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Reuse of reverse osmosis membranes for wastewater treatment (Beni Saf Water Company)

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Abstract. The current research project focuses on the feasibility of recycling and reusing utilized osmosis membranes from the Beni Saf water seawater desalination station in the province of Ain Temouchent. The composite Reverse Osmosis (RO) membrane, which is referenced BW30-400-FR and manufactured by Dow Filmtec TM, is used for all the tests. Three solvents are tested: potassium permanganate ($KMnO_4$), sodium hydroxide (NaOH), hydrogen peroxide (H_2O_2), and the mixture of NaOH with $KMnO_4$ for the degradation of the active layer of the RO membrane. A frontal filtration of wastewater using these modified membranes was carried out. An analysis of the physicochemical properties of the filtrate was performed using a spectrophotometer. The results of the frontal filtration performed under perpendicular pressure using a filtration ramp show that the membranes immersed in the NaOH and $KMnO_4$ mixture for 24 hours produced a higher hydraulic flux compared to those immersed in NaOH and H_2O_2. At the end of the proposed treatment, the samples are analyzed by scanning electron microscopy (SEM) in addition to analyzing the clogging powder by EDX. The obtained results show the effectiveness of the proposed treatment for the degradation of the active layer in order to transform it into microfiltration and/or ultrafiltration.

Keywords: membrane; membrane filtration; pollutants; reverse osmosis; wastewater treatment

1. Introduction

It is well established that wastewater is an indirect reflection of human activities. It detects industrial pollutants, drug residues, and illicit drugs in addition to viruses, bacteria and parasites, emitted in our stools and urine. Their analysis is a valuable source of data in the field of wastewater-based epidemiology (Lorenzo *et al*. 2019).

This approach was recently integrated into the strategies for monitoring the Covid-19 epidemic (Aguiar-oliveira *et al*. 2020), but it had previously been developed in France, to monitor viruses responsible for gastroenteritis (Prevost *et al*. 2015).

In the same line of thought, urban wastewater, even treated, contains pathogenic microorganisms as well as potentially toxic organic and mineral elements. The entrance of pharmaceuticals and homecare products into the environment via untreated wastewater, which has gained increased attention in recent years, posed major risks to human health and aquatic life. For instance, SARS-CoV-2 infects the respiratory tract principally, although it also replicates in the stomach tract. It is then eliminated in the faeces (Wolfel *et al*. 2020).

Consequently, the frequent use of body care products, such as soaps, deodorants, creams and toothpaste, leads to the introduction of certain organic compounds into the environment and generates concerns about their fate, in particular their potential effect on fauna and flora (Stuart *et al*. 2020). In fact, these compounds, used as antiseptics or preservatives, are introduced into the receiving environment mainly via effluents from treatment plants and urban discharges during rainy weather (Aguera *et al*. 2003). Thus, studies on the toxicity of triclosan (TCS) have shown its ability to accumulate in algae (Orvos *et al*. 2002), and to induce chronic toxicity in fish at a concentration of 22 mg/L (Ying *et al*. 2007). Following studies on the organism “Vibrio Fischer” (La Farré *et al*. 2008), it is identified as one of the main organic pollutants which currently contributes to the acute toxicity of domestic wastewater.

By the same token, the effect of the first containment (SARS-CoV-2) on the control of the epidemic (Wurtzer *et al*. 2020) is put forward by three fields which are; technology, science and medicine. The obepine project (epidemiological observatory in wastewater) which officially began in March 2020 with the first sars-cov-2 viral load measurements very quickly received support from CARE3 to coordinate a national surveillance plan. An interdisciplinary consortium bringing together teams from Sorbonne University, Eau de Paris, the University of Lorraine, IRBA and IFREMER, was quickly formed to offer tools and a national strategy for monitoring the epidemic via wastewater.

Enhancing wastewater treatment methods and developing strategies to minimize the detrimental effects of the organic and mineral components they contain would have a significant influence on the environment and public health. Among these methods, membrane separation technologies have been widely used in the chemical industry, food biochemistry, water treatment, and other fields due to their high rejection rates, environmental protection, and ease of

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Fig. 1 Photograph of a reverse osmosis membrane used

Model	Diameter Inches	Length Inches	Active Surface Area ft2 (m2)	Test Pressure
Filmtec BW30-400-FR	8.0	40	400(37)	225psi

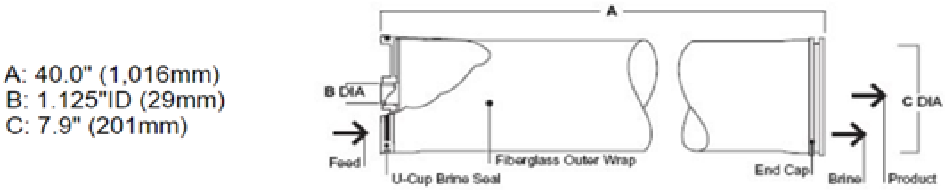


Fig. 2 Dimensions Filmtec BW30-400-FR

operation (Jung *et al*. 2019, Abdel-Fatah *et al*. 2020, He *et al*. 2019, Moradi *et al*. 2018, Saleh *et al*. 2020).

Recent research highlights the growing importance of developing advanced membrane technologies for wastewater treatment and the potential for reusing used reverse osmosis (RO) membranes. Membrane technologies, including ultrafiltration, nanofiltration, and reverse osmosis, have proven to be highly effective in treating wastewater due to their ability to remove a wide range of contaminants, including suspended solids, bacteria, and dissolved organic matter.

One key advantage of membrane technology is its efficiency in reclaiming water for various purposes, including industrial, agricultural, and even potable uses. The process involves passing wastewater through semi-permeable membranes, which filter out contaminants and produce high-quality effluent. This makes membrane technology a valuable tool in addressing water scarcity issues by turning wastewater into a resource. (Lin *et al*. 2023, Elorm *et al*. 2020).

In addition to conventional applications, there is a growing interest in reusing worn-out RO membranes for wastewater treatment. Used membranes can be repurposed for less demanding filtration tasks, extending their lifecycle and reducing waste. This approach not only offers an economical solution but also enhances the sustainability of membrane technologies. Studies have shown that reusing these membranes can still provide effective treatment, particularly when dealing with less polluted water sources (Hongjun *et al*. 2023).

The development and optimization of membrane technologies, including the reuse of spent reverse osmosis (RO) membranes, play a crucial role in sustainable wastewater management and resource recovery. In particular, these technologies enable the efficient treatment of wastewater, thereby reducing the need for new materials and and minimizing waste, while also helping to address water scarcity. Recent advancements include membrane bioreactor (MBR) systems and containerized solutions tailored to extreme environments, ensuring maximum flexibility and efficiency in various contexts (Vedrana *et al*. 2023).

On this basis, this research aims to test the possibility of recycling used membranes from the seawater desalination station of Beni Saf Water company of Ain Temouchent in order to purify wastewater using composite reverse osmosis (RO) membrane, reference BW30-400-FR, manufactured by Dow FilmtecTM for all the tests, the chemically-treated spent membranes are analyzed by scanning electron micro-scopy (SEM), as well as analyzing the clogging powder of the used membranes by EDX, while the chemical solutions proposed for the treatment of the used membranes are recovered and analyzed by UV-visible to estimate the components, which are released by unclogging of the films of the membranes. After that, we verified the efficiency of the recycled membranes by measuring the flow of wastewater and by determining the number of suspended solids in the wastewater.

The aim of this research is to degrade the active layer of used reverse osmosis membranes in order to transform it into microfiltration and/or ultrafiltration (elimination of clogged pores of small sizes), in order to recycle them for reuse in water treatment. Used. In the pursuance of this aim, we tested three solvents; potassium permanganate ($KMnO_4$), sodium hydroxide (NaOH), hydrogen peroxide (H_2O_2), and the mixture of NaOH with $KMnO_4$.

2. Materials and methods

Throughout this experimental analysis, we are interested in recycling used membranes for utilization in wastewater treatment procedures. The efficiency of the recycled

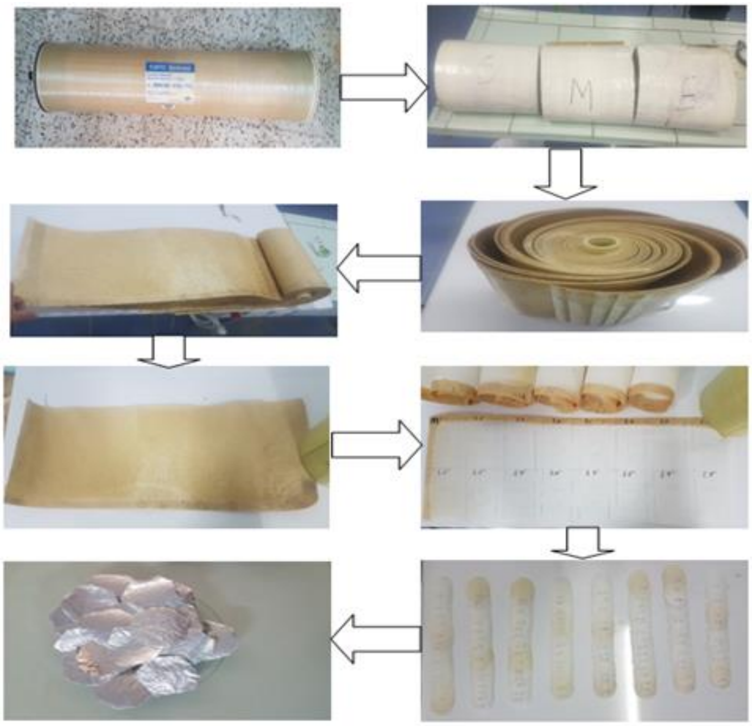


Fig. 3 Photograph of the dissection of cut discs (The 3 discs: entrance (E); middle (M); exit (S)

membranes was verified by measuring the following parameters:

A. Water flows

B. Determination of the number of suspended solids in water.

The objective is to deteriorate the reverse osmosis active layer in order to convert it to microfiltration and/or ultra-filtration.

2.1 Characteristics of the used membrane

Representative membrane:

A composite reverse osmosis (RO) membrane (see Fig. 1), reference BW30-400-FR, manufactured by Dow Filmtec TM was used for all the reverse osmosis tests. This membrane is typically used in desalination plants and can operate at pressures of over 60 bar. The performance of this membrane and the conditions of use recommended by the manufacturer are listed in Table 1.

The BW30-400-FR membrane is commonly used in seawater desalination, and its typical lifespan is 4 years at the Beni Saf Water Company plant.

2.2 Dissection of used membranes

The tool is divided by cutting it into three discs: the entrance; the middle; the exit. Each disc is 15 cm in length and is sawn at the level of the fibreglass starting from the surface of the membrane using a saw (see Fig. 3) The sheets in contact with the middle of the tool are removed and are not kept. The sheets of membrane-bound to the collecting tubes are recovered.

1. Unroll the cut-out disc from the tool

Table 1 Characterization of the BW30-400-FR Membrane (Home Water Purifiers and Filters)

Specifications	
Membrane Type:	Polyamide Thin-Film Composite (TFC)
Maximum Operating Temperature:	113F (45C)
Maximum Operating Pressure:	600 psi (41 bar)
Maximum Pressure Drop:	15 psi (1.0 bar)
pH Range, Continuous Operation:	2-11***
pH Range, Short-Term Cleaning:	1-13* (30min)
Maximum Feed Silt Density Index:	5 SDI
Free Chlorine Tolerance:	<0.1 ppm**
Permeate Flow Rate:	10,500 GPD (40 m3/day)*
Stabilized Salt Rejection:	99.5%

*Permeate flow and salt rejection based on the following standard conditions: 2,000 ppm NaCl, 225 psi (15.5 bar), 77F (25C), pH 8 and 15% recovery. Flow rates for individual elements may vary but will be no more than 7% below the value shown.

**Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation damage is not covered under warranty, Dow recommends removing residual free chlorine by pretreatment prior to membrane exposure. Most RO systems have carbon pre-filters for this purpose.

***Maximum temperature for continuous operation above pH 10 is 95F (35C).

2. Locate the positions of the slices also the membranes to be cut to study them:

-Choose the membranes (E1, E2, E8, E9, E18, E19, E25, E26, M3, M13, M23)

- Locate and name 16 pieces of 2*15cm² (L1, L2 ……. L8, L1’, L2’……. L8’), each piece is spaced by 10 cm

3. Cut and name the lots to identify:

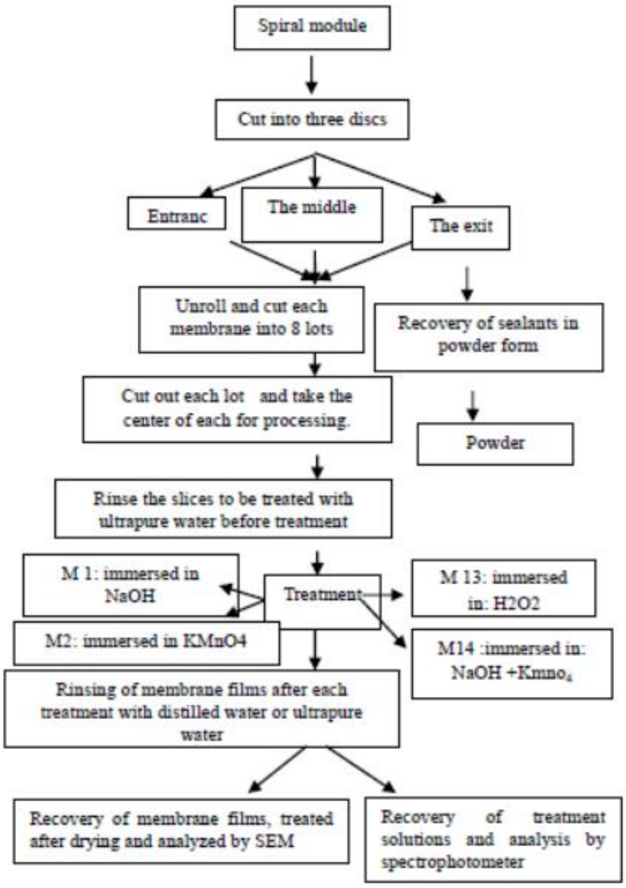


Fig. 4 Concentration load by stream and lake

Table 2 The concentrations of the oxidants used

Oxidant	Concentration needed to prepare	Manufacturer
H_2O_2 (30%)	Commercial undiluted	Prolabo, Paris
$KMnO_4$ (powder)	0,01M (2g/l)	Cheminiova, Spain
NaOH	5M (200g/l)	SNEP

Fig. 5 Treatment of membranes with NaOH

- Cut the centre of each batch to 2*2 cm².

- Keep each centre cut out in aluminium foil to avoid contamination, with a specific name.

2.3 Oxidizers used

Three oxidants are tested in order to recycle the membranes:

- $KMnO_4$
- NaOH
- H_2O_2

Table 3 Treatment solutions with dilute NaOH at different concentrations

Disc	Disc of lot1	Disc of lot2	Disc of lot3	Disc of lot4	Disc of lot5
Percentage (%) of NaOH	100	80	60	40	20

Table 4 Treatment solutions with KMno4 diluted to different concentrations

Disc	Disc of lot1	Disc of lot2	Disc of lot3	Disc of lot4	Disc of lot5
Percentage (%) $KMnO_4$	100	80	60	40	20

Fig. 6 Treatment of membranes with $KMnO_4$

Table 5 Treatment solutions with dilute H2O2 at different concentrations

Percentage (%) H_2O_2	100	80	60	40	20

Table 6 Initial hydraulic flow and after treatment

Parameters	Hydraulic flow initial (L/h*m²)	Hydraulic flow after treatment (L/h*m²)
RO immersed in NaOH	122,14	405,60
RO immersed in $KMnO_4$	122,14	2388,54
RO immersed in H_2O_2	122,14	2388,54
RO immersed in $NaOH+KMnO_4$	122,14	3070,97

- Mixture of the $NaOH+KMnO_4$

We group in the following table, the oxidants, their concentration as well as the manufacturer's.

For our tests, we will use the previous oxidants, either separately or in binary mixtures (50%-50%).

2.4 Membrane recycling protocol

We created small sections of a used RO membrane in the shape of a disc (diameter = 4 cm) to test them later, and then we calculated the flow of wastewater that flows through each sample via vacuum filtration.

In 250 ml beakers:

- Prepare 50ml of each oxidant solution
- Put each solution in a separate beaker
- Two pieces of the membrane are immersed in each beaker

Table 7 Diffusion of flow rates of treated membranes

	Time	TSS permeate mg/l	Qp	Jp (l/hm2)	1/jp
NaOH (75%)	68	35	3,970588235	316,129637	0,00316326
	88	47	3,068181818	244,281992	0,00409363
H_2O_2 (100%)	17	85	15,88235294	1264,51855	0,00079081
	38	107	7,105263158	565,705665	0,0017677
$kMnO_4$ (25%)	90	67	3	238,853503	0,00418667
	9	59	30	2388,53503	0,00041867
NaOH+k MnO_4 (50%)	4,26	67	63,38028169	5046,20077	0,00019817
	7	77	38,57142857	3070,97361	0,00032563
No treatment	176	85	1,534090909	122,140996	0,00818726
	40	42	6,75	537,420382	0,00186074

- Evaluate the effect of time
- We remove the first series after 24 hours and the rest after 7 days.

Test 1: Treatment with NaOH

Test 2: Treatment with $KMnO_4$

Test 3: Treatment with H_2O_2

Test 4: Binary mixtures (50%-50%) NaOH+$KMnO_4$

- At the end of the treatment, the treated discs are recovered and rinsed with distilled water.
- or ultra-pure water.
- The discs are then dried overnight in an oven at 27°C -30°C.
- After drying, the discs will be analyzed by SEM
- while the solutions after treatment will be analysed by UV-visible to estimate the components which are released by unclogging of the films of the membranes.

2.5 Frontal filtration protocol

Filtration was conducted under perpendicular pressure using a filtration ramp

-Hydraulic flow

Using the previously described frontal filtering cell to monitor hydraulic flow

Mass in Kg of water filtered per unit of time and per passing surface.

$$\text{hydraulic Flox} = \frac{\text{Volume of water filtered}}{\text{Filtration time} * \text{ filtration Surface}} \quad (1)$$

Filtration time/ hours

Filtration surface $A=\pi r^2$ cm² (diameter= 4 cm) or passage section Unit L/hcm² or (Kg/h cm²).

3. Results and discussion

Table 6 illustrates the initial hydraulic flow (L/hm²) and hydraulic flow after treatment (L/hm²)

Interpretation

According to the table, membranes immersed in the combination (NaOH, $KMnO_4$) for 24 hours had a larger hydraulic flow rate than those immersed in NaOH and H_2O_2. The hydraulic flow is the same in the membrane immersed in $KMnO_4$ and H_2O_2.This is due to the effectiveness of this mixture in removing the fouled active layer from the membrane. These results show that one day is sufficient for the regeneration of the membrane by immersion in the NaOH +$KMnO_4$ mixture.

3.1 Determination of the number of suspended solids in water

a- Principle: The procedure entails determining the amount of solid matter suspended in water before and after treatment.

Operating mode

Properly dries the filters using an oven at 105°C for 10 to 15 min.

· Weigh filters using an analytical balance, and carefully avoid contamination of the dust filter, using a desiccator.

- Place the filters in the funnel of the filtration system and connect it to a vacuum suction device (under pressure)
- Shake the bottle vigorously and transfer a determined volume of the sample into a graduated cylinder (1 L).
- Filter the sample.
- Rinse the test tube with distilled water, this portion is used to wash the filter and the filtration system if the water is very charged.
- Release the vacuum device when the filter is nearly dry and carefully remove it from the funnel using forceps.
- Place the filter on a watch glass and dry in the oven for one hour at 105°C. After drying, remove the filter from the oven and weigh.

Calculate the number of suspended solids according to the following formula:

$$x = \frac{m - m0}{v} \left(\frac{mg}{l}\right) \quad (2)$$

x: the number of suspended solids in mg/l.

m: mass of filter after filtration in mg.

m_0: mass of filter before filtration in mg.

v: volume of the filtered sample.

3.2 Evaluation of the degradation level via a convective-diffusive transfer model

To validate membrane breakdown and the formation of porosities, record the development of MES concentration in

Table 8 Diffusional flow rate, convection concentration

Parameteres	Membrane with no treatment	Membrane+NaOH	Membrane+$KMnO_4$	Membrane +H_2O_2	Membrane +NaOH+$KMno_4$
Diffusional flow rate Jdiff(mg h/m2)	6796	12898	2123	32757	78456
Convective concentration C conv (mg/l)	29,35	-5,8	58,11	59,09	51,45

Table 9 Results of filtration of wastewater by treated membranes

	NaOH	$KMnO_4$	H_2O_2	NaOH+$KMnO_4$	Raw water
Nitrate $NO3^-$	8,3	6,7	7,5	10,7	/
Nitrite ($NO2^-$)	29	20	26	32	/
phosphate (mg/l) PO_4^{3-}	0,058	0,047	0,0057	0,064	16
turbidity	43,8	35,7	53	52	300
PH	7,95	7,85	7,93	8,08	8
SEM	71	59	85	89	500
total chlorine (ug/l) Cl_2	343	267	318	430	
Cahardness (mg/l)	1,12	0,83	1,04	1,34	
Mg hardness (mg/l)	0,53	0,4	0,54	0,67	
SEM reduction rate	85,8	88,2	83	82,2	

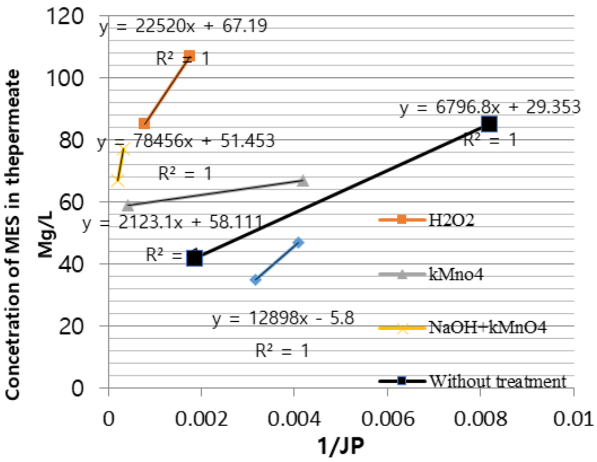


Fig. 7 Evolution of the permeate concentration as a function of the inverse of the permeate flow

permeate according to the inverse of flow rate when a solution of 85 mg L^{-1} of MES is filtered, and this for varied transmembrane pressures.

The slope of each of the straight lines obtained (Fig. 7) gives the diffusional flow rate and the ordinate at the origin of the concentration present in the permeate but having crossed the membrane according to a mechanism of forced convection through the porosities created by the degradation. of the active layer. For the RO membrane without treatment, the ordinate at the origin is non-zero, thus, for the samples treated with Kmno4, and the mixture of solvents ($KMnO_4$, NaOH), the ordinate at the origin is non-zero. This shows that a convective part is added to the transfer of matter by solubilization diffusion, at the origin of the reduction in the salt retention rate of the used membrane. For the membranes treated with NaOH and H_2O_2, the ordinate at the origin is zero, which confirms the nature of pure diffusion of the mass transfer in OI, the two solvents chosen do not have an effect on the degradation of the active layer (Ponte *et al*. 2008).

Interpretation

Researchers observed adequate diffusion for the two membranes submerged in H_2O_2 (100%) and a combination of NaOH and KMnO4 (50%). The two membranes submerged in H_2O_2 and the NaOH and $KMnO_4$ combination exhibit good convection concentrations, which are represented in the good degradation of the reverse osmosis membranes' active layer. The convection concentration of the membranes submerged in NaOH is negative, which can be interpreted as pore blockage (Fig.7).

3.3 Results of filtration of wastewater by treated membranes

The findings of table (9) above demonstrate the efficacy of the recommended solvents for membrane treatment. We can see that the membranes treated with solvents perform well in terms of SEM retention.

These findings demonstrate the efficacy of the proposed treatments for active layer degradation, as well as the feasibility of reusing it in wastewater purification to improve the quality of the purified wastewater released into the natural environment.

3.4 Results and discussion of scanning electron microscopy (SEM-EDS) analysis

Scanning electron microscopy (SEM) with an X-ray detector was used to examine the membrane's surface (EDS) SEM (Model JEOL 5410 LV equipment) photographs obstructed and treated membranes by projecting a beam of secondary electrons across the membrane's surface. This information makes it possible to qualitatively assess the

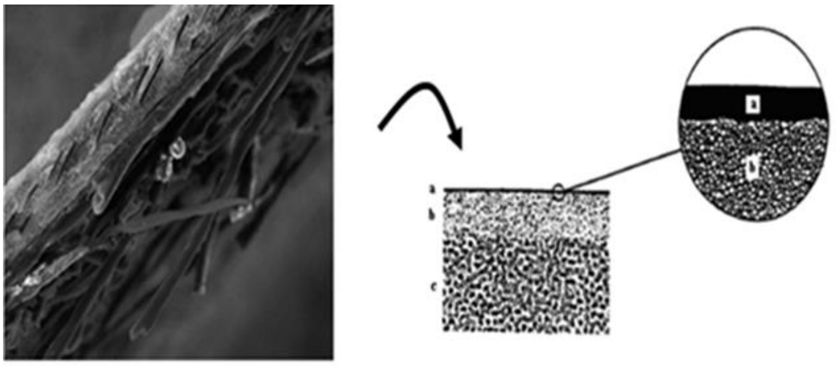
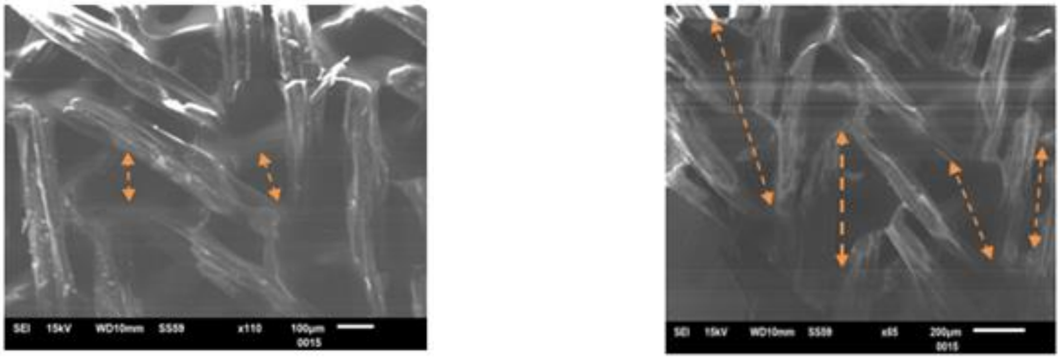
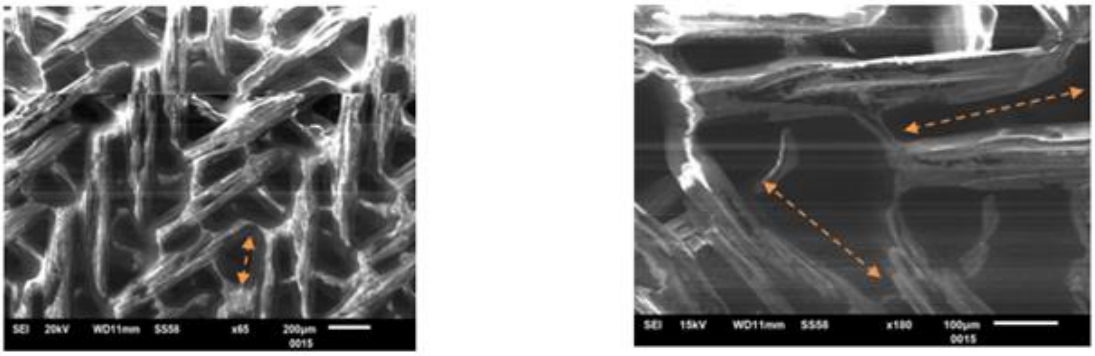


Fig. 8 Overview of the three different layers that make up a new membrane by SEM (a) Polyamide 0.2µm thick (b) Polysulfone 40µm (c) Polyester 120µm



(a)Spent membrane without

(b) Membrane immersed in H_2O_2



(c) Membrane immersed in NaOH

(d) Membrane immersed in $KMnO_4$

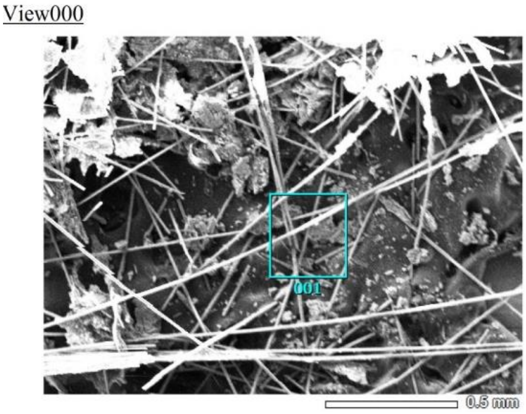
Fig. 9 Analysis of membranes pre and post SEM treatment(a) Spent membrane without treatment, (b) Membrane immersed in H_2O_2, (c) Membrane immersed in NaOH, (d) Membrane immersed in $KmnO_4$

structure and quantity of the deposit formed. An X-ray detector (Electron Detection Scan, EDS, EDS-analysis Quantax, Bruker AXS, Germany) was added to the microscope in order to be able to analyze the elemental composition of the filtration deposits. The membranes are dried and then covered with a thin layer of carbon before observation by SEM.

The carbon conductive layer (thickness of a few Angström) is employed to prevent the buildup of energy delivered by electrons on the non-conductive membrane and hence its degradation. The surface of the membranes is observed before and after treatment. The qualitative identification of the elements present on the membrane was also carried out by EDS and carried out with a 30 mm² SDD Bruker Quantax probe. Following the sending of electrons to a point on the surface of the membrane, an emission spectrum of the elements present at this point is obtained, each element present can be identified by its emission line whose position is fixed on the spectrum. If the element is present, a peak is then visible. It should be noted that this measure is a qualitative measure.

The RO membrane (Fig. 8) is made up of three layers: polyester support, an intermediate layer of microporous polysulfone and finally, on the surface of the membrane, an ultrathin layer of polyamide or its derivatives called the "active layer".

Following the observation of changes in the filtration capabilities of the RO membrane placed four years earlier on the site, the research of the state of degradation of the active layer of the used membrane for reuse in wastewater treatment



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JEOL  1/1

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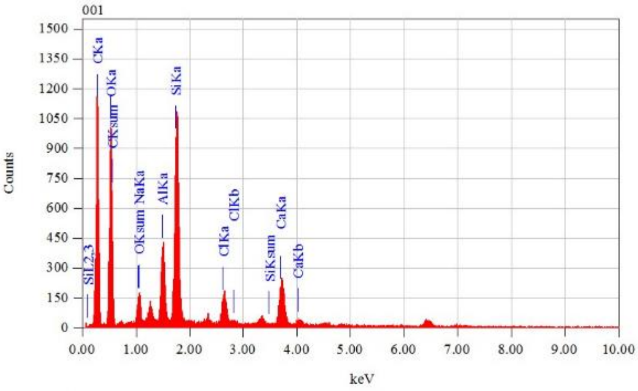
Fig. 10 Analysis of sealant powder recovered from the surface of outlet disc membranes by SEM



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PHA mode      : T3
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Live Time     : 30.00 sec
Dead Time     : 1 %
Counting Rate: 1688 cps
Energy Range :  0 - 20 ke\
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Fig. 11 Analysis of the sealant powder recovered from the surface of the outlet disc

consisted in adopting an autopsy technique. Thus, in this diagnostic approach, we were led to study the used membrane treated with different proposed solvents such as NaOH, H_2O_2, $KMnO_4$, and mixture ($KMnO_4$ and NaOH), with reference to the same type of used membrane, the evolution of the properties of productivity (hydraulic permeability) and efficiency (retention of suspended solids), but also the modifications of the surface of the membrane (analysis by SEM).

3.4.1 Analysis of membranes pre and post treatment by Scanning Electron Microscope (SEM)

This technique allowed the morphological characterization at the scale of a few micrometres of certain phases present. The microscope used is of the JEOL JSM 5000 type equipped with a field emission gun. The samples were deposited on a pellet containing silver lacquer and metallized with gold or carbon. The acceleration voltage is variable between 0.5 and 30 kV depending on the quality of the image obtained, the magnification up to x 150000 and the resolution of 1.6 nm at 20 kV. The observation is made by detecting secondary electrons.

Scanning microscopy makes it possible to observe the texture of the samples studied.

Interpretation

The SEM Figs. 9 shown above demonstrate the various findings achieved pre and post-treatment. Researchers notice the same shape and size of the pores present in the active layer for the membrane used without treatment and the membrane treated with NaOH, which is translated by the weak effect of the solvent used for the degradation of the active layer, which confirms what is already shown in the broadcast flow calculation.

For the membranes immersed in Hydrogen peroxide (H_2O_2), and immersed in potassium permanganate ($KMnO_4$), we see a deformation of the active layer of the membranes. and so we notice that the size of the pores of the latter is larger than that of the membrane immersed in the solution of sodium hydroxide (NaOH) and of the membrane worn without treatment, which was already shown in the flow calculation diffusion which confirms the good results of calculations.

These results show the effectiveness of Kmno4 and H_2O_2 for the degradation of the active layer of the reverse osmosis membrane, which is good for the recovery of the membranes in order to reuse them in the treatment of wastewater.

3.4.2 Analysis of sealant powder recovered from the surface of outlet disc membranes by SEM and EDS

Elemental analysis by X-ray spectrometry (EDS detector)

The energy of the X-rays released during the de-excitation of atoms hit by the electron cannon is determined by their chemical composition. We may do an elemental analysis by studying the X-ray spectrum, which allows us to determine what sorts of atoms are present in the sample and in what quantities.

We conducted a semi-quantitative analysis by EDX of the samples to determine the elemental composition of the membranes analyzed.

Interpretation

The X diffractogram of the sealant powder recovered from the surface of the outflow disc membranes after unrolling the membranes is shown in Fig. 10 above. This investigation allowed us to determine the type of sealant that is included in the powder’s composition.

In Fig. 10, the appearance of the peak at 0.277 keV indicates the presence of carbon in a high mass of 50.58% (the carbon comes from the support grid of the sample), also the appearance of the peaks at 0.525 keV, at 1.041 keV, at 1.48 keV, 1.74 Kev, 2.62 keV, and 3.49 keV indicate the presence of oxygen with a mass of 37%, and 1.55% sodium, and 2.06% respectively. aluminium, and 5.84% silicon, and 1.12% chlorine, 1.85% calcium.

Table 10 Composition of powder

Element	Mass %	atom %
C	50,58	60,56
O	37	33,26
Na	1,55	0,97
Al	2,06	1,10
Si	5,84	2,99
Cl	1,12	0,45
Ca	1,85	0,66

Table 11 Comparison with the Work of Other Researchers

Study	Description	Authors
Recycling of end-of-life reverse osmosis membranes for membrane biofilm reactors (MBfRs)	This study explores the recycling of spent reverse osmosis membranes for use in membrane biofilm reactors, aiming to enhance the sustainability of membrane technologies.	Morón -López *et al.* 2019
Direct recycling of discarded reverse osmosis membranes for domestic wastewater treatment with a focus on water reuse	This research investigates the direct recycling of used reverse osmosis membranes for treating domestic wastewater, emphasizing the potential for water reuse.	Lawler *et al.* 2020
Sustainability in Membrane Technology: Membrane Recycling and Fabrication Using Recycled Waste	This work addresses sustainability in membrane technology by focusing on the recycling of membranes and the fabrication of new membranes using recycled materials.	Noman Khalid Khanzada *et al.* 2024

Based on this analysis, we find that the reverse osmosis filtration membranes of BENI SAF are essentially clogged with carbon, oxygen, sodium, aluminium, silicon, chlorine and calcium, coming from the raw water treated by them.

3.4.3 Comparison with the Work of Other Researchers

Table 11 provides a comparison of this study with the findings of other researchers.

4. Conclusions

This research helped us properly understand the membrane's composition and role in water purification. After frontal filtration of raw water, the MES retention rate estimates show the SS retention efficiency of the treated membrane (retention rate reached 88,2 per cent). In the permeate of the treated membranes, we detected higher amounts of MES than in the wasted membranes without treatment. This appears to imply that the membrane has degraded, which we interpret as the formation of porosity through which the wastewater may travel, as demonstrated by SEM inspection of the membranes before and after treatment, in contrast to RO, which is a completely dense membrane.

Dentified limitations: Sensitivity to thermal or chemical degradation during the procedure of lively layer discount. Variability inside the overall performance of reprocessed membranes depending on the initial fouling conditions. Costs and complexities related to modifying the membranes for powerful reuse. Potential Directions for Future Research: Study the effect of different regeneration strategies at the structural and functional properties of the membranes.

Explore advanced characterization techniques to more precisely evaluate the properties of reprocessed membranes.

Optimize post-reuse treatment processes to maximize the lifespan and efficiency of the membranes. Methodological Improvements: Standardize the evaluation methods for the performance of reused membranes to ensure reproducibility of results. Integrate a life cycle analysis to assess the overall environmental impact of the regeneration processes. Collaborate with industries to test regenerated membranes at pilot or industrial scales.

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