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A NEW PILOT-SCALE MEMBRANE UNIT FOR THE STUDY OF PRO-ECOLOGICAL PRESSURE PROCESSES

Key words

Membrane processes, apparatus, clean technology, cleaning technology.

Summary

The new, integrated pilot installation for the investigation of pressure membrane processes, concerning wastewaters has been presented. Its process parameters and main process modules (MF, UF, NF and RO) have been fully described and discussed from the point of view of different applications. Results of the influence of different flows on the process modules as well as the primary results of tannery wastewater purification have been given and discussed.

Introduction

Membrane processes belong to the group of the molecular mixture separation techniques. Among them, because of the transmembrane pressure – the driving force of the process, one can distinguish the following pressure membrane processes, which can be used for liquid separation: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO).

Most of the applications, because of their purity are connected with environment protection. They enable the user to obtain less concentrated end streams of reagent for its further recycling or degradation.

Recently, the main area of their applications is connected with water treatment, softening, desalination and deionisation of water [1]. However, it has

also been shown in previous literature that they have applicability to the purification of municipal and industrial wastewaters [2].

The dynamic development of new membrane materials and constructions enables further extension of their applicability and stimulates new and further investigations. The new research, both model and experimental (laboratory and pilot scale), is connected mainly with the investigations of the complex phenomenon and flows which appear in the membrane elements during the filtration.

That is why, the new, integrated pilot installation for investigation of pressure membrane processes concerning wastewaters have been elaborated, built and implemented in the Department of Process and Environmental Engineering of Technical University of Radom.

1. Pilot installation

One mobile pilot-set consists of two different membrane modules: the first for micro- and ultrafiltration, and the second for reverse osmosis and nanofiltration. To have the possibility of various different applications, the installation has been divided into three separated but integrated modules: input, low pressure (pump 3 bar), high pressure (pump 16 bar), and a connection (pump 1 bar) module. The modules and three independent reservoirs are connected by a pipe system equipped in steering and measuring apparatuses (Fig. 1 and 2).

Fig. 1. Pilot membrane installation equipped with MF/UF and NF/RO membranes

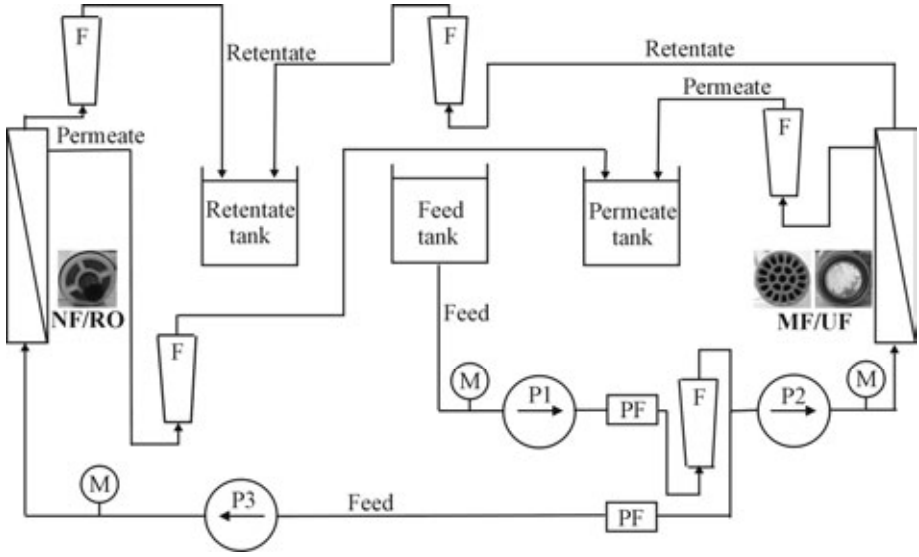

Fig. 2. Scheme of the pilot membrane installation: P1 – feed pump, P2 – circulation pump, P3 – high pressure pump, M – manometers, F – rotameters, PF – prefilters

2. Membranes and modules

The investigations have been performed for a few different membranes put into the stainless or PCV housings (Table 1 and Fig. 3).

Table 1. Characteristics of the membrane modules for MF, UF, NF and RO

	MF		UF		NF	RO
Manufacturer	Tami	Eurosep	Tami	Eurosep	Osmonics	Osmonics
Configuration	Tubular	Capillary	Tubular	Capillary	Spiral wound	Spiral wound
Membrane material	CeRAM	PP	CeRAM	PSU	composite	composite
Active area	0.35 m^2	0.701 m^2	0.35 m^2	0.35 m^2	1.2 m^2	1.2 m^2
Nominal cut-off	0.2 µm	0.2 µm / 0.3 µm	150 kD	50 kD	-	-
Temp. max.	350°C	40°C	350°C	70°C	50°C	50°C
Press. max.	5.5 bar	1.5 bar	5.5 bar	5.5 bar	31 bar	31 bar
pH	0-14	2-10	0-14	2-10	3-9	4-11

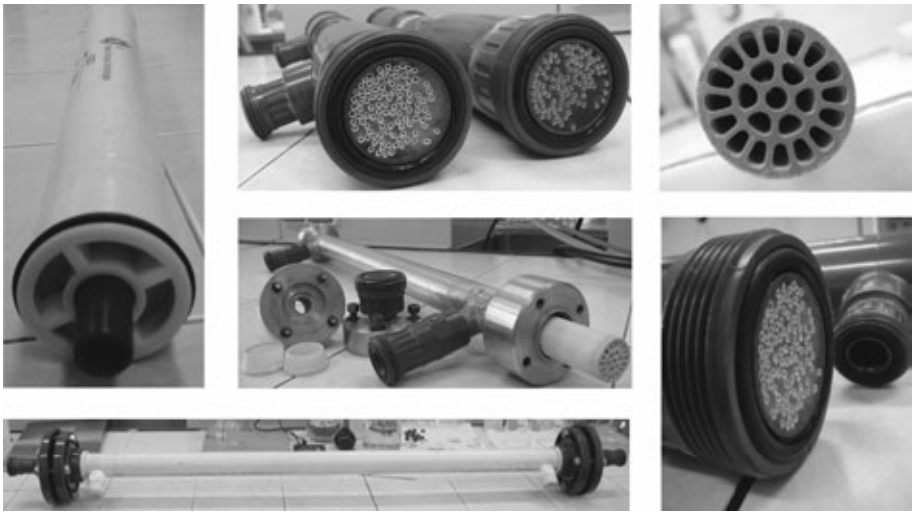

Fig. 3. Investigated membranes: spiral wound, hollow fibre and tubular ceramic

3. Preparation of the pilot installation for investigations

The work of installation has been checked, according to the producer recommendations, on washing and hydrophilisation procedures of new membranes as well as the conservation procedure. Moreover, to check the separation properties of the used membranes in different process parameters (speed of the flows, transmembrane pressure, temperature, etc.), many tests on water have been performed. The obtained values of permeation factors before and after washing procedure have been compared. The backflushing system for micro- and ultrafiltration has been checked for different times and frequency of loading. Also, the verification of applications of the new installation for different process conditions (stable continuous process, unstable process, reverse permeate or concentrate flow, two modules set, etc.) has been done. Finally, the range of parameters of all installation apparatuses and the safety procedure of the installation have been verified. Obtained results confirmed the applicability of the new pilot membrane installation for studying industrial effluent treatment.

4. Water permeability in membrane elements

The technological investigations have been performed in the conditions similar to those achieved in the industrial purification (also tanning wastewaters) plants. The model flows were composed from tap water and technical chemicals used in the industry. Primary investigations concerned tap water (hardness 380 mg $CaCO_3$/L, turbidity 0,8 NTU, conductivity 780–920 μS/cm) penetrability

of different membranes. Obtained results for all investigated membranes are presented on Fig. 4–7.

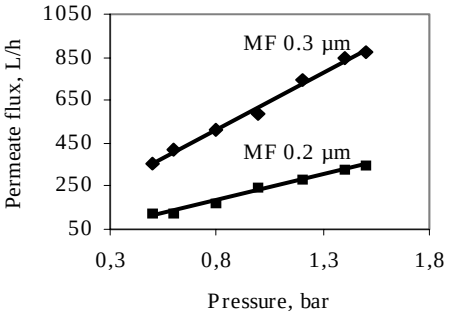

Fig. 4. Permeate flow versus pressure for microfiltration (0.3 and 0.2 µm) polypropylene membranes

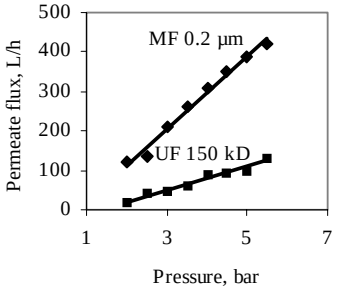

Fig 5. Permeate flow versus pressure for microfiltration (0.2 µm) and ultrafiltration (150 kD) ceramic membranes

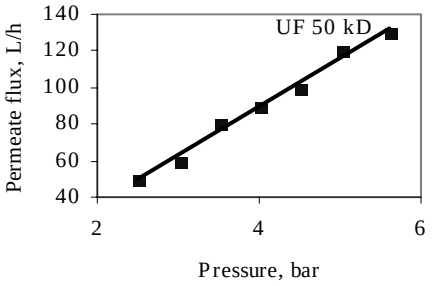

Fig. 6. Permeate flow versus pressure for ultrafiltration (50 kD) polysulphone membrane

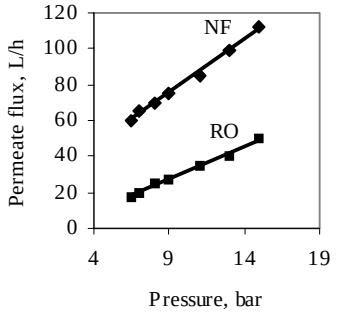

Fig. 7. Permeate flow versus pressure for nanofiltration and reverse osmosis composite membranes

5. Primary investigations of model tanning wastewaters separation

Based on tannery wastewater analysis, data from previous studies [3-5] and our experience coming from cooperation with the tannery industry we defined the representative range of tannery wastewater component concentrations. Based on this information, we prepared the modelled input flows for primary membrane separation in our installation, which allows for the investigation of technological processes at a pilot scale. We used the following model mixtures:

– mixtures of water and gelatine simulating animal proteins – for ultrafiltration,

– a mixture of animal fat and surfactant roksol (components of tanning baths) – for microfiltration,
– mixtures of water and chromal (the main component of tanning bath with $Cr(OH)SO_4$) – for reverse osmosis and nanofiltration.

The range of concentration for all these mixtures was similar to that which is used in the industry processes. Obtained results allowed for the determination of the membrane retention factors describing the process selectivity and overall separation efficiency (ratio of the main component flow and the input flow of the investigated module).

The measurements were carried out in the temperature range of 20–30°C and the input flows of the membrane modules were changed from 500 to 2500 L/h. Obtained results (Table 2). Observations enabled preparation of the further research program concerning the purification of the tannery wastewaters from tannery beamhouse operations.

Table 2. Selectivity of membrane separation in primery investigation of tannery wastewaters

Stream	Species			
	Oils, fats mg/L	Nitrogen mg/L	Chrome mg/L	Chrome mg/L
Permeate	17.0	53.0	584.6	0
Feed	84.0	307.3	3069.2	4384.6
Retentate	119.0	310.0	3361.5	4823.1
Operation	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis

Conclusions

The obtained results of the initial investigations confirm the applicability of the MF, UF, NF and RO membranes for proper removal of proteins, fats and Cr(III) from tannery wastewaters. However, based on these results, we can not yet firmly define the optimal parameters for the effective use of these processes. In turn, taking into account the results obtained for the model flows, we can find out that application of the above processes is able to reduce significantly the concentration of fats, proteins and Cr(III) in chromium tanning baths' regeneration.

Acknowledgements

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Reviewer:
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Nowa pilotowa instalacja do badań proekologicznych ciśnieniowych procesów membranowych

Słowa kluczowe

Procesy membranowe, aparatura, czyste technologie, technologie czyszczące.

Streszczenie

Zaprezentowano nową instalację pilotową zaprojektowaną, wykonaną i uruchomioną przez autorów w celu prowadzenia w skali półtechnicznej badań technologicznych oczyszczania ścieków przemysłowych z zastosowaniem ciśnieniowych procesów membranowych. Opisano zasadnicze parametry techniczne instalacji i możliwości badawcze z wykorzystaniem określonych modułów wyposażonych w elementy membranowe do mikro-, ultra-, nanofiltracji i odwróconej osmozy w różnych układach procesowych. Przeprowadzono badania hydrauliki przepływów w posiadanych elementach membranowych dla wody wodociągowej. Omówiono rezultaty wstępnych badań oczyszczania modelowych ścieków garbarskich przygotowanych z wody wodociągowej i chemikaliów o czystości technicznej. Potwierdzono zdolność instalacji do znacznego obniżenia stężenia tłuszczów, białek i chromu(III) w tych ściekach w warunkach półtechnicznych.