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Deliverable Report

D2.5 Nanofiltration unit

Work package no.:	WP2
Lead beneficiary:	NIVA
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1 Introduction to the project SERPIC

The project *Sustainable Electrochemical Reduction of contaminants of emerging concern and Pathogens in WWTP effluent for Irrigation of Crops – SERPIC* will develop an integral technology, based on a multi-barrier approach, to treat the effluents of wastewater treatment plants (WWTPs) to maximise the reduction of contaminants of emerging concern (CECs). The eight partners of the SERPIC consortium are funded by the European Commission and by six national funding agencies from Norway, Germany, Italy, Spain, Portugal and South Africa. The official starting date of the SERPIC project is 1. September 2021. The project has a duration of 36 months and will end 31. August 2024.

The overall aim of the SERPIC project is to investigate and minimise the spread of CECs and antimicrobial resistant bacteria/antibiotic resistance genes (ARB/ARG) within the water cycle from households and industries to WWTPs effluents, and afterwards via irrigation into the food chain, into soil and groundwater and into river basins, estuaries, coastal areas, and oceans with a focus on additional water sources for food production.

A membrane nanofiltration (NF) technology will be applied to reduce CECs in its permeate stream by at least 90 % while retaining the nutrients. A residual disinfection using chlorine dioxide produced electrochemically will be added to the stream used for crops irrigation (Route A). The CECs in the polluted concentrate (retentate) stream will be reduced by at least 80 % by light driven electro-chemical oxidation. When discharged into the aquatic system (route B), it will contribute to the quality improvement of the surface water body.

A prototype treatment plant will be set-up and evaluated for irrigation in long-term tests with the help of agricultural test pots. A review investigation of CECs spread will be performed at four regional showcases in Europe and Africa. It will include a detailed assessment of the individual situation and surrounding condition. Transfer concepts will be developed to transfer the results of the treatment technology to other regions, especially in low- and middle-income countries.

2 Report summary

The report contains the specification of the selected NF product, reports the successful procurement and shipping, and includes the description of the nanofiltration unit to be tested at the prototype treatment plant. The report also contains the brief description of the experimental assessment of the nanofiltration membranes carried out at NIVA in task T2.6, the selection process of best performing and most promising nanofiltration membranes tested at lab-scale for the removal of target CECs (extended version is reported in Deliverable 1.3)

3 Deliverable description as stated in the Project Description

Based on task **T2.6** results, the best performing membranes will be selected for prototype testing. The report/publication describing results of the experimental assessment of the membranes is foreseen. The NF modules will be up scaled, if necessary, and made available to be integrated in the on-site membrane unit at the municipal WWTP of Ciudad Real in task T2.8. The integrated NF unit, together with other components of the prototype, will be further tested (task T2.9) and optimized (task T2.10).

4 Introduction

The suitable NF membranes for lab testing were identified based on the market assessment towards identification of the main NF membrane suppliers and the review of the recent literature on CEC and ARGs removal with NF. Overall, 10 commercially available NF membranes were

investigated covering a wide spectrum of nanofiltration with a broad range of molecular weight cut-off (MWCO) and membrane material. The specifications of the individual membranes are listed in Table 1.

Table 1. Description of evaluated membranes.

Producer and brand name	MWCO [Da]	Membrane ID	Membrane type	Membrane material
SUEZ/GE, PW	10 000	NF#9	FS	Polyethersulfone
Alfa Laval, UFX-10pHt	10 000	NF#8	FS	Polysulphone
SUEZ/GE, GE	1 000	NF#7	FS	Polyamide
Pentair, HFW	1 000	NF#6	HF	Polyethersulfone
NX Filtration, dNF80	800	NF#5	HF	Polyethersulfone
DuPont NF270	200-400	NF#1	FS	Polyamide
SUEZ/GE, DL	250	NF#2	FS	Polyamide
SUEZ/GE, DK	150-300	NF#4	FS	Polyamide
Toray, TM600	150	NF#3	FS	Polyamide
Toray, TMH	100-150	NF#10	FS	Polyamide
MWCO – molecular weight cut off [Da]; FS - Flat sheet; HF – Hollow fibre;				

The nanofiltration tests were done at the bench-scale in cross-flow system fed with the effluent of the secondary wastewater treatment plant in Oslo, Norway. The effective membrane area used for experimental assessment was 99.4 cm^2 for flat sheet membranes and 500 or 800 cm^2 for hollow fibre membranes (Figure 1). A detailed description of the procedure can be found in Krzeminski et al. (2020).

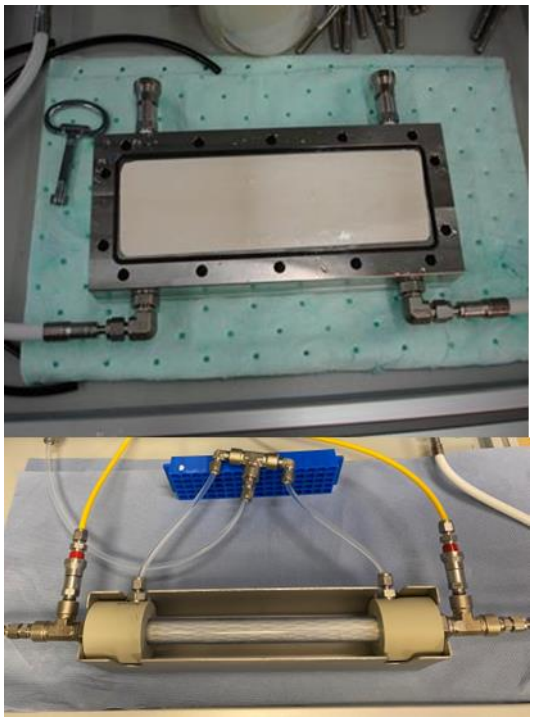

Figure 1. Flat and hollow fibre membranes used during bench-scale nanofiltration investigations at NIVA (Photos: P. Krzeminski).

5 Results

5.1 Nanofiltration membranes evaluation and selection

The experimental assessment of nanofiltration membranes was carried out in a stepwise approach including i) effectiveness for rejection of genetic marker, representing a microbial CEC, ii) effectiveness in separating nutrients (TP, TN, K, Ca, Mg, NH_4, NO_3) from WWTP effluent, iii) selected chemical CECs (Diclofenac, Sulfamethoxazole, Venlafaxine), iv) and antibiotic resistant bacteria (ARB) (*Escherichia coli*) and sul1 ARG marker.

Based on the carried-out assessment, 5 NF membranes were identified as promising for pilot testing. However, NF#5 and NF#6 were of a hollow fiber configuration not suitable for the pilot unit, NF#4 and NF#6 had lower expected efficiency for CECs removal. Furthermore, NF#3 turned out to be discontinued and the replacing product was less available from a supplier.

Therefore, considering both the lab-scale evaluation results and the technical compatibility with the RO system at UCLM, the NF#1 (DuPont NF270) membrane has been selected for the pilot-scale evaluation. The NF#1 membrane had provided > 6 LRV for ARG, >70 % retention of TN, and app. 80 % rejection of chemical CECs, was compatible with the pilot unit and readily available.

5.2 Nanofiltration unit

The pilot unit at UCLM is a small household unit which uses membranes in size of ca. 1.8 inch in diameter which corresponds to 1812 module (membrane area of 0.64 m^2). This module size is smaller than typical industrial standard for water treatment (2.5, 4 and 8 inch). While the NF#1 (DuPont NF270) membrane was not available in the desired module size of 1812 at the DuPont, it was available at the Oltremare (Italy) that DuPont collaborates with. Oltremare, part of Mann+Hummel, is a company manufacturing custom made elements in any desired size. Oltremare was capable of manufacturing 1812 size membrane elements with the DuPont NF270 membrane sheets inside. The DuPont NF270 membrane has a brand name NANO7-XL-1812 membrane at Oltremare. Technical specification of the NANO7-XL-1812 is provided in Annex 1.

Four elements of the 1812 module size NANO7-XL-1812 nanofiltration membranes were ordered and delivered to UCLM in early July 2023. Upon delivery NF#1 module was integrated into the treatment train, replacing the current reverse osmosis unit tested in the initial stage of prototype build up (T2.8).

6 Publications and other dissemination activities

Krzeminski P., Eggen E., Schwermer C.U., Wennberg A.C., Umar M., Anglès d'Auriac M. (2023) Effectiveness of membrane filtration for removal of cell free antibiotic resistance genes from water and wastewater, 10th IWA Membrane Technology Conference, 23-26 July 2023, St. Louis, USA

7 Literature

Krzeminski, P., Feys, E., d'Auriac, M.A., Wennberg, A.C., Umar, M., Schwermer, C.U., Uhl, W. (2020) Combined membrane filtration and 265 nm UV irradiation for effective removal of cell free antibiotic resistance genes from feed water and concentrate, Journal of Membrane Science 598C, 117676

8 Annex 1: Technical specification of membrane NANO7-XL-1812

See next page.