WETPOL 2023

Bruges Meeting & Convention Centre, Belgium

PERSONAL CARE PRODUCTS REMOVAL FROM GREYWATER USING NATURE-BASED SOLUTIONS FOR WATER REUSE IN SUSTAINABLE BUILDINGS: THE "RECARE" PROJECT APPROACH

Fernanda Cristina Muniz Sacco[1*], Silvia Venditti[1], Paul Wilmes[2], Joachim Hansen[1]

[1] University of Luxembourg- Campus Kirchberg - 6, rue Coudenhove-Kalergi, L-1359 Luxembourg

[2] University of Luxembourg- LCSB, 7, Avenue des Hauts Fourneaux L-4362 Esch-sur-Alzette

[*] fernanda.muniz@uni.lu

Introduction

The use of vertical-flow constructed wetlands (VFCWs) as selected nature-based solution to remove personal care products (PCPs) from wastewater and greywater has been already demonstrated to be sustainable for the scope. However, the PCPs removal mechanisms within VFCWs, such as phytoremediation, adsorption on soil and biodegradation, as well as the targeted design and dimensioning of VFCWs for this purpose need to be investigated in depth for the up-scale integration to a city's water services, which is the purpose of this project. The ReCare (Removal of personal care products from microbial processes in Constructed Wetlands for grey water recycling in sustainable buildings) project, funded by the FNR (Fonds National de la Recherche Luxembourg), started in November 2022 and will be carried out in a laboratory scale within a 4-year PhD study.

Methodology

The installation is composed of 6 lysimeters (L), with a total volume of 71L each, filled with different substrates mixed with sand: conventional zeolite and some innovative products such as biochar from plants (I), and biochar from cellulose-sewage (II), as follows: L1: 85% sand + 15% zeolite, L2: 95% sand + 5% zeolite, L3: 85% sand + 15% activated biochar-I, L4: 95% sand + 5% activated biochar-I, L5: 85% sand + 15% activated biochar-II, and L6: 95% sand + 5% activated biochar-II, as described in the **Fig.1**.

The lysimeters will be fed simultaneously and intermittently with three types of synthetic greywater (SGW) (**Tables 1 and 2**) in a vertical-flow configuration at a frequency of three times per day and 30 minutes of duration, with a daily inflow of 7.2L each. Concerning the spike of PCPs-micropollutants, 17 compounds were selected for the stock solution preparation (**Table 3**). The lysimeters will be also lighted 8 hours per day (led lamps).

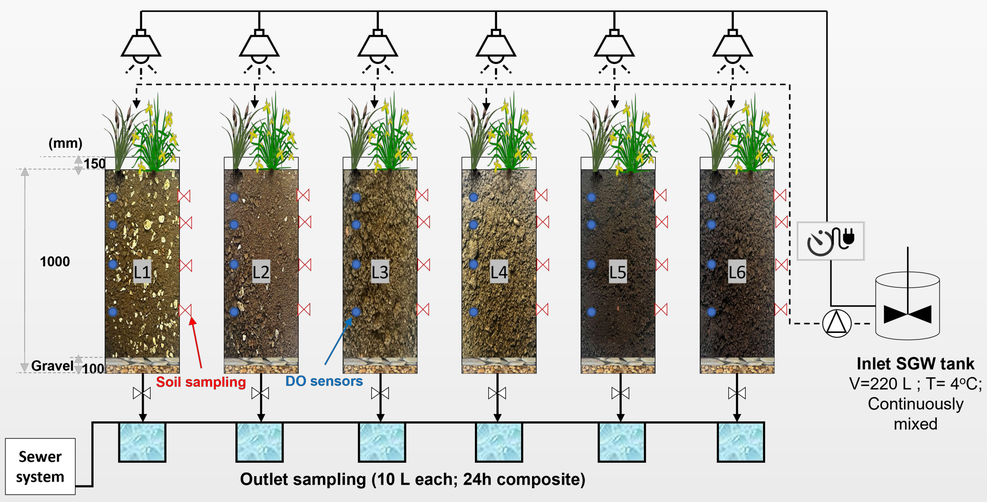


Fig.1. Schematic diagram of the ReCare Lab-scale installation. The inflow SGW through the lysimeter is indicated by the black dashed lines, and outlet sampling are indicated by the solid dark lines.

Table 1. Synthetic Grey Water (SGW) recipes: ingredients for each type (Light- LSGW, Medium-MSGW and Dark-DSGW).

	CAS Number	Types of Greywater: Light[1] bathroom	Medium[2] laundry and bathroom	Heavy or dark[3] combined GW (including kitchen)	Unit
Sodium dodecyl sulfate	151-21-3	40.0	40.0	40.0	mg/L
Glycerol (d= 1.26 g/mL)	56-81-5	159.0	159.0	159.0	µL/L
Lactic acid (d= 1.2 g/mL)	598-82-3	83.0	23.0		µL/L
Boric acid	10043-35-3		1.4		mg/L
Vegetable oil (d= 0.92 g/mL)	8001-25-0		8.0	100.0	µL/L
Dextrin	9004-53-9			85.0	mg/L
Soluble starch	65996-62-5			55.0	mg/L
Yeast extract	8013-zero 1-2			70.0	mg/L
Sodium carbonate	497-19-8			55.0	mg/L
Sodium hydrogen carbonate or sodium bicarbonate	144-55-8	70.0	25.0		mg/L
Sodium sulfate	7757-82-6	50.0	35.0		mg/L
Disodium hydrogen phosphate or sodium phosphate dibasic	7558-79-4		39.0		mg/L
Ammonium chloride	121125-02-9			75.0	mg/L
Potassium sulfate	7778-80-5			4.5	mg/L
Sodium dihydrogen phosphate	10049-21-5			11.5	mg/L

Adapted from:
[1]SGW from bathroom- Hourlier et al. (2010)
[2]SGW from laundry and bathroom- Diaper et al. (2018)
[3]SGW-combined (including kitchen sink)- Surendran and Wheatley (1998)

Table 2. Expected parameters in the Synthetic Grey Water (SGW): Light- LSGW, Medium-MSGW and Dark-DSGW.

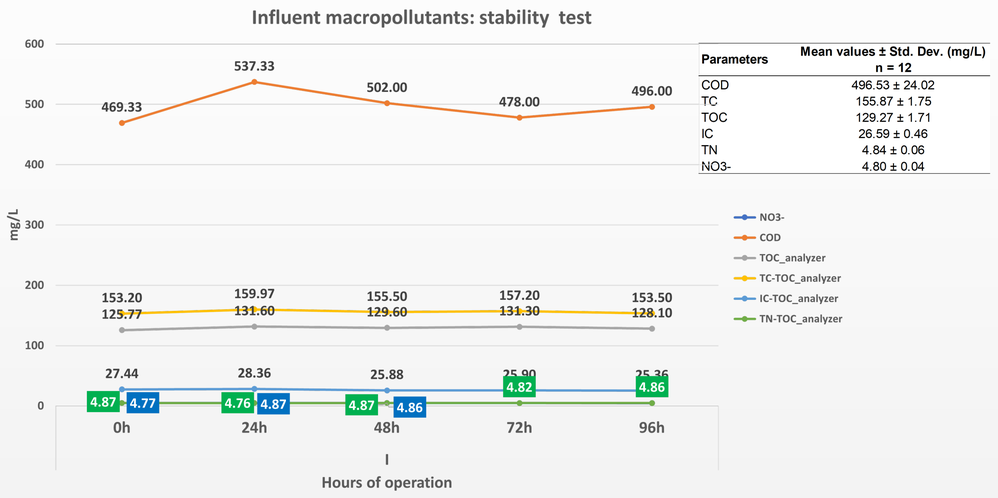
	Observation	Types of Greywater: Light bathroom	Medium laundry and bathroom	Heavy or dark combined GW (including kitchen)	Unit
COD	LCK 514	479.00	421.00	931.00	mg/L
TOC	TOC analyzer	137.60	105.50	158.70	mg/L
TC		158.20	127.10	185.90	mg/L
IC		20.57	21.60	27.24	mg/L
TN		4.62	4.51	32.40	mg/L
TN	LCK 238	6.18	6.78	35.60	mg/L
Nitrate	LCK 339	5.03	5.58	5.66	mg/L
NH4-N	LCK 304, 305, 303	<LOD	<LOD	22.10	mg/L
PO4-P	LCK 349, 348	<LOD	5.71	4.07	mg/L
Conductivity		440.00	426.00	599.00	uS/cm
pH		6.95	7.63	8.73	-
T		19.40	19.30	19.40	°C

Table 3. List of 17 PCPs and pharmaceutical compounds selected for the stock solution preparation for the "Micropollutants spike". Concentrations: stock solution: 100 µg of each compound/mL of methanol; compounds spike: 5 µg/L of synthetic water.

Category	Class	Substance (INCI)	CAS number	Abbreviation
Pharmaceuticals (4)	Anti-inflammatories (1)	Diclofenac	15307-86-5	DCF
	Antimycotics (3)	Clotrimazole	23593-75-1	CLOT
		Fluconazole	86386-73-4	FCZ
		Miconazole	22916-47-8	MIZ
Antiseptics (1)	Antiseptics (1)	Triclosan	3380-34-5	TCS
Insecticides (1)	Insecticides (1)	DEET	134-62-3	DEET
Preservatives (4)	Parabens (4)	Methylparaben	99-76-3	MeP
		Ethylparaben	120-47-8	EtP
		Propylparaben	94-13-3	PrP
		Butylparaben	94-26-8	BuP
Surfactants (4)	Phthalates (2)	DiethylhexylPhthalate	117-81-7	DEHP
		Monoethylhexylphthalate	4376-20-9	MEHP
	Non-ionic surfactants (2)	Nonylphenol	84852-15-3	NP
		Octylphenol	1806-26-4	OP
UV-filters (3)	UV-filters (3)	Avobenzone	70356-09-1	AVO
		Octocrylene	6197-30-4	OC
		Oxybenzone	131-57-7	OXY

Preliminary Results

The planned duration of the three different types of SGW tests is 6 months each. Therefore, the presented preliminary results are only for the LSGW. Considering that the tank lasts for 4-5 days, the macropollutants stability of the influent SGW was also tested and the daily representative samples were analyzed over the tank duration (**Fig.2**). The concentrations were stable within the week and the average (in mg/L) were: COD: 496.53, TC: 155.87, TOC: 129.27, IC: 26.59, TN: 4.84 and NO_3^-: 4.80.



Parameters	Mean values ± Std. Dev. (mg/L) n = 12
COD	496.53 ± 24.02
TC	155.87 ± 1.75
TOC	129.27 ± 1.71
IC	26.59 ± 0.46
TN	4.84 ± 0.06
NO3-	4.80 ± 0.04

Fig.2. Macropollutants stability test of the Light Synthetic Grey Water (LSGW) after the micropollutants' spike: concentration of the main parameters (Chemical oxygen demand (COD), Total carbon (TC), Total organic carbon (TOC), Inorganic carbon (IC), Total Nitrogen (TN), Nitrate (NO3-)): average values (n = 12) ± standard deviation.

Besides the macropollutants analysis, other measurement were monitored such as temperature (T), pH, electrical conductivity (EC) and dissolved oxygen (DO), which were important for better understanding the macropollutants removal rate (**Fig.3**). The EC for instance, the values of lysimeter effluent were always higher (≈ 900 µS/cm) than the influent (≈ 500), indicating the nutrients adsorption by the substrates and releasing of salts. The same for the DO, in which the values of the lysimeters and effluent were lower (≈ 5 mg/L) than the influent (≈ 6 mg/L), indicating the O_2 consumption by microorganisms activity.

Therefore, within the analyzed period of operation of 44 days, in which 309.6 L was treated (per lysimeter), the reached values of macropollutants removal (%) for L1, L2, L3, L4, L5 and L6 (**Fig.3**) were, respectively, **TOC**: around 100% for all of them; **TC**: 46, 46, 47, 49, 39 and 40%; most of **TC** is composed of **IC** which are being released in the effluent; **TN**: 100, 93, 85, 89, 95, and 86%; most of **TN** is composed of **NO_3^-**. In general, so far the zeolite (L1 and L2) demonstrated being the admixture with a better performance.

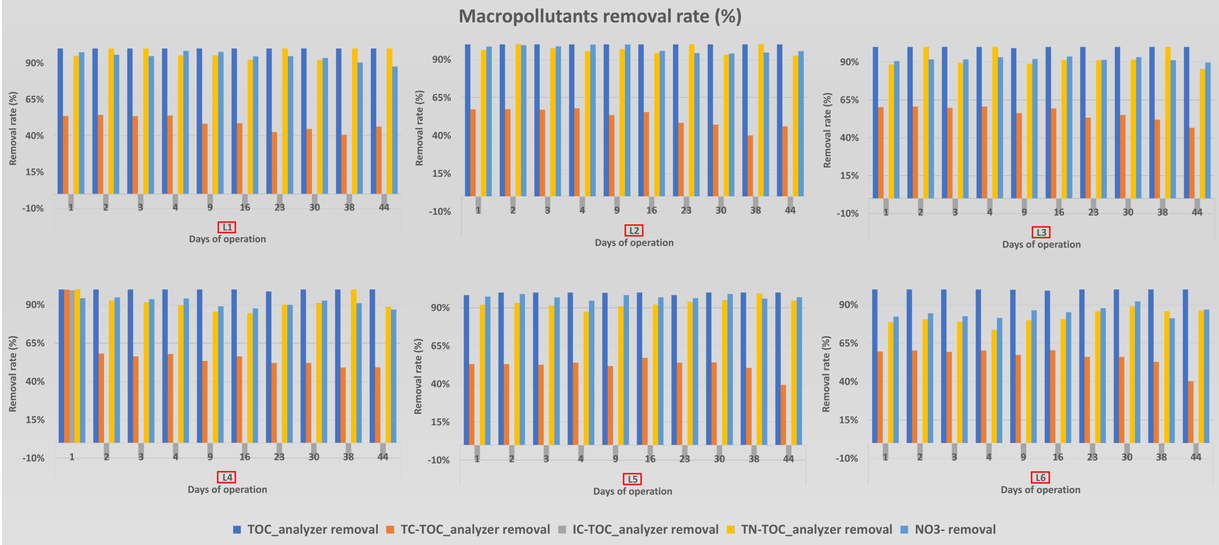


Fig.3. Macropollutants removal rate (in percentage) by the lysimeters within the 44 days of operation (sampling number: 12), in which 309.6 L was treated (per lysimeter).

Conclusion and next steps

- The presented results are not conclusive and other analyses have to be carried out before selecting the best lysimeter(s) based on pollutants removal rate, such as the micropollutants removal (PCPs) which was not concluded yet; the microorganisms monitoring will be also carried out to understand their role on the PCPs removal;
- The high values of IC released will be investigated. Some of the hypotheses are: it can be related to the microorganisms activity (free CO2 due to the respiration), the substrates cation/ anions exchanges, and releasing of Ca and Mg via leaching.
- The other types of SGW will be tested in a duration of 6 months each.
- Mesocosms experiments will be planned as a complementary study to investigate several variation with respect to type of plants, feeding regime, etc.

Luxembourg National Research Fund

Supported by the Luxembourg National Research Fund (ReCare-17112213)