

# Greywater Treatment in a Living Wall System

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Bauhaus-Universität Weimar

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Small Water and Wastewater Systems

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bauhaus institute for infrastructure solutions (b.is)

## Facing new conditions in our world

### Climate Change



- Heat Periods
- Drought
- Heavy Rain

### Air Pollution



- Health risks
- Destruction of building surfaces

### Reduced Biodiversity



- Extinction of Species
- Food security

### City Densification



- Storm water management
- Network overload

### Way of concept

Analysing Problems

|  |  |   |   |
|--|--|---|---|
| <b>Climate Change</b><br><br><ul style="list-style-type: none"> <li>Heat Periods</li> <li>Drought</li> <li>Heavy Rain</li> </ul> | <b>Air Pollution</b><br><br><ul style="list-style-type: none"> <li>Health risks</li> <li>Destruction of Building surfaces</li> </ul> | <b>Reduced Biodiversity</b><br><br><ul style="list-style-type: none"> <li>Extinction of Species</li> <li>Food security</li> </ul> | <b>City Densification</b><br><br><ul style="list-style-type: none"> <li>Storm water Management</li> <li>Network overload</li> </ul> |
|--|--|---|---|

Critical Thinking



Solution to all problems



Party



### Real Way of Concept

Mad idea at Party



Sober Thinking



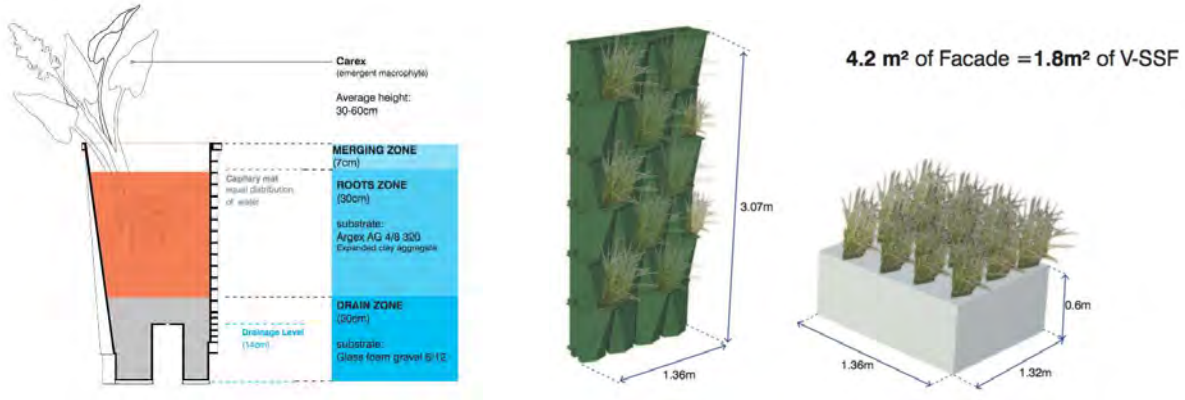
Feasibility Study



Could solve a lot of Problems

|  |  |   |   |
|--|--|---|---|
| <b>Climate Change</b><br><br><ul style="list-style-type: none"> <li>Heat Periods</li> <li>Drought</li> <li>Heavy Rain</li> </ul> | <b>Air Pollution</b><br><br><ul style="list-style-type: none"> <li>Health risks</li> <li>Destruction of Building surfaces</li> </ul> | <b>Reduced Biodiversity</b><br><br><ul style="list-style-type: none"> <li>Extinction of Species</li> <li>Food security</li> </ul> | <b>City Densification</b><br><br><ul style="list-style-type: none"> <li>Storm water Management</li> <li>Network overload</li> </ul> |
|--|--|---|---|

Technical Concept – Panos Sakkas (TU Delft)



Source : Master Thesis P.Sakkas  
available from: <http://resolver.tudelft.nl/uuid:76db9490-22d8-4739-a2b3-dcdc4def67c2>

Technical Concept – Panos Sakkas (TU Delft)



**4.2 m<sup>2</sup> of Facade** (one component)

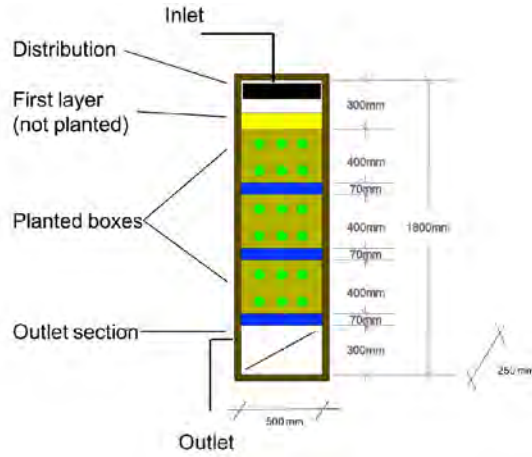
- Treats **105,6lt/day** of greywater (HLR=60lt/m<sup>2</sup>/day)
- = **120%** of daily greywater production per capita in the Netherlands
- = **29%-43%** saving on water consumption

|                   |   |                                      |                                      |
|-------------------|---|--------------------------------------|--------------------------------------|
|                   |   |                                      |                                      |
|                   | <b>38.5 cm</b>                            | <b>23.5 cm</b>                       | <b>14.5 cm</b>                       |
|                   | <b>LWS with water treatment</b>           | <b>LWS planter boxes</b>             | <b>LWS mineral wool</b>              |
| <b>NET WEIGHT</b> | <br><b>242 kg/m<sup>2</sup></b>           | <br><b>&gt; 150 kg/m<sup>2</sup></b> | <br><b>40-60 kg/m<sup>2</sup></b>    |
| <b>WATER</b>      | <br><b>OUT &gt; 60 lt/m<sup>2</sup>/d</b> | <br><b>IN 1-5 lt/m<sup>2</sup>/d</b> | <br><b>IN 1-5 lt/m<sup>2</sup>/d</b> |

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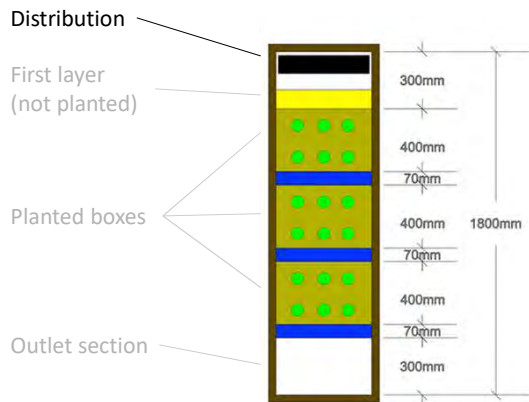
### The Bauhaus Eins Design – Principals

- First priority : Greywater treatment →
- Low weight module →
- Modular structure →
- Low level of maintenance →
- (Suitable plants) →



|                 |                      |
|-----------------|----------------------|
| Total surface   | : 0.9 m <sup>2</sup> |
| Planted surface | : 0.6 m <sup>2</sup> |

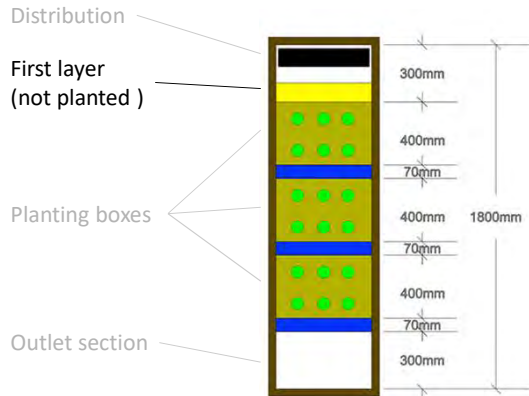
### The Bauhaus Eins Design - Distribution



Distribution System (own design)



### The Bauhaus Eins Design – First (biofilm measurement) layer



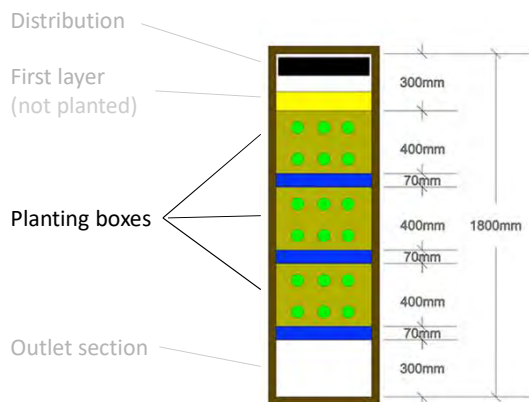
Filter Material Expanded Pumice Granulate (EG)



Filter Material Rockwool (RW)



### The Bauhaus Eins Design – Planted Boxes

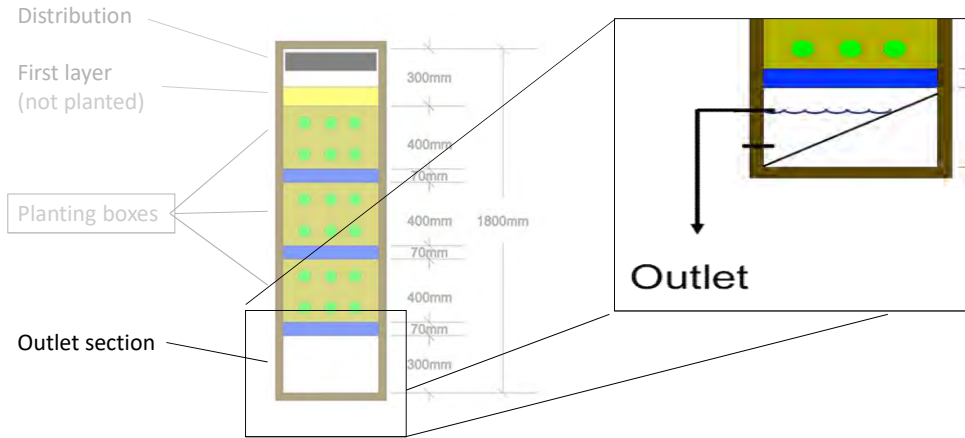


Removable Planting box



Dimension : 0.5 x 0.4 x 0.25 [m] (l x h x d),  
 45 l usable space, 1.8 kg each empty drawer  
 Initial weight :  
 Rock wool  
 Filled + plants + 1.2 l H<sub>2</sub>O = 4.1 kg  
 Expanded granulate :  
 Filled + plants + 1.2 l H<sub>2</sub>O = 9.4 kg

The Bauhaus Eins Design - Outlet section



The Bauhaus Eins Design – En vivo

The pure structure



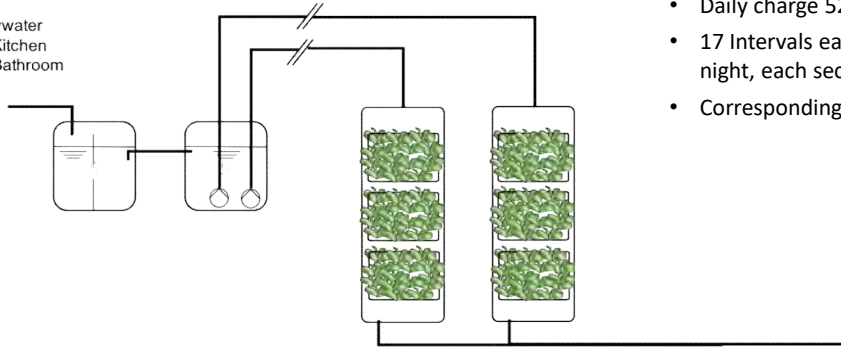
Test installation with expanded granulate (right) and rock wool (left)





## Field test setup

Greywater  
2 x Kitchen  
1 x Bathroom



Settlement tank

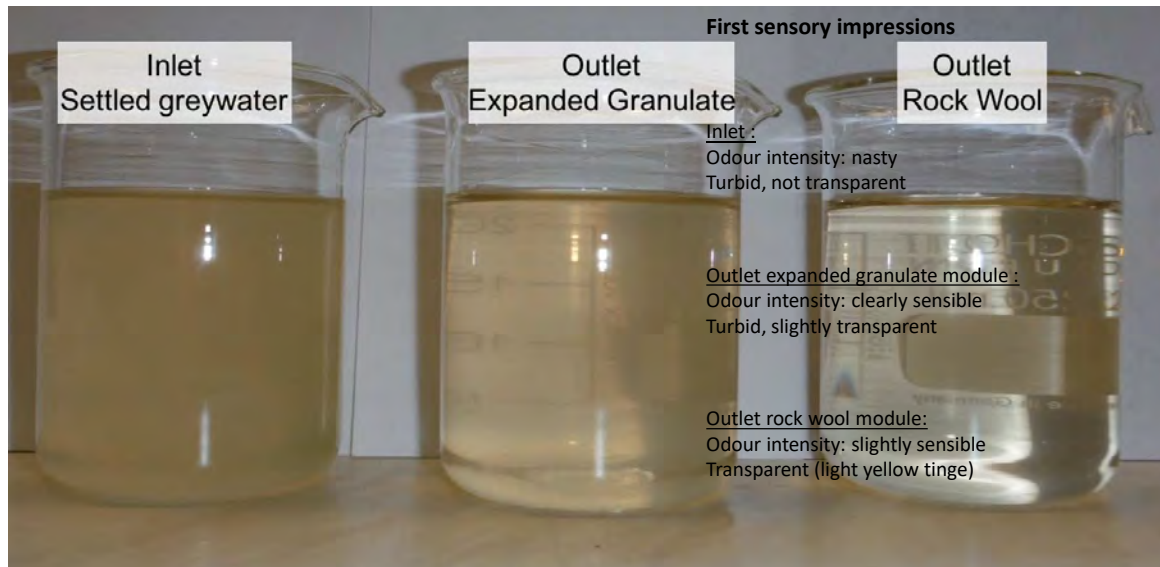
Collecting Tank

LWS-Modules

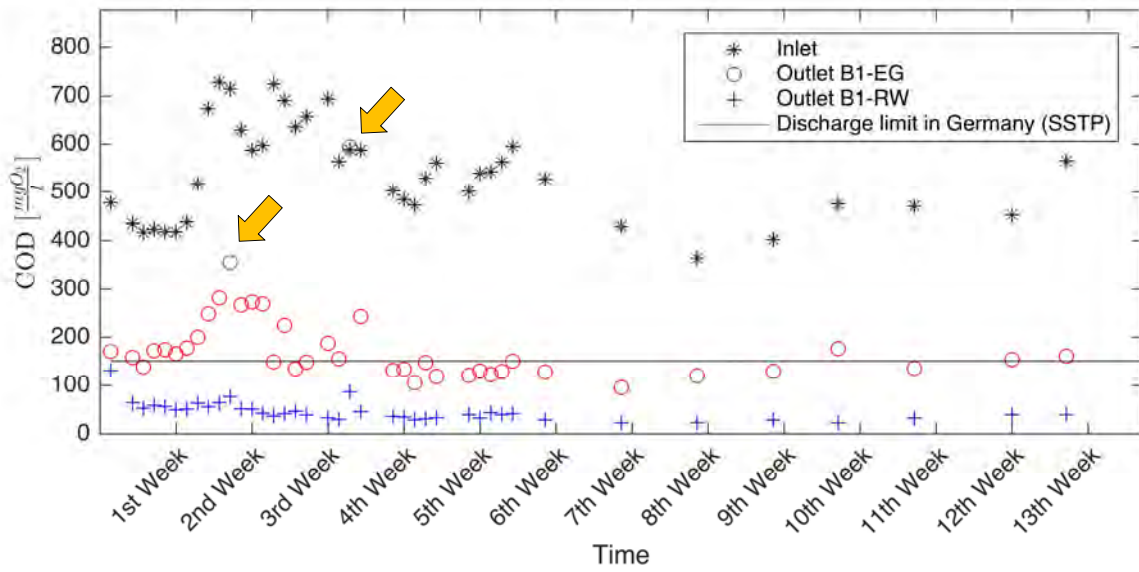
### The trial setup :

- Settled greywater was used
- Daily charge 52 l each module
- 17 Intervals each day (each hour per night, each second hour in daytime)
- Corresponding sampling at 9 am

## First visual and sensory results after 2 days with regular regime



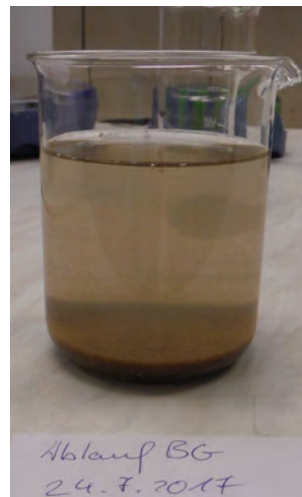
COD reduction while test trial - Expanded Granulate (B1-EG) and Rock Wool (B1-RW)



Outlet expanded granulate – The first flash after blackout 24.7.2017



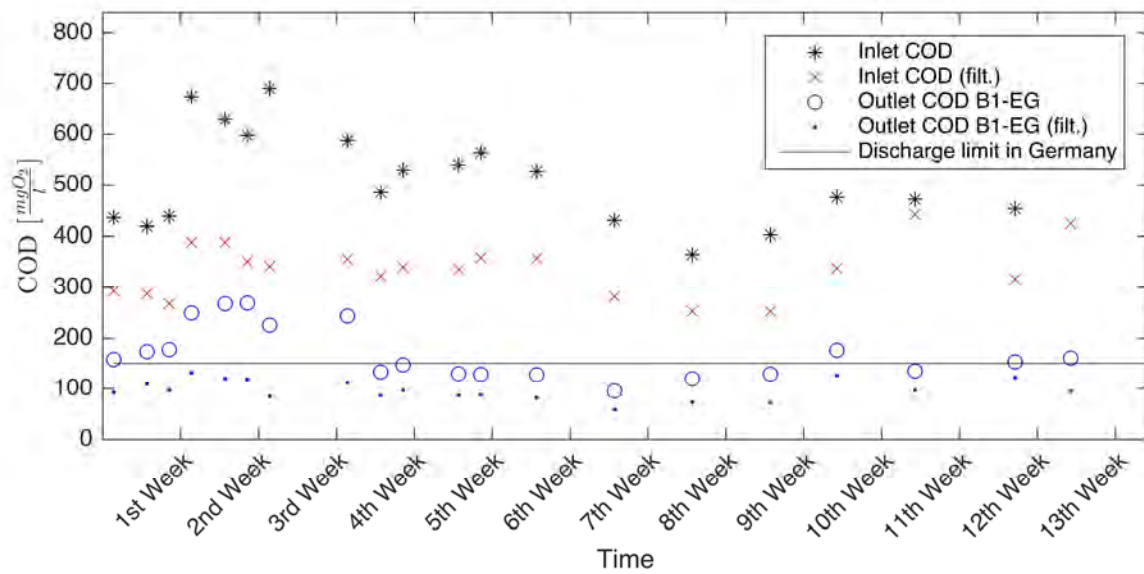
Outlet B1-EG (24-7-2017)



Outlet B1-EG (24-7-2017)



### Total and dissolved COD reduction while test trial - Expanded Granulate (B1-EG)

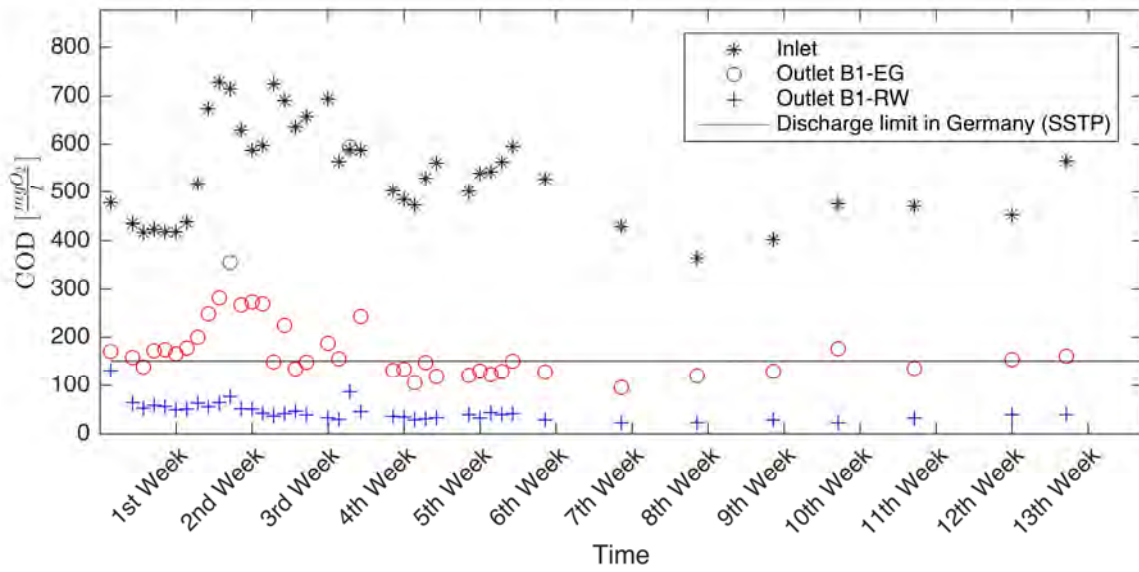


### Visual results of the outlet of expanded granulate – Nature interferes



Outlet B1-EG (8-8-2017) – Probably mosquito larvae

COD reduction while test trial - Expanded Granulate (B1-EG) and Rock Wool (B1-RW)



Visual results of the outlet of rock wool after 5 weeks of operation

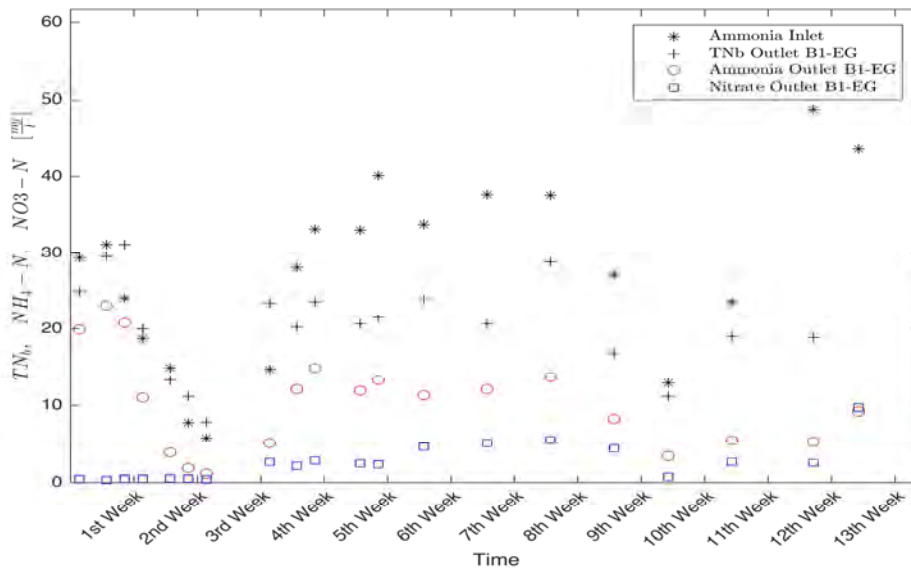


Outlet B1-RW (8-8-2017)

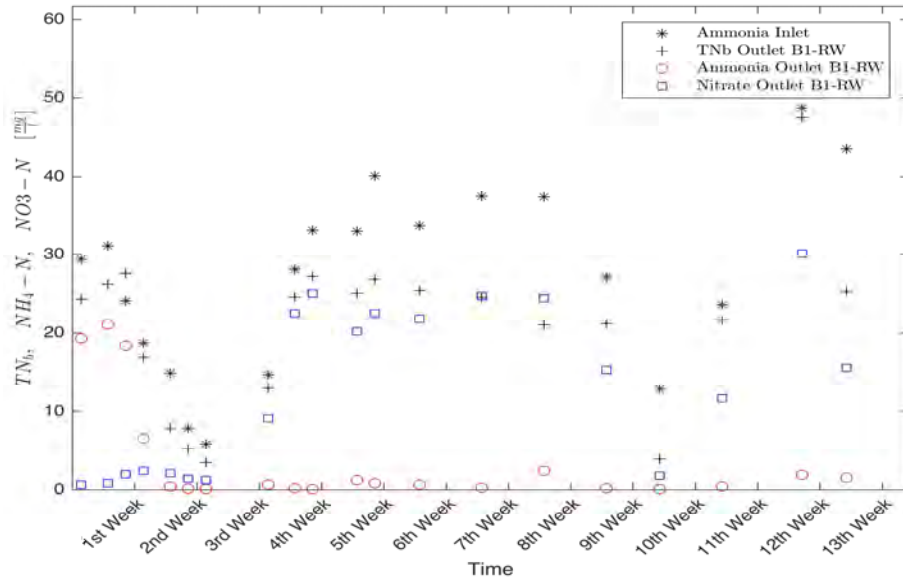
COD/BOD reduction over the test trial

| Parameter             | n  | Unit   | Inlet |      |     | Outlet B1-EG |           |           | Outlet B1-RW |          |           |
|-----------------------|----|--------|-------|------|-----|--------------|-----------|-----------|--------------|----------|-----------|
|                       |    |        | M     | SD   | Mdn | M            | SD        | Mdn       | M            | SD       | Mdn       |
| COD                   | 40 | [mg/l] | 539   | 99.0 | 534 | 181          | 88.1      | 153       | 45           | 19.9     | 40        |
| Efficiency            | 40 | [%]    | -     | -    | -   | <b>67</b>    | <b>14</b> | <b>68</b> | <b>91</b>    | <b>4</b> | <b>93</b> |
| COD <sub>filtr.</sub> | 20 | [mg/l] | 334   | 52.5 | 338 | 96.9         | 19.7      | 95.3      | 33.3         | 9.4      | 32.5      |
| Efficiency            | 20 | [%]    |       |      |     | <b>71</b>    | <b>6</b>  | <b>71</b> | <b>90</b>    | <b>3</b> | <b>91</b> |
| BOD                   | 18 | [mg/l] | 365   | 73.0 | 370 | 106          | 42.5      | 92.5      | 16.1         | 12.4     | 11.5      |
| Efficiency            | 18 | [%]    |       |      |     | <b>71</b>    | <b>9</b>  | <b>72</b> | <b>95</b>    | <b>4</b> | <b>96</b> |

Nitrogen fraction while test trial – Expanded Granulate (B1-EG)



Nitrogen fraction while test trial – Rock Wool (B1-RW)



Visual results of the plants – Expanded granulate

26-6-2017



1-9-2017



## Visual results of the plants – Rock Wool

26-6-2017



1-9-2017



## Some Conclusions

### Expanded granulate :

The general system works, but in the way of a trickling filter

More hydraulic retention time is highly recommended

New outlet/settlement/catchment for the biological sludge

Low water holding capacity of expanded granulate – pump failures effects plants severely

### Rock wool :

The general system works, but in the way of a biological activated filter

The module probably tolerates feed up to 75 l/d

High water holding capacity, robust against pump failures

**Greywater is highly applicable as irrigation water for special LWS – no additional nutrients are needed even the outlet is rich of nutrients**

**LWS can resolve or relive a lot of problems mentioned on slide two**

Thank you!

Special Thanks to:

Paul David Burkhardt  
Patrick Engel  
Jörg Londong



6-10-2018

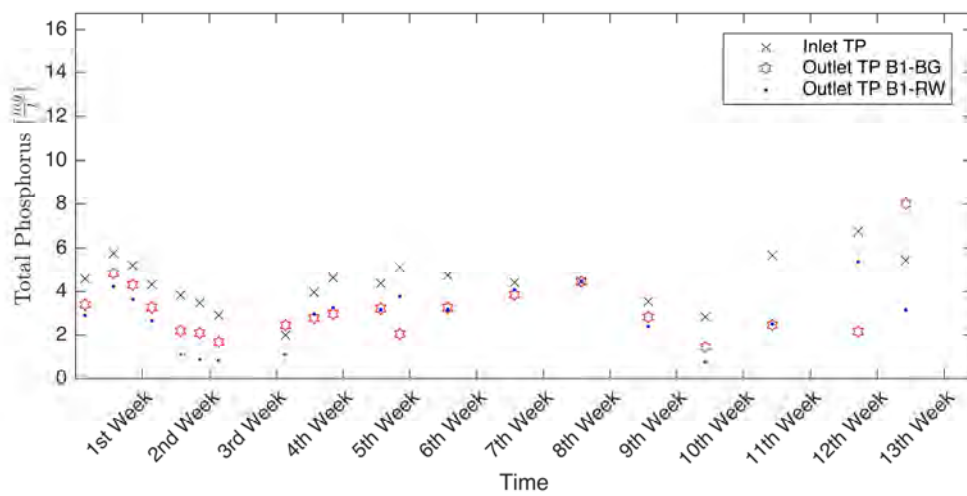


### Results of the plants

| Plant                         | B1-EG    | B1-RW               |
|-------------------------------|----------|---------------------|
| <i>Sedum album</i>            | S/P/S+   | S/D/S+              |
| <i>Trollius pumilus</i>       | S/D/S    | S/D/S               |
| <i>Bergenia cordifolia</i>    | P/S+/PP  | S/PP/PP             |
| <i>Myosotis palustris</i>     | S/D/D    | PP/D/P              |
| <i>Pachysandra terminalis</i> | PP/PP/PP | P/D <sup>1</sup> /P |
| <i>Heuchera micrantha</i>     | PP/PP/P  | P/P/P               |

1) Already dead at insertion

### Results phosphorous both modules



## Results for the pH

