Data Article

Data of the life cycle impact assessment and cost analysis of prospective direct recycling of end-of-life reverse osmosis membrane at full scale

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A B S T R A C T

This data includes the geographical data, the Life Cycle Inventory data and Life Cycle Assessment data of the implementation of end-of-life (EoL) reverse osmosis (RO) direct recycling implementation at full scale in a Spanish region. Besides, the data allows the comparison of the environmental profile between recycled membrane products with the commercial counterparts. The EoL-RO stock potential was analysed constrained to the Segura’s watershed. However, the distribution of recycled membranes was considered within the European Union’s borders. The International Life Cycle Data system (ILCD) midpoint impact categories and the indicator Service Life Ratio (SLR) are presented. This data could be used for deepening analyses as the externalities monetarisation or business model identification or policymakers. This data article is related to J. Senán-Salinas, A. Blanco, R. García-Pacheco, J. Landaburu-Aguirre, E.-García-Calvo. J Prospective Life Cycle Assessment and economic analysis of

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Specifications Table

| Subject          | Environmental Engineering |
|------------------|---------------------------|
| Specific subject area | Life Cycle Assessment and Geographic Information Systems |
| Type of data     | Tables / Graphs/ Figures/ Datasets |
| How data were acquired | Inventories were obtained from real experimentation, GIS databases, literature and databases (Ecoinvent v3.4). Life Cycle Impact Assessment was estimated with the ILCD method. Transport Costs were obtained from ACOTRAM v3.1 database. |
| Data format      | Raw /Analysed /Filtered |
| Description of data collection | Geographical information. Mass and energy flows from real experimentation, literature and LCA databases (Ecoinvent v3.4.). Other specific databases as AEDYR database for desalination facilities. |
| Data source location | Spain |
| Data accessibility | Repository name: Mendeley Data DOI: http://dx.doi.org/10.17632/z6db5w8d6k.1 URL: https://data.mendeley.com/datasets/z6db5w8d6k/1 |
| Related research article | J. Senán-Salinas, A. Blanco, R. Garcia-Pacheco, J. Landaburu-Aguirre, E. Garcia-Calvo. J Prospective Life Cycle Assessment and economic analysis of direct recycling of end-of-life reverse osmosis membranes based on Geographic Information Systems. J. Clean. Prod. In Press DOI: https://doi.org/10.1016/j.jclepro.2020.124400 |

Value of the Data

• The impact results with different functional units allow the comparison of the overall impact of of the full implementation of recycling strategies. The spatial information will allow further analysis of logistics within membrane direct recycling. Montecarlo Life cycle Inventory results allows the reproducibility of the study.
• Those results could be used for researchers focus on logistics and membrane recycling. As well as researchers focused on economic, circular economy transition and policy making.
• The data could be used for externalities quantification and monetisation, reproduce the research and develop further logistic analysis.

1. Data Description

The data consists on the geographic information, distance and payload distance analysis and the environmental indicators (eleven ILCD midpoint categories and their Service Life Ratio) (available at Mendeley repositary http://dx.doi.org/10.17632/z6db5w8d6k.1) concerning the recycling strategies analysed in [1] for the full-scale implementation of a recycling plant at the Segura$ watershed (Spain). Fig. 1 illustrates the boundaries of the case study and the desalination plants incuded int the studied region.

Table 1 includes the summary of the desalination facilities in the case study region obtained from AEDYR database. The main features included were the desalination capacity and the type of water treated (SW: sea water; BW: brackish water). This information allowed the estimation of the potential amount of EoL-RO generated by type en each facility.
The weights of the modules generated by the waste was extrapolated from the real measurement of 67 modules of different plants and the target water of the design (WD; if they were design to treat seawater (SW) or brackish water (BW)). Raw data can be found in the mendeley repository (DOI: 10.17632/z6db5w8d6k.1) in the file Modules weight.xlsx. Table 2 describes the fitted distributions from original measures of weights with the methodology described in section 2. Fig 2 illustrates i) the results of the measurement (Fig 2a and Fig. 2b), ii) the Monte Carlo simulations projected by type (Fig 2c and Fig. 2d) in histograms generated with R v3.4, and iii) the density functions of both generated with ggplot2 package of the same software.

The results for the four locations analysed are in the file RL_dib.csv at Mendeley dataset. It includes the results of the payload distance of each centroid with the expected waste stock estimated by the desalination capacity. The overall results are illustrated in the Fig 3. On the other side, The file Distances_dib.csv of the repository contents the logistic analysis results of the distribution of commercial and recycled modules. It includes the distances and payload distances by transport medium and the geographical information of locations.

Finally, the Life Cyce Impact Assessment and Service Life Ratio (SLR) results are at the repository in the file MC_prm_dib.csv. The Monte Carlo raw results and the summary in sum_prm_dbi.csv. Those results are aggregated around the functional unit of one recycled module at the secondary user location. In addition, the results were estimated with a secondary functional unit of the management of all the modules of Seguraš Watershed. The files MC_pw_dib.csv and sum_pw_dbi.csv of the repository include the Monte Carlo results and the summary, respectively. In both files the results include the analysis of different strategies called Com and BW that differ on what type of modules are recycled. Com represents the management of all the modules (SW and BW) and BW just the recycling of BW modules.
Table 1
Inventory of desalination plants, capacity and type of water treated (SW: sea water; BW: brackish water). Source: AEDYR database.

| Location              | Region    | Facility name                                         | Capacity (m³/day) | Water treated |
|-----------------------|-----------|------------------------------------------------------|-------------------|---------------|
| Torrevieja            | Valencia  | Desaladora de Torrevieja                              | 240,000           | SW            |
| Aguilas               | Murcia    | Águilas (Acuamed)                                     | 210,000           | SW            |
| Valdelentisco         | Murcia    | Valdelentisco                                         | 140,000           | SW            |
| Escombreras           | Murcia    | Escombreras                                           | 68,000            | SW            |
| Cartagena             | Murcia    | Canal de Cartagena                                     | 65,000            | SW            |
| Cartagena             | Murcia    | Canal de Cartagena Extension                          | 65,000            | SW            |
| Cartagena             | Murcia    | Canal de Cartagena. San Pedro del Pinatar. I          | 65,000            | SW            |
| Cartagena             | Murcia    | Canal de Cartagena. San Pedro del Pinatar. II         | 65,000            | SW            |
| Aguilas               | Murcia    | Aguilas                                               | 20,800            | SW            |
| Aguilas               | Murcia    | Aguilas                                               | 16,000            | SW            |
| Mazarrón              | Murcia    | CR Mazarrón                                           | 13,500            | BW            |
| Almería Pulpi         | Andalucía | Almería Pulpi                                         | 10,500            | SW            |
| Jacarilla             | Valencia  | Jacarilla – Alicante                                  | 8,750             | BW            |
| Cartagena             | Murcia    | Ampliación Refinería Repsol                           | 8,400             | SW            |
| Cabo de Palos         | Murcia    | Arco Sur                                              | 7,000             | BW            |
| Almería Pulpi         | Andalucía | Almería Pulpi                                         | 6,000             | SW            |
| Murcia                | Murcia    | IDAM LA MARINA                                        | 5,000             | SW            |
| Murcia                | Murcia    | Copisa El Pozo                                        | 4,000             | BW            |
| Cartagena             | Murcia    | Cartagena                                             | 3,600             | BW            |
| Murcia                | Murcia    | Cartagena                                             | 2,800             | SW            |
| Cartagena             | Murcia    | Cartagena                                             | 2,700             | BW            |
| Cartagena             | Murcia    | Cartagena                                             | 2,700             | BW            |
| Murcia                | Murcia    | Agrícola Escucha                                      | 2,700             | BW            |
| Campo Cartagena       | Murcia    | Campo Cartagena                                       | 2,000             | SW            |
| Murcia                | Murcia    | Murcia (Finca Torremolino)                            | 1,800             | BW            |
| Campo Cartagena       | Murcia    | Campo Cartagena                                       | 1,750             | BW            |
| Murcia                | Murcia    | Murcia (Agrohispaner)                                 | 1,175             | BW            |
| Abarán                 | Murcia    | Abarán                                                | 1,080             | BW            |
| Campo Cartagena       | Murcia    | Campo Cartagena                                       | 1,000             | SW            |
| Villaricos            | Andalucía | IDAM Covisa                                           | 1,000             | BW            |
| La Palma Mur          | Murcia    | La Palma Mur (Fejima)                                 | 600               | BW            |
| Murcia                | Murcia    | Murcia                                                | 600               | BW            |
| La Palma Mur          | Murcia    | Finca lo Triviño                                      | 500               | BW            |
| Campo Cartagena       | Murcia    | Campo Cartagena (Finca El Pasico)                     | 330               | BW            |
| Hondón                | Valencia  | Hondón (Alicante)                                     | 250               | SW            |
| Molina de Segura      | Murcia    | Golosinas Fini                                        | 225               | BW            |
| Murcia                | Murcia    | Murcia                                                | 220               | SW            |
| Murcia                | Murcia    | Murcia Hero                                           | 190               | BW            |
| Murcia                | Murcia    | Murcia                                                | 100               | BW            |

Table 2
Summary of modules weight and distribution parameters by water target of design (WD) (SW: sea water; BW: brackish water).

| WD       | Total Number(n) | Modules >=25 kg(n) | Modules <25 kg(%) | Modules >=25 kg(%) | Distribution < 25 kg | Distribution >= 25 kg |
|----------|-----------------|--------------------|-------------------|-------------------|----------------------|-----------------------|
| BW       | 51              | 6                  | 88.2              | 11.8              | Normal (15.95, 2.515) | Uniform (39–42)       |
| SW       | 16              | 6                  | 62.5              | 37.5              | Normal (16.95, 0.37)  | Uniform (33.4–41)     |

2. Experimental Design, Materials and Methods

2.1. Reverse logistics analyses and plant location

The recycling plant location was defined through the criteria of the minimum payload distance with the following methodology. A first assessment was performed among the centroids of four suitable areas. To estimate the payload distances the desalination plants and their ca-
Fig. 2. EoL-RO modules weight histograms for BW (a) and SW (b); Histogram of modelled weights by Monte Carlo results from 1,000 runs for BW (c) and SW (d); and comparison of density curves between the modelled and the real measures for BW (e) and SW (f). The adjust values (in e and f) are different to correct the different number of individuals.

Capacity of the area were identified (Table 1) to estimate the EoL-RO stock according to [2]. The distances were estimated by the shortest route with Google Earth roads in QGIS v3.8. Secondly, the modelling of EoL-RO module weights was performed with the experience of previous experimentations within Life-TRANSFORMEM project (http://www.life-transfomem.eu/). Fitdistrplus R package was used for fitting the weight distribution. The results were showed in Table 2. The centroid of Cartagena was chosen as the best option due to the lower payload distance (Fig 2) for further steps.
2.2. Comparison of distribution impact

For the comparison of the distribution impacts between recycled and new produced membranes three regions were defined related to the recycling plant location: regional, Iberian and European. Within these regions, 1,000 points per region were randomly obtained from ArcGIS v14. The selection of different functions available in different softwares was mainly defined by easiness and the software availability. In this case, it was a punctual use of a tool of ArcGIS v14 that was considered more practical. The comparison with the commercial distribution schemes was performed with two facilities in Germany and America. Euclidean distances were estimated and corrected by detour factor: 1.25 for road transport and 1.5 for shipping according to [3]. In the case of the transport from the American Facility, the closest docks were selected by end-user point (Table 3).

2.3. Goal and Scope

The goal of the LCA was the assessment of the recycling implementation. System boundaries and scope were defined in [1]. The data was aggregated around the functional unit of the one EoL-RO module recycled. This functional unit was chosen to increase the comparability with other previous studies focus on the alternative end-of-life options and recycling processes. Nonetheless, a secondary functional unit was also used for the Life Cycle Impact assessment: the recycling of all the EoL-RO modules of the Seguraš watershed generated in one year. This secondary functional unit evaluates the overall impact of the strategy. It allows the quantification of the impact of the strategy and the recycling in a macro scale allowing the comparison with other recycling activities or potential policies.
Table 3
Principal docks of Europe and their geographical coordinates.

| Name          | X            | Y            |
|---------------|--------------|--------------|
| Valencia Port | -0.325009508 | 39.444274513 |
| Algeciras Port| -5.439506287 | 36.124952104 |
| Barcelona Port| 2.162315633  | 41.350440512 |
| Sines Port    | -8.845309387 | 37.937172396 |
| Rotterdam Port| 4.144285591  | 51.944733094 |
| Antwerp Port  | 4.407435865  | 51.240416294 |
| Hamburg Port  | 9.966844272  | 53.506284553 |
| Bremenhaven Port | 8.546270031  | 53.57052673  |
| Piraeus Port  | 23.591384182 | 37.957916864 |
| Gioia Tauro   | 15.907300261 | 38.454453679 |
| Genoa Port    | 0.148985811  | 49.472485208 |
| Le Havre Port | 8.880227186  | 44.409939478 |
| Merseburg Port| 9.844891589  | 44.109712215 |
| Mersin Port   | 34.646849531 | 36.804510867 |
| Gdansk Port   | 18.70893352  | 54.385977389 |
| Marseille Port| 5.337508581  | 43.349267857 |

Table 4
The ILCD-Midpoint v1.0.5 method categories and abbreviations.

| Abbr. | Characterisation methods                                      | Reference unit       |
|-------|--------------------------------------------------------------|----------------------|
| A     | Acidification                                                 | mol H+ eq.           |
| GWP   | Climate change (100 years)                                   | kg CO2 eq.           |
| FE    | Freshwater eutrophication                                   | kg P eq.             |
| ME    | Marine eutrophication                                        | kg N eq.             |
| HT, c | Human toxicity, cancer effects                               | CTUh                 |
| HT, nc| Human toxicity, non-cancer effects                           | CTUo                 |
| IR-e  | Ionising radiation-ecosystems                                | kg U235 eq.          |
| IR-hh | Ionising radiation-human health                              | mol N eq.            |
| TE    | Terrestrial ecotoxicity                                       | CTUe                 |
| ET, f | Freshwater ecotoxicity                                       |                      |
| OD    | Ozone depletion                                               | kg CFC-11 eq.        |
| PCOF  | Photochemical ozone formation, human health                  | kg NMVOC eq.         |
| PM    | Particulate matter/Respiratory inorganics                    | kg PM 2.5 eq.        |
| LU    | Land use                                                     | kg C deficit         |
| RD, f+m | Resource depletion, mineral, fossils and renewables          | kg Sb eq.            |
| RD, w | Resource depletion water                                     | m3 water eq.         |

2.4. Life cycle impact assessment and service life ratio

The Life Cycle Impact Assessment was performed with OpenLCA v1.10 and R v3.4. The impact method ILCD-midpoint v1.05 (OpenLCA/NEXUS) was used. Midpoint categories were used to evaluate the direct effect to the environment of the alternatives (Table 4). In particular ILCD-midpoint categories provide a wide vision of the main environmental concerns with high degree of reliability. Also, the service Life Ratio was estimated following [4].

Ethics Statement

Declaration of Competing Interest

Eloy García-Calvo, Raquel García-Pacheco and Junkal Landaburu-Aguirre, co-authors, are also inventors of the Spanish Patent PCT/EP2016/30931 (08 July 2016): Transformation of spiral wound polyamide membranes after its industrial lifespan.
The authors declare that they have no known competing financial interests or other personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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