Revalorized Reverse Osmosis Membranes: A Sustainable Solution for Gray Water Treatment

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Abstract. Water scarcity has intensified global interest in wastewater reuse. Greywater, due to its lower contamination load, is a promising source for non-potable applications. This study evaluates the reuse of end-of-life reverse osmosis (RO) membranes, recovered through chemical cleaning and NaClO oxidation, to produce membranes suitable for greywater treatment. The membranes oxidized with 4% and 5% NaClO for 120 minutes were selected based on their permeability (15.3–55.8 $L \cdot h^{-1} \cdot m^{-2} \cdot bar^{-1}$) and structural integrity. Treated membranes demonstrated effective turbidity (>97%), TOC (55–70%), and COD removal, complying with Chilean irrigation standards. Although salt rejection was lower than that of commercial nanofiltration membranes, the effluent quality was adequate for reuse in applications not requiring strict TDS control. Wheat germination tests confirmed the suitability of the treated effluent for irrigation, showing plant growth comparable to that obtained with drinking water. This work highlights the technical and environmental feasibility of reusing oxidized RO membranes as a sustainable solution for decentralized greywater treatment, supporting circular economy practices and resource efficiency

Keywords: greywater, End-of-life membrane

1. Introduction

The increasing scarcity of freshwater resources is driven by population growth, climate variability and unregulated urban expansion [1]. These factors have heightened interest in alternative sources like greywater, which originates from domestic activities excluding toilets. Greywater contributes 30–50% of the organic load and 9–20% of the nutrient load in household wastewater [1] , and is well suited for non-potable reuse due to its relatively low contaminant levels. Among treatment options, membrane technologies stand out for their high removal efficiency and compact design [2]. Processes such as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) provide effective removal of suspended solids, organic matter and pathogens, enabling water recovery with consistent quality [3]. Despite their advantages, adoption is hindered by high costs, fouling and limited membrane lifespan [1,4].

This study explores the reuse of End-of-Life (EoL) RO membranes from brackish water treatment plants. Through chemical cleaning and controlled oxidation, the membranes are transformed into DUF or NF membranes for greywater treatment. This approach aims to reduce waste, extend membrane life and lower costs while maintaining performance for irrigation reuse. The study evaluates structural, hydraulic and operational performance under realistic conditions.

2. Materials and Methods

End-of-life spiral-wound reverse osmosis (RO) membranes were obtained from a brackish water treatment plant. The modules were disassembled, and the membrane sheets were subjected to chemical cleaning and oxidative treatment to remove the polyamide (PA) layer and expose the porous support, enabling their reuse in greywater filtration applications. Oxidation parameters were evaluated by treating membranes with NaClO solutions at varying concentrations (3% and 4%) and exposure times (60 to 120 minutes) to degrade the PA.

The structural changes of the revalorized membranes were evaluated using optical microscopy and scanning electron microscopy (SEM). Water permeability was measured in a laboratory-scale crossflow filtration unit operated.

Greywater was collected from a residential building and stored under refrigeration at 4 °C prior to testing. The filtration experiments were conducted using flat-sheet membrane cells with an effective area of 140 cm^2. The permeate was analyzed for turbidity, total suspended solids (TSS), chemical oxygen demand (COD), and conductivity, following standard methods (APHA 2017).

3. Results

The revalorized membranes exhibited intermediate behavior between commercial nanofiltration and ultrafiltration membranes, showing high permeability but significant rejection of both monovalent and divalent ions. Results indicated an increase in permeability of

Table 1. Greywater composition, membrane rejection performance, and compliance with Chilean irrigation water regulations (NCh 1333 and Law No. 21075)

Parameter	Greywater feed	Rejection (%)		Chilean regulation NCh 1333	Chilean Law No. 21075
		4% NaOCl - 120 min	5% NaOCl - 120 min		
pH	7.08	-	-	5.5 – 9.0	-
Conductivity (µS/cm)	439.7	32.1%	20.0%	< 750	-
TDS (ppm)	219.9	38.0%	20.0%	< 500	< 140
Turbidity (NTU)	106	99.8%	97.0%	-	-
Manganese	1.64	>69%	51.2%	< 0.2	-
Hardness ($CaCO_3$ mg/L)	40	>75%	>75%	-	-
TOC (mg/L)	648	69.6%	55.2%	-	< 240
BOD_5 (mg/L)	307	-	100.0%	-	< 240
COD (mg/L)	1483.3	51.7%	37.1%	-	-
Anionic surfactant (mg/L)	890	88.3%	35.3%	-	-
Cationic surfactant (mg/L)	26	38.5%	11.5%	-	-
Non-ionic surfactant (mg/L)	37.7	92.7%	83.9%	-	-
Fecal coliforms (MPN/100 mL) [1]	>1100	<2	<2	-	< 1000

[1]MacConkey agar lactose fermentation test

approximately 477% and 3000%, along with a decrease in salt rejection for NaCl and $MgSO_4$ to around 25%. Although the permeability values resemble those of UF membranes, the ion rejection suggests a transformation toward NF-type membranes.

The membranes oxidized with 4% and 5% NaOCl for 120 minutes were selected to perform filtration tests using real greywater collected from a washing machine. These revalorized nanofiltration and ultrafiltration membranes (Re NF/UF) demonstrated effective removal of key contaminants, meeting the quality standards established in NCh 1333 for agricultural and recreational irrigation (**Table 1**). Significant reductions in turbidity, organic matter (COD and TOC), and suspended solids were observed, indicating that recycled membranes are a viable option to improve the quality of treated water prior to reuse.

However, due to their lower salt rejection compared to commercial nanofiltration membranes, the total dissolved solids (TDS) content remained higher in some cases, which could affect specific agricultural applications sensitive to salinity. Nevertheless, the results confirm that revalorized membranes are promising for greywater filtration and other reuse applications where strict salt removal is not required.

As a final validation step, wheat growth tests were conducted using treated greywater (**Figure 1**). The objective was to assess the potential of the revalorized membrane-treated effluent for irrigation. The treated water supported healthy germination and development of the plants, showing comparable performance to control samples irrigated with potable water. These results reinforce the feasibility of using reclaimed greywater for agricultural reuse under controlled conditions

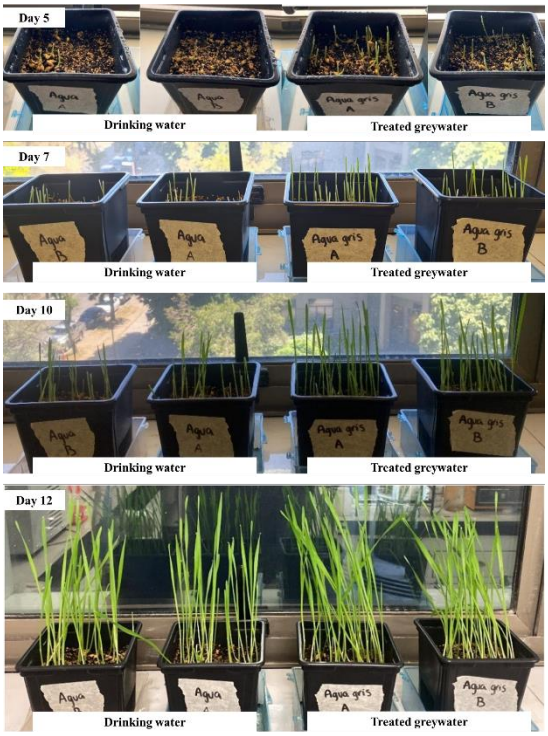

Figure 1. Wheat germination and growth comparison using drinking water (left) and treated greywater (right) after 5% NaOCl membrane filtration.

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