Reuse of Reverse Osmosis Membranes in Tajoura RO Desalination Plant

Bashir Brika
Eng and researcher
bashirforlibya@gmail.com

Overview

- Background
- Aims
- Tajoura RO desalination plant
- History of membranes used in Tajoura desalination plant
- Used membranes in the Tajoura desalination plant
- Experimental
- Results and discussion
- Reuse and recycling options
- Conclusions and recommendations

Background

- Libya has an increasing demand for water for drinking and irrigation due to the increasing population. Inadequate potable water remains a major concern in Libya today, in the small towns as well as big cities. The country has an annual average rainfall of less than 100 mm and its groundwater is being over-exploited, especially in the coastal regions.
- Desalination is considered to be the second most important non-conventional water resource adopted in Libya.
- As any other technology, desalination is likely to have significant effects on the environment.
- The main local environmental impacts that arise from the desalination process are from brine concentrate and from discharges of chemicals in the desalination process. Energy intensity and resulting emissions of greenhouse (thermal desalination techniques) are also considered.

- Safe and clean disposal of used membranes in reverse osmosis desalination plants should be taken into account while constructing new desalination plants. Environmental restrictions also have to be imposed
- At present, there is not much research or many studies in the field of recycling or reusing membranes; therefore, it is very important to investigate options to eliminate the negative impacts of RO used membranes and to look for new options to reuse membranes.

Aims

The aims of this paper are:

(i) to critically review the current disposal of the used membranes;

(ii) to discuss the possibilities of different reuse options.

The authors, therefore, intend making a proposal that includes a number of options for making use of the old membranes in other ways.

Tajoura RO desalination plant

Tajoura reverse osmosis desalination plant is one of the main plants in Libya. The plant is located at the coast of the Mediterranean sea. The plant produces 10,000 m^3/day of clean water which makes it the largest production of desalinated water in Libya using reverse osmosis membranes (RO technology). In spite of the plant has been running for almost 30 years, there have not been any investigation of any kind to examine or evaluate the negative impacts of the used membranes on the environment.

Membranes used in the Tajoura RO plant used to be installed every five to seven years. The estimated number of membrane modules in each period is 594 for each row (total rows = 4). This number clearly shows that the total number of membrane modules changed in the first stage (6 inches in diameter) reached 1188, while in the second stage (8 inches in diameter) 252 membrane modules were replaced by new ones.

History of membranes used in Tajoura desalination plant

The membranes used in the Tajoura plant are replaced after some time (usually over 5 years). The number of membranes already used and replaced in the Tajoura plant from 1984 till now might reach some 8000 units. Types of membranes and some of their specifications are presented in Table 1.

Data presented in Table1 summaries the membranes used in the Tajoura desalination plant. The total number of membranes that have been used is 8136 units, divided into two stages (6372 units in the first stage, and 1764 units in the second stage). Most of the membranes were 20 cm in diameter (8") and 1 m long. Consequently, a stock of used membranes has piled up over the years. These units can no longer be used for seawater desalination because they have lost their original properties due to fouling, scaling, etc. and might have an environmental impact when disposed of. Alternatively, it is suggested that these old membranes may have remaining value if reused in different applications

Table 1. Membranes used in the Tajoura RO desalination plant

Period	Membrane diameter	Number of units (elements)						Membrane model		Raw water source
		First stage				Second stage				
		R405	R406	R407	R408	R410	R411	First stage	Second stage	
1984-1989	6"+8"	594	594	594	594	252	252	TFC 1501	TFC 8600	S.W*-Br.W**
1990-1991	6"+8"	-	-	594	594	252	-	TFC 1501	TFC 8600	S.W-Br.W
1992-2000	6"+8"	594	594	-	-	252	-	TFC 1501	TFC 8600	S.W-Br.W
2000-2005	8"	-	-	270	270	-	-	TFC 282255-360	-	S.W
2005-2013	8"	270	270	270	270	-	-	TFC 282255-360	-	S.W

Used membranes in the Tajoura desalination plant

- Currently, used membranes in the Tajoura RO desalination plant are generally disposed of via landfill. Due to the disposal process of used membranes, these may take long time to reach their final place, which is mostly a land area filled with trash.
- When the lifespan of the membranes is reached, the quality control department at Tajoura plant take the right and safe action by doing all the necessary analysis regarding the produced desalinated water. If the results of the analysis lie outside Libyan standards for drinking water, the decision makers in the plant together with the Tajoura Nuclear Research Center have to seriously consider removing the used membranes and replacing them with new ones. The supervisors of the plant units will take the old membranes and place them in containers specifically brought for this purpose, as can be seen in Figure 1.

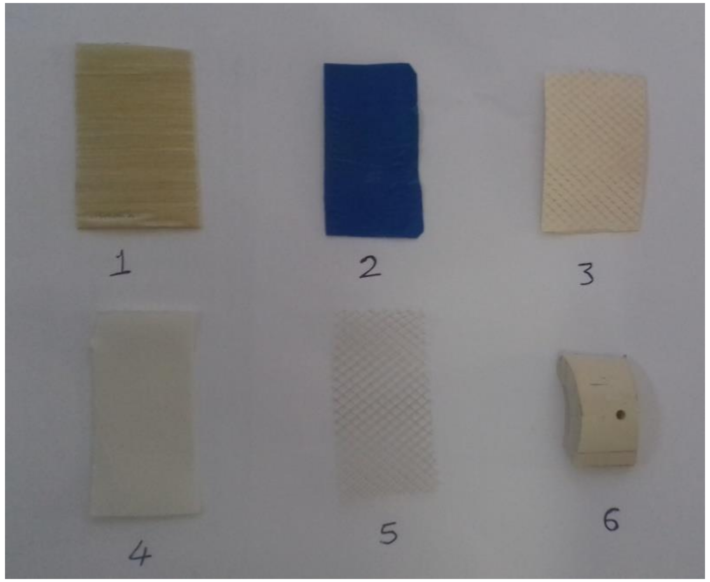
Figure 1 (a and b). The container and used membranes installed in a container

Experimental work

- During the development of this study, two experimental analyses were done to identify the chemical composition and the thermal stability of the main parts of the membrane. The membrane components were separated and cut into small samples and sent to the laboratory. Figure 2 shows the image of the membrane component samples analyzed in this study.

- The membrane components shown on figure 2 were analyzed by thermogravimetric (TGA) analysis and some of them, due to some difficulties, were characterized by Fourier transform infrared (FTIR).

Figure 2: Different membrane components that were tested in this study. From left to right: outer casing (1), glues (2), membrane sheet (3), permeate spacer (4), feed spacer (5), permeate tube (6)



Results and discussions

Combustion and carbonisation

Thermogravimetric analysis (TGA) is a thermal analysis technique that measures the weight, and hence the mass, of a sample as a function of temperature. TGA allows us to detect changes in the mass of a sample (gain or loss), evaluate stepwise changes in mass (usually as a percentage of the initial sample mass), and determine temperatures that characterize a step in the mass loss or mass gain curve.

Figure 3 shows the results of the thermogravimeric analyses of the membrane components. The figure shows that sample number 2 (glues) is the least thermally stable component, showing almost complete degradation around 480 °C, while sample number 5 (feed spacer) is the second least thermally stable component as it is completely combusted at 520 °C, followed by the permeate spacer (4) and permeate tube (6). The remaining membrane components including outer casing (1) and membrane sheet (3) are much more thermally stable as their curves decrease slowly towards a zero weight. In the case of the outer casing, which comprised mainly fiberglass, an inorganic residue of about 67wt% remains after TGA combustion.

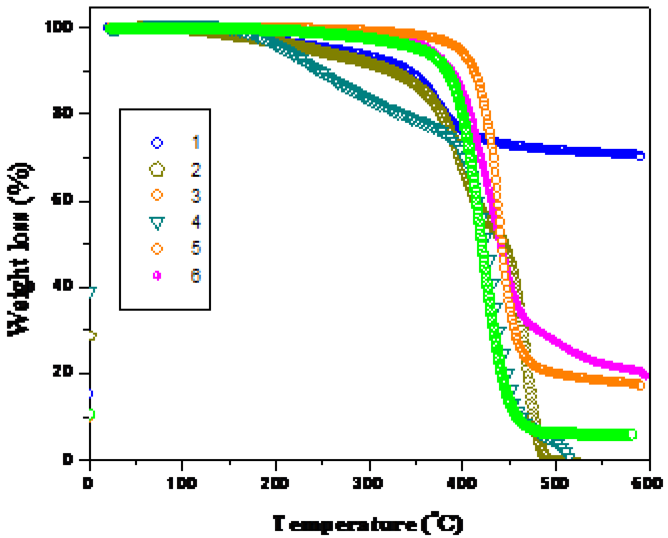


Figure ٣. Thermogravimetric analysis of membrane element components

Chemical composition

From the polymer recycling point of view, it is an important step to identify the raw material of each component of the membrane. The authors believe that it might be possible to suggest more recycling options of each membrane component individually. Based on this concept the Fourier transform infrared spectroscopic analysis (FTIR) was the only available technique to be used for identifying the polymer composition of the major membrane components.

The FT-IR spectra analysis confirms that the feed spacer is comprised of polypropylene and the permeate spacer is made of polyester. The permeate tube and end caps are comprised of an amorphous material such as acrylonitrile butadiene styrene (ABS). The FT-IR spectroscopic analysis further showed that the outer casing is clearly made of fiberglass. The detailed polymer composition of the membrane components are illustrated on Table 2.

Table 2: Composition of typical membrane components as it is exacted from FTIR analysis

Membrane co	Composition
Outer casing	Fiberglass
Feed spacer	Poly propylene (PP)
Permeate spacer	Polyester
Membrane sheet (thin film composite)	Aromatic pol yamide Microporous polysulfone (PSf)
Permeate tube/end caps	Acrylonitrile butadiene styrene (ABS)
Glues	Epoxy resin
Rubber o -rings	ethylene propylene diene monomer (EPDM)

Reuse and Recycling options

Regarding alternative suggestions for the disposal and reuse of used RO membrane elements, the authors suggest the following:

- ✓ Permeate tube: an alternative reuse option is to connect a number of permeate tubes and use for irrigation [figure 4]
- ✓ Feed/permeate spacers for agricultural and domestic applications:
  - Feed spacer to prevent mosquitoes attack via house's windows [figure 5]
  - Permeate spacer as geotextile as reported in previous studies [Piernavieja *et al*., 2001; Mohamedou *et al*., 2010; Prince *et al*., 2011; Pontie, 2014].

Figure 4. Permeate tube for irrigation

Figure 5. Window's protection from mosquitoes attack

- ✓ Feed spacer is considered to be a single-polymer plastic that is clean and homogenous. Therefore, it can also be directly recycled (mechanical recycling) and used as feed stock for the production of new products such as containers and packaging. This suggestion is in accordance with those stated in some previous investigations [Lawler et at., 2012]
- ✓ Mechanical grinding can be done for some old RO membrane elements such as the outer casing, which is made of fiberglass. Grinding is the most obvious processing method used for recycling fiberglass. It leads to reducing material to small pieces or powder to be reused in other products. Grinding of fiberglass could provide a filler material or aggregate that could be used in concrete. Fiberglass powder could be used to make thermoforming molds or other structures.
- ✓ RO membrane elements which comprise mixed plastic materials such as the membrane sheet can be used as an energy source. Gasification and pyrolysis are preferable processes to incineration because they produce fewer emissions.
- ✓ Another process was introduced more recently, called the remembrane project, which is aiming to prolong the lifecycle of membranes used in RO saltwater treatments through an innovative technology to improve membrane recovery, thus enabling their reuse. The objective of such innovative technology is to avoid waste, reduce costs and improve the overall efficiency of the desalination process [Remembrane, LIFE11 ENV/ES/000626].

Conclusions and recommendations

- ✓ This paper provided an overview of the old RO membranes in the Tajoura desalination plant. Since landfills, which are considered the only disposal route for old membranes, are facing capacity issues, alternative disposal or reuse options have become necessary.
- As it is considered to be the first serious piece of work that concerns the reuse of old seawater RO membranes from the Tajoura desalination plant, the authors highly recommend that further developments and additional work be done in this area at local and regional levels.
- Based on the findings of this work and other related investigations, the authorized governmental authorities should make a huge effort to find potential international users for expired membranes. In this regard, it is expected that this point be made clear in contracts when establishing new desalination plants.
- The local authorities and decision makers should take the initiative to invest partly or entirely in new, friendly desalination technology such as "the remembrane project".


Thank you for your attention