Indigenous intelligent materials for the textile field

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ABSTRACT – REZUMAT

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The present work reflects an area of cutting-edge research, bioengineering and industrial microbiology, emphasising the new physiognomy of macromolecular chemistry, supramolecular chemistry. Membranes are advanced materials whose specificity manifests itself in order, organisation, structural stability, and functional stability, explaining their own character of separation and selectivity.
A hypothesis finds applications in a variety of fields. The more numerous and diverse these fields are, the higher the probability that this hypothesis applies.
The aim of the paper is to present applications of polyurethane membranes in the textile industry by integrating them into garment structure and also in wastewater purification. The proposed membrane technology is innovative and will be of fundamental economic importance in the coming years.

Keywords: *membranes, textile, advanced materials, wastewater*

Materiale indigene inteligente pentru domeniul textil

Materialul prezentei lucrări reflectă un domeniu de cercetare de vârf, bioingineria, microbiologia industrială, subliniind noua fizionomie a chimiei macromoleculare, chimia supramoleculară. Membranele sunt materiale avansate care prezintă specificitatea manifestată prin: ordine, organizare, stabilitate structurală, stabilitate funcțională, explicând caracterul lor propriu de separare și selectivitate.
O ipoteză își găsește aplicații în cele mai diferite domenii. Cu cât aceste domenii sunt mai multe și mai variate, cu atât probabilitatea valabilității ipotezei respective este mai mare.
Scopul lucrării este acela de a prezenta aplicațiile membranelor poliuretanice în industria textilă, prin includerea lor în structura vestimentară, dar și în purificarea apei uzate. Tehnologia membranară propusă este una inovatoare și constituie o miză economică reală în anii viitori.

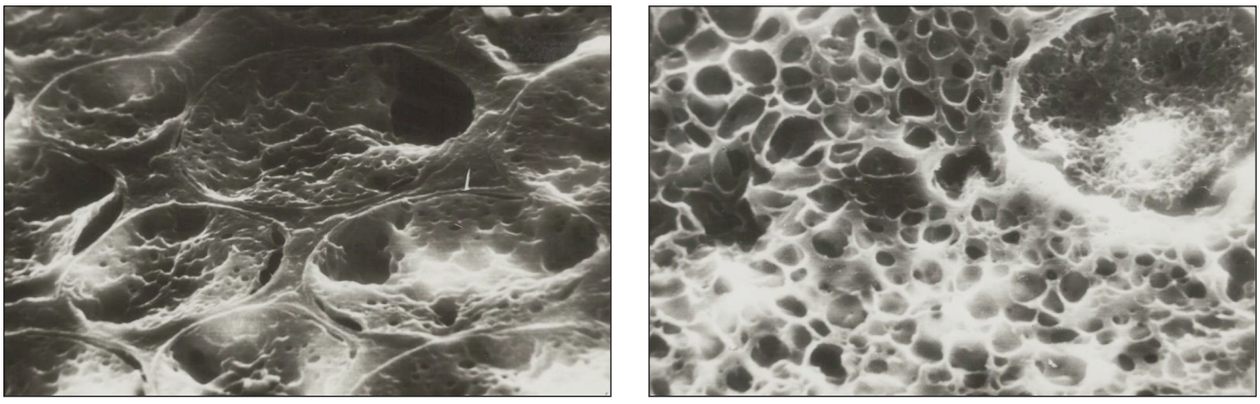
Cuvinte-cheie: *membrane, textile, materiale avansate, apă reziduală*

INTRODUCTION

Chemical science is based on the biological world by an axiom of existence: the simple fact that biological systems exhibit the fantastic complexity of structures and functions that the molecular universe can provide. Molecular recognition, self-assembly, and information transfer play an important role in the formation of artificial systems that mimic the behaviour of life.
Supramolecular chemistry is the "chemistry beyond the molecule" that produces more complex entities that arise from the combination of chemical species bound by intermolecular forces. Supramolecules (membranes) are characterised by the spatial arrangement of their compounds through the architecture of the superstructure and the nature of the intermolecular bonds that compose them.
In this way, advanced materials can be obtained that are endowed with properties reminiscent of the five senses [1]: specificity (mind), selectivity (understanding), stability (opinion), order (imagination), and organisation (feeling).
Supramolecular compounds can form membranes that provide the ability to separate healthy cells from microbes and viruses, allow transport and separation processes and are of particular importance in various fields: technology, chemistry, physics, biology, medicine, geochemistry, hydrology, agronomy, ecology, nutrition, etc. [2–4].

INDIGENOUS POLYMERIC MEMBRANES

The term membrane is a Latin word meaning coating, shell or sheet. In 1890, Pfeffer mentioned the cell surrounded by the membrane (cell membrane coating), but also the behaviour of the membrane as a universal barrier [1]. Thus, according to a rather simple definition cited by Spriggs, the membrane is a device in the form of a usually thin film that acts as a physical barrier between two fluids and allows some degree of permeability between them. The definition is incomplete and needs to be extended by specifying the factors that affect the behaviour of the membrane [1].
Mariana Bezdadea [5, 6] considers that membranes are gel-like synergistic colloidal systems with a specific supramolecular architecture, i.e., an associative and steric arrangement of hydrophilic and hydrophobic micro and macro phases that perform the same



a *b*

Fig. 1. Scanning electron microscopic images for polyurethane (PU) UF-MF membrane (×3000): *a* – glossy side; *b* – the matte side [1]

function and consist of hexagonal helical shapes compatible with spherical or cylindrical structures, which explains the presence of the pore system. In addition, membranes are mimetic systems that artificially or synthetically reproduce the properties and functions of a biological system, combining order with action (imperative of biological systems) [2–4, 7–9].

A chronology of important information in the study of supramolecular chemistry is: in 1982, Mariana Bezdadea with the doctoral thesis "Matrix polymerisation" [3], in 1987 the Nobel Prize of J.M. Lehn, in the same year 1987 independently of J.M. Lehn, Mariana Bezdadea interferes with the book "Matrix polymerisation (template) - biotechnology" [2]. In the following years [10–13], J.M. Lehn and co-workers pointed out that reactivity and catalysis are the fundamental features of the functionality of supramolecular systems, as molecular receptors carrying suitable groups that can complex the substrate under conditions of stability, selectivity and speed [14, 15]. In 2013 [16], J.M. Lehn pointed out the importance of adaptation through order, organisation, and reinforcement of self-assembly of components accessing functions such as training, knowledge, and learning during dynamic transformations and changes. Mariana Bezdadea noted the same adaptation through order, organisation, and self-organisation of components in the fabrication of membranes made of polyvinyl acetate (PVAc), polyurethane (PU), and polystyrene (PS) [1–9].

The "guest" molecules: vinyl acetate monomer or another polymer (PU), are activated on the one hand by the donor function exerted by the electron pair of the oxygen of the OH groups of the polysaccharide "host", an "electron pressure" and on the other hand by an "electron depression" due to the established hydrogen bonds. The "host" or molecular sieve, matrix, or template is both a donor and an acceptor. Thus, the "attraction/repulsion" mechanism of bifunctional catalysis exerted by the molecular sieves studied provides for the action of OH groups on one side and hydrogen bonds on the other [1–3].

In the mechanism of formation of asymmetric polyurethane (PU) membranes, the cellulose matrix serves as an orientation surface and produces an "induced adaptation", and the "lock and key" theory here is reminiscent of the model of enzymatic catalysis.

The polyurethane (PU) ultrafiltration membrane shows larger ellipsoidal or spherical macro phases on the glossy side (figure 1).

The structural-functional asymmetry of cross-linked or non-crosslinked polyurethane membranes reflects their rectifying property, which brings them closer to biological membranes. The rectification phenomenon is based on an asymmetry of the existing structure and energy barriers on the two sides of the membranes [1].

APPLICATIONS OF INDIGENOUS MEMBRANES IN INDUSTRIAL PRACTICE

In general, one can imagine a pyramid of membrane applications. At the top is a small amount of valuable, separate, purified products, while at the base of the pyramid are recovered substances with a low price and very high demand. Not surprisingly, most biotechnology activities are located at the top of the pyramid. The closer we get to the top of the pyramid, the more stringent the purity requirements become. This purity is the key cost factor. For example, up to 80% of the cost of obtaining therapeutic proteins is attributable to the extraction and purification processes (figure 2).

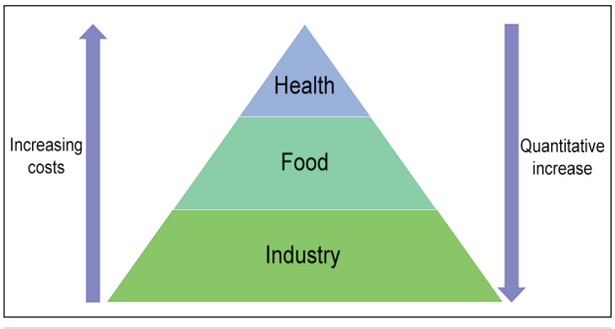


Fig. 2. Overview of membrane applications [1]

Process with indigenous polyurethane membrane in the advanced textile field

Smart textiles are used in a wide range of fields: protective equipment, sportswear, special clothing – recommended for medical treatments, such as bandages in the field of blood circulation, protection – for unstable climatic conditions or clothing that responds to temperature variations of the human body, protective equipment for places with poor visibility and/or firefighters. Advanced textiles show a special behaviour, modifying their properties under the action of an external factor [17, 18]. Materials with special properties can also be produced using membranes.

Information technology, biotechnology and nanotechnology are some of the development directions that influence the production of smart or advanced textiles, materials that can respond to specific stimuli.

In this context, both the physicochemical properties and the sanogenetic physiological indicators of a series of indigenous polyurethane membranes (PU) were studied in comparison with an imported membrane (polyamide) and a textile fabric (polyester). Studies on the flexibility and elasticity of indigenous polyurethane membranes indicate the need to use them in a suitable composite material [1].

The following materials were used: indigenous polyurethane membranes (PU) I3 and I4 non-cross-linked and I8 cross-linked [6, 19], Pall polyamide membrane (import/produced by Pall Corporation, USA) and polyester fabric.

The methods of material analysis were as follows:

- *Morphological structure* of the membranes was observed with a Tesla B.S. 300 electron microscope.
- *Porosity* (ε,%) is the fraction of the volume of the membrane not occupied by the polymer, calculated according to the following formula:

$$\varepsilon = n\pi r^2 \quad (1)$$

where n is the number of pores per cm^2 and r is the radius of the pore.

- *Pore size* (r, μm) of the membranes used was determined by the Bubble Point method.
- *Permeability for distilled water* (P, m/h) was determined on a vacuum ultrafiltration and microfiltration laboratory apparatus (UF-MF), with a front module (homemade device).
- *Vapour permeability* (μ, $g/m^2 \cdot h$) was measured by determining the mass loss by evaporation of the liquid (distilled water) using a Herfeld beaker according to GB/T 12704-91.
- *Air permeability* ($P_{a\Delta p}$, $m^3/min \cdot m^2$) is defined by the volume of air transmitted per unit time and per unit area of the material and was measured with a measuring system FX 3350 – Dynamic Air Permeability Tester, according to ASTM method D737-75.
- *Thermal conductivity* (λ, $kcal/m \cdot h \cdot {}^oC$) was determined by measuring the heat flux that flows through the product when placed in a temperature gradient, using a Shirley Tog Metre system.
- *Hydrophilicity* (%) was determined by determining the rate of capillary rise on samples sized following STAS 6146-87.
- *Hygroscopicity* (%) is the property of absorbing or releasing moisture in the form of vapours; it determines the sorption/desorption process, determined according to STAS 12749-89.
- *Flexibility* of the membranes used in comparison with a textile material was expressed in relative units, *H*% of the reference value, and determined on a Flexometer type FF 20 – Metrimpex, on samples, dimensioned according to STAS 8392-80; the flexibility *H* was defined by the ratio between the area under the variation diagram of the bending angle when increasing the free end of the sample by 10 mm and the area corresponding to the maximum flexibility (standard – absolutely flexible):

$$H = A/A_{abs} \cdot 100\ \% \quad (2)$$

- *Total germ content* was determined by the membrane method, according to STAS 3001-91.

Regardless of the destination, the structure of the garment must allow continuous or near-continuous air exchange, even when special treatments are applied. The ability to absorb and retain moisture depends on hydrophilicity and hygroscopicity, which in turn depend on the capillary system and porosity (number of pores – places not occupied by the polymer), pore size and their distribution. The ability to absorb and release water vapour to the atmosphere (hygroscopicity) depends on the affinity for water molecules of the functional groups in the OH<COOH<NH_2<OCONH polymer chain. The convective permeability (under the influence of an external force) to distilled water for the ensemble membrane/textile material is influenced and directed by the type of membrane structure.

Table 1 shows that the porosity of the membrane mainly influences the permeability to distilled water. Thus, the lowest permeability values are registered for polyurethane membranes I4 and Pall membrane 0.062 m/h and 0.88 m/h, respectively. In these membranes, where the pore size is minimal 0.91 μm and 0.78 μm respectively, the porosities are comparable, 44% and 49.05%, respectively, while in polyurethane membranes I3 and I8, with comparable and larger average pore size 4.17 μm and 3.24 μm, respectively different values of permeability for distilled water are recorded 6.05 m/h and 1.57 m/h, respectively.

The membrane/textile material ensemble shows changes in distilled water permeability values, compared to the textile material permeability, of 6.57 m/h. The lowest value, namely 0.06 m/h, was observed for the ensemble membrane I4 (PU)/textile material.

In general, there is a decrease in distilled water permeability values, from 6.57 m/h for the textile material to 0.06 m/h for the membrane I4/textile material ensemble, 0.42 m/h for the membrane I8/textile material ensemble, 0.24 m/h for the Pall membrane/textile material ensemble, and an increase to 7.89 m/h for the membrane I3/textile material ensemble. These differences confirm the importance of the link between the structural properties of the membrane and its final application.

Table 1

PHYSICO-CHEMICAL CHARACTERISTICS OF POLYURETHANE MEMBRANES I3, I4, I8, PALL MEMBRANE AND POLYESTER TEXTILE MATERIAL

Membrane/ material	Porosity ε (%)	Pore size r (μm)	Number of pores on cm^2 n (pores/cm^2)	Permeability to distilled water P (m/h)	Permeability to distilled water of ensemble membrane/textile material P* (m/h)
I3	70.38	4.17	1.28	6.05	7.89
I4	44.00	0.91	16.92	0.062	0.06
I8	65.27	3.24	1.98	1.57	0.42
Pall	49.05	0.78	25.67	0.88	0.24
Textile material	74.56	14.60	0.11	6.57	-

Note: P* represents the permeability to distilled water of membranes and textile material.

Table 2

SANOGENETIC PHYSIOLOGICAL INDICATORS OF POLYURETHANE MEMBRANES, COMPARED TO PALL MEMBRANE AND A TEXTILE MATERIAL (POLYESTER)

Membrane/ material	Vapour permeability μ (g/m^2·h)	Air permeability $P_{a\Delta p}$ (m^3/min·m^2)	Thermal conductivity λ (kcal/m·h·°C)	Hydrophilicity h (cm/sec.)	Hygroscopicity (%)	Flexibility H (%)		
						L	T	D
I3	17.68	0.125	0.0104	0.28	2.3	5.05	15.38	14.22
I4	7.77	0.070	0.0060	0.17	0.6	60.00	61.40	62.20
I8	13.23	0.075	0.0065	0.14	2.9	32.30	29.40	29.70
Pall	14.71	0.05	0.0113	0.12	0.9	15.33	24.38	2.66
Textile material	21.7	50	0.0095	0.02	16.2	9.33	38.10	24.70
Standard quality limits	1–50	0.166	0.01–0.05	0.2 at ½ h for cotton	8 for cotton 14 for wool 0.4 for polyester	-	-	-

Table 2 shows the sanogenetic physiological indicators air permeability $P_{a\Delta p}$, vapour permeability μ, thermal conductivity λ and hydrophilicity *h* for the studied polyurethane membranes and for the Pall membrane, in comparison with textile material.

Table 2 shows that all membranes are hydrophilic (the reference value is 0.2 cm/sec). It is also clear from the values of thermal conductivity λ between 0.006 kcal/m·h·°C and 0.01 kcal/m·h·°C that the membranes fall into the group of thermal insulation materials. All membranes have very low values for air permeability.

This property is specific to waterproof materials (wind or raincoats), for which the quality limit is 0.166 m^3/min·m^2. In addition, the membranes are vapour permeable, provided they are airtight (the quality limits vary widely, between 0 and 50 g/m^2·h).

The I4 polyurethane membrane has a vapour permeability of 7.77 g/m^2·h, which is close to that of a waterproof material that is considered control and for which the following properties have been determined:

- thermal conductivity, λ = 0.0148 kcal/m·h·°C;
- vapour permeability, μ = 7.18 g/m^2·h;
- air permeability, $P_{a\Delta p}$ = 0.166 m^3/min·m^2.

Flexibility determinations indicate structural uniformity and a low degree of cross-linking, affecting advanced materials' physiological, functional, and technical properties. Membrane I4 with the lowest degree of cross-linking has the highest flexibility value of 60%, but also structural uniformity in the three directions longitudinal (L), transverse (T), diagonal (D), the values for H,% are very close. Membrane I8 is less flexible (H, 30%), but has a uniform structure.

The ability of the textiles to absorb moisture from the body, combined with their thermal insulation capacity and air permeability, should create a feeling of comfort in an adverse environment. In fact, the feeling of comfort results from the balance between the energy generated and the exchange with the environment; this is done by the garment which is a component of the environment, an addition of protection. The values from table 2 show that the studied membranes could be extended to create composite garment structures (textile and membrane) intended for disposable clothing for medical personnel.

All membranes are hygroscopic within the specific limits of polyester and cotton in combination with synthetic or man-made fibres.

Vapour permeability is characteristic of an effortless state (up to 20 g/m^2·h) for polyester fabrics [20]. Low air permeability values do not affect product quality since vapour permeability, hydrophilicity, hygroscopicity, and thermal insulation are within normal limits.

Polyurethane membrane I4, which has the smallest pore radius (0.91 μm), the lowest porosity (44%), the largest number of pores per cm^2 (16.92/cm^2), and the lowest permeability to distilled water (0.062 m/h) compared to the other two polyurethane membranes, can be used by unconventional methods high-frequency current welding, ultrasonic welding, laser welding and can be extended to produce specific composite materials.

Polyurethane membranes belong to the group of heat-insulating materials and the group of waterproof materials; they can ensure the expansion of their use for special clothing products. For the disposable clothing of medical personnel, it was necessary to test the disinfecting properties of PU and Pall membranes.

Table 3 shows the results obtained according to STAS 3001-91, Membrane Method. It can be observed that the total number of germs/ml of permeate decreases drastically for membranes I3 and I4, which can be used as components of some clothing structures, disposables for doctors since they have disinfecting properties. The indigenous polyurethane membranes I3 and I4 show a considerable reduction in the total number of germs/ml in ultrafiltrated water, from 5 germs/ml in drinking water to 1 germ/ml in ultrafiltrated solution. Polyurethane membrane I8 did not show the same spectacular decrease, and Pall membrane recorded 0 total germs/ml in the ultrafiltrate. The use of polyurethane membrane I4 for disposable medical clothing is currently under investigation.

Table 3

DISINFECTANT CHARACTERISTICS OF POLYURETHANE AND PALL MEMBRANES FOR ULTRA- AND MICRO-FILTRATION

Membrane	Total number of germ/ml; 37°C initially	Total number of germ/ml; 37°C from permeate
I3	5	1
I4	5	1
I8	5	4
Pall	5	0

Membrane I3 exhibits some asymmetry (different morphological structure on both sides, different pore openings, negative charge mainly on one side and positive on the other) [19]. The positive charge generated on the skin surface attracts the negative charge of the active membrane side, and the posterior side of the membrane carries the positive charge, resulting in mutual cancellation of charges.

Membrane I4 is the most uniform and flexible. The flexibility in the three directions L, T, D is very close with values around 60%, in contrast to I3 and Pall membranes and the textile material. It can be concluded that the polyurethane membrane I4 has the following characteristics:

- is more flexible;
- is structurally uniform;
- has a fine membrane structure;
- has a higher ratio between soft and hard than the other native membranes;
- has physiological, functional and technical properties close to those of a modern textile material.

Process using indigenous polyurethane membrane for the unconventional treatment of wastewater from the textile industry

For environmental and economic reasons, wastewater is one of the significant environmental issues [21–23]. It is estimated that industry consumes nearly 20% of the world's available freshwater, and the textile industry consumes 4% of all freshwater extraction globally [24]. We could estimate that 2/3 of the dye mass used in a textile company ends up in a wastewater treatment plant or a river [1].

Wastewater and improperly treated water are discharged into rivers, contributing to excessive pollution. Textile processes thus pollute the environment by consuming large amounts of water and discharging residues into nature that can pollute the air, the water, and the soil. For example, processing one kilogram of textile material requires 100 litres of water, 15–20 kw/h of energy, and 5 kg of oxygen, which are used to generate thermal energy. The following wastes are generated: 60–70 g of sludge, 30–40 g of textile waste, 7 kg of CO_2, 400 g of slag (combustion of coal).

In textile cleaning, there are few cost-effective experiences so far. An interesting project would be the one that would allow the coupling: biological treatment - membrane separation (figure 3).

A technological process for wastewater quality correction using polyurethane membranes was studied [25, 26]. Four indigenous polyurethane membranes and one Pall membrane were used, and three types of membrane transport and three different membrane structures were recorded. The membrane techniques used were ultrafiltration and microfiltration (UF-MF).

The indigenous polyurethane membranes A, S1A, S2A, S3A and the Pall membrane were experimentally characterised by: porosity (%), degree of swelling for distilled water (g/g), density ρ (g/cm^3), by the pycnometer method, permeability for distilled water P (m/h), the pore size of the membrane, by the Bubble Point method (table 4) [26].

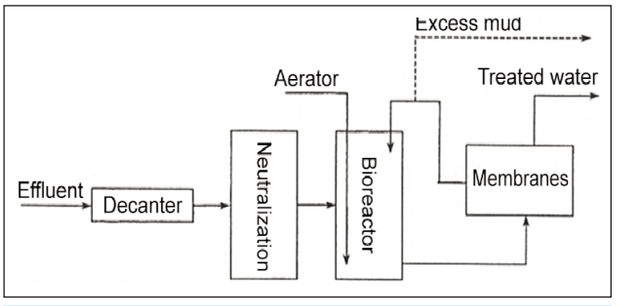


Fig. 3. Coupling scheme: biological-membrane separation [23]

Table 4

CHARACTERISATION OF THE USED MEMBRANES						
Membrane	**Pore diameter φ (μm)**	**Density ρ (g/cm^3)**	**Thickness δm·10^6 (m)**	**Porosity ε (%)**	**Degree of swelling (g/g)**	**Permeability to distilled water P* (m/h)**
A	3.36	7.7	85	65.6	1.90	11.23
S1A	1.85	4.8	22.5	63	1.69	0.31
S2A	1.56	1.98	61.61	58.14	1.38	0.70
S3A	5.09	8.5	12.26	63	1.72	2.20
Pall	0.5	1.78	43.96	77.4	3.44	1.88

Note: *Permeability to distilled water, at UF-MF at 20°C, in vacuum 40–60 mm Hg.

Table 5

EXPERIMENTAL DATA WITH UF-MF OF WASTEWATER*					
Membrane/ substance	**Organic substances (SO) (mg KmnO$_4$/l)**	**Total hardness D$_T$ (°G)**	**Permeability P·10^2 (m/h)**	**Diffusion coefficient D·10^6 (m^2/h)**	**Performance (m^3/h)**
A	37.92	7.61	1.06	0.90	29.95
S1A	47.00	7.39	0.37	0.08	10.45
S2A	28.44	8.28	0.88	0.54	24.90
S3A	50.56	9.40	0.55	0.06	15.54
Pall	12.64	9.98	1.26	0.55	35.60
Cationic resin	55.36	8.96	-	-	-
Anionic resin	52.18	8.40	-	-	-
Wastewater	37.97	24.08	-	-	-

Note: * Working conditions 20°C, vacuum 40–60 mm Hg, membrane surface 0.0030 m^2; Perfomance=permeability coeficient ·surface, in m^3/h.

The wastewater's ultra- and microfiltration were performed with a front filtration module in a laboratory unit. To improve the degree of demineralisation, UF-MF was repeated.

Organic matter (mg KMnO$_4$/l) was determined according to STAS 7587-96, and total hardness was expressed in German degrees (°G). Scanning microscopic images were obtained using a Tesla B.S. 300 electron microscope.

Membrane A was found to have a performance close to that of the Pall membrane: 29.95 m^3/h and 35.6 m^3/h, respectively (table 5).

Organic matter is best retained by the Pall membrane. With repeated UF-MF and 10 times larger active surface area (on industrial module), membrane A and membrane S2A show a drastic percentage decrease for organic matter and total hardness (table 6). Less significant differences occur for membranes S1A and S3A.

Membrane S2A has the lowest density of 1.98 g/cm^3 and has a loose structure explained by the removal of macromolecular chains after cross-linking.

The different behaviour of the indigenous membranes, A and SA, shows a higher degree of cross-linking than those of the SA series. Scanning electron microscopy images show different conformational supramolecular structures (figure 4) [1].

Table 6

REPEATED UF-MF OF WASTEWATER		
Membrane	**Decreasing D$_T$ (%)**	**Decreasing SO (%)**
A	33	45
S$_1$A	18	9
S$_2$A	34.8	41.2

Figure 4 shows the non-cross-linked membrane A and the cross-linked membrane S2A with the two surfaces: active and posterior. The microscopic images show an advanced degree of asymmetry in the native membranes. The Pall membrane is symmetrical.

Ion exchange resins respond well to demineralisation but do not retain organic matter (table 5). The Pall membrane performs better in reducing D$_T$ and organic matter (table 5).

The indigenous membranes A and the membranes of the series SA reach the degree of potability of the wastewater; however, with repeated UF-MF there is a drastic decrease in the content of organic substances and a better degree of demineralisation.

In order to correct the quality of industrial effluents, the possibility of removing traces of Cu^{2+} by mycelization with sodium lauryl sulfate was also studied. The

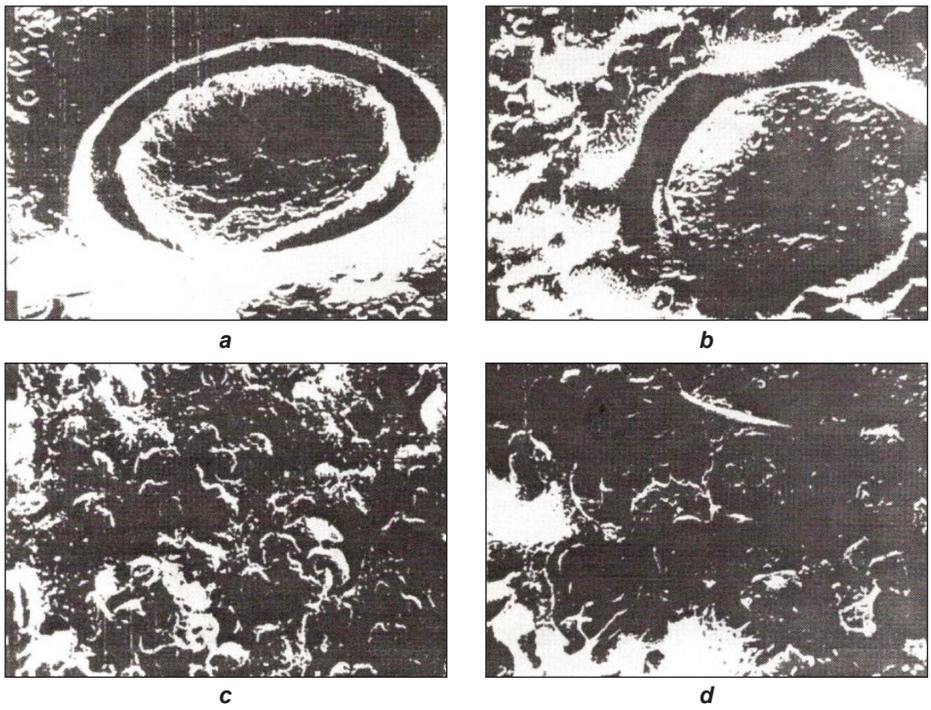


Fig. 4. Scanning electron microscopic images on the non-crosslinked polyurethane membrane A and the polyurethane membrane cross-linked with zeolite S2A: *a* – cross-linked membrane, active surface [x1800]; *b* – non-crosslinked membrane, active surface [x1800]; *c* – reticulated membrane, posterior surface [x3000]; *d* – non-crosslinked membrane, posterior surface [×3000]

separation process was based on micellar solubilisation, followed by the well-known ultrafiltration process MEUF (micellar enhanced ultrafiltration), a micellar intensification of ultrafiltration. By using surfactants at a critical micelle concentration where their molecules form micellar associations, this technique has successfully removed both the metal ion and the organic solution from wastewater [27].

CONCLUSIONS

This work reflects the physiognomy of supramolecular chemistry, dynamic chemistry given by the lability of non-covalent interactions. We are dealing with chemical dynamics, and supramolecular chemistry has the possibility of expressing molecular and supramolecular dynamical diversity. The new paradigm is selection through the dynamics of constitutional diversity, which responds to internal pressures and external factors to explain adaptability.

The hydrophilic/hydrophobic, flexible/rigid, amorphous/crystalline, soft/hard scales that occur in the structure of membranes depend on the type of hydrogen bonds and Van der Waals bonds that occur between their micro and macro phases.

Membranes find their application in the textile field by being integrated into the garment structure, which must at all times be a favourable environment for the absorption of moisture and other harmful emanations from the body.

The tests and determinations carried out highlight the properties of the membranes analysed, for which the following is noted:

- Polyurethane membrane I4 has sanogenetic physiological indicators comparable to those of waterproof material.
- The flexible behaviour, shown with high values in the three directions L/T/D, allows extending the use of the polyurethane membrane I4 in the form of composite material for the disposable clothing of the medical personnel.
- The disinfecting properties of polyurethane membranes I3 and I4 are highlighted by the decrease in the total bacterial count in ultrafiltration and microfiltration of drinking water [21, 28, 29].

The textile industry is polluting due to chemical processing. For example, textile raw materials, by-products, technologies, and machinery in the textile industry contain significant pollutants. The proposed membrane technology is innovative and will have real economic significance in the coming years.

Finally, a new purification technique is defined: micro- and ultrafiltration (MF-UF), a technique for the recovery and reuse of wastewater. A and SA series indigenous polyurethane membranes can be used to achieve the degree of potability of wastewater.

To conclude this review of the main applications of membranes produced with original methods, it is emphasised in the textile field that new horizons are opening in supramolecular chemistry [30, 31].

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