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REVERSE OSMOSIS, THE OPTIMUM SOLUTION FOR MEMBRANE WATER TREATMENT

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Abstract: *This paper is a short presentation of water treatment methods using membranes: microfiltration, ultrafiltration, nanofiltration and reverse osmosis. These methods are increasingly popular because water sources are getting more and more polluted and the classical methods prove to be inefficient. 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. Determinations were made for three types of water sources: water from a well, tap water and used water coming from an ecological landfill. The results prove that reverse osmosis is efficient in all of these cases.*

Key words: *reverse osmosis, potable water, water treatment, membranes.*

1. Introduction

Global development led to increasing need of water both for industrial purposes and for population. Fresh water resources on our planet are constantly diminishing, while water pollution is increasing. The need for water treatment is therefore greater than ever. This is why membrane water treatment techniques evolved so much during the last years. The membrane is a structure that withholds or at least blocks transport of substance through it. It only allows certain particles to pass through. The membranes that allow water to pass through are called semipermeable.

These membrane processes are based on gradually increasing pressure that creates a driving force which forces water molecules through semipermeable membranes. Hence, the name of baromembrane process.

2. Baromembrane Processes

According to the operating pressure and to the particles retention capacity of the membranes, baromembrane processes are classified as follows: microfiltration, ultrafiltration, nanofiltration and reverse osmosis.

Microfiltration was the first application of membrane separation techniques. The operating pressure range for microfiltration is 2 to 5 bar, while the pore size range is 0.1 to 4 μm. The resulted permeate needs post-treatment because this process does not retain viruses.

The development of polymer membranes led to ultrafiltration, which operates with

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pressures ranged between 1 to 10 bar. The size range of the removed suspended solids is 0.005 to 0.1 μm.

Reverse osmosis is the most common process. The pressure can vary between 15 bar and 100 bar and the suspended solids removed are as small as 0.0001 – 0.002 μm. [2]

Nanofiltration was developed in order to fill the void between ultrafiltration and reverse osmosis, with operating pressure range of 3 to 40 bar and removed suspended solids size range of 0.0008 to 0.01 μm.

As a comparison, the diameter of a human hair is approximately 75 μm. Even the suspended solids particles removed by microfiltration are twenty times smaller than that. By looking at the operating pressure and size range of the suspended solids removed by the membranes, we can say that the reverse osmosis process has the widest range of values.

The reverse osmosis is based on osmosis, a phenomenon which takes place naturally in different biological processes. Plants absorb water from the soil through osmosis. The stem acts a semipermeable membrane that allows certain nutrients to pass through, in order to feed the plant.

We can define osmosis as the phenomenon which occurs every time when two water solutions of different concentrations are separated by a membrane. The membrane allows the water to pass from the least concentrated solution towards the higher concentrated solution until the two solutions reach the same concentration (see fig. 1). Thus, the osmotic balance is achieved (see fig. 2).

If an extra pressure is applied on the higher concentrated solution, the reverse phenomenon takes place. So, the water from the solution on which pressure was applied will pass through the membrane. This process is called reverse osmosis (see fig. 3).

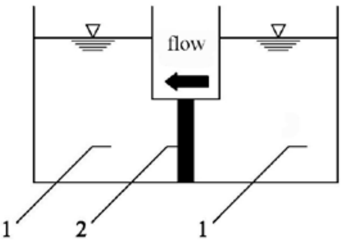


Fig. 1. *Osmosis, 1 – water solution; 2 – semipermeable membrane; 3 – water*

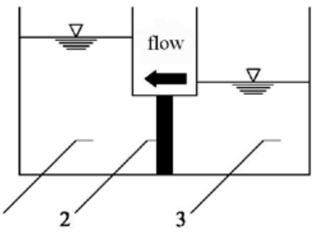


Fig. 2. *Osmotic balance, 1 – water solution; 2 – semipermeable membrane*

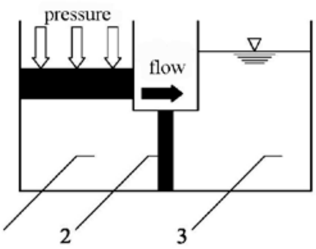


Fig. 3. *Reverse osmosis process, 1 – concentrated solution; 2 – semipermeable membrane; 3 – water*

3. Case Studies

Worldwide, reverse osmosis systems are found in a very wide range of processes, from technological to household applications, mostly in countries with freshwater deficit, respectively surface water deficit. In our country, these resources being sufficient for now, reverse osmosis systems are used in situations where a higher quality of water is needed, compared to drinking water, or in technological processes. This paper presents two reverse osmosis systems which are diametrically opposed. The first case refers to drinking water purification for the haemodialysis process, while the second case presents the system for treating leachate on an ecological landfill site.

3.1 Reverse Osmosis in Haemodialysis Clinics

The haemodialysis process needs pure water. As medical facilities, haemodialysis centres submit with Ministry of Health regulations. More precisely, the organizational and operational rules and regulations of haemodialysis units imply a list of procedures for preparing and using of the dialysis solution, i.e. purified water. During the process of water treatment all the steps stipulated in the regulations must be taken. Reverse osmosis is followed only by the safety measure, the UV sterilization lamp. Haemodialysis units are located either in hospitals, or in separate buildings, either they are connected to the public water supply network. Therefore, the water source for the water purifying unit is drinking, tap water. We analysed the parameters of drinking water during summer season and winter season and we found that in summertime some parameters have higher values, but within the accepted concentrations.

The water treatment unit consists of a pre-treatment stage, reverse osmosis and the UV sterilization. The first stage consists of a 200 μm cartridge filter, a sand filter, an activated carbon filter, a 100 μm cartridge filter, a softening system and a 10 μm cartridge filter. As a safety measure, a 5 μm cartridge filter is provided in front of the pump for the reverse osmosis membrane modules. The resulted permeate is stocked in a tank and is afterwards sterilized with the UV lamp. At this point, it is available for the patients.

In order to increase the resulted permeate volume, two reverse osmosis membrane modules are provided. The first module is used for treating the water resulted from the pre-treatment stage. The permeate, produced at this stage is transported to the permeate tank. The second module is used for treating the concentrate resulted from the first membrane module. Some of the second module concentrate is introduced back into the system before the pump, and the rest of it is ejected into the sewer system. The specific permeate parameters are observed according to the norms. The analysed parameters depend on the characteristics of the water source. In this case, we observed the levels of aluminium, arsenic, copper, nitrites, pH, ammonium, cadmium, free residual chlorine, led and zinc. The levels of the last five parameters are under the detection limits of the analysis method.

Representative parameters for the water used in haemodialysis Table 1

No.	Parameter	UM	Water Source	Permeate	Levels approved by European Pharmacopoeia and AAMI
1.	Aluminium	μg/l	23	8	10
2.	Nitrates	mg/l	3.54	0.35	2.0
3.	Free residual chlorine	mg/l	0.47	BDL	0.010

The water used in haemodialysis must comply with the quality requirements regulated by European Pharmacopoeia and by the Association of Advancement of Medical Instrumentation (AAMI). Aluminium, nitrites and free residual

chlorine are carefully monitored (table 1).
As we can see, after passing through the reverse osmosis modules, the free residual chlorine levels in water are below the detection limit, therefore it complies with the regulations. In haemodialysis water, aluminium is proved to be poisonous. Even if there is no aluminium in the water source used for producing drinking water, its presence must be tracked because aluminium sulphate is used as a clotting agent before the decantation stage. The aluminium levels in the permeate are reduced by 65% compared to the water source levels and are lower than the levels stipulated by European Pharmacopoeia and AAMI. In the case of the nitrites, these levels dropped by 90%. In terms of aluminium and nitrites, the water meets the quality requirements. For a clearer image of the results we created the chart in figure 4.

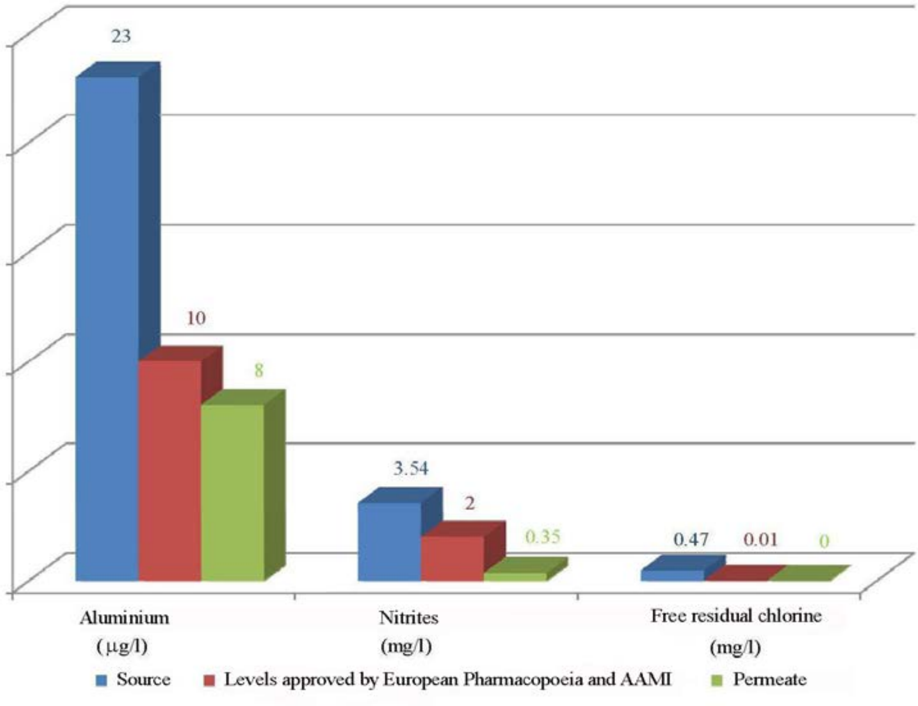


Fig. 4. *Levels of aluminium, nitrites and free residual chlorine in water source and permeate in comparison the maximum accepted levels*

3.2 Reverse Osmosis in Treating Leachate

The impact that landfills have on the environment is an actual topic and it creates national and international debates. A major problem is the leachate – the water resulted from rain, snow and from decaying waste. This water is full in pollutant substances and can pollute the soil and water if it makes it back into the environment. This is why landfills are provided with drainage systems and leachate retrieving systems.
Once retrieved, the leachate must be treated before it makes it back into the nature. Considering that, the levels of chemical components in the leachate vary from season to season so the reverse osmosis proved to be the best method of treating it. The reverse osmosis units for treating the leachate can be placed either in

tanks or indoors. In our case the system was built in a tank provided with double full opening doors and a stainless steel tray for collecting any leakage.

The first stage in the reverse osmosis system is a pH correction stage, from 8.5 pH units to 6.0 ÷ 6.5 ph units. Next comes pre-treating by using sand filters and cartridge filters, as safety measures. At this stage the leachate is pumped up at a 30 ÷ 60 bar pressure and then it is passed through the membrane modules. This part of process has two stages, the first one consists of nine serially connected membrane modules and the second stage consists of two serially connected membrane modules.

The membranes are made of modified polyamides, mounted on support discs provided with guiding elements.

They are set on a central axle inside pressure pipes. The resulted permeate is stored in an outdoor waterproofed pool, but sometimes before discharging it into the tank it needs pH adjustment. The concentrate is stored in a tank provided with retention and tiled with acid-proof stoneware.

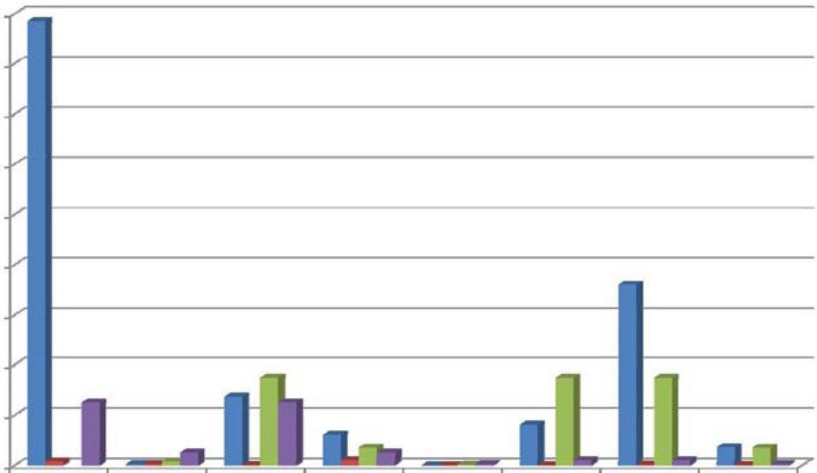
The leachate contains a big quantity of suspended and dissolved matter; this is why it's considered used water. The permeate must comply with the quality requirements imposed by NTPA-001/2002, completed and modified by HG 352/2005. The advice issued by the regional authority for water management stipulates that the maximum accepted levels shouldn't exceed 70% of the levels stated by regulations.

The permeate samples are analysed in comparison to the levels stipulated by the advice issued by authorities. We noticed that the permeate levels meet the requirements imposed by laws on drinking water. In Table 2 and Figure 5 we show a few representative parameters for leachate and permeate in comparison to NTPA-001/2005 and laws 458/2002 and 322/2004.

As we can see, after treating leachate by using reverse osmosis, the permeate quality meets even the requirements for drinking water. Therefore, it also meets requirements imposed by NTPA 001/2005 and it can be discharged into an emissary

Representative parameters for raw water and permeate Tabel 2

No.	Parameter	MU	Leachate	Permeate	70% of the levels approved by NTPA 001 [7]	Levels approved by Laws 458/2002 and 311/2004 [5]
1.	pH	pH units	8.4	6.1	6.5	≥ 6.50 ≤ 9.50
2.	Electrical conductivity	μS/cm	17700	147	-	< 2500
3.	Free residual chlorine	mg/l	0.05	0.05	0.14	0.50
4.	Chlorines	mg/l	2740	9.05	350	250
5.	Azotites	mg/l	1.2	0.2	0.7	0.5
6.	Nitrite	mg/l	0.037	0.007	17.5	50
7.	Aluminium	mg/l	1.62	0.0031	3.5	0.2
8.	Iron	mg/l	7.2	0.02	3.5	0.2
9.	Manganese	mg/l	0.72	0.01	0.7	0.05



	Electrical conductivity (mS/cm)	Free residual chlorine (mg/l)	Chlorines (g/l)	Azotites (mg/l)	Nitrite (mg/l)	Aluminium (mg/l)	Iron (mg/l)	Manganese (mg/l)
Leachate	17.7	0.05	2.74	1.2	0.000037	1.62	7.2	0.72
70% of NTPA	0.147	0.05	0.00905	0.2	0.000007	0.0031	0.02	0.01
Permeate		0.14	3.5	0.7	0.0175	3.5	3.5	0.7
Drinking water	2.5	0.5	2.5	0.5	0.05	0.2	0.2	0.05

Fig. 5. *Results of leachate and permeate samples in comparison to regulations NTPA 001/2005, Law 458/2002 and Law 311/2004*

Conclusion

As it can be seen from both case studies, the water quality obtained after the reverse osmosis process is higher than the quality imposed by the requirements of its subsequent use. In both cases polyamide membranes are used, and a part of the concentrate is recycled to increase the amount of resulting permeate. Finally, it can be said that reverse osmosis systems can provide a solution for water treatment regardless of the source water quality.

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