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Study for the evaluation of the processes of reuse and recycling of reverse osmosis components and membranes in the Canary Islands and Macaronesia

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ABSTRACT

This technical report is based on the study for the evaluation of the processes of reuse and recycling of reverse osmosis components and membranes in the Canary Islands and Macaronesia, within the DESAL+ project and in the framework of the DESAL+ LIVING LAB platform, coordinated by the Canary Islands Technological Institute (ITC) and the Canary Islands Agency for Research, Innovation and Information Society (ACIISI), with the support of the Interreg-MAC Programme.

Reverse osmosis membranes could be reused in the same or another desalination plant by replacing the membranes in the first, dirtier positions with those in the last, less damaged positions. Also, by changing the best first-stage membranes to the second and vice versa, the useful life of these membranes could be extended through chemical cleaning and a second life could be given in tertiary treatment plants, reuse in industrial processes where they use special reverse osmosis membranes and degrade rapidly, in processes with leachate from landfill waste and also an interesting option is the oxidation of reverse osmosis elements to obtain nanofiltration, ultrafiltration or microfiltration membranes for the removal of physical dirt.

The main categories of thermal processing recycling commonly used in industry include incineration and pyrolysis to produce energy, gas and fuel. These processes can be applied to mixed plastic waste, such as the combination of materials used in the manufacture of reverse osmosis membranes. The recycling of reverse osmosis elements from desalination plants is shown as an opportunity, nowadays existing pioneering initiatives in Europe.

Energy recovery, via incineration, is feasible but is not considered in accordance with the environmental, social and political problems that this may generate. However, the recycling of the reverse osmosis elements via pyrolytic industry for fuel production can be centralized in a new industry already planned in the Canary Islands and all the osmosis membranes that are obsolete can be sent there. This is a technically and economically viable business opportunity with a promising future in today's recycling market as studied in the technical report.

Keywords: Reuse; Recycling; Reverse osmosis; Membranes

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1. Introduction

This document develops a summary of the study "Evaluation of Processes to Increase the Shelf Life and Potential Reuse of Reverse Osmosis Components and Membranes in the Canary Islands and Cooperation AREA" – DESAL+ PROJECT. Within the framework of the DESAL+ LIVING LAB platform, coordinated by the Instituto Tecnológico de Canarias (ITC) and the Agencia Canaria de Investigación, Innovación y Sociedad de la Información (ACIISI), and with the support of the Interreg-MAC Programme.

A study of the evaluation of processes to increase the useful life and potential reuse of reverse osmosis components and membranes, especially in the Canary Islands and also in the entire Macaronesia cooperation area, is being carried out. All of this is carried out in order to comply with the strategic plan for R&D&I in desalination in the Canary Islands, which establishes as one of its priority actions the search for innovative, additional processes or forms of operation that reduce the fouling of reverse osmosis membranes, especially in open intakes or to maximise the conversion of the plants, as well as to extend their useful life. We are therefore working along these lines to achieve our objectives.

Opportunities are identified to increase the useful life of reverse osmosis membranes in other processes or the direct use of membranes and their components in the Canary Islands in particular and in Macaronesia in general. Proven solutions for the reuse of membranes in tertiary treatment plants or as filters in industrial processes are discussed. Solutions for the reuse of effluent or by-products from other processes for the components are proposed.

Results are obtained to increase the useful life of the elements, as well as the existence of by-products that open up new opportunities for the waste or industrial sector.

A qualitative and quantitative diagnosis of the membranes generated especially in the Canary Islands and in Macaronesia in general, materials, periodicity, etc. is carried out. The prospective and feasibility of using used membranes in other processes is studied, as well as the prospective and feasibility of using used membrane components as a by-product of other processes.

As a result of the study, a proposal is proposed for the feasibility of applying the most promising reuse options, as well as possible interested companies. Concrete results, technical and economic feasibility and a technical-business approach for the exploitation of these results will be clearly defined for each island scale, plant or operating company, together with the capitalisation of these results. This study is related to the circular economy and the blue economy, as an intersection of environmental aspects, the efficient use of material, economic and social resources as drivers of growth and innovation for sustainable economic development [1–3].

2. Background

Making seawater drinkable is one of the possible solutions to the shortage of drinking water. By desalinating seawater, fresh water suitable for water supply and irrigation can be obtained [4–6].

Desalination has placed the Canary Islands on the world technological map of industrial water production, turning it into a large laboratory with the implementation of large-scale pilot plants, which developed a broad spectrum of existing desalination technologies over the years [3–6].

The growth in demand for water and the impossibility of forcing the use of natural resources further forces the development of water desalination, particularly in the Canary Islands and in Macaronesia in general, to cover the water needs of the population, tourism, industry and agriculture [6].

Water desalination has enabled the subsistence of the economic and business fabric of the Canary Islands, especially in those areas that lacked the necessary water resources to meet demand.

At present, water desalination in the Canary Islands in particular and in Macaronesia in general allows us to reuse reverse osmosis elements from water desalination processes, in such a way that they can help to improve and optimise the blue economy of these regions [6–10]. Figs. 1–4 show the final result of the compilation study of the different desalination plants distributed in the Canary Islands and classified by different variables.

From this study, we obtained an approximate count of 50,000 reverse osmosis membranes in operation in all the desalination plants in the Canary Islands, with an annual replacement of around 10,000 membranes that would fall into disuse, an annual replacement rate of 20%. This estimate has been arrived at taking into account an average life of these reverse osmosis elements of 5 y, which is 2 y longer than the standard warranty of membrane manufacturers, which is 3 y. We have taken into account brackish water plants whose replacement is lower, seawater plants with a higher replacement, especially large desalination plants that have an open intake collection and the requirements of energy efficiency and water potability such as less than 1 mg/L of boron in the permeate, which currently require a higher replacement of membranes. The Canary Islands also have the particularity that membranes are used more and last longer but still meet the above estimation. In general, membranes end up in landfills to be buried.

Of an estimated total of 687,000 m^3/d of desalinated water production from reverse osmosis membrane desalination plants in Macaronesia, approximately 660,000 m^3/d in the Canary Islands, 20,000 m^3/d in Cape Verde and 7,380 m^3/d in Porto Santo, and taking into account an average work flow depending on whether these facilities have an open intake or well intake, seawater, brackish water or tertiary treatment plants, the following quantity of membranes in disuse per year can be broken down by island, approximately, as shown in Table 1:

3. Results

This section shows the results of this study.

3.1. Re-use of reverse osmosis elements

Different possibilities for the reuse of reverse osmosis membranes in other processes have been investigated in this study and the following can be highlighted:

- In two-stage seawater plants, due to the fouling of the first-stage membranes compared to the second-stage

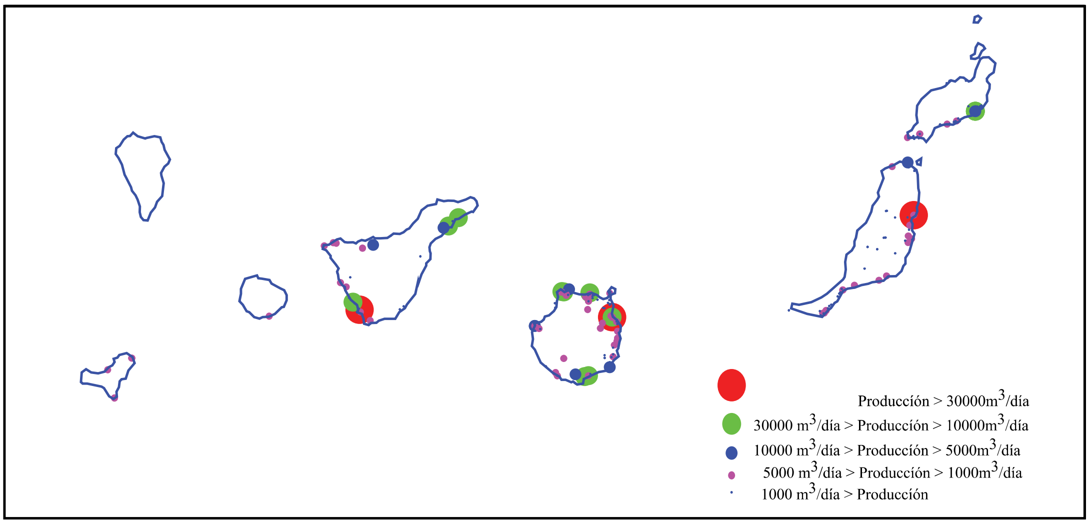

Fig. 1. Geographical representation of the desalination plants in the Canary Islands according to their daily production flow in m³/d.

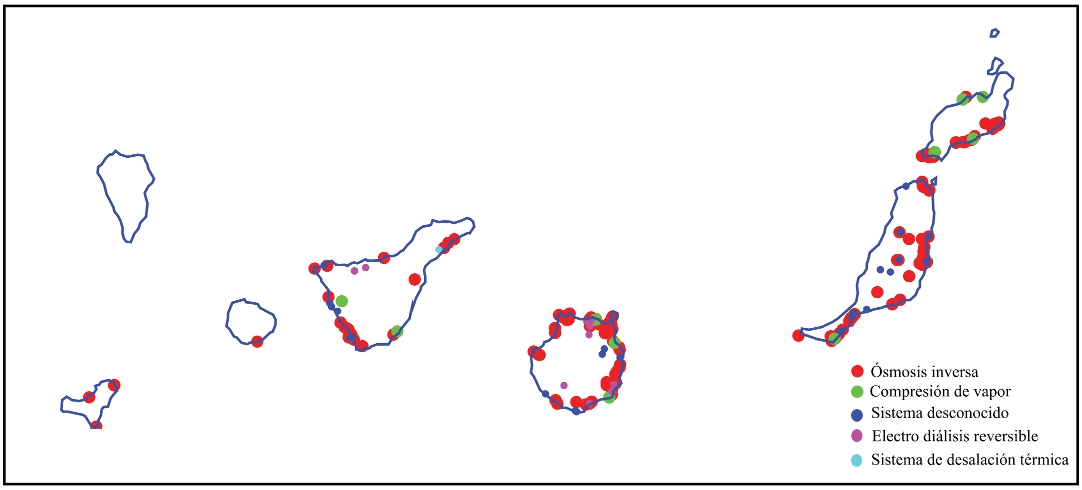

Fig. 2. Geographical representation of desalination plants in the Canary Islands according to the water desalination method used.

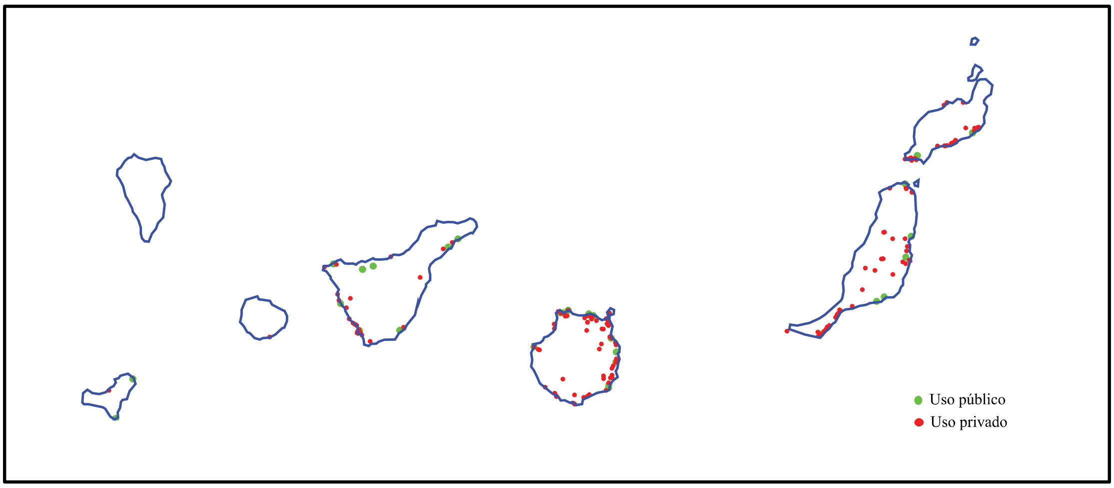

Fig. 3. Geographical representation of desalination plants in the Canary Islands according to the type of public or private operation.

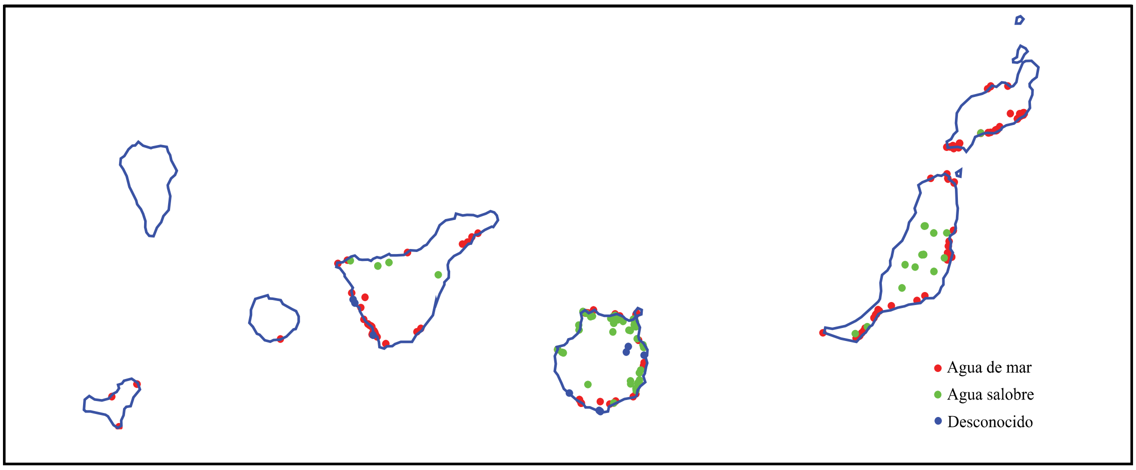

Fig. 4. Geographical representation of the desalination plants in the Canary Islands according to the type of feed water.

Table 1
Number of membranes, annual replacement, weight and volume of membranes per island in Macaronesia

Island	No. of membranes in use per year	Annual membrane replacement	Weight (kg) replacement	Volume (M^3) replacement
Lanzarote (Canary Islands)	8,000	1,600	32,000	67
Fuerteventura (Canary Islands)	8,650	1,730	34,600	73
Gran Canaria (Canary Islands)	23,500	4,700	94,000	197
Tenerife (Canary Islands)	9,350	1,870	37,400	79
El Hierro (Canary Islands)	350	70	1,400	3
La Gomera (Canary Islands)	150	30	600	1
Porto Santo (Madeira)	450	45	900	2
Praia-Palmarejo (Cape Verde)	700	100	2,000	4
St Vincent (Cape Verde)	350	50	1,000	2
Salt (Cape Verde)	350	50	1000	2

membranes, it is proposed to replace them before disposal and after cleaning. An individualised study of the permeate quality of each membrane is required, which is simple to carry out by means of a "tubing", with a probe that enters the permeate tube and collects a sample of the water quality of each membrane in order to choose the best ones. In this way, seawater membranes, the most expensive and difficult to give a second life to, could be reused in the same or another desalination plant by changing the best first stage membranes to the second stage and vice versa.

- The membranes in a brackish water plant are more likely to be extended by chemical cleaning, but in these plants which usually have several stages, the membranes can also be combined between the two stages before disposal. Similarly, brackish water plants usually have a minimum of two or three stages to achieve conversions close to 75%, and this can help us to reuse the older membranes in the third or sacrificial stage where they are more likely to precipitate the salts earlier and be used to produce some more water until they have finally been exploited to 100%. If the plant is a two-stage plant, these older membranes could also perform this sacrificial function in the last positions of the pressure tubes of the second stage. In this way the membranes could be reused in the same installation or in other brackish water desalination plants.
- Brackish water reverse osmosis membranes can also have a second life in tertiary treatment plants that do not require a very demanding quality of permeate for irrigation, especially if they are membranes with low fouling or with a large spacer, since the water coming from the treatment plant to the tertiary treatment plant is normally dirtier than the water from a brackish well installation, which is the most common way of collecting this type of water in the Canary Islands in particular and in Macaronesia in general. Therefore, the membranes of the brackish water plant may have suffered salt precipitation, especially in the last positions of the second or third stage, but the best ones can be selected and after a chemical cleaning they can be proposed for reuse in a tertiary treatment plant, where the problem may be not so much salt precipitation but the fouling of the water. The membranes will eventually become clogged, but only after a second life and after they have been exploited 100%. Furthermore, the water from the reverse osmosis

tertiary treatment plant will be used for irrigation or returned to the sea, so as it will not be used for drinking water because the law does not allow it, unlike in other countries such as Singapore, we do not run the risk that the reused membranes may have some kind of leak that could worsen the quality of the water and make it unsuitable for human consumption.

- On the contrary, transferring used membranes from a tertiary to a brackish water desalination plant for public supply is more complicated because they will be dirtier, their condition will be worse and they may carry biological contamination, but there are specific industrial processes where they could be reused, for example, to discharge water into the sewage network that originally does not meet the conditions for it with the appropriate pre-treatment so that the membranes are not damaged from the beginning.
- There are some industrial processes where they use special reverse osmosis membranes and end up very dirty in less than a month, so they have to replace many in a short time. By studying each industrial application that requires osmosis, depending on the salinity and pressures, it is possible to propose the reuse of second-hand membranes from other desalination plants in these processes to exploit them further before throwing them away. Other industrial processes such as coffee concentrate, for example, where special reverse osmosis membranes are used and end up black in less than a month, meaning that many have to be replaced in a short time. By studying each industrial application that requires osmosis, depending on the salinity and pressures, it is possible to propose the reuse of second-hand membranes from other desalination plants in these processes in order to exploit them even more before throwing them away.
- There is also the possibility of leachate from landfill waste and other waste, which is sometimes treated by reverse osmosis to concentrate it, and this process makes the membranes very dirty, and it is very difficult to find one that has a sufficiently long life to be profitable. In these cases, the option of reusing seawater membranes can be considered, if the salinity of the leachate is close to that of seawater, which is very common, or membranes from tertiary or brackish water plants if the salinity is lower. In this way, these reverse osmosis elements would be used in a final leachate concentration process before disposing of the membranes after they have been used 100%. With regard to the treatment of leachate, there are leachate evaporation systems in the Complexes, although it has been accepted in WWTPs that they may currently be treating the excess leachate. However, it has always been thought, after consultation with experts in waste management, that the leachate could be used as fertiliser after treatment. As salinity is one of the big problems, I think that treatment with membranes could be very interesting. There is bibliography on the subject and it is believed that it could be an interesting line of work, even starting with a project.
- The membranes in a brackish water plant are more likely to be extended by chemical cleaning, but in brackish water plants that usually have several stages, the membranes can also be combined between the two stages before disposal. Similarly, brackish water plants normally have a minimum of two or three stages to achieve conversions close to 75%, and this can help us to reuse older membranes in the third or sacrificial stage where they are more likely to precipitate salts earlier and be used to produce some more water until they are finally exploited to 100%.
- A very practical and interesting option is the oxidation of reverse osmosis membranes, both seawater and chlorinated brackish water, to obtain nanofiltration membranes with lower salt rejection, ultrafiltration or microfiltration for physical dirt removal in the line of cartridge filters. A schematic of the membrane oxidation process is shown in Fig. 5:

Depending on the pore size, permeability and rejection capacity, polymeric membranes can be classified into: microfiltration, ultrafiltration, nanofiltration and reverse osmosis. The rejection of these elements depends on the pore size and by oxidising them we increase the pore diameter as shown in Fig. 6.

- Membrane oxidation has already been carried out and has worked successfully at the Barranco Seco WWTP of Emalsa (Las Palmas de Gran Canaria), so it has been taken into account for the reuse of reverse osmosis elements and its technical and economic feasibility will be studied at a later date in order to carry it out.
- The oxidation of reverse osmosis membranes must be carried out under the dosage of the following amounts of free chlorine over time, as indicated in Table 2.
- The positive effects of reusing reverse osmosis membranes by oxidising them and transforming them into nanofiltration, ultrafiltration or micorfiltration membranes are basically the following:
- The reuse of a reverse osmosis membrane has a lower environmental impact than the production of a new one. Water consumption during the membrane transformation process for membrane reuse is 20 times lower than the consumption for the production of new membranes.
- The carbon footprint of reused membranes in other processes is 40 to 60 times lower than the production of commercial membranes and he price of reused

Fig. 5. Oxidation process of reverse osmosis membranes in nanofiltration or ultrafiltration membranes.

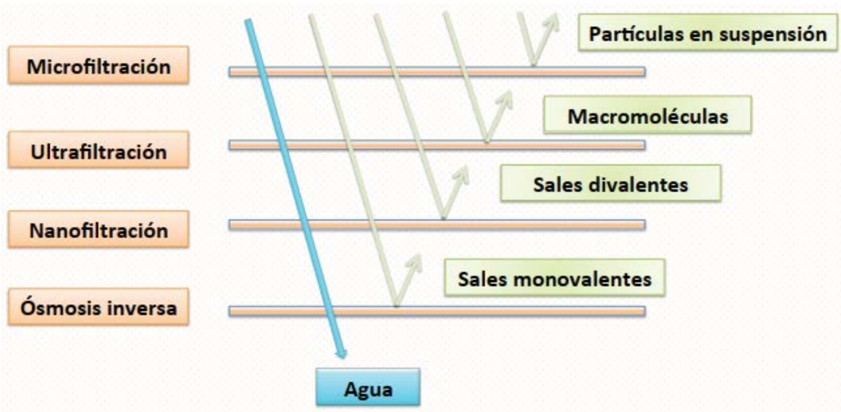

Fig. 6. Particle rejection as a function of pore size for different reverse osmosis, nanofiltration, ultrafiltration or microfiltration membranes.

Table 2
Free chlorine concentrations for the oxidation of reverse osmosis membranes

Case	Free chlorine concentration (ppm)	Exposure time (h)	Exposure level (ppm × h)
A	124	50 (NF) – 242 (UF)	6,200 (NF) 30,000 – 300,000 (UF)
B	1,240	5 (NF) – 24.2 (UF)	
C	6,200	1 (NF) – 4.84 (UF)/48.4 (UF)	
D	12,400	0.5 (NF) – 2.42 (UF)	

membranes is 10 times lower than the price of new membranes. Therefore, in only 1–2 y of operation of reused membranes, the transformation process to reuse membranes is already beneficial both economically and environmentally.
- The membrane oxidation process can be either actively in a pilot plant with pressure tubes or passively in a tank with several submerged membranes. From an economic and environmental point of view, passive processing of reverse osmosis membranes is better.

In addition, the opportunities for reuse of reverse osmosis membranes to treat brine from seawater desalination plants and tertiary by-products from wastewater treatment plants or brackish water plants have also been taken into account. In this sense, the following opportunities can be accredited with by-products from reverse osmosis membrane processes:

- Used reverse osmosis membranes could be considered as a feasible technology for energy production from brine, using salinity gradients.
- Emerging technologies can also take advantage of the reuse of osmosis membranes to produce energy from the osmotic potential of the brine. We have previously discussed how direct osmosis or forward osmosis can be used to carry out this process with brine from a desalination plant.
- In tertiary treatment plants, the membranes can also be reused to take advantage of the synergies with the brine from a nearby seawater desalination plant and, between the two, carry out a forward osmosis process to produce energy and dilute the brine discharge into the sea. We have two brine streams, the one coming from the lower salinity tertiary and the one coming from the high salinity seawater desalination plant. By mixing them through a semi-permeable direct osmosis membrane, water is transferred from the lower salinity stream to the higher salinity stream to dilute it. In this way we obtain two by-products: energy and a more diluted brine than that of the seawater desalination plant, which will make it easier and less costly to evacuate it to the sea, as well as reducing its environmental impact. If the treatment plant does not have a tertiary treatment plant, this process can also be carried out with the effluent from the plant and the brine from the desalination plant for both purposes.
- The tertiary treatment of wastewater treatment plants as wastewater treatment for productive purposes and valorisation of wastewater rejects. By optimising these water treatment processes, including the reverse osmosis tertiary treatment by reusing membranes from another plant, it is possible to obtain a source of resources such as the regeneration of water suitable for irrigation, the obtaining of nutrients or fertilisers from nitrogen and phosphorous concentration, and the production of energy.

3.2. Recycling of reverse osmosis components and elements

In this section, the results concerning the opportunities found in the recycling of reverse osmosis membrane components can be described.

The treatment and recycling of solid plastic waste can be divided into four main categories: primary (re-extrusion), secondary (mechanical), tertiary (chemical) and quaternary (energy recovery). Primary recycling is generally carried out at the manufacturing plant by reintroducing clean waste into the extrusion cycle. This process cannot generally be applied to dirty waste products, such as clean reverse osmosis modules, as the recycling materials are not expected to reach the required quality. While only a small number of recycling options are directly applicable to the recycling of RO membranes, assessing their validity is an important step in the process of investigating all recycling opportunities.

During the mechanical recycling process, plastics are physically shredded to product size, separated from contaminants, washed and used as raw material for the production of new products. Assimilable or incompatible polymers can cause deterioration of the mechanical property during the process, so for mechanical recycling to be economically viable it is important that there is a large amount of clean and homogeneous single plastic polymer waste.

For membrane materials, each component must be considered individually to determine its potential suitability for mechanical recycling, assuming it can be successfully and economically separated. For example, the polypropylene feed spacer, shown in Fig. 2, has the capacity to be recycled directly using this method. In fact, polypropylene is commonly recycled in containers and packaging because of the strength, thermal and chemical resistances it can maintain, even after recycling. In the Canary Islands this can be done by the company CP5, S.A. de transformados plásticos located on the island of Tenerife. Depending on the type of polyester components used shown in Fig. 1, such as the permeate spacer, these also have the capacity to be mechanically recycled. Due to the nature of their polymer, ABS or noryl materials, such as the end caps and permeate tubes shown in Fig. 2, may suffer from deterioration of physical properties when recycled by these methods, so they are generally reprocessed using other techniques. Finally, the flat membrane sheets, which make up a large proportion of the element, are constructed of different materials. In addition, the membrane sheets can become contaminated with any kind of substance after prolonged use. Due to the nature of the process and the reasons mentioned above, direct mechanical recycling of the module can be prohibitively labour and cost intensive. This is because, as shown in Fig. 1, there are many components together in the flat membrane (aromatic polyamide, polysulphone, polyester, glue, etc.) which together with the physical fouling that can be added, biofouling, salt fouling and so on make it technically almost impossible to separate these materials as at source and cost excessive time and money.

Chemical (or feedstock) recycling is a process that breaks down plastic material into small molecules, to be used as feedstock for petrochemical processes, using the method used to create the polymer chains, such as depolymerisation and degradation. Polyester materials (as in permeate spacer and flat membrane components) are useful for chemical recycling processes and hydrolysates are used to reverse the reaction of condensates used to make polymers, with the addition of water to the composition caused. Chemical recycling cannot typically be used with contaminated materials, and although it is cheaper and more complex than mechanical and primary recycling, its main advance is that heterogeneous polymers with limited use of pre-treatment can be processed. In this case, chemical recycling is more feasible than mechanical recycling for the treatment of reverse osmosis membranes and could be viable through a pyrolytic industry that is being planned for 2021 on the island of Tenerife.

These processes can be considered as viable recycling options. The main categories of thermal processing commonly used in industry include incineration, pyrolysis and thermal processing in the absence of oxygen, gasification, which is partial combustion with limited air to produce gas, and catalytic conversion to fuel. From an environmental point of view, gasification and hydrocarbons offer advantages over simple incineration as they produce fewer emissions, reduce waste and increase energy recovery. Most importantly, these processes can be applied to mixed plastic waste, such as the combination of materials used in the manufacture of reverse osmosis membranes.

To collect the obsolete membranes in landfills in the Canary Islands you pay between 20 and 30 Euros per tonne and this is cheaper than giving it another treatment outside the Canary Islands, losing the opportunity to obtain a by-product from it such as energy recovery or fuels from processes such as pyrolysis.

The recycling of reverse osmosis elements does not exist in the Canary Islands, it is a new business opportunity in the waste sector. In Europe, there is only one manager in Germany that recycles the membranes, it is the company MEMRE and it costs 25 Euros per reverse osmosis membrane, but with the addition of transport it is more expensive than taking them to landfill. Therefore, a considerable option would be to do the same recycling, but here in the Canary Islands.

The increase in the use of reverse osmosis membranes is considerable and standard recycling companies are not able to treat them directly. This could also apply to Nano and Ultra Filtration membranes which are also showing growth in the market.

This type of recycling industry starts with the registration of the membranes in operation in a manufacturer-independent database. In the case of a membrane change, the data will be updated. This is the same for any other data or information of a specific plant. Due to the possible cooperation with any membrane manufacturer, the data can also be transferred directly and retrieved at any time.

Membrane autopsies can be carried out and a certificate of disposal is issued by the company to its customers which conclusively confirms the processing and recycling of the membranes s valid for any public administration.

Pyrolysis is a thermal degradation of a substance in the absence of oxygen, whereby these substances are decomposed by heat, without the combustion reactions taking place. The basic characteristics of this process are as follows: the only oxygen present is that contained in the waste to be treated and the working temperatures are lower than those of gasification, ranging from 300°C to 800°C. As a result of the pyrolysis process, the following is obtained: gas, liquid waste and solid waste, each with the following characteristics:

- The basic components of the gas are CO, CO_2, H_2, CH_4 and more volatile compounds from the cracking of organic molecules, together with those already existing in the waste. This gas is very similar to the synthesis gas obtained in gasification, but there is a greater presence of tars, waxes, etc. to the detriment of gases, due to the fact that pyrolysis works at lower temperatures than gasification. The gaseous products are a highly energetic fuel with a calorific value of approximately 50 MJ/m^3.

- The liquid residue is basically composed of long-chain hydrocarbons such as tars, oils, phenols, waxes formed by condensation at room temperature.
- Solid waste, consisting of all non-combustible materials, which are either unprocessed or originate from molecular condensation with a high content of carbon, heavy metals and other inert components of these wastes.

Liquid and gaseous waste can be utilised by combustion in a steam cycle for the production of electricity. Solid waste can be used as fuel in industrial plants, for example, cement plants.

Pollutants are also produced in this process such as bottom or fly ash, contaminated waste water and emissions of pollutants into the atmosphere (solid particles, heavy metals, acid gases, pyrolysis and incomplete combustion products).

For energy recovery and incineration of the membranes, it is necessary to remove the encapsulated glass fibre from them, which is not difficult, and the rest of the elements that are very difficult to separate because they are glued and mixed together are all plastic elements (aromatic polyamide, polysulphone, polyester, polyethylene, noryl, etc.) that can be incinerated to produce energy. Likewise, pyrolysis is a thermal treatment that mixes different plastics such as those that make up reverse osmosis membranes, as it has no PVC, metals or organic materials that would be harmful, finally obtaining high calorific value fuels as by-products of these elements.

There is no incinerator in the Canary Islands, but it could be centralised on an island to collect all these reverse osmosis membranes and treat them. Similarly, there is no pyrolysis industry in the Canary Islands, but one has already been planned in Tenerife (Plastics Energy) where all the reverse osmosis elements could be sent for this purpose. The technical and economic feasibility of these processes will also be studied at a later date.

The processes that are carried out in this type of industry to develop its function are the following:

- Plastic waste is received for processing, in our case obsolete reverse osmosis membranes, but plastics collected in the yellow bin by the municipal cleaning and waste collection services can also be received.
- Mechanical pre-treatment is performed to remove contaminants from the plastic such as metals, plastics and heavy materials, moisture from the plastic and to separate the plastics to be treated such as high and low density polyethylene, polypropylene and polystyrene. Anaerobic Thermal Conversion (TAC) is designed to convert end-of-life plastic waste into a new feedstock to create clean recycled plastics or low-carbon alternative fuels. For every tonne of end-of-life plastic waste processed, 850 L of TACOIL chemical feedstock are produced.
- Atmospheric distillation columns receive the hydrocarbon vapour and according to molecular weights separate the vapour into crude diesel (higher molecular weight accumulation at the bottom), light oil (in the middle) and synthetic gas components at the top).
- The process is repeated, the naphtha and diesel are supplied to the petrochemical industry to produce original plastic again and the synthetic gas is used to start up the facility.

The recovery of plastics, both material and energy, is going to be vital in the near future and, given that the Administration is focused on domestic and commercial waste, it will be up to the private sector to take the initiative, and to try, together with the Administration, not to create unfair competition by depositing this type of waste in landfill sites, It is currently much cheaper to do so, and the implementation of other more environmentally sustainable technologies will not be favoured if it is not promoted, which is why a very interesting line is emerging in this sense and it is possible to create a project for the development of this route.

With regard to cogeneration at the Salto del Negro and Juan Grande Environmental Complexes (Gran Canaria), these consist of the use of the biogas generated in the biological processes and in the landfill, and therefore have nothing to do with the energy recovery of plastic waste.

4. Conclusions

In addition to the great advantages of desalination, there are aspects that can be improved, such as the reuse of reverse osmosis elements in seawater, brackish and tertiary desalination processes.

Reuse of the reverse osmosis elements in the same plant or in tertiary plants with partial replacements, replacing the membranes in the dirtiest first positions with those in the least damaged last positions, is an economically viable alternative at a very low cost.

On the other hand, the oxidation of obsolete reverse osmosis membranes, in order to reuse, for example, the very damaged ones such as the first positions in the pressure tubes, gives us the opportunity to obtain a new by-product such as a cartridge filter (microfiltration), ultrafiltration or nanofiltration. In this sense, it shows the feasibility of betting on oxidation and selling the new membranes at 15 Euros.

The recycling of reverse osmosis elements from desalination plants is shown as an opportunity, as a pioneering initiative in Spain and with some experiences already contracted in Europe, there is only one manager in Germany that recycles the membranes, which is the company MEMRE, at a cost of EUR 25 per reverse osmosis membrane.

Energy recovery, via incineration, is feasible, but is not considered in view of the environmental, social and political problems it may generate.

On the other hand, at the recycling of reverse osmosis elements is feasible via the pyrolytic industry and sending all obsolete osmosis membranes there.

This is a technically and economically viable business opportunity with a promising future in today's recycling market.

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