On-site light greywater treatment using a vertical-flow constructed wetland for the removal of personal care products and water reuse in a Luxembourgish public school

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Key message

Water scarcity has currently been considered one of the main concerns due to the population growth and society development which implies an increase in potable water consumption. In Luxembourg, households are responsible for 60% of potable water consumption, with an average of 132 liters per person per day. However, from this amount, 27% is used for flushing toilets, which do not need potable water quality (AGE, 2023; VDL-Luxembourg, n.d.).

The on-site greywater treatment can be an alternative to save potable water in households by reusing the treated water for non-drinking purposes, such as toilet flushing, car washing, garden watering, and others. The greywater (GW) comprises all the wastewater produced in a household, excluding the water from toilets (blackwater-BW). The GW can be also divided into three types, light-LGW: wastewater from showers, baths and hand sinks, medium-MGW: LGW + laundries wastewater, and dark-DGW: LGW + MGW + kitchen sinks and dish washers.

However, the reuse of water requires a minimum quality according to the purposes, and this is where the on-site treatment using a vertical-flow constructed wetland (VFCWs) comes in. In previous studies, VFCWs have already proven being a promising option for macro and micropollutants removal from on-site greywater, and therefore, this technology was chosen to be tested in this study in which a pilot-scale VFCW will treat the LGW fraction from a Luxembourgish public school.

In this context, by locally treating GW, besides the possibility of removing micropollutants, such as personal care products (PCPs), at the source of pollution, at least 1/3 of potable water could be saved in households when using the treated water for flushing toilets.

Keywords: On-site greywater treatment, vertical-flow constructed wetland, water recycling.

Materials and Methods or Description of Intervention

The GreyReuse project, funded by the Luxembourgish water agency-AGE (Administration de la gestion de l'eau), within a 2-year pilot-project aims to evaluate the viability of using a VFCW for the removal of macropollutants, such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrogen (NO3-N and NH4-N) and phosphorus (PO4-P and TP), as well as the removal of micropollutants, such as PCPs from GW, more specific LGW, in a Luxembourgish public school for the toilets flushing purpose). Post-treatment technologies for the removal of bacteriological pollution will be also tested.

For this, three VFCWs, with a volume of $1m^3$, will be filled with an admixture substrate with 85% sand + 15% activated biochar produced from plants residues, and a drainage layer at the bottom composed of expanded clay and gravel (diameters coarse 4–8mm and fine 2–8 mm). Two of the VFCWs will be planted with a mix of *Phragmites australis* and *Iris pseudacorus*; the other one will be only filled with the admixture substrate. For a better plants' development, as the VFCWs will be an indoor installation at a functional basement of the swimming pool, artificial light will be offered 8 hours per day (***Figure 1***).

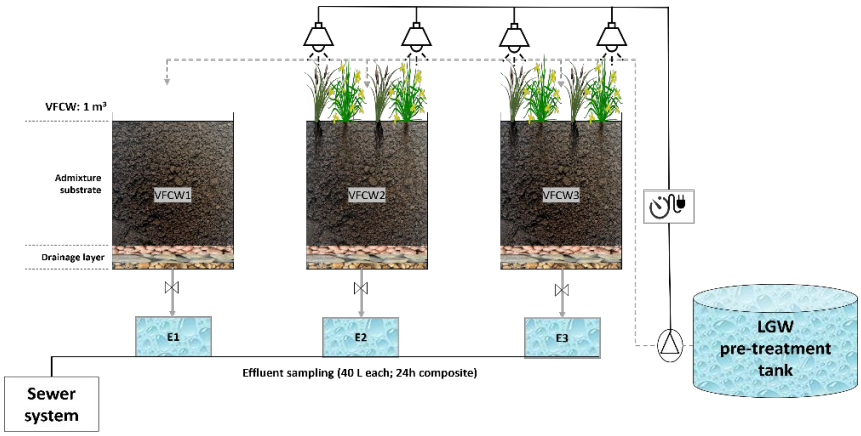

Figure 1. Schematic diagram of the pilot-scale project GreyReuse. The influent direction to the vertical-flow constructed wetlands (VFCWs) is indicated by the grey dashed lines and the effluent sampling is indicated by the grey solid lines. The substrate composition is VFCW1 = VFCW2 = VFCW3 = 85% sand + 15% biochar from plants residues. Mix of plants: *Phragmites australis* and *Iris pseudacorus* (VFCW2 and VFCW3).

The LGW from bathrooms (showers and hand-sinks) will be pre-cleaned using a drum filter system to remove large particles and then, will feed the VFCWs, both in parallel and alternately, at a frequency of three times per day with a duration of 30 minutes, offering a Hydraulic Loading Rate (HLR) from initially 100 L d^{-1} m^{-2}, using pumps and distribution systems automatically timer controlled. After the wastewater being drained by gravity through the VFWCs, a 24h composite of 40 L will be sampled in reservoirs placed at bottom of each unit for bi-monthly monitoring analyses.

With this, the LGW composition (macropollutants and micropollutants, with focus on PCPs) within the year seasons will be characterized, microbial community will be investigated, as well as the pollutants removal efficiency of the VFCWs will be monitored within the duration of the project. Finally, the quality of the treated water will be tested to meet the standards for water reuse in sustainable buildings (for toilet flushing).

Results and Discussion

The preliminary characterization of the LGW showed micropollutants' values (in mg/L) of: BOD (102), COD (237), TN (11.1), NH4-N (5.0) and TP (1.3). Concerning the target compounds of PCPs, their values are summarized in ***Table 1***. Considering that these characteristics can vary throughout the year, this study will analyse them at different seasons.

Table 1. Preliminary characterization of pharmaceuticals and PCPs in the LGW of a Luxembourgish public school.

Category	Group	Sub-group	Compound	CAS number	Abbreviation	Analytical level of quantification (LoQ) - ng/L	Measured sample - ng/L (n:1)
Pharmaceuticals	**Anti-inflammatories**		Diclofenac	15307-86-5	DCF	10.00	**174.17**
	Antimycotics		Clotrimazole	23593-75-1	CLOT	25.00	<LOQ
			Fluconazole	86386-73-4	FCZ	10.00	<LOQ
			Miconazole	22916-47-8	MIZ	25.00	**32.49**
PCPs	**Antiseptics**		Triclosan	3380-34-5	TCS	100.00	<LOQ
	Insect repellent		N,N-diethyl-meta-toluamide or diethyltoluamide	134-62-3	DEET	10.00	**142.48**
	Preservatives	**Parabens**	Methylparaben	99-76-3	MeP	100.00	<LOQ
			Ethylparaben	120-47-8	EtP	25.00	<LOQ
			Propylparaben	94-13-3	PrP	25.00	**155.25**
			Butylparaben	94-26-8	BuP	25.00	<LOQ
	Surfactants	**Phthalates**	Di(2-ethylhexyl) phthalate (metabolites):	117-81-7	DEHP	-	
			Mono(2-ethylhexyl) phthalate	4376-20-9	MEHP	25.00	<LOQ
			Mono(2-ethyl-5-hydroxyhexyl) phthalate	40321-99-1	5OH-MEHP	25.00	<LOQ
			Mono(2-ethyl-5-oxohexyl) phthalate	40321-98-0	5oxo-MEHP	25.00	<LOQ
		Non-ionic surfactants	Nonylphenol	84852-15-3	NP	100.00	**111.87**
			Octylphenol	1806-26-4	OP	100.00	<LOQ
	UV-filters		Avobenzone	70356-09-1	AVO	100.00	<LOQ
			Octocrylene	6197-30-4	OC	100.00	<LOQ
			Oxybenzone	131-57-7	OXY	10.00	**23.45**

References

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