possible to predict GW disinfection efficiency by simple MLR model → take it into consideration for system design.

- A correction factor (7.5) was established between Laboratory based collimated beam results and Field, flow through reactors.
Thank you for your attention

Questions?

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