https://doi.org/10.48047/AFJBS.6.15.2024.10471-10482

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

# Quality control and evaluation of the desalination process of drilling water by the reverse osmosis technique (Calgaz Ouargla desalination plant)

**Yasmina MOKHBI[1], Soumia RAHMOUNI[2], Zineb AKCHICHE[1], Bakhta RECIOUI[2], Rebha GHEDAMSI[2], Ahmed El Mahdi MESKINE[1]**

[1] *Process Engineering Laboratory (PEL), Kasdi Merbah University, Ouargla, 30000, Algeria.*
[1] *Laboratoire Dynamique, Interactions et Réactivité des Systèmes (DIRE)*
[2] *Resource Valorization and Promotion Laboratory Saharan Islands (LVPRS), Kasdi Merbah University, B.P. 511, 30000, Ouargla, Algeria*

*Corresponding Author: mokhbi.yasmina@univ-ouargla.dz, mokhbi26@gmail.com

**Article History**
**Volume 6, Issue 15, 2024**
**Received : 11 Jul 2024**
**Accepted : 20 Sep 2024**
**Published: 20 Oct 2024**
doi: 10.48047/AFJBS.6.15.2024.10471-10482

**Abstract**
In this study, we examined the efficacy of reverse osmosis groundwater treatment. Calgaz Company uses this method in its desalination facility, where groundwater is introduced into the system and treated to get rid of pollutants and impurities. Reverse osmosis technology is one of the most well-known methods for purifying water. It is based on the use of a semi-permeable membrane that allows pure water to pass while retaining large molecules and pollutants. The process involves several steps, starting with preliminary filtration to remove large particles, and then the water passes through a high-pressure pump that pushes it through the membranes. Then, the pure water is collected in a storage tank, while the water concentrated in pollutants is discharged. This pure water is used in various industrial and agricultural applications and even for consumption after additional treatment.

Water samples were collected at the inlet and outlet of the station, and then this study was conducted by tracking the changes in physical and chemical elements: pH, electrical conductivity, TAC, HT, AT and $Cl^-$ concentration. The results of comparing the measured values of each element with the established standards showed that the reduction efficiency exceeded 90 %, meaning that the water at the outlet of the treatment station is of very good quality.

**Keywords:** Reverse osmosis, Groundwater, Semi-permeable membrane, Filtration.

## 1. Introduction

Rapidly changing urban and industrial environments have created significant challenges for water management worldwide. The increasing demand for quality water, combined with increasing pressure on resources, requires innovative solutions to ensure a safe and sustainable water supply.

Technological advances in water management, including membrane processes such as reverse osmosis, electrodialysis, nanofiltration and distillation, have opened new avenues for water treatment and purification [Randy Ncube and Freddie L. Inambao, 2019, Khaled Walha et al. 2008]. These advances offer efficient ways to produce drinking water from unconventional sources such as seawater or treated wastewater [M. Chávarro, 2015].

Reverse osmosis is widely used for seawater desalination to meet drinking water needs in arid or coastal regions. Similarly, nanofiltration and other membrane techniques are being used for water reuse in industries, helping to reduce pressure on freshwater resources [Sunil J. 2013, Robert J. 1993].

These technologies play a crucial role in sustainable water management by enabling more efficient and responsible use of water resources. They help meet the growing demand for water while minimizing the environmental impact associated with its treatment and distribution [Sunil J. 2013, Satish K., et al. 2023, Shahid A. et al. 2024]. By investing in these innovative technologies, countries can build resilience to water challenges and ensure a safe water supply for future generations [Khaled Walha et al. 2008, Robert J. 1993, Lee, K. et al. 2011]. This technology is widely used in a variety of water treatment applications, including the production of drinking water from seawater [Bruggen, B., and Vandecasteele C., 2002], brackish water, contaminated groundwater, and surface water [Z. Yang et al., 2019, Paul Fu,1995, Loeb, S.1965]. It is also used in industry for wastewater treatment, industrial water recycling, pharmaceutical and electronics water production, and other specialized applications [Schaep J., 1998, Gorenflo, A., 2002].

Teodosiu et al. (1999) studied the possibilities of using ultrafiltration as a pre-treatment for RO, in a membrane filtration system which can assure the water quality requirements needed for recycling secondary (biologically) treated refinery effluent as cooling water make-up. In this system, ultrafiltration can remove suspended, colloidal material, bacteria and viruses and organic compounds, while RO removes dissolved salts, thus leading to a lower consumption of corrosion inhibitors, anti-scaling agents, biocides and chemicals in the cooling tower. The treatment of oil shale retorting wastewaters with organics (phenolics and aliphatic acids), inorganics (alkalinity, $NH_3$, $Cl^-$, $S^{2-}$), oils, suspended solids, color, and odor using RO membranes was reported by Siler and Bhattacharyya (2002).

In Algeria, Sadi and Kehal (2002) and Kehal (2003) conducted experiments on a reverse osmosis desalination plant installed in Hassi Khebi (south-eastern Algeria) with a capacity of 0.85/h driven by a photovoltaic generator. This unit was acquired as part of the collaboration between the research center CDER (Algeria) and the Commissariat a l'Energie Atomique (CEA France). They presented the evolution of power and pressure versus time; the results were encouraging during the experimentation period, giving a conversion rate of 40.7%.

## 2. Reverse Osmosis

Reverse osmosis is a water purification method that uses essential physical and chemical principles to purge raw water of contaminants, impurities, and dissolved salts [Randy Ncube and Freddie L. Inambao, 2019, N.A. Khan, 2019]. In this approach, a semi-permeable membrane is used to selectively allow water molecules to pass through while retaining unwanted particles. External pressure is applied to the solution to be treated, forcing the water through the membrane, leaving the contaminants and impurities trapped on the other side (Figure1).

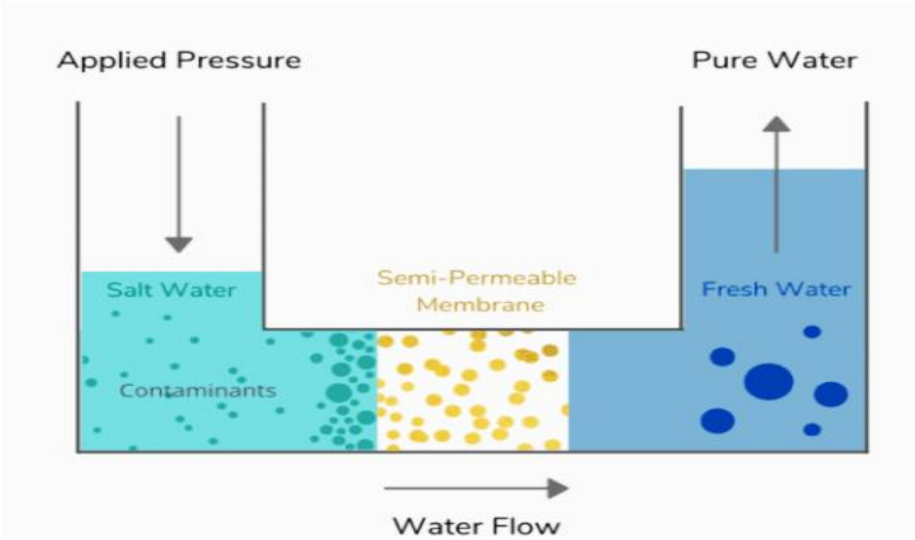


**Figure1**: Reverse Osmosis Water Treatment Process.

## 3. Reverse osmosis membranes

Reverse osmosis membranes are used in the form of flat, tubular, hollow fiber, or spiral modules (Figure 2), and the module(s), placed in series or in parallel, are inserted into the production process as shown in figure 3. The reverse osmosis membranes used in the RO unit are of the dense type; they are made up of a superposition of several layers of polymers (composite membranes), often polyamide. The other materials constituting the support are not involved in the process.

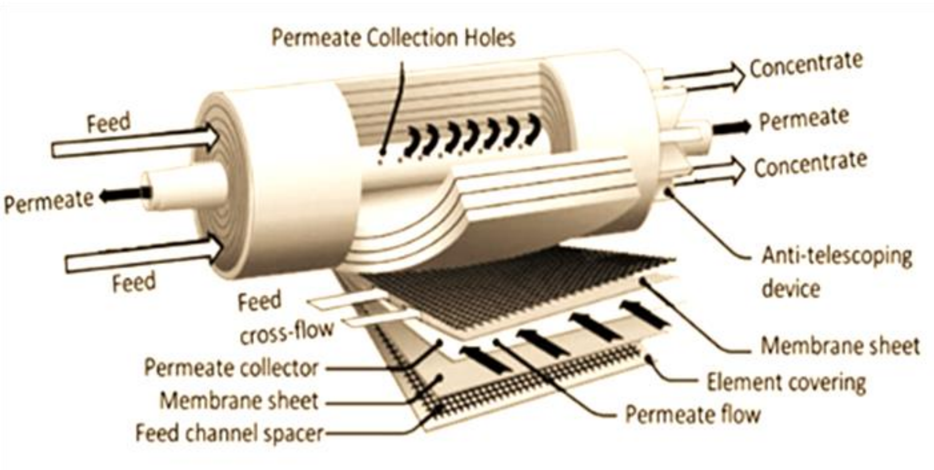


**Figure 2:** Reverse osmosis module schematic showing raw water inlet and permeate and brine outlet.

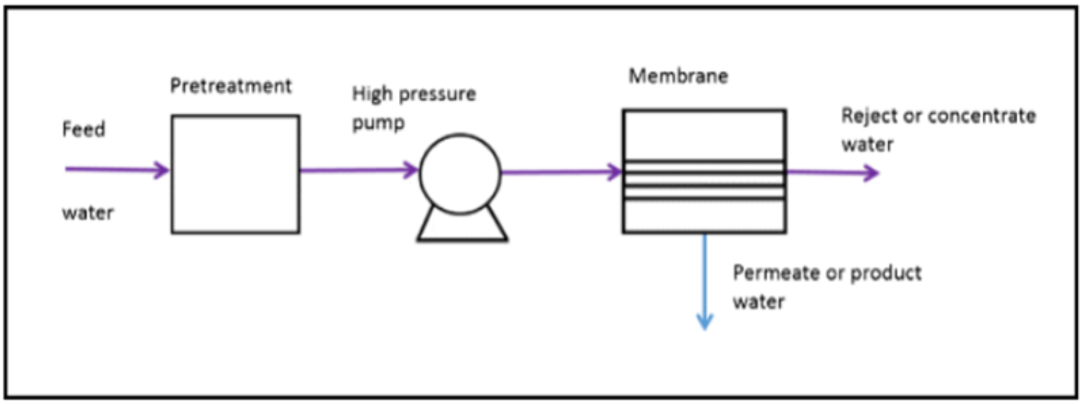


**Figure 3:** General diagram of water treatment by reverse osmosis.

In the majority of cases, these modules are used in tangential filtration (the flow of water to be treated circulates parallel to the membrane, the filtrate or permeate passing through it perpendicularly) to minimize the accumulation of salts on the membrane, which leads to rapid clogging.

## 4. Geographical location of the desalination plant

Drilling water is the raw material for the Calgaz desalination plant. This plant is located in Ouargla province at the exit of the city (Hay Ennasr). This area is located about 15 km from the capital of the province and about 180 km from the province of Ghardaia. It is bordered by the RN°49 national road that leaves Ouargla and heads towards Ghardaia. It is located opposite the Guelala production center and about 3 km away from it. It is also located about 20 km from the Berkaoui oil production basin towards Ghardaia.


**Figure 4:** Geographical location of the Calgaz complex.

## 5. Materials and Methods

### 5.1.Raw water treatment processes by reverse osmosis

The essential elements of a reverse osmosis installation include:

- Membranes and modules ;
- High-pressure pump and many storage tanks, as well as all the required measuring instruments (conductivity meter, flow meter, pressure gauge, thermometer, etc.);
- Measuring pumps;
- Pretreatment station ;
- Dosing pumps ;
- Sand filter (figure 5);
- Cartridge filter (figure 6).

**Figure 5**: Sand filter **Figure 6**: Cartridge filter

**5.2.Experimental protocol**

The water treatment process begins with drilling raw water, which is then stored in a tank with a capacity of 500 cubic meters. The amount of raw water is estimated at 100 cubic meters per day.

Then, we add 48° chlorometric bleach to the raw water tank at a rate of 10 ml/$m^3$. Then, the water is pumped to a sand filter where impurities and suspended particles are removed. The water enters at a flow rate of 26 $m^3$/h and exits at a flow rate of 21$m^3$/h. Then, the water passes through three cartridge filters, two of them have a pore size of 5 um and one with a pore size of 1 um.

Then, the antiscalant is added to the water before it enters the reverse osmosis system, at a rate of 6 ml/$m^3$, where it helps inhibit the formation of calcium and mineral deposits in the reverse osmosis system. Sodium bisulfite is also added to the water at a rate of 8ml/$m^3$. Sodium bisulfite also acts as an antioxidant agent by preventing the oxidation of compounds present in the water, which can help preserve the quality of the treated water and extend the life of the treatment equipment (reverse osmosis membranes).

The filtered water passes through the $1^{st}$ stage of the reverse osmosis system under pressure of the order of 10.2 bars exerted by a high-pressure pump.

The permeate (osmosis water) is stored in a 500 $m^3$ tank, and the 1st discharges are introduced into the $2^{nd}$ stage of the osmosis unit under a pressure of 9.1 bars and outlet under pressure of 8.2 bars.

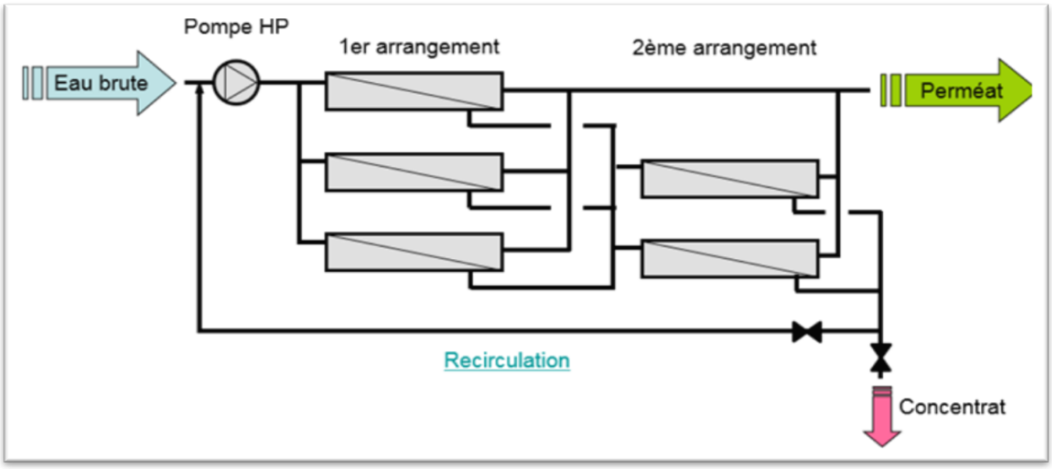


**Figure7:** Reverse osmosis with two stages

### 5.3.Water sampling

Sampling is a critical step in water analysis and must be carried out carefully to ensure accurate and representative results. Water sampling at the study sites consists of opening a water outlet valve, then letting the water flow for a few minutes. The water will be collected and placed directly in 500 ml glass bottles labeled (site name and sampling date). The samples collected are immediately sent to the Calgaz reverse osmosis unit laboratory for various physicochemical analyses.

## 6. Results and Discussion

A summary of the results of physical and chemical analyses of drilling water during and after treatment with reverse osmosis technology is shown in the following table:

**Table 1:** Physical and chemical properties of drilling water before and after treatment

| Days | points | pH | Conductivity | Total HT | TAC | AT | $Cl^-$ |
|---|---|---|---|---|---|---|---|
| 15/01/2024 | E | 7,5 | 2702 | 95 | 15 | 00 | 355 |
| | S | 6.9 | 28 | 0.7 | 1.8 | 00 | 4.1 |
| 16/02/2024 | E | 7.85 | 2650 | 70.4 | 08 | 00 | 325.7 |
| | S | 6.9 | 29.7 | 0.8 | 1.5 | 00 | 9.3 |
| 17/03/2024 | E | 7.65 | 2311 | 70 | 09 | 00 | 405 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | S | 6.7 | 18 | 0.53 | 1 | 00 | 12 |
| **18/04/2024** | E | 7.2 | 2557 | 86 | 08 | 00 | 354.4 |
| | S | 7 | 31.72 | 0.68 | 2 | 00 | 5.5 |
| **19/05/2024** | E | 7.63 | 2600 | 76 | 07 | 00 | 251 |
| | S | 6.8 | 22 | 0.47 | 1 | 00 | 17 |

**a. pH**

Figure 8 shows the pH levels of the borehole water (incoming water) and the RO water (outgoing water) over a five-month period. In general, the outgoing water has a consistently lower pH level than the incoming water, indicating a slight acidification during the process; this variation is mainly due to the demineralization of the water, which shows the efficiency of the RO membranes in retaining mineral salts (the increase in pH due to the presence of mineral salts such as $Ca^{+2}$, $CO_3^{+2}$, etc.).

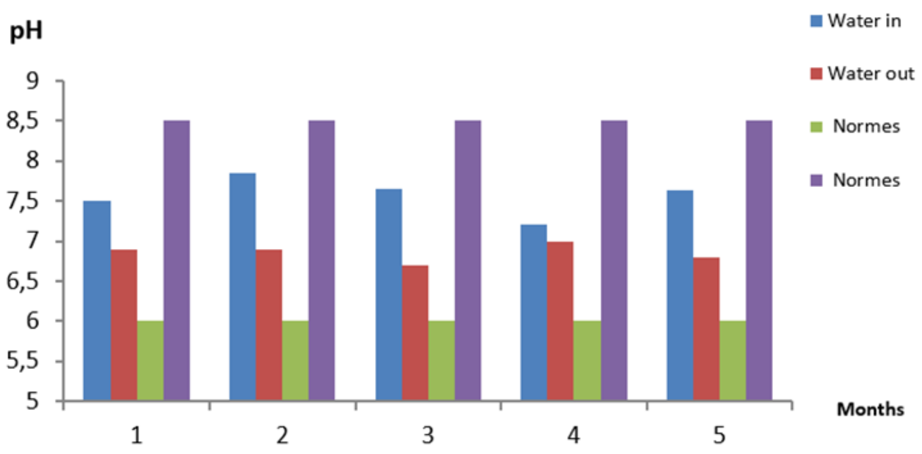


**Figure 8**: Variation in pH of the water analyzed at the inlet and outlet of the reverse osmosis unit.

**b. Conductivity**

Table 1 and Figure 9 reveal a significant variation between the conductivity values measured at the inlet and outlet of the reverse osmosis unit. Before membrane filtration, the conductivity values are considerably higher than after treatment. For the inlet water, the maximum and minimum values recorded are 2702 µS/cm and 2311 µS/cm, respectively, with an average of 2564 µS/cm. This high conductivity is due to the high concentration of mineral ions in the borehole water. In contrast, the water treated by reverse osmosis displays an average of 25,884µS/cm. The results obtained comply with the standards in force, with values lower than 50µS/cm.

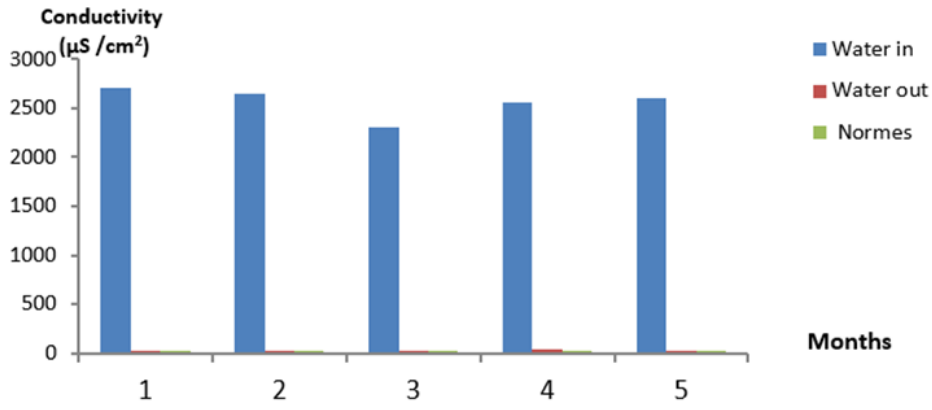


**Figure 9**: Variation in the conductivity of the water analyzed at the inlet and outlet of the reverse osmosis unit.

**c. Total Alkali Content**

The total alkalimetric title (TAC) corresponds to the content of water in alkalis (hydroxides), carbonates and bicarbonates (or alkaline and alkaline-earth hydrogen carbonates). Figure 10 shows the TAC values for the incoming and outgoing water of the reverse osmosis system. On average, the reverse osmosis system shows an effective reduction of TAC, varying between 75% and 88.89%, demonstrating a stable and reliable performance in reducing the alkalinity of the water. This reduction is due to the proper functioning of the osmosis membranes in retaining carbonate and hydrogen carbonate ions. The results obtained are in accordance with the company standards; 0<TAC<2°F.

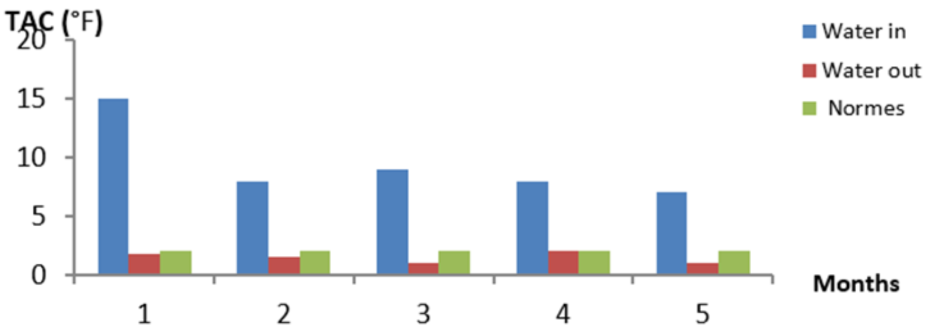


**Figure 10:** Variation in TAC values of water analyzed at the inlet and outlet of the reverse osmosis 1unit.

**d. Total Hydrotimetric Title**

Total hardness or hydrotimetric title "TH" which is the sum of calcium and magnesium concentrations, it is expressed in meq g / L, it is also expressed in French degrees [Amir A., 2012]:

$$1°F = 5 \text{ meq g /L de } ([Ca] + [Mg])$$

Figure 11 shows the evolution of TH of the incoming water (drilling water) and outgoing water (osmosis water) after reverse osmosis treatment. The total TH of the incoming water varies between

70 and 95, while that of the TH outgoing water remains constantly low, oscillating between 0.47 and 0.8. This shows the high efficiency of the reverse osmosis system in removing minerals and salts from the water. This decrease is explained by the elimination of almost all the calcium and magnesium carbonate ions contained in the drilling inlet water. The results obtained comply with the company's standards; 0<TH<1 °F.

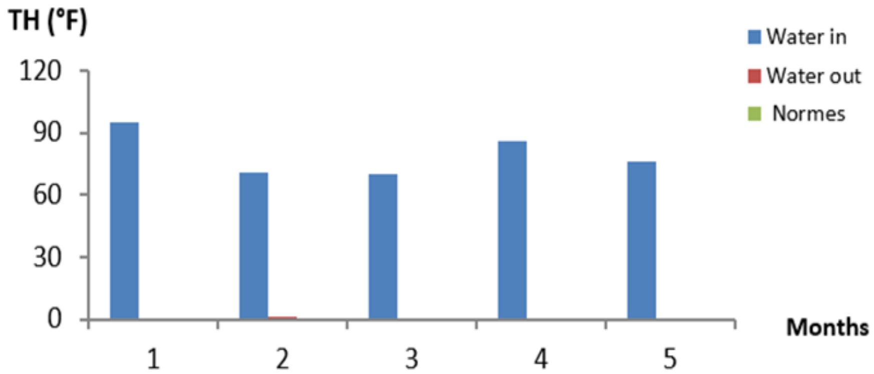


**Figure 11:** Variation of total TH values of water analyzed at the inlet and outlet of the reverse osmosis unit.

**e. Alkalimetric title**

The alkalimetric title (TA) is the quantity used to determine the total concentration of carbonate ion $CO_3^{2-}$(aq) and strong base ($HO^-$) in water. According to the results presented in Table 1, the alkalimetric title of all the water samples analyzed is zero during the study period. This is explained by the fact that the pH values of the analyzed waters are less than 8.3. Therefore, there are no strong bases, carbonates or free alkalis present in the analyzed water samples.

**f. $Cl^-$ Concentration**

The chloride ion has different characteristics from other mineral ions; it is not adsorbed by geological formations, does not combine easily with chemical elements and remains very mobile. This element can be of geological origin and mainly linked to the dissolution of salt or anthropogenic formations [Ouhmidou et al, 2015]. The chloride contents in raw water measured during the study period vary between 405 mg/l and 251 mg/L and are higher than the standard which was set at 70 mg/L.

According to the curve presented in Figure 12, we note that the chloride removal efficiencies obtained at the outlet of reverse osmosis vary between 93% and 98% and the corresponding residual chloride concentrations are much lower than 70 mg/L for all samples.

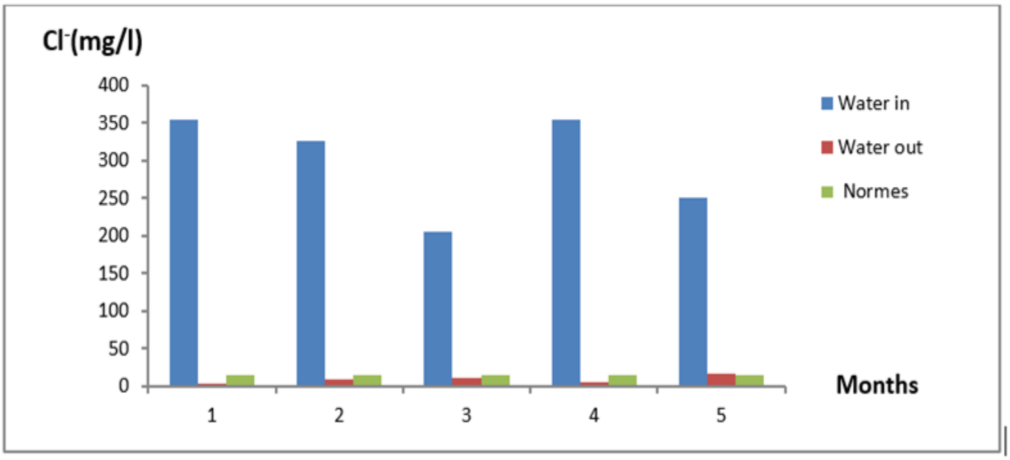


**Figure 12:** Variation of $Cl^-$ Concentration values of water analyzed at the inlet and outlet of the Reverse Osmosis unit.

## 7. Conclusion

The objective of this study was to observe the efficiency of water desalination by the reverse osmosis technique. This is done by monitoring the physicochemical quality of raw and treated water at the desalination plant for borehole water at the Calgaz Ouargla station.

The analyses carried out have demonstrated that the reverse osmosis units produce very good-quality water. The values of the various parameters, such as pH, conductivity, TAC, HT, AT, and $Cl^-$ concentration, are all excellent and comply with the established standards, thus proving the effectiveness of the treatments applied at each stage of the process.

In conclusion, reverse osmosis water treatment is an effective method to produce purified water by removing contaminants using semi-permeable membranes. However, for this process to work properly, pre-treatment is required to remove suspended particles, organic matter, and other contaminants from the raw water. Methods such as sand filtration, coagulation-flocculation, and granular media filtration are used for this. By combining reverse osmosis treatment with proper pre-treatment, it is possible to produce high-quality water for various applications. This process helps in ensuring a clean and safe water supply to meet the needs of society while conserving water resources.

The technology of desalination of groundwater by reverse osmosis is the technology of choice that requires serious study to generalize it throughout Algeria.

**Acknowledgements**

The authors of this paper would like to express their gratitude to all of the people who have assisted us in this work, especially our colleagues from the Department and Laboratory of Process Engineering (PE) at Kasdi Merbah University, Ouargla, for their outstanding contributions to this study.

## References

Amir A. Izadpanah, Asghar Javidnia, **The Ability of a Nanofiltration Membrane to Remove Hardness and Ions from Diluted, Water**, 2012, 4(4):283-294.

Bruggen, B.V.; Vandecasteele, C. **Distillation vs. membrane filtration: Overview of process evolutions in seawater desalination**. Desalination 2002, 143, 207–218.

Gorenflo, A.; Velazquez-Padron, D.; Frimmel, F.H. **Nanofiltration of a German groundwater of high hardness and NOM content: Performance and coast**. Desalination 2002, 151, 253–265.

Kehal, S.: **Retrospectives and perspectives of desalination in Algeria. Desalination**, 2003, 152 (1–3), 113–124.

Khaled Walha, Raja Ben Amar, Francis Quemeneur, Pascal Jaouen, **Treatment by nanofiltration and reverse osmosis of high salinity drilling water for seafood washing and processing Abstract,** Desalination, Volume 219, Issues 1–3, 25 January 2008, Pages 231-239.

Lee, K.P.; Arnot, T.C.; Mattia, D. A **review of reverse osmosis membrane materials fordesalination-Development to date and future potential**. J. Membr. Sci. 2011, 370, 1–22.

Loeb, S.; Sourirajan, S. Sea, **Water Demineralization by Means of an Osmotic Membrane**, Adv. Chem. Ser. 1963, 38, 117–132

M. Ouhmidou, A. Chahlaoui1, A. Kharroubi, M. Chahboune, **Study of the physico-chemical and bacteriological quality of the barrage Hassan Addakhil of Errachidia (Morocco),** J. Mater. Environ. Sci. 2015, 6 (6) 1663-1671.

M. R. Chávarro Roa, **Drilling Wastewater Post-Treatment by Reverse Osmosis Method. Discussion and Practical Results,** Environment and Sustainability Conference, Bogotá, Colombia, July 2015.

N.A. Khan, S.U. Khan, S. Ahmed, I.H. Farooqi, A. Dhingra, A. Hussain, F. Changani, **Applications of nanotechnology in water and wastewater treatment: a review**, Asian J. Water Environ. Pollut. 2019, 16 (4) 81–86.

Paul Fu, Hector Ruiz, Jim Lozier, Ken Thompson, Carl Spangenberg, **A pilot study on groundwater natural organics removal by low-pressure membranes,** Desalination, Volume 102, Issues 1–3, 1995, 47-56.

Randy Ncube and Freddie L. Inambao, **A review of desalination systems using the reverse osmosis technique**, International Journal of Mechanical Engineering and Technology (IJMET) Volume 10, Issue 11, November 2019, pp. 353-370.

Robert J. Petersen, **Composite reverse osmosis and nanofiltration membranes**, Journal of Membrane Science, 1993, 83, 81-150.

Saadi, A., Kehal, S., **Retrospectives and potential use of saline water desalination in Algeria**. Desalination. 152, 51–56 (2002)

Satish Kumar Singh , Chhaya Sharma , Abhijit Maiti, **Modeling and experimental validation of forward osmosis process: Parameters selection, permeate flux prediction, and process optimization,** Journal of Membrane Science**,** 672, 15 April 2023, 121439.

Schaep J Van der Bruggen B Uytterhoeven S Croux R Vandecasteele C and Wilms D E., **Removal of hardness from groundwater by Nanofiltration Desalination,** 1998,119(1-3) pp 295-301.

Shahid Aziz, Abdur Rehman Mazhar, Ali Ubaid, Syed Muhammad Hamza Shah, Yasser Riaz, Tariq Talha & Dong-Won Jung**, A comprehensive review of membrane-based water filtration techniques,** Applied Water Science**,** Volume, 2024,14, 169.

SILER JL, BHATTACHARYYA D. **Low pressure reverse osmosis membranes: concentration and treatment of hazardous wastes**. Hazard Waste Hazard Mater. 1985; 2(1):45- 65.

Sunil J. Wimalawansa, **Purification of Contaminated Water with Reverse Osmosis: Effective Solution of Providing Clean Water for Human Needs in Developing Countries**, International Journal of Emerging Technology and Advanced Engineering, 2013, 9001(12).

Teodosiu CC, Kennedy MD, van Straten HA, Schippers JC. **Evaluation of secondary refinery effluent treatment using ultrafiltration membranes**. Water Res. 1999; 33(9):2172-80.
Z. Yang, Y. Zhou, Z. Feng, X. Rui, T. Zhang, Z. Zhang, **A review on reverse osmosis and nanofiltration membranes for water purification**, Polymers, 2019, 11 (8) 1252.