Treatment and reuse of domestic greywater through green walls

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Funded by

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Greywater: domestic greywater excluding toilet flushing.

- **Light** from persona cleaning (hand basin, shower, bath)
- **Dark** personal cleaning, laundry, house cleaning, dishwasher (sometimes kitchen sink)

In Italy around **100 L/PE daily**

**Local treatment**
- Less quantity of wastewater that is collected and treated in centralised treatment plants
- Different quality of the remaining wastewater collected (more concentrated pollution)

**Re-use**
- Reduction of **potable water** consumption up to 50%
- Less quantity of wastewater

**Nature-based solutions**
- Less chemicals products for treatment
- Environmental and human benefits in urban areas (e.g. air quality, biodiversity, heating islands, noise, stress, building value)
Aim of the study:
Evaluation of treatment performances of different growing media in a pilot green wall system

1. Outdoor pilot system
   - Synthetic GW prepared every two days
   - One column = one growing medium (three independent replicates per media)
   - Base growing medium: coconut fibre and perlite
   - Multiple panels system
   - 24 L per column per day
   - HLR 750 L/m²/day
   - **Additive** in growing media
     - 20% polyacrilate (older) - columns prepared during pre-test
     - 20% polyacrilate
     - 20% compost
     - 20% polyacrilate + 20% biochar
     - 10% granular active carbon
     - 20% biochar – columns analysed in both phases
     - 20% biochar (new)
     - 20% biochar + 5% graphene

   - **Phase 1:** Jan-Apr 2019
     - 9 samples
     - 7 configurations

   - **Phase 2:** May-Jul 2019
     - 8 samples
     - 3 configurations

2. Water flow and sampling
   - Vertical flow along each column
   - Sampling at the outflow of the lowest row
   - Period: Jan – Jun 2019
   - Frequency: every one/two weeks

3. Water samples analysis
   - **On site** analysis
     - Temperature
     - Electric conductivity
     - pH
     - Dissolved oxygen
   - **Laboratory** analysis
     - COD
     - BOD₅
     - TKN
     - NH₄⁺
     - NO₃⁻
     - TSS
     - TP
     - SO₄²⁻
     - Cl⁻
     - MBAS
     - E.coli

4. Statistical tests
   - **Mann-Kendall trend test:**
     It verify if a monotonic trend exists treating each series separately

   - **Wilcoxon signed rank test:**
     It compares two series data by data, testing if a configuration with additive performs better than the base medium (blue squares in the graphs)
Evaluation of treatment performances:
Comparison between mixes with addictive

**COD Removal efficiency (%)**

- **Phase 1:** Jan-Apr 2019 9 samples
- **Phase 2:** May-Jul 2019 8 samples

- The most of the configurations in **phase 1** increases performance along time (except polyacrilates)
- **Phase 2** shows better removal performances
- Substantial differences in GW input concentration

**BOD\textsubscript{5} Removal efficiency (%)**

- Phase 1: over 90% on average for all the configurations along time
- Phase 2 shows decreasing performances along time and worst average performances
- Additives do not increase system performances compared to base medium alone
- No substantial differences in GW input concentration

**GW input [mg/L]**

<table>
<thead>
<tr>
<th></th>
<th>Avg (std)</th>
<th>Max - Min</th>
<th>Avg (std)</th>
<th>Max – Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Medium</td>
<td>274.22 (90.25)</td>
<td>137.00-381.00</td>
<td>75.13 (17.81)</td>
<td>56.00-97.00</td>
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<tr>
<td>Polyacrilate</td>
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<td></td>
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<tr>
<td>older Polyacrilate</td>
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</tr>
<tr>
<td>Polyacrilate &amp; Biochar</td>
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<tr>
<td>Compost</td>
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<tr>
<td>Granite Active Carbon</td>
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<tr>
<td>Biochar</td>
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<tr>
<td>new Biochar</td>
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<tr>
<td>Biochar &amp; Graphene</td>
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**GW input [mg/L]**

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</tr>
</thead>
<tbody>
<tr>
<td>Base Medium</td>
<td>52.37 (8.97)</td>
<td>36.20-71.30</td>
<td>59.59 (21.88)</td>
<td>18.80-81.70</td>
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Evaluation of treatment performances:
Comparison between mixes with addictive and base mix medium

- In **phase 1**, the most of the configurations **increases performance** along time (except polyacrilate+biochar and compost).
- In **phase 2**, configurations show **no trend** in removal performances.

### Total Nitrogen Removal efficiency (%)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>GW input [mg/L]</th>
<th>Avg (std)</th>
<th>Min-max</th>
<th>Avg (std)</th>
<th>Min-max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Medium</td>
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<tr>
<td>Polycrilate</td>
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<tr>
<td>Polycrilate+Biochar</td>
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<tr>
<td>Compost</td>
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<tr>
<td>Granule Active Carbon</td>
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<tr>
<td>Biochar</td>
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<tr>
<td>new Biochar</td>
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<td>Biochar+Graphene</td>
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### E. Coli Removal efficiency (%)

- All configurations reach a plateau **close to 100%** in removal efficiency.
- Configurations in **phase 1** shows an **increasing trend** (except biochar).

[^GW_in]:

<table>
<thead>
<tr>
<th>GW input [MPN/100mL]</th>
<th>Avg (std)</th>
<th>Min-max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg (std)</td>
<td>1.3e5 (9.7e4)</td>
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<tr>
<td>Min-max</td>
<td>2.5e5-1.3e4</td>
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<tr>
<td>Avg (std)</td>
<td>8.0e4 (4.9e4)</td>
<td></td>
</tr>
<tr>
<td>Min-max</td>
<td>2.0e4-1.3e5</td>
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Conclusions and further analysis

- The system has a great tolerance to high HLR (ten times more the value used is common VF CW)
- pH in the range 7.2±7.6 for all the configurations
- Increasing of DO in output shows a good aeration of the vertical flow system
- $\text{BOD}_5$ and E. coli show excellent treatment performances (removal efficiency almost 100%)
- COD removal increases over time
- Input COD concentration decreases with temperature, possibly due to biochemical degradation into the tank
- TN removal is significantly increased by the presence of additives to base medium (except polyacrilate)

Next experimental phase
- Evaluation of the treatment performance along each column