SUSTAINABLE SOLUTION FOR WATER AND ENERGY SAVINGS BY REUSING COOLING TOWER BLOWDOWN WATER

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ADQIUIMICA S.A.

Summary:

The study evaluates the increasing in performance gains, water and energy savings, the operating cost reductions and CO_2 emissions reductions that have resulted from the use of a specifically designed phosphorus-free, biodegradable antiscalant and a cleaner that does not contain EDTA or phosphorus in its formulation in a real reverse osmosis plant treating cooling tower blowdown water for reuse.

Prior to ADIQUIMICA's intervention, the reverse osmosis plant was affected by severe biofilm fouling and the membranes had to be cleaned frequently, causing a drastic decrease in performance. In addition, the plant was operating at a lower conversion rate than designed, due to the high fouling power of the water and the use of a non-specific, broad-spectrum anti-fouling agent formulated with organic phosphorus.

Treatment with a specific, biodegradable antiscalant formulated from a synergistic blend of phosphorus-free active ingredients and the use of an environmentally friendly cleaner resulted in sustainable management of the reverse osmosis plant, with an increase in the use of reused water, savings in water consumption and a reduction in discharge. Energy savings were achieved and CO emissions were reduced$_2$. Costs associated with membrane replacement, plant downtime for cleaning and chemical consumption were also reduced.

1 INTRODUCTION

Water scarcity resulting from population growth poses a threat to economic growth, water security and ecosystem health. Industry consumes large quantities of water and produces significant amounts of wastewater. If this wastewater is not adequately treated, its discharge leads to pollution of the environment, adversely affecting aquatic ecosystems and public health. Increased exploitation of water resources due to increased demand, problems arising from climate change such as droughts, pollution of aquatic environments, stricter regulations and rising water prices make water reuse a growing necessity to guarantee water quantity and quality. Water reuse minimises the volume and environmental risk of discharged wastewater, and also reduces the pressure on ecosystems from water abstraction.

In many industrial installations such as in the chemical industry, power generation plants or the oil industry, cooling systems are responsible for a large part of the water consumption. In cooling towers, water that is lost through evaporation, entrainment and blowdown it is supplied as feed water. Reuse of blowdown is an alternative source of water that can be used to feed cooling towers or boilers. The properties of the blowdown water depend on the quality of the cooling tower feed water; the number of cycles of concentration that increase the salinity and fouling species in the water; the degree of microbiological contamination; and the chemicals dosed for anti-fouling, anti-corrosion and biocide treatment of the tower (Ahmed *et al.*, 2020). Reverse osmosis is one of the most widely used technologies in cooling tower blowdown reuse, because it is effective in the salinity range of the blowdowns, and a high recovery rate is achieved with a high quality of treated water. It is necessary to design an appropriate reverse osmosis pretreatment, depending on the quality of the purge water. When the permeate water from the reverse osmosis is reused to feed the cooling towers, it is mixed with the feed water, achieving a reduction in consumption, an improvement in the quality of the feed water, operating the tower at a higher number of cycles of concentration and a reduction in discharge.

Apart from the energy cost of operating reverse osmosis plants, the cost of membrane replacement is also significant. Membrane replacement depends on the lifetime of the membranes. Membranes are replaced when the desired performance is not achieved, i.e. they do not produce sufficient permeate flow or salt rejection is reduced resulting in water with high conductivity. There are two types of factors that reduce the performance of membranes and therefore reduce their useful life, leading to increased energy consumption, operating costs and environmental impact. On the one hand, there are the factors inherent to the membrane and the plant, which are the ageing of the membrane, and the configuration of the plant. When a membrane is installed, its performance progressively decreases due to temperature, pressure, operating time and compaction. On the other hand, there are the factors that can be minimised, extending the membrane lifetime, which are the effects of fouling, and the frequency and effectiveness of chemical membrane cleaning. Membrane fouling is a persistent problem in all reverse osmosis systems. The loss of membrane performance is mostly caused by four types of fouling: fouling and metal fouling, caused by the precipitation of low solubility inorganic salts and metal oxides/hydroxides in the reject; adsorption of organic matter; biofilm formation on the membrane surface due to microorganism activity; and membrane surface clogging due to the deposition of colloidal and particulate material (Weinrich et al, 2013 and Goh et al., 2018). In order to maximise the recovery of reverse osmosis systems, prevent fouling and achieve maximum reuse of cooling system blowdowns, it is necessary to design an appropriate and particular treatment for each plant.

The objective of this study is to evaluate the increase in performance, water and energy savings, reduction in operating costs and reduction in CO_2 emissions resulting from the use of a specifically designed phosphorus-free, biodegradable antiscalant and a cleaner that does not contain EDTA or phosphorus in its formulation in a real reverse osmosis plant treating cooling tower blowdown water for reuse.

2 CASE STUDY OF A REVERSE OSMOSIS PLANT TREATING COOLING TOWERBLOWDOWN WATER FOR REUSE

2.1 Description of the plant before the intervention of ADIQUIMICA

Figure 1 shows the process flow diagram for the reuse of cooling tower blowdown from the actual case studyplant.

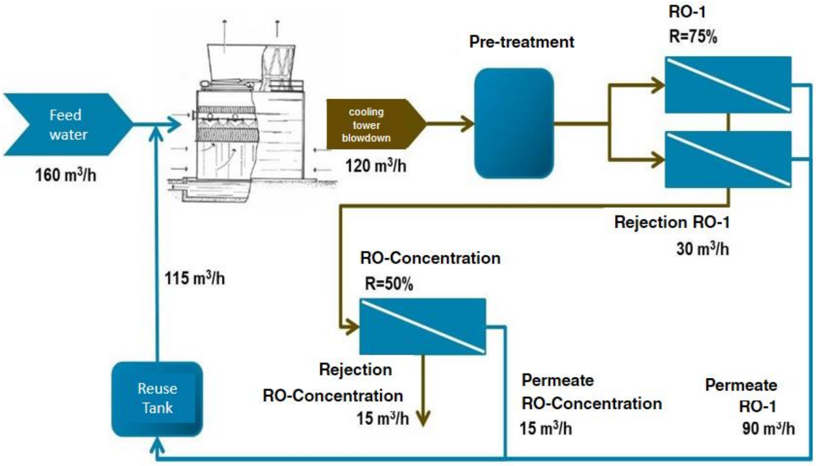

Figure 1. Flow diagram of the cooling tower blowdown reuse process.

Due to the concentration process that takes place in the cooling towers, the blowdown contains a high concentration of salts. The purge flow of 120 m^3 /h is treated for reuse by two equal reverse osmosis lines with pre-treatment. Each reverse osmosis line consists of two stages, operating at 75% conversion. A total permeate flow of 90 m^3 /h is obtained and reused to feed the cooling towers.

In order to increase the flow rate reused as input to the cooling towers, the 30 m^3 /h rejection flow from the reverse osmosis lines that treat the purges feeds a reverse osmosis for the recovery of rejects. This water has a high concentration of scaling salts. Because of the salinity concentration process that takes place inside thereverse osmosis membranes, there is the possibility of insoluble inorganic compounds exceeding the solubility limit and precipitating on the surface of the membranes. The rejection is where there is the greatest danger of precipitation, due to the high concentration of insoluble salt components. The permeate flow fromthe reject recovery plant is also reused to feed the cooling towers. The reverse osmosis reject recovery plantconsists of two stages with a configuration of three pressure tubes in the first stage and two tubes in the second stage. Each tube contains 6 8040 HYDRANAUTICS ESPA2-LD membranes.

Before ADIQUIMICA's intervention, to prevent the formation of scale on reverse osmosis membranes, a conventional treatment was carried out with the dosing of a non-specific broad-spectrum anti-scalant formulated on the basis of organic phosphorus. The performance of reverse osmosis for reject recovery waslimited by the high scaling potential of calcium sulphate in the reject. The formation of calcium sulphate scale occurs when the individual ionic species of sulphate and calcium reach a concentration that exceeds solubility limits. Oversaturation of calcium sulphate results in scale formation. Calcium sulphate is a crystalline salt that precipitates in the form of needles forming very stable rosettes or stars, which grow as scale that is very difficult to remove. The solubility of calcium sulphate with respect to temperature is similar to that of calciumcarbonate, i.e. solubility decreases with increasing temperature. However, while the precipitation of calcium carbonate can be minimised by decreasing the pH with acid dosage, the solubility of calcium sulphate has very little dependence on pH. Therefore, calcium sulphate precipitation cannot be prevented by lowering the feed pH, consequently, scale cannot be removed by using acidic cleaning agents. Calcium sulphate fouling leads to a decrease in permeate flow rate, an increase in feed pressure, an increase in Delta P and an increase in the passage of salts. This effect is more important in membranes located in the last positions of the installation.

The design conversion of the reverse osmosis reject recovery was 65%. However, due to the high calcium sulphate fouling potential of the water in the concentrate, operating at the design conversion the broad- spectrum antiscalant that was dosed was not effective in preventing its precipitation. In order to protect the membranes from calcium sulphate fouling, the conversion had been lowered to 50%. By operating at a lower conversion than design, the fouling potentials of calcium sulphate and other insoluble species had been reduced. The fouling power of the water at 50% conversion was within the limits of effectiveness of the broad spectrum antiscalant. However, the design permeates flow rate being reused was reduced to 15 m^3 /h. Therefore, the total reuse of the cooling tower blowdowns was 87.5%, which corresponded to the sum of the permeate flow rate of the two reverse osmosis lines treating the blowdowns (90 m^3 /h) and the permeate flow rate of the reject recovery reverse osmosis (15 m^3 /h). The total reject from the reuse system was 15 m /h.[3]

On the other hand, the reject recovery plant showed symptoms of severe fouling, which required frequent chemical cleaning. Figure 2 shows the evolution of the normalised permeate flow rate. Normalised parameters are the best indicators of membrane fouling. The normalisation of the operating data was performed according to ASTM *D 4516 Standard Practice for Standardizing Revere Osmosis Performance Data* (American Society for Testing Materials, 2010). The performance of a reverse osmosis plant is influenced by feed water composition, feed pressure, temperature and conversion. Variation in any of these variables implies variation in productivity and permeate water quality. Normalisation makes it possible to distinguish whether the loss of performance is due to the variation of these variables, or whether it is due to fouling. The normalised permeate flow rate is calculated from the plant permeate flow rate corrected for composition, temperature and pressure variables at the time of the flow measurement reading, and compared to a reference value. Therefore, a loss of performance in the standardised parameters is attributed to fouling processes only.

The normalised data indicate that, during the period studied, the normalised permeate flow rate progressively decreased by 46% from 14 to 7.5 m^3 /h. Seven chemical cleanings were carried out over a period of one year. The high frequency of cleaning and the cleaning protocols applied were ineffective and failed to restore the normalised permeate flow.

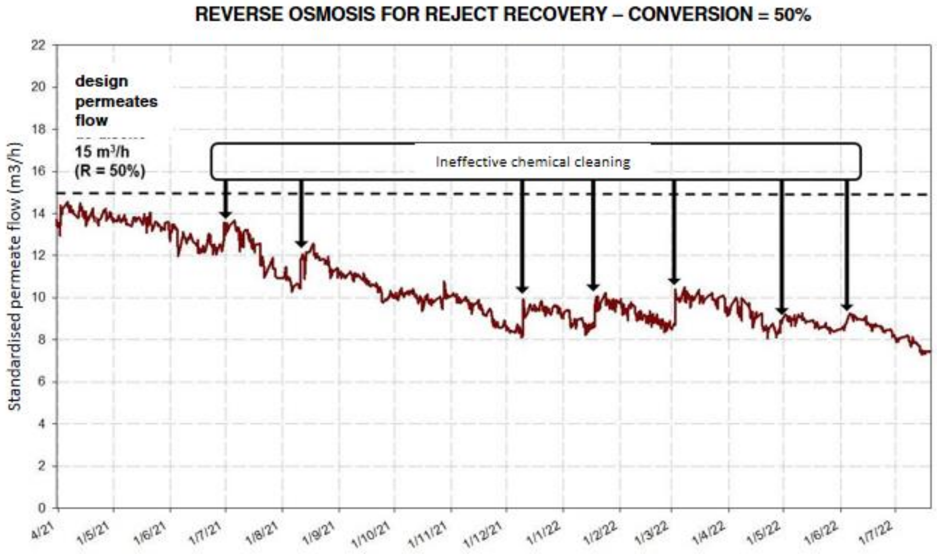

Figure 2. Standardised permeate flow rate of the reject recovery RO. Design flow rate operating at 50% conversion and frequency of chemical cleaning.

3 IMPROVEMENT ACTIONS TO INCREASE THE PERFORMANCE OF THE REVERSE OSMOSIS PLANT FOR REJECT RECOVERY

In order to increase the performance of the reverse osmosis reject recovery, ADIQUIMICA established two improvement actions:

1. Increase plant conversion and minimise reject volume by dosing a specific antiscalant to inhibit calcium sulphate precipitation, formulated from a synergistic blend of biodegradable and phosphorus-free active ingredients.
2. Implement an effective cleaning protocol to restore membrane performance, and establish a preventive programme to minimise fouling and frequency of cleaning.

3.1 Strategy to increase the conversion of reject recovery reverse osmosis

3.1.1 Phosphorus-free, biodegradable antifouling agent specifically for inhibiting the formation of calcium sulphate fouling

In order to increase the conversion of reverse osmosis reject recovery to the design value of 65%, the specific antiscalant ADIC RO-64 AdicGreen was developed with a high efficiency to inhibit the formation of calcium sulphate scale in membrane systems. It is also effective against the formation of other inorganic scale such as calcium carbonate, barium sulphate, strontium sulphate, calcium fluoride and calcium phosphate, as well as inhibiting the formation of iron, aluminium, silica and manganese deposits.

Antiscalants containing phosphorus in their formulation are widely used for scale control in reverse osmosis systems. However, their low biodegradability and phosphorus content are some of the reasons for concern about the environmental impact of the discharge of these compounds. When phosphorus-containing antiscalants are discharged, they can act as a source of nutrients for algae and bacteria, and can cause eutrophication (Fritzmann *et al*, 2007). Consequently, environmental regulations and quality requirements for the rejection quality of reverse osmosis plants are becoming increasingly restrictive with regard to the discharge of chemicals used in water treatment. In this context, the anti-scalant developed is formulated from a synergistic blend of active ingredients that do not contain phosphorus in their composition. Furthermore, it is a biodegradable product according to the standard method for the assessment of biodegradability OECD 302 B (OECD, 1992). The biodegradability tests determine the susceptibility of the antiscalant to microbial degradation under ambient conditions, so that its safety can be established when poured. In the experimental tests, the biodegradation process is monitored by determining the COD (chemical oxygen demand) of different mixtures containing the developed antiscalant, nutrients and active sludge over a period of 28 days.

3.1.2 Software for antifouling treatment design, modelling of water ionic equilibria and prediction of fouling potentials

To design the optimal antiscalant treatment operating at the design conversion rate of 65%, it is essential, on the one hand, to accurately model the composition and behaviour of the water inside the membranes, and to predict the formation of scale very accurately. On the other hand, it is also essential to have an antifouling dosing model. The ADICRO application is a software developed entirely by ADIQUIMICA (Adroer *et al.*, 2001), which for more than 30 years has been meeting these objectives by providing knowledge and effective treatment of reverse osmosis plants with a minimisation of operating costs and environmental impact. It is a programme in constant improvement and innovation, based on the knowledge acquired in laboratory and pilot plant tests, on the experience acquired in real plants and on the most recent scientific bibliography. The ADICRO software makes it possible to determine very precisely the fouling potentials and to calculate the minimum antifouling dosage to ensure complete protection of the membranes.

3.1.3 Design of anti-fouling treatment of reverse osmosis reject recovery system

The objective of the study was to determine the optimum dosage of the specific antiscalant to operate at the design conversion of 65% without danger of calcium sulphate scaling. A simulation study was carried out using ADICRO software based on the composition of the feed water from the reverse osmosis reject recovery plant, with a high concentration of sulphate (3368 mg/L SO_4) and calcium (1316 mg/L Ca). Table 1 shows the composition of the feed water and reject water operating at 65% conversion.

The ADICRO software was used to calculate the fouling power of the reject water operating at 65% conversion and the optimum dosage of the specific antiscalant to prevent fouling. The ADICRO software calculates the fouling potentials, which allow the fouling hazard in the reject to be determined. The fouling potential is expressed as the percentage of the maximum permissible limit for the different supersaturation and fouling rates. A fouling potential higher than 100% means that the corresponding supersaturation index is higher than the maximum permissible limit for this index and that the insoluble compound can precipitate. The simulation results indicated that the fouling potentials without antiscalant treatment of calcium carbonate, calcium sulphate, calcium fluoride, calcium phosphate, strontium sulphate, iron and silica exceeded the value of 100%, indicating that there was a risk of membrane fouling by these compounds. With the dosing of the specific antiscalant, the fouling potentials for these insoluble compounds decreased to values below 100%.

Table 1. Composition of reject recovery reverse osmosis feed water and concentrate water at 65% conversion

Parameter	**Water supply**	**Reject water (Conversion=65%) simulated (ADICRO software)**
pH	7.50	7.78
Calcium	1316 mg/L Ca	3730 mg/L Ca
Magnesium	353 mg/L Mg	1001 mg/L Mg
Sodium	1185 mg/L Na	3361 mg/L Na
Potassium	95 mg/L K	269 mg/L K
Strontium	10.2 mg/L Sr	28.9 mg/L Sr
Iron	0.12 mg/L Fe	0.33 mg/L Fe
Aluminium	0.04 mg/L Al	0.12 mg/L Al
Sulphate	3368 mg/L SO_4	9546 mg/L SO_4
Chloride	2563 mg/L Cl	7264 mg/L Cl
Fluoride	0.39 mg/L F	2.52 mg/L F
Bicarbonate	255.2 mg/L HCO_3	583.9 mg/L HCO_3
Carbonates	3.3 mg/L CO_3	21.9 mg/L CO_3
CO_2	13.3 mg/L H_2CO_3	13.3 mg/L H_2CO_3
Nitrate	103 mg/L NO_3	292 mg/L NO_3
Silica	45 mg/L SiO_2	128 mg/L SiO_2
Phosphate	0.17 mg/L PO_4	0.49 mg/L PO_4
Ionic strength	0.173	0.436

Figure 3 shows the simulated results of the reduction of the scaling potentials of the reject water with the dosing of the specific antiscalant. It is concluded that, with the dosing of the specific antiscalant and operating at the design conversion of 65%, the system is perfectly protected against fouling and scale formation, including calcium sulphate.

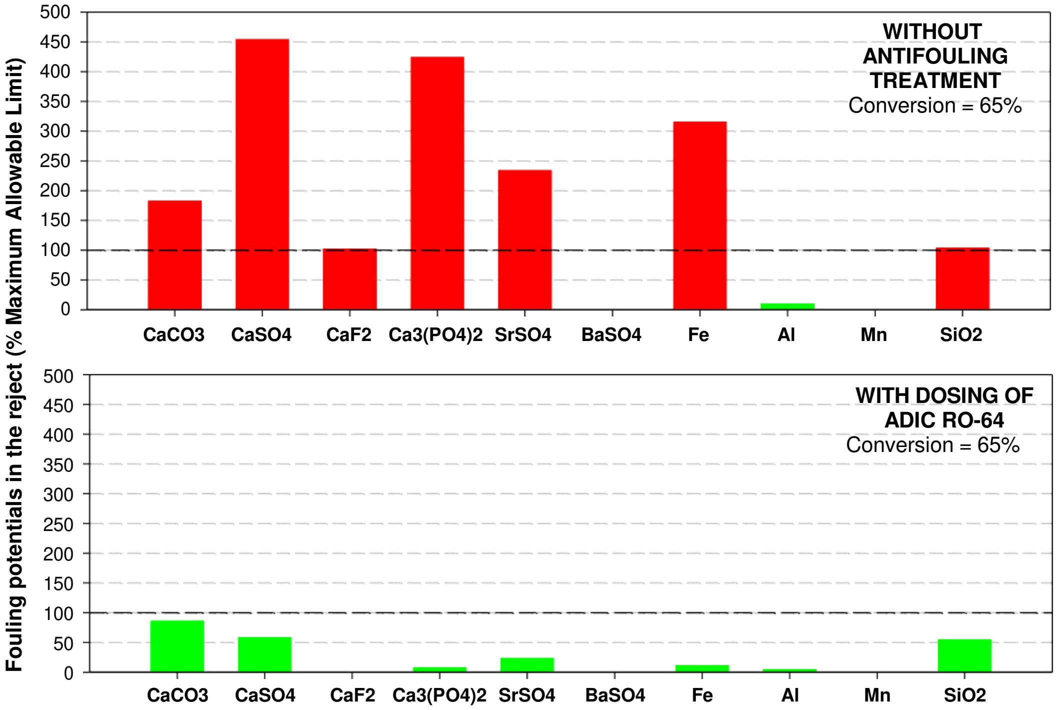

Figure 3. Fouling potentials in the reject for each insoluble species without antiscalant treatment and withdosing of the specific antiscalant operating at 65% conversion.

3.2 Strategy for the control and prevention of fouling of reverse osmosis membranes

3.2.1 Characterisation of membrane fouling

The reject recovery plant showed symptoms of severe fouling, which required frequent chemical cleaning. In order to characterise the fouling affecting the membranes, an autopsy of a HYDRANAUTICS ESPA2-LD element from the first position of the first stage of the reject recovery plant was performed.

Autopsy results indicated that the membrane surface was contaminated by an abundant layer of deposit (Figure 4) corresponding mostly to biofilm (Vrouwenvelder *et al.*, 2010 and Matin *et al.*, 2011).

Figure 4. Appearance of the membrane surface and the plastic food-rejection spacer heavily contaminatedwith biofilm.

3.2.2 *Effective cleaning protocol and preventative programme for fouling control*

The high number of chemical cleanings that had been carried out before ADIQUIMICA's intervention were not effective. For this reason, after determining the composition and fouling mechanism of the membranes by autopsy, cleaning tests were carried out in a reverse osmosis pilot plant using samples of the autopsied membrane. The aim of the cleaning tests was to design the most effective cleaning protocol for biofilm removal taking into account environmental and economic criteria.

3.2.2.1 Environmentally friendly cleaning product free of phosphorous and EDTA

Both cleaning products and cleaning protocols play a key role in restoring membrane performance. Standard cleaning protocols using generic chemicals are often ineffective and do not remove fouling. If the cleaning products are not appropriate, the desired efficacy may not be achieved or the membrane may be damaged. The use of formulated cleaners ensures high efficacy and compatibility with the membranes, extending their service life. Formulated cleaners are a blend of ingredients that act synergistically. These products include active ingredients that remove specific fouling.

Cleaning products containing ethylenediaminetetraacetic acid (EDTA) and phosphorus in their formulation are widely used for the cleaning of reverse osmosis membranes. However, their biodegradability and phosphorus content are some of the reasons for the growing concern about the environmental impact of discharging these compounds. The fact that EDTA is not biodegradable means that it is found in considerable quantities in water, with serious environmental consequences. Discharges of phosphorus-containing products can lead to eutrophication because they are a source of nutrients for algae and bacteria.

The chemical cleanings were carried out using the innovative and environmentally friendly liquid cleaner ADICLEAN 202 AdicGreen. It is an alkaline pH liquid cleaner, which does not contain EDTA or phosphorus in its formulation. It is a highly formulated product containing environmentally friendly active ingredients that replace non-biodegradable active ingredients that contribute to eutrophication. It is highly effective in removing biofilm and alumino-silicate (clay) fouling. It is effective at low doses and is economically viable. Its use reduces operating costs and minimises the environmental impact of disposal.

3.2.2.2 Optimisation of the chemical cleaning protocol for biofilm removal

The results of the cleaning tests indicated that the most effective cleaning protocol to remove biofilm and restore membrane performance consists of the following steps:

1. Sanitisation with the use of the non-oxidising biocide compatible with ADICLEAN 128 reverse osmosis membranes.
2. Cleaning with an alkaline product ADICLEAN 202 AdicGreen formulated with the ability to penetrate, reach and completely remove the inner layers of biofilm. The cleaner is also effective in removing alumino-silicates.

The cleaning protocol was designed according to the membrane manufacturer's recommendations regarding pressure, flow rate, pH and temperature of the cleaning solution.

3.2.2.3 Maintenance programme for biofilm control

It was recommended to apply a maintenance programme for biofilm control with a non-oxidising biocide compatible with the RO membranes. This minimised and controlled microbiological growth on the surface of the reverse osmosis membranes.

4 RESULTS OF IMPROVEMENT ACTIONS

4.1 Increased performance

In July 2022, the integral solution proposed by ADIQUÍMICA was applied in the reverse osmosis plant for the recovery of rejects, which consisted of the following improvement actions:

1. The chemical cleaning protocol combining the non-oxidising biocide ADICLEAN 128 and the environmentally friendly cleaner ADICLEAN 202 AdicGreen was applied.
2. Dosing of the phosphorus-free, biodegradable antiscalant ADIC RO-64 AdicGreen was started with a high efficiency in inhibiting calcium sulphate scale formation, which increased the plant's conversion to the design value of 65%.
3. The maintenance programme for biofilm control was applied.

Figure 5 shows the evolution of the normalised permeate flow rate before and after applying the improvement actions. By applying the proposed cleaning protocol, the membrane performance was restored to its design values. The dosing of the specific antiscalant for calcium sulphate allowed the plant's conversion to be increased to the design value of 65%, with an average normalised permeate flow rate of 19.5 m^3 /h. The normalised permeate flow rate increased by 30% over the previous design flow rate, when operating at 50% conversion. The dosing of specific antiscalant and the maintenance programme for biofilm control have kept the permeate flow rate stable at the maximum design value, with no symptoms of scale formation or biofilm fouling. The plant has operated for 6 months without stoppages for chemical cleaning, extending the useful life of the membranes.

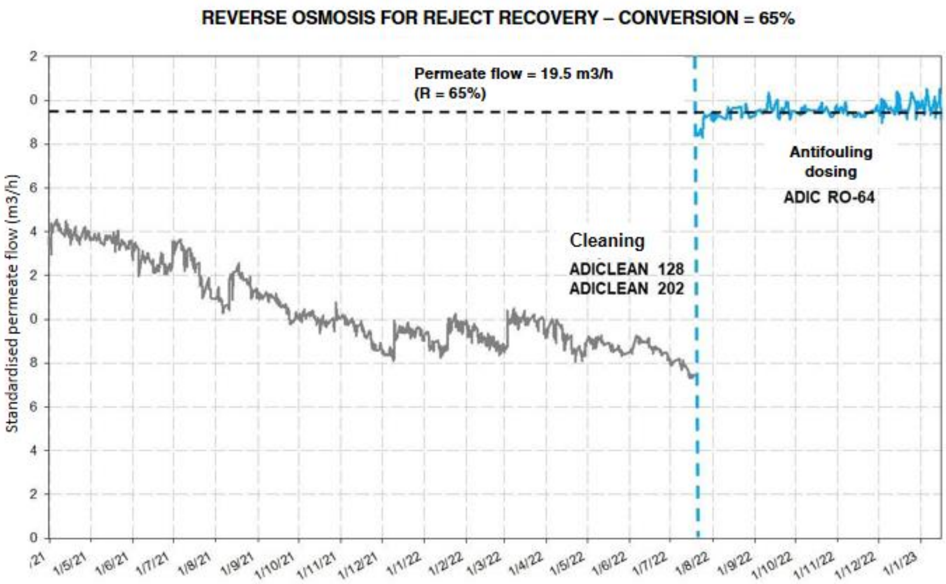

Figure 5. Evolution of the normalised permeate flow after implementation of the improvement actions.

4.2 Water and energy savings, cost reductions and contribution to sustainability

The high efficiency of the environmentally friendly antiscalant and liquid cleaner, as well as the appropriate maintenance treatment, improved plant performance by increasing conversion, and prevented membrane fouling. This increased performance led to an increase in permeate flow rate while operating at lower feed pressures, thereby reducing energy costs and reducing the carbon footprint. The energy savings and CO_2 emissions reductions achieved by the implementation of the improvement actions were determined. Specific energy consumption, which corresponds to energy consumption per m^3 of permeated water expressed in kWh/m^3 (Li, 2013), and CO emissions$_2$ (Ministry for Ecological Transition, 2022) were calculated in the following scenarios: (a) before ADIQUIMICA's intervention and (b) after implementing the improvement actions. Table 3 corresponds to the calculation of the specific energy consumption and CO emissions$_2$ under the operating conditions of each scenario.

The results indicate that in July 2022, before ADIQUIMICA's intervention, due to the massive fouling affecting the membranes, it was operating at a feed pressure of 18.8 bar, corresponding to the maximum limit of the pump. This high pressure resulted in high energy consumption. Although operating at maximum pressure, the permeate flow produced was 8.9 m^3 /h with a conversion rate of 31%. These values were significantly lower than the initial design conditions of 15 m^3 /h production at 50% conversion. The specific energy consumption required was 2.12 KWh/m^3 .

With the implementation of the improvement actions, the plant's performance increased. In January 2023, the permeate flow rate increased to 19.4 m^3 /h, operating at 65% conversion. The specific energy consumption under these conditions was 0.76 KWh/m^3 . Therefore, the flow rate was increased by 118% and the specific energy consumption was reduced by 64% compared to the operating conditions with the membranes affected by massive fouling. These results lead to an annual energy saving of 6141 €, assuming an electricity cost of 0.17 €/KW. The annual reduction of CO_2 emissions was 17.7 Tn, which corresponds to a 35% reduction.

Table 3. Specific energy and CO_2 emissions before and after implementing the improvement actions in the rejects recovery plant.

Date	July 2022 (Before the intervention of ADIQUIMICA)	January 2023 (After implementing ADIQUIMICA improvement actions)
Permeate flow rate	8.9 m^3/h	19.4 m^3/h
Feed flow rate	29.2 m^3/h	29.8 m^3/h
Conversion	31 %	65 %
Feed pressure	18.8 bar	14.4 bar
Specific energy consumption per m^3 of permeate	2.12 KWh/m^3	0.76 KWh/m^3
Energy consumption	18.9 KWh	14.7 KWh
Annual energy consumption	165284 KWh/year	129157 KWh/year
Annual electricity cost	28098 €	21957 €
CO_2 emissions	51.2 Tn/year	33.5 Tn/year

The improvement actions have also led to sustainable management by increasing the use of reused water as an input for the cooling towers. Water consumption has been reduced and discharge has been reduced, with the consequent economic savings. Biodegradable and environmentally friendly chemical products are used to minimise the impact of their discharge into the environment. The minimisation of fouling problems has led to a reduction in costs associated with plant stoppages for chemical cleaning, the consumption of chemical products and the replacement of membranes due to the increase in their useful life.

5 CONCLUSIONS

One of the key factors limiting the operation of reverse osmosis plants is water quality. The design of a sustainable and specific treatment for reverse osmosis plants that treat cooling tower blowdown water for reuse leads to a reduction in cooling tower feed water consumption and minimisation of discharge water, with consequent economic savings and environmental benefits.

Reverse osmosis performance was increased by applying a customised treatment that included chemical cleaning of the membranes using an environmentally friendly cleaner that does not contain EDTA or phosphorus in its formulation; the dosing of a biodegradable, phosphorus-free antiscalant with high efficiency in inhibiting the formation of calcium sulphate scale; and the application of a maintenance programme for biofilm control. These improvement actions achieved:

- Eliminate the massive fouling affecting the membranes and restore their performance to design values.
- Increasing plant performance by increasing conversion to the design value, avoiding fouling.
- Reducing energy consumption and costs by operating at a lower feed pressure.
- Reducing carbon footprint by reducing CO emissions$_2$.
- Increasing the flow of reclaimed water for reuse and reduce discharge.
- Maintaining clean membranes and no plant shutdowns for chemical cleaning, reducing costs associated with shutdowns and chemical consumption.
- Extend the life of membranes, reducing the costs associated with membrane replacement.
- Use biodegradable and environmentally friendly chemicals that minimise the impact of their discharge into the environment.

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