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REVERSE OSMOSIS, THE OPTIMAL SOLUTION FOR WATER TREATMENT WITH MEMBRANES TECHNOLOGY

A. DEAC[1] C.A. IACOB[2]

Abstract: *This paper is a short presentation of water treatment methods using membranes: microfiltration, ultrafiltration, nanofiltration, electro-dialysis and reverse osmosis. Throughout the paper, reverse osmosis systems are described more thoroughly because at the moment reverse osmosis is the most effective water treatment technique. In order to prove this affirmation, several water sources, as well as the outcoming permeate were studied and analyzed. In the case study presented here, water is treated to the required quality level both for population needs and industrial process by using reverse osmosis. Measurements showed the high efficiency of this treatment method.*

Key words: *reverse osmosis, baromembrane processes, potable water, water treatment.*

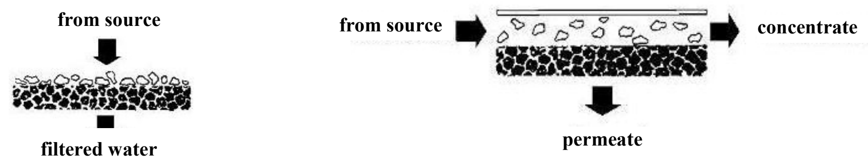
1. Introduction

Due to continuous development of industrial processes and of population's consumption and demand, the quality of water sources varies significantly from area to area. While in urban areas the water sources quality is influenced by population's needs, in rural areas adjacent to cities, water quality is related to ground structure. Therefore, water treatment methods are required to be implemented such as to meet the usage specific needs. In certain cases classic treatment methods involving grit removal, settlement, filtration, and chlorination are not suitable regarding both water quality and area needed for installing process equipment. In such cases, water treatment systems based on membrane technology can be used. Such systems include microfiltration, ultrafiltration, nanofiltration, electro-dialysis and reverse osmosis

2. Water Treatment Using Membrane Technology

Water treatment processes using membrane technology are based on tangent flow or transversal flow which allow for a continuous treatment of water. Figures 1.a and 1.b comparatively present the classic filtering and membrane filtering principles.

[1] Faculty of Building Services, Technical University of Cluj-Napoca.
[2] Faculty of Building Services, Technical University of Cluj-Napoca.



.a *classic* .b *with membranes*

Fig. 1. *Water filtration [2]*

Membrane is a structure interposed between two phases or compartments, which can prevent or restrict the passing of substance through it, or allows for passing only certain types of particles. In other words, membrane is an imperfect barrier between two phases, where the phase components are passed through the membrane at uneven rates, thus allowing for their separation (Fig. 2). As per definition, membranes may be gaseous, liquid, solid or a combination thereof. As regards economical aspects, the membrane should restrain certain substances and allow the passing of others.

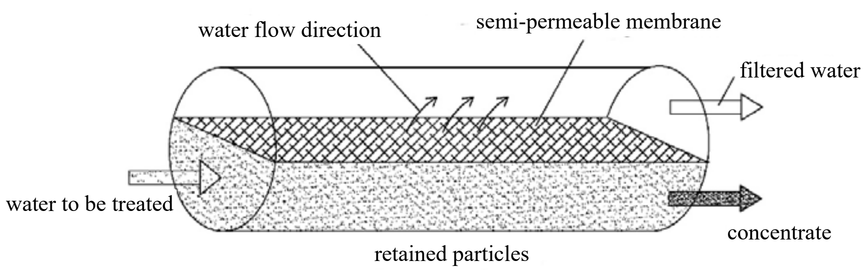


Fig. 2. *Diagram representation of a membrane [3]*

In order to perform separation through membranes, pressure is required to be exerted on permeate. According to the size of particles retained in membranes, to the size of membrane pores and to the force applied, the membrane separation processes are classified as follows: microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO).

For an overview of application fields for each baromembrane process, the processes using pressure as filtering motric force have been classified (Fig. 3).

Microfiltration is a membrane technology which allows for clearing a liquid containing very fine, micronic and submicronic suspended particles under a transversal pressure gradient along the microporous membrane. This process has the lowest working pressure of all baromembrane processes.

Ultrafiltration is a process separating undissolved impurities using filtration through membranes at low pressure levels. With this method, dissolved particles with low molecular mass can be retained, as well as bacteria, viruses, proteins. The ultrafiltration process was the first to use cellulose acetate and cellulose nitrate membranes.

The first use of nanofiltration was for water softening, as an alternative to chemical softening. This proved to be a process which also controls the precursors of disinfection products. Thus, it is a process used for treating underground water with a relatively low content of total dissolved salts, but with a high level of hardness.

Osmosis process is a phenomenon occurring naturally in various biological processes. For instance, the abstraction of water from soil to be transported through the stem to all plant parts. If additional pressure is exerted on water, the plant will receive only water while the substances remain on plant's surface. Thus, the new process is reverse osmosis. This process has been known for more than 300 years, however its uses have been developed at the end of the 1940s.

Reverse osmosis became a familiar technology in almost any industry requiring the separation of a dissolved substance from its solvent, which usually is water. The most common application of reverse osmosis is water purification implying simple removal of unwanted contaminants. Industries frequently use this application to produce pure water required for various technical processes.

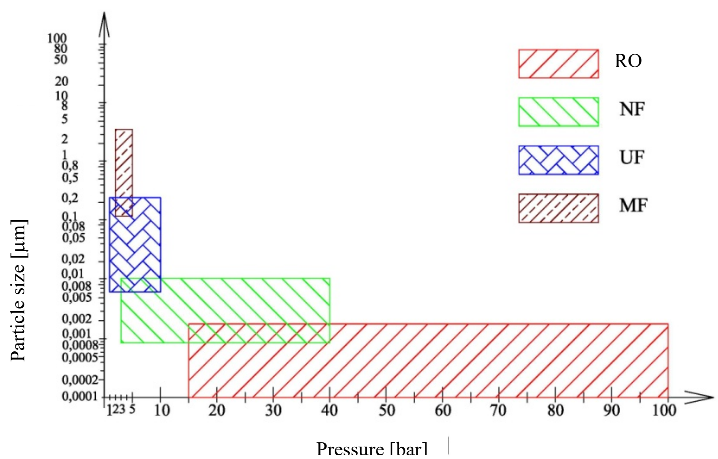


Fig. 3. *Classification of baromembrane processes according to pressure and size of retained particles [1]*

From the figure above, it can be noticed that baromembrane processes overlap to a small amount both in the area of retained particles and applied pressure. Nevertheless, the reverse osmosis process is by far the system covering a wide spectrum as regards the retained particles as well as the possibility to operate with various pressure levels according to water source particularities. Consequently a case study based on a reverse osmosis system will be presented below.

3. Case Study

The constant development of industry led to the expansion of cities and to the construction of new factories. Some factories are located in small towns that don't have water supply network. That is why an important issue in choosing the location is the producing of drinking water for the employees and for technological processes. Such a unit was developed between Cluj and Dej. The raw water is collected from an 80 m deep well. As the factory was located between those two regions well-known for their salted water springs and salt mine, high levels of chlorides were found in the raw water, which means high conductivity.

Knowing all these aspects, they looked for a water treatment method that would meet the requirements both for the drinking water and for the technological water. The latter is used in producing steam necessary for technological processes. The reverse osmosis systems proved to be the best choice, because they meet the requirements for both applications.

In order to increase the life of the membrane modules, the water is pre-treated by using a sand filter and a cartridge filter. Another safety measure is to inject inhibitor substances into the membranes to prevent impurities from depositing on their surface.

The pressure needed for the reverse osmosis process is produced by a low-noise centrifugal vertical pump. There are three identical membrane modules: two of them are serially connected and produce the first stage permeate, the third module is used for treating the concentrate from the first stage and produces permeate. The two outputs of the membrane modules are connected to each other and fill the permeate storage pool. The second stage concentrate is introduced back into the system in order to increase the permeate quantity and to reduce the concentrate quantity.

A general view of the reverse osmosis system implemented in the production facility is presented in Figure 4, where the pump producing the pressure required for reverse osmosis, the two membrane modules serially connected at the bottom and the third module above them can be observed. Also, we can see the automation unit, which allows for the system operation monitoring and real time measurement of electric conductivity, which is an important parameter of water salinity.

Fig. 4. *General view of reverse osmosis system*

In order to determine if the reverse osmosis system works properly, we measured six parameters for raw water and permeate. First stage produces 75% of total permeate and second stage produces the other 25%. At first we observed all the parameters given by Law 458/2002 and Law 311/2004. As we noticed, a number of these parameters registered levels below the detection limit or even zero, so we chose to monitor only those who have significant variations and those who have exceeded the limit. The parameters we chose to monitor are the following: pH, electrical conductivity, iron, chlorines and hardness (see Table 1).

Representative parameters for raw water and permeate Table 1

No	Parameter	MU	Raw water	Stage I permeate	Stage II permeate	Levels approved for technological water	Levels approved by Law 458/2002 and Law 311/2004
1.	**pH**	unit. pH	6.18	6.06	5.89	> 9	≥ 6.50 ≤ 9.50
2.	**Electrical conductivity**	μS/cm	2130	49.60	47.50	< 500	< 2500
3.	**Iron**	mg/l	0.05	0.01	0.01	< 0.05	0.2
4.	**Chlorines**	mg/l	282	9.5	8.7	-	250
5.	**Hardness**	ºG	30.29	0.04	0.03	-	≥ 5
6.	**Turbidity**	NTU	0.12	9.2	3.12	-	≤ 5

By looking at the technological water parameters first, we see that electrical conductivity and iron levels in permeate are situated below the levels required by the feed-water deaerator and boiler data sheet. PH value does not meet the requirement, which means that an adjustment by injecting nitrates is needed.

In terms of drinking water, both stages of permeate meet the quality requirements of Romanian laws. Here too, pH levels are below the regulated minimum value of 6.5 units, therefore a pH adjustment is necessary, as it is in the case of technological water.

The results are also presented in Figure 6, where by permeate we mean the first stage permeate mixed with second stage permeate.

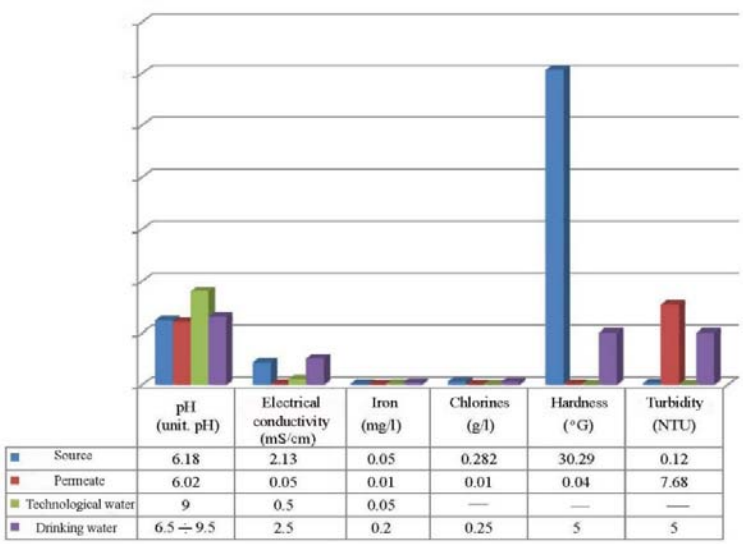


Fig. 5. *Results for well water and system permeate in comparison to quality requirements for technological and drinking water* [1]

4. Conclusions

Analysis of monitored parameters mentioned above reveals that from the point of view of both potability and technological process requirements, reverse osmosis is the appropriate process for source treatment. However, both uses require pH correction. The most significant correction of permeate quality can be noticed in electrical conductivity value, water hardness and turbidity.

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