Use of ornamental plants in constructed wetlands for greywater treatment in Lesbos, Greece

Deligianni A.[1], Fountoulakis M.[2], and Ritzema H.[1]

[1]Water Resource Management Group, Wageningen University and Research, Wageningen, The Netherlands
[2]Department of Environment, University of the Aegean, Mytilene, Lesbos, Greece

Introduction

Small scale (household-level) natural greywater treatment systems and specifically constructed wetlands (CWs) were tested in this study, as a sustainable long-term solution to tackle water scarcity. CWs could be an economical and energetically efficient method to treat greywater on-site. However, the commonly used reeds as vegetation are not favorable when CWs are applied in houses or buildings. To increase the acceptability of those systems by the users, 3 different native ornamental plant species (*Pittosporum tobira, Polygala Myrtifolia and Hedera Helix*) were tested instead of reeds.
Research question: Are *Pittosporum tobira, Polygala Myrtifolia and Hedera Helix* appropriate for greywater treatment in CWs in Lesbos, Greece and which of them performs better in order the greywater to get treated according to the guidelines for reuse?

Greywater
- Household wastewater without the input of toilets
- Constitutes 50-80% of the total household wastewater
- Less contaminated compared to the total wastewater
- It can be treated at household level by natural systems such as CWs

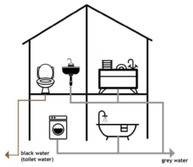


Figure: Greywater fraction of household wastewater

Constructed wetlands (CWs)
- Nature inspired systems
- Appropriate for grey water treatment
- They have additional environmental, economic and social co-benefits (e.g. they are low cost, easy to build and maintain, increase the green spots in the cities etc.)

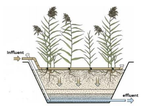


Figure: Schematic layout of a constructed wetland with a vertical flow (VFCW)

Methodology

Experimental design
- Type of CW: Vertical Flow Constructed Wetland (VFCW)
- 12 small scale VFCWs we tested. 3 replicates of 3 different VFCWs, each one planted with each examined ornamental plant specie and 3 replicates of VFCWs without plantation as a control.
- The experiment is divided in 2 phases, where 2 different Hydraulic Loading Rates (HLR) we used. (HLR_1=74 mm/d lasted for 2 months and HLR_2=110 mm/d lasted for 1 month)
- Total duration of the experiment: 3 months

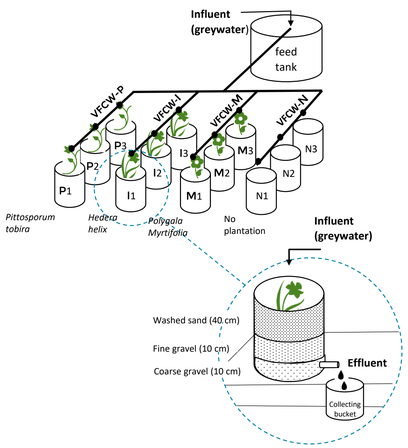


Figure: Experimental design

Sampling and water quality determination
- Weekly sampling collection and analysis
- Sample analysis for water quality determination based on the *Standard Methods for the Examination of Water and Wastewater* (see table below).

Table: Methodology for water quality determination

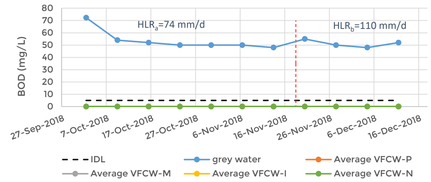
Parameter	Method
pH	Electrochemical analyzer CONSORT C932
EC	Portable EC-meter LF95
BOD	Respirometric Method (APHA et al., 2005)
COD	Closed Reflux, Colometric Method (APHA et al., 2005)
TSS	Total Suspended Solids Dried at 103-105°C (APHA et al., 2005)
TP	Persulfate Digestion Method & Ascorbic acid Method (APHA et al., 2005)
TC and E.coli	Membrane Filtration Using Simultaneous Detection Technique (USEPA, 2002)

Statistical analysis
- Microsoft excel
- SPSS Statistics (One-way ANOVA)

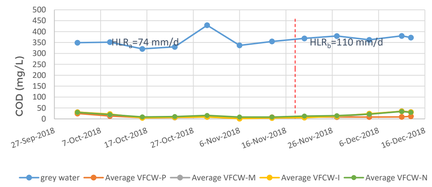
Results

Water quality of the influent (grey water) and the effluent water during the experiment.

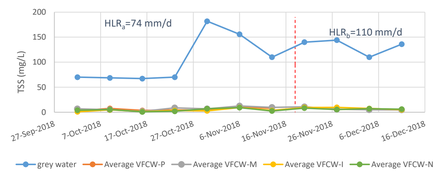
Biological Oxygen Demand (BOD)
- BOD is significantly decreased in the effluent water of all the tested VFCWs (BOD removal efficiency: 89,6-100%).
- No differences between the treatments.



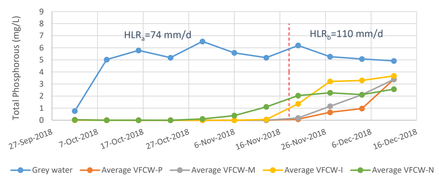
Chemical Oxygen Demand (COD)
- COD is significantly decreased in the effluent water of all the tested VFCWs. (COD removal efficiency: 90,7-97%).
- No significant differences between the treatments (COD=1-35,4 mg/L).



Total Suspended Solids (TSS)
- TSS is significantly decreased in the effluent water of all the tested VFCWs (TSS removal efficiency: 87,9-99%).
- No differences between the treatments.



Total Phosphorous (TP)
- TP is decreased in the effluent water of all the tested VFCWs. (TP removal efficiency: 25,3-100%).
- TP removal decreased when a higher HLR was used.
- No clear differences between the treatments



Pathogens (Total Coliforms and *E.coli*)
- While using HLR_a=74 mm/d
  TC removal: 2-3 log_{10} units
  E.Coli removal: 3-4 log_{10} units
- While using HLR_b=110 mm/d
  TC removal: 2 log_{10} units
  E.Coli removal: 0-2 log_{10} units

Date	Pathogens	Greywater	VFCW-P	VFCW-M	VFCW-I	VFCW-N
15-Nov-2018	TC (CFU/100ml)	6×10^6	$2{,}2 \times 10^3$	$7{,}35 \times 10^3$	5×10^5	$6{,}33 \times 10^4$
	E. coli (CFU/100ml)	2×10^4	1,67 x 10	5 x 10	8,33 x 10	0
14-Dec-2018	TC (CFU/100ml)	4×10^6	$2{,}72 \times 10^4$	$2{,}12 \times 10^4$	$1{,}29 \times 10^4$	$4{,}18 \times 10^4$
	E. coli (CFU/100ml)	5×10^4	$5{,}5 \times 10^2$	$2{,}17 \times 10^2$	1×10^2	$8{,}33 \times 10^4$

Conclusion

According to the results of this study, no significant differences in the grey water treatment performance occurred between all the tested VFCWs. All VFCWs both vegetated and non vegetated showed similar grey water treatment performance during the 3-months experiment.

This study has shown that all the tested VFCWs, combined with a disinfection process are appropriate for greywater treatment in Lesbos and can provide an alternative source of water for non-drinking reuse applications based on the Greek Wastewater Reuse Guidelines. By using HLR 110 mm/d the water quality parameters BOD, COD, TSS and TP were below the reuse standards, except phosphorus, which presented value equal to the reuse standards. Therefore, an HLR lower than 110 mm/d is recommended in order to be ensured that the phosphorus removal is in line with the Greek standards for wastewater reuse.

Recommendations

- Longer duration of the experiment to assess the grey water treatment performance of the tested VFCW systems over a longer period and throughout the year.
- The study of the plant growth and the root development before and during the experiment in order to ensure the influence of the ornamental plant species on the greywater treatment performance of the tested VFCWs.
- The study of the water balance in order to monitor the water losses in that environmental context and be able to assess the treated water that can be provided by such systems.
- The experimentation of some fluctuations on the flow of the influent water, in order to assess the performance of the VFCW systems under real conditions.
- Apart from the technical feasibility of those systems, also the adoption part should be studied by investigating their acceptability by the local users.

Author's contact details

Anastasia Deligianni
deligiannianastasia@gmail.com
+30 6956426758